TETRA TECH

January 30, 2017

ISSUED FOR USE
FILE: W14103567-21
Via Email: elise.bingeman@gov.yk.ca

Government of Yukon
Department of Community Services
Infrastructure Development
Box 2703
Whitehorse, YT Y1A 2C6

Attention: Ms. Elise Bingeman, Senior Project Manager

Subject: Geotechnical Evaluation - Sanitary and Water Underground Utility Upgrades - North Section
Dawson City, YT

1.0 INTRODUCTION

1.1 General

Government of Yukon, Department of Community Services (YG-CS) retained Tetra Tech Canada Inc. (Tetra Tech) to complete a geotechnical evaluation for proposed upgrades to the sanitary and water underground utilities in Dawson City, YT. Ms. Elise Bingeman authorized the work by way of signed Government Contract C00035734, dated October 3, 2016.

YG-CS is planning to replace the lift station at the corner of York Street and Second Avenue, upgrade buried utilities along Second Avenue, King Street, Fifth Avenue, and Craig Street, and replace the hydraulic tower (buried vault) at the southeast end of Craig Street. For reporting purposes we have split the study area into two sections (North and South) with the division at the municipal wastewater treatment plant on Fifth Avenue.

For additional conditions regarding the use of this report, please refer to Tetra Tech's General Conditions included in Appendix A.

1.2 Scope of Services

Tetra Tech's scope of services for this project was presented in a proposal submitted to YG-CS on September 26, 2016 and is as follows:

- Review available historical geotechnical information from along the proposed utility route and surrounding areas;
- A geotechnical drilling program to characterize the subsurface conditions along the proposed utility route; and
- Prepare a report summarizing geotechnical conditions, and providing recommendations for trench excavation, pipe bedding, trench backfill, road surfacing, and pipe insulation as well as recommendations for foundation design and construction for the lift station.

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1.3 Project Location

The location of the lift station site and proposed utility alignment is presented in Figure 1. The study area includes the path of the underground utilities running along Second Avenue, King Street and Fifth Avenue; between the lift station on Second Avenue and the municipal wastewater treatment plant on Fifth Avenue.

2.0 GEOTECHNICAL SITE ASSESSMENT

The geotechnical site assessment was completed on November 3 and 4, 2016. Donjeck Drilling of Whitehorse, YT was retained by Tetra Tech to drill three boreholes (BH16-01, -05, and -06), as shown on Figure 1. The boreholes were drilled to depths of 8.1, 5.5, and 4.0 m, respectively. Prior to commencing the site assessment, underground utility locates were completed.

During the drilling program, the soil profile was logged by Tetra Tech's field representative, Mr. Taidhg Mulroy, EIT, and both standard penetration test and disturbed grab samples were collected and returned to Tetra Tech's Whitehorse laboratory for routine geotechnical index testing.

Upon completion of the drilling program, the UTM coordinates were recorded with a handheld GPS and the boreholes were backfilled to grade with drill cuttings and compacted by the drill.

3.0 SITE CONDITIONS

3.1 Surface Features

BH16-01 was drilled adjacent to the lift station building, on a cleared and developed lot. BH16-05 and -06 were drilled on existing roadways in Dawson City. Topography followed the generally flat shape of the downtown Dawson City area.

3.2 Subsurface Conditions

The borehole logs and geotechnical laboratory testing results are included in Appendix B. Please note that the borehole logs and laboratory results contain detailed information describing the geotechnical conditions, and should be read in preference to the generalized descriptions provided below.

The soil profile at the lift station site and along the proposed utility alignment consists of sand and gravel fill, underlain by silt, underlain by frozen gravel and sand. The thicknesses of each soil unit encountered are summarized in Table 1.

Table 1: Summary of Subsurface Soil Conditions

Soil Type	Strata Depth Range (m)		
	BH16-01	BH16-05	BH16-06
SAND and GRAVEL (FILL)	Surface to 1.5 m	Surface to 1.0 m	Surface to 0.9 m
ORGANIC SILT	1.5 – 3.0	1.0 – 3.0	0.9 – 1.7
SILT	3.0 – 6.7	-	1.7 – 3.0
GRAVEL and SAND	6.7 – 8.1	3.0 – 5.5	3.0 – 4.0
End of Borehole	8.1	5.5	4.0

3.3 Groundwater Conditions

Groundwater was encountered in BH16-01 and -05, at approximately 4.4 and 2.8 m below ground surface, respectively. Groundwater was not encountered in BH16-06. The groundwater encountered may be the result of a thawed zone of permafrost and is expected to be localized to the area where it was encountered. The lift station site is within the permafrost region of Dawson City and is likely not fully hydraulically connected to the fluctuating seasonal water levels of the Yukon River.

However, based on proximity to the Yukon River it is possible that the river level has some influence on groundwater elevation at the lift station site. Tetra Tech has reviewed the historical Yukon River water level data from the monitoring station (09EB001) that is located at the north end of town. From the 46 years of available historical data collected between 1944 and 2015, Tetra Tech was able to determine that the Yukon River elevations during the winter months (October to May) ranged from 311.8 to 314.3 m and peak levels during the summer months (May to October) ranged from 314.3 to 318.8 m. The lift station site ground elevation is approximately 319.1 m. Assuming the river level does partially influence groundwater elevation, construction completed in early May or late September could potentially encounter groundwater at an elevation of 314.3 m, about 4.8 m below ground surface.

3.4 Permafrost and Seasonal Frost Penetration

Permafrost was encountered in all three boreholes, at depths of approximately 7.0, 5.3, and 2.3 m below ground surface in BH16-01, -05, and -06, respectively.

In BH16-01 and -05, permafrost was encountered in the gravel and sand. It is possible that the frozen gravel is thaw-stable as the ice may be confined to natural voids between the gravel particles. Due to the method if investigation (auger drilling) the samples returned to surface were very disturbed and it was not possible to discern ice content in the gravel strata. If excess ice is present in the gravel, settlement may occur if future permafrost thaw occurs in this area.

The permafrost in BH16-06 was encountered in the silt. Excess ice was visible in the form of ice crystals and randomly oriented seams. Given the visually confirmed presence of excess ice, settlement should be anticipated if future permafrost thaw occurs in this area.

Seasonal frost was encountered near surface in all three boreholes. Based on the soil profile and regional climate data, the maximum depth of seasonal frost penetration can be assumed to be about 3.5 m below ground surface.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Underground Utility Replacement

4.1.1 Trench Excavation

Tetra Tech understands that the underground utility upgrades will be completed using conventional cut and cover trenching techniques with depths of installation between about 1.5 and 4.5 m below ground surface. At these depths, the exposed subgrade is generally anticipated to consist of either soft silt with variable organic and sand contents, or gravel and sand. If possible, Tetra Tech recommends that the trench be excavated within the footprint of the trench for the existing underground utilities. This will reduce disturbance to native ground, and confine the new underground utilities to areas where permafrost has been previously exposed.

Frozen soils will likely be encountered during trench excavation, particularly in areas where shallow permafrost was encountered during drilling (BH16-06). The frozen soil will likely begin thawing rapidly if exposed to ambient summertime temperatures. Depending on the time of year when excavation takes place, seasonal frost may be present as well in the trench excavation.

Also depending on the time of year when excavation takes place, groundwater may be encountered in the trench. As such, it will be necessary to have pumps readily available during construction, so that seepage can be managed.

In general, the exposed subgrade soils at the base of the trench excavation should be considered to be relatively wet and therefore very sensitive to disturbance. Upon excavation, the base of the trench should be immediately covered with non-woven geotextile filter fabric and a 150 mm thick layer of 25 mm bedding stone (pipe bedding material as per the gradation specifications presented in the following Table 2) placed to protect the subgrade soil and provide a stable working surface during underground utility installation.

Table 2: Bedding Stone Gradation Specifications

Bedding Stone	
Sieve Size (mm)	**% Passing By Mass**
25.000	100
20.000	70 – 100
12.500	55 – 100
10.000	30 – 80
5.000	0 – 40
2.000	0 – 10

Trenching should be carried out in accordance with applicable *Occupational Health and Safety Regulations*. Trenches deeper than 1.2 must be sloped or shored according to Yukon *Workers' Compensation Health and Safety Board Regulations* prior to workers entering the trench.

4.1.2 Trench Backfilling

As discussed above, 25 mm bedding stone is proposed for use as pipe bedding. This type of material can be considered to be practically self-compacting; however, nominal compaction effort (rodding, small plate tamper, or similar) should be applied during placement to ensure that the stone particles are well seated against one another and that no voids remain adjacent to or below the pipe. All pipe bedding should be fully encapsulated in non-woven geotextile filter fabric to prevent internal erosion and migration of fine particles into the bedding stone from the surrounding soils.

Tetra Tech understands that the remainder of the trench will be backfilled using the native and/or fill materials removed during the excavation, which is standard practice in Dawson City. This is considered acceptable, provided the backfill is placed in relatively thin lifts (approximately 150 mm maximum thickness), moisture conditioned and compacted to at least 95% Standard Proctor Maximum Dry Density (SPMDD as per ASTM D698) to within a depth of 1.0 m from final grade. The upper 1.0 m of trench backfill is to be placed in approximately 150 mm thick lifts, moisture conditioned and compacted to 98% SPMDD. Furthermore, we recommend that saturated and/or highly organic soils not be used as trench backfill, as these soils will likely prove difficult to place and compact.

The road surface should be re-established with at least 300 mm of compacted, well-graded gravel, in accordance with standard practice in Dawson City. Road surface materials should be placed in maximum 150 mm thick lifts, moisture conditioned and compacted to at least 98% SPMDD.

4.1.3 Insulation Requirements

Based on the standard 75 mm thickness of factory insulation installed on the outside of the pipe, additional insulation is not required to protect permafrost below the new underground utilities.

However, some disturbance and localized thawing of permafrost should be anticipated during underground utility installation when frozen soil is exposed to ambient above freezing temperatures. The impact of thawing permafrost can be reduced by staging construction activities to install the underground utilities in relatively small 20 to 30 m segments; thereby, minimizing the amount of time that the frozen soils are exposed to thawing conditions between excavation and backfilling.

Notwithstanding any measures taken to minimize impacts, some permafrost thaw and associated settlement should be anticipated beneath the underground utilities due to disturbance caused during installation as well as long-term climate change effects. The new water forcemain will convey its contents under pressure and is not dependent on pipe gradient to operate effectively; therefore, it is not anticipated that thawing permafrost will have a significant detrimental effect on the operation of the water forcemain over its design life. However, the new sewer main is dependent on pipe gradient to operate effectively; therefore, the pipe should be installed at a steeper gradient in accordance with standard practice in Dawson City, such that any settlement caused by permafrost thaw will not render the sewer main inoperable. As noted previously, installing the new underground utilities within the existing trenches will minimize the amount of disturbance to native ground and will locate the new utilities in areas that have already undergone preliminary settlement from thawing permafrost.

4.2 Lift Station Replacement

Based on the results of the drilling program, Tetra Tech considers a buried concrete foundation feasible to support the proposed wet well. A thickened monolithic slab-on-grade is considered feasible to support the small building at surface. For the purposes of this report, Tetra Tech has assumed that the underside of the wet well foundation will be at least 6 m below ground surface and the underside of thickened portions of the slab-on-grade for the building will be at least 0.3 below ground surface.

4.2.1 Site Preparation

Site preparation for the lift station replacement should be completed in accordance with the following recommendations:

- The existing ground should be excavated to the gravel (approximately 6.7 m depth). The excavation should be completed such that there is minimal disturbance to the native gravels encountered at the excavation base. The excavation should be shaped in accordance with applicable *Occupational Health and Safety Regulations.* Tetra Tech recommends that any large overhanging material (such as cobbles or boulders) be removed from the sidewalls. Shoring methods (wood or steel framed slipforms) should be used if steeper sidewall slopes are desired;

- The surficial sand and gravel fill is suitable for reuse as backfill. It should be carefully stripped and stockpiled nearby. The silts are not suitable for use as backfill;

- The base of the excavation could be below the local groundwater elevation, resulting in seepage into the bottom of the excavation. Depending on the time of excavation (should consider April/May as the Yukon River

elevation is typically at is lowest elevation), dewatering efforts may be required to prevent water accumulation. Upon completion of the excavation, the exposed subgrade should be inspected by a qualified geotechnical engineer to confirm that suitable bearing conditions have been achieved and to provide additional recommendations, if necessary;

- Backfill should be completed using suitable material stockpiled on site and/or 80 mm pit run gravel, placed in 200 mm lifts, moisture conditioned, and compacted to at least 98% Standard Proctor Maximum Dry Density (SPMDD). The recommended gradations for the 80 mm pit run gravel are provided in Table 3;
- A minimum 150 mm thick layer of 20 mm crushed basecourse should be placed immediately below the underside of footings for both the wet well and the building. The 20 mm crushed basecourse should be moisture conditioned and compacted to at least 98% SPMDD. This will provide a smooth, level bearing surface on which to cast the concrete foundations. The recommended gradations for the 20 mm crushed basecourse are provided in Table 3;
- The excavation around and above the wet well should be backfilled with native material and/or 80 mm pit run gravel, placed in 200 mm lifts, moisture conditioned, and compacted to at least 98% SPMDD. Large rock particles should not be placed adjacent to the well wet structure;
- The excavation must be protected from the inflow of surface water at all times and foundation elements should not be cast directly onto or over seasonally frozen soils.

Table 3: Recommended Gradation for Granular Fill Materials

80 mm Pit Run Gravel		20 mm Crushed Basecourse	
Particle Size (mm)	**% Passing (by weight)**	**Particle Size (mm)**	**% Passing (by weight)**
80	100	-	-
25	55 – 100	20	100
12.5	42 – 84	12.5	64 – 100
5.00	26 – 65	5.00	36 – 72
1.25	11 – 47	1.25	12 – 42
0.315	3 – 30	0.315	4 – 22
0.080	0 – 8	0.080	3 – 6

4.2.2 Foundation Design and Construction

4.2.2.1 Limit States Design

The 2015 edition of the National Building Code of Canada (NBCC 2015) stipulates that foundation design must be carried out using Limit State Design (LSD) methods. Under LSD, a minimum of two loading cases must be considered by geotechnical and structural designers; the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS). The ULS and SLS bearing resistances are calculated differently. The ULS bearing resistance is the maximum pressure that can be applied to the soil without causing bearing failure. The SLS bearing pressure is the maximum allowable pressure required to limit the settlement to a tolerable amount. Both the ULS and SLS bearing resistances are highly dependent on soil properties and footing geometry, including the footing size, shape, and burial depth.

Resistance factors are applied to the calculated (unfactored) resistances to determine the maximum allowable factored design load. Geotechnical resistance factors for design of shallow foundations against vertical bearing failure (ULS), horizontal displacement (sliding under lateral loading), and overturning, per NBCC 2015, are provided in Table 4.

Table 4: Geotechnical Resistance Factors - Shallow Foundations

Item	Resistance Factor
Vertical Bearing Resistance (ULS)	0.5
Sliding (ULS)	0.8
Overturning (ULS)	0.5

4.2.2.2 Foundation Recommendations

As noted above, Tetra Tech considers a buried concrete foundation feasible to support the wet well, and a thickened monolithic slab-on-grade feasible to support the building at surface. As such, design and construction of the foundations at the site should be undertaken in accordance with the following recommendations:

- Strip footings refer to thickened areas within the structural slab-on-grade that are designed to provide the required bearing resistance under building loads. For the purpose of design, Tetra Tech has assumed a slab thickening of 0.3 m and a minimum depth of cover of 0.3 m from final grade;
- Tetra Tech has assumed a footing thickness of 0.3 m and a minimum depth of cover of 6.0 m from original ground to the underside of footing for the wet well;
- Unfactored bearing resistances are provided based on minimum footing dimensions of 0.4 m wide for strip footings, and 1 m square for spread footings. If significantly different footing sizes are preferred for this project, Tetra Tech should be contacted to review and adjust the calculated bearing resistances, as necessary; and
- Unfactored bearing resistances for the wet well and building are provided below in Table 5. SLS bearing resistances have been calculated based on 25 mm of tolerable elastic settlement.

Table 5: Unfactored Bearing Resistances for Shallow Foundations

Limit State	Wet Well Foundation		Building Foundation	
	1 m Spread Footings	0.4 m Strip Footings	1 m Spread Footings	0.4 m Strip Footings
ULS	450	300	390	260
SLS	600	600	600	600

4.2.2.3 Frost Protection

Frost heave is a common cause to foundation damage in cold climates and occurs when three conditions are satisfied; the ground temperature is below freezing, frost-susceptible soils are present, and the soil pore space is near 100% saturation. In this case, the native soils are considered to be frost-susceptible; however, these soils are to be excavated and replaced with non-frost-susceptible 80 mm pit run gravel and 20 mm crushed basecourse, therefore, Tetra Tech does not consider insulation necessary for this site.

4.2.3 Site Grading

Final site grading should enhance positive drainage and direct water away from the foundation elements of the structure. Ponding adjacent to the structure must be prevented, as infiltration to the foundation elements could have detrimental effects on structural elements. Roof runoff should be directed onto splash pads away from the building. This is particularly important in late fall, just prior to freeze-up.

4.2.4 Concrete

Concrete should be cast onto a clean, compacted, unfrozen, granular bearing surface. It is important that no loose and/or disturbed material be allowed to remain on the bearing surface. As noted above, foundation bearing surfaces should consist of 20 mm basecourse gravel, moisture conditioned and compacted to at least 98% SPMDD.

Tetra Tech recommends that all concrete be design, mixed, placed, and tested in accordance with the most recent edition of the Canadian Standards Association (CSA) Standard CAN/CSA-A23.1 and A23.2. According to these standards, concrete should be designed to at least satisfy the minimum durability requirements as defined by the exposure class.

The exposure class of the concrete is dependent on the presence or lack of chlorides, sulphates, freezing and thawing conditions, and the soil saturation. Based on the aforementioned recommendations, the governing exposure class for the foundation system will be “C-1”. If the concrete will have the potential to be exposed to specialized chemicals used in the operation and maintenance of either the lift station, it is recommended that Tetra Tech be given the opportunity to review the concrete class recommendation.

In addition to the above, CAN/CSA-A23.1 also provides recommendations for cold weather concrete placement. These include protecting freshly placed concrete from freezing temperatures.

4.2.5 Seismic Site Classification

NBCC 2015 requires that a seismic site classification be established for proposed buildings. As such, Tetra Tech recommends that the lift station site be considered Site Classification D, per Table 4.1.8.4.A in NBCC 2015.

5.0 CONSTRUCTION TESTING AND MONITORING

All recommendations presented are site-specific and based on the assumption that an adequate level of monitoring during excavation, installation, and construction will be provided, and that all construction will be carried out by a suitably qualified, experienced contractor. An adequate level of construction monitoring also provides opportunity to verify that the recommendations based on geotechnical data obtained from the borehole are applicable to the entirety of the proposed utility alignment and lift station site. Appropriate quality assurance and quality control testing should be undertaken during construction to confirm that construction is completed in accordance with the recommendations provided in this report.

Furthermore, it is recommended that Tetra Tech be given the opportunity to review the details of the final design related to the geotechnical aspects of the foundation, prior to construction. Past experience has shown that this action may prevent inconsistences, poor performance, and/or increased costs that may lead to disputes.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Government of Yukon, Department of Community Services and their agents. Tetra Tech Canada Inc. (operating as Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Government of Yukon, Department of Community Services, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in Tetra Tech's General Conditions that are provided in Appendix A of this report.

7.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
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Attachments: Figures (1)
Appendix A: Tetra Tech's General Conditions
Appendix B: Borehole Logs and Laboratory Test Results

FIGURES

Figure 1 Site Plan Showing North Section Borehole Locations

LEGEND

- BOREHOLE LOCATION
- UNDERGROUND UTILITY UPGRADE AREA

0 250m

Scale: 1:5,000 @ 8.5"x11"

CLIENT

Yukon Government

TETRA TECH

GEOTECHNICAL SERVICES
SANITARY AND WATER UNDERGROUND UTILITIES UPGRADE
DAWSON CITY, YUKON

SITE PLAN SHOWING NORTH SECTION BOREHOLE LOCATIONS

PROJECT NO.	DWN	CKD	REV
W14103567-21	CB	TM	0

OFFICE	DATE
EBA-WHSE	November 23, 2016

Figure 1

Q:\Whitehorse\Data\0201drawings\Dawson City Area\W14103567-21 Dawson City Underground Utilities\W14103567-21 North Section.dwg [FIGURE 1] November 23, 2016 - 2:33:41 pm (BY: BUCHAN, CAMERON)

APPENDIX A

TETRA TECH'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT – YUKON GOVERNMENT

This report incorporates and is subject to these “General Conditions”.

1.1 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of TETRA TECH’s Client, the Yukon Government. TETRA TECH does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than TETRA TECH’s Client unless otherwise authorized in writing by TETRA TECH. Any unauthorized use of the report is at the sole risk of the user.

1.2 ALTERNATE REPORT FORMAT

Where TETRA TECH submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed TETRA TECH’s instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by TETRA TECH shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of TETRA TECH’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except TETRA TECH. TETRA TECH’s instruments of professional service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

1.3 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.4 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.5 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.6 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.7 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.8 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.9 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.10 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.11 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

1.12 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

1.13 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

1.14 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of the report, TETRA TECH may rely on information provided by persons other than the Client. While TETRA TECH endeavours to verify the accuracy of such information when instructed to do so by the Client, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

BOREHOLE LOGS AND LABORATORY TEST RESULTS

TERMS USED ON BOREHOLE LOGS

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (major portion retained on 0.075mm sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as inferred from laboratory or in situ tests.

DESCRIPTIVE TERM	RELATIVE DENSITY	N (blows per 0.3m)
Very Loose	0 TO 20%	0 to 4
Loose	20 TO 40%	4 to 10
Compact	40 TO 75%	10 to 30
Dense	75 TO 90%	30 to 50
Very Dense	90 TO 100%	greater than 50

The number of blows, N, on a 51mm O.D. split spoon sampler of a 63.5kg weight falling 0.76m, required to drive the sampler a distance of 0.3m from 0.15m to 0.45m.

FINE GRAINED SOILS (major portion passing 0.075mm sieve): Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as estimated from laboratory or in situ tests.

DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH (KPA)
Very Soft	Less than 25
Soft	25 to 50
Firm	50 to 100
Stiff	100 to 200
Very Stiff	200 to 400
Hard	Greater than 400

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil.

GENERAL DESCRIPTIVE TERMS

Slickensided - having inclined planes of weakness that are slick and glossy in appearance.
Fissured - containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.
Laminated - composed of thin layers of varying colour and texture.
Interbedded - composed of alternate layers of different soil types.
Calcareous - containing appreciable quantities of calcium carbonate.;
Well graded - having wide range in grain sizes and substantial amounts of intermediate particle sizes.
Poorly graded - predominantly of one grain size, or having a range of sizes with some intermediate size missing.

MODIFIED UNIFIED SOIL CLASSIFICATION

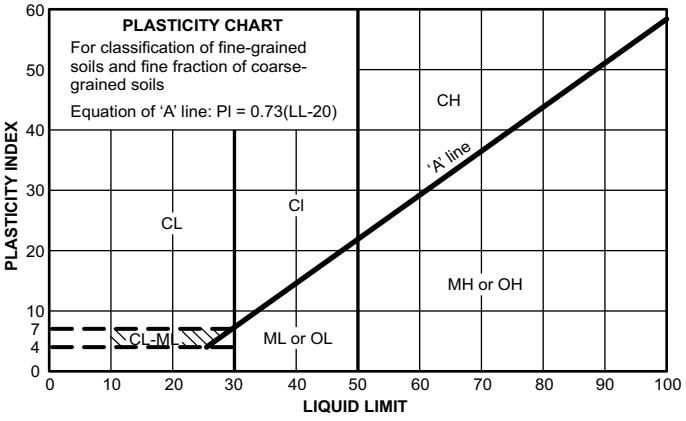
MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE - GRAINED SOILS More than 50% retained on No. 75 µm sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly-graded sands and gravelly sands, little or no fines
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (by behavior) 50% or more passes 75 µm sieve*	SILTS	Liquid limit <50	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands of slight plasticity
		Liquid limit >50	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
	CLAYS Above "A" line on plasticity chart negligible organic content	Liquid limit <30	CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Liquid limit 30-50	CI	Inorganic clay of medium plasticity, silty clays
		Liquid limit >50	CH	Inorganic clay of high plasticity, fat clays
	ORGANIC SILTS AND CLAYS	Liquid limit <50	OL	Organic silts and organic silty clays of low plasticity
		Liquid limit >50	OH	Organic clays of medium to high plasticity
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils

LABORATORY CLASSIFICATION CRITERIA

Classification on basis of percentage of fines
GW, GP, SW, SP
GM, GC, SM, SC
Borderline classification requiring use of dual symbols

$C_U = D_{60} / D_{10}$ Greater than 4 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3		
Not meeting both criteria for GW		
Atterberg limits plot below 'A' line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols	
Atterberg limits plot above 'A' line and plasticity index greater than 7		
$C_U = D_{60} / D_{10}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3		
Not meeting both criteria for SW		
Atterberg limits plot above 'A' line and plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols	
Atterberg limits plot above 'A' line and plasticity index greater than 7		

Less than 5% pass 75 µm sieve
More than 12% pass 75 µm sieve
5% to 12% pass 75 µm sieve



* Based on the material passing the 75 mm sieve

† ASTM Designation D 2487, for identification procedure see D 2488 USC as modified by PFRA

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

VISIBLE ICE LESS THAN 50% BY VOLUME

GROUP SYMBOL	SYMBOL	SUBGROUP DESCRIPTION	
V	Vx	Individual ice crystals or inclusions	
	Vc	Ice coatings on particles	
	Vr	Random or irregularly oriented ice formations	
	Vs	Stratified or distinctly oriented ice formations	

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm thick	

NOTES:

1. Dual symbols are used to indicate borderline or mixed ice classifications.
2. Visual estimates of ice contents indicated on borehole logs ± 5%
3. This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes.

LEGEND: Soil ☐ Ice ■

Yukon Government

Borehole No: **BH16-01**

Project: Dawson City Undergruond Utilities	Project No: W14103567-21
Location: York St. and 2nd Ave. Lift Station	
Dawson City, YT	UTM: 576530 E; 7105092 N; Z 7

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	SPT (N)	Moisture Content (%)	Depth (ft)
0							SPT (N) 20 40 60 80	0
							Plastic Limit / Moisture Content / Liquid Limit 20 40 60 80	
0	Solid stem auger	SAND and GRAVEL (FILL) - some silt, well graded, frozen, compact, greyish brown,	Seasonally Frozen					0
1		- damp	Unfrozen		SA01		14.4	3
		- fibrous organic inclusions						
2		ORGANIC SILT - trace sand, trace gravel, moist, firlm, dark grey, fibrous organic inclusions, faint diesel odour			SA02	11	36	6
3		SILT - some sand, some clay, trace gravel, moist, soft, dark grey, fibrous organic inclusions			SA03	2	38.3	10
4								13
5	Hollow stem auger	- wet, very soft, peaty odour			SA04	2	43.5	16
6						2		20
7		GRAVEL and SAND - some silt, well graded, round to subrounded, very wet, dark grey, no visible organics	Probable Permafrost Surface		SA05	46	18.3	23
		- trace silt			SA06	40 /75mm	70.4	/75 26
8		END of BOREHOLE at 8.1 m (Auger Refusal)						27
9								29
10								32

3/11/2016

3/11/2016

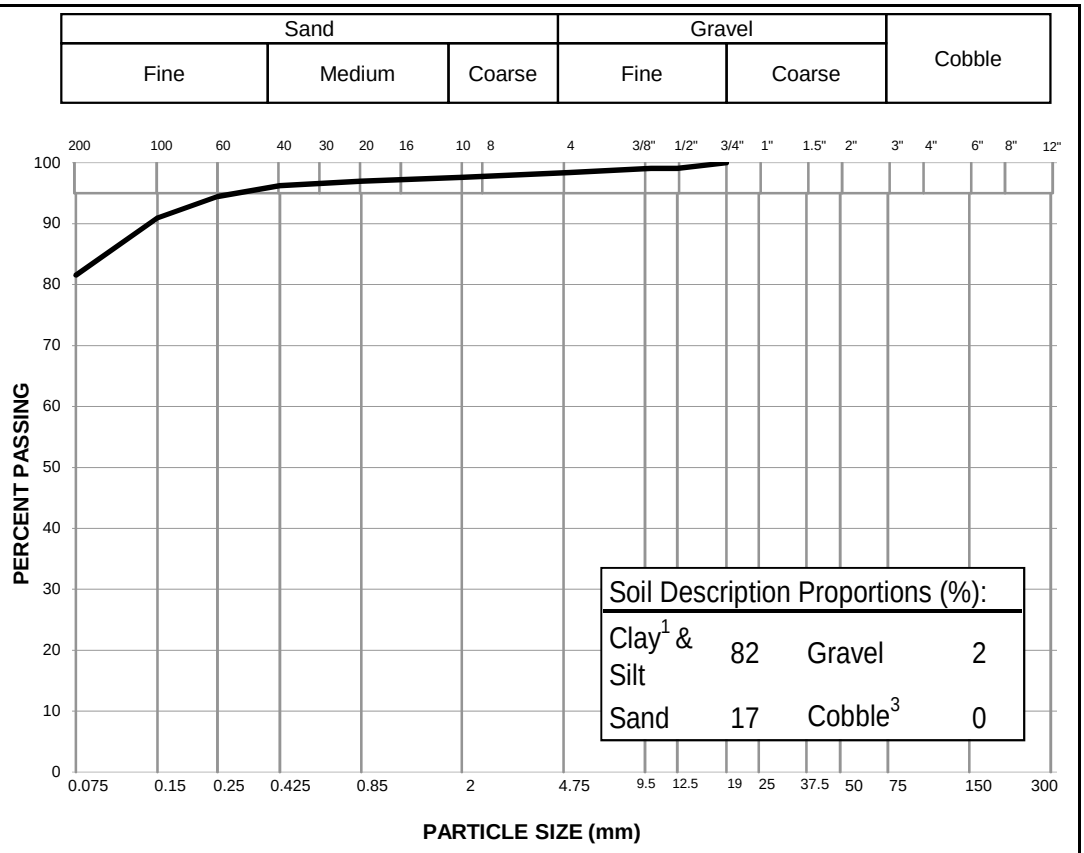
TETRA TECH	Contractor: Donjeck Drilling	Completion Depth: 8.1 m
	Drilling Rig Type: Truck Mounted CME75	Start Date: 2016 November 3
	Logged By: TM	Completion Date: 2016 November 3
	Reviewed By:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Underground Utilities - Geotech.	Sample No.:	SA04
Project No.:	W14103567-21	Material Type:	
Site:	Dawson City, YT	Sample Loc.:	BH16-01
Client:	YG - Community Services	Sample Depth:	4.6 m
Client Rep.:	Elise Bingeman	Sampling Method:	Grab
Date Tested:	December 7, 2016 By: AMT	Date sampled:	November 3, 2016
Soil Description[2]:	SILT - some sand, trace gravel	Sampled By:	TM
		USC Classification:	Cu: #N/A
Moisture Content:	43.5%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	
38	
25	
19	100
12.5	99
10	99
5	98
2	98
0.85	97
0.425	96
0.25	94
0.15	91
0.075	81.6



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: _____

Remarks: _____

Reviewed By: _____ P.Eng.

TETRA TECH

Yukon Government

Borehole No: **BH16-05**

Project: Dawson City Undergruond Utilities	Project No: W14103567-21
Location: King St. and 4th Ave.	
Dawson City, YT	UTM: 576640 E; 7104958 N; Z 7

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Plastic Limit / Moisture Content / Liquid Limit (20 40 60 80)	Depth (ft)
0								0
	Solid stem auger	SAND and GRAVEL (FILL) - some silt, well graded, frozen, compact, light greyish brown	Seaonally Frozen		SA23	8.3	●	1–2
1		ORGANIC SILT - some sand, trace clay, frozen, dark grey, fibrous organic inclusions			SA24	18.1	●	3–4
		- damp, firm	Unfrozen					5–6
2		- trace sand, faint diesel odour			SA25	26.2	●	7–8
3		GRAVEL - silty, sandy, well graded, round, wet, dark grey						9–10
					SA26	21	●	11–12
4								13–14
5			Probable Permafrost Surface					15–16
		END of BOREHOLE at 5.5 m (Auger Refusal).						17–18
6								19–20
7								21–22
								23–24
8								25–26
								27–28
9								29–30
								31–32
10								

04/11/2016 ▼ (3 m)

04/11/2016 ▼ (9 ft)

TETRA TECH

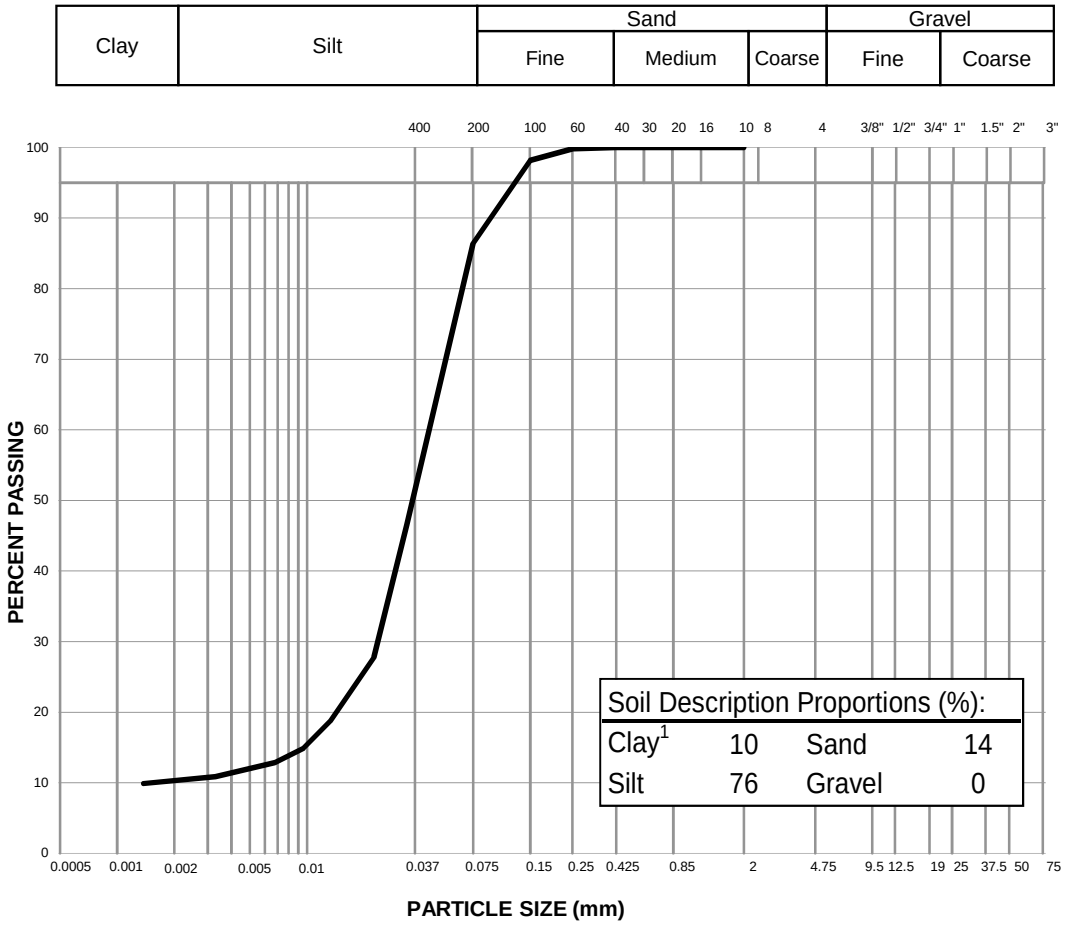
Contractor: Donjeck Drilling	Completion Depth: 5.5 m
Drilling Rig Type: Truck Mounted CME75	Start Date: 2016 November 4
Logged By: TM	Completion Date: 2016 November 4
Reviewed By:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Underground Utilities - Geotech.	Sample No.:	SA24
Project No.:	W14103567-21	Material Type:	
Site:	Dawson City, YT	Sample Loc.:	BH16-05
Client:	YG - Community Services	Sample Depth:	1.2 m
Client Rep.:	Elise Bingeman	Sampling Method:	Grab
Date Tested:	December 7, 2016 By: AMT	Date sampled:	November 3, 2016
Soil Description[2]:	SILT - some sand, trace clay	Sampled By:	TM
		USC Classification:	Cu: 30.3
Moisture Content:	11.6%		Cc: 7.6

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	
5	
2	100
0.85	100
0.425	100
0.25	100
0.15	98
0.075	86.4
0.0335	46.5
0.0225	27.7
0.0133	18.8
0.0095	14.9
0.0068	12.9
0.0033	10.9
0.0014	9.9



Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: _____

Remarks: _____

Reviewed By: _____ P.Eng.

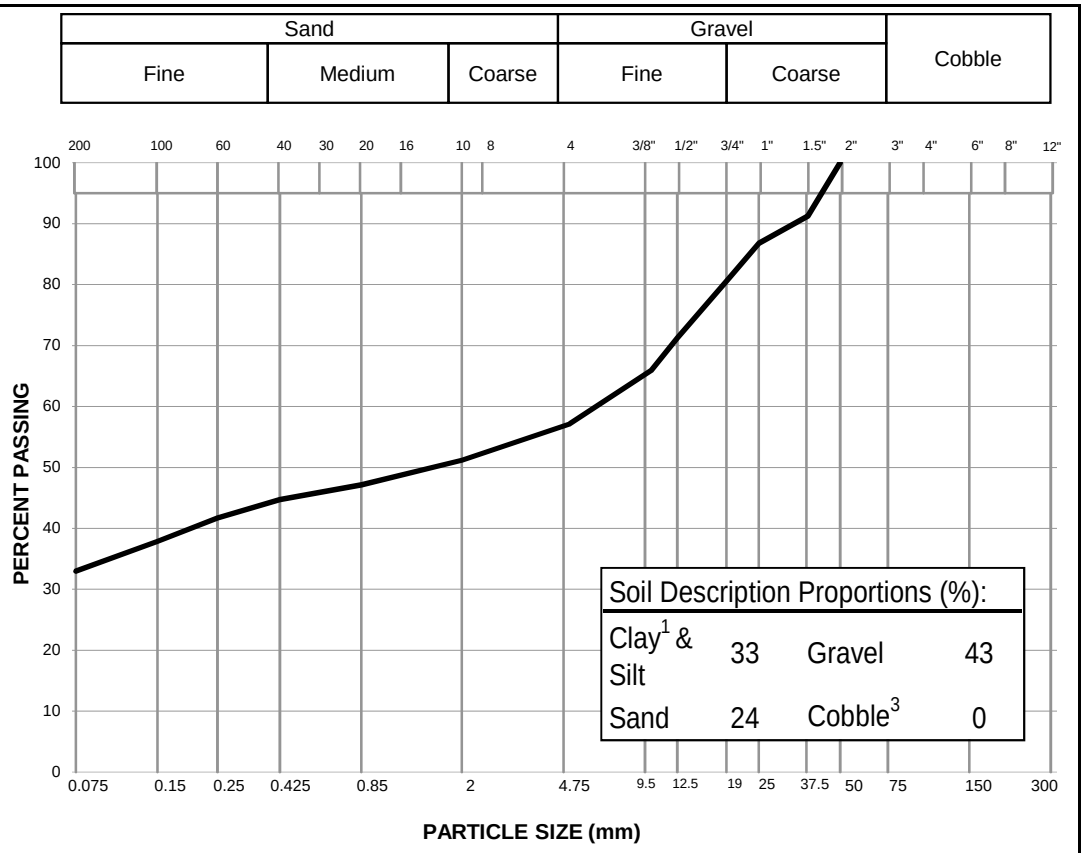
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Underground Utilities - Geotech.	Sample No.:	SA26
Project No.:	W14103567-21	Material Type:	
Site:	Dawson City, YT	Sample Loc.:	BH16-05
Client:	YG - Community Services	Sample Depth:	3.7 m
Client Rep.:	Elise Bingeman	Sampling Method:	Grab
Date Tested:	December 8, 2016 By: AMT	Date sampled:	November 4, 2016
Soil Description[2]:	GRAVEL - silty, sandy	Sampled By:	TM
		USC Classification:	Cu: #N/A
Moisture Content:	21.0%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	100
38	91
25	87
19	81
12.5	71
10	66
5	57
2	51
0.85	47
0.425	45
0.25	42
0.15	38
0.075	33.0



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification:

Remarks: 7.8 grams wood and organic material removed during sieve, was not included in soil weights.

Reviewed By: _____ P.Eng.

TETRA TECH

Yukon Government

Borehole No: **BH16-06**

Project: Dawson City Undergruond Utilities	Project No: W14103567-21
Location: Queen St. and 5th Ave.	
Dawson City, YT	UTM: 576627 E; 7104740 N; Z 7

Depth (m)	Method	Soil Description	Ground Ice Description	Sample Type	Sample Number	Moisture Content (%)	Depth (ft)
0	Solid stem auger	GRAVEL and SAND (FILL) - some silt, well graded, frozen, compact, light grey	Seasonally Frozen		SA27	16.8	0
1		ORGANIC SILT - sandy, some gravel, frozen, dark brown, fibrous organic inclusions, - damp, soft			SA28	24.3	3
			Unfrozen				
2		SILT - some clay, trace sand, moist, soft, medium plastic, grey			SA29	27.3	6
		- frozen, firm, non plastic	Nbe Permafrost (well bonded, excess ice)		SA30	85.3	8
3		GRAVEL and SAND - trace silt, well graded, round, frozen, dense, grey					10
					SA31	11.9	12
4		END of BOREHOLE at 4.0 m (Aguer Refusal).					13
5							16
6							20
7							23
8							26
9							30
10							32

Plastic Limit | Moisture Content | Liquid Limit
20 40 60 80

TETRA TECH

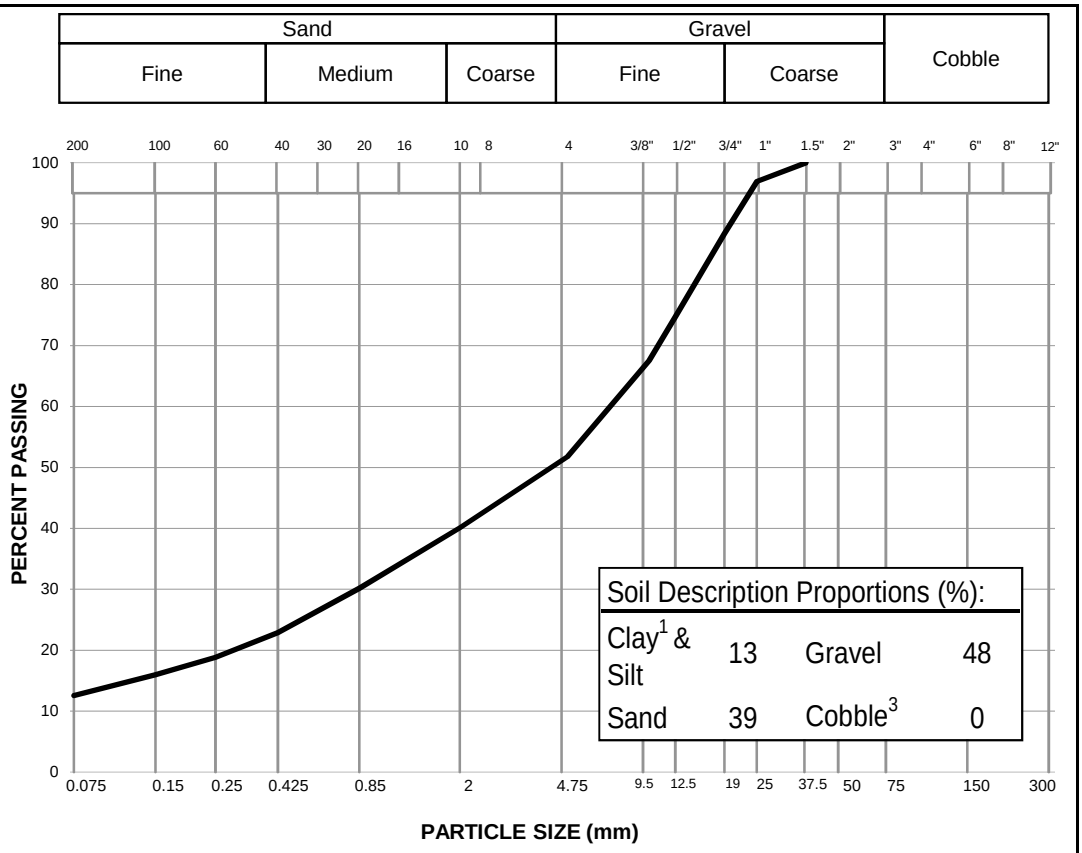
Contractor: Donjeck Drilling	Completion Depth: 4 m
Drilling Rig Type: Truck Mounted CME75	Start Date: 2016 November 4
Logged By: TM	Completion Date: 2016 November 4
Reviewed By:	Page 1 of 1

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Underground Utilities - Geotech.	Sample No.:	SA28
Project No.:	W14103567-21	Material Type:	
Site:	Dawson City, YT	Sample Loc.:	BH16-06
Client:	YG - Community Services	Sample Depth:	0.9 m
Client Rep.:	Elise Bingeman	Sampling Method:	Grab
Date Tested:	December 8, 2016 By: AMT	Date sampled:	November 4, 2016
Soil Description[2]:	GRAVEL and SAND - some silt	Sampled By:	TM
		USC Classification:	Cu: #N/A
Moisture Content:	24.3%		Cc: #N/A

Particle Size (mm)	Percent Passing
300	
200	
150	
100	
75	
50	
38	100
25	97
19	88
12.5	75
10	68
5	52
2	40
0.85	30
0.425	23
0.25	19
0.15	16
0.075	12.6



Notes:
[1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols
[3] If cobbles are present, sampling procedure may not meet ASTM C702 & D75

Specification: _____

Remarks: _____

Reviewed By: _____ P.Eng.

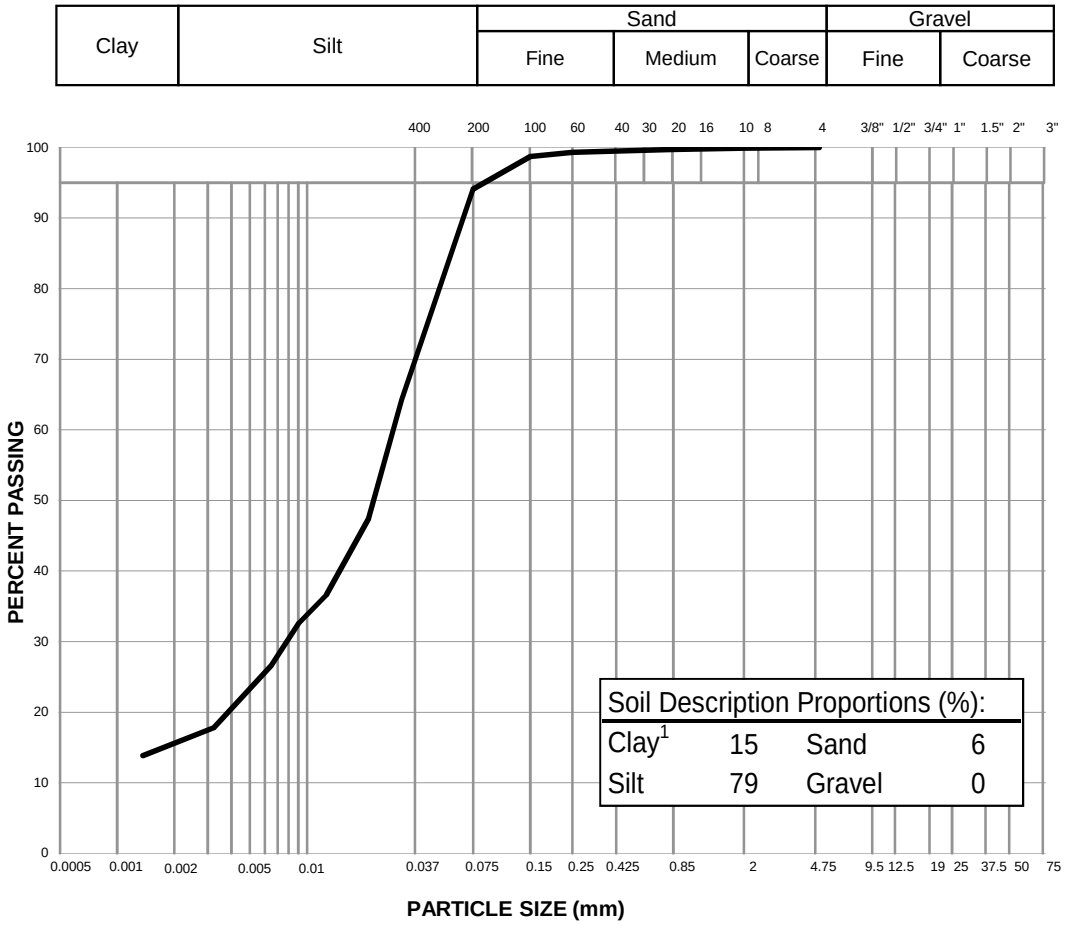
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Underground Utilities - Geotech.	Sample No.:	SA29
Project No.:	W14103567-21	Material Type:	
Site:	Dawson City, YT	Sample Loc.:	BH16-06
Client:	YG - Community Services	Sample Depth:	1.8 m
Client Rep.:	Elise Bingeman	Sampling Method:	Grab
Date Tested:	December 7, 2016 By: AMT	Date sampled:	November 3, 2016
Soil Description[2]:	SILT - some clay, trace sand	Sampled By:	TM
		USC Classification:	Cu: #N/A
Moisture Content:	27.3%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	
5	100
2	100
0.85	100
0.425	99
0.25	99
0.15	99
0.075	94.1
0.0315	64.3
0.0212	47.5
0.0126	36.6
0.0090	32.6
0.0065	26.7
0.0032	17.8
0.0014	13.8



Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: P.Eng.

TETRA TECH