Project Site 25757 – Rice Bridge Geotechnical Assessment

PRESENTED TO

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1.0 INTRODUCTION

1.1 General

Tetra Tech Canada Inc. (Tetra Tech) has been retained by the Ministry of Transportation and Infrastructure (MoTI) to provide geotechnical engineering services in support of the response and recovery work from flooding and erosion associated with the 2021 OKS Atmospheric River Event near Tulameen, BC.

Tetra Tech understands that during the 2021 OKS Atmospheric River Event, water levels within Granite Creek were elevated to the underside of Rice bridge, which resulted in debris striking the bridge superstructure. During the emergency works, the bridge was cleared of debris to assess the structural integrity of the bridge superstructure. MoTI has determined that a new elevated crossing needs to be constructed to allow for future elevated water flows.

The MoTI have engaged McElhanney Ltd., (McElhanney) to provide hydrotechnical and structural engineering services for the crossing. It is Tetra Tech's understanding the proposed crossing has a span of 30 m and will be supported by open-pipe piles.

The MoTI requested that Tetra Tech undertake a geotechnical investigation to gain an understanding of the soil properties to a minimum depth of the anticipated pile toe elevation. This report presents the results of the geotechnical site investigation as well as Tetra Tech's geotechnical recommendations for open-pipe pile design and slope recommendations within the project area.

Tetra Tech's services are being provided in accordance with the BC Ministry of Transportation Contract No. 862CS1842.

1.2 Site Description

The Rice Bridge crossing is located on Rice Road approximately 1.4 km southeast from Coalmont, BC (see Figure 1). The terrain near the northern abutment typically slopes downwards to the south from an old, elevated river terrace. The terrain near the southern abutment gently slopes to the east along the current river terrace and alluvial fan deposits. Granite Creek flows to the east underneath the existing bridge structure where it converges with the Tulameen River approximately 150 m downstream of the existing bridge location. The surrounding areas typically rise to mountainous terrain as the subject site is situated within a localized valley bottom. The approximate elevation of Rice Road at the existing bridge location is 739 m. The elevation was estimated from the contours sourced from the MoTI topographic survey undertaken in February and April 2022.

2.0 BACKGROUND REVIEW

2.1 Surficial Geology

The Geological Survey of Canada (GSC) surficial geology map for the area (Clague, 1982) suggests that the site is underlain by continuous sandy till cover with thicknesses greater than 10 m on valley walls and lower slopes, and 1 to 3 m in most other areas.

2.2 Bedrock Geology

The GSC bedrock geology map for the area (Schiarizza, P. and Church, 1996) indicates that the bedrock underlying the site comprises undifferentiated mafic to felsic volcanic and volcaniclastic rocks including lava flows, ruffs and breccia, lesser argillite, greywacke, and limestone.

2.3 Groundwater Monitoring Wells

Reference to the Provincial Well Database, iMapBC, indicates that one water well (Tag #116180) was installed within 250 m of the site. The water well data is summarized in Table 1.

Table 1: Water Well Summary

Water Well No.	Approx. Distance from Center of Site (m)	Lithology	Depth (m bgl)	Static Groundwater (m bgl)
116180	250 m (NW)	Sand and Gravel	0.0 – 1.2	1.8
		Silty Sand and Gravel	1.2 – 8.5	
		Water Bearing Silty Sand and Gravel	8.5 – 14.0	

*Data taken from iMapBC Water Well Reports (https://maps.gov.bc.ca/ess/hm/imap4m/)

3.0 GEOTECHNICAL INVESTIGATION

3.1 Subsurface Drilling

Tetra Tech conducted a geotechnical site investigation between May 20 and May 23, 2022, utilizing a Fraste MDXL track mounted drill rig operated by Geotech Drilling Services Ltd. from Prince George, BC. The geotechnical site investigation comprised the advancement of three testholes to a maximum depth of 31.1 m utilizing the overburden excentric drilling (Odex) technique. A testhole was performed within the south and north bridge abutment, and an additional testhole was performed within the southern approach.

The geotechnical site investigation was supervised by Tetra Tech field personnel, Mr. Dylan Bryce, P.Eng, who logged the encountered material and collected representative soil samples for laboratory testing.

The location and elevation of the testholes was established using a Magellan Triton 400 handheld GPS receiver with an estimated horizontal accuracy of +/- 3.0 m. Testhole elevations were estimated from the survey data provided by MoTI. Table 2 provides a summary of the testhole location, elevation, and termination depth. The geodetic location of the testholes is also shown on Figure 1 and detailed testhole logs are included in Appendix B.

During drilling at testhole TH22-01 a 1.5 m section of casing was lost in the hole due to driller error and the original location had to be abandoned and the upper 6 m redrilled. The approximate coordinates of the lost casing are 5486076 N and 668104 E, which is approximately 0.9 m east of TH22-01.

Table 2: Geotechnical Site Investigation Summary

Testhole No.	Northing (m NAD83)	Easting (m NAD83)	Collar Elevation (m)	Termination Depth (m)	Termination Reason
TH22-01	5486076	668103	741.2	31.1	Target Depth Reached
TH22-02	5486110	668102	742.4	31.1	Target Depth Reached
TH22-03	5486031	668138	740.4	15.8	Target Depth Reached

3.2 Soil Laboratory Testing

Following the completion of the subsurface drilling, laboratory testing was conducted on a select number of representative soil samples, at Tetra Tech's Canadian Council of Independent Laboratories (CCIL) certified laboratory. Testing was carried out in general conformance with the relevant ASTMs and results are summarized in Table 3. The testhole logs along with detailed results are presented in Appendix C.

Table 3: Summary of Particle Size Distribution and Moisture Contents

Testhole No.	Depth (m)	Moisture Content (%)	Grain Size Analysis (%)			
			Gravel	Sand	Fines	
					Silt	Clay
TH22-01	15.2 – 15.8	11.8	50	35	16	
TH22-01	21.3 – 21.9	7.2	57	37	6	
TH22-01	24.4 – 25.0	9.5	49	38	13	
TH22-02	4.6 – 5.2	8.9	69	26	5	
TH22-02	12.2 – 12.8	22.8	3	39	58	
TH22-02	18.3 – 18.9	8.8	57	35	8	
TH22-02	27.4 – 28.0	14.5	37	56	7	
TH22-03	4.6 – 5.2	14.8	31	59	5	
TH22-03	7.6 – 8.2	18.4	23	69	8	

Selected samples were also sent to CARO Analytical Services (CARO) for Soluble Chloride content testing in accordance with MoTI requirements (ASTM C1218-17 and CSA, 2019 respectively). pH testing was also conducted at CARO's laboratory in accordance with Carter 16.2 / SM 4500-H+ (2017). Test results are presented in Table 4 and detailed results are attached in Appendix C.

Table 4: Summary of Chemical Test for Rice Bridge

Testhole No.	Depth (m)	Soluble Sulfate Content (%)	Soluble Chloride Content (%)	pH
TH22-01	2.1 – 2.7	<0.05	<0.002	7.77

4.0 SUBSURFACE CONDITIONS

4.1 Soil Conditions

The following interpreted soil profile was encountered within the proposed south abutment of the proposed bridge (TH22-01):

- **Fluvial Deposits**, comprising loose to compact gravel and sand, with a varying amount of silt, cobbles, and wood debris. The fluvial deposits are typically greyish brown to dark grey in color, dry to moist, medium to coarse grained sand and fine to coarse subrounded to subangular gravel, with SPT “N-values” in the range of 7 to 10 (average of 9). The deposits were encountered form the surface to a depth of approximately 4.9 m.

- **Glaciofluvial Deposits**, comprising compact to very dense gravel and sand, with a varying amount of silt and cobbles. The glaciofluvial deposits are typically greyish brown to dark grey, wet, fine to coarse grained sand and fine to coarse subrounded to angular gravel, with SPT “N-values” in the range of 14 to 60 (average of 33). The glaciofluvial deposits are present from a depth of approximately 4.9 m to the maximum extents investigated by TH22-01 (i.e., 31.1 m).

The southern approach has a similar interpreted soil profile (TH22-03) at the southern abutment. However, due to the testhole being located away from Granite Creek, the glaciofluvial deposits extended from the surface to the maximum depth investigated by TH22-03 (i.e., 15.8), with SPT “N-values” in the range of 18 to 60 (average of 36).

The following interpreted soil profile was encountered within the proposed north abutment of the proposed bridge (TH22-02):

- **Fluvial Deposits**, comprising compact gravel and sand, with varying amounts of silt, and cobbles. The fluvial deposits are typically grey in color, dry to wet, fine to coarse grained sand and fine to coarse subrounded to subangular gravel, with SPT “N-values” in the range of 12 to 14 (average of 13). The deposits were encountered form the surface to a depth of approximately 4.6 m.

- **Glaciofluvial Deposits**, comprising compact to very dense gravel and sand, with varying amounts of silt and cobbles. The glaciofluvial deposits are typically greyish brown to grey, wet, fine to coarse grained sand and fine to coarse subrounded to angular gravel, with SPT “N-values” in the range of 17 to 77 (average of 39). A layer of Silt and Sand was noted at depths ranging between 12.2 and 13.7 m. The glaciofluvial deposits are present from a depth of approximately 4.6 m to the maximum extents investigated by TH22-02 (i.e., 31.1 m).

4.2 Groundwater Conditions

Groundwater was encountered at a depth of between 3.4 m and 4.0 m in all testholes. These depths correspond to geodetic elevations of between 737.8 m and 738.4 m for TH22-01 and TH22-02, respectively. The soil samples were typically described as “wet” below the water table elevations.

It should be noted that groundwater levels may fluctuate during certain times of year, particularly during periods of heavy rainfall and snow melt or high-water levels in Granite Creek where groundwater levels may be higher than those recorded.

5.0 DESIGN CRITERIA

5.1 Consequence Classification

For the purposes of this assessment, the project team determined that the consequence classification for the bridge is “Typical” as defined in accordance with the terminology in Section 6.5.1 of the Canadian Highway Bridge Design Code S6-19 (CHBDC) (CSA, 2021) and the BC Bridge Standards and Procedures Manual Supplement to CHBDC (MoTI, 2022).

It is Tetra Tech’s understanding that Rice Road is being designed as a Low Volume Road (LVR), which typically is designed as a “Low Consequence” classification in accordance with LVR design standards. However, in the absence of a determination of consequence level by the owner, the consequence classification shall be considered to be typical as per Section 6.5.1 of CSA, 2021.

In discussions with the project team, no determination has been made by the owner, therefore, “Typical” consequences have been utilized for the embankment design.

5.2 Consequence Factor

Based on the “Typical” consequence classification, the Ultimate Limit State (ULS) and Serviceability Limit State (SLS) consequence factor, ψ, shall be taken as 1.0 as shown in Table 6.1 within Section 6.5.2 of the CHBDC S6-19.

5.3 Degree of Site and Prediction Model Understanding

Tables 6.2a of MoTI (2022) provides guidance on selecting a degree of understanding of ground conditions for deep foundations. Based on the completed geotechnical site investigation, available historical information, and the completed geotechnical analysis to be discussed later in this report, the site and prediction model understanding has been identified as a “Typical” understanding.

5.4 Geotechnical Resistance Factors

Table 6.2 of CSA (2021) stipulates geotechnical resistance factors for varying geotechnical systems and degrees of understanding. Based on the “Typical” understanding that was defined in Section 5.3, Tetra Tech has summarized the recommended geotechnical resistance factors for static analysis of deep foundations as shown in Table 5.

Table 5: Geotechnical Resistance Factors for Deep Foundations

Geotechnical System Application	Geotechnical Resistance Factors for Typical Degree of Understanding		
	Compression	Tension	Lateral
Deep Foundation (Static Analysis)	0.4	0.3	0.5

5.5 Structural Loads

The lateral structural loads and corresponding load cases were provided to Tetra Tech by Mr. Ben Ticknor, P.Eng. of McElhanney in an email titled "SA08 Program – LPile Analysis for Rice Bridge" dated January 23, 2023. The critical loads provided are summarized in Table 6 and Table 7 for the axial and lateral loads of individual piles, respectively.

Table 6: Max Axial Loading Combinations for Individual Piles

Load Case	Maximum Factored Axial Pile Loads					
	South Abutment Piles			North Abutment Piles		
	SLS	ULS	ULS5	SLS	ULS	ULS5
Total Load (DL + LL)	860 kN	1180 kN	740 kN	860 kN	1180 kN	740 kN

Table 7: Max Lateral and Axial Loading Combinations for Individual Piles

Abutment	Load Case	Forces at Underside of Pile Cap			
		Scour Depth	Vf	Mf	Pf
North	LC-2.2 (ULS.1)	0.0 m	340 kN	0 kN-m	740 kN
	LC-1.4(ULS.5)	5.2 m	240 kN	0 kN-m	740 kN
South	LC-2.2 (ULS.1)	0.0 m	340 kN	0 kN-m	740 kN
	LC-1.4 (ULS.5)	4.0 m	240 kN	0 kN-m	740 kN

5.6 Climate Change Considerations

The BC MoTI Technical Circular T-04/19 "Resilient Infrastructure Engineering Design – Adaptation to the Impacts of Climate Change and Weather Extremes", March 27, 2019, was used as a reference for inclusion of climate change considerations into our geotechnical assessment and design. As there is a lack of definitive geotechnical oriented data and precedence related to climate change in the project area, it was generally assumed that climate will be reflected by increased frequency and magnitude of extreme precipitation events and temperatures.

To account for the temperature changes in the pile design, Tetra Tech has used the historical temperatures in the frost depth analysis which are typically lower than the forecasted temperatures.

6.0 SEISMIC CONSIDERATIONS

6.1 Site Classification and Seismic Hazard Values

In accordance with Table 4.15 of MoTI (2021), performance-based design criteria for seismic design of the bridge, it has been assumed that the bridge will be classified as an "Other Bridge" structure.

In accordance with Table 4.1 of CSA (2021) and with consideration of the subsurface conditions, the seismic site classification at the proposed crossing site is Site Class D "Stiff Soil". The site classification was determined based on the SPT blow counts within TH22-01 averaging 30 blows within the depths investigated.

National Building Code of Canada (NBCC, 2015) 2015 seismic hazard values for reference ground conditions (Class C, 2% in 50 years) were obtained using Natural Resources Canada (NRC) online hazard calculator tool (NRC, 2022). Site coefficients were then obtained from Section 4.4.3.3 of CHBDC S6-19 and applied to the reference ground conditions for Site Class D using a PGA reference value of 0.131 g to obtain the site specific hazard values used for the Rice Bridge and listed in Table 8.

Table 8: Seismic Design Criteria for Rice Bridge

Annual Exceedance Probability (AEP)	PGA_{ref} (g)	F(PGA)	Design PGA (g)
1/2,475	0.131	1.231	0.16

The relative contribution of the earthquake sources to the seismic hazard in terms of distance and magnitude can be obtained by deaggregation of the seismic hazard. The deaggregation data for the NBCC 2015 design model has been obtained from Earthquakes Canada, which provides the mean and modal magnitude of the seismic hazard near the Rice Bridge subject site, as summarized in Table 9.

Table 9: Design Earthquake Magnitudes

Magnitude Contribution	PGA
Mean	6.35
Modal	4.85

6.2 Liquefaction Triggering Assessment

Liquefaction potential was assessed using CSR/CRR ratio comparison utilizing PGA and mean magnitude degradation data provided by NRC for NBCC 2015 seismic hazard values. The PGA used was 0.16 g and the mean magnitude earthquake was 6.35. Our CSR/CRR analysis showed that the soils beneath the site have a very low to no susceptibility to liquefaction under the design earthquake scenario and further assessment is not required.

7.0 GEOTECHNICAL DESIGN

7.1 General

It is Tetra Tech’s understanding through coordination with McElhanney representatives that the bridge foundation will comprise 610 mm driven steel pipe piles. Each abutment will be supported by 3 x 610 mm diameter driven steel pipe piles equally spaced at 2.4 m. The pile wall thickness will be 19 mm. The analysis was conducted for the critical loading scenario based on various structural inputs at each scour elevation. The input parameters are described in the following sections.

7.2 Lateral Pile Resistance

7.2.1 General

The lateral pile analysis was undertaken using LPile software (2019, Version 11) to estimate the pile displacement, fixity depth, bending moments, and shear forces within the pile. It is Tetra Tech’s understanding that the critical ULS structural lateral load per pile was 240 kN for LC-1.4 (ULS.5) under a 5.2 m and 4.0 scour event for the north and south abutment, respectively.

7.2.2 Structural Inputs

The following structural inputs were used for the lateral pile analysis following discussions with Mr. Ben Ticknor, P.Eng. of McElhanney and the information provided within the draft design drawings:

- The pile was modeled as a 610 mm open-pipe pile with a 19 mm wall thickness.
- The grade of steel is ASTM A252 Grade 2 (Fy – 240 MPa).
- The Elastic Modulus of the steel pipe pile was 200 GPa.
- The pile was to be filled with 30 MPa concrete and reinforced with 14-25 M bars with a 10 M spiral bar to a depth of 10 m. The remaining pile depth is to be left with native soil infill.

7.2.3 Geotechnical Inputs

The geotechnical parameters utilized to undertake the lateral pile analysis are presented in Table 10 and Table 11 for the north and south abutments, respectively. Soil parameters were determined based on the testhole logs, SPT N-values, published correlations, Caltrans Geotechnical manual for Soil Correlations (2014), and the API (1993). A detailed breakdown for each soil input parameter is provided below.

- **Unit Weight, Effective Friction Angle** – Caltrans Geotechnical Manual for Soil Correlations (2014); and,
- **Initial Modulus of Subgrade Reaction** – Figure 3.33 from the 2019 LPile Technical Manual.

The groundwater elevation was set at the top of the soil profile for each scour scenario. It should be noted that the top of the piles for the north and south abutment are 741.907 m and 740.744 m, respectively. As discussed in the LPile Technical Manual, initial modulus of subgrade reactions were adjusted from the recommended values based on the gradation results.

Table 10: Geotechnical Parameters used for Lateral Pile Design North Abutment

Geodetic Elevation (masl)	Material	LPile Model	Unit Weight (KN/m^3)	Friction Angle	Initial Modulus of Subgrade Reaction (kN/m^3)
742.4 – 737.5	Compact Gravel and Sand, trace to some silt (completely scoured)	-	-	-	-
737.5 – 731.4	Dense Gravel, Sandy, trace silt	API Method for Sand	20.5	38	25,300
731.4 – 729.9	Dense Silt and Sand, trace gravel	API Method for Sand	19	32.5	10,000
729.9 – 722.6	Dense Gravel, Sandy, trace to some silt	API Method for Sand	20	37.5	34,500
722.6 – 719.5	Compact Sand and Gravel, some silt	API Method for Sand	19	33	19,800
719.5 – 716.5	Very Dense Sand and Gravel, trace silt	API Method for Sand	20	36	28,600
716.5 – 711.4	Very Dense Sand and Gravel, trace silt	API Method for Sand	20	39	39,600

Table 11: Geotechnical Parameters used for Lateral Pile Design South Abutment

Geodetic Elevation (masl)	Material	LPile Model	Unit Weight (KN/m^3)	Friction Angle	Initial Modulus of Subgrade Reaction (kN/m^3)
741.2 – 736.6	Loose to Compact Sand and Gravel, trace to some silt	API Method For Sand	18	33	19,800
736.6 – 730.5	Compact Gravel and Sand, some silt	API Method For Sand	20	36.5	31,050
730.5 – 727.2	Compact Gravel and Sand, trace silt	API Method For Sand	19	34.5	25,460
727.2 – 722.3	Compact to Dense Gravel and Sand, trace to some silt	API Method For Sand	19	35.5	30,475
722.3 – 715.3	Dense Gravel and Sand, trace to some silt	API Method For Sand	20	36.5	29,700
715.3 – 710.1	Very Dense Sand, gravelly, trace silt	API Method For Sand	20	35.5	29,150

7.2.4 Lateral Pile Resistance Analysis Results

The lateral pile resistance analysis results for the provided factored structural loads per pile are summarized in Table 12. Appendix D shows the detailed LPile analysis results for the critical scenarios shown in Table 12.

Table 12: Lateral Pile Analysis Results

Abutment	Load Case	Scour Depth (m)	Maximum Unfactored Moment (KN-m per pile)	Maximum Unfactored Shear Force (kN per pile)	Maximum Pile Top Displacement (cm)	Fixity Depth Below Top of Pile (m)
North	LC-1.4(ULS.5)	5.2	1592	-475	14.6	16.0 m
South	LC-1.4 (ULS.5)	4.0	1303	-403	9.1	15.0 m

Based on the lateral pile assessment Tetra Tech recommends utilizing a fixity depth 16.0 m and 15.0 m below the bottom of the pile cap for the north and south abutment, respectively. The contractor shall choose a construction methodology to ensure that the pile is advanced to the maximum pile tip elevation.

The results of the lateral pile resistance analysis should be reviewed and confirmed by the structural engineer of record prior to construction to ensure that the proposed pile design can accommodate the calculated bending moments, shear forces, and that the calculated pile displacements are within the acceptable limits.

7.3 Axial Resistance of Driven Open-Pipe Piles

7.3.1 General

The axial resistance of driven open-pipe piles was estimated according to the procedure provided in the CHBDC S6-19 by implementing effective stress analyses using the “Beta Method” for the cohesionless soils that were encountered at the Rice Bridge site. The ultimate geotechnical axial resistance of a driven open-pipe pile is calculated by adding the ultimate shaft resistance with the ultimate tip resistance. Tip resistance has been calculated assuming that no soil plug will form during pile driving.

Considering the above, the analysis was performed based on the following assumptions:

- Beta (β) and N_t values were selected from Table 18.1 from the CFEM (2006).
- Limiting skin friction values and limiting end bearing values were applied based on American Petroleum Institute document titled "Recommended Practice for Planning, Designing and Construction Fixed Offshore Platforms – Load and Resistance Factor Design" (1993)".
- Group interaction factors were not accounted for within the preliminary design.
- A resistance factor of 0.4 (compression) was used when calculating the factored geotechnical resistance at ULS based on "Typical Understanding" as per Section 6.5.3.2 of the CHBDC.

7.3.2 Geotechnical Inputs and Soil Model Parameters

The soil parameters for the axial pile analysis were determined based on the testhole logs, SPT N-values, correlations from the Canadian Foundation Engineering Manual (CFEM, 2006), and Caltrans Geotechnical Manual for Soil Correlations (2014), and the API (1993). Table 13 and Table 14 provides the soil parameters utilized in the axial pile design for each proposed abutment.

Table 13: Soil Parameters Utilized for Axial Pile Design (North Abutment)

Geodetic Elevation (masl)	Material	Beta	Unit Weight (KN/m^3)	N_t	Shaft Resistance Limit (kPa)	Tip Resistance Limit (kPa)
742.4 – 737.5	Compact Gravel and Sand, trace to some silt	0.582	19	189	95.7	9,600
737.5 – 731.4	Dense Gravel, Sandy, trace silt	0.792	20.5	234	114.8	12,000
731.4 – 729.9	Dense Silt and Sand, trace gravel	0.708	19	216	67.0	2,900
729.9 – 722.6	Dense Gravel, Sandy, trace to some silt	0.736	20	222	114.8	12,000
722.6 – 719.5	Compact Sand and Gravel, some silt	0.568	19	186	81.3	4,800
719.5 – 716.5	Very Dense Sand and Gravel, trace silt	0.61	20	195	114.8	12,000
716.5 – 711.4	Very Dense Sand and Gravel, trace silt	0.736	20	222	114.8	12,000

Table 14: Soil Parameters Utilized for Axial Pile Design (South Abutment)

Geodetic Elevation (masl)	Material	Beta	Unit Weight (KN/m^3)	N_t	Shaft Resistance Limit (kPa)	Tip Resistance Limit (kPa)
741.2 – 736.6	Loose to Compact Sand and Gravel, trace to some silt	0.626	18	177	81.3	4,800
736.6 – 730.5	Compact Gravel and Sand, some silt	0.764	20	228	95.7	9,600
730.5 – 727.2	Compact Gravel and Sand, trace silt	0.554	19	183	95.7	9,600
727.2 – 722.3	Compact to Dense Gravel and Sand, trace to some silt	0.624	19	198	114.8	12,000
722.3 – 715.3	Dense Gravel and Sand, trace to some silt	0.68	20	210	114.8	12,000
715.3 – 710.1	Very Dense Sand, gravelly, trace silt	0.708	20	216	114.8	12,000

7.3.3 Axial Pile Design Results

It is Tetra Tech's understanding that the required Factored Ultimate Geotechnical Axial Resistance at ULS is 1,180 kN and 740 kN per pile with no scouring and during a scour event, respectively.

The factored geotechnical axial resistances have been calculated for a single 610 mm diameter open-pipe piles. The results for the north abutment are shown in Figure 2 and Figure 3 for no scour and a 5.2 m scour event, respectively. Figures 4 and Figures 5 show the results for no scour and a 4.0 m scour event for the south abutment, respectively.

Based on our geotechnical assessment, the northern piles would have an anticipated depth of 22 m during a 5.2 m scour event, however, Tetra Tech proposes that the anticipated pile depth be advanced to a depth of 25 m to terminate in the "Dense Gravel and Sand" stratigraphy unit. Similar to the northern piles, the geotechnical assessment indicates that a depth of 20 m is required to achieve the required capacity; however, Tetra Tech recommends that the anticipated pile depth be extended to 22 m to embed the piles into the "Dense Gravel and Sand" stratigraphy unit.

It should be noted that the assumed weight of the piles has been subtracted only from the factored ultimate geotechnical resistance values.

7.4 Frost Penetration

Frozen soils can produce heaving and uplift forces upon shallow foundations due to the propensity of the soil to allow for the formation of ice lenses and heaving during freeze thaw cycles. The magnitude of the forces is related to the soil's exposure to freezing temperatures, the type of soil, and the depth to the groundwater table.

The depth of frost penetration depends on several factors such as soil type, water content, depth of the groundwater table, type of soil cover, heat loss from structures, minimum temperatures, and duration that the subgrade soils are frozen. The CFEM states that the modified Berggren equation as shown in Equation 9.1 is the most useful relationship and standard in industry practice.

$$X = \lambda\sqrt{\frac{2(k_f)I_S}{L_S}}$$ (Berggren, Equation 9.1)

Where: X = Depth of frost penetration
I_S = surface freezing index which can be estimated from the air freezing index times a ground surface interface factor “n” (Equation 13.5, CFEM)
k_f = Thermal conductivity of the frozen soil (Figure 13.6, CFEM)
L_s = Volumetric latent heat of the soil (Equation 13.6, CFEM)
λ = A dimensionless coefficient (Figure 13.8 from the CFEM)

Historical climate data indicates that the freezing index for the subject site is approximately 700-degree days below 0°C. The CFEM Table 13.2 recommends an N-value between 0.9 and 0.95 for gravel which is anticipated to cover the subject site, so Tetra Tech elected to use a value of 0.925 for the purpose of this analysis.

Based on the frost depth calculations and the subsurface soil conditions, the anticipated frost depth for the subject site below the finished site grades is 2.3 m.

7.5 Uplift Forces Due to Frost Jacking

In areas where frost penetrates deeply below the ground surface, frost expansion of the soil can cause uplift forces on the pile. Frost heave uplift forces are computed by integration of the frost heave adhesion over the area subject to frost penetration in frost susceptible soils, while the uplift resistance of a pile is equal to the shaft resistance of the pile beneath the maximum anticipated frost depth.

Typically, open gravels such as those found on-site are not considered frost susceptible, however, Tomlinson (2008) states that groundwater movements at periods of thawing might wash fine grained soil particles into the voids in the gravel, leading to the formation of a silty gravel which is susceptible to frost heave.

To prevent frost jacking, the pile embedment in soils must be sufficient to resist uplift forces caused by frost heave. The Tsytovich (Andersland, 2004) rule is that the embedment of the pile should be at least two to three times the active layer depth, which for the subject site is between 4.6 m and 6.9 m, respectively. Andersland (2004) also states that in the absence of experimental field data, a frost jacking force of 80 kPa for regions have soil temperature of -3°C or higher and 60 kPa for regions with soil temperatures below -3°C. Due to no frost probe or ground temperature data at the subject site, Tera Tech has conservatively recommends using an 80 kPa frost jacking force within the anticipated frost depths.

Based on the anticipated pile depths calculated in Section 7.3.3, the pile design provides adequate uplift resistance against frost jacking forces.

8.0 CHEMICAL DEGRADATION OF REINFORCED CONCRETE

8.1 General

The types of chemical degradation that occur in concrete are associated primarily with chemical changes occurring within the hydrated cement matrix. The most common threat to concrete durability is sulfate attacks or the introduction of chloride salts either as contaminants within the concrete or exposure to a sulfate or chloride laden environment.

Sulfate attacks will cause damages to concrete due to the formation of sulfate ions, which when reacting with the cement aluminates will create voluminous calumnious calcium sulpholuminate crystals. Chloride attacks on concrete deteriorates the durability of concrete by corroding the reinforcement.

The last chemical degradation of concrete that is typical of concrete is an acid attack, since the components in cement paste are typically basic, and many are readily dissolved by acids. Typically, an acidic attack lead to loss of finder and strength in the concrete, leading to the eventual loss of a concrete section.

8.2 Acid Attack

Groundwater and soil pH typically gives an indication of an acidic attack on concrete infrastructure. CSA. AS23.1 does not provide allowable parameters for ground or surface water in contact with concrete infrastructure; however, considering the PH levels of the soils were basic (7.77), Tetra Tech is of the opinion that an acid attack is unlikely.

8.3 Sulfate Attack

Table 3 of CSA A23.1 provides various exposure classes for concrete subject to sulfate attack. Based on the water-soluble sulfate content in the soils (<0.05%) being less than the “moderate” exposure class of 0.1% to 0.2% in the soil, the risk of sulfate attack on the concrete is considered to be low.

8.4 Chloride Attack

Table 2 of CSA A23.1 provides various exposure classes for concrete subjected to chemical and environmental conditions, with the “C” classes pertaining to chloride exposure. The results of the chloride in soil (<0.002%) are lower than the required limits for chloride exposure concrete and therefore no specific chloride exposure class concrete is required.

Chloride exposure potential from de-icing chemics or other environmental exposures (fertilizer) should be considered separately when determine the risk of chloride exposure to the concrete at the subject site.

9.0 PILING INSTALLATION RECOMMENDATIONS

The general construction sequencing proposed by the Contractor should be reviewed by the Geotechnical Engineer of Record to verify that the proposed construction methodology adheres to the geotechnical design.

The testhole logs indicate that during pile driving, cobbles should be anticipated, and we recommend that driving shoes are used to protect the integrity of the piles during driving. Due to the design accounting for shaft resistance, any proposed pile shoes shall be shaped to avoid reducing shaft friction. Any driving shoe that is an “outside fit” to the pile toe will not be accepted, as the driving shoe will not be flush with the exterior of the pile therefore reducing the skin friction.

An additional consideration with respect to pile installation at this site will be the 1.5 m section of drill casing that was lost during the subsurface investigation. The position of this casing should be noted through the design process of the temporary bridge crossing.

After the installation of the piles, the Geotechnical Engineer shall inspect the piles to ensure the straightness of the pile installation and the plumpness of the piles. Tetra Tech recommends utilizing a guide system to aid in keeping the pile plumb during installation.

A Geotechnical Engineer or designated representative should be on site to provide full time pile monitoring to verify the subsurface conditions encountered during piling are consistent with those assumed in the design.

10.0 GEOTECHNICAL RECOMMENDATIONS

10.1 Temporary Excavations

Based on the soil conditions encountered in the testholes and project area, Tetra Tech recommends a maximum temporary cut slope angle of 1.2H:1V (horizontal: vertical) up to a maximum height of 3.0 m. If these sloping requirements cannot be achieved, temporary shoring may be required prior to entering the excavation.

Temporary excavation work should be carried out in accordance with the requirements specified by WorkSafe BC Occupational Health & Safety Regulations, Part 20. Flatter excavations may be required if soil sloughing, the development of tension cracks along the crest of the slope, groundwater seepage, or loose soils are encountered. A Geotechnical Engineer shall review any excavation greater than 1.2 m in depth.

10.2 Permanent Cut and Fill Slopes

Tetra Tech recommends that permanent cut and fill slopes shall not be graded steeper than a 2H:1V (horizontal: vertical). Permanent fill slopes shall typically be over-built with a WGB material and then trimmed back to the recommended inclination before recompacting the slope.

Permanent cut and fill slopes shall be vegetated with native grasses and pocket planted shrubs immediately after construction to prevent surface erosion. Vegetation growing on slopes assists in stabilizing by root-binding, preventing erosion and lowering soil moisture content.

In areas where angular rockfill or Class 250 kg riprap is utilized as the fill material, a 1.5H:1V slope can be utilized. Tetra Tech understands that this material will be utilized in the approach fills and the channel banks, therefore these slopes will not need to be vegetated with native grasses and planted shrubs.

11.0 PILE GEOTECHNICAL DESIGN SUMMARY

Tetra Tech has provided a geotechnical pile design summary in Table 15 based on given design requirements provided by McElhanney and the results from the axial and lateral pile analysis.

Table 15: Pile Design Summary

Abutment	Pile Type	Pile Diameter (mm)	Wall Thickness (mm)	Anticipated Bedrock Elevation (m)[1]	Pile Cut-Off Elevation	Anticipated Pile Length	Anticipated Pile Toe Elevation	Maximum Pile Toe Elevation
North	Open Steel Pipe Pile	610	19.0	NA	741.907	25.0	716.906	725.906
South	Open Steel Pipe Pile	610	19.0	NA	740.744	22.0	718.544	725.544

[1] Bedrock was not encountered within the depth of the geotechnical investigation and is anticipated to be well below the anticipated pile toe elevation.

12.0 CLOSURE

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

Respectfully Submitted,
Tetra Tech Canada Inc.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
J. D. BRYCE
65[illegible]

Dylan Bryce

2024-11-22

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PERMIT TO PRACTICE
TETRA TECH CANADA INC.

PERMIT NUMBER: 1001972

REFERENCES

Anderland, O.B. and Ladanyi, B. (2004). Frozen Ground Engineering Second Edition. The American Society of Civil Engineers (ASCE) and Jon Wiley & Sons, Inc. Published by Jon Wiley & Sons, Inc. Hoboken, New Jersey.

American Petroleum Institute, 1993. “Recommended Practice for Planning, Designing and Construction Fixed Offshore Platforms – Load and Resistance Factor Design”. 1st Edition, July 1, 1993.

ASTM C1218-17 Standard Test Method for Water-Soluble Chloride in Mortar and Concrete, ASTM International, West Conshohocken, PA, 2020.

Carter, M.R., & Gregorich, E.G. (Eds.). (2007). Soil Sampling and Methods of Analysis (2nd ed.). CRC Press. https://doi.org/10.1201/9781420005271

Caltrans Geotechnical Manual (2014). “Soil Correlations”.

CFEM, 2006. Canadian Foundation Engineering Manual; 4th edition. Canadian Geotechnical Society. 488 p.

Clague, J.J, Fulton, R.J; Ryder J.M, 1982. “Surficial geology, Vancouver Island and adjacent mainland, British Columbia” Geological Survey of Canada, Open File 837, 2 sheets

CSA, 2021. Canadian Standards Association Canadian Highway Bridge Design Code S6-19 and Commentary. Published in November 2019 and reprinted in 2021. Includes Update No.1 (2021).

CSA, 2019. Canadian Standards Association A23.1-14 / A23.2-14 Concrete Materials and methods of concrete construction / Test methods and standard practices for concrete.

Halchuk, S.C., Adams, J.E., and Allen, T.I. 2015. “Fifth generation seismic hazard model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada”. Geological Survey of Canada Open File 7893

Ministry of Transportation and Infrastructure (2022). Bridge Standards and Procedures Manual; Volume 1 Supplement to CHBDC S6-19. July.

NRC, 2022. National Building Code of Canada seismic hazard values (2015 NBC). http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php, accessed June 08, 2022.

NBCC, 2015. National Building Code of Canada 2015. Canadian Commission of Building and Fire Codes.

Schiarizza, P. and Church., N., 1996. The Geology of the Thompson - Okanagan Mineral Assessment Region. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 1996-20.

Tomlinson, M and Woodward, J (2008). Pile Design and Construction Practice Fifth Edition. Published by Taylor & Francis, New York, New York.

WorkSafeBC, 2008. “Occupational Health and Safety Regulations, Part 20”/

FIGURES

LEGEND

- ⊕ Approximate Testhole Location
- 〜 1 m Contour (2022)
- 〜 5 m Contour (2022)
- 🟥 Survey Boundary

NOTES

Base data source:
- Orthoimagery sourced from ESRI Orthographic Basemap Services (date: September 2020)
- Inset Map sourced from ESRI Topographic Basemap Services
- Contours sourced from survey provided by MoTI (date of survey February-April, 2022)

STATUS
ISSUED FOR REVIEW

RICE BRIDGE GEOTECHNICAL ASSESSMENT

Testhole Location Plan

PROJECTION
UTM ZONE 10

DATUM
NAD83

Scale: 1:600
10 5 0 10
Metres

FILE NO.
KGEO03692-02.07 Rice Figure 1.mxd

OFFICE	DWN	CKD	APVD	REV
Kelowna	MG	SL	DB	0

DATE
August 22, 2022

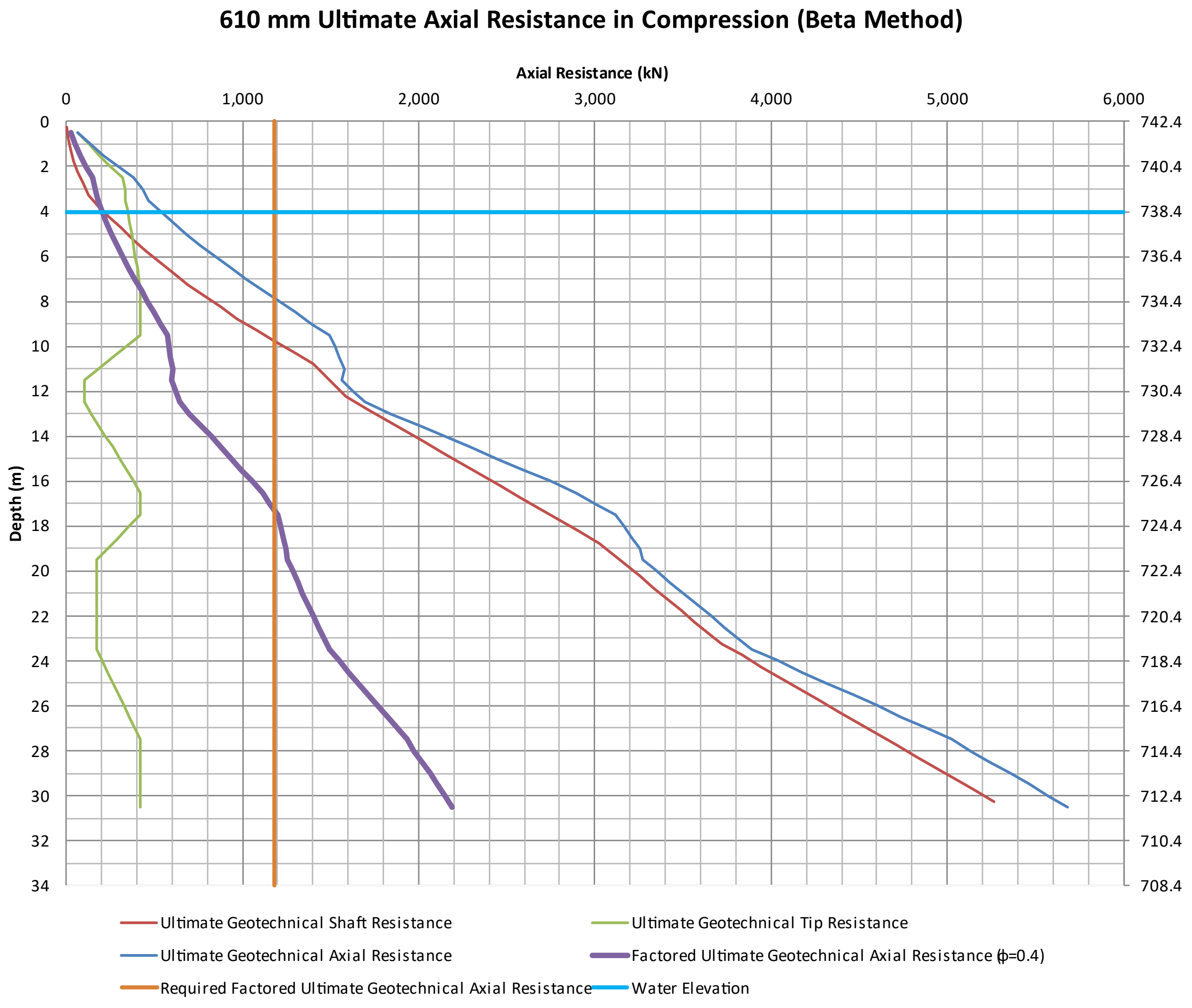
PROJECT NO.
ENG.KGEO03692-02.007

CLIENT
British Columbia Ministry of Transportation and Infrastructure

TETRA TECH

Figure 1

Q:\Kelowna\GIS\ENGINEERING\KGEO\KGEO03692-01 November 2021 Mudside and Flooding\Maps\KGEO03692-02.07 Rice Figure 1.mxd modified 8/22/2022 by murray.gaffney



LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile
- Assume driving shoe is not an exterior weld
- Calculated using the Beta Method
- Geotechnical Resistance Factor of 0.4 was utilized to calculate the Factored Geotechnical Axial Resistance
- The weight of the pile has been subtracted from the Factored Ultimate Geotechnical Resistance values

STATUS
ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

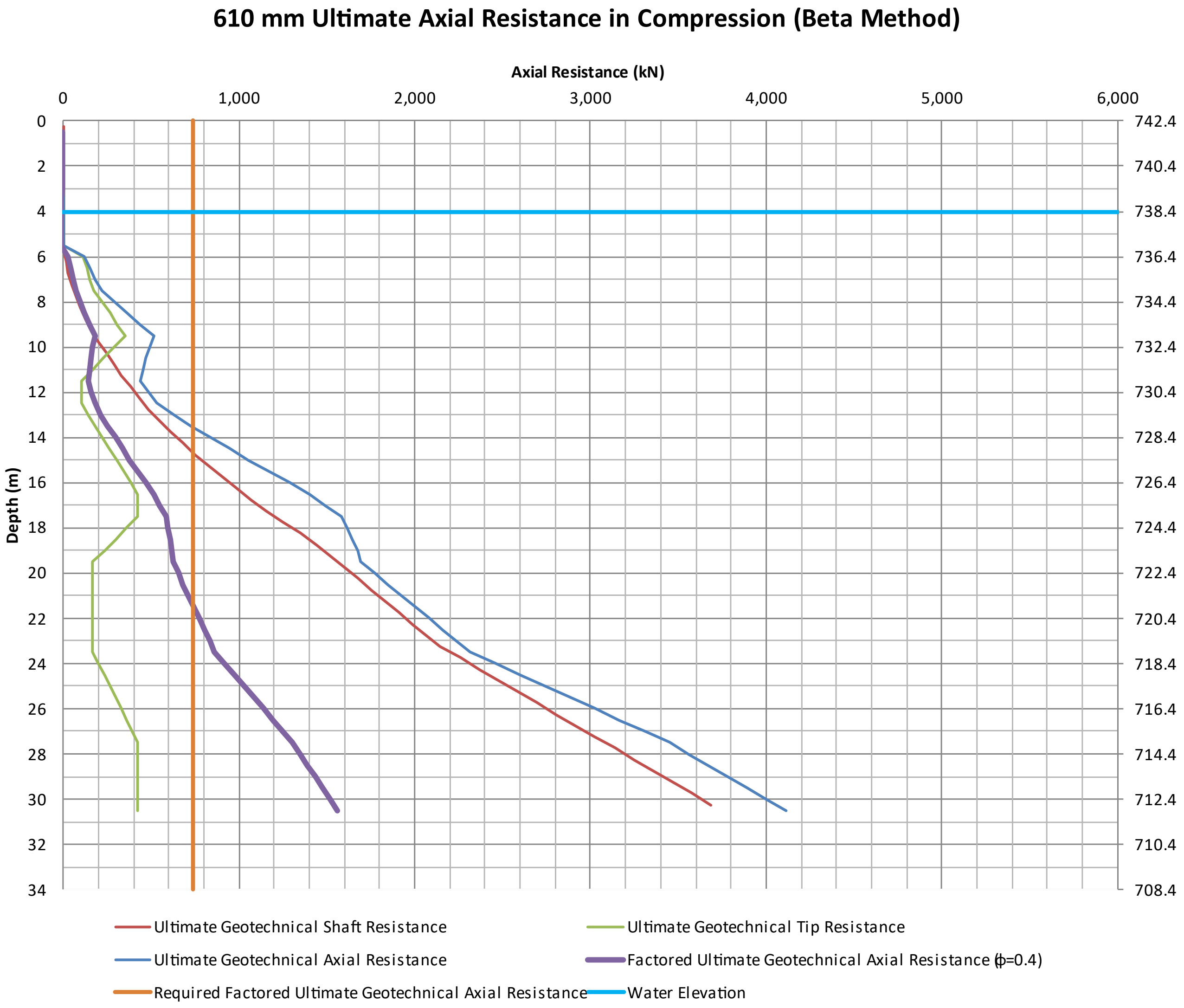
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
Axial Resistance vs Depth
North Abutment (No Scour)

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Figure 2



LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile
- Assume driving shoe is not an exterior weld
- Calculated using the Beta Method
- Geotechnical Resistance Factor of 0.4 was utilized to calculate the Factored Geotechnical Axial Resistance
- The weight of the pile has been subtracted from the Factored Ultimate Geotechnical Resistance values

STATUS

ISSUED FOR REVIEW

CLIENT

British Columbia
Ministry of Transportation and Infrastructure

TETRA TECH

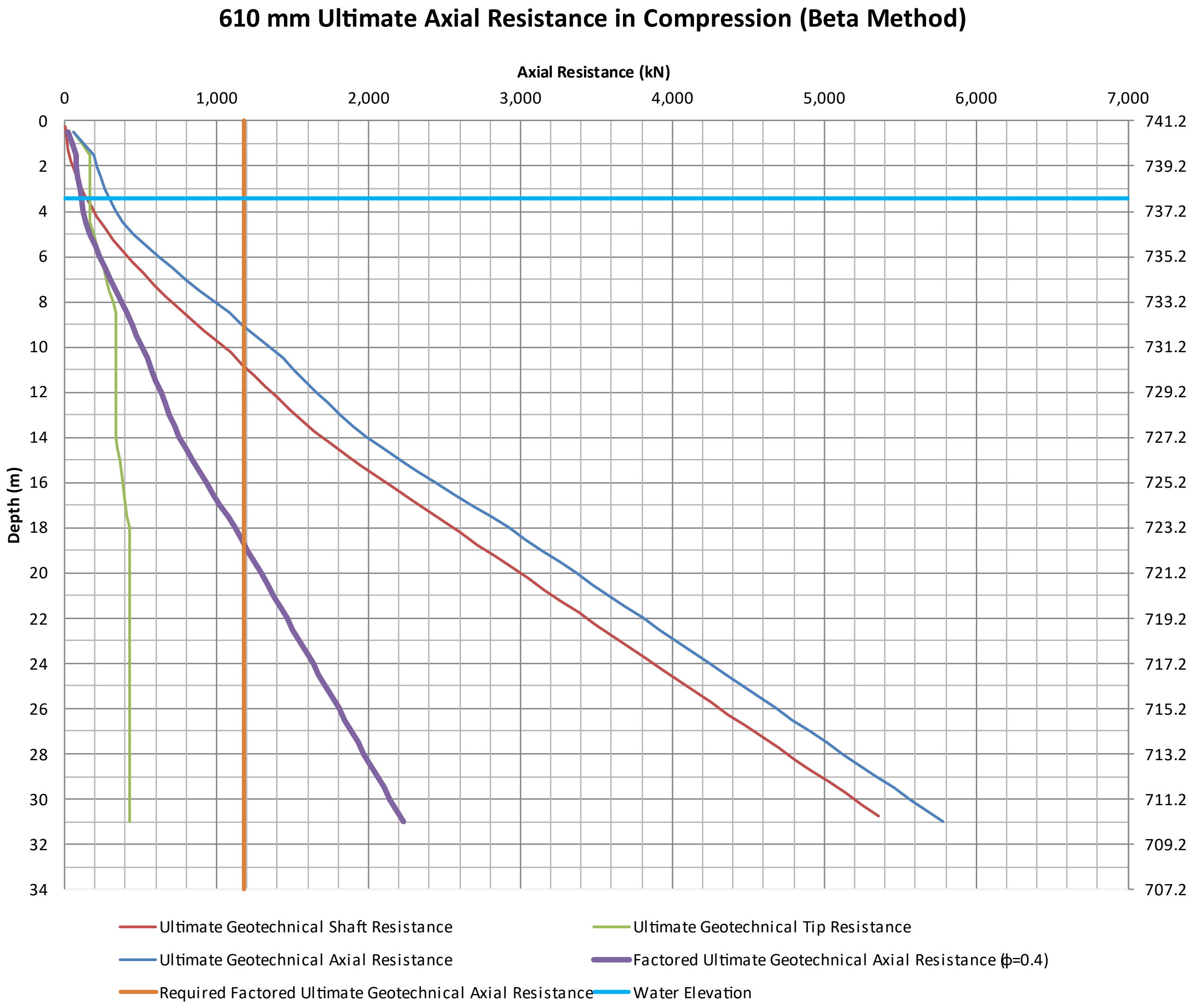
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
Axial Resistance vs Depth
North Abutment (5.2 m Scour)

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	XXX

OFFICE	DATE
Kelowna	Nov 07, 2024

Figure 3



LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile
- Assume driving shoe is not an exterior weld
- Calculated using the Beta Method
- Geotechnical Resistance Factor of 0.4 was utilized to calculate the Factored Geotechnical Axial Resistance
- The weight of the pile has been subtracted from the Factored Ultimate Geotechnical Resistance values

STATUS

ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

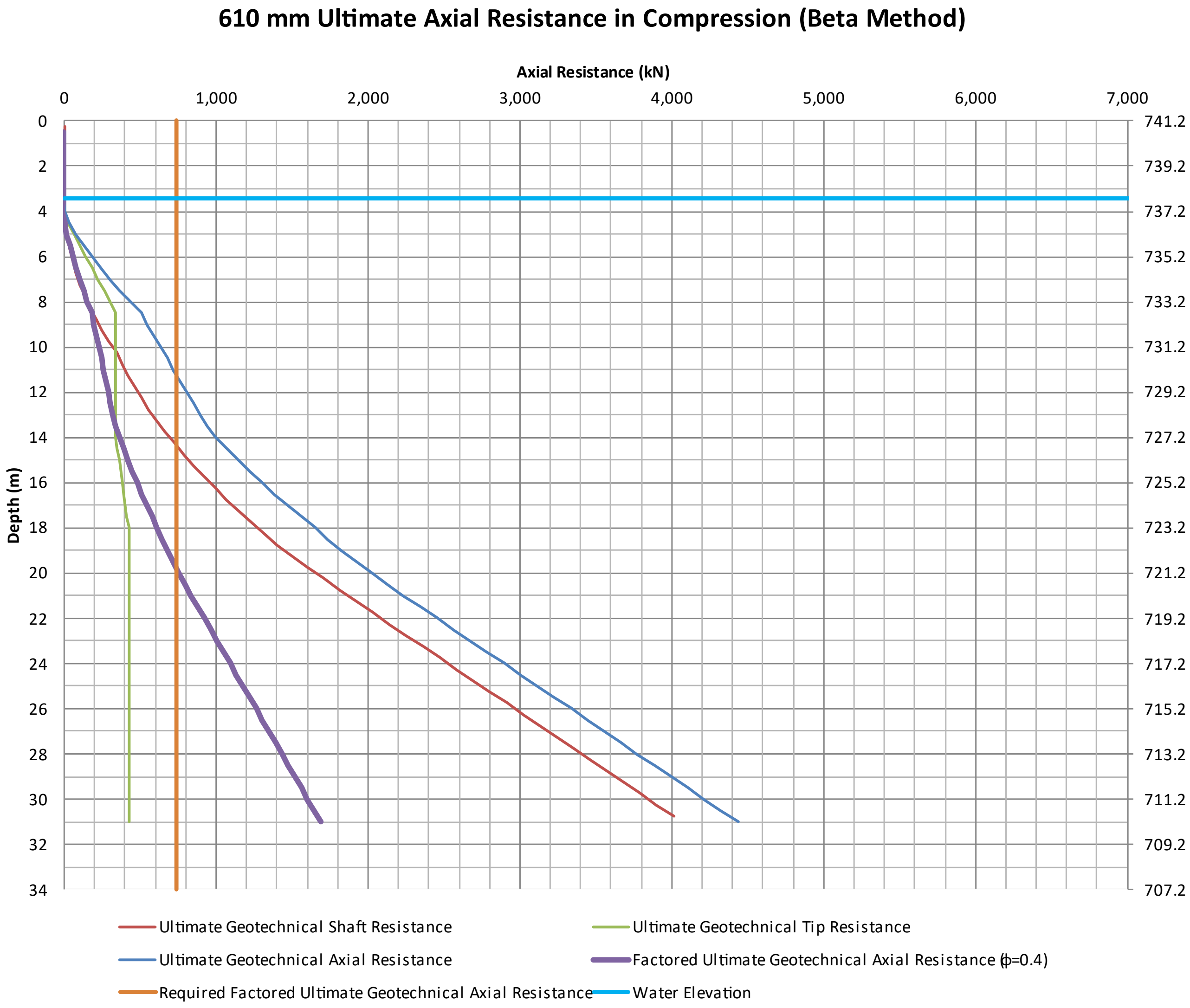
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
Axial Resistance vs Depth
South Abutment (No Scour)

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	XXX

OFFICE	DATE
Kelowna	Nov 07, 2024

Figure 4



610 mm Ultimate Axial Resistance in Compression (Beta Method)

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile
- Assume driving shoe is not an exterior weld
- Calculated using the Beta Method
- Geotechnical Resistance Factor of 0.4 was utilized to calculate the Factored Geotechnical Axial Resistance
-The weight of the pile has been subtracted from the Factored Ultimate Geotechnical Resistance values

STATUS
ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
Axial Resistance vs Depth
South Abutment (4.0m Scour)

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	SG	SG	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Figure 5

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or 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. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, 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 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards 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.

1.9 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.

1.10 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 historical 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 exploration and review may be necessary.

1.11 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.

1.12 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.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact 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, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and 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.

1.15 DRAINAGE SYSTEMS

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. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters 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 used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 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.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX B

TESTHOLE LOGS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

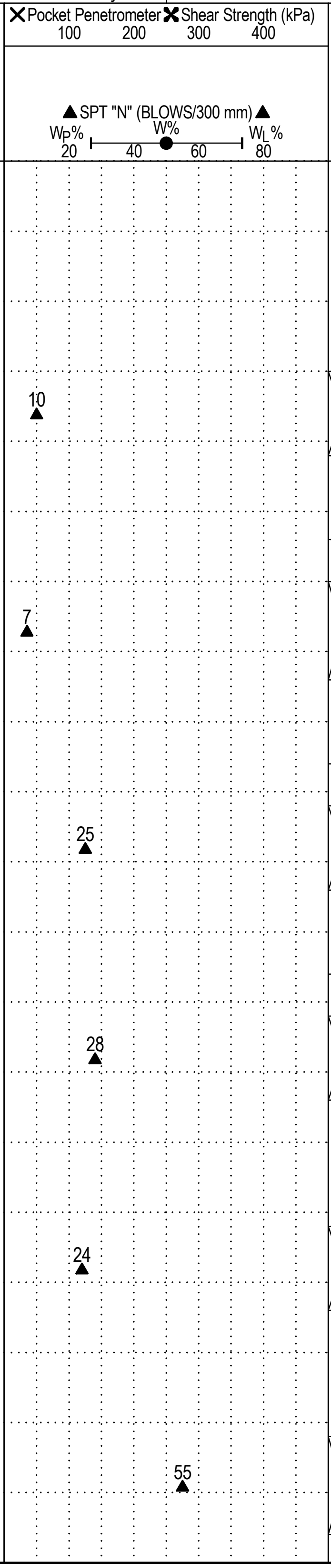
Drill Hole #: **TH22-01**

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC

Prepared by: KGEO03692-02.007
Tetra Tech
Logged by: DB Reviewed by: SG

Datum: 10
Northing/Easting: 5486076 , 668103
Elevation: 741.2 m
Alignment:
Station/Offset:
Coordinates taken with GPS 05/21/2022

Date(s) Drilled: 5/20/2022-5/21/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



Drilling details: 3.4m 5/20/2022 (water level)

Sample Type	Sample No	Recovery (%)	SPT "N"
S-Split Spoon	SPT1	8	10
O-Odex	DS2		
S-Split Spoon	SPT3	13	7
O-Odex	DS4		
S-Split Spoon	SPT5	25	25
O-Odex	DS6		
S-Split Spoon	SPT7	42	28
S-Split Spoon	SPT8	50	24
S-Split Spoon	SPT9	42	55

Depth (m)	Soil Description	Classification	Comments Testing Drillers Estimate *{G % S % F %}*
0	GRAVEL and SAND, trace silt, trace to some cobbles, and fragments of wood debris, poorly graded, dry, compact, greyish brown; medium to coarse sand; fine to coarse subrounded to subangular gravel	GP-GM	
2.1m	SAND and GRAVEL, trace to some silt, trace to some cobbles, poorly graded, moist, loose to compact, dark grey; medium to coarse sand; fine to coarse subrounded to subangular gravel -water table encountered, material becomes wet, brown	SP-SM	
4.9m	GRAVEL, sandy, some silt, trace to some cobbles, well graded, wet, compact, dark grey; fine to coarse sand; fine to coarse subrounded gravel -1.5 m section of casing was lost in hole. Hole was abandoned and moved to the shown co-ordinates	GP-GM	
7.6m	SAND and GRAVEL, trace to some silt, trace to some cobbles, well graded, wet, compact, greyish brown; fine to coarse sand; fine to coarse subrounded to subangular gravel	SP-SM	
9.1m	SAND, gravelly, trace silt, poorly graded, wet, very dense, greyish brown; medium sand, coarse subangular gravel	SP-	

Depth (m)	Elevation (m)
0	741
1	740
2	739
3	738
4	737
5	736
6	735
7	734
8	733
9	732
10	

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

SUMMARY LOG

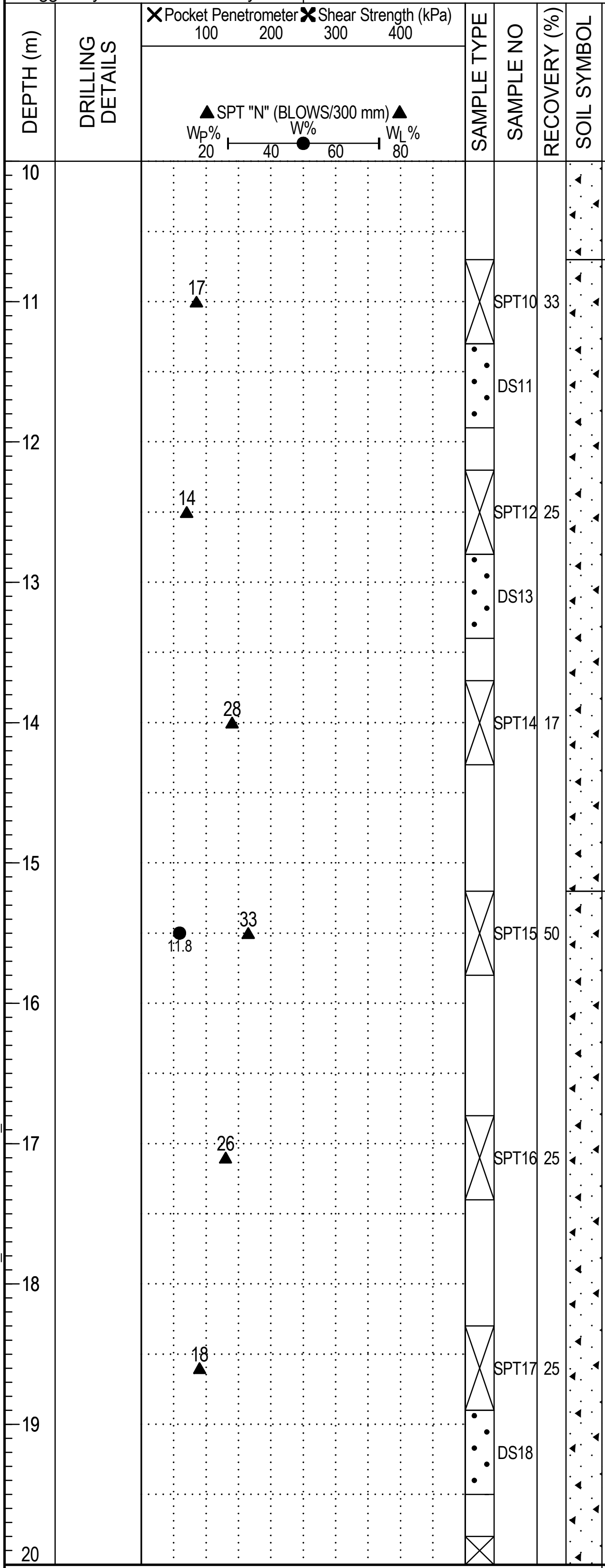
Drill Hole #: TH22-01

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC

Prepared by: KGEO03692-02.007
Tetra Tech
Logged by: DB Reviewed by: SG

Datum: 10
Northing/Easting: 5486076 , 668103
Elevation: 741.2 m
Alignment:
Station/Offset:
Coordinates taken with GPS 05/21/2022

Date(s) Drilled: 5/20/2022-5/21/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



SAMPLE NO	RECOVERY (%)	SPT "N"	W%
SPT10	33	17	
DS11			
SPT12	25	14	
DS13			
SPT14	17	28	
SPT15	50	33	11.8
SPT16	25	26	
SPT17	25	18	
DS18			

SOIL DESCRIPTION

SAND, gravelly, trace silt, poorly graded, wet, very dense, greyish brown; medium sand, coarse subangular gravel *(continued)*

CLASSIFICATION: SM

10.7m

GRAVEL and SAND, trace silt, trace to some cobbles, poorly graded, wet, compact to dense, grey; coarse sand; fine to coarse angular gravel

CLASSIFICATION: GP-GM

15.2m

GRAVEL and SAND, some silt, trace to some cobbles, poorly graded, wet, dense, grey; fine to coarse sand; fine to coarse subrounded to subangular gravel

-becomes compact, trace silt at 16.8 m

-becomes dense at 19.8 m

COMMENTS TESTING

Drillers Estimate
{G % S % F %}

Sieve (Sa#SPT15)
G:50% S:35% F:16%

ELEVATION (m)
731
730
729
728
727
726
725
724
723
722

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

Prepared by: KGEO03692-02.007
Tetra Tech

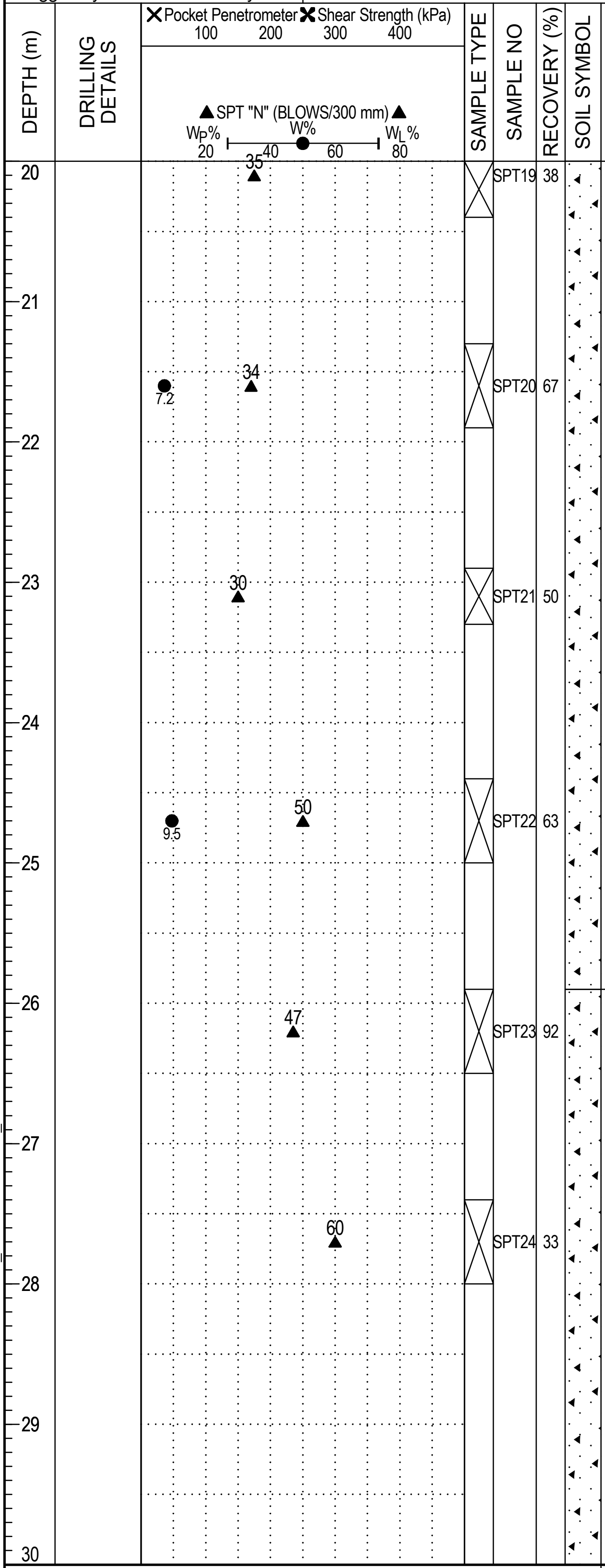
Logged by: DB Reviewed by: SG

SUMMARY LOG

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC
Datum: 10
Northing/Easting: 5486076 , 668103
Elevation: 741.2 m
Alignment:
Station/Offset:
Coordinates taken with GPS 05/21/2022

Drill Hole #: **TH22-01**

Date(s) Drilled: 5/20/2022-5/21/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



SOIL DESCRIPTION

GRAVEL and SAND, some silt, trace to some cobbles, poorly graded, wet, dense, grey; fine to coarse sand; fine to coarse subrounded to subangular gravel *(continued)*

-becomes very dense, some silt at 24.4 m

25.9m

SAND, gravelly, trace silt, trace to some cobbles, poorly graded, wet, dense, grey; medium sand; fine to coarse subrounded gravel

-becomes very dense, fine to medium sand, some gravel at 27.4 m

CLASSIFICATION

GP-GM

SP-SM

COMMENTS TESTING

Drillers Estimate
{G % S % F %}

Sieve (Sa#SPT20)
G:57% S:37% F:6%

Sieve (Sa#SPT22)
G:49% S:38% F:13%

ELEVATION (m)

721
720
719
718
717
716
715
714
713
712

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

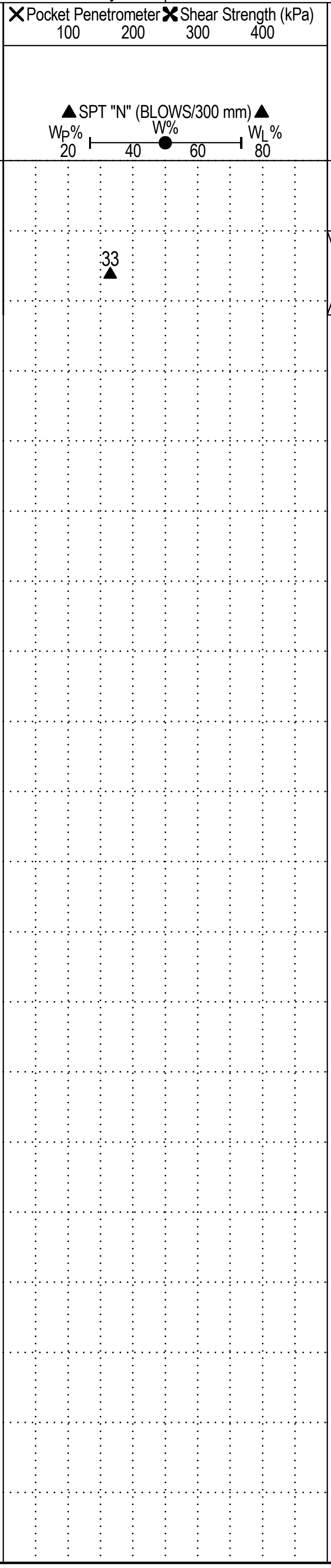
SUMMARY LOG

Drill Hole #: TH22-01

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC
Datum: 10
Alignment:
Northing/Easting: 5486076 , 668103
Station/Offset:
Elevation: 741.2 m
Coordinates taken with GPS 05/21/2022

Prepared by: KGEO03692-02.007
Tetra Tech
Logged by: DB Reviewed by: SG

Date(s) Drilled: 5/20/2022-5/21/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



DEPTH (m)	DRILLING DETAILS	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
30						SAND, gravelly, trace silt, trace to some cobbles, poorly graded, wet, dense, grey; medium sand; fine to coarse subrounded gravel *(continued)*			711
		☒	SPT25	58					
31						31.1m			710
						End of testhole at 31.1 m. Target depth reached.			
32									709
33									708
34									707
35									706
36									705
37									704
38									703
39									702
40									

Legend Sample Type: A-Auger, B-Becker, C-Core, G-Grab, V-Vane, L#-Lab Sample, S-Split Spoon, O-Odex (air rotary), W-Wash (mud return), T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

SUMMARY LOG

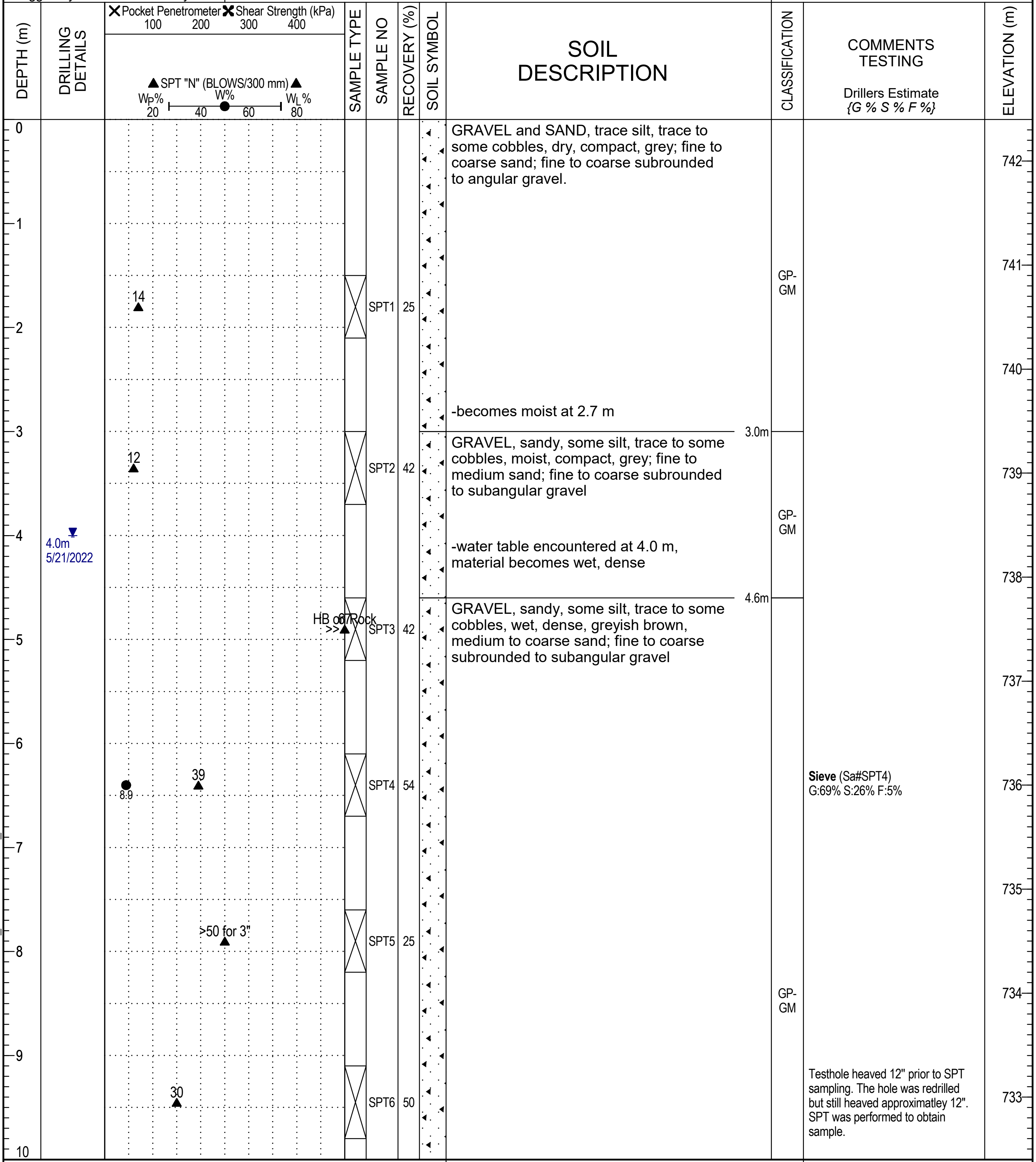
Drill Hole #: **TH22-02**

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC

Prepared by: KGEO03692-02.007
Tetra Tech
Logged by: DB Reviewed by: SG

Datum: 10
Northing/Easting: 5486110 , 668102
Elevation: 742.4 m
Alignment:
Station/Offset:
Coordinates taken with GPS 05/22/2022

Date(s) Drilled: 5/21/2022-5/22/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



SAMPLE NO	RECOVERY (%)
SPT1	25
SPT2	42
SPT3	42
SPT4	54
SPT5	25
SPT6	50

SOIL DESCRIPTION

GRAVEL and SAND, trace silt, trace to some cobbles, dry, compact, grey; fine to coarse sand; fine to coarse subrounded to angular gravel. — GP-GM

-becomes moist at 2.7 m

3.0m

GRAVEL, sandy, some silt, trace to some cobbles, moist, compact, grey; fine to medium sand; fine to coarse subrounded to subangular gravel — GP-GM

-water table encountered at 4.0 m, material becomes wet, dense

4.6m

GRAVEL, sandy, some silt, trace to some cobbles, wet, dense, greyish brown, medium to coarse sand; fine to coarse subrounded to subangular gravel — GP-GM

COMMENTS TESTING

Drillers Estimate
{G % S % F %}

Sieve (Sa#SPT4)
G:69% S:26% F:5%

Testhole heaved 12" prior to SPT sampling. The hole was redrilled but still heaved approximatley 12". SPT was performed to obtain sample.

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

Ministry of Transportation and Infrastructure
BRITISH COLUMBIA

SUMMARY LOG

Drill Hole #: TH22-02

Prepared by: KGEO03692-02.007
Tetra Tech

Logged by: DB Reviewed by: SG

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC
Datum: 10
Alignment:
Northing/Easting: 5486110 , 668102
Station/Offset:
Elevation: 742.4 m
Coordinates taken with GPS 05/22/2022

Date(s) Drilled: 5/21/2022-5/22/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX

✕ Pocket Penetrometer ✕ Shear Strength (kPa) 100 200 300 400
▲ SPT "N" (BLOWS/300 mm) ▲
W_P% W% W_L% 20 40 60 80

DEPTH (m)	DRILLING DETAILS	SPT "N" (BLOWS/300 mm)	W%	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
10							GRAVEL, sandy, some silt, trace to some cobbles, wet, dense, greyish brown, medium to coarse sand; fine to coarse subrounded to subangular gravel *(continued)* -becomes compact, trace silt at 10.7 m			732
11		21		S-Split Spoon	SPT7	50				731
12										
12.2m							SILT and SAND, trace gravel, moist, dense, grey; fine sand; fine subrounded gravel	ML		730
		32	22.8	S-Split Spoon	SPT8	100			**Sieve** (Sa#SPT8) G:3% S:39% F:58%	
13										729
13.7m							GRAVEL and SAND, trace to some silt, trace to some cobbles, wet, very dense, grey; medium to coarse sand; fine to coarse subrounded to subangular gravel	GP-GM		
14		52		S-Split Spoon	SPT9	50				728
15							-becomes dense at 15.2 m			727
		46		S-Split Spoon	SPT10	25				
16										726
17		35		S-Split Spoon	SPT11	17	-becomes sandy at 16.8 m			725
18							-becomes compact at 18.3 m			724
		26	8.8	S-Split Spoon	SPT12	38			**Sieve** (Sa#SPT12) G:57% S:35% F:8%	
19										723
19.8m										
20				S-Split Spoon						

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

SUMMARY LOG

Drill Hole #: **TH22-02**

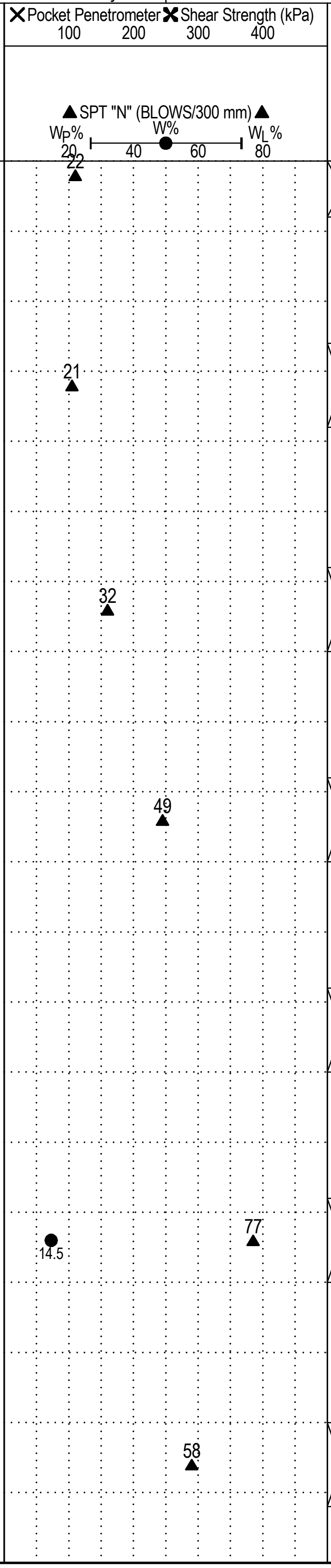
BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

Prepared by: KGEO03692-02.007
Tetra Tech

Logged by: DB Reviewed by: SG

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC
Datum: 10
Alignment:
Northing/Easting: 5486110 , 668102
Station/Offset:
Elevation: 742.4 m
Coordinates taken with GPS 05/22/2022

Date(s) Drilled: 5/21/2022-5/22/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



DEPTH (m)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)
20	S-Split Spoon	SPT13	33
21.5	S-Split Spoon	SPT14	46
23	S-Split Spoon	SPT15	58
24.5	S-Split Spoon	SPT16	58
26	S-Split Spoon	SPT17	33
27.5	S-Split Spoon	SPT18	63
29	S-Split Spoon	SPT19	38

SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*
SAND and GRAVEL, some silt, trace to some cobbles, wet, compact, grey; medium to coarse sand; fine to coarse subrounded to subangular gravel *(continued)* -becomes dense, sandy at 22.9 m	SP-SM	
25.9m SAND and GRAVEL, trace silt, wet, dense to very dense, grey; medium sand; fine to coarse subrounded gravel	SP-SM	Testhole heaved 14" prior to SPT sampling. The hole was redrilled but still heaved approximatley 14". SPT was performed to obtain sample. **Sieve** (Sa#SPT18) G:37% S:56% F:7%
29.0m GRAVEL and SAND, trace silt, wet, very dense, grey; medium to coarse sand; fine to coarse subrounded to subangular gravel		

DEPTH (m): 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

ELEVATION (m): 722, 721, 720, 719, 718, 717, 716, 715, 714, 713

Legend Sample Type: A-Auger, B-Becker, C-Core, G-Grab, V-Vane, L#-Lab Sample, S-Split Spoon, O-Odex (air rotary), W-Wash (mud return), T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

SUMMARY LOG

Drill Hole #: **TH22-02**

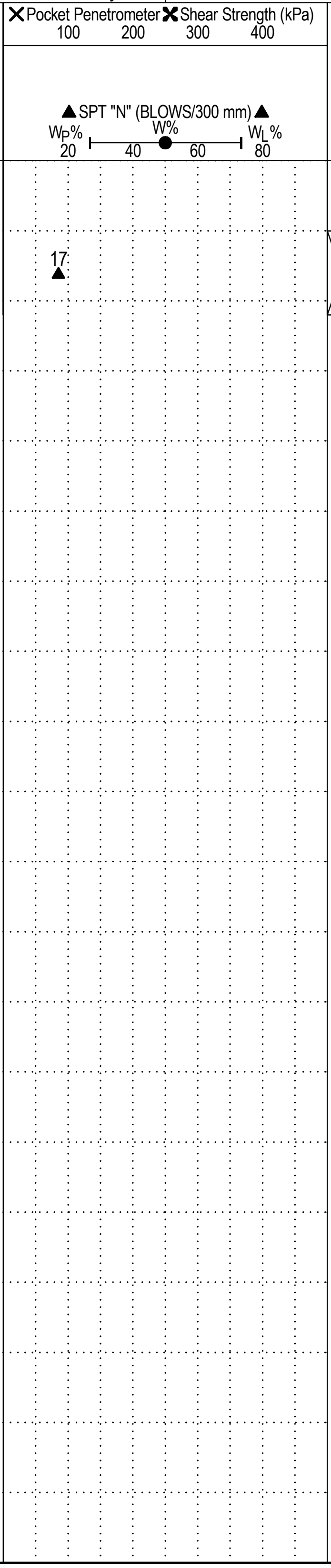
Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC

Prepared by: KGEO03692-02.007
Tetra Tech

Logged by: DB Reviewed by: SG

Datum: 10
Alignment:
Northing/Easting: 5486110 , 668102
Station/Offset:
Elevation: 742.4 m
Coordinates taken with GPS 05/22/2022

Date(s) Drilled: 5/21/2022-5/22/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



DEPTH (m)	DRILLING DETAILS	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*	ELEVATION (m)
30						GRAVEL and SAND, trace silt, wet, very dense, grey; medium to coarse sand; fine to coarse subrounded to subangular gravel *(continued)* -becomes compact at 30.5 m	GP-GM		712
		☒	SPT20	29					
31						31.1m			
						End of testhole at 31.1 m. Target depth reached.			711
32									710
33									709
34									708
35									707
36									706
37									705
38									704
39									703
40									

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 31.1 m
Depth to Top of Rock:

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

Prepared by: KGEO03692-02.007
Tetra Tech

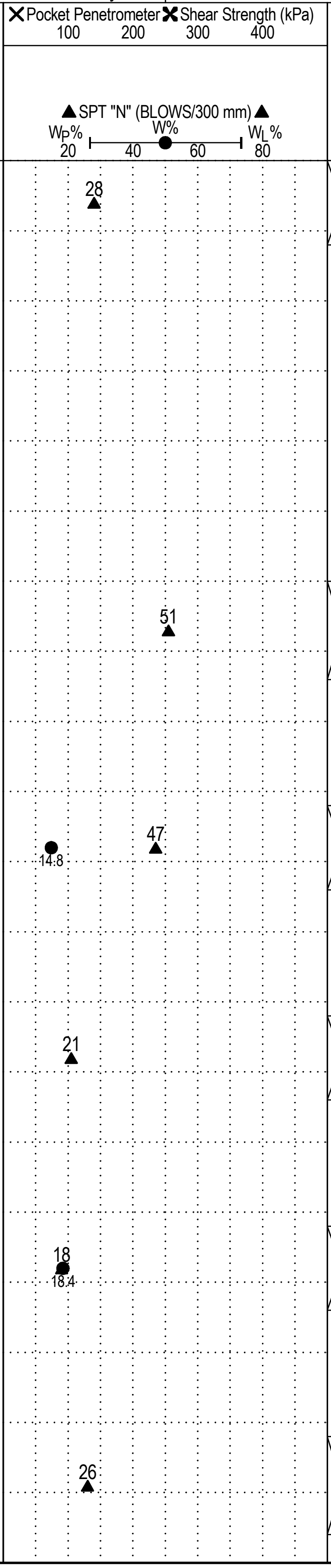
Logged by: DB Reviewed by: SG

SUMMARY LOG

Project: 25757 - 233 Rice Bridge 6543 at Rice Road
Location: Coalmont, BC
Datum: 10
Alignment:
Northing/Easting: 5486031 , 668138
Station/Offset:
Elevation: 740.4 m
Coordinates taken with GPS 05/23/2022

Drill Hole #: TH22-03

Date(s) Drilled: 5/22/2022-5/23/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



DEPTH (m)	DRILLING DETAILS	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SPT "N"	W%
0.3		S	SPT1	63	28	
3.4	3.4m 5/22/2022 (water level)	S	SPT2	42	51	
4.9		S	SPT3	71	47	14.8
6.4		S	SPT4	46	21	
7.9		S	SPT5	54	18	18.4
9.4		S	SPT6	42	26	

Depth to base	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*
0.9m	SAND and GRAVEL, trace silt, occasional cobbles and boulders, dry, compact, grey; fine to coarse sand; fine to coarse subrounded to subangular gravel	SP	
2.1m	BOULDER		
4.6m	GRAVEL and SAND, trace silt, moist, very dense, grey; medium to coarse sand; fine to coarse subrounded to subangular gravel -water table encountered at 3.4 m, material becomes wet	GP	
6.1m	SAND, gravelly, trace to some silt, wet, dense, grey; medium sand; fine to coarse subrounded gravel	SP-SM	**Sieve** (Sa#SPT3) G:31% S:59% F:5%
7.6m	GRAVEL, sandy, trace silt, wet, compact, greyish brown; medium sand; fine to coarse subrounded to subangular gravel -becomes some silt at 6.7 m	GP-GM	
	SAND, gravelly, trace to some silt, wet, compact to dense, grey; medium sand; fine to coarse subrounded gravel -becomes sand and gravel at 9.1 m		**Sieve** (Sa#SPT5) G:23% S:69% F:8%

DEPTH (m)	ELEVATION (m)
0	
	740
1	
	739
2	
	738
3	
	737
4	
	736
5	
	735
6	
	734
7	
	733
8	
	732
9	
	731
10	

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 15.8 m
Depth to Top of Rock:

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SUMMARY LOG

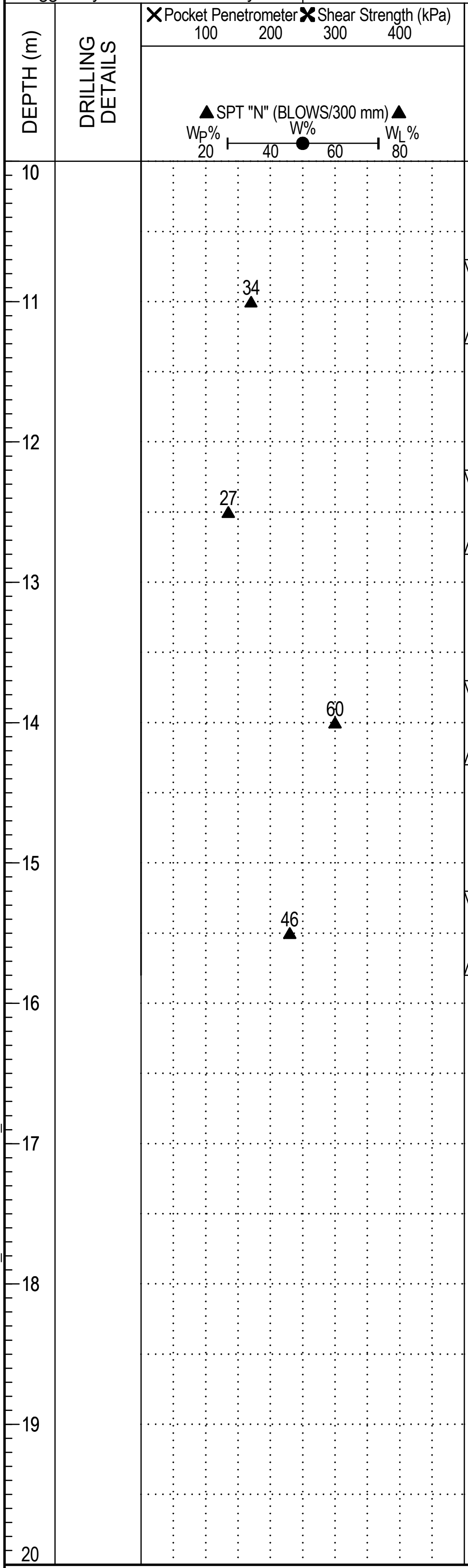
Drill Hole #: **TH22-03**

Project: **25757 - 233 Rice Bridge 6543 at Rice Road**
Location: Coalmont, BC

Prepared by: KGEO03692-02.007
Tetra Tech
Logged by: DB Reviewed by: SG

Datum: 10
Northing/Easting: 5486031 , 668138
Elevation: 740.4 m
Alignment:
Station/Offset:
Coordinates taken with GPS 05/23/2022

Date(s) Drilled: 5/22/2022-5/23/2022
Company: Geotech Drilling Services Ltd.
Driller: Nicholas Westbrook
Drill Make/Model: Fraste MDXL
Drilling Method: ODEX



SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SPT "N"
☒	SPT7	54	34
☒	SPT8	46	27
☒	SPT9	54	60
☒	SPT10	71	46

SOIL DESCRIPTION

SAND, gravelly, trace to some silt, wet, compact to dense, grey; medium sand; fine to coarse subrounded gravel *(continued)*

CLASSIFICATION: SP-SM

15.8m

End of testhole at 15.8 m. Target depth reached.

COMMENTS TESTING
Drillers Estimate
{G % S % F %}

ELEVATION (m): 730 729 728 727 726 725 724 723 722 721

Legend
Sample Type:
A-Auger
B-Becker
C-Core
G-Grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 15.8 m
Depth to Top of Rock:

APPENDIX C

LABORATORY TESTING RESULTS

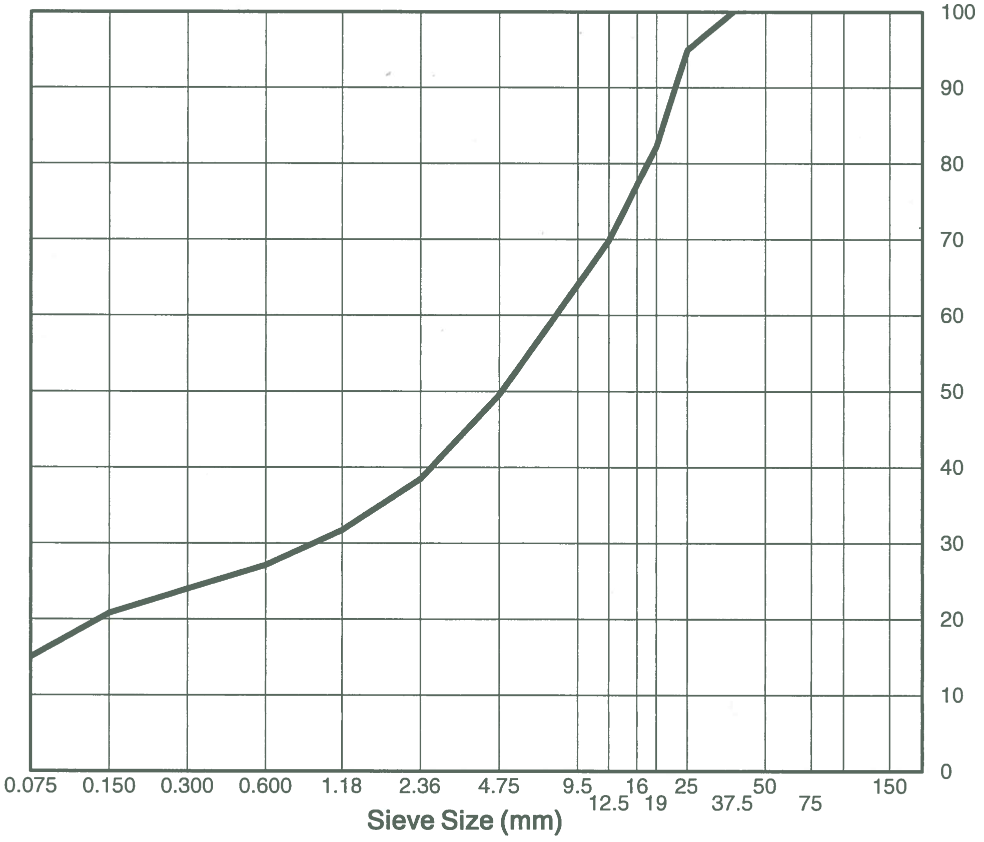
SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007
Project: Rice Bridge Geotechnical Assessment
Client: B.C. Ministry of Transportation
Attention: See e-mail distribution
Email: See e-mail distribution
Description: 37.5 mm (-) GRAVEL, sandy, some silt
Source: N/A
Depth: 50' - 52'
Sample Location: TH22-01, SPT 15
Specification: N/A

Sample No.: KS-10000
Date Sampled: May 20, 2022
Sampled by: DB
Date Tested: May 31, 2022
Tested by: CP Office: Kelowna
Moisture Content (as received): 11.8%
No. Crushed Faces: One (1) or Two (2)
By particle mass:

Sieve Size	Percent Passing
37.5	100
25	95
19	82
12.5	70
9.5	64
4.75	50
2.36	38
1.18	32
0.600	27
0.300	24
0.150	21
0.075	15.0



Remarks:

Reviewed By: C.Tech.

TETRA TECH

SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007

Project: Rice Bridge Geotechnical Assessment

Client: B.C. Ministry of Transportation

Attention: See e-mail distribution

Email: See e-mail distribution

Description: 37.5 mm (-) GRAVEL and SAND, trace silt

Source: N/A

Depth: 70' - 72'

Sample Location: TH22-01, SPT 20

Specification: N/A

Sample No.: KS-10001

Date Sampled: May 20, 2022

Sampled by: DB

Date Tested: May 31, 2022

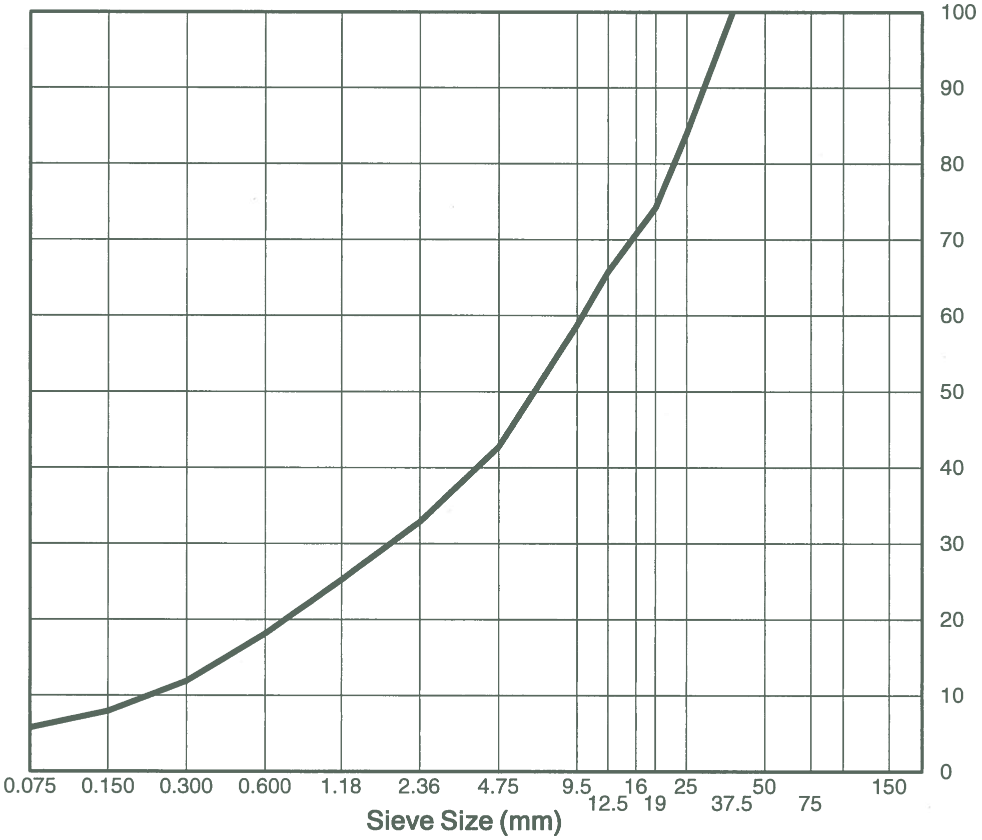
Tested by: CP Office: Kelowna

Moisture Content (as received): 7.2%

No. Crushed Faces: One (1) or Two (2)

By particle mass:

Sieve Size	Percent Passing
37.5	100
25	84
19	74
12.5	66
9.5	59
4.75	43
2.36	33
1.18	25
0.600	18
0.300	12
0.150	8
0.075	5.7



Remarks:

Reviewed By: C.Tech.

TETRA TECH

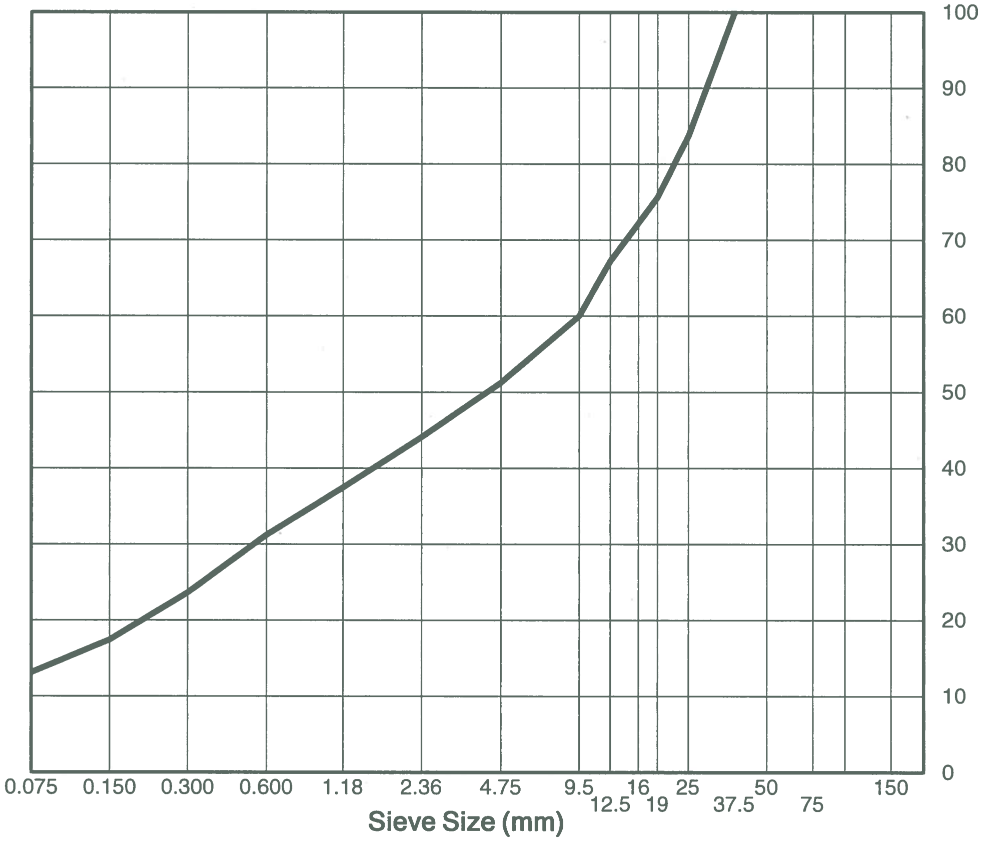
SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007
Project: Rice Bridge Geotechnical Assessment
Client: B.C. Ministry of Transportation
Attention: See e-mail distribution
Email: See e-mail distribution
Description: 37.5 mm (-) GRAVEL and SAND, some silt
Source: N/A
Depth: 80' - 82'
Sample Location: TH22-01, SPT 22
Specification: N/A

Sample No.: KS-10002
Date Sampled: May 20, 2022
Sampled by: DB
Date Tested: May 31, 2022
Tested by: CP Office: Kelowna
Moisture Content (as received): 9.5%
No. Crushed Faces: One (1) or Two (2)
By particle mass:

Sieve Size	**Percent Passing**
37.5	100
25	84
19	76
12.5	67
9.5	60
4.75	51
2.36	44
1.18	37
0.600	31
0.300	24
0.150	17
0.075	13.1



Remarks:

Reviewed By: C.Tech.

TETRA TECH

SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007

Project: Rice Bridge Geotechnical Assessment

Client: B.C. Ministry of Transportation

Attention: See e-mail distribution

Email: See e-mail distribution

Description: 37.5 mm (-) GRAVEL, sandy, trace silt

Source: N/A

Depth: 20' - 22'

Sample Location: TH22-02, SPT 4

Specification: N/A

Sample No.: KS-10003

Date Sampled: May 21, 2022

Sampled by: DB

Date Tested: May 31, 2022

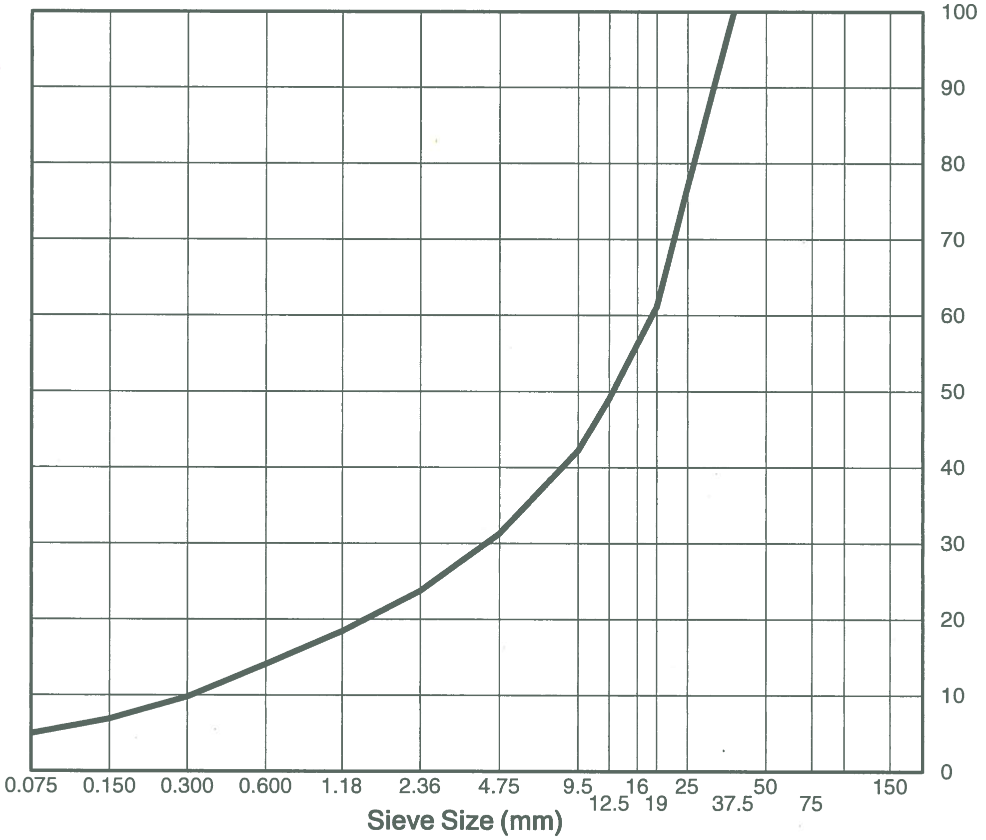
Tested by: CP Office: Kelowna

Moisture Content (as received): 8.9%

No. Crushed Faces: One (1) or Two (2)

By particle mass:

Sieve Size	Percent Passing
37.5	100
25	77
19	61
12.5	49
9.5	42
4.75	31
2.36	24
1.18	18
0.600	14
0.300	10
0.150	7
0.075	5.0



Remarks:

Reviewed By: C.Tech.

TETRA TECH

SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007

Project: Rice Bridge Geotechnical Assessment

Client: B.C. Ministry of Transportation

Attention: See e-mail distribution

Email: See e-mail distribution

Description: 37.5 mm (-) SILT and SAND, trace gravel

Source: N/A

Depth: 40' - 42'

Sample Location: TH22-02, SPT 8

Specification: N/A

Sample No.: KS-10004

Date Sampled: May 21, 2022

Sampled by: DB

Date Tested: May 31, 2022

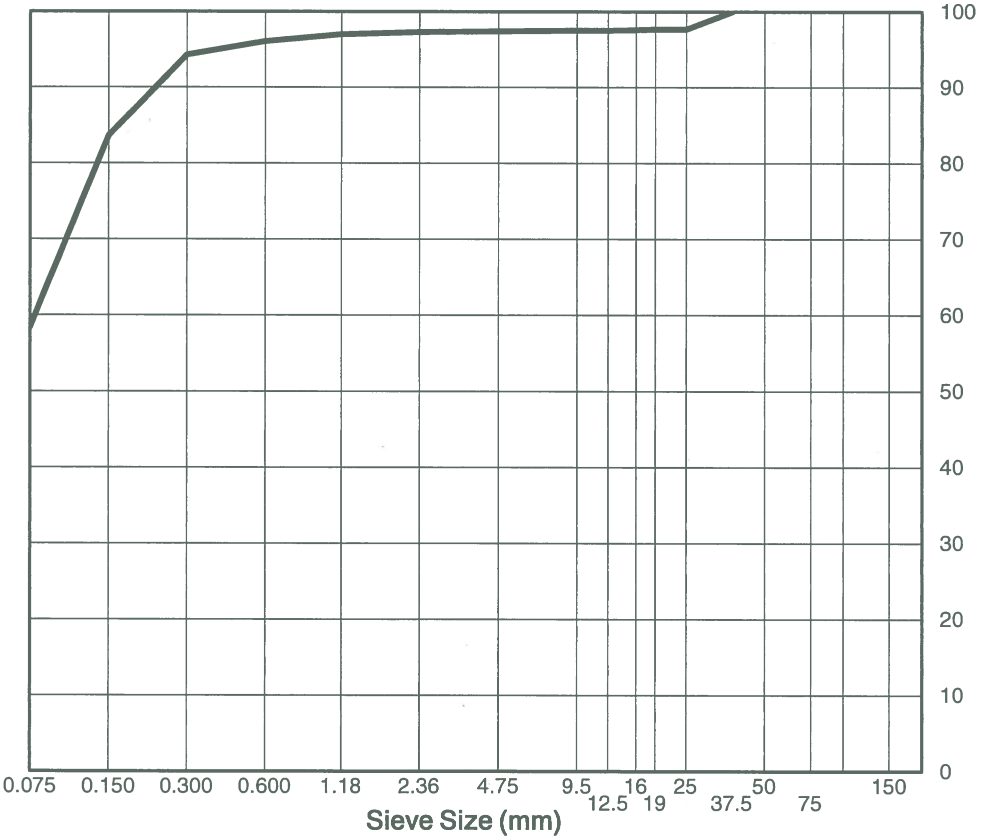
Tested by: CP Office: Kelowna

Moisture Content (as received): 22.8%

No. Crushed Faces: One (1) or Two (2)

By particle mass: ______ ______

Sieve Size	Percent Passing
37.5	100
25	98
19	98
12.5	97
9.5	97
4.75	97
2.36	97
1.18	97
0.600	96
0.300	94
0.150	84
0.075	58.4



Remarks:

Reviewed By: ______________ C.Tech.

TETRA TECH

SIEVE ANALYSIS REPORT

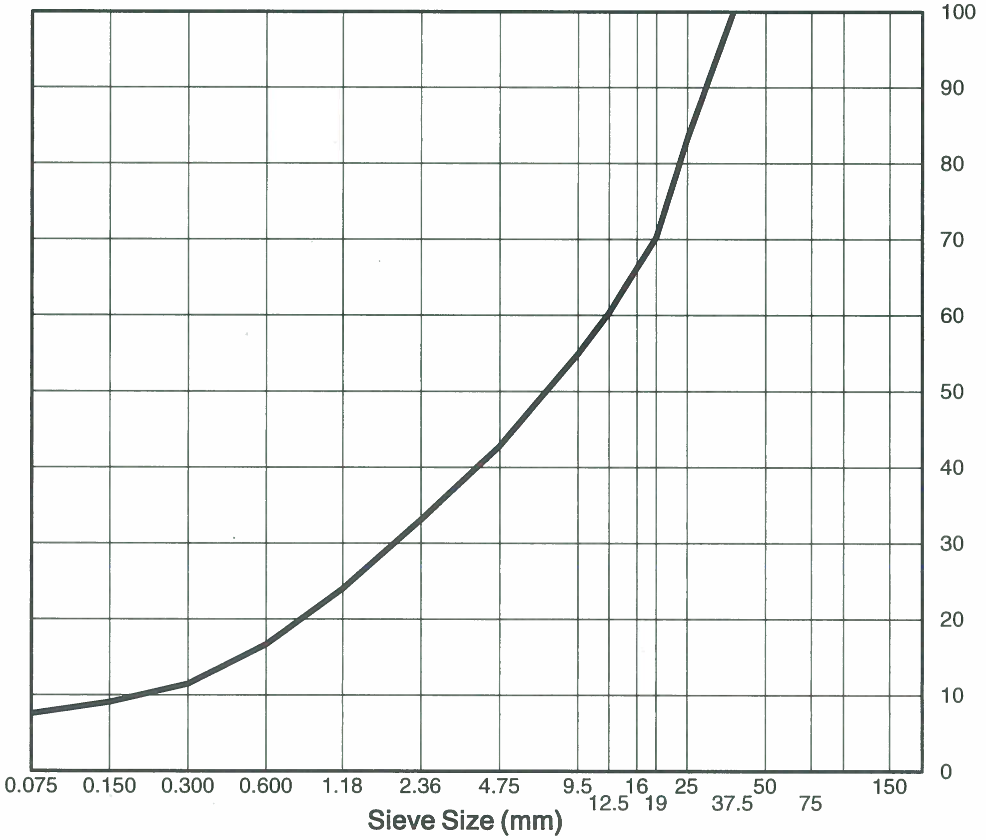
Washed Sieve: ASTM C136 and C117

Project No.:	704-ENG.KGEO03692-02.007	Sample No.:	KS-10005
Project:	Rice Bridge Geotechnical Assessment	Date Sampled:	May 21, 2022
		Sampled by:	DB
Client:	B.C. Ministry of Transportation	Date Tested:	May 31, 2022
Attention:	See e-mail distribution	Tested by:	CP Office: Kelowna
Email:	See e-mail distribution	Moisture Content (as received):	8.8%
Description:	37.5 mm (-) GRAVEL and SAND, trace silt	No. Crushed Faces:	One (1) or Two (2)
Source:	N/A	By particle mass:	
Depth:	60' - 62'		

Sample Location: TH22-02, SPT 12

Specification: N/A

Sieve Size	Percent Passing
37.5	100
25	83
19	70
12.5	60
9.5	55
4.75	43
2.36	33
1.18	24
0.600	17
0.300	11
0.150	9
0.075	7.6



Remarks:

Reviewed By: C.Tech.

TETRA TECH

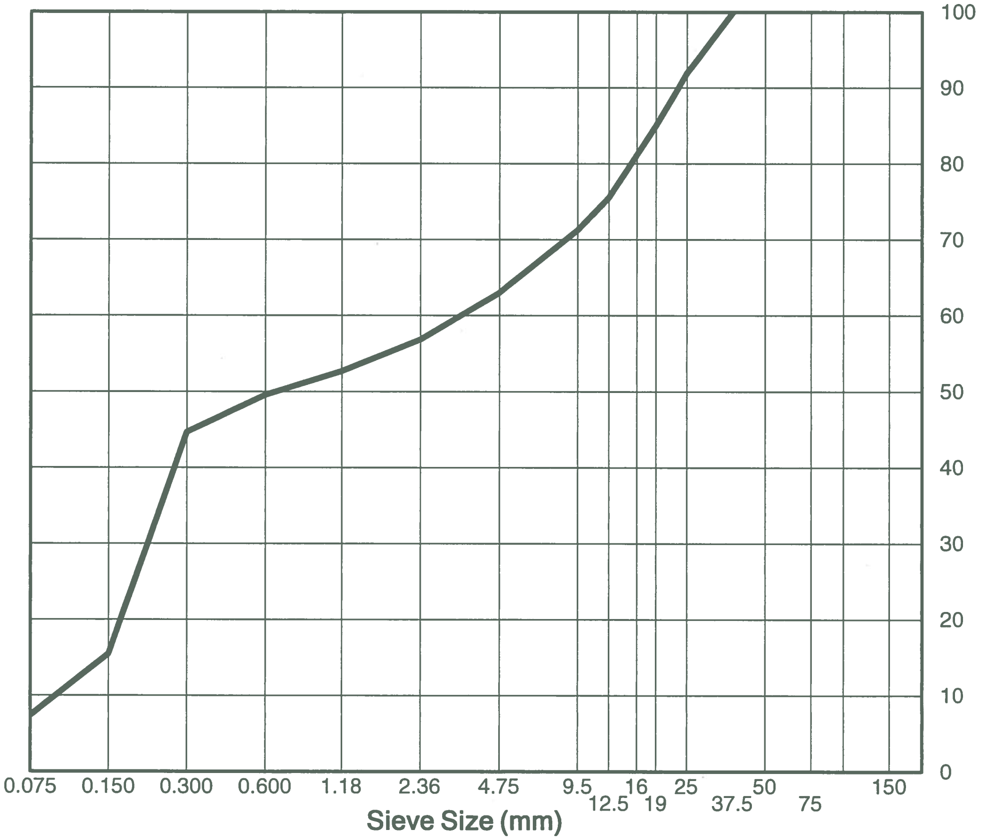
SIEVE ANALYSIS REPORT

Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007
Project: Rice Bridge Geotechnical Assessment
Client: B.C. Ministry of Transportation
Attention: See e-mail distribution
Email: See e-mail distribution
Description: 37.5 mm (-) SAND and GRAVEL, trace silt
Source: N/A
Depth: 90' - 92'
Sample Location: TH22-02, SPT 18
Specification: N/A

Sample No.: KS-10006
Date Sampled: May 21, 2022
Sampled by: DB
Date Tested: May 31, 2022
Tested by: CP Office: Kelowna
Moisture Content (as received): 14.5%
No. Crushed Faces: One (1) or Two (2)
By particle mass:

Sieve Size	Percent Passing
37.5	100
25	92
19	85
12.5	76
9.5	71
4.75	63
2.36	57
1.18	53
0.600	50
0.300	45
0.150	15
0.075	7.4



Remarks:

Reviewed By: C.Tech.

SIEVE ANALYSIS REPORT

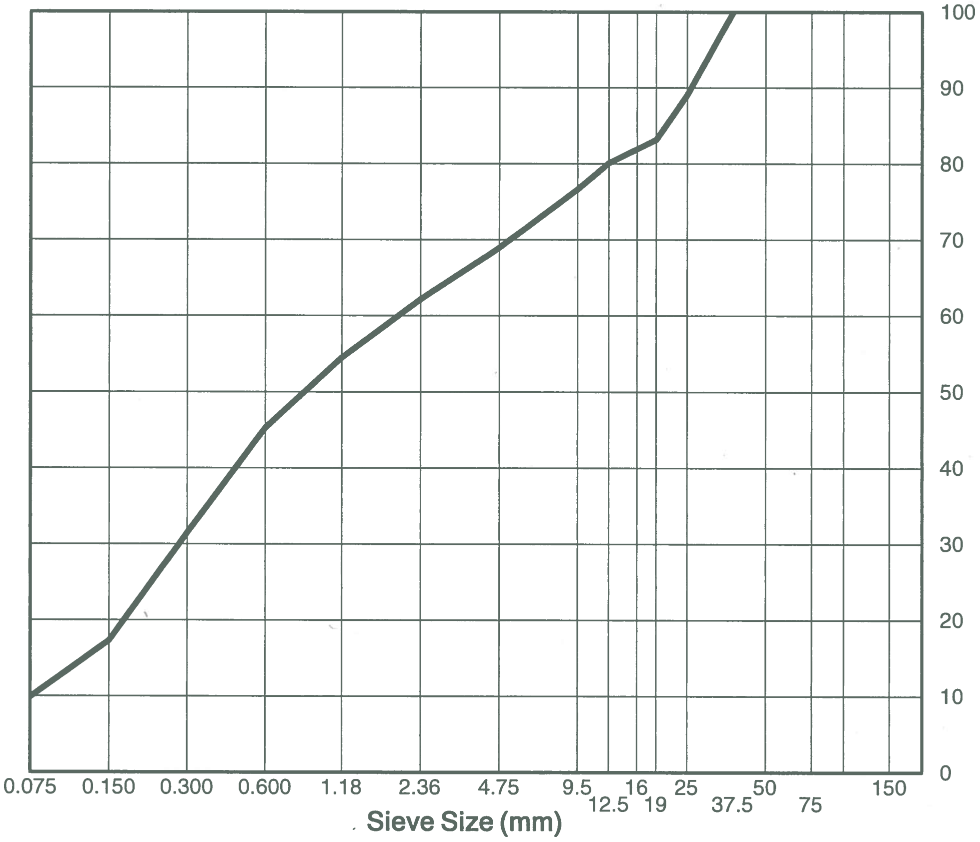
Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007
Project: Rice Bridge Geotechnical Assessment
Client: B.C. Ministry of Transportation
Attention: See e-mail distribution
Email: See e-mail distribution
Description: 37.5 mm (-) SAND and GRAVEL, trace silt
Source: N/A
Depth: 15' - 17'

Sample No.: KS-10007
Date Sampled: May 22, 2022
Sampled by: DB
Date Tested: May 31, 2022
Tested by: CP Office: Kelowna
Moisture Content (as received): 14.8%
No. Crushed Faces: One (1) or Two (2)
By particle mass:

Sample Location: TH22-03, SPT 3
Specification: N/A

Sieve Size	Percent Passing
37.5	100
25	89
19	83
12.5	80
9.5	77
4.75	69
2.36	62
1.18	55
0.600	45
0.300	31
0.150	17
0.075	9.9



Remarks:

Reviewed By: C.Tech.

TETRA TECH

SIEVE ANALYSIS REPORT

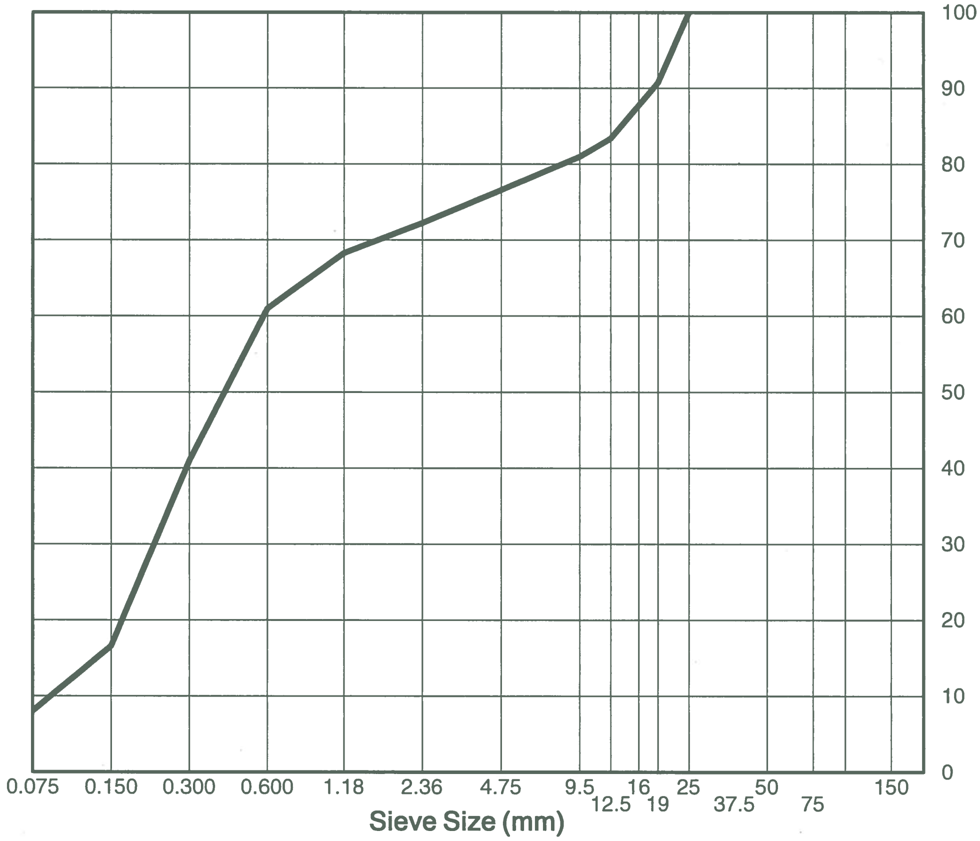
Washed Sieve: ASTM C136 and C117

Project No.: 704-ENG.KGEO03692-02.007
Project: Rice Bridge Geotechnical Assessment
Client: B.C. Ministry of Transportation
Attention: See e-mail distribution
Email: See e-mail distribution
Description: 25 mm (-) SAND, gravelly, trace silt
Source: N/A
Depth: 25' - 27'

Sample No.: KS-10008
Date Sampled: May 22, 2022
Sampled by: DB
Date Tested: May 31, 2022
Tested by: CP Office: Kelowna
Moisture Content (as received): 18.4%
No. Crushed Faces: One (1) or Two (2)
By particle mass:

Sample Location: TH22-03, SPT 5
Specification: N/A

Sieve Size	**Percent Passing**
25	100
19	91
12.5	83
9.5	81
4.75	77
2.36	72
1.18	68
0.600	61
0.300	41
0.150	17
0.075	8.0



Remarks:

Reviewed By: C.Tech.

TETRA TECH

CERTIFICATE OF ANALYSIS

REPORTED TO Tetra Tech EBA Inc. (Kelowna)
150 - 1715 Dickson Ave.
Kelowna, BC V1Y 9G6

ATTENTION Dylan Bryce

WORK ORDER 22L1431

PO NUMBER 704-ENG.KGEO03692-02
PROJECT 704-ENG.KGEO03692-02
PROJECT INFO

RECEIVED / TEMP 2022-12-13 14:52 / 17.6°C
REPORTED 2022-12-20 13:54
COC NUMBER B095873

Introduction:

CARO Analytical Services is a testing laboratory full of smart, engaged scientists driven to make the world a safer and healthier place. Through our clients' projects we become an essential element for a better world. We employ methods conducted in accordance with recognized professional standards using accepted testing methodologies and quality control efforts. CARO is accredited by the Canadian Association for Laboratories Accreditation (CALA) to ISO/IEC 17025:2017 for specific tests listed in the scope of accreditation approved by CALA.

Big Picture Sidekicks

You know that the sample you collected after snowshoeing to site, digging 5 meters, and racing to get it on a plane so you can submit it to the lab for time sensitive results needed to make important and expensive decisions (whew) is VERY important. We know that too.

We've Got Chemistry

It's simple. We figure the more you enjoy working with our fun and engaged team members; the more likely you are to give us continued opportunities to support you.

Ahead of the Curve

Through research, regulation knowledge, and instrumentation, we are your analytical centre for the technical knowledge you need, BEFORE you need it, so you can stay up to date and in the know.

By engaging our services, you are agreeing to CARO Analytical Service's Standard Terms and Conditions outlined here:
https://www.caro.ca/terms-conditions

If you have any questions or concerns, please contact me at rpshyk@caro.ca

Authorized By:

Regan Pshyk
Account Manager

TEST RESULTS

REPORTED TO	Tetra Tech EBA Inc. (Kelowna)	**WORK ORDER**	22L1431
PROJECT	704-ENG.KGEO03692-02	**REPORTED**	2022-12-20 13:54

Analyte	Result	RL	Units	Analyzed	Qualifier
3692-02-03 SPT3 10'-12' (22L1431-01) | Matrix: Soil | Sampled: 2022-05-23					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2022-12-19	
Chloride, Water-Soluble	< 0.002	0.002	%	2022-12-20	
pH (1:2 H2O Solution)	**7.92**	0.10	pH units	2022-12-19	
3692-02-08 SPT1 0'-2' (22L1431-02) | Matrix: Soil | Sampled: 2022-05-23					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2022-12-19	
Chloride, Water-Soluble	< 0.002	0.002	%	2022-12-20	
pH (1:2 H2O Solution)	**7.50**	0.10	pH units	2022-12-19	
3692-02-07 GST1 7'-9' (22L1431-03) | Matrix: Soil | Sampled: 2022-05-23					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2022-12-19	
Chloride, Water-Soluble	< 0.002	0.002	%	2022-12-20	
pH (1:2 H2O Solution)	**7.77**	0.10	pH units	2022-12-19	

APPENDIX 1: SUPPORTING INFORMATION

REPORTED TO	Tetra Tech EBA Inc. (Kelowna)	**WORK ORDER**	22L1431
PROJECT	704-ENG.KGEO03692-02	**REPORTED**	2022-12-20 13:54

Analysis Description	Method Ref.	Technique	Accredited	Location
Chloride, Water Soluble in Soil	ASTM C1218-17	Hot Water Extraction / Hot Water Extraction		Richmond
pH in Soil	Carter 16.2 / SM 4500-H+ B (2017)	1:2 Soil/Water Slurry / Electrometry	✓	Richmond
Sulfate, Water-Soluble in Soil	CSA A23.2-3B / CSA A23.2-2B	Extraction (HCl) / Gravimetry (Barium Sulfate Precipitation)		Richmond

Glossary of Terms:

RL	Reporting Limit (default)
%	Percent
<	Less than the specified Reporting Limit (RL) - the actual RL may be higher than the default RL due to various factors
pH units	pH < 7 = acidic, ph > 7 = basic
ASTM	ASTM International Test Methods
CSA	Canadian Standards Association Chemical Test Methods
SM	Standard Methods for the Examination of Water and Wastewater, American Public Health Association

General Comments:

The results in this report apply to the received samples analyzed in accordance with the Chain of Custody document. This analytical report must be reproduced in its entirety. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued or once samples expire, whichever comes first. Longer hold is possible if agreed to in writing.

Please note any regulatory guidelines applied to this report are added as a convenience to the client, at their request, to help provide some initial context to analytical results obtained. Although CARO makes every effort to ensure accuracy of the associated regulatory guideline(s) applied, the guidelines applied cannot be assumed to be correct due to a variety of factors and as such CARO Analytical Services assumes no liability or responsibility for the use of those guidelines to make any decisions. The original source of the regulation should be verified and a review of the guideline(s) should be validated as correct in order to make any decisions arising from the comparison of the analytical data obtained to the relevant regulatory guideline for one's particular circumstances. Further, CARO Analytical Services assumes no liability or responsibility for any loss attributed from the use of these guidelines in any way.

APPENDIX 2: QUALITY CONTROL RESULTS

REPORTED TO	Tetra Tech EBA Inc. (Kelowna)	**WORK ORDER**	22L1431
PROJECT	704-ENG.KGEO03692-02	**REPORTED**	2022-12-20 13:54

The following section displays the quality control (QC) data that is associated with your sample data. Groups of samples are prepared in “batches” and analyzed in conjunction with QC samples that ensure your data is of the highest quality. Common QC types include:

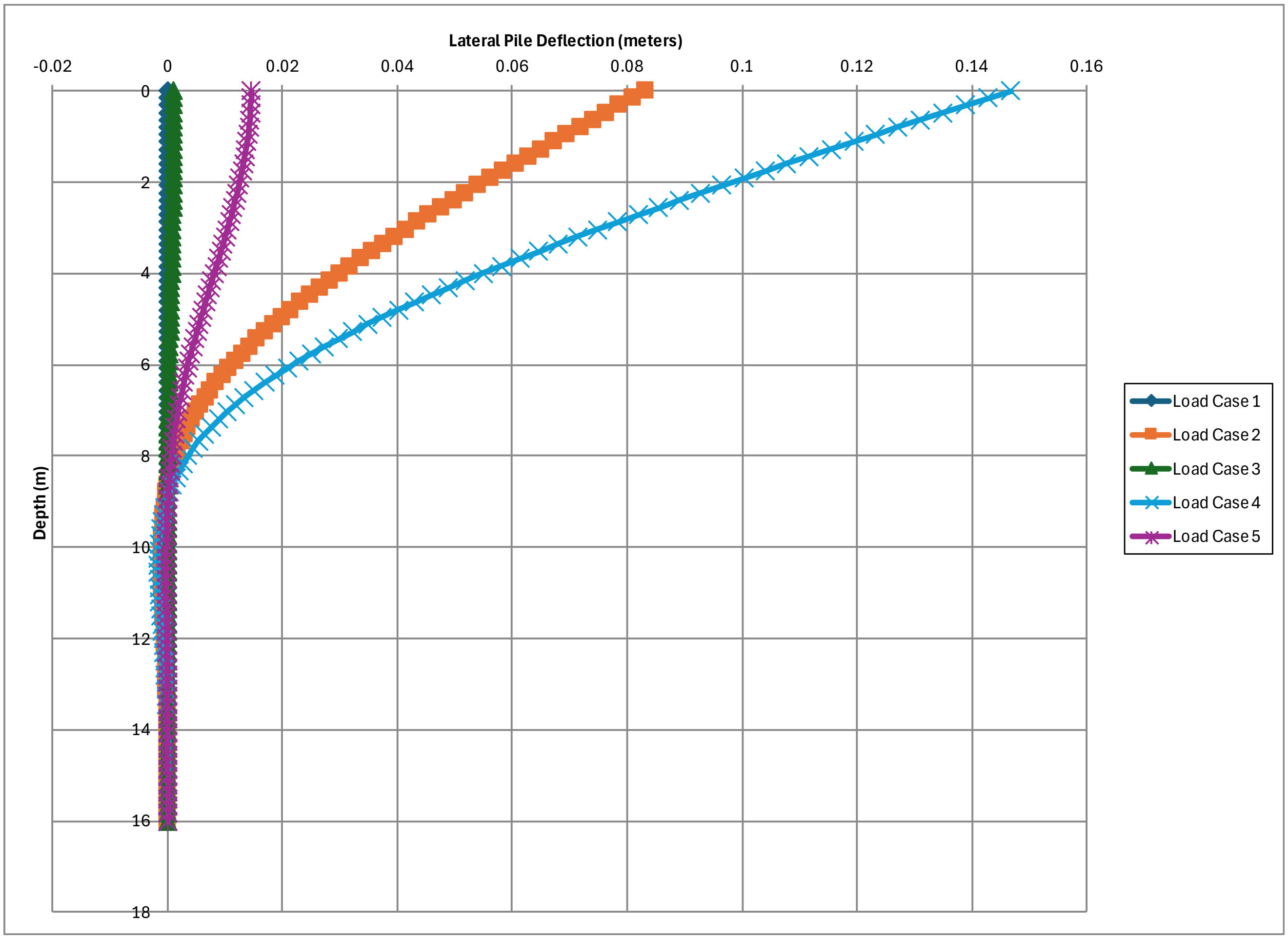
- **Method Blank (Blk)**: A blank sample that undergoes sample processing identical to that carried out for the test samples. Method blank results are used to assess contamination from the laboratory environment and reagents.
- **Duplicate (Dup)**: An additional or second portion of a randomly selected sample in the analytical run carried through the entire analytical process. Duplicates provide a measure of the analytical method's precision (reproducibility).
- **Blank Spike (BS)**: A sample of known concentration which undergoes processing identical to that carried out for test samples, also referred to as a laboratory control sample (LCS). Blank spikes provide a measure of the analytical method's accuracy.
- **Matrix Spike (MS)**: A second aliquot of sample is fortified with a known concentration of target analytes and carried through the entire analytical process. Matrix spikes evaluate potential matrix effects that may affect the analyte recovery.
- **Reference Material (SRM)**: A homogenous material of similar matrix to the samples, certified for the parameter(s) listed. Reference Materials ensure that the analytical process is adequate to achieve acceptable recoveries of the parameter(s) tested.

Each QC type is analyzed at a 5-10% frequency, i.e. one blank/duplicate/spike for every 10-20 samples. For all types of QC, the specified recovery (% Rec) and relative percent difference (RPD) limits are derived from long-term method performance averages and/or prescribed by the reference method.

Analyte	Result	RL	Units	Spike Level	Source Result	% REC	REC Limit	% RPD	RPD Limit	Qualifier
General Parameters, Batch B2L1908										
Blank (B2L1908-BLK1)				Prepared: 2022-12-17, Analyzed: 2022-12-19						
Sulfate, Water-Soluble	< 0.050	0.050	%							
General Parameters, Batch B2L1986										
General Parameters, Batch B2L2016										
Blank (B2L2016-BLK1)				Prepared: 2022-12-19, Analyzed: 2022-12-20						
Chloride, Water-Soluble	< 0.002	0.002	%							

APPENDIX D

LATERAL PILE ANALYSIS RESULTS



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	16	0	0	860	610	30	10	SLS1
2	16	150	0	1180	610	30	10	ULS1
3	16	10	Fixed Rot.	680	610	30	10	ULS4
4	16	240	0	740	610	30	10	ULS5
5	16	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS
ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

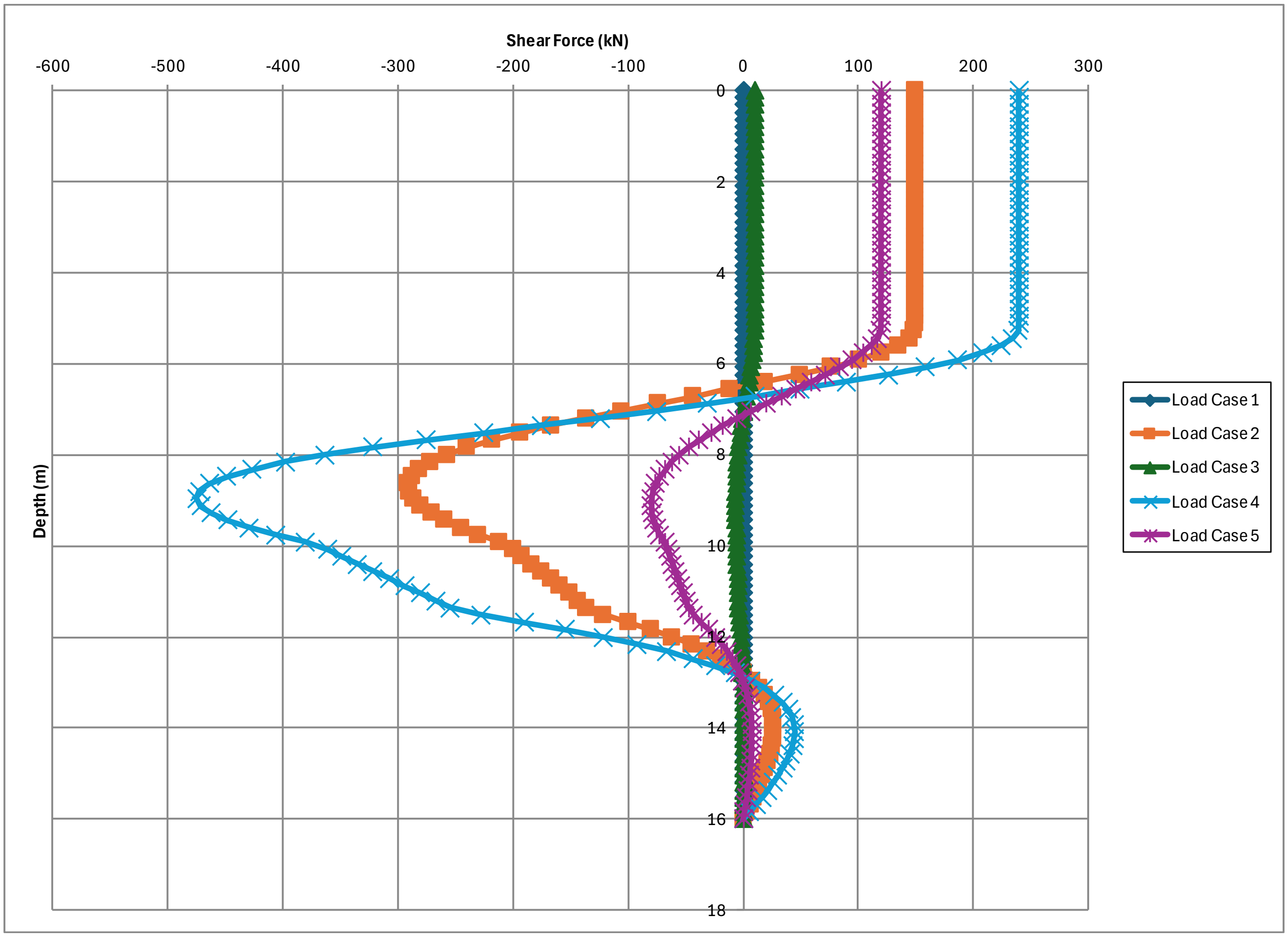
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
North Abutment (5.2 m Scour)
Lateral Analysis Deflection

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.1



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	16	0	0	860	610	30	10	SLS1
2	16	150	0	1180	610	30	10	ULS1
3	16	10	Fixed Rot.	680	610	30	10	ULS4
4	16	240	0	740	610	30	10	ULS5
5	16	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS

ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

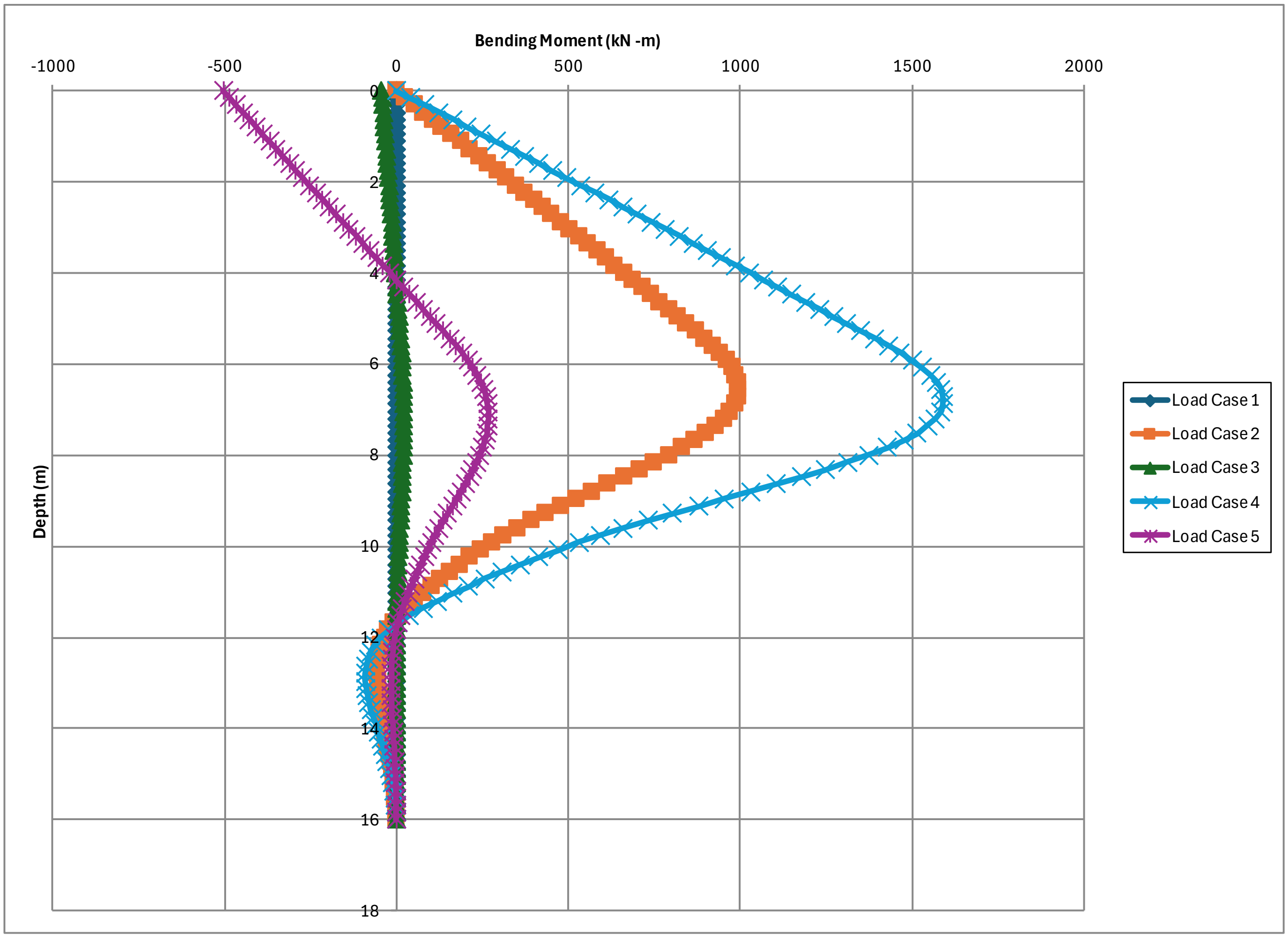
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
North Abutment (5.2 m Scour)
Lateral Analysis Shear Forces

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.2



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	16	0	0	860	610	30	10	SLS1
2	16	150	0	1180	610	30	10	ULS1
3	16	10	Fixed Rot.	680	610	30	10	ULS4
4	16	240	0	740	610	30	10	ULS5
5	16	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS

ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

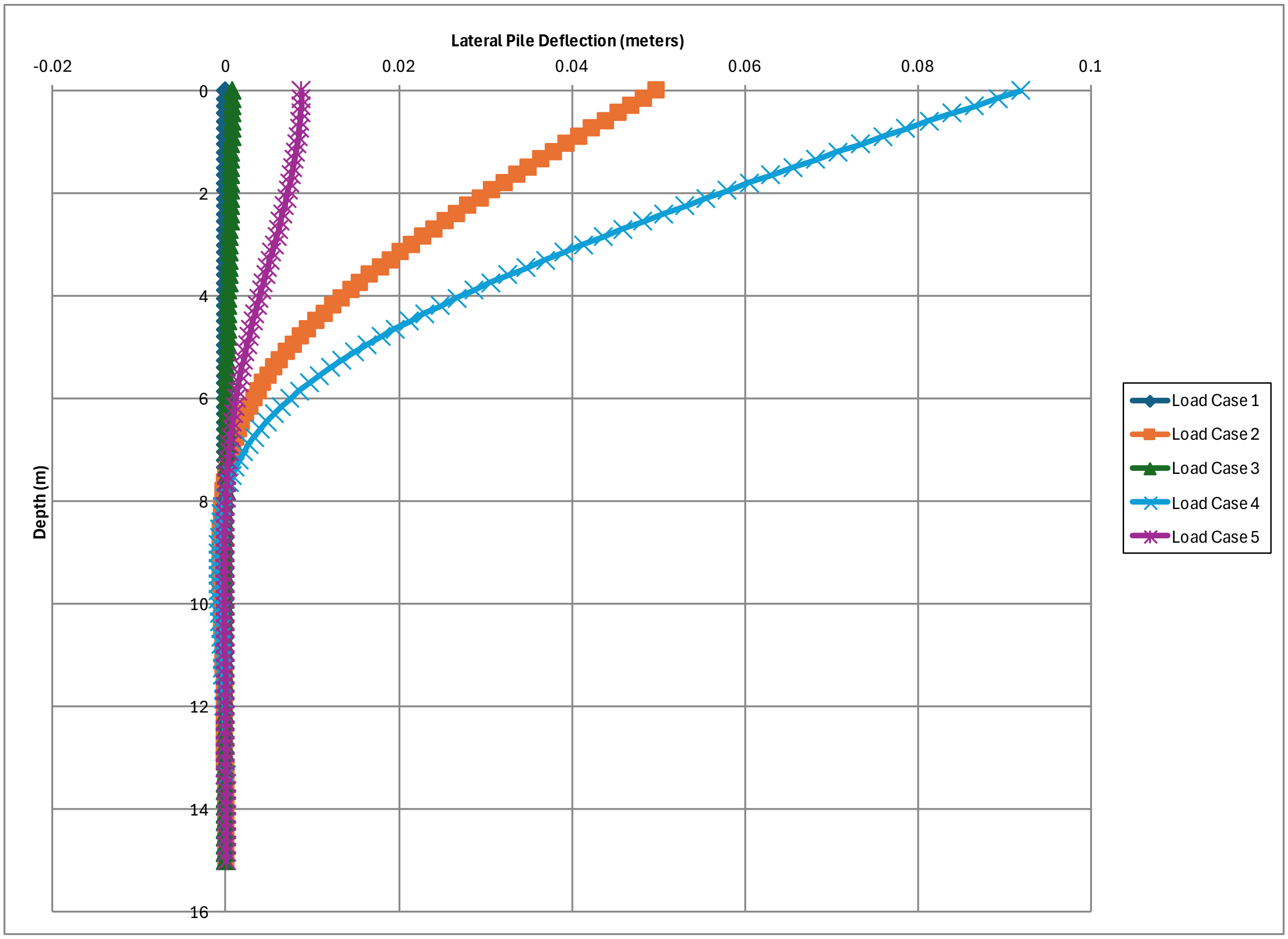
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
North Abutment (5.2 m Scour)
Lateral Analysis Bending Moment

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.3



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	15	0	0	860	610	30	10	SLS1
2	15	150	0	1180	610	30	10	ULS1
3	15	10	Fixed Rot.	680	610	30	10	ULS4
4	15	240	0	740	610	30	10	ULS5
5	15	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS
ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

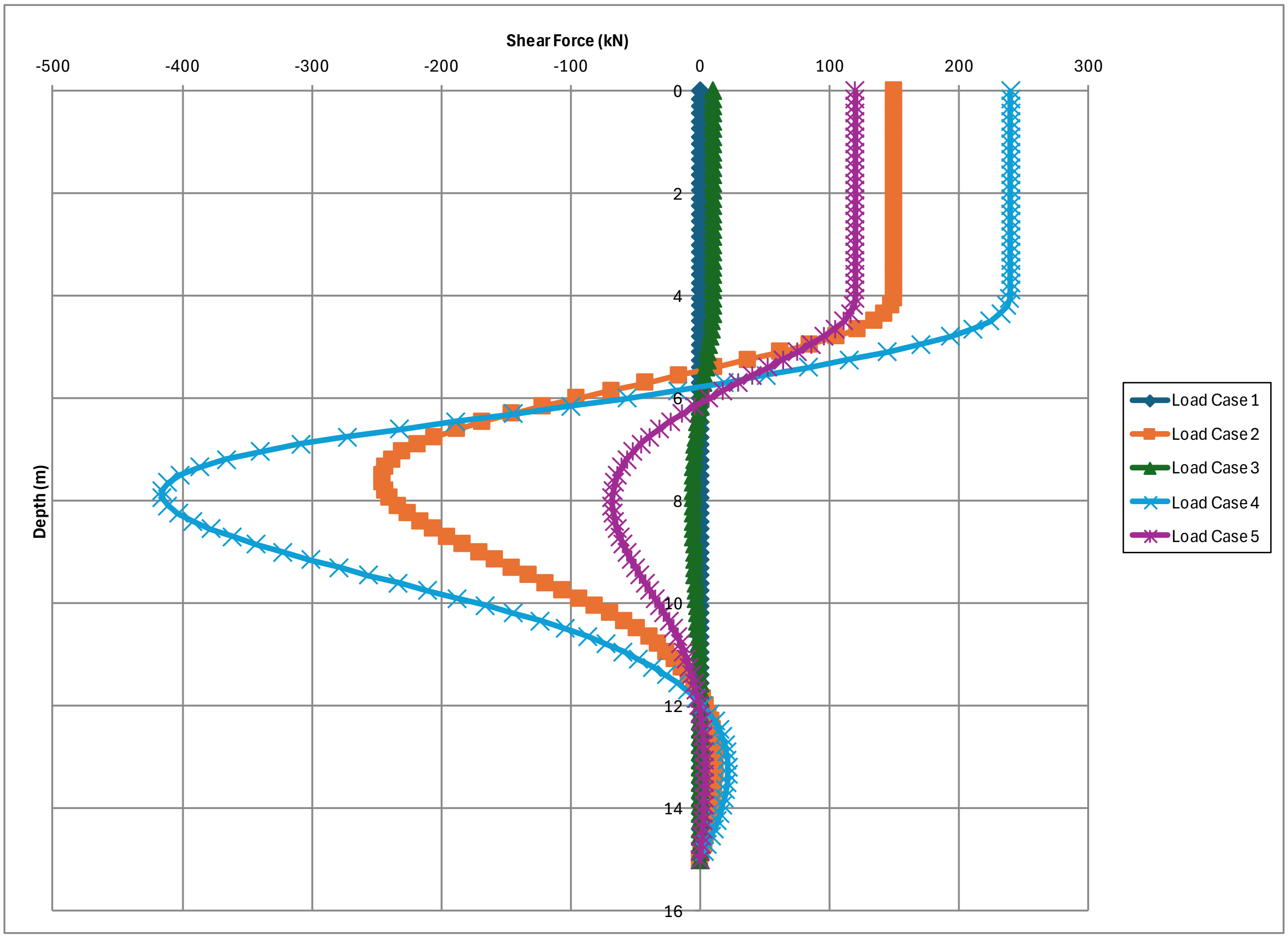
Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
South Abutment (4.0 m Scour)
Lateral Analysis Deflection

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.4



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	15	0	0	860	610	30	10	SLS1
2	15	150	0	1180	610	30	10	ULS1
3	15	10	Fixed Rot.	680	610	30	10	ULS4
4	15	240	0	740	610	30	10	ULS5
5	15	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS
ISSUED FOR REVIEW

CLIENT
British Columbia Ministry of Transportation and Infrastructure

TETRA TECH

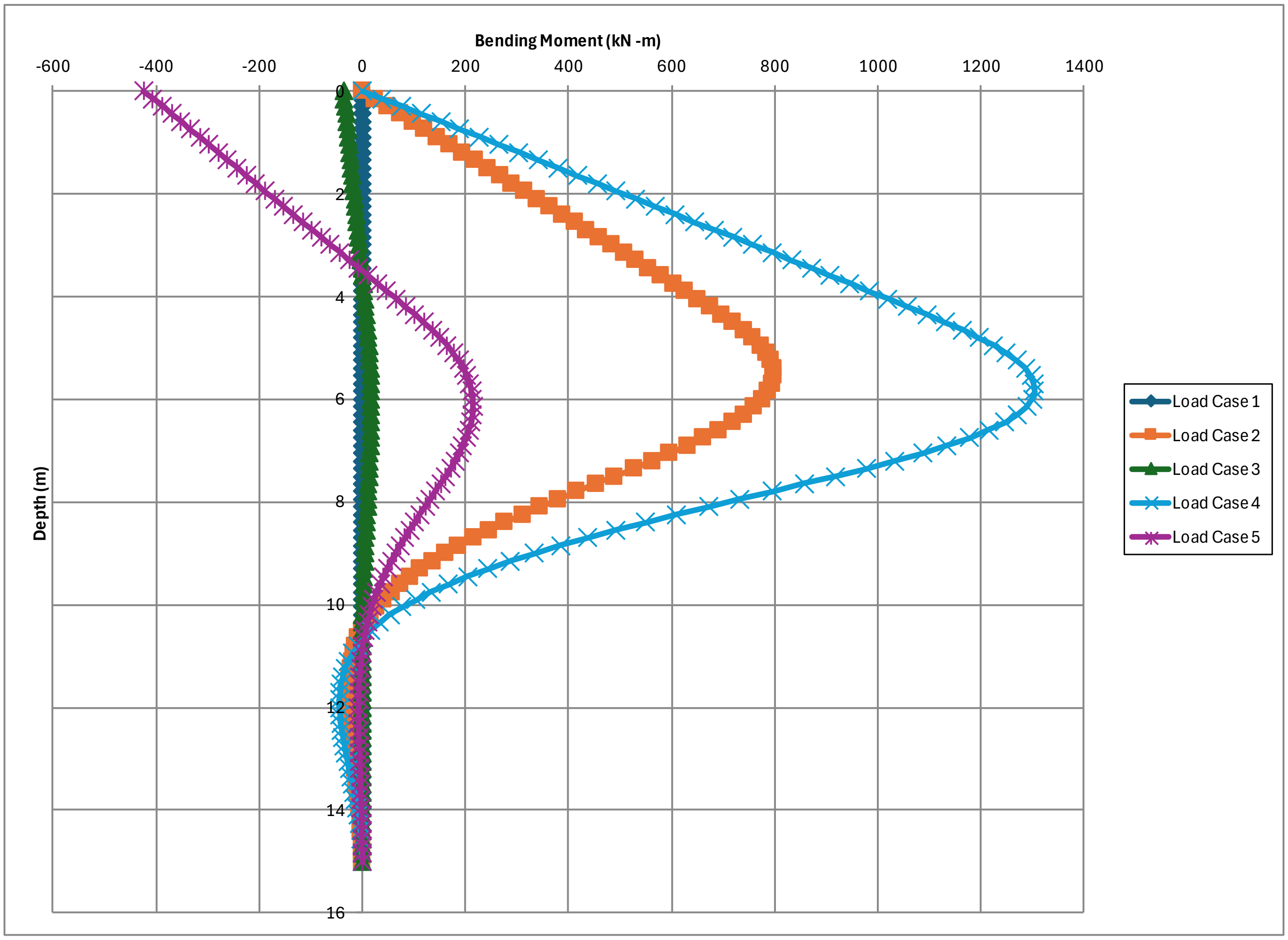
Rice Bridge Geotechnical Assessment Tulameen, BC

610 mm Open-Pipe Pile South Abutment (4.0 m Scour) Lateral Analysis Shear Forces

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.5



Case	Pile Depth (m)	Forces at Top of Pile / Underside of Pile Cap			Pile Diameter (mm)	Anticipated Concrete Strength (MPa)	Anticipated Length of Rebar (m)	Notes:
		Vf (kN)	Mf (kN-m)	Pf (kN)				
1	15	0	0	860	610	30	10	SLS1
2	15	150	0	1180	610	30	10	ULS1
3	15	10	Fixed Rot.	680	610	30	10	ULS4
4	15	240	0	740	610	30	10	ULS5
5	15	120	Fixed Rot.	740	610	30	10	ULS5

LEGEND

NOTES

- Calculated for a single 610 mm diameter Open-Pipe Pile

STATUS
ISSUED FOR REVIEW

CLIENT

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

TETRA TECH

Rice Bridge Geotechnical Assessment
Tulameen, BC

610 mm Open-Pipe Pile
South Abutment (4.0 m Scour)
Lateral Analysis Bending Moment

PROJECT NO.	DWN	CKD	APVD	REV
ENG.KGEO03692-02.07	DB	GM	DB	

OFFICE	DATE
KELOWNA	Nov 07, 2024

Appendix D.6