TRANS MOUNTAIN EXPANSION PROJECT KAMLOOPS TERMINAL ADDITION

PRESENTED TO
TETRA TECH OGD INC.

FEBRUARY 2015
ISSUED FOR REVIEW
FILE: V13103101-02

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EXECUTIVE SUMMARY

A geotechnical investigation was undertaken for a proposed pump station addition in Kamloops, BC. The proposed development includes 4 x 3,730 kW pumps, a new pump house, a new containment pond, pipe supports and the possible requirement of a retaining structure. The geotechnical investigation included drilling with ODEX (air rotary) with standard penetration tests to characterize the density of the soil and to obtain soil samples for further laboratory testing. Sand and silt with some gravel (possible till) was generally encountered at the borehole locations. Within the southwest corner of the site, where some cut slopes or retaining walls may be required, refusal was encountered at a depth of 5.5 m in one of the boreholes.

Shallow foundations consisting of footing or raft slabs may be used for foundation support. Driven steel pipe piles are not recommended (there are risks associated with pile driving on this site), however, if used would need a minimum of 5.0 m of embedment for foundation support.

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LIMITATIONS OF REPORT

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1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by Tetra Tech OGD Inc. (Tetra Tech OGD) to undertake a geotechnical investigation for the Kamloops pump station site. The Kamloops geotechnical investigation was undertaken as part of Phase I of the Enhanced FEED of the Trans Mountain Expansion Project.

This geotechnical investigation and report follows up on the preliminary geotechnical assessment provided in February 2013. As discussed in meetings subsequent to the issuing of the 2013 preliminary memo, Tetra Tech EBA has attempted to keep our recommendations from our recent investigations consistent with those previously provided if proof of concept exists (i.e., if previous foundation design recommendations have historically been shown as being suitable at a site, we have attempted to retain those recommendations as much as possible). Further to the above, it is our understanding that Kinder Morgan (KMC) would like to keep designs between the various pump stations as consistent as possible.

The proposed development includes 4 x 3,730 kW pumps, a new pump house, a new containment pond, pipe supports and the possible requirement of a retaining structure. Further to the above, it is understood that the foundation types preferred by Tetra Tech OGD are:

- Concrete spread footings, grade beams and slab on grade for the pump station building;
- Large concrete block base (raft footing) for the main pump and motor equipment; and
- Pile foundation for pipe supports, which generally consists of driven or screw piles, but can as well be cast in place concrete piles.

2.0 SITE DESCRIPTION

The site is located south of Highway #1, near the western boundary of Kamloops, BC. The proposed site is located on a north facing slope. Some benching has been done for the existing development.

3.0 BACKGROUND INFORMATION

The following geotechnical reports were reviewed as part of the desktop study:

- Golder Associates Ltd. (Golder), 1992, Geotechnical Investigation for Containment Structure;
- Golder, 1995, Geotechnical Investigation for Tertiary Containment System; and
- EBA, 2013 Preliminary Geotechnical Input – Kamloops Station.

A brief summary of subsurface information considered relevant to this study is provided below.

3.1 Golder, 1992

The 1992 Golder site investigation was completed for a proposed containment structure. It was noted in the report that the site was located between Dufferin Hill and Ironmask Hill, 3.5 km south of the Thompson River. The subsurface investigation consisted of nine test pits excavated to 1.8 m to 3.0 m depth. Test pits (TP) 1, 5 and 6 are located closest to the proposed expansion area as shown on Figure 1.

The general ground conditions observed over the entire site consisted of the following:

- Approximately 0.15 m to 0.6 m of surficial topsoil or fill materials were underlain by loose to compact weathered till which grades into dense to very dense unweathered till. The surficial and till soils consisted of variable mixtures of silt, sand and gravel; and
- All testpits except for TP2 were dry during excavation. In TP 2, located about 150 m east of the proposed expansion and lower on the slope, groundwater was encountered at a depth of 1.1 m. TP 2 was terminated at a depth of 1.8 m due to groundwater seepage and sloughing.

The general ground conditions observed in the three test pits located closest to the proposed expansion area consisted of the following:

- TP 1 – 0.05 m drain rock fill underlain by very dense sand, silt, gravel and cobbles (possible till) (max. size 250 mm) to 2.2 m depth;
- TP 5 – 0.3 m topsoil, underlain by loose sand with some silt to 0.7 m depth; underlain by compact sand with some silt and gravel to 1.8 m depth; underlain by very dense sand (possibly till) with some silt and gravel and trace cobbles to 2.8 m depth; and
- TP 6 – 0.6 m topsoil, underlain by loose sand, some silt trace gravel and cobbles to 1.3 m depth, underlain by sand and gravel to 1.6 m depth, underlain by compact to dense sand (possible till), some silt, some gravel to 2.6 m depth.

3.2 Golder, 1995

The 1995 Golder investigation is a supplementary geotechnical investigation for the conceptual design of a tertiary containment system. The subsurface investigation consisted of seven hollow stem auger holes drilled to 6.5 m depth except for three boreholes where drilling refusal occurred at depths of 2 m to 5 m. Boreholes (BH) 1 and 2 are located 120 m southeast of the proposed expansion area and BH 6 and 7 are located approximately 150 m north of the proposed expansion area. The general ground conditions observed in these four boreholes consisted of the following:

- BH 1 encountered 1.2 m of loose silt and sand, over compact to dense silt and sand, with the very dense sand till below a depth of 3.8 m and auger refusal at a depth of 5.0 m;
- BH 2 is located close to BH1 but had somewhat different soil conditions consisting of loose to compact silt and sand to 1.4 m, over dense to very dense silty sand with some gravel (possible till), with a very stiff clay below 4.9 m;
- BH 6 and BH 7, located to the north and further downslope, encountered compact to dense silty sand with some gravel (possibly weathered till), and drill refusal occurred at depths of 4.1 m and 2.1 m respectively, on what is expected to be a very dense till; and
- In BH 2 and BH 6, where standpipes were installed, groundwater levels were later measured to be at depths of 2.0 m.

3.3 EBA, 2013

The 2013 Tetra Tech EBA preliminary geotechnical investigation memo summarized the general geotechnical conditions of the area of the proposed development and provided preliminary geotechnical recommendations based on a site reconnaissance and desktop study of available information.

4.0 SUBSURFACE PROFILE

4.1 Investigation Results

The subsurface investigation was conducted between November 19 and 22, 2013. Mr. Trevor Janicki of Tetra Tech EBA's Kelowna office was onsite to oversee the drilling and log the borehole information. Detailed soil descriptions can be found on the borehole logs in Appendix B.

Five boreholes ranging from depths of 5.5 m to 9.9 m were drilled using a track mounted auger drill rig with ODEX capabilities owned and operated by On The Mark Drillers. The approximate borehole locations are shown on Figure 1.

- BH01 was located on the southwest slope and required some drill pad levelling and road access construction. Drilling encountered approximately 3.0 m of SAND and SILT, underlain by very dense silty SAND to 4.6 m, overlying very dense SILT to a depth of 5.5 m due to drill refusal;
- BH02 was also located on the southwest slope, near the crest of the proposed cut slope. This borehole required drill pad levelling and road access construction. Drilling encountered approximately 0.9 m of loose to compact soil, becoming dense to very dense SAND to a depth of 6.7 m, underlain by compact to very dense sandy SILT to a depth of 9.3 m;
- BH03 was located on the southwest slope, near the toe, and some limited pad levelling and access road construction was required. Drilling encountered 1.2 m of loose to compact soil, underlain by dense to very dense fine grained SAND and SILT to a depth of 2.4 m, underlain by a 0.5 m layer of very dense gravel, underlain by very dense SAND to a depth of 6.1 m, underlain very dense SILT to a depth of 8.9 m;
- BH04 encountered 3.7 m of silty SAND which was very dense below 3.0 m, overlying intermittent layers of very dense SAND/SILT to 5.3 m (the SILT was classified as having some clay) which was underlain by very dense SAND to a depth of 9.9 m; and
- BH05 encountered SAND to a depth of 3.5 m, overlying dense SILT to a depth of 4.6 m. Below this are intermittent layers of very dense SAND/SAND and SILT down to 9.9 m. Groundwater was encountered in this borehole at a depth of 3.4 m.

It should be noted that, the top 3 m (approximately) of the boreholes were hydrovaced in compliance with KMC pipeline protection requirements. Therefore, these soils were logged based on downhole observations during the hydrovacing process. In areas allowed by the project inspector (BH02 and BH03), some dynamic cone penetration testing was carried out in the top 3 m in order to ascertain the consistency / strength of the shallow soils.

4.2 Generalized Soil Profile

Based on our review of the existing background information and the results of this investigation, the following general soil profile and ground conditions are expected at the proposed expansion site:

- Although some variability is expected, the general soil profile is a compact sand or sand and silt layer overlying dense to very dense sands and silts (possible till);
- Generally, the dense to very dense silts and sands were encountered at a depth of 1.2 m or less, however, this was difficult to ascertain in most of the boreholes with hydrovacing taking place to a depth of 3 m;

- Groundwater was encountered in BH05 (proposed pump station location) at a depth of 3.4 m. Although groundwater was not encountered in any of the other boreholes, the relatively shallow silt with clay layers at some of the locations could cause a perched water table during periods of heavy precipitation or snow melt; and

- Although the boreholes did not encounter any cobbles or boulders, TP 6 from the 1992 Golder investigation encountered trace cobbles.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 Geotechnical Overview and Considerations

- This site is considered to be suitable for the construction of the proposed project structures;

- All topsoil should be removed from the proposed pump station area prior to construction. Although no fill was encountered during the investigation, if any is encountered, it should be proof rolled with loose areas being compacted to 98% Standard Proctor Maximum Dry Density (SPMDD) (ASTM Test Method D698);

- From the plans provided by Tetra Tech OGD, the site being considered for the new pump station has a limited level area, and excavation into the slope will be required to create sufficient level area for the development. Dense to very dense sands and silts (possible till) encountered during the drilling investigation will require use of appropriate equipment and methods to complete the excavation into very dense soils;

- It is our understanding that an excavation into the slope is proposed to develop a level area for the development, and therefore the impact on the stability of the slope must be checked, and a retaining wall with soil/rock anchors may be needed;

- It should be noted that, from a constructability point of view, it may be of greater benefit to move the site to an area that does not require a cut into an existing slope. This might require the placement of structural fill on slopes elsewhere on the site instead of the above proposed excavation into the existing slope;

- The dense to very dense sands and silts (possible till) will be an excellent foundation soil with shallow foundations likely being the preferred foundation, with the possible use of driven piles as well (although difficult pile driving conditions may exist). A thick raft footing could be used to support heavy machine loads and a slab-on-grade is considered suitable for heated buildings with lightly loaded floors. It is our understanding that the pump buildings are not heated;

- The very dense nature of the sands and silts and potential for shallow bedrock (i.e., BH01) will need to be considered if driven piles are to be used, as appropriate equipment, and heavier walled piles, would be needed to achieve the required depth and limit pile damage. Pre-boring or churn drilling may be required to install piles to the required depth and plumbness;

- Raft foundations with heated structures are also a good choices for sites with frost susceptibility such as this one; and

- Due to the dense nature of the silts and sands with varying amounts of gravel and occasional cobbles, piles are not recommended at this site. However, in case piles are to be considered, we have provided recommendations for their installation in the sections below.

5.2 Soil Resistivity and Corrosivity

Soil resistivity and corrosivity testing were performed by Corrosion Service Company Limited (CSC) on soil samples ranging in depth from 0.9 m (combined BH01 and BH05) to 3.4 m in BH05. Resistivity values varied from 1,400 Ohm-cm in the combined sample from BH01/05 to 3,200 Ohm-cm in BH01. Corrosivity evaluation results for the two samples are summarized in Appendix C.

It should be noted that the resistivity and corrosivity evaluation was done on laboratory soil samples approximately 1 week after drilling; therefore results may vary from the actual in situ site conditions. Corrosivity and resistivity tolerances were not provided, and as a result we are unable to assess at this time how the resulting values compare with project requirements.

5.3 Dynamic Soil Properties

The properties provided in Table 1 are recommended for use in assessing the overall damping and movement for various modes of vibration. The soil damping values only include internal soil damping, not radiation damping. Soil damping is generally much less than radiation damping for modes of vibration other than rotational. The total damping for each mode of vibration will depend on the shape, depth of burial, and mass and thickness of slab or pile configuration.

Dynamic Shear Modulus (Gmax) values in Table 1 are calculated directly from the SPT blow counts and overburden stress.

Table 1: Dynamic Soil Properties for Sand / Silt Till

Parameter	Recommended Value	Probable Range
Dynamic Shear Modulus, G_{max} (MPa)	150	100 to 400
Poisson's Ratio	0.3	0.3 to 0.4
Unit Weight kN/m^3	21	20 to 23
Damping Ratio (%)	5	2 to 10

For pipe stress analysis the following properties may be used for the dense sand and silt at site:

- Friction factor – tan(fϕ), where f is 0.8 for rough steel, f is 0.7 for smooth steel and ϕ is the friction angle of the trench backfill material (35° for granular backfill material);
- Unit weight of soil 21 kN/m^3; and
- Friction angle 30°.

5.4 Seismic Design

Peak Ground Acceleration (PGA) and spectral acceleration Sa(T) values corresponding to the site location were obtained from the Natural Resources Canada website (http://www.earthquakescanada.nrcan.gc.ca) for the 10% in 50 year (1 in 475) and 2% in 50 year (1 in 2475) probabilities of exceedance and are summarized in the Table below.

Table 2: 2010 NBC Seismic Hazard Values

Seismic Event	PGA	Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)
1 in 475	0.072 g	0.135 g	0.092 g	0.057 g	0.034 g
1 in 2475	0.138 g	0.277 g	0.172 g	0.108 g	0.063 g

Based on the expected soil conditions the site is classified as Site Class C, in accordance with the 2012 BC Building Code/ National Building Code of Canada. Based on the site classification, a F_a value of 1.0 and an F_v value of 1.0 are considered appropriate for preliminary design.

5.5 Frost Action

The silt at this site has a moderate propensity for frost heaving during freezing. The frost penetration was calculated from methods outlined in Section 13 of the Canadian Foundation Engineering Manual (2006) and from Environment Canada data. The data from the winter of 1995 / 1996 was used as it has been recognized as one of the coldest winters in the past two decades.

From the above, it has been calculated that the frost penetration depth is 1.5 m at this site.

All structures within the depth of frost penetration will be subject to adfreeze forces. Adfreeze forces tend to vary depending on a numerous factors. However, average adfreeze bond stresses are in the order of 150 kPa between coarse grained fills and steel, and lesser between coarse grained soils and concrete.

6.0 RECOMMENDATIONS

It is understood that the foundation types preferred by Tetra Tech OGD are:

- Large concrete block base (raft footing) for the main pump and motor equipment;
- Pile foundation for pipe supports, which generally consist of driven or screw piles, but can as well be cast in place concrete piles; and
- Concrete spread footings, grade beams and slab on grade with insulation used for the pump station building.

Geotechnically, shallow foundations are preferred, given the dense near surface till-like soils. Pile installation may be problematic.

6.1 General Site Preparation

Based on the preliminary site layout provided by Tetra Tech OGD, it is anticipated that the site will have significant cuts and fills.

Minimal topsoil, fill or other deleterious materials are expected at the proposed expansion area and therefore the minimum stripping depth is only expected to be approximately 0.1 m. Any such materials must be removed from the building area, and no floor slabs should be constructed on these soils. Sub-excavation may be required to establish suitable bearing in previous excavation areas such as pipe trenches. After sub-excavation to remove unacceptable materials, the area should be built to design grade with properly compacted structural fill. The sub-excavation and replacement with structural fill must extend beyond the outer edge of the footing, a minimum horizontal distance equal to the depth of the fill below the footing.

Once the subgrade is exposed, it should be moisture conditioned to within 2 percent of optimum moisture content and compacted with a vibratory roller to 95% Standard Proctor Maximum Dry Density (SPMDD) as per ASTM D698. Once moisture conditioning is complete, the site surface should be proof-rolled under the supervision of a geotechnical engineer. Soft spots which are identified should be subexcavated and replaced with either common fill backfill as described below.

Common backfill may consist of sand or sand and gravel with a maximum particle size of 75 mm. The existing sand and gravel fill on site may be potentially reused as common backfill if they meet these requirements. Some screening or crushing of larger particles may be required in order for the material to meet these gradation specifications. Common backfill should be compacted in lifts to a minimum of 95% Standard Proctor Maximum Dry Density (SPMDD) as per ASTM D698. Compaction should occur at moisture contents which are between -2% and 2% above the material’s optimum moisture content.

Structural backfill (i.e., placed within the footprint of structures) may consist of sand or sand and gravel with a maximum particle size of 25 mm and no more than 5% of material by weight finer that 0.075 mm. Structural backfill should be compacted in lifts to a minimum of 98% SPMDD. Compaction should occur at moisture contents which are between -2% and 2% above the material’s optimum moisture content. Local shallow soils are expected to have generally high fines content. It is not expected that any excavated soils will be suitable as structural fill in the building area.

6.2 Site Preparation for Slab-On-Grade

For the proposed pump station building, we recommend that the floor slab consist of a slab-on-grade.

Structural backfill moisture conditioned and compacted, as described above, should be used to raise the building footprint to within 150 mm of the elevation of the bottom of the slab-on-grade. A 150 mm thick layer of 19 mm minus crushed gravel compacted to 100% SPMDD is recommended below the floor slab to provide a capillary break to limit upward migration of moisture. The crushed gravel will function as a drainage layer and should be hydraulically connected to the foundation drains to mitigate water pressure build-up below the slab. This is typically accomplished by installing weep holes through the foundation wall.

A vapour transmission protection system should be installed between the crushed aggregate and the concrete slab-on-grade to provide protection against moisture. The structural design of the slab and the design of a vapor transmission protection system should be completed by a structural engineer, in accordance with 2012 BCBC.

6.3 Shallow Foundations

We recommend that shallow foundations be used to support the proposed pump station building. These foundations may consist of either pad and spread footings or an expanded edge slab-on-grade. The bearing surfaces from these foundations must be constructed to bear on structural fill, or undisturbed, non-frozen, native sand and gravel soils.

Site preparation for the shallow foundations should consist of local excavation to the design grade of the underside of the footings. If soft spots, loose, frozen or water softened soils are encountered and subexcavation is required below the elevation of the proposed footing, then the width of subexcavation should be equal to the footprint of the footing plus a horizontal distance equal to the depth of the subexcavation and extending on all sides of the footing. The structural backfill (as defined in Section 6.1) below the footings should be have a maximum particle size of 25 mm and should be compacted in lifts to a minimum of 98% SPMDD.

Footings founded at shallow depths may impart stresses onto adjacent foundations, utilities, etc. Bridging, deepening, or utility relocations may be required to address such constraints. Footings should be located such that the risk of significant stress increase on the adjacent footings or foundation walls is mitigated. Footings should be founded below a line projected up at 2H:1V from any lower footing excavation, service trench excavation or load sensitive structure.

Shallow foundations for heated buildings may be founded at a depth of 0.6 m if the perimeter of the structure is insulated. For unheated building founded at the project location, insulation would be installed underlying the whole building and extending a minimum of 2.44 m out from all sides. This insulation would be situated at a minimum depth of 300 mm. However, in our 2006-2007 work on the Trans Mountain Pipeline, insulation was not recommended below any of the buildings as the designers believed that the soils on site had low frost susceptibility. We understand that none of the buildings designed and constructed due to our 2006-2007 recommendations has encountered significant issues with movement and distress due to frost. The types and varieties of soils encountered during that project were similar to those encountered during the current project. Based on this, and the adequate performance of the existing pump stations, if minor frost related deformation to the structures is acceptable, then it is our recommendation that no insulation be provided below any unheated buildings. This recommendation should be explored further with additional testing and modeling during detailed design.

Shallow foundations for heated buildings may be founded at a depth of 0.6 m if the perimeter is insulated. For an internal building temperature of 7°C, a minimum of 50 mm of insulation is recommended for this site. The insulation should be buried a minimum of 0.6 m below grade, must extend a minimum of 1.2 m from the building wall, and should be sloped at 2% away from the building. The insulation should also cover the foundation and extend up the outside of the building wall to at least the elevation of the internal wall insulation. The horizontal insulation should be protected on both top and bottom with a minimum thickness of 75 mm of sand with a maximum particle size less than 4.75 mm and with less than 5% of the material by weight finer than 0.075 mm. The insulation should be installed in a minimum of two layers with staggered joints. Furthermore, the thickness of insulation should be increased by 50% at the corners of the building.

Polystyrene insulation can deteriorate over time when exposed to hydrocarbons. However, at this facility, the insulation may be subject to hydrocarbon contact during the life of the project. Therefore, we recommend the use of an alternative to polystyrene material or wrapping of the polystyrene in a synthetic liner which is impervious to hydrocarbons. Alternative products for consideration included bottom ash (typically 1 m required with geotextile and gravel cover) and cellular concrete (typically 300 mm thick). This requirement can be reviewed during detailed design and construction.

If the site preparation recommendations outlined in this section are implemented, then footings founded on native compact to dense sand and gravel or structural fill may be designed for the bearing resistances provided in Table 3. These bearing pressures are applicable to minimum footing widths of 450 mm and 600 mm for strip and pad footings, respectively. They are also applicable to a maximum pad footing size of 3.6 m by 5.5 m as proposed for the support of each individual pump.

The bearing resistances are calculated assuming that the loads will be vertical and concentric and that the footing will be situated on a level subgrade which is not in proximity to a slope. If the structural loads are to be inclined, or result in eccentric loading, then the bearing resistances will be lower than those presented in this section and should be checked by Tetra Tech EBA using the actual design loads, eccentricities and inclinations.

Table 3: Shallow Foundation Design Parameters

Foundation Parameters	Foundation Stratum: Dense Till Like Material (Silt/Sand)	
	Static	Dynamic
Ultimate Limit State Bearing Pressure (kPa):	450	250
Maximum Allowable Bearing Pressure (kPa):	150	90
Serviceability Limit State Bearing Pressure (kPa):	150	90

6.4 Piled Foundations

It is expected that piled foundations may be difficult to install/construct due to the presence of cobbles, dense till-like soils, potential shallow groundwater and potential for sloughing soils at shallow depth. Therefore open ended driven steel pipe piles or H-piles are preferred due to the presence of course gravel and cobbles. High driving energy, pre-boring or churn drilling may be required to install driven piles.

Cast-in-place concrete piles are not commonly used in this area due to the soil conditions and with the lack of this type of equipment in the area; this is not expected to be the preferred foundation type.

6.4.1 Driven Piles

The following geotechnical design parameters are recommended for the design of driven steel piles:

- Minimum embedment depth: 5 m.

Table 4: Driven Steel Pipe Pile Design Parameters

Elevation (m)	Static		Dynamic	
	Ultimate Skin Friction (kPa)	Ultimate End-Bearing (kPa)	Ultimate Skin Friction (kPa)	Ultimate End-Bearing (kPa)
Mix of Sand, Silt and Gravel (0 m – 2 m)	0	n/a	0	n/a
Dense to Very Dense Silt and Sand (Till)	140	1,100	90	700
Soil Resistance Factors:	0.4 Ultimate End-Bearing, 0.4 Ultimate Skin Friction (without load or PDA testing) 0.5 Ultimate End-Bearing, 0.5 Ultimate Skin Friction (with PDA testing)			

For driven piles, we recommend that one test pile be installed and subject to dynamic testing using a Pile Driving Analyzer (PDA) prior to construction. If test piles were to be installed and PDA testing undertaken, the Factored Geotechnical Resistance at Ultimate Limit State (ULS) may be determined using a geotechnical resistance factor of 0.5.

6.4.2 Cast-in-Place Concrete Piles

Augered cast-in-place piles are technically feasible, but will likely encounter installation difficulties due to the very dense gravel till, and occasional cobbles and boulders at depth. As well, cast-in-place concrete piles are not commonly used in southern BC based on the less favourable soil conditions, and with the lack of this type of equipment in the area, it is unlikely that this would be a cost effective foundation type.

6.4.3 Screw Piles

The use of screw piles is not recommended due to the installation difficulties related to the dense to very dense soils, with occasional cobbles that are expected on site.

6.4.4 Pile Completion and Quality Assurance

It should be noted that pile design is an iterative process and is not complete until every pile has been driven and/or pile load testing is complete. Inspection is considered an integral part of the design of deep foundations. Therefore, full-time inspection of the pile installation by Tetra Tech EBA is required to confirm that the piles are satisfactorily embedded in the subsurface strata and to determine if adjustments to the embedment depth are required.

6.4.5 Pile Settlement

Actual pile settlement is a function of installation method, soil and relative shaft and base resistance.

The driven piles discussed in this section derive their capacity from shaft friction as well as end bearing, with shaft friction mobilizing about 5 mm of settlement. With additional post-construction settlements of up to 5 mm, the total estimated settlement is approximately 10 mm.

6.5 Roadways

The alignment and roadway areas should be grubbed and stripped of any topsoil, organics and deleterious material. If necessary, additional soil should then be excavated in order to accommodate the gravel pavement design proposed in this section.

Following the site stripping and grading, the proposed roadway should be moisture conditioned to within 2 percent of optimum moisture content and compacted to a minimum of 95% SPMDD with a vibratory roller. The prepared subgrade surface should then be proof-rolled under the supervision of a geotechnical engineer. Soft spots which are identified should be subexcavated and replaced with common fill or pit run as detailed in Table 5 and compacted in lifts to a minimum of 95% SPMDD. Common fill may also be used to raise the site grade to the level of the bottom of the design pavement section provided it is compacted in lifts to a minimum of 95% SPMDD.

We understand that a gravel surfaced road is preferred for this facility. Once the subgrade is prepared in the manner described above, a gravel road structure may be constructed. The gravel road structure should be established using the materials with gradations provided in Tables 5 and 6. The subbase and base layers should both be compacted to a minimum of 98% SPMDD. Granular material should be free from clay lumps, organic matter, and other extraneous material, screened to remove all gravel and cobble particles in excess of maximum diameter specification. For water control, ditches should be excavated beside the roadway to a depth of 0.5 m below the elevation of the bottom of the sub-base. The side slopes should be sloped no steeper than of 2H:1V.

For light vehicle and low traffic volumes, the following pavement structure is recommended:

- Minimum 200 mm thick sub-base layer consisting of pit run sand and gravel or crushed (75 mm minus).
- Minimum 150 mm thick granular base course (25 mm minus), placed as a surface layer.

For heavier vehicle traffic, the following road structure is recommended:

- Minimum 300 mm thick sub-base layer consisting of pit run sand and gravel or crushed (75 mm minus).
- Minimum 200 mm thick granular base course (25 mm minus), placed as a surfacing layer.

Table 5: Pit Run Gravel (Sub-base) Gradation Specification

Pit Run Gravel Gradation Specification	
Sieve Designation (mm)	**Percent Passing**
75	100
50	70 – 100
25	50 - 85
4.75	22 - 50
0.236	5 - 30
0.075	2 - 8

Table 6: High Fines Base Course Gradation Specification

Base Course Gradation Specification	
Sieve Designation (mm)	**Percent Passing**
25	100
19	85 - 100
9.5	60 - 85
4.75	40 - 70
1.18	20 - 50
0.300	10 - 30
0.075	5 - 15

Proper crowning of the road surface, and road side ditches, are required to encourage runoff and limit ponding of water.

6.6 Cut Slopes

Based on the proposed construction drawing plans provided by Tetra Tech OGD, the SW corner of this site will require a significant cut into the southern slope. As discussed in Section 4.1, we have drilled 3 boreholes along the proposed cut area and along the toe of the slope.

Current topography indicates that existing slopes in the area vary from 10° to 12°. Given these slopes and the soil stratigraphy, cut slopes of 1.5H:1V and more than 3 m in height should be stable, however, this should be assessed on site by Tetra Tech EBA. Gullying, some ravelling and slope crest regression will likely occur in the long term. Subject to on site evaluation by Tetra Tech EBA, slopes less than 3 m in height may be cut at 1H:1V if armoured with boulders and cobbles.

If limited by space and steeper slope angles are needed, some type of retaining wall may be required. This scope of work does not include this design. If required, this will take place in the detailed design phase.

6.7 Other

6.7.1 Contaminated Soils

It should be noted that this is an active industrial site and it is possible that during the site investigation or site development, contaminated soils or groundwater may be encountered. Mitigation of contaminated soil or groundwater could result in additional costs.

6.7.2 Permeability of On Site Soils

The soils observed at this site were predominately sand and silt and judged to be of low to medium permeability. This would slightly impede the infiltration of hydrocarbons but would not be considered suitable for construction of an impermeable barrier. A synthetic liner would be required if natural soil was used. Generally, the water table is deeper than 9 m at this site and liquids would tend to infiltrate to at least this depth.

6.7.3 Excavations

The contractor must undertake all excavation work per WorkSafe BC Occupational Health and Safety (OHS) Regulations Part 20. For this project, the depth of excavation is anticipated to be moderate and will be carried out for such components as service trenches, foundations and buried pipelines. Excavations greater than 1.2 m must be sloped no steeper than 1H:1V, however, localized sloughing may occur requiring flatter slopes. Where steeper or vertical excavations are necessary, shoring cage should be installed in the excavation and reviewed by a geotechnical engineer in accordance with WorkSafe BC OHS Regulations Part 20.

Excavations are not anticipated to extend to a depth where groundwater is encountered. Water should not accumulate within the excavation. If water is observed in the excavation, contractors should be prepared to remove it with sump pumps.

6.7.4 Trench Backfilling

In order to reduce the potential of differential settlement and frost heave movements roadways or building footprint areas, a minimum of 98% SPMDD is recommended for all trenches.

Structural backfill selected and compacted as defined in Section 6.1 may be used for service trenches providing it is free of organics. It should be noted that the ultimate performance of the trench backfill is directly related to the uniformity of the backfill compaction.

6.7.5 Backfill Materials

The local soils consisting primarily of sand and silt with varying amounts of gravel, and will not likely be suitable for use as structural fill. With the variable nature of the material encountered on site, it is possible for some pockets of materials to be suitable, however this would need to be assessed by Tetra Tech EBA onsite.

6.7.6 Concrete

Sample sulfide tests in all the boreholes came back negative or showing trace amounts, and in addition, soluble sulphate attack on concrete is not known to be an issue in this general area. It is expected that normal cement can be used on this site. See Appendix C for test results.

6.8 Review of Design and Construction

Tetra Tech EBA should be given the opportunity to review the details of the design and specifications related to geotechnical aspects of the project prior to construction.

All recommendations presented in this report are based upon the assumption that an adequate level of monitoring will be provided during construction, and that all construction will be carried out by suitably qualified contractors, experienced in earthworks and foundation construction. Adequate levels of monitoring are considered to be:

- For deep foundations, full time monitoring and design review during construction;
- For shallow foundations, inspection of bearing surfaces and excavations; and
- For earthworks, full time monitoring and compaction testing.

All such quality assurance monitoring should be carried out by suitable qualified persons, on behalf of the owner, independent of the contractor. One of the purposes of providing an adequate level of monitoring is to check that the provided recommendations, which are based on the findings at discrete borehole locations, are relevant to other areas of the site. Tetra Tech EBA will provide these services upon request.

7.0 CLOSURE

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

Respectfully submitted,
Tetra Tech EBA Inc.

Prepared by:

ISSUED FOR REVIEW

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REFERENCES

Canadian Foundation Engineering Manual, 4th Edition, 2006. Canadian Geotechnical Society;

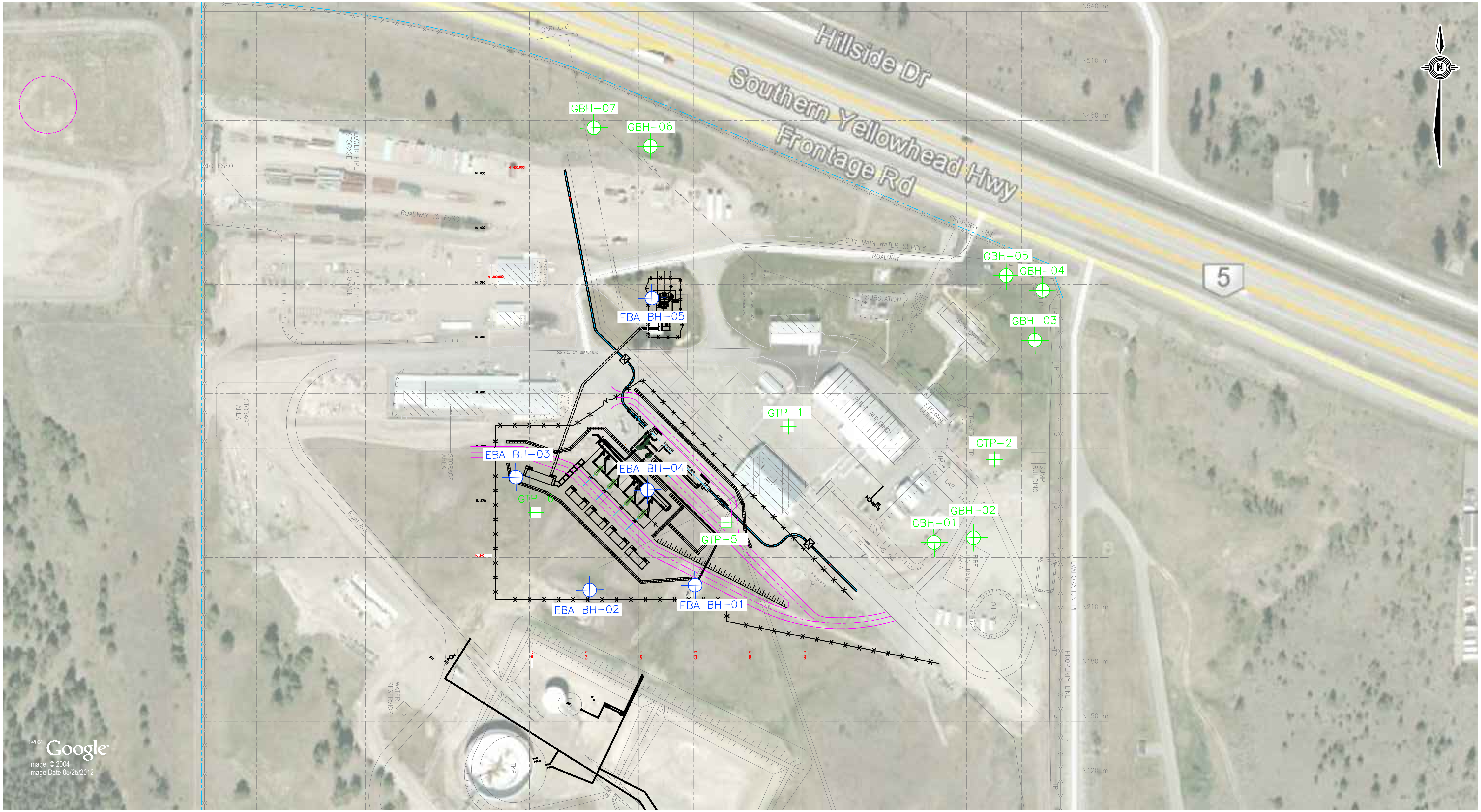
British Columbia Building Code 2012 – Province of British Columbia;

Golder Associates Ltd. (Golder), 1992, Geotechnical Investigation for Containment Structure;

Golder, 1995, Geotechnical Investigation for Tertiary Containment System; and

EBA, 2013 Preliminary Geotechnical Input – Kamloops Station.

FIGURES



LEGEND:

⊕ - EBA BOREHOLE

⊕ - GOLDER 1995 BOREHOLE

⊞ - GOLDER 1992 TESTPIT

0 100

Scale: 1: 2 000 (metres)

NOTES

STATUS
ISSUED FOR REVIEW

CLIENT
TRANSMOUNTAIN

TETRA TECH

TMEP ENHANCED FEED PHASE 1
KAMLOOPS PUMP STATION, BC

BOREHOLE LOCATION PLAN

PROJECT NO.	DWN	CKD	REV
V13103101-02	CC	AW	0

OFFICE	DATE
NANAIMO	February 23, 2015

Figure 1

Q:\Nanaimo\Engineering\N131\Projects\projects\V13103101-01 Trans Mountain Expansion Project\Kamloops pump station\kamloops pump station overlay with borehole locations.dwg [FIGURE 1] February 23, 2015 - 3:43:01 pm (BY: KITCHINGMAN, ISAAC)

APPENDIX A

TETRA TECH EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEOTECHNICAL REPORT

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

1.0 USE OF REPORT AND OWNERSHIP

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

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

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of Tetra Tech EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

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

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

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

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

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

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

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

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA 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.

5.0 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.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

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

7.0 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.

8.0 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.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

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

10.0 OBSERVATIONS DURING CONSTRUCTION

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

11.0 DRAINAGE SYSTEMS

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

12.0 BEARING CAPACITY

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

13.0 SAMPLES

Tetra Tech EBA 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.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

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

APPENDIX B

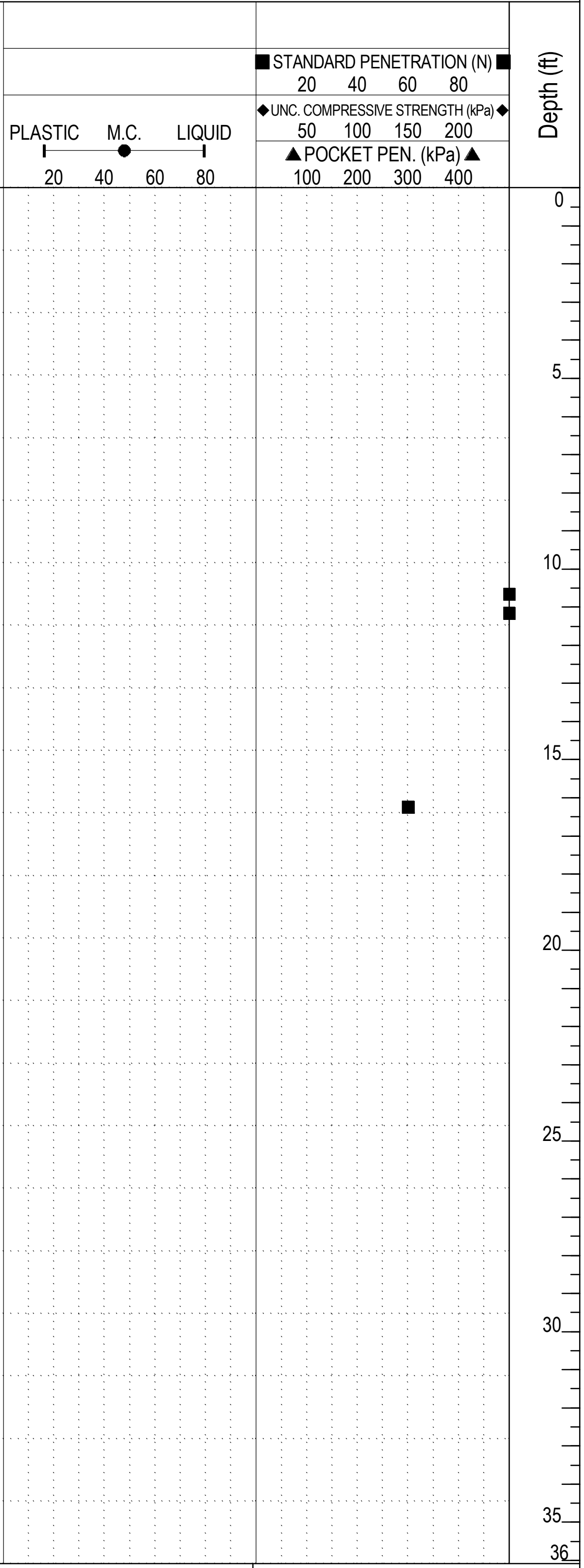
BOREHOLE LOGS

Trans Mountain Expansion Project	Kinder Morgan	PROJECT NO. - BOREHOLE NO.
682742.00 m E; 5615436 .00 m N	Drill Method: B57	V13103101-02-BH13-01
Kamloops	Driller: On The Mark	

SAMPLE TYPE ■ DISTURBED ◿ NO RECOVERY ☒ SPT ☰ A-CASING ▥ SHELBY TUBE ▮ CORE

BACKFILL TYPE ■ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)	MOISTURE CONTENT
0				
1	SAND and SILT, trace gravel, moist, brown; fine grained sand (12.5 mm MINUS); fine grained sub-rounded gravel			
3	SAND, silty, trace gravel, moist, brown, very dense; fine grained sand (12.5 mm MINUS); fine grained sub- rounded gravel; SPT 3.0 m to 3.5 m 16/97/100	■	100 100	
5	SILT, some clay, trace gravel, hard, moist; SPT 4.6 m to 5.3 m 18/34/26/38/46	☒	60	
	EOH at 5.5 m refusal at bedrock			



TETRA TECH EBA

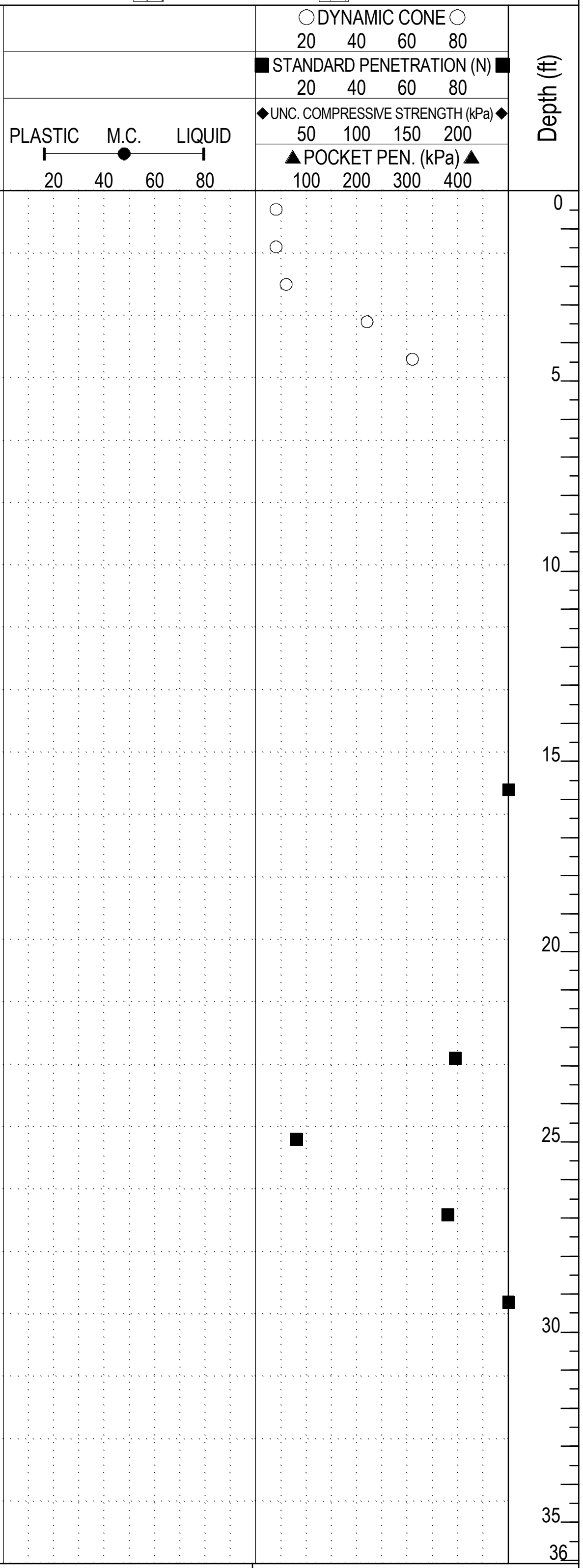
LOGGED BY: TJ	COMPLETION DEPTH: 5.5 m
REVIEWED BY: AW	COMPLETE: 11/21/2013
DRAWING NO: 1	Page 1 of 1

Trans Mountain Expansion Project	Kinder Morgan	PROJECT NO. - BOREHOLE NO.
682689.00 m E; 5615431.00 m N	Drill Method: B57	V13103101-02-BH13-02
Kamloops	Driller: On The Mark	

SAMPLE TYPE ▇ DISTURBED ◸ NO RECOVERY ☒ SPT ☰ A-CASING ▥ SHELBY TUBE ▌ CORE

BACKFILL TYPE ▇ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▨ DRILL CUTTINGS ⁘ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)	DCPT (N)	MOISTURE CONTENT
0				8	
				8	
				12	
1				44	
	SAND, some silt, some gravel, moist, brown; fine grained sand (25 mm MINUS); fine grained sub-angular gravel	▇		62	
2					
3	- becomes trace gravel, dry, light brown; coarse to medium grained sand (9.5 mm MINUS); fine grained angular gravel at 3.0 m	▇			
4					
5	- becomes very dense, moist, brown; medium to fine grained sand(12.5 mm MINUS); fine grained angular gravel at 4.6 m; SPT 4.6 m to 5.0 m 80/88/70	☒	100		
	- becomes silty; medium to fine grained sand (9.5 mm MINUS) at 5.0 m	▇			
6					
7	- becomes gravelly, medium to fine grained sand (19 mm MINUS) at 6.7 m; SPT 6.7 m to 7.2 m 18/30/49	☒	79		
	SILT, sandy, some gravel, compact, moist, brown; fine grained sand; fine grained angular gravel (9.5 mm MINUS); low plastic fines; SPT 7.3 m to 7.9 m 3/6/10	☒	16		
8	- becomes very dense at 7.9 m SPT 7.9 to 8.5 m 10/20/56	☒	76		
9	SPT 8.5 m to 9.3 m 27/60/57/73/110	☒	100		
	EOH at 9.3 m due to sloughing				
10					
11					



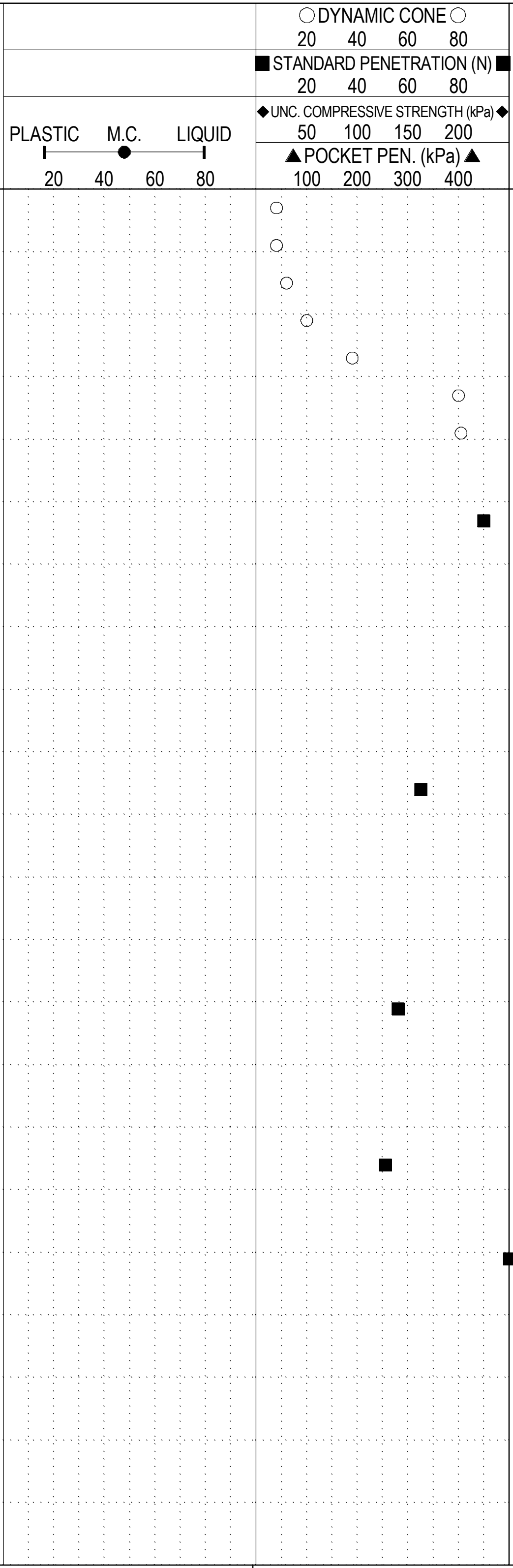
LOGGED BY: TJ	COMPLETION DEPTH: 9.3 m
REVIEWED BY: AW	COMPLETE: 11/21/2013
DRAWING NO: 1	Page 1 of 1

TETRA TECH EBA

Trans Mountain Expansion Project	Kinder Morgan	PROJECT NO. - BOREHOLE NO.
682647.00 m E; 5615484.00 m N	Drill Method: B57	V13103101-02-BH13-03
Kamloops	Driller: On The Mark	

SAMPLE TYPE	▨ DISTURBED	◸ NO RECOVERY	☒ SPT	☰ A-CASING	▥ SHELBY TUBE	▮ CORE
BACKFILL TYPE	▨ BENTONITE	⁘ PEA GRAVEL	▥ SLOUGH	⁘ GROUT	▧ DRILL CUTTINGS	⁘ SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)	DCPT (N)	MOISTURE CONTENT	Depth (ft)
0				8		0
				8		
				12		
1				20		
	SAND and SILT, brown; fine grained sand	▨		38		5
				80		
2				81		
	GRAVEL, sandy, very dense, moist to wet, brown; medium to coarse grained sand; fine grained angular to sub-angular gravel (25 mm MINUS) SPT 2.4 m to 2.9 m 10/10/80	☒	90			
3	SAND, silty, some gravel, moist, dark brown; medium to coarse grained sand (4.75 mm MINUS); fine grained angular to sub-angular gravel;	▨				10
4						
	- becomes very dense, light brown; fine grained sand (19 mm MINUS); fine grained angular gravel;low plastic fines at 4.4 m; SPT 4.4 m to 5.2 m 25/33/32/78/55	☒	65			15
5	- becomes trace gravel, brown; medium to fine grained sand (12.5 mm MINUS); fine grained angular to sub-angular gravel at 4.6 m	▨				
6						
	SILT, very dense, moist, light brown/grey, low plastic fines; SPT 6.1 m to 7.0 m 18/26/30/32/46/42	☒	56			20
7		▨				
	- SPT 7.6 m to 8.4 m 13/21/30/45/51	☒	51			25
8		▨				
	SAND, silty, moist to wet, brown; medium to fine grained sand; SPT 8.2 m to 8.9 m 16/44/58/98/100	☒	100			
9	EOH @ 8.9 m					30
10						
11						35 36



TETRA TECH EBA

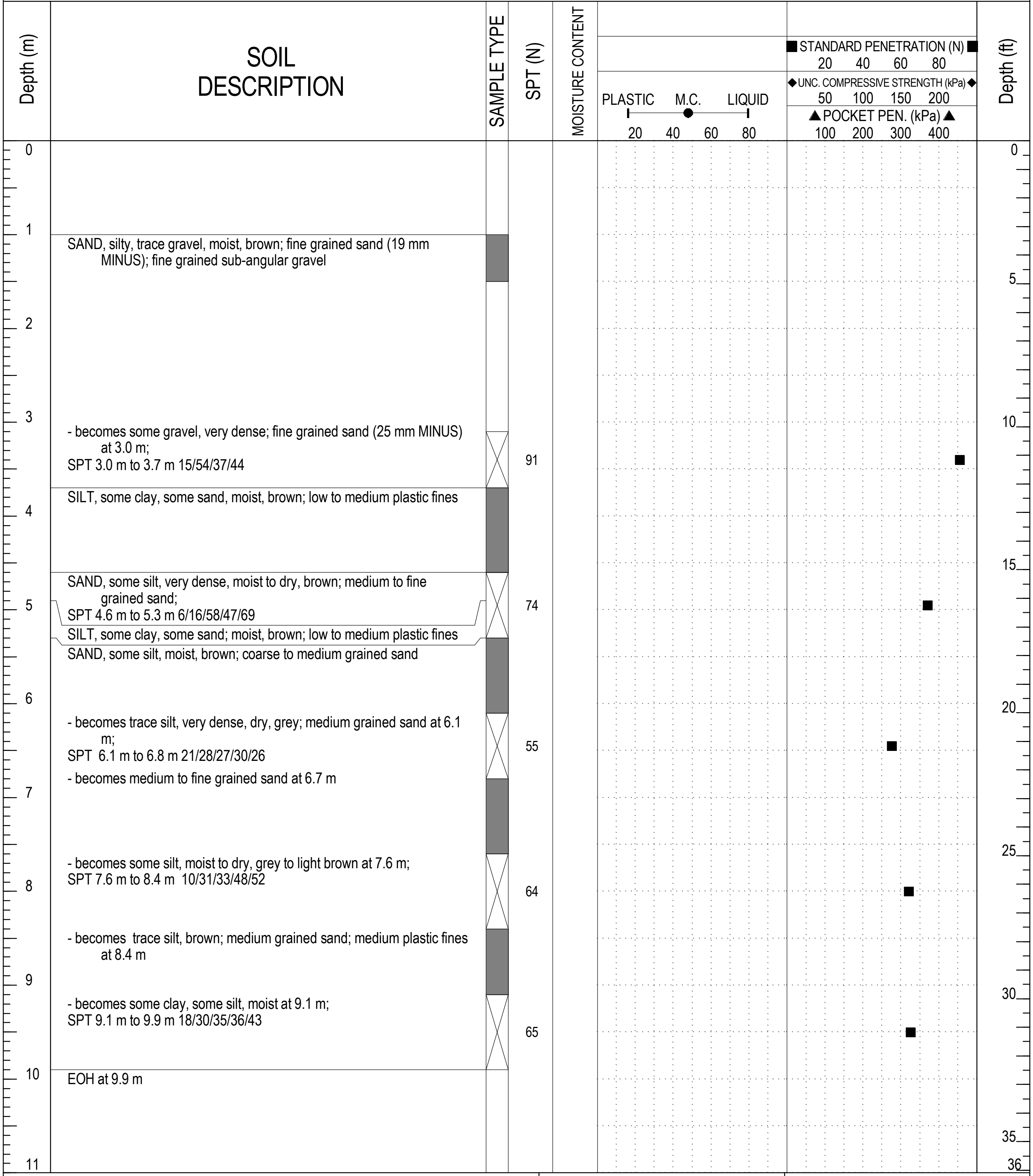
LOGGED BY: TJ	COMPLETION DEPTH: 8.9 m
REVIEWED BY: AW	COMPLETE: 11/21/2013
DRAWING NO: 1	Page 1 of 1

Trans Mountain Expansion Project	Kinder Morgan	PROJECT NO. - BOREHOLE NO.
682720.00 m E; 5615488.00 m N	Drill Method: B57	V13103101-02-BH13-04
Kamloops	Driller: On The Mark	

SAMPLE TYPE ▨ DISTURBED ◺ NO RECOVERY ☒ SPT ☰ A-CASING ▥ SHELBY TUBE ▮ CORE

BACKFILL TYPE ▨ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▧ DRILL CUTTINGS ⁘ SAND

SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)
SAND, silty, trace gravel, moist, brown; fine grained sand (19 mm MINUS); fine grained sub-angular gravel	▨	
- becomes some gravel, very dense; fine grained sand (25 mm MINUS) at 3.0 m; SPT 3.0 m to 3.7 m 15/54/37/44	☒	91
SILT, some clay, some sand, moist, brown; low to medium plastic fines	▨	
SAND, some silt, very dense, moist to dry, brown; medium to fine grained sand; SPT 4.6 m to 5.3 m 6/16/58/47/69	☒	74
SILT, some clay, some sand; moist, brown; low to medium plastic fines		
SAND, some silt, moist, brown; coarse to medium grained sand	▨	
- becomes trace silt, very dense, dry, grey; medium grained sand at 6.1 m; SPT 6.1 m to 6.8 m 21/28/27/30/26	☒	55
- becomes medium to fine grained sand at 6.7 m	▨	
- becomes some silt, moist to dry, grey to light brown at 7.6 m; SPT 7.6 m to 8.4 m 10/31/33/48/52	☒	64
- becomes trace silt, brown; medium grained sand; medium plastic fines at 8.4 m	▨	
- becomes some clay, some silt, moist at 9.1 m; SPT 9.1 m to 9.9 m 18/30/35/36/43	☒	65
EOH at 9.9 m		



TETRA TECH EBA

LOGGED BY: TJ	COMPLETION DEPTH: 9.9 m
REVIEWED BY: AW	COMPLETE: 11/22/2013
DRAWING NO: 1	Page 1 of 1

Trans Mountain Expansion Project	Kinder Morgan	PROJECT NO. - BOREHOLE NO.
682723.00 m E; 5615586.00 m N	Drill Method: B57	V13103101-02-BH13-05
Kamloops	Driller: On The Mark	

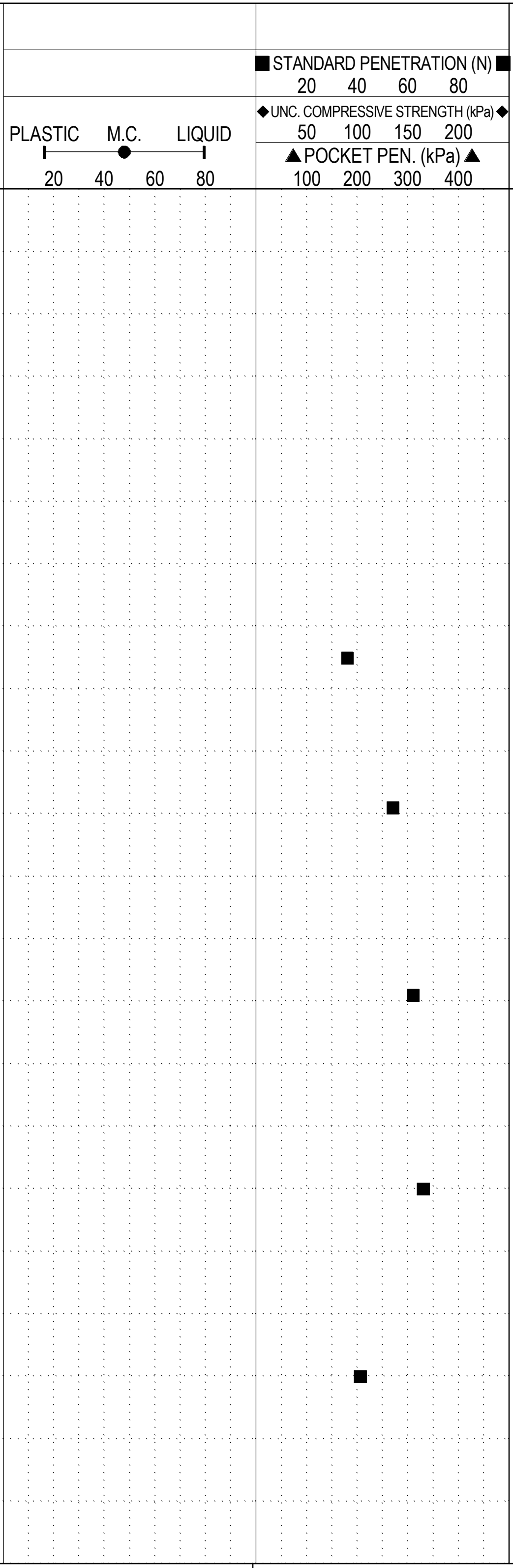
SAMPLE TYPE ▨ DISTURBED ⧄ NO RECOVERY ☒ SPT ☰ A-CASING ▥ SHELBY TUBE ▮ CORE

BACKFILL TYPE ▨ BENTONITE ⁘ PEA GRAVEL ▥ SLOUGH ⁘ GROUT ▧ DRILL CUTTINGS ⁘ SAND

Depth (m): 0 1 2 3 4 5 6 7 8 9 10 11

Depth (ft): 0 5 10 15 20 25 30 35 36

SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)	MOISTURE CONTENT
SAND, silty, trace gravel, moist, brown; fine grained sand (12.5 mm MINUS); fine grained sub rounded gravel	▨		
SILT, hard, wet, brown; homogeneous; non-plastic fines; SPT 3.4 m to 4.1 m 5/15/21/42/65 - groundwater encountered at 3.4 m - becomes sandy, trace clay, moist, brown; low plastic fines at 4.1 m	☒ ▨	36	
SAND, silty, very dense, moist, brown; medium to coarse grained sand; low plastic fines; SPT 4.6 m to 5.3 m 15/23/31/36/36	☒	54	
SAND and SILT, trace clay, moist to wet, brown; medium to coarse grained sand; low plastic fines - becomes silty, moist; fine grained sand at 6.1 m; SPT 6.1 m to 6.8 m 10/24/38/48/49	▨ ☒	62	
SAND and SILT, wet, brown; fine grained sand; low plastic fines	▨		
SAND, silty, very dense, moist, brown; fine grained sand; SPT 7.6 m to 8.4 m 14/25/41/55/50	☒ ▨	66	
SAND and SILT, dense, moist, brown/grey; fine grained sand; non-plastic; SPT 9.1 m to 9.9 m 12/25/16/45/ 90	☒	41	
EOH at 9.9 m			



TETRA TECH EBA

LOGGED BY: TJ	COMPLETION DEPTH: 9.9 m
REVIEWED BY: AW	COMPLETE: 11/22/2013
DRAWING NO: 1	Page 1 of 1

APPENDIX C

SOIL RESISTIVITY AND CORROSIVITY EVALUATION

CORROSION
SERVICE

December 9, 2013

EBA, A Tetra Tech Company
150 715 Dicson Ave.
Kelowna, B.C.
V1Y 9G6

Attention: Mr. Trevor Janicki, B.Sc.
Laboratory Supervisor

Re: Soil Sample Testing
File: V13103101-02-001

As requested, testing was completed for the subject provided samples. Descriptions of the test equipment and procedures as well as summary comments covering the testing results are discussed below.

1. Test Procedures and Equipment

1.1 Resistivity: Resistivity of the subject samples was measured utilizing a Wenner Four Pin Array type apparatus complete with MC Miller Test Box. This assembly is widely used in the testing of soil resistivity or conductivity and is a recommended for use in the ANSI/AWWA C-105 Soil Test Methodology, commonly referred to as the “10 Point System” for measuring soil corrosivity.

The procedure involves passing a D.C. current through the material under test and measuring the voltage drop between apparatus electrodes. Measurements are recorded with a Neilson Model 400 Soil Resistance Meter. The meter provides an ohmic reading which is then converted to an ohm-centimeter reading by multiplying the value by a correction factor (cross-sectional area of the sample divided by its length).

1.2. pH: Soil sample pH was measured utilizing a copper-copper sulphate half cell electrode to antimony half cell electrode. Millivolt measurements are subsequently converted to standard numeric pH values. Note that pH measurements become less accurate when exposed to air as a result of testing delays.

1.3 Soil Sulphides and Redox Potential: Soil samples were checked for the present of sulphides utilizing 3% sodium azide in 0.1 normal iodine solution. In the presence of sulphide bacteria the immersed sample will produce gas. Sample results are characterized as Negative (as absence of gas bubbling), Trace (minor gas bubbling) or Positive (vigorous gas bubbling). A test of the oxidation-reduction potential was also completed which provides an indication of the degree of aeration of the soil. Low or negative values indicate an anaerobic environment, which may support sulfate-reducing bacteria. Note that sulphide and redox measurements become less accurate when exposed to air as a result of testing delays.

2. Sample Testing

A total of 6 soil samples were submitted by EBA Company for testing. The samples were individually bagged and identified based on a submitted Test Program document. Note also that “As Received” moisture content (Damp, Saturated, etc.) were noted for each sample.

3. Test Results

Please see Appendix I for a tabulation of the test results. As the data show the “As Received” resistivities were in the range of 2,600 - 10,000 ohm-cms. Note to convert to ohm-meters divide the test measurements by 100.

After initial testing the samples were subsequently saturated with distilled water and note previous tests of the distilled water confirmed a resistivity in the range of 650,000 ohm-cms. After saturation the samples were allowed to sit for several minutes in order to allow measurement values to stabilize. As the data show the resistivities were lower for all 6 samples, ranging from 1,400 – 3,200 ohm-cms.

In addition, three samples showed trace results for sulphides, while pH was neutral to somewhat acidic. Redox potentials were positive indicating a relatively aerobic environment.

We trust this information is as required and your invoice for the testing work and this report will be sent out directly from our Toronto office. If you have questions please contact us at our Vancouver area office.

Yours truly,

Corrosion Service Company Limited

Ross Armstrong
Branch Manager
NACE Certified No. 6520

Encl.

APPENDIX I

Soil Sample Testing
For: EBA Engineering Ltd.
Project: Kinder Morgan Samples
Kamloops, B.C.

SOIL RESISTIVITY DATA

TESTING DATE:November 29, 2013

REFERENCE **SAMPLE TESTS**

Location Ref.	Depth	As Received Sample Moisture	Miller Type Soil Box Presented in Ohm-Cms.* As Received	Saturated[1]	Sample PH Value	Sample Redox	Sample Sulfides
BH13-01	10'-15'	Moist	8,700	3,200	5.7	+122	Negative
BH13-02	10'-15'	Moist	10,000	3,100	6.1	+117	Negative
BH13-03	8'-15'	Moist	2,600	1,500	6.4	+105	Trace
BH13-04	10'-15'	Moist	5,500	1,600	6.6	+104	Trace
BH13-05	11'-15'	Moist	5,400	2,700	6.2	+86	Negative
BH13-01/05	3'-5'	Moist	3,200	1,400	6.7	+95	Trace

* To convert to Ohm-Meters divide by 100.

1: Samples saturated with distilled water (resistance > 650,000 ohm-cms.)