TRANSMOUNTAIN

Trans Mountain Expansion Project

Geotechnical HDD Feasibility Assessment Thompson River at SSEID 005.8 KP 842.9

KMC Document #01-13283-S5A-0000-PL-RPT-0006 R0

KINDER MORGAN CANADA INC.

Rev No.	Prepared by/ Date	Reviewed by/ Date	Approved by/ Date	Reviewed by TMEP	Pages Revised	Issued Type
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AN APPLIED EARTH SCIENCES COMPANY

TRANS MOUNTAIN PIPELINE ULC

TRANS MOUNTAIN EXPANSION PROJECT

GEOTECHNICAL HDD FEASIBILITY REPORT – THOMPSON RIVER AT SSEID 005.8 KP 842.9

PROJECT NO.: 0095150-14
DOCUMENT NO.: TMEP18-068
DATE: July 6, 2018

EXECUTIVE SUMMARY

As part of the engineering design and assessment for the Trans Mountain Expansion Project (TMEP), BGC Engineering Inc. (BGC) has been retained to complete geotechnical feasibility assessments for trenchless crossings at select watercourse and overland crossings along the proposed pipeline corridor.

This report provides a feasibility-level geotechnical assessment of the Thompson River crossing located at Kilometre Post (KP) 842.9, in Kamloops, British Columbia.

The scope of work for this assessment included a desktop review of the relevant regional and local geological settings, and completion of geotechnical site investigations including drilling and geophysical surveys. The scope of work also included the compilation and interpretation of this data to provide, from a geotechnical perspective, an indication of the feasibility of the proposed horizontal directional drilling (HDD) crossing.

In November of 2013 and December of 2014, BGC monitored the drilling of four geotechnical boreholes adjacent to the preliminary HDD crossing of the Thompson River. Advisian (formerly WorleyParsons), under sub contract to BGC, completed geophysical surveys at the same site in November of 2013. In April 2018, UniversalPegasus International (UPI) provided BGC with a revised HDD alignment for the Thompson River Crossing. This report has been issued to update earlier findings with consideration of the most recent HDD alignment at Thompson River.

Analysis of historical aerial photographs indicates that the banks of the Thompson River appear stable and the proposed HDD alignment is not expected to be compromised by bank erosion or avulsion. The HDD entry and exit points are below the 200-year flood elevation of 346.7 masl by approximately 4.3 m and 2.4 m, respectively. This flood depth is not expected to result in scour at the HDD entry and exit points, but as a protective measure it is recommended that a minimum burial depth of 1.5 m be maintained where the pipeline crosses the floodplain. Given the HDD entry and exit points are located in a floodplain, the timing of the installation of the HDD borepath should consider the potential for flooding during the yearly freshet.

The 200-year scour depth is estimated to be approximately 1.7 m below the channel thalweg elevation and corresponds to an elevation of 333.5 masl. Under this event, the HDD borepath is expected to maintain greater than 25 m of cover should the maximum scour occur.

The results of the site investigation and terrain mapping indicate that the HDD alignment enters and exits through a fluvial sand deposit. The fluvial deposit consists of loose, poorly graded, fine to medium grained sand with trace silt and trace fine grained gravel. A coarse sand and/or gravel deposit was inferred in the fluvial deposit (at 335.3 masl) due to drill action at BH-BGC14-TR-02. As the HDD moves southeast below the Thompson River, the borepath is expected to encounter interbedded sand and silt material, interpreted to be glaciolacustrine in origin. At approximately 1275 m along the borepath, the HDD is expected to enter similar fluvial deposits to those encountered at the entry point, before exiting at an elevation of 344.3 masl.

Given the above, and based on the desktop study, and results of the geotechnical site investigation, an HDD at this location can be considered feasible from a geotechnical perspective, provided the following risks can be addressed during detailed design and construction:

- Sloughing and hole collapse: In general, soils encountered during geotechnical drilling appeared to be stable with minor sloughing observed at BH-BGC14-TR-03 and BH-BGC14-TR-04. The fluvial, glaciofluvial, and glaciolacustrine deposits encountered in the geotechnical drilling program consisted predominantly of sands and silts, with lesser quantities of fine gravel in some areas. However, coarser materials may be present within these units; a coarse sand or gravel deposit was inferred in the fluvial deposit at BH-BGC14-TR-02 (at 335.3 masl) based on drill action. There is the potential for collapse in the loose fluvial sand deposits near the HDD entry and exit points. Possible mitigation includes careful drill fluid management (viscosity and pressure) and/or casing to maintain the integrity of the borepath during HDD construction.
- Loss of drilling fluids: Loose, cohesionless, coarse grained sand may be present within the fluvial, glaciofluvial and glaciolacustrine deposits that could cause drilling fluid circulation losses. Circulation losses in the glaciofluvial sand deposit were observed to be as high as 35%. The potential for fluid loss can potentially be mitigated by adapting the drill mud mixes.
- Encountering cobbles and boulders: The presence of boulders or cobbles was not evident during the geotechnical drilling program. However large clasts (i.e., cobbles and boulders) may generally be encountered in fluvial/glaciofluvial deposits. ERT survey results indicate a zone of high resistivity material (ranging from approximately 250 to 350 ohm-m) approximately 1000 m from the proposed entry point. This may indicate an incised and buried channel and coarse sediments may be present in this zone. Encountering cobbles and boulders may deflect the HDD borepath and/or damage the carrier pipe when it is pulled into the borepath. Preparation for variable drilling conditions, use of casing and/or altering the reaming direction may be considered in detailed design.

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AMENDMENTS

This report is an update to the Preliminary Geotechnical HDD Feasibility Assessment – Thompson River at V10 RK 846.8, originally dated February 20, 2015. This revision includes a rename for updated SSEID alignment (SSEID 005.8) issued by UPI in May 2018.

Title Page:

Report title renamed for updated SSEID alignment.

Executive Summary:

Updated to include the alternate HDD alignment issued by UPI in April 2018. Revised text included for the geotechnical challenges and uncertainties that have been updated, as described below.

Section 1.0:

Revised text to include the revised SSEID alignment.

Section 2.0:

Revised text to include the revised SSEID alignment.

Section 3.1:

Revised text to include the revised SSEID alignment.

Figure 3-1 has been updated to show the revised alignments.

Section 3.6:

Updated text to include the revised SSEID alignments.

Updated the flood frequency analysis for Thompson River with additional hydrometric gauge data from Water Survey of Canada.

Section 4.1:

Updated text to include the revised HDD alignment.

Included Table 4-1 to summarize borehole depths, elevations and locations during the 2013 and 2014 geotechnical investigations.

Section 5.0, 5.1:

Revised text to include a summary of the geological units identified during BGC's site investigations including the current understanding of the site's geologic engineering model.

Included Table 5-1 to summarize the geologic units and conditions encountered during BGC's site investigations.

Section 6.1:

Revised text to update general considerations, and those related to borepath stability, circulation and potential for loss of fluids, and geotechnical feasibility in light of the geologic engineering model and geotechnical investigation results.

Drawings:

Drawings 01A, 01B, 02, 03, 04 and 05 have been updated with the revised SSEID alignment and geologic engineering model.

Appendix A – BC Water Well Records

Updated to include PDFs of the water well records.

Appendix B – Hydrotechnical Assessment Methodology

Updated memo provided March 22, 2018.

Appendix C – Borehole Logs

Included minor revisions.

Appendix D – Laboratory Test Results:

Updated title block information and added data from BH-BGC13-TR-01 and BH-BGC14-TR-02, -03, and -04 on attached grain size analysis plot.

LIMITATIONS

BGC Engineering Inc. (BGC) prepared this document for Trans Mountain Pipeline ULC (Trans Mountain). The material in this report reflects the judgment of BGC staff based upon the information made available to BGC at the time of preparation of the report, including that information provided to it by Trans Mountain. Any use which a third party makes of this report or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility whatsoever for damages, loss, expenses, loss of profit or revenues, if any, suffered by any third party as a result of decisions made or actions based on this report.

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1.0 PROJECT DESCRIPTION

Trans Mountain Pipeline ULC (Trans Mountain) is a Canadian corporation with its head office located in Calgary, Alberta. Trans Mountain is a general partner of Trans Mountain Pipeline L.P., which is operated by Kinder Morgan Canada Inc. (KMC), and is fully owned by Kinder Morgan Energy Partners, L.P. Trans Mountain is the holder of the National Energy Board (NEB) certificates for the Trans Mountain pipeline system (TMPL system).

The TMPL system commenced operations in 1953 and now transports a range of crude oil and petroleum products from Western Canada to locations in central and southwestern British Columbia, Washington State and offshore. The TMPL system currently supplies much of the crude oil and refined products used in British Columbia.

In December 2016, the NEB granted approval for the Trans Mountain Expansion Project (referred to as “TMEP” or “the Project”) under Section 52 of the *National Energy Board Act (NEB Act).* The proposed expansion will comprise the following:

- Pipeline segments that complete a twinning (or “looping”) of the pipeline in Alberta and BC with about 987 km of new buried pipeline
- New and modified facilities, including pump stations and tanks
- Three new berths at the Westridge Marine Terminal in Burnaby, BC, each capable of handling Aframax class vessels.

As part of the design process for the twinning of the pipeline, geotechnical and hydrotechnical investigations are being undertaken at watercourse crossings and where the pipeline will be installed by trenchless methods to avoid existing infrastructure. These investigations support the feasibility assessments for establishing the preferred crossing methodology, and where appropriate, contingency options.

Known reference points along the existing Trans Mountain pipeline system are commonly referred to as Kilometer Post or “KP”. KP 0.0 is located at the Edmonton Terminal where the existing Trans Mountain system originates. KPs are approximately 1 km apart and are primarily used to describe features along the pipeline for operations and maintenance purposes. All references to KPs along the TMEP corridor are for the Route SSEID 005.8 alignment provided by UniversalPegasus International (UPI) in May 2018.

2.0 SCOPE OF WORK

As part of the engineering design and assessment for installing new sections of pipeline, Trans Mountain has retained BGC Engineering Inc. (BGC) to complete geotechnical feasibility assessments for trenchless crossings at select locations along the pipeline corridor. A trenchless crossing by horizontal directional drilling (HDD) is proposed for the Thompson River crossing, located at SSEID 005.8 KP 842.9, at the western edge of Kamloops, British Columbia. A 1358 m long (2D horizontal length in plan view) HDD crossing is proposed for this site, as illustrated in the design drawing for the proposed HDD crossing (UPI 2018).

BGC's scope of work for the feasibility assessment of the Thompson River crossing included the following:

- A desktop study including:
    - A review of the published literature on the regional geology and the local geological setting at the HDD crossing.
    - A review of the 1:20,000 scale terrain mapping assessment (Trans Mountain 2014) along the pipeline corridor.
    - A hydrotechnical assessment of the site, which consists of a flood frequency analysis and assessments of hydrotechnical hazards including scour and lateral migration.
- Drilling of four geotechnical boreholes adjacent to the proposed HDD crossing (monitored and logged by BGC).
- Completion of geophysical surveys along the proposed crossing (completed by Advisian, formerly WorleyParsons).

Planning for contingency river crossing methods is outside the scope of this study and will be addressed by the pipeline design engineer for the portion of the route under consideration, in this case, UPI. As such, no comments on the applicability of the current route to alternate crossing methods are provided herein.

The purpose of this report is to summarize the anticipated geotechnical site conditions at the proposed Thompson River crossing, and to provide an indication, from a geotechnical perspective, of the feasibility of an HDD crossing at this location.

3.0 SITE DESCRIPTION, GEOLOGY AND HYDROLOGY

3.1. Overview

The Thompson River site is situated within the city limits of Kamloops, BC, just southeast of the Kamloops Airport. The site is located at KP 842.9 along the proposed TMEP alignment as shown in Figure 3-1 below.

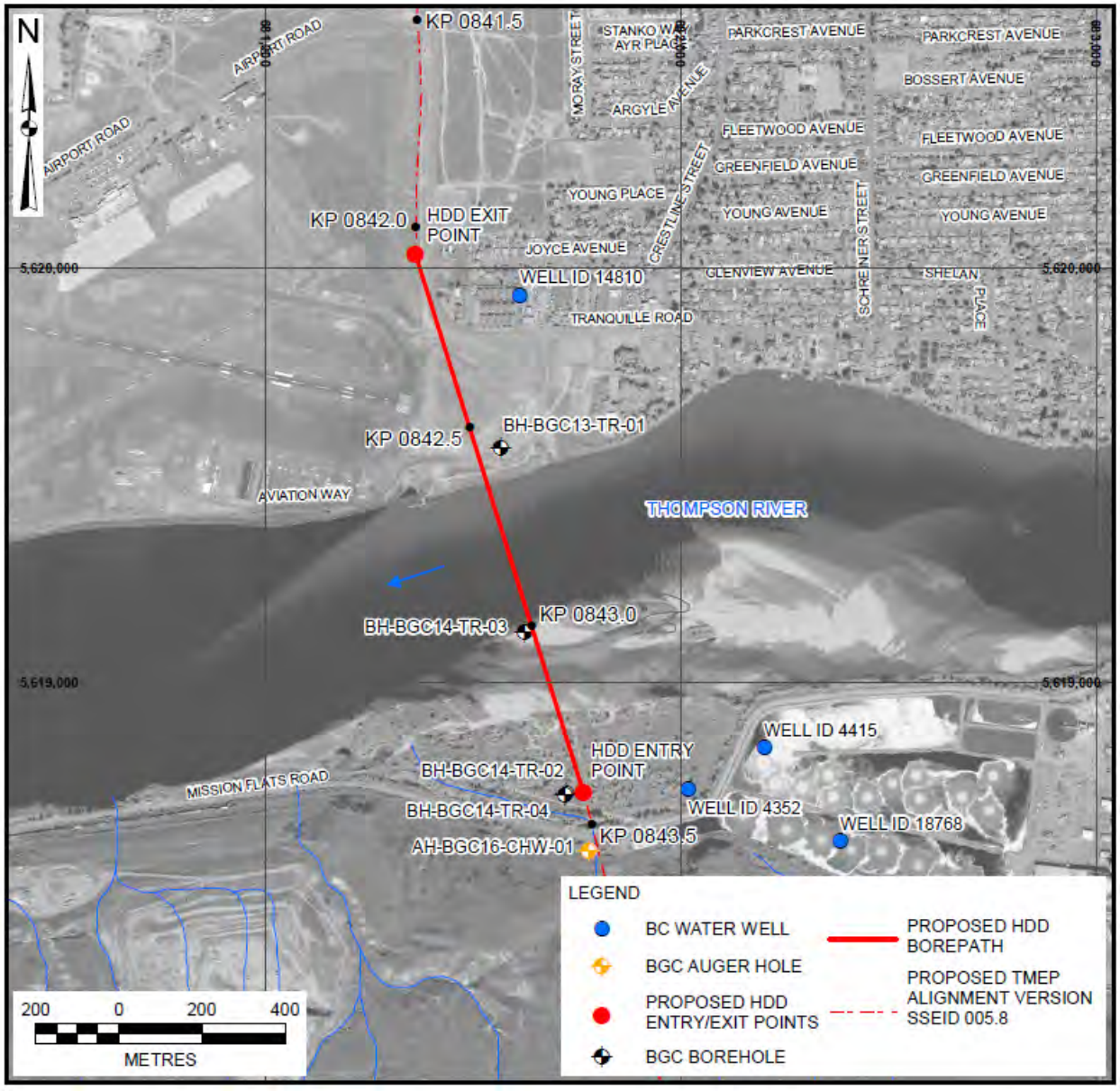

Figure 3-1. Location of the proposed Thompson River pipeline crossing.

At the proposed crossing location, the active river channel is located along the southern margin of the Thompson River valley, and has a bankfull width of approximately 570 m. At this site, the proposed HDD entry point is located approximately 190 m south of the left bank of the Thompson

River. The HDD exit point is situated approximately 600 m north of the right bank of the Thompson River and 15 m west of Tranquille Road. From entry to exit points, the proposed HDD borepath is approximately 1358 m long (2D horizonal length in plan view). The horizontal portion of the borepath of the proposed HDD alignment is designed to be at an elevation of approximately 295.0 metres above sea level (masl), approximately 45.0 mbgs.

3.2. Surficial Geology

The proposed TMEP crossing of the Thompson River is within the Thompson Plateau physiographic subregion of the Interior Plateau physiographic region.

At the maximum of the Fraser Glaciation 14,000 to 16,000 years before present, ice flowed to the south across the Interior Plateau as a continental ice dome (Tipper, 1971; Ryder et al., 1991). Maximum ice thickness was approximately 500 to 1000 m and the Interior Plateau was ice free at Kamloops approximately 10,000 years before present (Fulton, 1967; Ryder et al., 1991). During glaciation and post-glaciation, till and glaciofluvial materials were deposited in large volumes, which were then eroded and modified by post-glacial and modern rivers to form terraces along fluvial channels. Stagnant ice during deglaciation created blockages of the drainage network, forming glacial lakes into which large volumes of sediment were deposited (Ryder et al., 1991). Pre-glacial sediments have been mapped along valley walls, including the Thompson River valley (Fulton, 1975; 1976), and reflect pre-Fraser Glaciation, glacial and non-glacial environments (Fulton and Smith, 1978).

Following deglaciation, Glacial Lake Thompson formed in the South Thompson Valley near Kamloops, created by ice damming at both its eastern and western margins. During this period, significant quantities of silt were deposited into Glacial Lake Thompson (Fulton, 1965).

The dominant surficial materials of the Thompson Plateau are fluvial, glaciofluvial, colluvium, till, bedrock, and glaciolacustrine (Tipper, 1971; Fulton, 1975; 1976; Bednarski, 2009). Till deposits mantle and blanket valley walls and upland surfaces. Colluvial deposits are common along valley slopes and in fans and cones. Plains and terraces are composed of active fluvial, glaciofluvial, and glaciolacustrine deposits. Overburden thickness may be thin along high valley walls and ridge tops, and thickest in valley bottoms (Trans Mountain, 2013).

Active fluvial deposits are characterized as well sorted sands, gravels, silts and minor organic materials. Inactive fluvial fan deposits contain poorly sorted gravels, sands, silts, and clays. Glaciolacustrine deposits are typically laminated silts with lesser amounts of clay and sand (Fulton, 1975; 1976). Glaciofluvial sediments are commonly sands and gravels (Bednarski, 2009). Pre-Fraser sediments are characterized as unconsolidated sands, silts and gravels. Tills comprise poorly sorted sands, gravels, and silts with variable clast content (Fulton, 1975; 1976). Bedrock outcrops are common, and may include lesser amounts of weathered bedrock, colluvium, and till deposits.

Surficial geology mapping of the Kamloops area shows glaciolacustrine, till, pre-Fraser glacial sediment, and kettle terrace deposits in the lower Thompson Valley, indicating a complex,

proglacial depositional environment (Fulton, 1976). At the proposed HDD crossing location, the surficial geology shows modern fluvial deposits consisting of sand, gravel, silt, and peat (Fulton, 1976), with no indication of the thickness of these deposits.

3.3. Bedrock Geology

The Thompson Plateau is characterized by rock of the Quesnellia Terrane (Journeay et al., 2000). Bedrock at the proposed Thompson River HDD crossing is comprised of the Kamloops and Nicola Groups. The Kamloops Group consists of volcanic basalt and andesite breccias and tuffs (Monger and McMillan, 1989), as well as minor amounts of mudstone, shale, sandstone and conglomerate (Massey et al., 2005). The Nicola Group consists primarily of mudstone, sitstone, shale, and fine clastic sedimentary rocks (Monger and McMillan, 1989).

3.4. Terrain Mapping

As part of an overall terrain assessment for TMEP, BGC has completed terrain mapping along the proposed pipeline corridor at a nominal scale of 1:20,000 from the analysis of air photos, satellite imagery, and LiDAR topography. Terrain mapping was spot-checked by site visits and field observations (Trans Mountain, 2014). Local variations in terrain over areas of about 2 to 3 hectares, or over distances of less than approximately 150 meters may not be captured in the scale of terrain mapping. Terrain mapping for the Thompson River crossing is shown on Drawing 01A and a terrain code legend is shown on Drawing 01B.

3.4.1. Terrain Types

Terrain types mapped at the Thompson River crossing and shown on Drawing 01A include the deposits described below:

A. Fluvial

   Fluvial material is predominately composed of sand and gravel deposited by surface water and meltwater streams. Cobbles and boulders may also be present. Fluvial deposits may contain lesser amounts of silt that can be deposited in low flow settings such as overbank flooding. Fluvial material is mapped across the Thompson River floodplain at both the entry and exit points.

B. Colluvium

   Colluvium consists of surficial materials transported downslope by gravity through a range of processes including gradual downslope creep, landsliding, rockfall and debris flows. Colluvium is present on the south side of the Thompson River just south of the modern floodplain, within about 150 m of the HDD entry.

C. Glaciolacustrine

   Glaciolacustrine sediments typically consist of silts, clays and fine sands deposited in the bottom of glacial lakes. Deposits are often layered due to seasonal variations in source material, or a change in source material location. Glaciolacustrine material is common in

the Thompson Valley near Kamloops, and is mapped on the south side of the Thompson River HDD crossing.

D. Bedrock

Steep sloping bedrock that is subject to rockfalls and covered by a colluvium veneer is exposed in a small section approximately 250 m southeast of the HDD entry point.

E. Glacial Till

A glacial till outcrop is present approximately 400 m southwest of the HDD entry point.

BGC completed a terrain stability analysis in conjunction with terrain mapping of the TMEP route (Drawing 01A). This analysis classified a range of stability classes for the regions along the proposed HDD crossing. The areas near the HDD entry and exit points are classified as Stability Class I, suggesting that no significant stability problems exist at those locations.

3.5. Existing Borehole Data

An auger hole, AH-BGC16-CHW-01, was drilled approximately 135 m south of the proposed HDD entry point as part of a preliminary assessment of CP Rail crossings in the area (BGC, 2017a). AH-BGC16-CHW-01 is shown relative to the proposed HDD alignment in Figure 3-1 and Drawing 01A (plan view) and Drawing 02 (cross-section and plan view). Results from AH-BGC16-CHW-01 indicated the subsurface soils consisted of, in descending order: fluvial, glaciolacustrine, and till deposits.

A sonic drill hole, SD-BGC17-KLP-04 (Drawing 01A), was also drilled in the vicinity of the HDD crossing at Thompson River, approximately 650 m north of the proposed exit point (BGC, 2018). The sonic hole was drilled on the south side of the CN Railway, and encountered fluvial sand from surface until a target depth of 10.7 mbgs. The fluvial deposit consisted of fine to medium grained, compact, well graded, silty sand with trace clay.

The British Columbia Ministry of Environment provides data from watersheds, water monitoring sites, aquifers, water wells and flood protection works through the BC Water Resources Atlas (BCMOE). The BC Water Resources Atlas (BCMOE, 2018) indicates four water wells have been drilled within approximately 450 m of the proposed HDD alignment. Given the lack of geotechnical information available, they are not considered a reliable source of data and provide limited information. The well depths ranged from 4.6 mbgs to 23.5 mbgs. Bedrock was not recorded in any of the water wells recorded in the nearby area. The records indicate a thick unit of sand at depth. Table 3-1 is a summary of the basic information from the BC Water Resources Atlas including the Well Identification (ID) number. Appendix A includes the well records and subsurface information for Well ID 14810 and 18768.

Table 3-1. Borehole depths, elevations and locations.

Well ID	Depth		Year drilled	Subsurface information
	(mbgs)	(ftbgs)		
14810	23.5	77	1956	Yes
4415	4.6	15	1950	No
4352	N/A	N/A	1950	No
18768	15.3	50	1964	Yes

Note: No third-party geotechnical boreholes were available to BGC in the area at the time of writing.

3.6. Hydrotechnical Assessment

LiDAR coverage, historical aerial photographs, 2016 survey data, and ground observations were used to assess the potential for hydrotechnical hazards to impact the proposed pipeline. Hazards evaluated by BGC included scour, bank erosion, and avulsion. The methodologies used to complete this hazard assessment are presented in Appendix B.

3.6.1. Flood Frequency Analysis

Flood quantiles at the Thompson River crossing were estimated using a flood frequency analysis (FFA). The drainage area at the crossing was estimated to be 38,260 km^2 and a prorated FFA was used to estimate peak instantaneous streamflow (Q_{IMAX}) for various return periods. This FFA is based on the gauging stations: *North Thompson River at McClure* (08LB064) and *South Thompson River at Chase* (08LE031), which are located approximately 45 km upstream on the North Thompson River and 54 km upstream on the South Thompson River, respectively. The stations have a corresponding record length of 43 years between years 1971 and 2014, and have published watershed areas of 19,600 km^2 and 15,800 km^2, respectively. The flood quantiles for the crossing were adjusted with a climate change allowance of +10% based on guidance by APEGBC[1] (2012). Peak instantaneous flow estimates at the proposed Thompson River crossing for various return periods are as listed in Table 3-2.

Table 3-2. Peak instantaneous flow estimates (Q_{IMAX}) for the Thompson River [KP 842.9] crossing.

Pipeline Crossing	Basin Area (km^2)	Q_{IMAX} for Given Return Periods (m^3/s)						
		2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr
Thompson River	38,260	2,965	3,526	3,892	4,345	4,676	5,000	5,317

Average cross-sectional flow hydraulics for the crossing were estimated using Manning's equation, a surveyed cross-section, a channel gradient of 0.006% and the peak flows listed in Table 3-2. The cross-section used for the evaluation is based on a surveyed cross-section by Midwest Surveys Inc. on September 20, 2016. The water elevation for the 200-year return period

[1] The Association of Professional Engineers and Geoscientists of BC (APEGBC) recently changed its name to Engineers & Geoscientists British Columbia (EGBC).

flood is reported as 346.2 m above sea level (masl) at the crossing by the City of Kamloops (2004). Given the climate change allowance of +10% and the resulting 200-year flood presented in Table 3-2, the corresponding augmented 200-year return period flood elevation is 346.7 m. The elevations of the proposed HDD entry and exit points are 342.4 masl and 344.3 masl, respectively. The HDD entry point on the left (south) bank floodplain is approximately 4.3 m below the 200-year flood elevation and the HDD exit point is approximately 2.4 m below the 200-year flood elevation on the right (north) bank. Both the entry and the exit are at risk of being inundated should the banks be overtopped during a major flood event. A dyke is present on the right (north) bank floodplain that provides flood protection to the proposed HDD exit point (Kamloops Dyking, 1989). The dyke extends along Aviation Way and encircles the Kamloops Airport (Drawing 03). The top of dyke elevation is reported as 345.9 masl by the City of Kamloops (2004). This elevation is 0.8 m below the augmented 200-year flood elevation which means the dyke could be potentially overtopped during such a flood event.

As a protective measure it is recommended that a minimum burial depth of 1.5 m be maintained where the pipeline crosses the 200-year floodplain between approximately KP 840.9 and 843.6.

3.6.2. Scour

BGC has completed a scour analysis for the Thompson River site to evaluate general scour conditions across the channel where the proposed HDD alignment crosses the Thompson River. The scour analysis was conducted using the estimated peak flows presented in Table 3-2 above, and the channel cross-section was developed using a topographic survey by Midwest Surveys Inc. on September 20, 2016. Results from the analysis estimate a maximum scour depth of approximately 1.7 m below the channel thalweg (deepest flow within the channel) elevation of 335.2 masl during a 200-year flood event, corresponding to a maximum scour elevation of 333.5 masl. The approximate extent of this scour is shown on Drawing 02. It is noted, however, that the potential 200-year scour depth applies to the active channel and a section of the overbank where the active channel could potentially migrate laterally within the lifespan of the pipeline.

The depth of cover between Thompson River channel and the proposed HDD borepath remains greater than 25 m should the maximum scour occur. Given this result, scour is not considered a hazard for the proposed HDD borepath.

3.6.3. Bank Erosion

BGC completed an evaluation of the historical lateral erosion of the Thompson River using a comparison of historical aerial photographs between the years 1951 and 2016. See Table 3-3 for the complete list of photographs used in this analysis. Drawing 03 demonstrates how the channel planform has changed. The comparison shown on Drawing 03 illustrates that there are changes in the position of the channel banks of 10 m to 25 m. While some of this change may be associated to error with the air photo rectification (~10 m), the bank changes observed are <5% of the bankfull width (570 m) over the period of the air photo record, or approximately 0.1% of the bankfull width

per year. The relatively small change suggests that the channel planform has experienced minimal change over the past 65 years in the region of the proposed HDD crossing alignment.

Table 3-3. Thompson River historic aerial photographs database.

Date	Ref No.	Photo No.	Scale	Source
2016	N/A	N/A	N/A	City of Kamloops
2004	BCC04029	91, 92, 93, 95	1:30,000	Government of British Columbia
2000	BCC00007	121, 122, 123, 124	1:15,000	
2000	BCC00009	33	1:15,000	
1992	BCC92004	41, 42, 44, 45	1:15,000	
1992	BCC92007	135	1:15,000	
1986	BC86032	148, 150, 151, 152, 154,	1:15,000	
1986	BC86018	143, 144	1:15,000	
1974	BC7643	208, 210, 212, 213, 214	1:16,000	
1974	BC7640	7, 8	1:16,000	
1966	BC4369	139, 141, 143, 174, 175, 177, 178	1:15,840	
1959	BC2609	74, 76, 78, 80	1:12,800	
1959	BC2642	65, 67	1:12,800	
1948	BC702	99, 100	1:25,000	
1948	BC622	94, 95	1:25,000	
1948	BC616	67	1:25,000	

The pipeline crossing is located at the western edge of Kamloops, and the predominant land use in the surrounding area is urban and residential development. As a result, both banks of the channel have been modified by anthropogenic disturbances including the construction of the Kamloops Airport in the early 1930's adjacent to the right bank floodplain.

There are two existing Trans Mountain pipelines (TMPL) at the crossing that run parallel to the proposed HDD borepath. Evidence of bank erosion has not been observed on either TMPL crossing, and bank erosion is not considered an active hazard (BGC, 2013 and 2017b). Furthermore, a July 26, 2014 site visit by BGC observed no bank instability adjacent to the proposed HDD alignment. Both banks of the Thompson River crossing are well vegetated, which also contributes to bank stability. The entry point is located approximately 200 m south of the left bank and the exit point is located approximately 570 m north of the right bank. Given these results, bank erosion in the vicinity of the proposed HDD crossing is not considered a hazard for the proposed HDD borepath.

3.6.4. Avulsion

The proposed pipeline crossing is located approximately 7 km downstream of the confluence of the North and South Thompson Rivers and is situated along a 3 km long straight reach upstream of a slight right bend near the mouth of Kamloops Lake. The channel is restricted within a wide floodplain at the proposed crossing and has a limited capacity for lateral migration or avulsion due to presence of urban development on both channel banks. No relic channel scars have been identified within the vicinity of the proposed HDD crossing. In addition, there are no signs of active bank erosion or channel adjustment along either bank that may indicate potential for an avulsion channel during flood events. Given these observations, avulsion is not considered a hazard for the proposed HDD borepath.

4.0 SITE INVESTIGATION

BGC monitored the drilling of four boreholes adjacent to the proposed HDD alignment at Thompson River between the winter of 2013 and 2014. A preliminary borehole was drilled in November 2013, with three additional boreholes drilled in December 2014.

Advisian (now WorleyParsons), under sub contract to BGC, completed geophysical surveys along the HDD alignment in November 2013, using electrical resistivity tomography (ERT), seismic refraction and MASW survey methods (Drawings 04). Ground based ERT was carried out along the alignment on both the north and south river banks, extending approximately 100 m beyond the preliminary entry and exit points. Waterborne ERT surveys were conducted across the Thompson river. In 2014, supplementary longitudinal ERT surveys were performed to produce a more complete ERT profile along the HDD alignment.

Seismic refraction and MASW surveys were also performed at this time. Survey data could not be collected along approximately 400 m of the alignment within the river channel due to restricted watercraft access in shallow water and survey equipment depth limitations in deeper water. The seismic refraction and MASW surveys were performed along an approximately 470 m long section of the HDD alignment, between the HDD entry point and the middle of the river channel.

4.1. Geotechnical Drilling Data

The borehole locations from the site investigations completed in 2013 and 2014 are shown relative to the proposed HDD alignment in Drawing 01A (plan view) and Drawing 02 (cross-section and plan view) and are described in Table 4-1.

Table 4-1. Borehole depths, elevations and locations.

Borehole	Coordinates UTM NAD 83 Zone 10U[1]		Location Relative to HDD Borepath Alignment	Ground Surface Elevation[2]	Final Elevation/Depth	
	Easting (m)	Northing (m)		masl	masl	mbgs
BH-BGC13-TR-01	681567	5619565	56 m east of alignment	345.0	276.4	68.6
BH-BGC14-TR-02	681724	5618733	42 m west of alignment	342.0	301.8	40.2
BH-BGC14-TR-03	681624	5619120	22 m west of alignment	342.0	281.0	61.0
BH-BGC14-TR-04	681719	5618729	48 m west of alignment	343.0	307.3	35.7

Notes:
1. Borehole coordinates measured with handheld GPS.
2. Borehole collar elevation measurements from LiDAR provided by UPI, and received on September 25, 2014.

Boreholes BH-BGC14-TR-02 and BH-BGC14-TR-04 were drilled within 5 m of each other on the south bank of the river. BH-BGC14-TR-04 was drilled adjacent to BH-BGC14-TR-02 to support the seismic liquefaction assessment for the pipeline. Similar soil profiles were encountered between these boreholes and only BH-BGC14-TR-02 is discussed in detail. Two vibrating wire piezometers were installed in BH-BGC14-TR-02 at 15 mbgs and 30 mbgs prior to grouting the borehole.

All four boreholes were drilled using mud rotary drilling methods with Standard Penetration Tests (SPTs) completed every 1.5 m to 3 m.

Data collected includes the following:

- SPT blow counts (ASTM D1586) at 1.5 m intervals. The SPT split spoon was 61 cm long with a 5 cm outside diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil.
- Description of soil units in terms of lithology, colour, grain size, bedding, and structural features (ASTM D2487, ASTM D2488, and the Unified Soil Classification System) based on the visual examination of material retrieved in the SPT and in drill cuttings using rotary drilling techniques.
- Moisture content (ASTM D2216), grain size distribution (ASTM D422), and hydrometer (ASTM D221) of selected samples, based on laboratory testing of recovered samples.
- Depth to the water level as observed in the open borehole each morning, prior to the recommencement of drilling.

The geotechnical borehole logs and results from laboratory analyses are provided in Appendices C and D, respectively. Appendix C includes the geotechnical borehole logs for the four boreholes drilled as part of the site investigation as well as the auger and sonic drill hole drilled as part of previous MOTI and CN Railway investigations. The drilling and sampling methods used did not retrieve particles larger than gravel size (50 mm), so the relative fraction of larger sized clasts was inferred from drill action. Figures D-01 to D-04 in Appendix D provide results of the grain size analysis for materials derived from the observed geologic units. Appendix E contains instrumentation details for the installed vibrating wire piezometers.

4.2. Geophysical Survey Data

The geophysics survey scope for the Thompson River crossing included provision of the following from Advisian:

- An ERT survey along the entire length of the preliminary HDD alignment to a depth exceeding that of the maximum borepath depth, including approximately 600 m of waterborne ERT across the Thompson River. Due to equipment and access limitations the depth of the ERT, the survey data was limited to within the river channel along a 400 m length of the preliminary HDD alignment.
- A seismic refraction survey along a 472 m segment of the preliminary HDD alignment.

- A multichannel analysis of surface waves (MASW) in tandem with the seismic survey along a 331 m southern portion of the preliminary HDD alignment.
- Interpretations of the anticipated subsurface geology based on the aforementioned survey methods.

In order to draw inferences from the ERT data, the resistivity scale shown on each survey is unique. The electrical resistivity range shown on Drawing 04 is indicated in Figure 4-1.

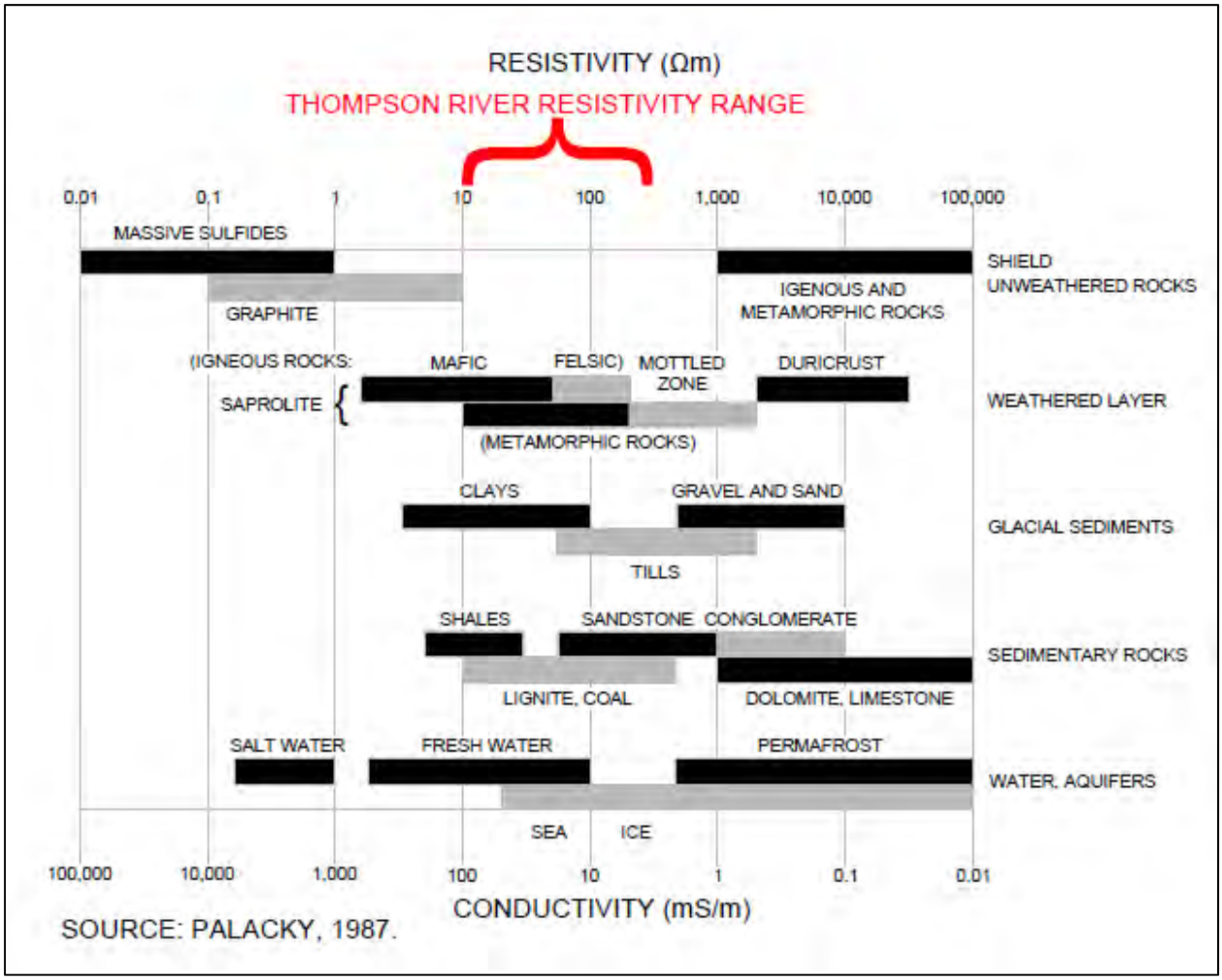

Figure 4-1. The electrical resistivity range for the Thompson River ERT survey.

The relatively narrow range of electrical resistivity values measured at this site are toward the middle of the scale shown above, indicating the presence of fine grained sediments such as silt and sand.

For the Thompson River ERT survey, the resistivity survey values are interpreted to indicate the presence of the following materials:

- < 100 ohm-m: Saturated fine-grained materials (e.g., dominant sands and silts).
- > 100 ohm-m: Unsaturated fine-grained materials (e.g., dominant sands and silts) or saturated coarse-grained materials (e.g., dominant clean sands and gravels).

ERT survey results indicate a zone of high resistivity material (ranging from approximately 250 to 350 ohm-m) that will be encountered by the borepath approximately 1000 m from the entry point (Drawing 04). This may indicate an incised and buried channel and coarse sediments (sand, gravel and potentially larger clasts) may be present in this zone.

4.3. Groundwater Observations

Water levels were measured in the BGC boreholes prior to the completion of drilling after the boreholes had been left open overnight for approximately 12 hours. Given the potential effects of the drilling mud, unknown permeability of the formations, and the limited time between drilling and water level readings, the reported water levels may not represent stabilized long-term groundwater levels. The groundwater elevations measured in BH-BGC13-TR-01 and BH-BGC14-TR-03, -04, and -05 are described below in Table 4-2.

Table 4-2. Groundwater observations in BH-BGC13-TR-01 and BH-BGC14-TR-02, -03, and -04

Borehole	Hole Depth (mbgs)	Casing (mbgs)	Inferred Water Level	
			masl	mbgs
BH-BGC13-TR-01	68.6 (End of Hole)	2.70	337.6	7.4
BH-BGC14-TR-02	40.2 (End of Hole)	No Casing Installed	338.4	3.6
BH-BGC14-TR-03	61.0 (End of Hole)	No Casing Installed	340.6	1.4
BH-BGC14-TR-04	35.7 (End of Hole)	No Casing Installed	339.8	3.2

Note: There was no evidence of artesian conditions in any geotechnical boreholes.

Vibrating wire piezometer readings in BH-BGC14-TR-02 indicate a phreatic surface of approximately 3.6 and 4.1 mbgs for the piezometers at 15 m and 30 m depths respectively. This indicates a downward groundwater gradient and groundwater discharge.

5.0 GEOTECHNICAL CONDITIONS ALONG THE BOREPATH

A summary of the geologic units identified during BGC's geotechnical investigation is provided below, based on the results and of geotechnical drilling, geophysical surveys and the review of existing available geotechnical data. A description of the drilling conditions encountered within those units is also provided. The following units are interpreted to exist along the proposed HDD:

SAND (Fluvial Deposits)

This unit was encountered at all four boreholes from ground surface to elevations ranging from 331.0 to 317.2 masl (unit thickness of 11.8 to 12.9 m thick), and consisted of loose to compact, fine to medium grained sand with traces of fine to coarse gravel and woody organic material.

High to very high (80% – 100%) drilling mud returns were generally experienced while drilling at all four boreholes throughout this unit. Some borehole wall sloughing occurred in boreholes BH-BGC14-TR-03 and BH-BGC14-TR-04 within this unit, causing 5 cm to 10 cm of loose material to accumulate at the bottom of the borehole. Drilling resistance in BH-BGC14-TR-02 indicated a possible coarser sand or gravel layer from 6.7 to 6.9 mbgs.

Interbedded SAND and SILT (Glaciolacustrine Deposits)

Interbedded sand and silt deposits were encountered underlying the fluvial sands to a maximum depth of 66.0 mbgs. The material generally consisted of fine to medium grained sand interbedded with silt in a laminated structure. The silt content of this unit increases with depth and the density varied from compact to very dense. Grain size distribution tests performed on five samples (TR-01-SPT-22, -32, and -41, and TR-03-SPT-10, and -30) showed an average content of 0.0% gravel (ranging from 0.0 to 0.1%), 62.6% sand (ranging from 30.4 to 86.0%), and 37.4% fines (14.0 to 69.6%). Moderate to very high (75% – 100%) drilling mud returns were experienced in all four boreholes throughout this unit. No borehole instability was observed in this unit.

These sediments are interpreted to be Fraser Glaciation Kamloops Drift deposits that have been deposited in a lacustrine environment. Johnsen (2004) describes the Fraser Glaciation lake bottom sediments as typically consisting of fine sand and silt deposits. These sediments are labelled as "Glaciolacustrine" on the borehole logs and on Drawing 02.

SAND (Glaciofluvial Deposits)

This unit was encountered underlying the glaciolacustrine deposit in all four boreholes between 27.0 and 66.0 mbgs and consisted of dense to very dense fine to coarse grained sand. The base of this unit was not encountered during investigative drilling. Moderate to very high (65% – 100%) drilling mud returns were experienced in all four boreholes in this unit. Some borehole wall sloughing occurred in this unit, causing up to 10 cm of loose material to accumulate at the bottom of the borehole.

Bedrock was not encountered during drilling at this crossing, nor was it inferred from seismic survey results. The proposed HDD borepath is not expected to encounter bedrock along its length.

A summary of the geological units identified and the drilling conditions encountered during BGC's geotechnical investigation is provided in Table 5-1.

Table 5-1. Summary of geological units identified during BGC's geotechnical drilling investigation.

Geological Unit	Depth (mbgs)				Elevation[1] (masl)				Typical Soil Description	SPT Blow Counts[2] (N)	Relative Density/ Consistency	Typical Drilling Fluid Recovery
	BH-BGC13-TR-01	BH-BGC14-TR-02	BH-BGC14-TR-03	BH-BGC14-TR-04	BH-BGC13-TR-01	BH-BGC14-TR-02	BH-BGC14-TR-03	BH-BGC14-TR-04				
Fluvial	0.0 – 14.0	0.0 – 11.8	0.0 – 14.0	0.0 – 12.9	345.0 – 331.0	342.0 – 330.2	342.0 – 328.0	343.0 – 330.1	SAND (SP - SM), Fine to medium, trace to some silt, trace gravel, fine to coarse, poorly graded, maximum particle size = 40 mm	2 to 17	Very loose to compact	80 to 100 %
Glaciolacustrine	14.0 – 66.0	11.8 – 27.0	14.0 – 55.4	12.9 – 27.1	331.0 – 279.0	330.2 – 315.0	328.0 – 286.6	330.1 – 315.9	Interbedded SAND (SP or SP - SM) and SILT (ML) SAND (SP or SP - SM), Fine to medium, trace to some silt, trace clay, poorly graded SILT (ML), Some sand to and sand, fine to medium, low plasticity	6 to R	Loose to Very Dense	75 to 100 %
Glaciofluvial	66.0 – 68.6	27.0 – 40.2	55.4 – 61.0	27.1 – 35.7	279.0 – 276.4	315.0 – 301.8	286.6 – 281.0	315.9 – 307.3	SAND (SP - SM), Fine to coarse, trace to some silt, poorly graded, maximum particle size = 15 mm	13 to R	Compact to Very Dense	65 to 100 %

Notes:
1. Borehole collar elevation estimated from LiDAR data provided by UPI on September 25, 2014, based on position estimated by hand held GPS.
2. 'R' indicates SPT refusal, i.e., 50 blows in any 150 mm increment, 100 blows in any single test, or no observed advance in 10 successive blows.

5.1. Southern Bank (HDD Entry Point)

The proposed HDD entry point is situated approximately 200 m south of the Thompson River at an elevation of approximately 342.4 masl. Subsurface materials at the HDD entry point consisted of a 10 to 15 m thick deposit of loose fluvial sands with small amounts of gravel and woody organic material. Some drilling fluid circulation losses may be encountered throughout this unit. Approximately 80 to 100 m from the entry point (2D horizontal length in plan view), the borepath is expected to intersect a glaciolacustrine unit composed of interbedded sands and silts that underlies the fluvial sand.

5.2. Main Channel (HDD Borepath)

The borepath is expected to remain in the glaciolacustrine deposit for the majority of its borepath. The soils within this glaciolacustrine deposit consist of interbedded sands and silts which tend to be compact near the surface and increase in density with depth to very dense/stiff near its base, with the silt content also increasing with depth. Low to moderate circulation losses may be encountered throughout this unit. At its maximum depth of approximately 297.4 masl (45.0 mbgs), the borepath extends horizontally for approximately 700 m and is anticipated to continue through the glaciolacustrine deposit. A glaciofluvial sand unit is interpreted to lie beneath the glaciolacustrine sands and silts, and may be encountered by the proposed HDD borepath. Although this lower contact was intersected in all four boreholes, the exact location in between boreholes is uncertain given the extrapolation of unit boundaries between the four borehole point locations, and the discrepancies suggested by the geophysics results, and it is possible that the HDD borepath may encounter it.

ERT survey results indicate a zone of high resistivity material (ranging from approximately 250 to 350 ohm-m) that may be encountered by the borepath approximately 1000 m from the entry point (Drawing 04). This may indicate an incised and buried channel and coarse sediments may be present in this zone.

5.3. Northern Bank (HDD Exit Point)

The HDD exit point is located on the northern floodplain approximately 600 m north of the Thompson River's right bank. In its upward ascent, the HDD borepath is expected to re-enter the 10 to 15 m thick loose fluvial sand deposit approximately 60 to 80m southeast (2D horizontal length in plan view) from the proposed HDD exit point. It is expected that the borepath will remain in this unit until it exits to surface at an elevation of approximately 344.3 masl. The uncertainty associated with the unit boundaries in between BH-BGC13-TR-01, -02, and -03, as well as to the northwest near the proposed HDD exit point is depicted by the desktop geology symbols.

The estimated length along the borepath for the soil transitions indicated above should be taken as a general guide, as the transition to materials encountered within each zone could vary significantly from what is interpreted. This is due to the relatively low angle of the

intersection of the borepath with the geological unit boundaries and the extrapolation of unit boundaries between the widely spaced boreholes.

6.0 PRELIMINARY GEOTECHNICAL FEASIBILITY ASSESSMENT

The following conclusions can be drawn from the regional surficial and bedrock geology, terrain mapping, local hydrology, and the results of the subsurface investigations and geophysical surveys completed along the proposed HDD crossing in 2013 and 2014 and are based solely on the limited scope of the investigation undertaken at this time.

6.1. General Considerations

- The banks of the Thompson River appear stable and the proposed HDD alignment is not expected to be compromised by bank erosion or avulsion. The HDD entry and exit points are below the 200-year flood elevation of 346.7 masl by approximately 4.3 m and 2.4 m, respectively. This flood depth is not expected to result in scour at the HDD entry and exit points, but as a protective measure it is recommended that a minimum burial depth of 1.5 m be maintained where the pipeline crosses the 200-year floodplain (between approximately KP 840.9 and 843.6).
- The 200-year scour depth is estimated to be approximately 1.7 m below the channel thalweg elevation and corresponds to an elevation of 333.5 masl. Under this event, the HDD borepath is expected to maintain greater than 25 m of cover below the river channel should the maximum scour occur.
- The presence of boulders or cobbles was not evident during the investigative drilling program. The fluvial, glaciolacustrine and glaciofluvial deposits encountered in the drilling investigation consisted predominantly of sands and silts, with lesser quantities of fine gravel in some areas, though coarser materials may be interbedded with these units. The contact between the glaciolacustrine silt/sand and the underlying glaciofluvial sand and gravel is uncertain, given the extrapolation of unit boundaries between the borehole point locations and the large distance between each borehole. ERT survey results indicated a zone of high resistivity material (ranging from approximately 250 to 350 ohm-m) may be encountered by the HDD approximately 1000 m from the proposed entry point. This could potentially indicate an incised and buried channel, and presence of coarse sediments (sand, gravel and potentially larger clasts)..
- Bedrock was not encountered during investigative drilling and was not indicated by geophysical survey results. Bedrock is not expected to be encountered by the HDD borepath.

6.2. Borepath Stability

- Minor borehole sloughing was encountered in boreholes BH-BGC14-TR-02, BH-BGC14-TR-03 and BH-BGC-TR-04 within the fluvial and glaciofluvial units. The loose upper fluvial sand deposit at the entry and exit points may have potential for collapse given the orientation and large diameter of the HDD borepath. The use of appropriate drilling fluids, installation of casing or other means should be considered to maintain integrity of the borepath during HDD construction.

6.3. Circulation & Potential for Loss of Fluids

- Generally drilling mud returns were high (>80%), however, a maximum of 35% of drilling mud circulation loss was experienced while drilling through the glaciofluvial unit, indicating that circulation losses will likely be encountered over portions of the HDD borepath, particularly if the borepath penetrates the glaciofluvial unit at depth. Circulation losses will need to be addressed during design and construction of the HDD borepath using appropriate drilling fluids, the use of casing, or other methods.
- The minimum separation between the proposed HDD borepath and the river bed is approximately 45 m. Assuming hydrostatic pressures, the anticipated drill fluid pressures should not exceed the confining stress provided by the overburden above the drill path considering the minimal elevation difference between the river and the entry/exit points. As such, the risk of loss of containment where drilling fluids may enter the river is anticipated to be moderate. However, given the nature of the cohesionless fluvial soils observed during investigative drilling, the risk of loss of containment should be further assessed during detailed design.

6.4. Geotechnical Feasibility

Given the above, and based on the desktop study, and results of the geotechnical site investigation, an HDD at this location can be considered feasible from a geotechnical perspective, provided the following risks can be addressed during detailed design and construction:

- Sloughing and hole collapse: In general, soils encountered during geotechnical drilling appeared to be stable with minor sloughing observed at BH-BGC14-TR-03 and BH-BGC14-TR-04. The fluvial, glaciofluvial, and glaciolacustrine deposits encountered in the geotechnical drilling program consisted predominantly of sands and silts, with lesser quantities of fine gravel in some areas. However, coarser materials may be present within these units; a coarse sand or gravel deposit was inferred in the fluvial deposit at BH-BGC14-TR-02 (at 335.3 masl) based on drill action. There is the potential for collapse in the loose fluvial sand deposits near the HDD entry and exit points. Possible mitigation includes careful drill fluid management (viscosity and pressure) and/or casing to maintain the integrity of the borepath during HDD construction.
- Loss of drilling fluids: Loose, cohesionless, coarse grained sand may be present within the fluvial, glaciofluvial and glaciolacustrine deposits that could cause drilling fluid circulation losses. Circulation losses in the glaciofluvial sand deposit were observed to be as high as 35%. The potential for fluid loss can potentially be mitigated by adapting the drill mud mixes.
- Encountering cobbles and boulders: The presence of boulders or cobbles was not evident during the geotechnical drilling program. However large clasts (i.e., cobbles and boulders) may generally be encountered in fluvial/glaciofluvial deposits. ERT survey results indicate a zone of high resistivity material (ranging from approximately 250 to 350 ohm-m) approximately 1000 m from the proposed entry point. This may indicate an incised and buried channel and coarse sediments may be present in this

zone. Encountering cobbles and boulders may deflect the HDD borepath and/or damage the carrier pipe when it is pulled into the borepath. Preparation for variable drilling conditions, use of casing and/or altering the reaming direction may be considered in detailed design.

7.0 CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

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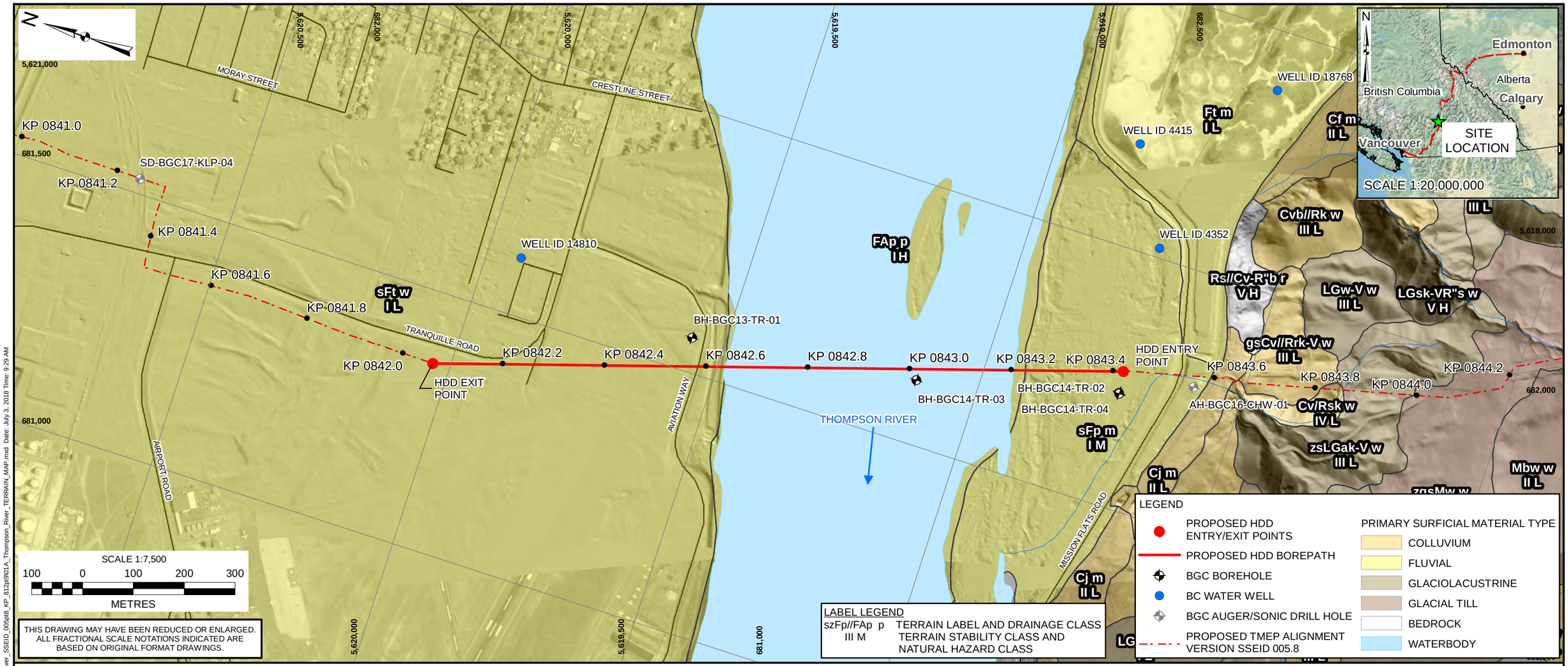
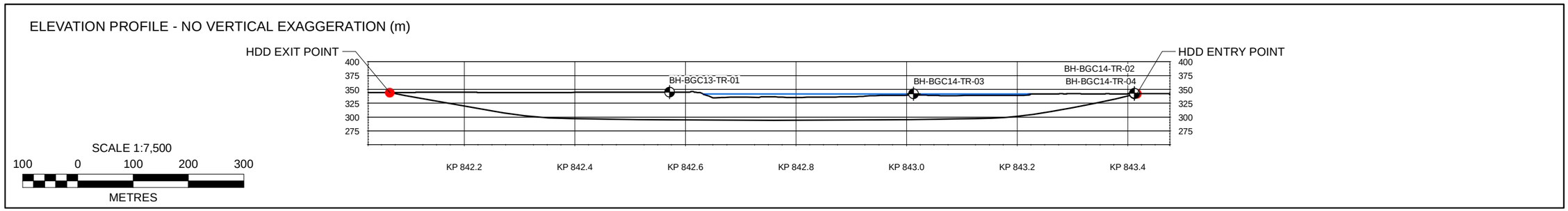
DRAWINGS





NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER SSEID 005.8 AT KP 842.9 - REVISION 1", AND DATED JULY 2018.
3. PROPOSED TMEP SSEID 005.8 PIPELINE ALIGNMENT PROVIDED BY UPI. DATED MAY 2018.
4. PROPOSED HDD ALIGNMENT PROVIDED BY UPI, DRAWING NO. 01-13283-M002-XD160-01 REV 2A, ISSUED APRIL, 2018.
5. FOR A FULL EXPLANATION OF THE TERRAIN MAPPING TERMS AND SYMBOLS SEE THE COMPLETE LEGEND IN DRAWING 01B. TERRAIN POLYGONS BASED ON TERRAIN MAPPING COMPLETED UP TO JULY 2015 BY BGC.
6. THIS MAP IS A SNAPSHOT IN TIME. CHANGES IN LAND USE (E.G. DEVELOPMENT, RIVER MIGRATION) MAY WARRANT RE-DRAWING OF CERTAIN AREAS.
7. PROJECTION IS NAD 1983 UTM ZONE 10N.
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DATE:	JUL 2018
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APPROVED:	KSJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER SSEID 005.8 AT KP 842.9 - REVISION 1

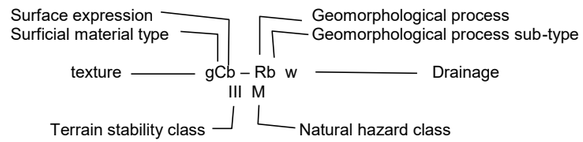
TITLE: TERRAIN MAP

PROJECT No.:	DWG No.:
0095-150	01A

X:\Projects\0095\150\GIS\Production\Reports\20180531_Geotechnical_HDD_Feasibility_Assessment_Thompson_River_SSEID_005p8_KP_812p8\901A_Thompson_River_TERRAIN_MAP.mxd Date: July 3, 2018 Time: 9:29 AM

Terrain Mapping Legend

Simple Terrain Symbols: Used when one surficial material is present within a polygon



Composite Terrain Symbols: Used when 2 or 3 terrain types are present within a polygon

Cv.Mv	indicates that 'C' and 'M' are roughly equal in extent
Cv/Mv	indicates that 'C' is greater in extent than 'M' (about 60:40)
Cv//Mv	indicates that 'C' is much greater in extent than 'M' (about 80:20)
Cv.Rs/Mv	indicates that 'C' and 'R' are roughly equal in extent and both are greater in extent than Mv (about 40:40:20)

Stratigraphic Terrain Symbols

Cv|Mj indicates that 'Cv' overlies 'Mj'

Surficial Material Types

A	Anthropogenic	I	Ice	R	Bedrock
C	Colluvium	L	Lacustrine	WG	Glaciomarine
D	Weathered bedrock	LG	Glaciolacustrine	U	Till, Glaciolacustrine, Glaciofluvial (interbedded)
E	Eolian	M	Glacial Till		
F	Fluvial	N	Not mapped (usually a lake or large river)		
FG	Glaciofluvial	O	Organic		

Surface Expressions

a	Moderate slope (15-26°)	p	Plain (0-3°)
b	Blanket (>2 m thick deposit)	r	Ridge
c	Cone (>15°)	s	Steep slope (>35°)
f	Fan (<15°)	t	Terrace
h	Hummocky	u	Undulating
j	Gentle slope (4-14°)	v	Veneer (0-2 m thick deposit)
k	Moderately steep slope (27-35°)	w	Variable thickness deposit)
m	Rolling	x	Very thin veneer (0-.5m thick deposit)

Activity Level

FAp	'A' Indicates active floodplain (subject to channel changes)
CIf	'I' Indicates inactive fan

Textural Terms and Symbols

a	blocks	g	gravel	s	sand
b	boulders	h	humic organics	u	mesic organics
c	clay	k	cobbles	x	angular fragments
d	mixed fragments	m	mud	z	silt
e	fibric organic	p	pebbles		

Geomorphologic Processes

A	Snow avalanches	M	Meandering channel
B	Braided channel	N	Nivation
E	Melt water channels	P	Piping
F	Slow landslide (runout zone)	R	Rapid landslide (runout zone)
F"	Slow landslide (initiation zone)	R"	Rapid landslide (initiation zone)
G	Anthropogenic ground disturbance	S	Solifluction
H	Kettled	U	Flooding
I	Irregular channel	V	Gully erosion
J	Anastamosing channel	W	Washing
K	Karst	X	Permafrost
L	Seepage	Z	Periglacial processes

Geomorphological Process Subtypes

a	Channel avulsion	g	Rock creep	s	Debris avalanches
b	Rock fall	k	Tension cracks/sackung	u	Surficial material slump
c	Soil creep	m	Bedrock slump	Ud	Debris floods
d	Debris flows	r	Rock slides	x	Slump/earth flow combined
e	Earth flow				

Terrain Stability Class

I	No significant stability problems exist.
II	There is a very low likelihood of landslides following right of way clearing, pipeline and or road construction. Minor instability is expected along cut slopes, especially for 1 or 2 years following construction.
III	There is a low likelihood of landslide initiation following right of way clearing, pipeline and or road construction. Minor instability is expected along cut slopes, especially for 1 or 2 years following construction.
IV	Expected to contain areas with a moderate to high likelihood of landslide initiation following right of way clearing, pipeline and or road construction. Wet season construction will significantly increase the potential for construction-related landslides.
V	Expected to contain areas with a high likelihood of landslide initiation following right of way clearing, pipeline and or road construction. Wet and or winter season construction will significantly increase the potential for construction-related landslides.

Natural Hazard Classes

L	No existing hazard, or hazard is dormant. i.e. hazard has not been active in the last 100 to 1,000 years or it has developed under different climatic conditions.
M	Hazard is inactive. Re-vegetated tracks can be observed in airphotos. Smaller more frequent events, such as rock falls, may affect a small area of the polygon. No evidence that the hazard has been active within 20 years but trigger is present. Hazard is unlikely to occur within the life of the project.
H	Hazard is currently active or shows evidence of activity in the last 20 years. Hazard likely to occur within the life of the project.

Soil Drainage Classes

r	Rapidly drained	Water is removed from the soil rapidly in relation to supply.
w	Well-drained	Water is removed from the soil readily but not rapidly.
m	Moderately well-drained	Water is removed from the soil somewhat slowly in relation to supply.
i	Imperfectly drained	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season.
p	Poorly drained	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen.
v	Very poorly drained	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen.

Examples

Rs//Cv – VR"bd V H	Steep bedrock slope with <20% cover of a colluvial veneer; gullied with initiation zones for rock fall and debris flows. Expected to contain areas with a high likelihood of landslide initiation following road construction. Debris flows and rock fall are likely to occur within the life of the project.
sgFAp -U i I M	Active floodplain composed of sand and gravel potentially subject to flooding. Imperfectly drained. No significant stability problems exist. Inactive flood hazard is unlikely to occur during the lifetime of the project
zcLGks-VR"s m V M	Moderately steep to steep glaciolacustrine slope composed of silt and clay, with gullies, moderately well drained. High likelihood of debris avalanches following major landform changes. Small natural debris slides are possible within 20 years.
Cj – F"g	Thick, gentle colluvium forming a rock glacier
Cf – Rd	Colluvial fan subject to debris flows
Ck – Rb	Colluvial slope subject to rock fall (talus slope)

SACKUNG

LANDSLIDE SCARP

LANDSLIDE PATH

NOTES:
1. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER SSEID 005.8 AT KP 842.9 - REVISION 1", AND DATED JULY 2018.
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CHECKED:	SAA
APPROVED:	KSJ

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CLIENT: TRANSMOUNTAIN

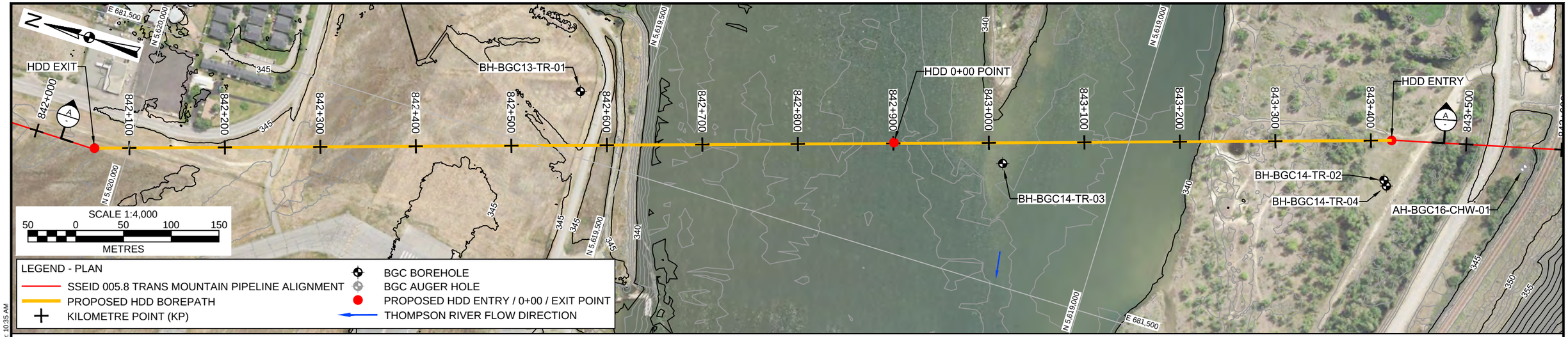
PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER SSEID 005.8 AT KP 842.9 - REVISION 1

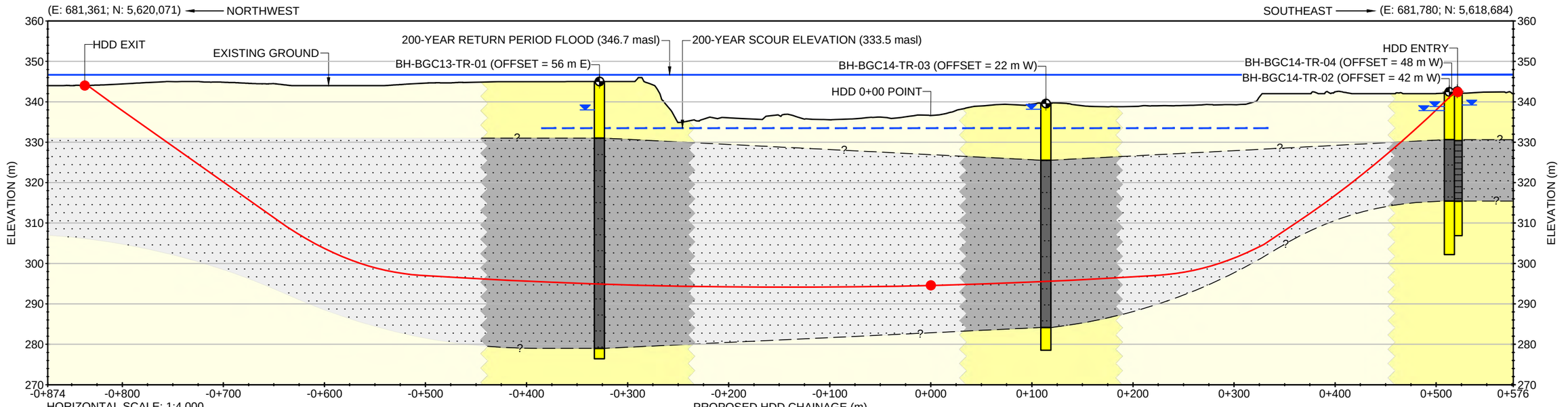
TITLE: TERRAIN MAP LEGEND

PROJECT No.: 0095-150

DWG No.: 01B

X:\Projects\0095150\GIS\Production\Reports\20180531_Geotechnical_HDD_Feasibility_Assessment_Thompson_River_SSEID_005p8_KP_812p9\01B_Terrain_Legend.mxd Date: July 3, 2018 Time: 9:29 AM





HORIZONTAL SCALE: 1:4,000
VERTICAL SCALE: 1:1,000 (4x VERTICAL EXAGGERATION)

CROSS-SECTION A

CROSS-SECTION AT BEARING 162.7°

SCALE 1:4,000
50 0 50 100 150
METRES

GROUNDWATER OBSERVATIONS			
BOREHOLE	INFERRED WATER LEVEL (mbgs)	WATER LEVEL ELEVATION (masl)	COMMENTS
BH-BGC13-TR-01	7.4	337.6	OBSERVED IN OPEN HOLE WITH CASING AT 2.7 m DEPTH ON NOVEMBER 16, 2013
BH-BGC14-TR-02	3.6 / 4.6	338.4	RECORDED FROM VWPS INSTALLED AT 15.0 mbgs AND 20.0 mbgs, ON DECEMBER 8, 2014
BH-BGC14-TR-03	1.4	340.6	OBSERVED IN OPEN HOLE WITH NO CASING ON DECEMBER 9, 2014
BH-BGC14-TR-04	3.2	339.8	OBSERVED IN OPEN HOLE WITH NO CASING ON DECEMBER 9, 2014

BOREHOLE | INTERPRETED GEOLOGY | DESKTOP INTERPRETED GEOLOGY
FLUVIAL / GLACIOFLUVIAL SAND AND GRAVEL
GLACIOLACUSTRINE SILT AND SAND

LEGEND - CROSS-SECTION
PROPOSED HDD PROFILE
GROUND SURFACE (2014)
BGC BOREHOLE
PROPOSED HDD ENTRY / 0+00 / EXIT POINT
INFERRED WATER LEVEL
INFERRED GEOLOGICAL INTERFACE
200-YEAR RETURN PERIOD FLOOD
200-YEAR SCOUR ELEVATION

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9", AND DATED JULY 2018.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY UPI LTD., DATED SEPTEMBER 25, 2014. CONTOUR INTERVAL IS 1.0 m.
4. BATHYMETRIC SURVEY DATA PROVIDED BY OPUS STEWART WEIR, DATED JUNE 3, JUNE 24, JULY 19 TO 22, AND JULY 26, 2014.
5. IMAGE SOURCE: ESRI WORLD IMAGERY SERVER RETRIEVED FROM BING IMAGERY.
6. PROPOSED TMEP SSEID 005.8 PIPELINE ALIGNMENT PROVIDED BY KMC, DATED MAY 2018. PROPOSED HDD ALIGNMENT PROVIDED BY UPI, DRAWING NO. 01-13283-M002-XD00160-01 REV 2A, ISSUED APRIL 25, 2018.
7. PREDICTED 200 YEAR FLOOD LEVEL IS BASED ON A CROSS-SECTIONAL GEOMETRY ONLY AND MAY NOT REFLECT THE TRUE EXTENT OF OVERBANK FLOODING.
8. PROJECTION IS UTM NAD83 ZONE 10.
9. SPECIFIC OBSERVATIONS PERTAINING TO THE WATER LEVEL MEASUREMENTS ARE AVAILABLE IN THE REPORT.
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SCALE:	1:4,000
DATE:	JUL 2018
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APPROVED:	KSJ

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CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: INTERPRETED GEOLOGIC CROSS-SECTION

PROJECT No.: 0095-150

DWG No.: 02

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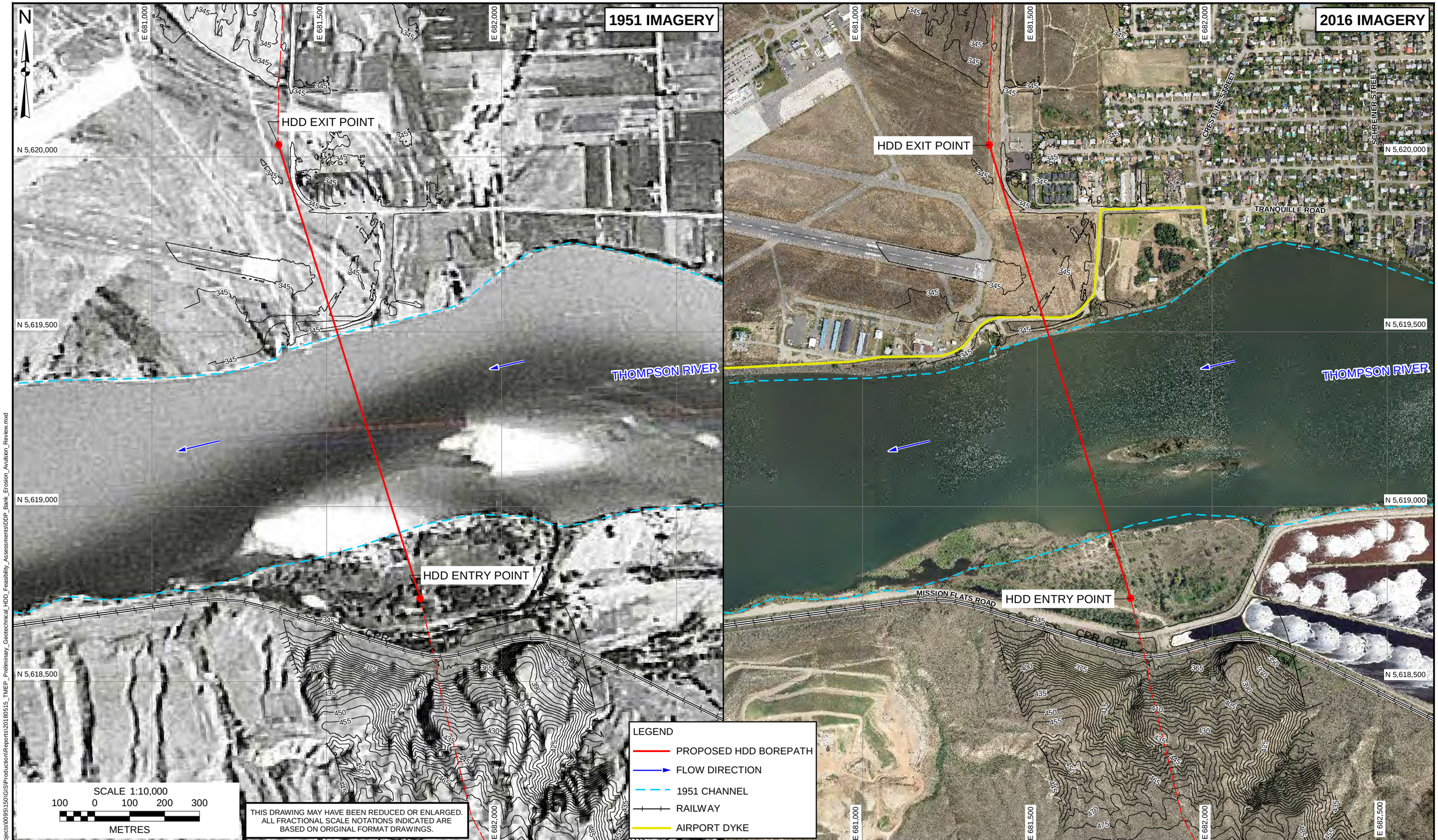

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4. BASE TOPOGRAPHIC DATA BASED ON GEOBASE DEM RETRIEVED MARCH 2013. CONTOUR INTERVAL 10 m. PROJECTION IS NAD 83 ZONE 10U.
5. 2016 IMAGERY PROVIDED BY CITY OF KAMLOOPS.
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PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER SSEID 005.8 AT KP 842.9

TITLE: BANK EROSION AND AVULSION REVIEW

PROJECT No.: 0095-150

DWG No.: 03

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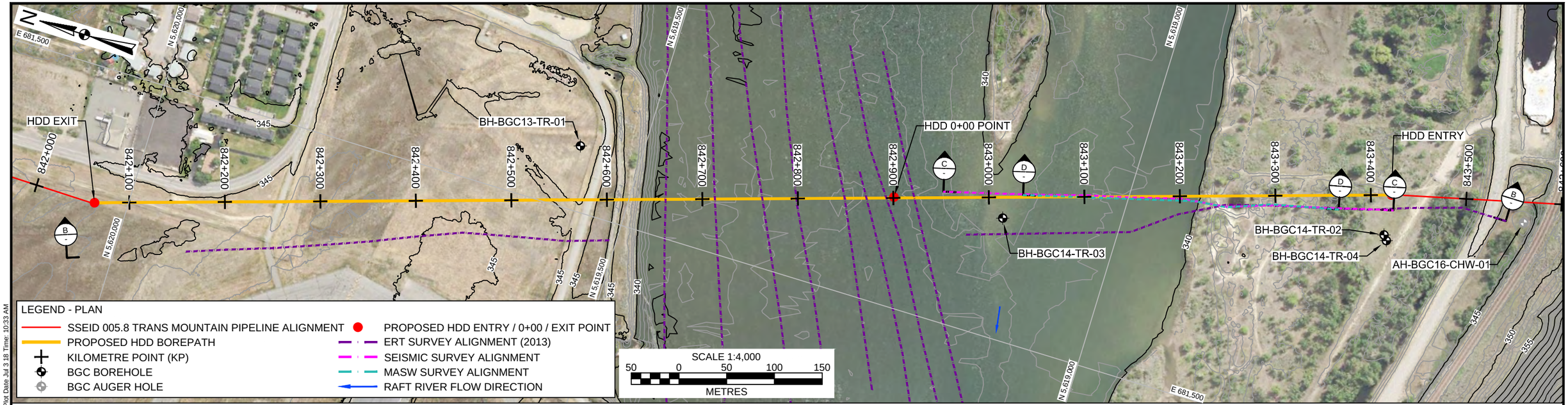

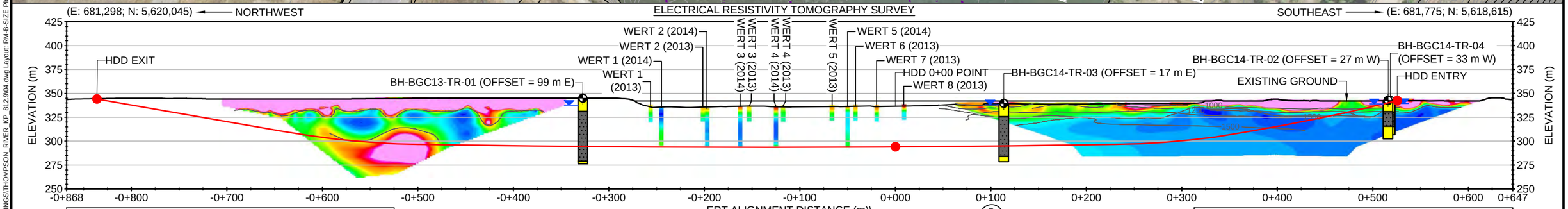

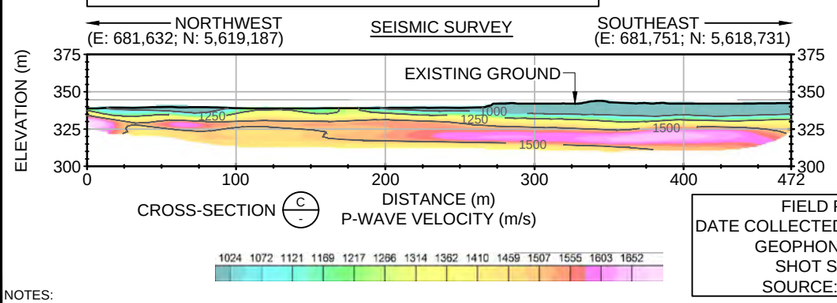

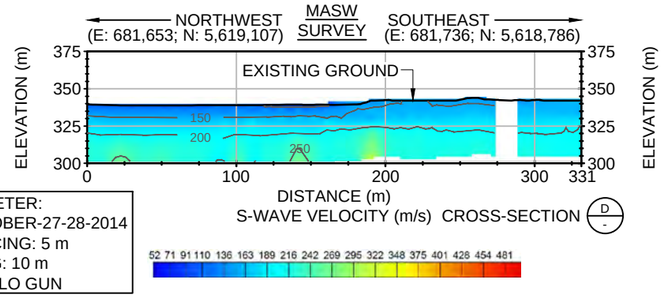

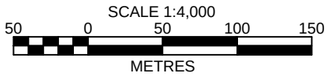

LEGEND - CROSS-SECTION

- PROPOSED HDD PROFILE
- GROUND SURFACE (2014)
- BGC BOREHOLE
- PROPOSED HDD ENTRY / 0+00 / EXIT POINT
- INFERRED WATER LEVEL
- INFERRED GEOLOGICAL INTERFACE
- SEISMIC P-WAVE VELOCITY CONTOURS
- SEISMIC S-WAVE VELOCITY CONTOURS
- 200-YEAR RETURN PERIOD FLOOD
- 200-YEAR SCOUR ELEVATION

BOREHOLE

- FLUVIAL SAND, GRAVE, COBBLES, AND BOULDERS
- GLACIOLACUSTRINE SILT AND SAND

NOTES:

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3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY UPI LTD., DATED SEPTEMBER 25, 2014. CONTOUR INTERVAL IS 1.0 m.
4. BATHYMETRIC SURVEY DATA PROVIDED BY OPUS STEWART WEIR, DATED JUNE 3, JUNE 24, JULY 19 TO 22, AND JULY 26, 2014.
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7. PROJECTION IS UTM NAD83 ZONE 10.
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PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: GEOPHYSICS RESULTS

PROJECT No.: 0095-150

DWG No.: 04

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PHOTO 1: LOOKING NORTH ACROSS THOMPSON RIVER FROM BOREHOLE BH-BGC14-TR-03, MARKED WITH A PINK STAKE.

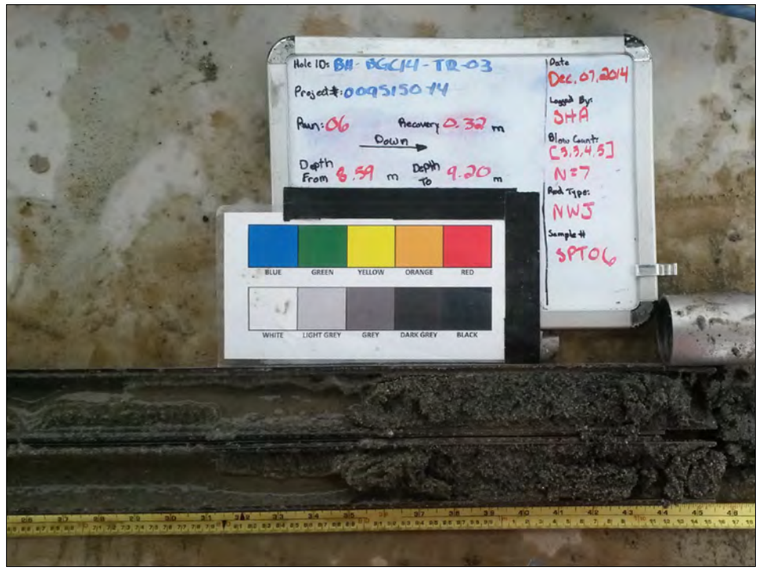

PHOTO 2: BH-BGC14-TR-03 SPT06 SAMPLE FROM 8.59 m bgs - 9.20 m bgs. TYPICAL FLUVIAL SAND.

PHOTO 4: BH-BGC13-TR-01 SPT30. SAMPLE FROM 48.16 m bgs - 48.77 m bgs. TYPICAL GLACIOLACUSTRINE INTERBEDDED SAND AND SILT.

PHOTO 5: BH-BGC14-TR-03 SPT32 SAMPLE FROM 52.78 m bgs - 53.39 m bgs. GLACIOLACUSTRINE INTERBEDDED SAND AND SILT WITH HIGH SILT CONTENT.

PHOTO 6: BH-BGC14-TR-04 SPT23 SAMPLE FROM 35.06 m bgs - 35.67 m bgs. TYPICAL GLACIOFLUVIAL SAND.

NOTES:
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DATE:	JUL 2018
DRAWN:	CR
CHECKED:	SAA
APPROVED:	KSJ

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CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: FIELD PHOTOS

PROJECT No.: 0095-150

DWG No.: 05

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APPENDIX A
BC WATER WELL RECORDS

[redacted] Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 14810
Well Identification Plate Number:
Owner Name: SCHOOL DISTRICT 24
Licenced Status: UNLICENSED

Well Status: NEW
Well Class:
Well Subclass:
Intended Water Use: Unknown Well Use

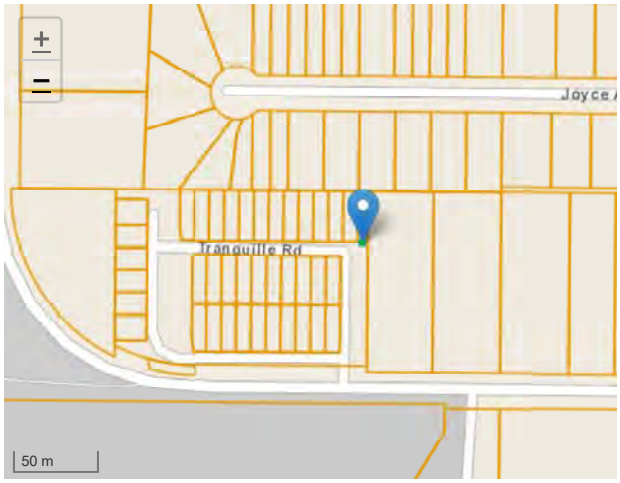
Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number: 282
Alternative specs submitted (if required): No

Location Information

Street Address:
Town/City:
Legal Description:

Lot	
Plan	
District Lot	
Block	
Section	22
Township	20
Range	18
Land District	25 KAMLOOPS (KDYD)
Property Identification Description (PID)	

Description of Well Location:
BCGS Mapsheet Number: 092I078221



Leaflet | Powered by Esri | Government of British Columbia, DataBC, GeoBC

Geographic Coordinates - North American Datum of 1983 (NAD 83)

Latitude: 50.702814
Longitude: -120.428023
UTM Northing: 5619933
UTM Easting: 681613
Zone: 10
Location Accuracy Code: D

Well Activity

Construction Date (YYYY-MM-DD)	Alteration Date (YYYY-MM-DD)	Decommission Date (YYYY-MM-DD)	Drilling Company
1956-06-01			G. & G. Well Drilling

Well Completion Data

Total Depth Drilled:
Finished Well Depth: 60 feet
Final Casing Stick Up:
Depth to Bedrock:
Ground Elevation:
Elevation Determined By:

Static Water Level (BTOC):
Estimated Well Yield: 30 GPM
Artesian Flow:
Artesian Pressure:

Well Cap:
Well Disinfected: No
Drilling Method: UNK
Orientation of Well: vertical

Lithology

From (feet)	To (feet)	Lithology Raw Data	Description	Material Description	Relative Hardness	Colour	Water-Bearing Estimated Flow	Observations
0	10	silty sand						
10	29	coarse sand dry						
29	38	medium sand						
38	45	medium fine sand						
45	66	sand water (55-66)						
66	77	fine sand						

Casing Details

From (feet)	To (feet)	Diameter (inches)	Casing Material	Wall Thickness (inches)	Drive Shoe

Surface Seal and Backfill Details

Surface Seal Material: Other
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Length:
Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

No liner information available.

Screen Details

No screen assembly information available.

Intake Method:
Type:
Material: Other
Opening:
Bottom:

Well Development

Developed By:
Development Total Duration:

Well Yield

Well Decommissioning

Reason for Decommission:
Method of Decommission:
Decommission Details:
Sealant Material:
Backfill Material:

Comments

Additional Documentation

No additional documentation currently available for this well.

Disclaimer

The information provided should not be used as a basis for making financial or any other commitments. The Government of British Columbia accepts no liability for the accuracy, availability, suitability, reliability, usability, completeness or timeliness of the data or graphical depictions rendered from the data.

[redacted] Groundwater Wells and Aquifers

Well Summary

Well Tag Number: 18768
Well Identification Plate Number:
Owner Name: HOFFMAN CONSTRUCTION
Licenced Status: UNLICENSED

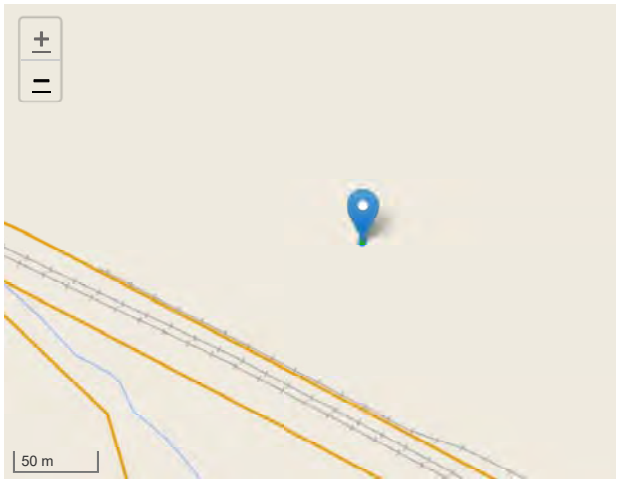
Well Status: NEW
Well Class:
Well Subclass:
Intended Water Use: Unknown Well Use

Observation Well Number:
Observation Well Status:
Environmental Monitoring System (EMS) ID:
Aquifer Number: 284
Alternative specs submitted (if required): No

Location Information

Street Address: MISSION FLATS
Town/City: KAMLOOPS
Legal Description:

Lot	
Plan	
District Lot	
Block	
Section	
Township	
Range	
Land District	25 KAMLOOPS (KDYD)
Property Identification Description (PID)	



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Description of Well Location:
BCGS Mapsheet Number: 092I068444

Geographic Coordinates - North American Datum of 1983 (NAD 83)

Latitude: 50.690777
Longitude: -120.417751
UTM Northing: 5618620
UTM Easting: 682385
Zone: 10
Location Accuracy Code: D

Well Activity

Construction Date (YYYY-MM-DD)	Alteration Date (YYYY-MM-DD)	Decommission Date (YYYY-MM-DD)	Drilling Company
1964-08-01			Pacific Water Wells

Well Completion Data

Total Depth Drilled:
Finished Well Depth: 50 feet
Final Casing Stick Up:
Depth to Bedrock:
Ground Elevation:
Elevation Determined By:

Static Water Level (BTOC): 10 feet
Estimated Well Yield: 50 GPM
Artesian Flow:
Artesian Pressure:

Well Cap:
Well Disinfected: No
Drilling Method: UNK
Orientation of Well: vertical

Lithology

From (feet)	To (feet)	Lithology Raw Data	Description	Material Description	Relative Hardness	Colour	Water-Bearing Estimated Flow	Observations
0	18	dug hole - no record						
18	35	medium brown sand						
35	50	medium gray sand						

Casing Details

From (feet)	To (feet)	Diameter (inches)	Casing Material	Wall Thickness (inches)	Drive Shoe

Surface Seal and Backfill Details

Surface Seal Material: Other
Surface Seal Installation Method:
Surface Seal Thickness:
Surface Seal Length:
Backfill Material Above Surface Seal:
Backfill Depth:

Liner Details

No liner information available.

Screen Details

No screen assembly information available.

Intake Method:
Type:
Material: Other
Opening:
Bottom:

Well Development

Developed By:
Development Total Duration:

Well Yield

Well Decommissioning

Reason for Decommission:
Method of Decommission:
Decommission Details:
Sealant Material:
Backfill Material:

Comments

Additional Documentation

No additional documentation currently available for this well.

Disclaimer

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reliability, usability, completeness or timeliness of the data or graphical depictions rendered from the data.

APPENDIX B
HYDROTECHNICAL ASSESSMENT METHODOLOGY

A.1. INTRODUCTION

This appendix documents the methodology followed by BGC Engineering Inc. (BGC) to complete hydrotechnical assessments at pipeline watercourse crossings. A description of hydrotechnical hazards is provided in Section A.2, followed by the flood frequency analysis (FFA) methodology in Section A.3. The hydrotechnical assessment methods specific to each hydrotechnical hazard are presented in Sections A.4 (scour), A.5 (bank erosion and encroachment), and A.6 (avulsion).

Several industry terminology conventions are used in this methodology report, and in supporting hydrotechnical reports. Definitions of the terminology are as follows:

Downstream	Direction of water flow.
Upstream	Direction opposite to water flow.
Right & left banks	Reference convention for banks when facing downstream.
DoC	Depth of cover (burial depth) over the pipeline.
RoW	Pipeline right of way.
Thalweg	Line defining the lowest points along the length of a river bed or valley.
Hazards	Characterisation of hydrotechnical processes such as scour, channel bed degradation, and bank erosion that could result in a loss of DoC.
Likelihood	Qualitative assessment of how often an event may occur (e.g., the likelihood of scour hazard occurring is high).
Probability	Quantitative assessment of how often an event may occur (e.g., the probability of scour hazard occurring is 0.05 yr^{-1}).
Return Period	The inverse of probability, it gives the estimated average time interval between events of a similar intensity (e.g., 1/[0.05 yr^{-1}] = 20 yr return period).

A.2. HYDROTECHNICAL HAZARDS

The following hydrotechnical hazards are included as part of the hydrotechnical assessment:

- Scour of the channel bed;
- Bank erosion caused by lateral channel migration or channel widening;
- Encroachment of the channel towards the pipeline due to bank erosion; and
- Avulsion of the channel within the floodplain.

A.2.1. Scour

Scour is the localized removal of granular bed material from the channel substrate by hydrodynamic forces during a flood event. Scour can happen at any location where local flow velocities increase within an otherwise uniform flow situation. Scour also occurs when the

direction of flow changes at channel bends, confluences, constrictions, obstructions, and impingements. There are two types of scour: general scour and local scour.

General scour occurs due to the complex interaction between flow rates and volumes, sediment transport rates, and channel morphology. Intermittent general scour occurs when a mobile-bed watercourse floods and the channel bed degrades (lowers) to accommodate the increased flow. Pipelines can become exposed or undermined during an intermittent flood event, becoming vulnerable to damage. The channel bed can experience significant scour during a flood event but this is often not detected because of compensating deposition that can occur as the flood flows decline (Leopold et al. 1964).

Local scour results from acceleration of flow due to an obstruction or constriction to flow near piers, abutments, riprap revetments, large woody debris or other structures obstructing or constricting the flow. These obstructions cause vortices with accelerated flow that erode the surrounding bed and bank sediments. Contraction scour is a form of local scour where acceleration of flow is caused by a local narrowing of the channel.

Local and general scour depths are shown in the schematic in Figure 0-1. General scour depth is measured relative to the design flood water level and local scour depth is measured from the bottom of the general scour elevation. Both general and local scour contribute to the total scour depth below the design flood water level.

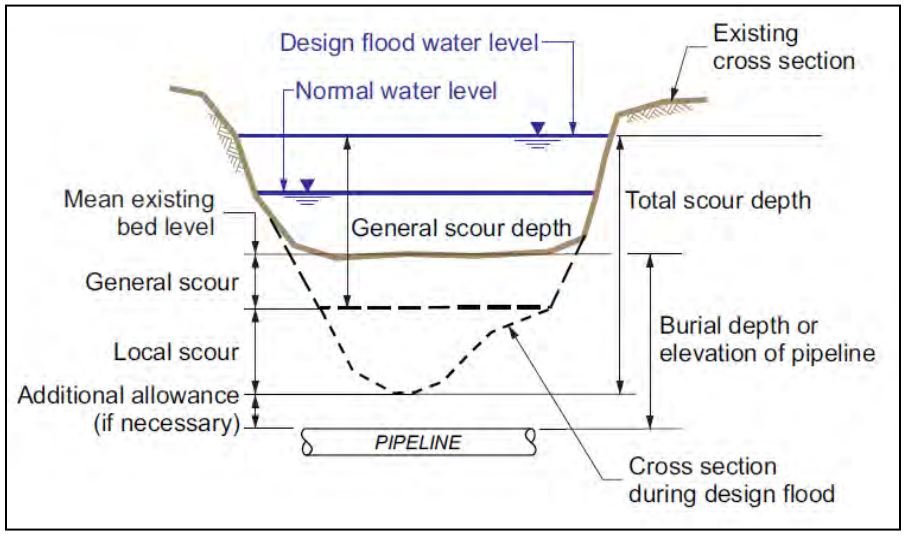

Figure 0-1. Schematic of general and local scour (reproduced from Veldman 2008).

A.2.2. Bank Erosion and Encroachment

Patterns of sediment transport and deposition naturally cause the channel banks to migrate laterally, resulting in bank erosion. Erosion can take place slowly over a period of years or suddenly during a single flood event. Gradual bank erosion most often occurs on outer bends of low gradient, meandering river channels. Large flood events may cause sudden widening, particularly in braided or wandering rivers, as the channel geometry adjusts to convey the

additional flow. Bank migration (erosion) at a pipeline crossing, either through lateral migration or episodic widening, can result in exposure of the sagbends and overbends of the pipeline.

Encroachment may be a hazard to the pipeline where bank erosion is occurring along a section of the channel that flows parallel and adjacent to the pipeline RoW. Bank erosion can lead to lateral movement of the watercourse toward the pipeline, potentially leading to exposure and freespan of a section of the pipeline outside of a designed watercourse crossing.

A.2.3. Avulsion

Avulsion, also referred to as outflanking or abandonment, occurs when streams leave their present channel and establish a new channel. This process can lead to pipe exposure if the new channel intersects the pipeline outside of the designed watercourse crossing where the top of pipe elevation may be higher. Avulsion frequently takes place on alluvial fans that carry high loads of bed material. It may also occur where rivers meander on a wide floodplain, although in this case the avulsion is typically into an existing side channel or abandoned channel. For the latter scenario, avulsion typically occurs progressively over a period of years rather than suddenly during a large flood event (although the large flood event may be the final tipping point for the avulsion to occur).

In braided channels, the term avulsion is sometimes used to describe a shift in the main thread of current to the other side of a mid-channel bar, but in general, is intended to denote a complete shift of the main channel. Avulsions commonly result when an event (usually a flood) of sufficient magnitude occurs along a reach of river that is at or near an avulsion threshold (Schumm 2005).

Avulsion channels can be characterized as active, transitional, or inactive based on the hydrological regime. Active avulsions are characterized by the presence of standing or flowing water. Transitional avulsions are dry without established vegetation. Inactive avulsions are dry and vegetated in the channel suggesting conditions have remained constant for several years.

A.3. FLOOD FREQUENCY ANALYSIS

Flood discharge magnitudes and frequencies are estimated using a flood frequency analysis (FFA). Flood discharge quantiles are estimated for one or several representative hydrometric gauge stations, which are then related to the pipeline crossing using a site-specific relationship to estimate flood discharge quantiles at the crossing. This relationship could be a proration using a station on the same watercourse or a regression using several representative stations near the crossing. The flood discharge quantiles estimated using an FFA form the basis for the hydrotechnical hazard assessment for scour, bank erosion, encroachment, and avulsion. The methods used to conduct an FFA are described herein.

The FFA is based on an approach known as Annual Maximum Series (AMS), which uses the maximum discharge value over a period of time. The selected AMS is the maximum peak instantaneous streamflow for each year on record, which is assumed to be a random sample from the underlying population of hydrological events and can thus be estimated by the selection of an appropriate statistical distribution.

Extreme value statistics are used to estimate flood discharge quantiles from the AMS. A distribution known as the Generalized Extreme Value (GEV) distribution, which is described by location, scale, and shape parameters, is fitted to the AMS to estimate the flood discharges associated with selected event probabilities (Gilleland and Katz 2006). This statistical analysis is conducted using the Extremes package in R, a non-proprietary software environment for statistical computing and graphics (Gilleland 2016).

A.3.1. Historical Peak Flow Records

The FFA requires the input of streamflow data. In Canada, the Water Survey of Canada (WSC) monitors and manages hydrometric stations and publishes their data. The hydrometric stations for FFA are selected based on proximity to the crossing, available streamflow data (i.e., record length), drainage basin area, station elevation, hydro-climatic zone, and regulation type.

The preferred input to the FFA is peak instantaneous streamflow (Q_{IMAX}) for each available year on record. However, peak streamflow records at hydrometric stations are often limited to maximum average daily streamflow (Q_{MAX}) which are lower in magnitude than Q_{IMAX}. The difference between peak instantaneous and average daily flows are typically greater for small basins than for very large drainage areas. In some cases, Q_{IMAX} values may be estimated from available Q_{MAX} records using regression analyses techniques.

A.3.2. Prediction Limit of Dataset

The maximum return period for which a peak streamflow can be estimated reliably (i.e., the prediction limit) at a given hydrometric station is limited by the record length of the dataset defined by the number of years with a complete peak streamflow record. Generally, in cases where the record length of the station of interest is too short, the dataset can sometimes be extended using a correlation analysis with another nearby hydrometric station to estimate flood frequencies of higher return periods.

A.3.3. Climate Change

Flood frequency analyses use extreme value statistics that rely on assumptions of stationarity and homogeneity in the hydrologic data; however, climate change may invalidate the assumption of stationarity by producing a temporal trend in flood magnitude over time. Flood magnitude may be directly influenced by changes in annual precipitation or intensity, but is also indirectly affected by changes in precipitation phase related to temperature fluctuations (e.g., greater frequency of rain-on-snow events). The assumption of homogeneity in flow records will also be invalidated in many regions, as hydrologic regimes may shift from snowmelt-dominated or hybrid to rainfall-dominated, creating mixed populations of data.

The impacts of climate change on hydrology are expected to vary regionally based on differences in temperature and precipitation changes across Canada. Potential impacts are described in the following sub-sections for select regions according to Canadian Ecozones (i.e., broad ecological units) (Li and Hélie 2014), as shown in **Error! Reference source not found.**. These regions were

selected to capture the geographic range of hydrotechnical assessments for the Trans Mountain Expansion Project.

The magnitude and timing of climate change impacts on hydrology in these different regions are uncertain. It is expected that some areas will experience more frequent, high-intensity flood events while others will experience less frequent flood events of the same intensity. These descriptions are intended to serve as general information only. Statistical analyses have not been incorporated in the FFAs to account for regional climate change impacts on hydrology at this time. Instead, flood quantiles for sites in all ecozones are conservatively increased by 10% to account for this uncertainty.

Figure 0-2. Geographic map of Canadian ecozones across the geographic range of the Trans Mountain Expansion Project.

A.3.3.1. Pacific Maritime

The dominant form of precipitation dictates runoff patterns throughout much of Canada (Whitfield 2001). Thus, although changes in the annual volume of precipitation due to climate change are uncertain (e.g., Zwiers et al. 2011), much of the Pacific Maritime region will experience changes in runoff timing as a result of increased winter temperature, as the contribution of snowmelt to annual runoff decreases. As a result, many streams in the Pacific Maritime region will shift from nival (i.e., snowmelt-dominated) to hybrid regimes, which are characterized by earlier snowmelt and more frequent rain-on-snow events (Loukas and Quick 1999; Whitfield 2001). Meanwhile hybrid streams are anticipated to transition to a fully pluvial regime, as the

importance of the spring freshet decreases due to a loss of winter snowpack, especially in coastal areas (Zwiers et al. 2011; Schnorbus et al. 2014). As nival watersheds trap precipitation from winter storms in the snowpack, releasing it gradually during the spring freshet, this transition may be accompanied by an increase in the size and variability of floods (Pitlick 1994). To date, the impacts appear to be greatest in headwater streams; the Columbia River, for example, has shown little change in runoff magnitude or timing (Hatcher and Jones 2013), though this resilience is in part due to an increase in snowpack at high elevations (Schnorbus et al. 2014).

A.3.3.2. Semi-Arid Plateaux

A decrease in the number and magnitude of flood events is predicted for many snowfall-dominated watersheds, particularly in the semi-arid interior regions of British Columbia (Loukas et al. 2002). In drier climates, evaporation from water surfaces and from the land as well as transpiration from vegetation make up a large component of the regional water balance suggesting that temperature changes have the potential to affect runoff. Trends suggest that the Okanagan Basin is getting warmer and wetter with minimum temperatures and the number of frost-free days increasing (Cohen and Kulkarni 2001). Climate change scenarios predict an increase in winter temperature of 1.5 to 4.0 ºC and an increase in summer temperatures by approximately 2 to 4 ºC by the 2050s compared to the 1961 to 1990 baseline (Merritt et al. 2006).

Taylor and Barton (2004) analyzed precipitation records from six sites in the Okanagan Basin and identified statistically significant positive trends in spring-time and summer precipitation for most stations. In contrast, climate change scenarios show precipitation increases on the order of 5 to 20% during the winter season and more variable predictions in the summer with changes ranging from no change to a 35% decrease by the 2050s compared to the 1961to1990 baseline, depending on the Global Climate Model and emission scenario (Merritt et al. 2006). Despite the warmer and wetter climate, little impact on the total water supply has been observed to date, which likely reflects a cancellation of the increase in precipitation inputs versus evapotranspiraton losses (Fleming and Barton 2015). Most studies seem to agree that climate change is resulting in an earlier onset of the spring freshet, a more rainfall-dominated hydrograph, and reduction in the annual and spring flow volumes with large variation in the flow volume and magnitude of the timing shift (Cohen and Kulkarni 2001; Merritt et al. 2006; Fleming and Barton 2015).

A.3.3.3. Montane Cordillera

Extreme flooding in the Montane Cordillera is often associated with rain-on-snow events during the spring freshet (Harder et al. 2015). Although the effects of climate change on precipitation are not clear in this region, projected increases in temperature are expected to have the largest impact on annual minimum temperatures occurring in the winter months (Harder et al. 2015). As a result, the temperature rise will dramatically impact the ratio of rainfall to snowfall throughout the winter and spring, leading to a decrease in snowpack accumulation and changes in melt timing (Farjan et al. 2016). Researchers anticipate that streamflow will increase in the winter and spring in this region due to earlier snowmelt and more frequent rain-on-snow events (Schnorbus et al. 2014; Farjan et al. 2016).

The effects of temperature change differ throughout the region, however, based on watershed elevation; high elevation regions throughout parts of the Montane Cordillera are projected to experience increases in snowpack, which would limit changes to peak flow in high elevation basins (Loukas and Quick 1999). To date, the sustained snowpack accumulation in some watersheds has limited changes in peak flows from climate change (Schnorbus et al. 2014, Harder et al. 2015). For example, Whitfield and Pomeroy (2016) recently studied the historical flow record for the upper Bow River, which contains over 100 years of records, and found that when flood events generated by different processes (snowmelt versus rain-on-snow) are analyzed separately, there are no clear trends in flood magnitude associated with climate index. The continued resilience of high elevation watersheds to future change is uncertain, though, as climate change is anticipated to affect snowpack accumulation at increasingly higher elevation regions throughout the century (Schnorbus et al. 2014, Harder et al. 2015).

A.3.3.4. Boreal Plains

Global Circulation Model predictions are in general agreement that the climate in the southern boreal forest will likely become warmer and drier in the future, especially in the summer due to greater water loss by evapotranspiration (Cubasch et al. 2001; Gregory et al. 1997). Regional climate models indicate that the predicted warming could increase evaporation by up to 55% in certain areas of Alberta, Saskatchewan, and Manitoba (Schindler and Donahue 2006). Paleolimnological studies have shown a drying trend with reduced flood frequency and intensity in the northern Boreal Plains since 1850 (Wolfe et al. 2006).

In contrast to temperature, precipitation trends are weaker and less certain. None of the data from reference climate stations within the Boreal Plains show significant trends in total precipitation over the time period 1950 to 2010 (Ireson et al. 2015). Data from some stations show a decline in annual snowfall and consequently a reduction in the fraction of precipitation that falls as snow due to the shortening cold season (Mekis and Vincent 2011). The response of hydrological processes to winter warming is highly uncertain. Earlier spring snowmelt and delayed autumn snowfall are predicted to be very likely but the impacts are not clear due to the complex runoff generation mechanisms in the Boreal Plains. For example, earlier melt could mean a shift to an earlier peak in streamflow and less water available in the late summer or it could mean more soil infiltration due to the increased proportion of rainfall over snowmelt which could increase soil moisture, stream baseflow, and hydraulic connectivity between wetland and streams (Barnett et al. 2005). Nevertheless, the net effect will be warmer and drier over time due to an increase in air temperature (Ireson et al. 2015).

A.3.3.5. Prairies

Peak runoff in the Canadian Prairies is primarily a result of spring snowmelt over frozen soils but can also be caused by intense rainfall from summer storms (Shook and Pomeroy 2012). The fraction of spring snowmelt forming runoff is strongly influenced by the rate of melt and the presence of ice layers near the surface in frozen soils or at the base of the snowpack, all of which can be influenced by rainfall in the spring and late fall. In 2008, earlier occurrence of spring runoff

and decreasing trends in the spring snowmelt runoff volume, magnitude of peak flow, and summer baseflows were attributed to a combination of a reduction in snowfall and increases in temperatures during the winter months (Burn et al. 2008).

More recently, the fraction of monthly precipitation falling as rain was found to increase at many locations in the Canadian Prairies over the periods 1901 to 2000 and 1951 to 2000 (Shook and Pomeroy 2012). Short-duration summer convective rainfall events show significant decreases in frequency while multiple-day rainfall events have significantly increased in frequency at many locations in the Canadian Prairies over these time periods. Longer rainfall events strongly suggest greater spatial extents for storms and increasing tendencies for basin-scale rainfall–runoff events (Shook and Pomeroy 2012). Warming air temperatures, increased rainfall fraction in peak flows, earlier snowmelt, and higher occurrence of multiple-day rainfall events have, along with extensive wetland drainage (and corresponding reduction in runoff storage within basins), have resulted in an increase in flows generated from snowmelt, rain-on-snow, and rainfall runoff processes, with the greatest increases for rainfall runoff and a relative decline in the proportion of streamflow derived from snowmelt from over 85% in the 20th century to less than 50% in the last 5 years (Dumanski et al. 2015).

A.3.4. Pro-rated FFA

In cases where a single representative station is located along the same watercourse as the proposed pipeline crossing, a pro-rated FFA can be conducted by transposing the flood quantiles from the station to the crossing. This type of FFA uses a pro-rated calculation to relate the Q_{IMAX} quantiles at the hydrometric station to the pipeline crossing based on basin area. The equation used for this relation is as follows (Eq. A-1):

$$\frac{Q_U}{Q_G} = \left(\frac{A_U}{A_G} \right)^n \qquad \text{[Eq. A-1]}$$

where Q_U and Q_G are the peak instantaneous flow estimates (m^3/s) at the ungauged site (pipeline crossing) and gauged site (hydrometric station) respectively, A_U and A_G are the drainage basin areas (km^2) for the ungauged and gauged sites respectively, and *n* is a site-specific exponent that relates peak streamflow data at both sites (Transportation Association of Canada [TAC] 2004). The value of *n* is selected based on the drainage area, as shown in Table 0-1. The drainage area at the pipeline crossing is typically estimated by BGC using available topographic datasets while drainage areas for the hydrometric stations are obtained from WSC records.

Table 0-1. Approximate drainage area exponents for prorating flood quantiles (from TAC 2004)

Drainage Area (km^2)	Exponent, n
10 to 100	0.8
100 to 1000	0.65

1000 to 10,000	0.5
10,000 to 100,000	0.35
100,000 to 1,000,000	0.2

A.3.5. Regional FFA

A regional FFA approach is used to estimate design flood flows at the proposed pipeline crossing when there are several representative hydrometric stations in the area, either along the crossing watercourse or on nearby watercourses with similar catchment characteristics. A regional FFA is conducted using regression analysis, where Q_{IMAX} quantiles are estimated from a regression with the form of a power law, which is described by equation (Eq. A-2):

$$Q_p = aA^b \quad \text{[Eq. A-2]}$$

where Q_p is the peak flood estimate at the pipeline crossing, A is the upstream drainage area for the crossing, and a and b are regression coefficients developed from the estimated Q_{IMAX} and calculated drainage area of several regional hydrometric stations (TAC 2004).

A.4. SCOUR ANALYSIS

Scour is the localized removal of granular bed material from the channel substrate by hydrodynamic forces during a flood event. The likelihood of a pipeline becoming exposed due to scour in a flood event is assessed by estimating the maximum scour depth associated with a range of return period floods. If the pipe's crown elevation within the bankfull channel is higher than the estimated scour elevation, then the pipe is considered to be susceptible to exposure for that particular magnitude of flood event. The scour elevation is estimated by subtracting the predicted scour depth from the design flood elevation, which is generated using an estimate of channel hydraulics with Manning's equation.

A.4.1. Channel Hydraulics

As part of the scour assessment, hydraulic parameters (i.e., water surface elevation, average flow depth etc.) are estimated at the pipeline crossing site for the design flood. The hydraulics are assessed by modeling flow through the study reach, or by applying Manning's equation at the pipeline crossing. Manning's equation is an empirical formula for open channel flow, and it is applicable in cases where flow is driven by gravity and is considered uniform. Manning's equation is defined in equation A-3.

$$V = \frac{1}{n} {R_h}^{2/3} \cdot S^{1/2} \quad \text{[Eq. A-3]}$$

where V is the cross-sectional average velocity (m/s), n is Manning's roughness coefficient (unitless), R_h is the hydraulic radius (m), and S is the slope of the water surface (m/m). The

hydraulic radius, R_h, is calculated as the cross-sectional area of the flow divided by the wetted perimeter. The slope of the water surface is generally assumed to be comparable to the regional slope of the channel bed for uniform flow. Manning's coefficient values typically range from 0.025 to 0.07 for streams with boulder to sand substrates; selection of an appropriate value is based on professional judgment.

A.4.2. General Scour Equations

Various empirical hydraulic equations have been developed to estimate general scour depth during a peak flow event (Table 0-2). The selection and use of these equations requires engineering judgment, resulting in semi-quantitative results. Each method was designed by its authors based on a specific range of boundary conditions, and care must be taken to select appropriate methods for the site under study.

Table 0-2. Methods for estimating the potential depth of general scour.

Method	Reference
Lacey's Regime	Lacey (1930)
Blench Regime	Blench (1969)
Yaremko and Cooper	Yaremko and Cooper (1983)

A.4.2.1. Lacey's Regime

Most of the work on general scour can be traced back to the concept of channel regime, starting with Lacey in 1930. The regime concept is generally considered synonymous with that of equilibrium or balance, and was a concept that originated with British engineers working in India from the study of the dimensions of stable alluvial, irrigation canals. The regime concept was originally formalized by Lindley (1919) who noted that "when an artificial channel is used to convey silty water, both bed and banks scour or fill, changing depth, gradient, and width, until a state of balance is attained at which the channel is said to be in regime."

Lacey (1930) expanded on the regime concept of Lindley by quantifying it. He defined a regime channel as a channel carrying a constant discharge under uniform flow in an unlimited incoherent alluvium having the same characteristics as that transported without changing the bottom slope, shape, or size of the cross-section over a period of time. Using data from irrigation canals on the Indian subcontinent, Lacey developed equations that related hydraulic parameters – namely wetted perimeter, velocity, hydraulic radius, and channel slope – to discharge and a silt factor (*f*), which takes into consideration the effect of sediment size on the channel dimensions. Lacey's regime equation for mean depth is shown in Equation A-4.

$$d_m = 0.47\left(\frac{Q}{f}\right)^{1/3} \quad \text{[Eq. A-4]}$$

where:

- d_m is the mean hydraulic depth of the main channel at the design discharge (m)
- Q is the design discharge (m^3/s)
- f is Lacey's silt factor = 1.76 $(D_{50})^{1/2}$, (s^{-1})
- And D_{50} is the median bed particle size (mm).

The regime method of Lacey is limited to channels with a sand[1] bed, similar to conditions observed at the irrigation canals. However, Lacey also stated he was "inclined to believe that his formulas were general for all channels in the alluvium with which the engineer may be called upon to deal." While the equation was developed from canal data, it has since been checked against data from a number of stable bridge sites on large sand-bed rivers, with remarkably good agreement (Neill 1964).

The silt factor was introduced to account for differences in velocity-depth relations between different canal systems and was initially assumed to be a function of the grain size of transported sediment. For standard "silt" (actually medium sand) of 0.4 mm, the silt factor was taken as 1.

The above equation only gives an estimated mean depth across the channel. To estimate the maximum general scour depth for a given flow, a multiplying factor must be applied. Lacey (1930) stated that "in a river flowing through a stable reach the maximum depth should approximate to the mean depth multiplied by 1.273 (elliptical section). For moderate, severe and right-angled bends, he recommended replacing the multiplier by 1.5, 1.75, and 2.0 m (the last based on a triangular section), respectively. However, Lacey (1930) gave no numerical guidance as to sharpness of curvature. Table 0-3 gives coefficients (Z_f factors) recommended by the Indian bridge code (1966), which are based mainly on consideration of the local channel morphology.

Table 0-3. Empirical Lacey Z factors for maximum scour depth (after Neill 1973).

Channel Morphology	Correction Factor (Z_f Factor)
Straight reach	1.25
Moderate bend	1.5
Severe bend	1.75
Right-angled abrupt turn	2.0
Noses of piers	2.0
Alongside cliffs and weirs	2.25
Noses of guide banks	2.75

The resulting equation is then:

$$d_s = Z_f d_m \qquad \text{[Eq. A-5]}$$

[1] The term "silt" was used at that time in India for canal sediment (Neill 1964).

where d_s is the scour depth below the channel bed (m) and Z_f is the correction factor (Table 0-3). The average depth, d_m (m), is assumed to be the hydraulic depth over the incised portion of the channel. It is further noted that the above equations are based on an unconstrained river, where the width is not constricted or imposed. As an example, if the mean channel depth for a given flow is estimated by Equation A-4 to be 2.0 m and the site is at a moderate bend, then the maximum scour depth estimated using Equation A.5 would be 1.5 times the mean depth, or 3.0 m, as measured from the water level for the given flow. Most subsequent regime equations for estimating general scour are variants of Lacey's equations.

A.4.2.2. Blench Regime Depth

Blench (1969) extended previous regime methods to include cases of different bank material. With this method, the bed factor is similar to Lacey's silt factor. Blench defined the regime depth as follows:

$$d_r = q^{2/3}/F_b^{1/3} \quad \text{[Eq. A-6]}$$

Where d_r = regime depth (m)

q = Q/b = unit discharge ($m^3/s/m$)

Q = design discharge (m^3/s)

b = water surface width (m)

F_b = F_{bo} (1 + 0.12 C) = bed factor (m/s^2)

F_{bo} = zero bed factor (m/s^2)

C = bed load charge.

The value of F_{bo} is the larger of the values determined from Equation A-7, which has been converted by BGC to metric units, or from Figure 0-3:

$$F_{bo} = 14.63\ (D_{50}/d_r)^{0.5} \quad \text{[Eq. A-7]}$$

where D_{50} = median diameter of bed material (m).

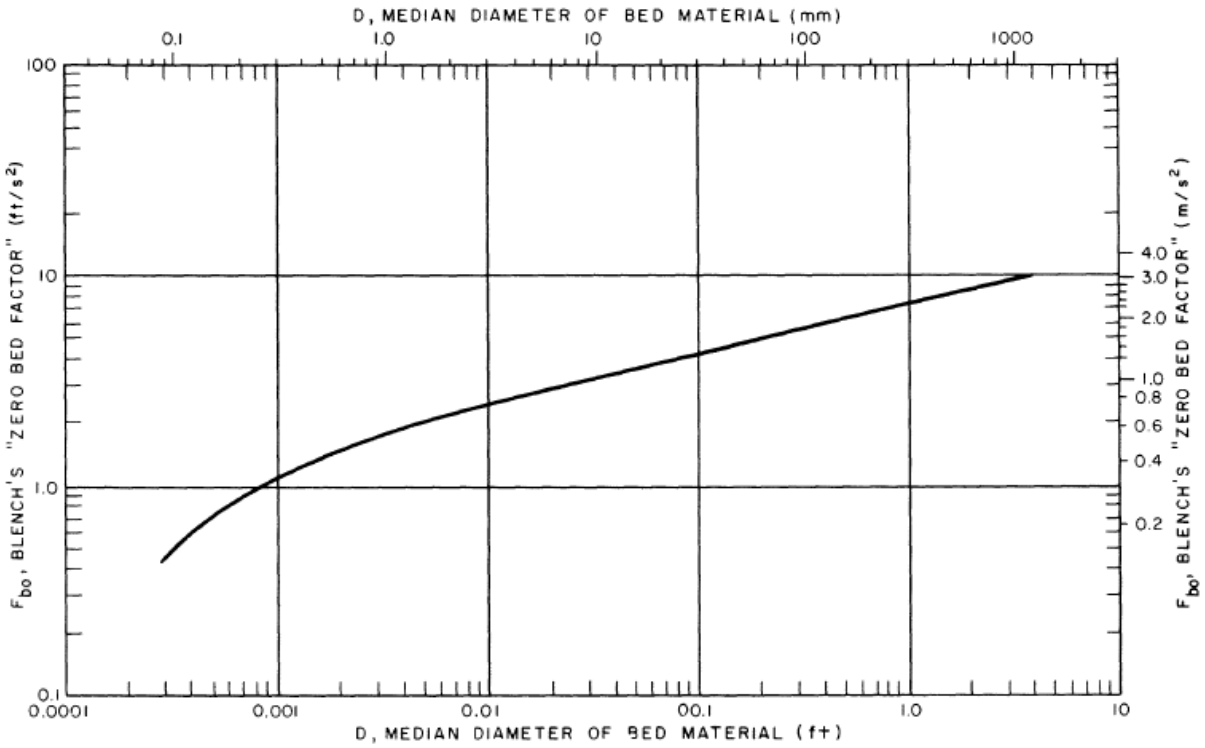

Figure 0-3. Blench's zero bed factor, F_{bo}, versus particle diameter, D_{50}, from Pemberton and Lara (1984).

F_{bo} is the zero bed factor, or the value to which the bed factor tends as *C* tends to zero. Because the value of F_{bo} is calculated using the regime depth, solving the equation is an iterative process. The estimated bed load charge, C, is essentially an adjustment factor to dampen estimated scour depths when significant bed load transport occurs; under these conditions a portion of the stream's energy is committed to sediment transport rather than to scour of the channel bed. BGC's does not generally adjust for bed load charge as this leads to less conservative results.

Finally, similar to Lacey's method, the regime depth is multiplied by a Z factor to calculate the scour depth as per Equation A-8:

$$d_s = Z_f d_r \qquad \text{[Eq. A-8]}$$

where d_s is the scour depth relative to the design flood stage (m), Z_f is the empirical correction factor, and d_r is Blench's regime depth (m). Northwest Hydraulic Consultants Ltd. (NHC) (1973) investigated Z_f factors to be applied to the Blench regime equation using both field and model results, and recommended the values shown in Table 0-4.

Table 0-4. Z_f factors for scour depth applied to Blench's regime equation (after NHC 1973).

Channel Morphology	Correction Factor (Z_f factor)
Forced, Rigid Bends	1.4 – 2.5
Free, Eroding Bends	1.4 – 1.75
Confluence	1.5 – 2.0
Tip of Spurs	2.0 – 2.75
Braided Channel[1]	2.5 – 3.0

Note:
1. Applicable to the bankfull mean depth of the largest existing channel in the vicinity of the crossing.

There is considerable range in Z_f factors for a given channel morphology, and NHC noted that selection of appropriate Z_f factors requires considerable experience in river engineering design. A conservative Z_f factor at the upper end of the range is typically selected to account for uncertainty in the scour analysis inputs and empirical methods.

A.4.2.3. Yaremko and Cooper

Yaremko and Cooper's (1983) scour equation assumes that scour depth is proportional to the mean channel depth for a given flow event. Essentially, the Yaremko and Cooper equation is a simplification of other regime equations, with the assumption that the mean depth is an approximation of the regime depth (Figure 0-4). The mean channel depth is assumed to be the hydraulic depth (wetted area/top width). The Yaremko and Cooper scour equation is defined by equation A-9.

$$d_s = Z_f d_r \qquad \text{[Eq. A-9]}$$

where d_s is the depth of maximum scour relative to the design flood stage (m), d_r is defined as the hydraulic depth over the main (incised) portion of the channel, and Z_f is the correction factor. For appropriate Z_f factors, the authors quote the values shown in both Table 0-3 and Table 0-4.

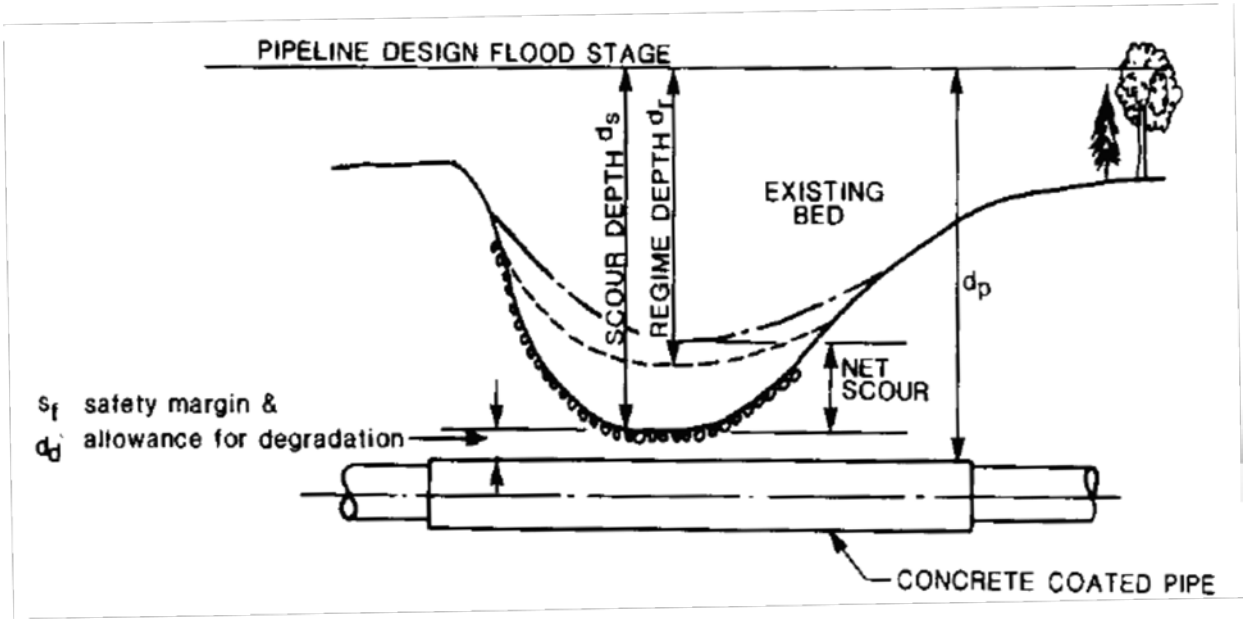

Figure 0-4. Application of estimated scour depths relative to the design flood stage (after Yaremko and Cooper 1983).

Yaremko and Cooper (1983) note that on northern pipeline projects, a great deal of attention was focused on the importance of accurately estimating an appropriate design discharge for use in determining depth of scour. However, the authors note that the design procedure for estimating scour is much more sensitive to the selection of an appropriate Z factor, than it is to the accurate determination of a design flood discharge.

A.4.2.4. BGC Z Factors

As a general rule, BGC uses the Z factors specified in Table 0-3 and Table 0-4. An atypical example might be a braided river, where a local multiplier of 3 is used to account for increased scour at confluences, which are characteristic features of such rivers due to multiple channels and mid-channel bars. The mid-channel bars add geomorphic complexity that results in convergent flow downstream of these deposits, which can cause localized changes in bed planform, including scour holes (Ashworth 1996). Galay et al. (1987) indicate that scour multipliers for braided rivers can be as high as 5 under certain circumstances.

A.4.3. Maximum Bed Mobility

Channel bed mobility controls the adjustment of alluvial river channels and is driven by scour and entrainment. The maximum mobile particle size is estimated based on a combination of the shear velocity (u*) and channel bed shear stress (τ_b), which are calculated using Equations A-10 and A-11, respectively.

$$u^* = (gRS)^{1/2} \quad \text{[Eq. A-10]}$$

$$\tau_b = g\rho RS \quad \text{[Eq. A-11]}$$

where g is acceleration due to gravity (9.81 m/s^2), R is the hydraulic radius (m), S is the regional channel slope (m/m), and ρ is the density of water (1000 kg/m^3). Shear velocity is expressed in units of m/s.

Several empirical equations are available to estimate the maximum mobile particle size and each is considered a check on the others (Table 0-5) (Pemberton and Lara 1984). The methods described below use channel hydraulic flow parameters, shear velocity, and channel bed shear stress. The maximum mobile particle size in a channel is estimated by taking the average of the different methods.

Table 0-5. Methods for estimating bed material mobility.

Method	Reference
Shields' Incipient Motion	Shields (1936)
Lane's Tractive Force Theory	Pemberton and Lara (1984)
Borah Bed Armouring	Borah (1989)
Meyer-Peter Muller	Pemberton and Lara (1984)

The estimated maximum mobile particle size is used to assess the mobility of the bed material in the channel by comparison with an estimate of the median particle size present in the channel. Under conditions where the maximum mobile particle size is greater than the median particle size of the channel bed, the bed material is considered to be frequently mobile. Alternatively, in cases where the maximum mobile particle size is less than the median particle size of the channel bed, bed mobility is considered infrequent.

A.4.4. Wolman Sampling

Various regime and scour equations require an estimation of the median diameter of the bed material (D_{50}). For gravel-bed rivers, the D_{50} of the bed material is assessed using field data collected following the standardized Wolman river bed material sampling method (Wolman 1954). This technique involves randomly picking up and measuring at least 100 pebbles from the river bed at the pipeline crossing or in a representative location in the same reach). The pebbles are measured and classified by size, then counts of pebbles in each size class are compiled to develop a grain size distribution, from which the D_{50} particle size is estimated.

A.4.5. Channels with Cohesive Beds

Conventional approaches to scour prediction were developed from field observations and laboratory experiments in non-cohesive soils, and are generally regarded as overly conservative when applied to cohesive soils. Accurate and accepted methods for predicting scour depths in the more scour-resistant cohesive soils are not yet available to practicing geomorphologists and engineers. The lack of an accurate predictive method often results in an overly conservative design scour depth for cohesive bed channels.

Quantification of channel bed resistance to erosion is site specific and requires laboratory analysis on in-situ samples. Given that the cohesiveness and scour resistance of the substrate is generally not quantified, it is typically assumed by BGC that the bed materials at the pipeline crossings are non-cohesive. In cases where the channel bed material is obviously cohesive, scour depth results may be overestimates.

A.5. BANK EROSION AND ENCROACHMENT ANALYSIS

Much of the methodology presented in the following section has been developed by BGC, and rely significantly on engineering judgement. Bank erosion occurs when bank locations change due to erosion at the channel margins, generally due to channel widening or progressive, gradual erosion from lateral migration of the channel. Channel widening occurs in response to flood events where the channel is forced to convey large flows. Bank erosion may also occur in the absence of large flow events and as a result of gradual erosion along one bank; in this case, the erosion typically occurs along the outer bank of a meander bend and is systematically balanced by the deposition of a point bar on the opposite bank, thus maintaining the channel width (Figure 0-5) (Fuller 2007). Encroachment occurs when bank erosion results from migration of the channel bank toward a pipeline that travels parallel and adjacent to the channel flow direction.

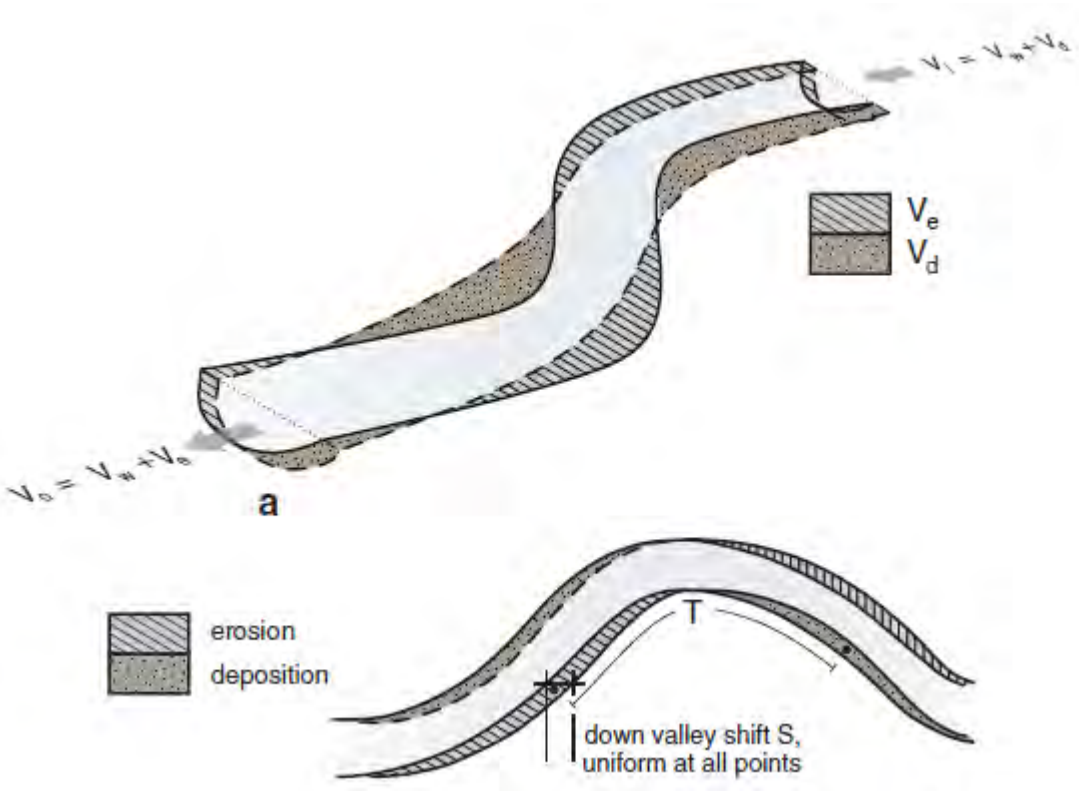

Figure 0-5. Illustration of gradual lateral channel migration in meandering rivers (Church 2006).

Figure 0-6 illustrates different channel planforms as related to sediment supply and channel stability. These channel types can similarly be related to different forms of bank erosion; erosion due to channel widening is typically associated with inherently unstable channels such as braided

or wandering rivers, whereas progressive lateral channel migration is commonly observed in unconfined to semi-confined meandering rivers. The following sections describe the methods used by BGC to assess and quantify bank erosion.

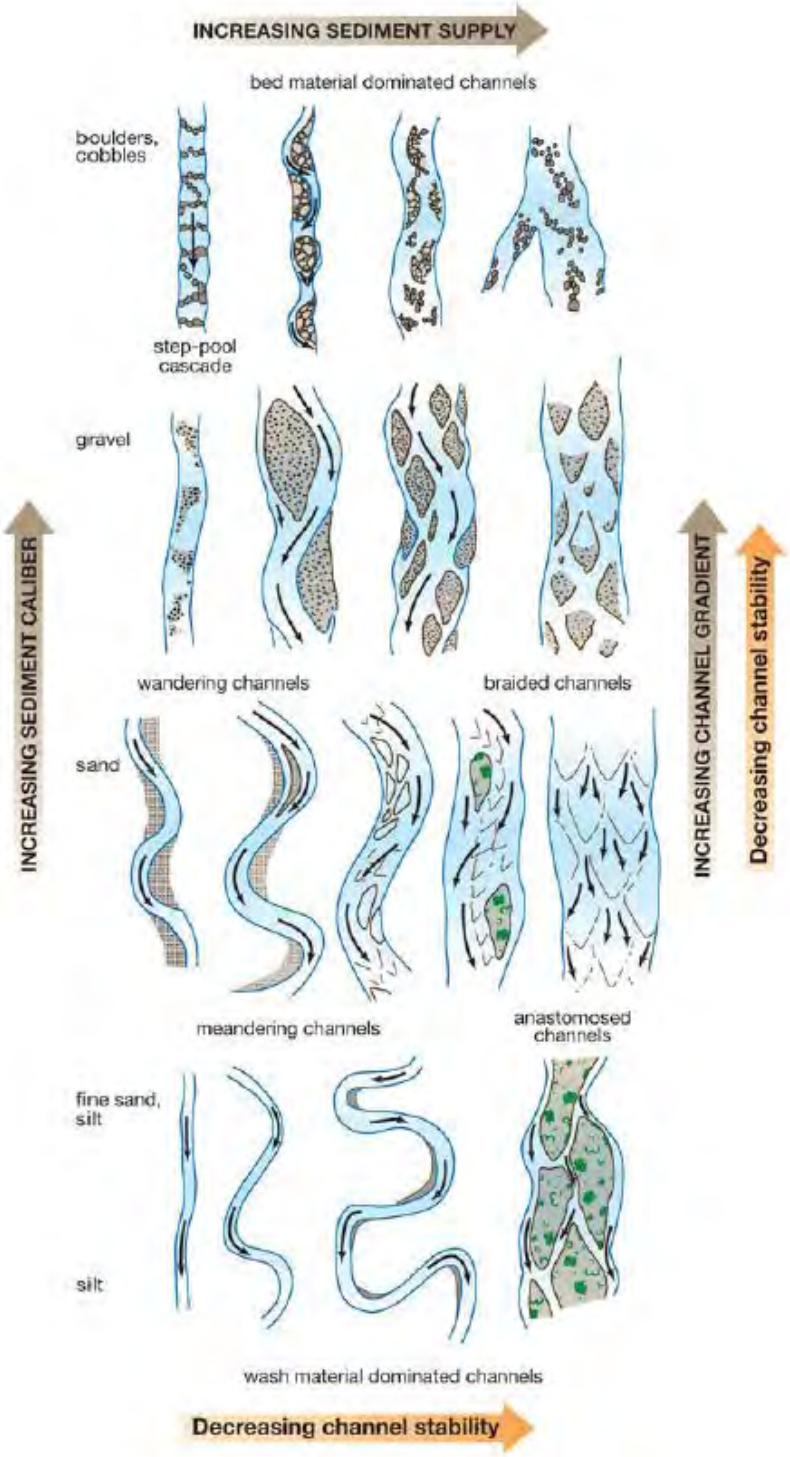

Figure 0-6. Illustration of channel planform and related sediment supply and stability (Church 2006).

A.5.1. Historical Assessment of Channel Changes

A channel's susceptibility to lateral migration can be assessed by looking at changes in channel position over time. Historical aerial photographs and satellite imagery can be used to compare and measure changes in the channel position and planform over time. The oldest available aerial photograph is compared to the most recent available imagery (satellite image or orthophoto) to observe noticeable trends in channel stability and lateral movement over a period of decades. This method will generally provide more accurate and reliable results for medium to large rivers (> 15-20 m width) due to limitations in the spatial scale of available imagery and the precision of mapping techniques. Historical aerial photographs at a scale of 1:30,000 or larger are preferred for this assessment.

Aerial photographs are manually georeferenced to enable 2-dimensional (2D) comparison. Georeferencing is done using control points that are constant over time; where possible, a higher density of control points near the watercourse or in the valley is used to minimize distortion near the river banks. For some sites where adequate control data such as LiDAR are available, high-precision orthorectified models are created that are viewable in 3-dimensional (3D) space using the program Summit Evolution™. In both 2D and 3D cases, banks are delineated from the aerial photographs or models using geographic information system (GIS) software, and the differences in bank locations, which represent erosion or deposition, can be observed and quantified, as relevant. When multiple sets of LiDAR topographic data are available, change analysis techniques can be used to obtain higher precision estimates of recent channel change.

Similar methodologies for historical imagery comparison using both aerial photographs and LiDAR imagery have resulted in spatial error of +/- 2.5 m (Fuller 2007). The spatial accuracy in the BGC method is estimated to be typically about +/-15 m because aerial photographs were not flown specifically for the proposed pipeline crossings and therefore may not be centered, resulting in potential distortion near the crossing location during the georeferencing process.

A.5.2. Encroachment

Progressive lateral movement of the channel toward the pipeline as a result of bank erosion can be evaluated using the same qualitative and quantitative methods as outlined for bank erosion described in the section above. An example of an encroachment hazard is shown in (Figure 0-7).

Figure 0-7. Example of an encroachment hazard. The blue arrow indicates the channel centerline and flow direction and the red line shows a pipeline centerline location (imagery source: Google Earth, 2004).

A.6. AVULSION ANALYSIS

A.6.1. Background

Avulsion is the creation of a new channel on a floodplain or alluvial fan adjacent to the existing channel location. Scour within an avulsion channel could expose a pipeline, especially where the pipeline rises (and DoC decreases) outside of the boundaries of the main channel or existing channel location. Figure 0-8 depicts a typical avulsion hazard in plan view and cross-section.

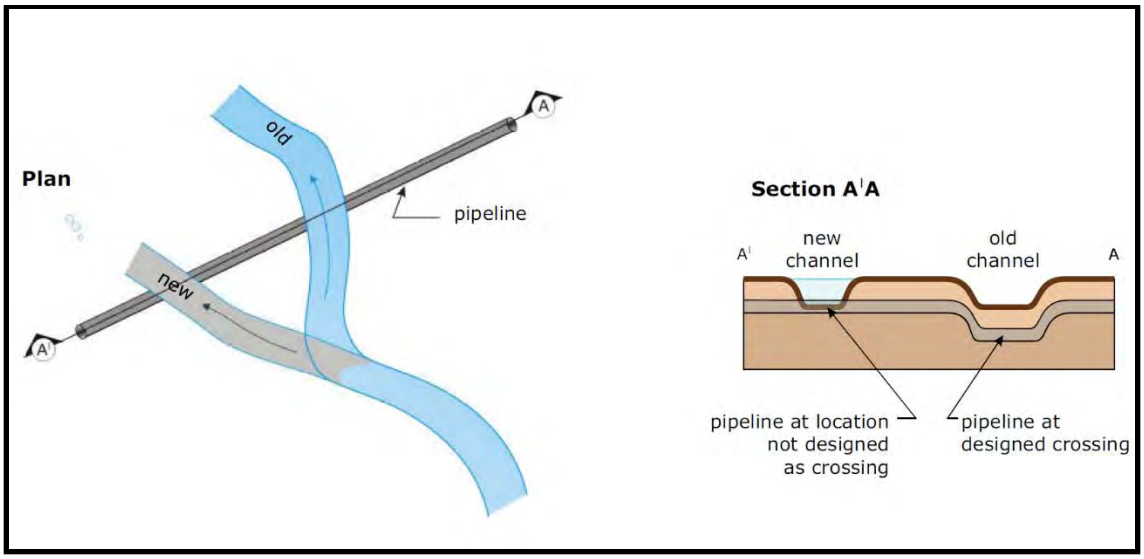

Figure 0-8. Example of avulsion in plan view (left) and cross-section (right).

Avulsions in floodplains tend to occur within a limited area known as the channel migration zone (Olson et al. 2014). This zone comprises the modern valley bottom as well as adjacent areas that could be incorporated into the valley bottom through erosion and it can be defined based largely on historical landforms visible in aerial photographs and satellite imagery; however, in streams subject to post-glacial incision, distinguishing between recent and historical landforms that may be abandoned (e.g., oxbow lakes on floodplain surface versus those on elevated terraces) can require considerable judgement.

Within the channel migration zone, the likelihood of island-forming avulsions to occur is highest in previously abandoned secondary channels (Konrad 2012). In meandering streams, avulsion is most likely to occur between meander bends from the formation of neck and chute cutoffs (Slingerland and Smith 2004). Avulsions typically occur in response to a trigger, such as channel blockage (e.g. a log jam) or overland flooding, and the likelihood of avulsion will be greatest when at least one of these triggers is present.

According to Schumm (2005), the underlying causes of avulsions can be organized into four groups as shown in Table 0-6. The groupings represent different processes and events that create instability and can lead to avulsion. Generally, increases in the ratio of the potential avulsion path gradient (S_a) to the gradient of existing main channel (S_e) the lead to greater instability and potentially to avulsion. Slingerland and Smith (1998) observed that avulsion tends to occur when the S_a/S_e ratio is greater than 4. Therefore, Groups 1 and 2 include processes or events that affect the S_a/S_e ratio in different ways, while processes and events in Group 3 and 4 are not related to the S_a/S_e ratio.

Table 0-6. Causes of avulsions according to Schumm (2005).

Processes and events that create instability and lead to avulsion		Ability of the existing main channel to transport sediment and/or discharge
Group 1		
Avulsion due to increased ratio of S_a/S_e resulting from a decrease in S_e	a) Sinuosity increases	Decrease
	b) Delta growth (lengthening of channel)	Decrease
	c) Base level fall	Decrease
	d) Tectonic uplift	Decrease
Group 2		
Avulsion due to increased ratio of S_a/S_e resulting from an increase in S_a	a) Natural levee/alluvial ridge growth	No change
	b) Alluvial fan and delta growth (convexity)	No change
	c) Tectonism (resulting in lateral tilting)	No change
Group 3		
Avulsion not associated with a change in ratio of S_a/S_e	a) Hydrologic change in flood peak discharge	Decrease
	b) Increased sediment load	Decrease
	c) Vegetative encroachment	Decrease
	d) Log Jams	Decrease
	e) Ice Jams	Decrease
Group 4		
Other avulsions	a) Animal trails	No Change
	b) Capture (diversion into adjacent drainage)	No Change

Note: S_e is the gradient of the existing (main) channel and S_a is the gradient of the potential avulsion course.

Avulsion potential is assessed with qualitative consideration for various factors. Without a floodplain or fan, for example, the potential for avulsion is restricted spatially; channel patterns formed through avulsion (streams with multiple adjacent channels) generally occur in floodplains that are at least four times wider than the bankfull channel width (Beechie and Imaki 2014). Avulsion therefore poses little hazard in entrenched streams as it requires flooding onto elevated terraces, which would only be possible under extreme flows.

In reaches bounded by floodplains, avulsion is most likely to occur within the channel migration zone, typically through the reoccupation of abandoned side channels or as cutoffs between successive meander bends. Avulsion is of greatest concern in aggrading streams, often typified by braided or anabranching channel patterns, where sediment deposition and other triggering factors such as large woody debris may force flows onto the adjacent floodplain (Slingerland and Smith 2004).

Another factor that influences avulsion is the resistance of the valley bottom to vertical erosion. Factors that influence erosion resistance include the nature and abundance of vegetation and the composition and cohesion of floodplain sediments (Constantine et al. 2009; Dunne et al. 2010). Avulsion channels may be more likely to develop in areas with sparse vegetation, such as tilled agricultural fields, than in those with forest cover (Olson et al. 2014).

Olson et al. (2014) recommend that the following factors be considered in an assessment of avulsion potential:

- Cross-valley gradients relative to main channel gradients;
- Areas at lower elevations than the main channel with downstream outlets;
- The presence of abandoned, side or secondary channels that have steeper slopes than the main channel;
- The composition and cohesion of the floodplain and valley bottom sediments;
- Abundance and type of vegetation in potential avulsion pathways;
- Indications of active channel aggradation; and
- Accumulations of large woody debris and channel-spanning log jams.

A.6.2. Assessment

The first step in assessing the potential avulsion hazard for proposed crossings is to delineate the floodplain or fan extents, if relevant, and to identify any contributing factors such as levees, cutoff structures, debris jams, sediment accumulation, beaver dams, debris flow potential, or extreme flooding.

Next, the threshold flow depth for avulsion to occur is quantitatively defined based on the bank elevations at the crossing, which are obtained from survey and LiDAR data. The bank elevation is determined visually as the maximum elevation of the land that separates the stream channel from the floodplain, or the height of the terrace if no floodplain is present. The minimum bank elevation, which is the elevation of the lower of the two banks, defines the threshold flow depth needed to cause overbank flooding and to enable avulsion at the crossing. If this threshold is high, which is typically the case for entrenched reaches, then the design flow does not overtop the banks and avulsion cannot develop in the absence of a blockage. This is common in many Canadian streams, where they flow through valleys carved by larger glacial meltwater channels and are bounded by glaciofluvial terraces. Due to the complex nature of the combination of mechanisms that can initiate avulsion, it is difficult to predict exact avulsion flow paths through a floodplain or fan, even with detailed topographic information for the entire study area.

In addition to establishing an elevation threshold for avulsion at the proposed crossing, avulsion is assessed qualitatively with consideration for additional contributing factors at the reach scale. Avulsion most often initiates at locations with triggering factors (e.g. log jams), or in existing or abandoned side channels that begin in locations where bank elevations are lower than at the crossing; therefore, if active or abandoned side channels are evident in imagery or on the crossing elevation profile, then this may indicate that the elevation threshold for avulsion is lower in a location upstream of the crossing.

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APPENDIX C
BOREHOLE LOGS

SYMBOLS AND TERMS

FOR SOIL DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project | Project Number: 0095-150-14

USCS CLASSIFICATION [1]

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
Coarse grained soils — more than 50% retained on No. 200 (0.075 mm) sieve	Gravel > 50% of coarse fraction retained on No. 4 (4.75 mm) sieve	Clean gravel <5% smaller than No. 200 sieve	GW	Well graded gravel, fine to coarse gravel
			GP	Poorly graded gravel
		Gravel with >12% fines	GM	Silty gravel
			GC	Clayey gravel
	Sand >= 50% of coarse fraction passes No. 4 sieve	Clean sand < 5% passes No. 200 sieve	SW	Well graded sand, fine to coarse sand
			SP	Poorly graded sand
		Sand with >12% fines	SM	Silty sand
			SC	Clayey sand
Fine grained soils — more than 50% passes No. 200 sieve	Silt and clay Liquid limit < 50	Inorganic	ML	Silt
			CL	Clay
		Organic	OL	Organic silt, organic clay
	Silt and clay Liquid limit >= 50	Inorganic	MH	High plasticity silt
			CH	High plasticity clay
		Organic	OH	Organic clay, organic silt
Highly organic soils			PT	Peat

PROPORTION OF MINOR COMPONENTS BY WEIGHT[4]

"and"	> 35%
"y/ey"	20% to 35%
"Some"	10% to 20%
"Trace"	> 0% to 10%

PARTICLE SHAPE[2]

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and Elongated	Particles that meet both criteria

ANGULARITY[2]

Angular	Particles have sharp edges and relatively planar sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have some rounded edges.
Subrounded	Particles have nearly planar sides but have well rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

CLASSIFICATION BY PARTICLE SIZE[1]

NAME	SIZE RANGE (mm) [3]	US STANDARD SIEVE SIZE Retained	US STANDARD SIEVE SIZE Passing
Boulders	>300	12 inch	-
Cobbles	75 - 300	3 inch	12 inch
Gravel: Coarse	19 - 75	0.75 inch	3 inch
Fine	4.75 - 19	No. 4	0.75 inch
Sand: Coarse	2 - 4.75	No. 10	No. 4
Medium	0.43 - 2	No. 40	No. 10
Fine	0.075 - 0.43	No. 200	No. 40
Fines (Silt or Clay)[4]	<0.075	-	No. 200

DENSITY OF GRANULAR SOILS[4]

DESCRIPTION	SPT N [6, 9]	FIELD IDENTIFICATION
"Very Loose"	0-4	None
"Loose"	4-10	Easily penetrated by 13 mm rod pushed by hand
"Compact"	10-30	Easily penetrated by 13 mm rod driven by hammer
"Dense"	30-50	Penetrated 0.3 m by 13 mm rod driven by hammer
"Very dense"	>50	Penetrated few cm by 13 mm rod driven by hammer

CONSISTENCY OF COHESIVE SOILS

GRADE	DESCRIPTION	SPT "N" [8, 9]	UNDRAINED SHEAR STRENGTH - "S_u" kPa [7]	FIELD IDENTIFICATION
S1	"Very soft"	<2	<12	Easily penetrated several cm by the fist.
S2	"Soft"	2-4	12-25	Easily penetrated several cm by the thumb.
S3	"Firm"	4-8	25-50	Can be penetrated several cm by the thumb with moderate effort.
S4	"Stiff"	8-15	50-100	Readily indented by the thumb but penetrated only with great effort.
S5	"Very Stiff"	15-30	100-200	Readily indented by the thumb nail.
S6	"Hard"	>30	>200	Indented with difficulty by the thumbnail.

SYMBOLS AND TERMS

FOR SOIL DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project Project Number: 0095-150-14

PLASTICITY OF COHESIVE SOILS (10)

DESCRIPTION	SILT	CLAY	CRITERIA
High	W_L >50%	W_L >50%	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.
Low	W_L<50%	W_L<50%	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Non-Plastic	NP	-	A 1/8 inch (3 mm) thread cannot be rolled at any water content.

PLASTICITY OF COHESIVE SOILS(10)

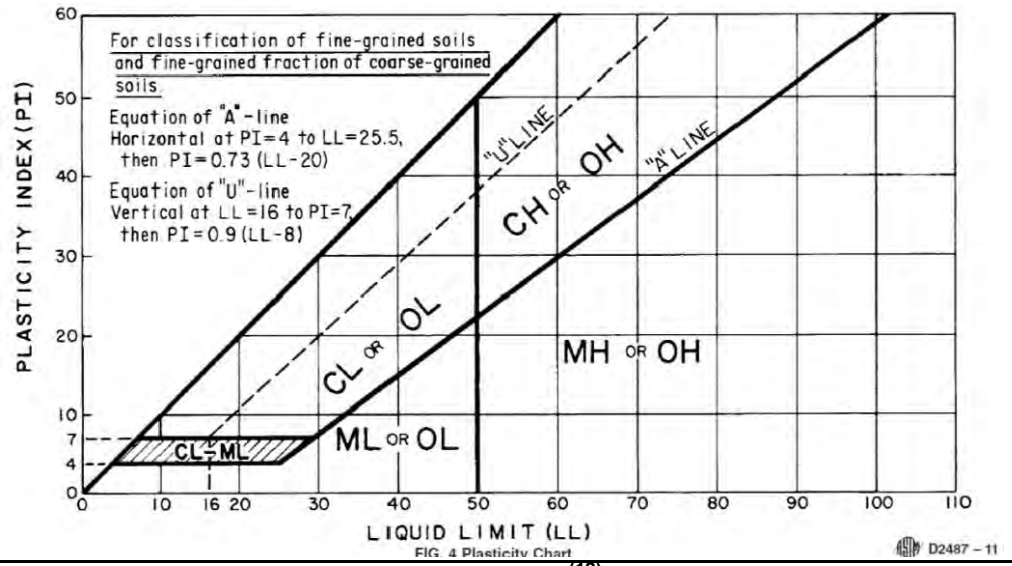


FIG. 4 Plasticity Chart

MOISTURE CONDITION (2)

Description	Criteria
Dry	Absence of moisture
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

CEMENTATION (2)

Description	Criteria
Weak	Crumbles or breaks with handling or little pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

DILATANCY(12)

Description	Criteria
None	No visible change in the spec-men during shaking or squeezing
Slow	Water appears slowly on the surface of the specimen during shaking and disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

Notes:
(1) ASTM D2487-11, Unified Soil Classification System (USCS).
(2) ASTM D2488-09a.
(3) Approximate metric conversion.
(4) Canadian Foundation Engineering Manual (CFEM), 2006.
(5) Fines are classified as silt or clay on the basis of Atterberg limits (refer to Plasticity Chart).
(6) Standard Penetration Test (SPT) blow count uncorrected, after Terzaghi and Peck, 1948.
(7) Undrained shear strength can be estimated by shear vane (gives S_u), pocket penetrometer (gives unconfined compressive strength, qu = 2 * S_u), or unconfined compression test (gives qu = 2 * S_u).
(8) Approximate correlation with Standard Penetration Test blow counts, after Terzaghi and Peck, 1948.
(9) "R" represents sampler refusal during Standard Penetration Test.
(10) This plasticity classification conforms to the Unified Soil Classification System (USCS) and to ASTM D-2487
(11) W_L = Liquid Limit (%)
(12) Test for dilatancy conducted by shaking and squeezing a moulded ball of soil that is 12 mm in diameter.
(13) Test for dry strength conducted on natural soil pieces or moulded balls about 25 mm in diameter that have been dried at less than 60°C.

SYMBOLS AND TERMS

FOR SOIL DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project

Project Number: 0095-150-14

STRUCTURE [2]

Description	Criteria
Stratified	Alternating layers of varying material or colour with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or colour with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes or fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same colour and appearance throughout
Heterogeneous	Colour and appearance vary throughout

SENSITIVITY[2]

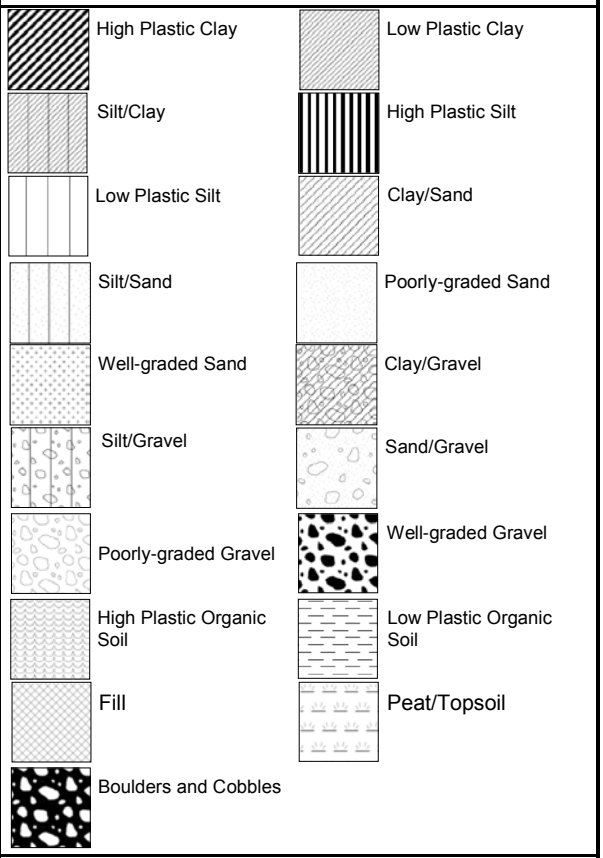
St = Ratio of intact to remoulded strength

St	Sensitivity
St < 2	Low Sensitivity
2 < St < 4	Medium Sensitivity
4 < St < 8	Sensitive
8 < St < 16	Extra Sensitive
St > 16	Quick Clay

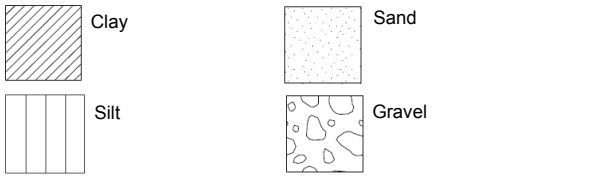
DRY STRENGTH [2]

Description	Criteria[13]
None	The dry specimen crumbles into powder upon applying pressure or handling
Low	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very High	The dry specimen cannot be broken between the thumb and a hard surface

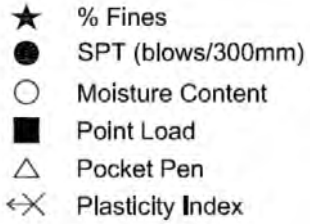
Soil Symbols Legend



Simplified Soil Symbols



Testing Results Legend



Sample Symbols

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

TRANSMOUNTAIN

SYMBOLS AND TERMS

FOR ROCK DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project Project Number: 0095-150-14

WEATHERING/ALTERATION (14)

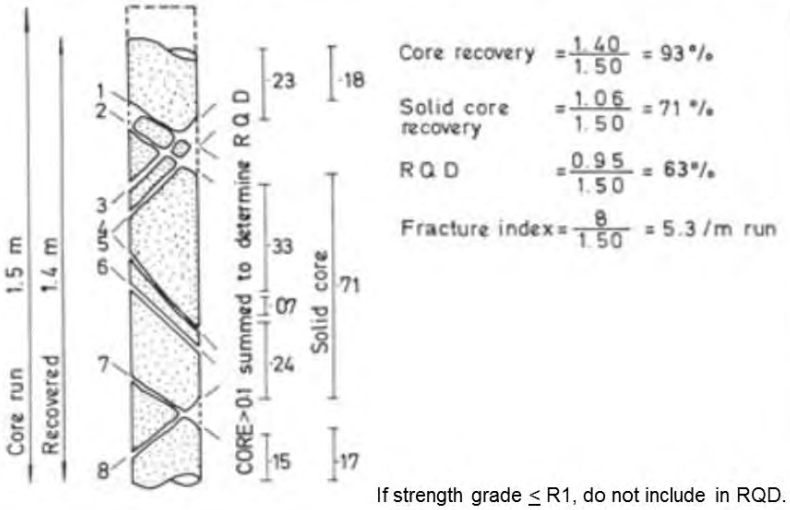
GRADE	Description	Field Identification
A/W 1	Fresh and Unweathered	No visible sign of rock material weathering
A/W 2	Slightly Weathered or Altered	Discolouration indicated weathering of rock material and discontinuity surfaces. All rock material may be discoloured by weathering and may be weaker than in its fresh condition.
A/W 3	Moderately Weathered or Altered	Less than 50% of rock material decomposed and/or disintegrated to soil. Fresh/ discoloured rock present as a continuous framework or corestones.
A/W 4	Highly Weathered or Altered	More than 50% rock material is decomposed or disintegrated to soil. Fresh/ Discoloured rock present as discontinuous framework or corestones.
A/W 5	Completely Weathered or Altered	All rock material decomposed and/or disintegrated to soil. Original mass structure still largely intact
A/W 6	Residual Soil	All rock material converted to soil; mass structure and material fabric destroyed.

HARDNESS CLASSIFICATION FOR ROCK (15)

GRADE	Description	Field Identification
R6	Extremely Strong	Specimen can only be chipped with flat end of geological hammer
R5	Very Strong	Specimen requires many blows of flat end of geological hammer to fracture
R4	Strong	Specimen requires more than one blow of flat end of geological hammer to fracture
R3	Medium Strong	Cannot be scraped or peeled with pocket knife; can be fractured with single firm blow of flat end of the geologic hammer
R2	Weak	Can be peeled with pocket knife with difficulty; shallow indentation made by firm blow with point of geological hammer
R1	Very Weak	Crumbles under firm blow with point of geological hammer; can be peeled by a pocket knife
R0	Extremely Weak	Indented by thumbnail

JOINT CONDITION(16)

Condition of Joints	Rating
Very rough surfaces. Not continuous. No separation. Hard joint wall rock.	25
Slightly rough surfaces. Separation <1mm. Hard joint wall rock.	20
Slightly rough surfaces. Separation <1mm. Soft joint wall rock.	12
Slickensided surfaces or gouge <5mm thick or joints open 1-5mm. Continuous joints.	6
Soft gouge >5mm thick or joints open >5mm. Continuous joints.	0



If strength grade ≤ R1, do not include in RQD.

(14) After ISRM, 1981.
(15) ISRM, 1977
(16) Joint condition is a numerical index that summarizes the typical surface properties and infilling of discontinuities within an interval (Bieniawski, 1976).

SYMBOLS AND TERMS

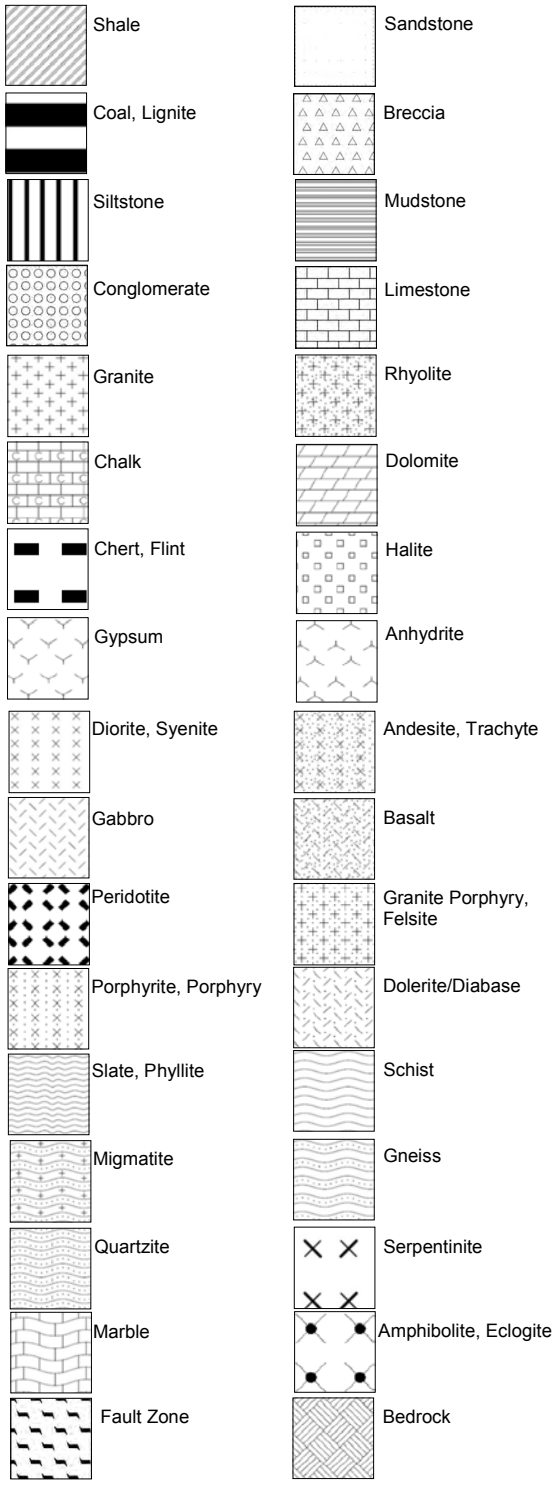
FOR ROCK DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project

Project Number: 0095-150-14

Lithological Graphic Log Legend

Rock



Texture (14)

Term	Particle Size	Examples
Very Coarse	> 60 mm	Porphyritic
Coarse	2 - 60 mm	Breccia, Gneiss (measurable grains)
Medium	0.06 - 2 mm	Sandstone, Gabbro, Granite, Schist (visible grains)
Fine	0.002 - 0.06 mm	Tuff, Siltstone, Claystone, Mudstone, Basalt
Very Fine	< 0.002 mm	

Fabric

Term	Description
Homogeneous/ Uniform	Equigranular or homogeneous grains
Bedded	Deposited in layers, can be sedimentary or volcaniclastic rocks
Foliated	Minerals are aligned due to shearing or metamorphism
Gneissic	Alternating layers of different colour or texture with mineral alignment and typically parts along layers
Porphyritic	Crystalline texture with bimodal grain size distribution, fine to medium grained groundmass with coarse to very coarse phenocrysts
Stockwork	Veins (typically quartz, calcite, or gypsum/anhydrite) make up greater than 10% of the rock mass, they may be aligned with foliation or irregularly oriented
Microfractured	Hairline fractures are the primary fabric of the rock, typically oriented in all directions and intersecting one another
Brecciated	Healed or welded angular clasts with matrix, may be matrix – or clast-supported

Rock Mass Rating (17)

RMR	Rock Quality
81-100	Very Good
61-80	Good
41-60	Fair
21-40	Poor
0-20	Very Poor

(17) The Rock Mass Rating (RMR) system, published by Bieniawski (1976) classifies rock on a linear scale of 0-100 based on the sum of the ratings given to five parameters. The five parameters are: rock quality designation, fracture intercept, joint condition, intact strength, and groundwater conditions. For core logging purposes, the value of the groundwater condtions parameter is assumed to be 10. The sum of the rating may then be used to assess the quality of the rock based on the classification table.

SYMBOLS AND TERMS

FOR ROCK DESCRIPTIONS ON BOREHOLE LOGS

Project Name: Trans Mountain Expansion Project | Project Number: 0095-150-14

REFERENCES

American Society for Testing and Materials. Standard D2487-11: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). West Conshohocken, PA.

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Methods for the Quantitative Description of Discontinuities in Rock Masses. Committee on Field Tests, Document No. 4, pp. 319-368.

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Terzaghi, K., and Ralph B. Peck, 1948, Soil Mechanics in Engineering Practice, John Wiley and Sons, New York

Revision: June 11, 2015

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SM) Fine to medium, some silt, trace gravel, poorly graded, very loose to compact, maximum particle size = 40 mm, subrounded, brown, no odour, moist, weak cementation, heterogeneous, no foreign materials. [FLUVIAL]	
4		SPT-01			SPT 01 - Recovered 0.46 m (75%).	1 2 2
5						
6		SPT-02			SPT 02 - Recovered 0.46 m (75%). Changes to very loose.	0 1 1
7		SPT-03			SPT 03 - Recovered 0.41 m (67%). Changes to compact, grey.	4 5 7
8					Water depth measured at 7.4 m below ground surface on November 16, 2013 with the borehole at final depth of 68.6 metres below ground surface (mbgs) and casing to 2.7 mbgs.	

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

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Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SM) Fine to medium, some silt, trace gravel, poorly graded, loose to compact, maximum particle = 40 mm, subrounded, grey, no odour, moist, weak cementation, heterogeneous, no foreign materials. [FLUVIAL]	
9		SPT-04			SPT 04 - Recovered 0.38 m (62%).	6 5 6
10		SPT-05			SPT 05 - Recovered 0.48 m (79%). Changes to loose.	3 4 4
11						
12		SPT-06			SPT 06 - Recovered 0.41 m (67%).	5 5 5
13		SPT-07			SPT 07 - Recovered 0.43 m (70%).	4 4 5
14					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, loose, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm.	
15		SPT-08			SILT (ML) Some fine to medium sand, low plasticity, firm, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.53 m (87%).	2 2 4
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
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Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
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Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, stiff to very stiff, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT-09			SPT 09 - Recovered 0.41 m (67%). Sand changes to compact, silt changes to stiff.	7 8 6
17					SPT 10 - Recovered 0.51 m (84%). Silt changes to very stiff.	
18		SPT-10				6 7 10
19					SPT 11 - Recovered 0.51 m (84%). Silt changes to stiff.	
		SPT-11				6 6 7
20					SPT 12 - Recovered 0.53 m (87%). Silt changes to very stiff.	
21		SPT-12				5 8 8
22					SPT 13 - Recovered 0.36 m (59%). Silt changes to stiff.	
		SPT-13				6 6 8
23						
24					SPT 14 - Recovered 0.61 m (100%).	

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
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Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
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Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24		SPT-14			Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	9 8 7
25		SPT-15			SPT 15 - Recovered 0.51 m (84%).	8 7 9
26						
27		SPT-16			SPT 16 - Recovered 0.38 m (62%).	12 11 14
28						
29		SPT-17			SPT 17 - Recovered 0.33 m (54%). Sand changes to dense, silt changes to hard.	13 15 16
30		SPT-18			SPT 18 - Recovered 0.41 m (67%).	15 15 18
31						
32		SPT-19			SPT 19 - Recovered 0.43 m (70%).	10 15 20

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

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Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
33		SPT-20			SPT 20 - Recovered 0.58 m (95%). Sand changes to compact, silt changes to very stiff.	5 8 15
34						
35		SPT-21			SPT 21 - Recovered 0.46 m (75%).	2 10 11
36		SPT-22			SPT 22 - Recovered 0.58 m (95%). SAND (SM) 0.0% gravel, 63.2% sand, 36.8% fines.	7 10 12
37						
38		SPT-23			SPT 23 - Recovered 0.61 m (100%).	4 8 8
39		SPT-24			SPT 24 - Recovered 0.61 m (100%).	4 4 13
40						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

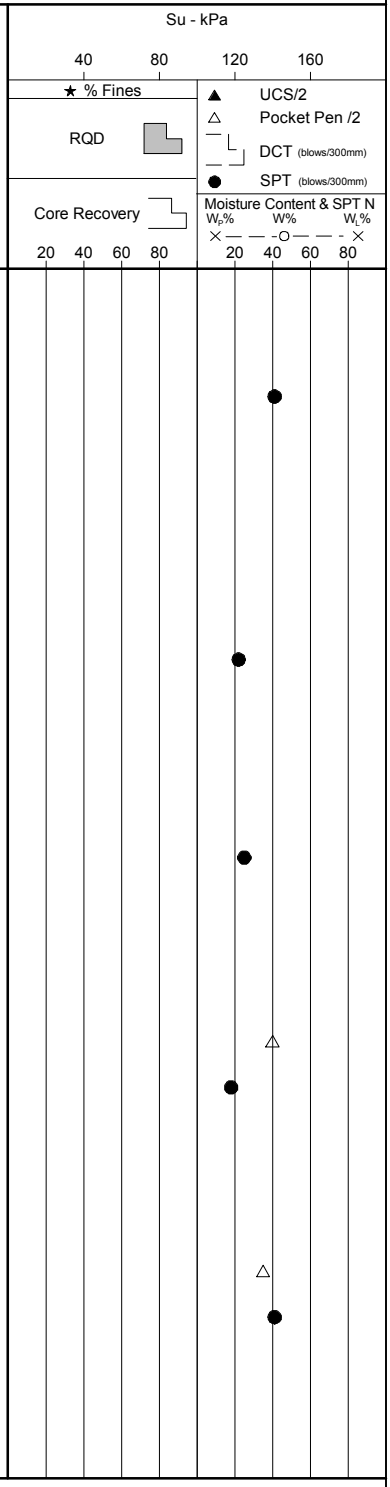
(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
40					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
41		SPT-25			SPT 25 - Recovered 0.56 m (92%). Sand changes to dense, silt changes to hard.	13 19 22
42		SPT-26			SPT 26 - Recovered 0.61 m (100%). Sand changes to compact, silt changes to very stiff.	4 9 13
43						
44		SPT-27			SPT 27 - Recovered 0.48 m (79%).	7 12 13
45		SPT-28			SPT 28 - Recovered 0.61 m (100%).	5 6 12
46						
47		SPT-29			SPT 29 - Recovered 0.56 m (92%). Sand changes to dense, silt changes to hard.	10 18 23
48						



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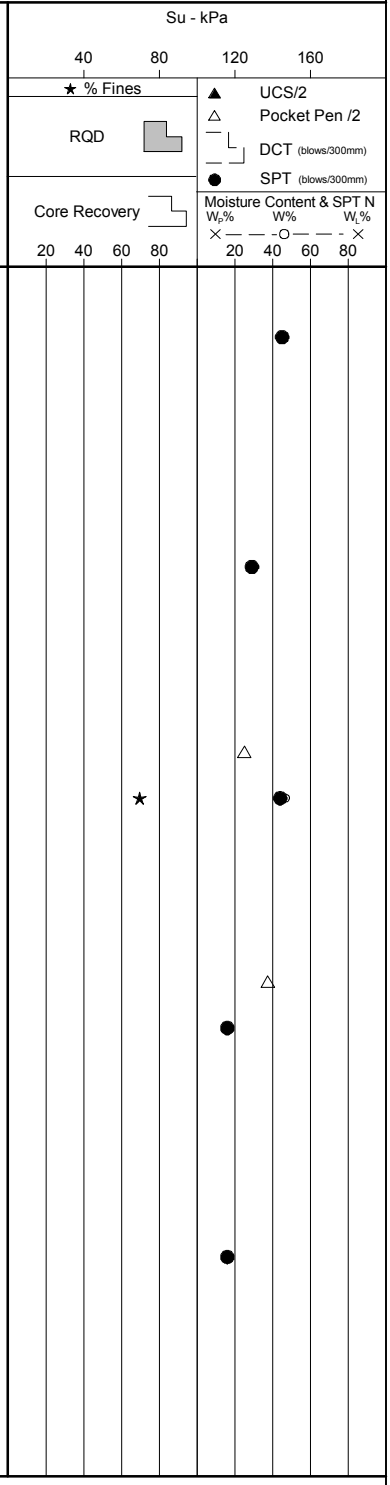
Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
48					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT-30			SPT 30 - Recovered 0.43 m (70%).	14 21 24
49						
		SPT-31			SPT 31 - Recovered 0.38 m (62%). Sand changes to compact, silt changes to very stiff.	13 13 16
50						
51						
		SPT-32			SPT 32 - Recovered 0.61 m (100%). Sand changes to dense, silt changes to hard. SILT (ML) 0% gravel, 30.3% sand, 69.6% fines.	7 16 28
52						
		SPT-33			SPT 33 - Recovered 0.61 m (100%). Sand changes to compact, silt changes to very stiff.	3 5 11
53						
54						
		SPT-34			SPT 34 - Recovered 0.61 m (100%).	3 4 12
55						
56						



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Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
56		SPT-35			SPT 35 - Recovered 0.61 m (100%). Sand changes to dense, silt changes to hard. Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, dense to very dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	20 23 23
57						
		SPT-36			SPT 36 - Recovered 0.38 m (62%). Sand changes to very dense.	26 26 27
58						
59		SPT-37			SPT 37 - Recovered 0.28 m (46%).	15 24 29
60						
		SPT-38			SPT 38 - Recovered 0.36 m (59%).	R
61						
62		SPT-39			SPT 39 - Recovered 0.36 m (59%).	20 35 40
63						
		SPT-40			SPT 40 - Recovered 0.48 m (79%).	10 26
64						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20, 40, 60, 80

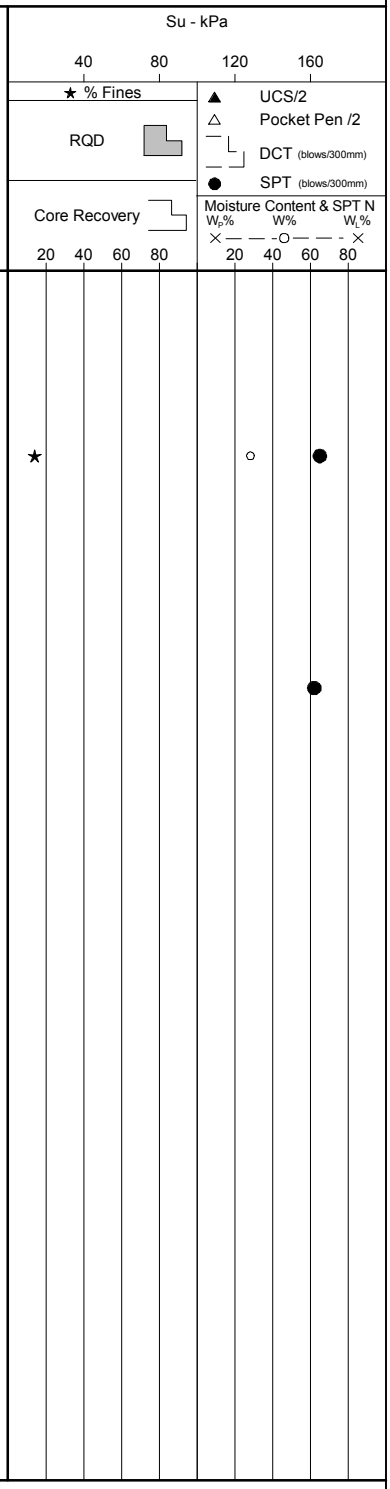
(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
64					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, very dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	28
65		SPT-41			SPT 41 - Recovered 0.36 m (59%). SAND (SM) 0.0% gravel, 86.0% sand, 14.0% fines.	21 30 35
66					SAND (SM) Fine to medium, some silt, poorly graded, very dense, maximum particle size = 2 mm, subrounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL]	
67		SPT-42			Zone of 30% drilling mud circulation loss begins. SPT 42 - Recovered 0.48 m (79%).	25 30 32
68		SPT-43			SPT 43 - Recovered 0.38 m (62%).	R
69					Borehole completed at target depth of 68.6 m. Borehole grouted to surface with bentonite grout. No instrumentation installed. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586.	
70					Pocket penetrometer tests conducted perpendicular to borehole axis. Tests were conducted on disturbed samples. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
71						
72						



Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
0				SAND (SP) Fine to medium, trace silt, trace gravel, fine to coarse, poorly graded, loose, maximum particle size = 30 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [FLUVIAL]		
1						
2		SPT 01		SPT 01 - Recovered 0.47 m (77%).	3 3 4	
3		SPT 02		SPT 02 - Recovered 0.34 m (56%). SAND (SP) 95.4% sand, 4.6% fines.	2 3 3	
4				Water level measured at 3.58 m below ground surface on December 8, 2014.		
5		SPT 03		4.5 m - 10 - Drilling mud circulation loss of 15% begins. SPT 03 - Recovered 0.38 m (66%).	3 4 5	
6		SPT 04		SPT 04 - Recovered 0.38 m (62%).	4 3 5	
7				From 6.7 - 69 m Drilling mud circulation loss increases to 20%. Possible gravel or coarse sand layer.		
8		SPT 05		SPT 05 - Recovered 0.36 m (59%).	3	

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
8				SAND (SP) Fine to coarse, trace silt, trace gravel, fine to medium, poorly graded, loose, maximum particle size = 30 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [FLUVIAL]	3 5	
9				9.0 m - Drilling mud circulation loss decreases to 0%.		
		SPT 06		SPT 06 - Recovered 0.37 m (61%). Sand changes to fine to coarse. SAND (SP) 0.9% gravel, 92.9% sand, 6.2% fines.	2 2 4	
10						
11		SPT 07		SPT 07 - Recovered 0.55 m (90%).	3 4 5	
12				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, loose, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses.		
		SPT 08			2 4 6	
13				SILT (ML) And sand, low plasticity, stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.52 m (85%).		
14		SPT 09		SPT 09 - Recovered 0.38 m (62%). Silt changes to firm.	3 3 3	
15						
		SPT 10		SPT 10 - Recovered 0.46 m (75%). Silt changes to stiff. SAND (SP) 0.3% gravel, 95.6% sand, 4.1% fines.	4 4 6	
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
RQD
DCT (blows/300mm)
● SPT (blows/300mm)
Core Recovery: 20, 40, 60, 80
Moisture Content & SPT N: W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
16				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, loose to compact, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses. SILT (ML) And sand, low plasticity, stiff to very stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]		
17		SPT 11		SPT 11 - Recovered 0.38 m (62%). Sand changes to compact.	6 7 8	
18		SPT 12		SPT 12 - Recovered 0.48 m (79%).	7 7 7	
19						
20		SPT 13		SPT 13 - Recovered 0.55 m (90%). Silt changes to very stiff.	7 11 13	
21						
22		SPT 14		SPT 14 - Recovered 0.42 m (69%).	7 8 8	
23		SPT 15		22.5 m - Drilling mud circulation loss increases to 25%. SPT 15 - Recovered 0.35 m (57%). SAND (SP) 0.2% gravel, 95.2% sand, 4.6% silt.	7 9 10	
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
24				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, compact, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses.		
		SPT 16			8 13 11	
25				SILT (ML) And sand, low plasticity, very stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 16 - Recovered 0.52 m (87%).		
26		SPT 17		SPT 17 - Recovered 0.50 m (82%).	10 14 14	
27				SAND (SP) Fine to coarse, trace silt, poorly graded, dense, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL]		
		SPT 18		SPT 18 - Recovered 0.42 m (69%).	13 17 13	
28						
29		SPT 19		SPT 19 - Recovered 0.47 m (77%).	13 27 23	
30				30.0 m - Drilling mud circulation loss increases to 35%.		
		SPT 20		SPT 20 - Recovered 0.48 m (79%).	9 19 17	
31						
32						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
32		SPT 21		SAND (SP) Fine to coarse, trace silt, poorly graded, compact to dense, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL] SPT 21 - Recovered 0.43 m (70%). Changes to compact. SAND (SP) 0.3% gravel, 95.5% sand, 4.2% fines.	7 14 13	
33						
34		SPT 22		SPT 22 - Recovered 0.38 m (62%). Changes to dense.	10 15 16	
35		SPT 23		SPT 23 - Recovered 0.48 m (79%).	16 22 27	
36						
37		SPT 24		SPT 24 - Recovered 0.61 m (100%). Changes to some silt, compact.	8 12 17	
38		SPT 25		SPT 25 - Recovered 0.61 m (100%).	10 15 14	
39						
40		SPT 26		SPT 26 - Recovered 0.61 m (100%). Changes to dense.	17	

Su - kPa
40 80 120 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
RQD
DCT (blows/300mm)
● SPT (blows/300mm)
Core Recovery
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
40				Borehole completed at target depth of 40.2 m below ground surface. Borehole grouted to surface with bentonite grout. Vibrating wire piezometers (Model VW2100-0.35) installed at 15.0 m and 30.0 m depth. VW31076 Installed at 30.0 m depth. VW31070 Installed at 15.0 m depth. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	19 20	
41						
42						
43						
44						
45						
46						
47						
48						

Su - kPa
40 80 120 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
RQD
Core Recovery
20 40 60 80
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 15 mm, subrounded to subangular, brown to grey, no odour, moist, heterogeneous, weak cementation, visible muscovite and quartz, no foreign materials. [FLUVIAL]	
1		SPT01			SPT 01 - Recovered 0.34 m (56%).	3 3 3
					Groundwater level measured to be 1.38 m below ground surface on December 9, 2014.	
2						
		SPT02			SPT 02 - Recovered 0.35 m (57%). SAND (SP) 4.4% gravel, 92.0% sand, 3.6% fines.	2 1 3
3					2.95 m - Transition from brown to grey.	
4		SPT03			SPT 03 - Recovered 0.34 m (56%).	4 3 3
5						
		SPT04			SPT 04 - Recovered 0.30 m (49%).	2 2 2
6						
7		SPT05			SPT 05 - Recovered 0.32 m (52%). Maximum particle size decreases to 7 mm. SAND (SP) 2.9% gravel, 94.4 sand, 2.7% fines.	2 3 3
8						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 7 mm, subrounded to subangular, grey, no odour, moist, heterogeneous, weak cementation, visible muscovite and quartz, no foreign materials. [FLUVIAL]	
9		SPT06			SPT 06 - Recovered 0.32 m (52%).	3 3 4
10		SPT07			SPT 07 - Recovered 0.39 m (64%).	3 4 4
11						
12		SPT08			SPT 08 - Recovered 0.34 m (56%).	3 5 5
13		SPT09			SPT 09 - Recovered 0.37 m (61%). Changes to compact.	5 6 7
14					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	
15		SPT10			SILT (ML) Sandy,low plasticity, stiff, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 10 - Recovered 0.46 m (75%). SAND (SM) 0.0% gravel, 83.2% sand, 16.8% fines.	3 5 5
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, stiff to very stiff, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT11			SPT 11 - Recovered 0.46 m (75%).	4 5 5
17						
18		SPT12			SPT 12 - Recovered 0.32 m (52%). Silt changes to very stiff.	6 8 12
19						
		SPT13			SPT 13 - Recovered 0.28 m (46%). Changes to trace fine gravel.	10 14 16
20						
21		SPT14			SPT 14 - Recovered 0.40 m (66%).	10 12 14
22						
		SPT15			SPT 15 - Recovered 0.37 m (61%). Changes to no gravel.	8 12 16
23						
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24		SPT16			SPT 16 - Recovered 0.33 m (54%). Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact to dense, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	7 13 16
25		SPT17			SILT (ML) Sandy,low plasticity, very stiff to hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 17 - Recovered 0.49 m (80%). Sand changes to dense, silt changes to hard.	12 13 18
26						
27		SPT18			SPT 18 - Recovered 0.31 m (51%). Sand changes to compact, silt changes to very stiff. SAND (SP) 0.0% gravel, 92.9% sand, 7.1% fines.	9 12 15
28						
29						
30		SPT19			SPT 19 - Recovered 0.31 m (51%). Sand changes to dense, silt changes to hard.	11 18 27
31						
32						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact to dense, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, very stiff to hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
33		SPT20			SPT 20 - Recovered 0.49 m (80%). Sand changes to compact, silt changes to very stiff.	10 14 15
34						
35						
36		SPT21			SPT 21 - Recovered 0.42 m (69%). Sand changes to dense, silt changes to hard.	17 21 29
37						
38		SPT22			SPT 22 - Recovered 0.35 m (57%).	18 19 20
39		SPT23			SPT 23 - Recovered 0.33 m (54%).	10 14 20
40						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
40					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, dense to very dense, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	
41		SPT24			SILT (ML) Sandy,low plasticity, hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 24 - Recovered 0.61 m (100%).	8 17 22
42		SPT25			SPT 25 - Recovered 0.57 m (93%).	9 14 24
43						
44		SPT26			SPT 26 - Recovered 0.29 m (48%). Sand changes to very dense.	16 26 30
45						
46		SPT27			SPT 27 - Recovered 0.47 m (77%). Sand changes to dense.	18 23 22
47		SPT28			SPT 28 Recovered 0.55 m (90%). Sand changes to very dense.	14 21 31
48						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
48					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to and silt, poorly graded, dense to very dense, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT29			SPT 29 - Recovered 0.53 m (87%). Sand changes to dense.	12 19 23
49						
		SPT30			SPT 30 - Recovered 0.62 m (101%). SAND (SM) 0.1% gravel, 50.1% sand, 49.8% fines.	13 18 21
50						
51						
		SPT31			SPT 31 - Recovered 0.68 m (111%).	11 15 21
52						
53		SPT32			SPT 32 - Recovered 0.62 m (101%).	11 21 24
54						
		SPT33			SPT 33 - Recovered 0.54 m (89%).	14 20 22
55						
56						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

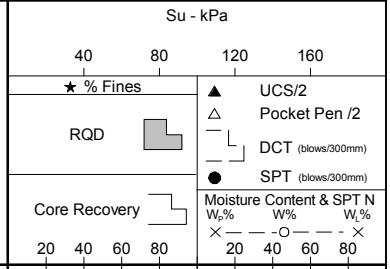
(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
56						
		SPT34			SAND (SM) Fine to medium, some silt, poorly graded, very dense, maximum particle size = 2 mm, subrounded to rounded, equidimensional to flat, grey, no odour, moist, heterogeneous, weak cementation, visible muscovite, no foreign materials. [FLUVIAL] SPT 34 - Recovered 0.43 m (70%).	20 28 33
57						
		SPT35			SPT 35 - Recovered 0.28 m (46%).	12 37 48
58						
59		SPT36			SPT 36 - Recovered 0.44 m (72%).	20 27 30
60						
		SPT37			SPT 37 - Recovered 0.28 m (46%).	20 31 36
61					Borehole completed at target depth of 61.0 m below ground surface. Borehole grouted to surface with bentonite grout. No instrumentation installed. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
62						
63						
64						



Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [FLUVIAL]	
1						
2		SPT 01			SPT 01 - Recovered 0.46 m (75%).	3 2 2
3		SPT 02			SPT 02 - Recovered 0.49 m (80%). Lenses of sand have orange oxidation staining. SAND (SP) 0.0% gravel, 94.3% sand, 5.7% fines. Water level measured at 3.20 m below ground surface on December 10, 2014.	4 4 3
4						
5		SPT 03			SPT 03 - Recovered 0.50 m (82%).	4 3 4
6		SPT 04			SPT 04 - Recovered 0.32 m (52%). Changes to some fine gravel. SAND (SP) 10.1% gravel, 86.4% sand, 3.5% fines.	3 2 2
7					6.8 m - Thin layer (<10 cm) of 10% drilling fluid circulation loss.	
8		SPT 05			SPT 05 - Recovered 0.48 m (79%). Changes to trace fine gravel.	4

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [FLUVIAL]	5 5
9		SPT 06			SPT 06 - Recovered 0.38 m (62%).	5 5 3
10						
11		SPT 07			SPT 07 - Recovered 0.38 m (62%). SAND (SP) 0.2% gravel, 95.9% sand, 3.9% fines. Drilling fluid circulation loss of 15% begins; was resolved at 23.5 m depth with modification of drilling mud density.	3 3 4
12						
13		SPT 08			SAND (SP) Fine to medium, trace silt, poorly graded, loose to compact, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.57 m (93%). Changes to no gravel.	4 4 3
14		SPT 09			SPT 09 - Recovered 0.52 m (85%).	5 4 4
15						
16		SPT 10			SPT 10 - Recovered 0.39 m (64%).	4 4 5

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16						
17		SPT 11			SPT 11 - Recovered 0.54 m (89%). Changes to compact.	6 7 8
18						
19		SPT 12			SPT 12 - Recovered 0.40 m (66%).	9 9 8
20		SPT 13			SPT 13 - Recovered 0.43 m (71%). SAND (SP) 0.8% gravel, 94.3% sand, 4.9% fines.	7 7 7
21						
22		SPT 14			SPT 14 - Recovered 0.37 m (61%).	8 8 8
23		SPT 15			SPT 15 - Recovered 0.38 m (62%).	7 7 7
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24					SAND (SP) Fine to medium, trace silt, poorly graded, compact, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
25		SPT 16			SPT 16 - Recovered 0.56 m (92%).	7 8 7
26		SPT 17			Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 4 mm, rounded, equidimensional, grey, faint organic odour, laminated to stratified, weak cementation, trace woody organics. SILT (ML) Sandy, low plasticity, very stiff, grey, faint organic odour, laminated to stratified, weak cementation, no foreign materials. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	8 7 10
27					SPT 17 - Recovered 0.58 m (95%). SAND (SP-SM) 0.0% gravel, 88.7% sand, 11.3% fines.	
28		SPT 18			SAND (SP) Fine to coarse, trace silt, poorly graded, compact, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, wet, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL] SPT 18 - Recovered 0.44 m (72%).	6 6 7
29		SPT 19			SPT 19 - Recovered 0.54 m (89%).	8 8 10
30						
31		SPT 20			SPT 20 - Recovered 0.53 m (87%).	9 10 11
32						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32						
		SPT 21			SPT 21 - Recovered 0.38 m (62%). Changes to trace fine gravel. SAND (SP) 0.3% gravel, 95.0% sand, 4.7% fines.	7 7 8
33						
		SPT 22			SPT 22 - Recovered 0.68 m (111%). Changes to no gravel.	10 15 16
34						
35						
		SPT 23			SPT 23 - Recovered 0.51 m (84%).	10 13 11
36					Borehole completed at target depth of 35.7 m below ground surface. Borehole grouted to surface with bentonite grout. No instrumentation installed.	
					SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586.	
37					Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
38						
39						
40						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

AUGER HOLE # AH-BGC16-CHW-01

Project: Trans Mountain Expansion Project
Project No.:0095-150-16

Reference #: TP 847.503 - 1
Location: T3810.0 & T3808.0, Chuwhels Station

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 681,779E; 5,618,597N
Ground Elevation (m): 342.6
Datum: NAD83 UTM Zone 10U

Drill Designation: Marl M5T
Drilling Contractor: Mobile Augers
Drill Method: 6" Solid Stem Auger
Auger Size: 6"
Depth to Water (m): 2.6

Drill Date: 07 Oct 16
Final Depth of Hole (m): 6.1
Logged by: YY
Reviewed by: LDM
Approved by: AJB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description
0				[ORGANICS] Topsoil, rootlets; brown, moist.
				CLAY (CL) And sand, silty, some gravel, low plasticity, soft to firm, brown, drier than plastic limit, no cementation, organic odour, mottled red and orange oxidation, scattered organics, slow to no dilatancy. Coarse fraction is subrounded, some angular, equidimensional, max observed particle size = 55 mm. [FLUVIAL]
1				
				1.4 m - Material becomes stiff. 1.5 m - Material grades to some clay, some gravel, near plastic limit. S1 (1.52 - 3.05 m) Laboratory analysis results: 15% gravel, 35% sand, 37% silt, 13% clay, moisture content 16.3%, fines classify as CL with LL = 29%, PI = 11%.
2		S1		
				CLAY (CL) Some silt, trace fine sand, trace gravel, low plasticity, stiff, grey, wetter than plastic limit, heterogeneous, no cementation, no odour, no weathering, no organics, no dilatancy. Coarse fraction is subangular to subrounded, equidimensional, max observed particle size = 55 mm. [GLACIOLACUSTRINE] 2.6 m - Interpreted water table. Material becomes wetter than plastic limit. 3.0 m - Material becomes grey mottled with brown weathering discolouration.
3				
		S2		GRAVEL (GC) Some clay, some silt, trace sand, well graded, dense, angular to subrounded, equidimensional, grey, wet, heterogeneous, no cementation, no odour, no weathering, no foreign materials, max observed particle size = 55 mm. Fine fraction is near plastic limit, low plasticity and no dilatancy. [TILL] 4.6 m - Material grades to and sand, clayey, trace silt, very dense.
4				
5				
6				End of hole at 6.1 m.
				NOTES: 1. Auger hole terminated at 6.1 m of 5.0 m target depth. DCPT-BGC16-CHW-01 encountered refusal at 4.9 m. 2. Water table interpreted at 2.6 m from increase in moisture content. 3. Hole backfilled with cuttings and bentonite chips. 4. Soil relative density/consistency estimated from auger drill action and DCPT completed at the same coordinates as AH-BGC16-CHW-01 prior to auger drilling. 5. Soil structure interpreted from disturbed soil samples obtained from auger flights. 6. Auger hole coordinates obtained with Garmin GPSMAP 62s handheld GPS, accuracy +/- 3 m. Ground elevation based on LiDAR (McElhanney, April 2014).
7				
8				

Su - kPa: 40, 80, 120, 160
VANE PEAK ◆ REMOLD ◇ FIELD ◆ LAB ■ □ ★ % Fines
Moisture Content: W_P% × 20 — W% ○ 40 — 60 — W_L% × 80

KINDER MORGAN (AUGER_FIGURE) KINDERMORGAN_AUGER.GDL BGC.GDT 4/13/17

DRILL HOLE # SD-BGC17-KLP-04

Reference Number: KP 0841.25
Location: Kamloops Airport, BC

Project No.: 0095-150-16

Survey Method: Handheld GPS
Co-ordinates (m): 681,529E, 5,620,694N
Ground Elevation (m): 344.1
Datum: NAD83 UTM ZONE 10U
Dip (degrees from horizontal): 90
Direction: N/A

Drill Designation: Compact Roto Sonic
Drilling Contractor: Downrite Drilling
Drill Method: Sonic
Fluid: Water
Casing: 5.75" Matrix Thread **Cased To (m)**: 10.7
Depth To Rock (m): N/A
Depth To Water (m): N/A

Start Date: 27 Nov 17
Finish Date: 27 Nov 17
Final Depth of Hole (m): 10.7
Logged by: VPC
Reviewed by: LDM
Approved by: AB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
0					ORGANICS, clayey, dark brown, very soft [TOPSOIL]
					SAND (SM) Fine to medium, and silt to silty, trace clay, well-graded, compact, equidimensional to flat, subrounded to subangular, grey, dry to wet, laminated, maximum particle size 1 mm, fines are low plasticity, medium to rapid dilatancy, moderate orange weathering discoloration, trace decomposed organics [FLUVIAL]
1					0.45 - 1.5 m - Silt, some fine sand, some clay, dry, trace organics
					1.7 m - Transitions from 'and' silt to silty, moist
2					
3					2.75 - 3.05 m - Orange weathering discoloration becomes intense
4					3.7 m - Becomes grey, moist, laminated to stratified, decomposed organics as layers up to 10 mm
					4.6 m - Becomes wet
5		S1			S1 (4.8 - 5.0 m) Laboratory analysis results: 0% gravel, 51.8% sand, 43.2% silt, 5% clay, moisture content 39.5%. Fines classify as NP.
6					
7					
8					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

DRAFT

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,529E, 5,620,694N
Ground Elevation (m): 344.1
Datum: NAD83 UTM ZONE 10U
Dip (degrees from horizontal): 90
Direction: N/A

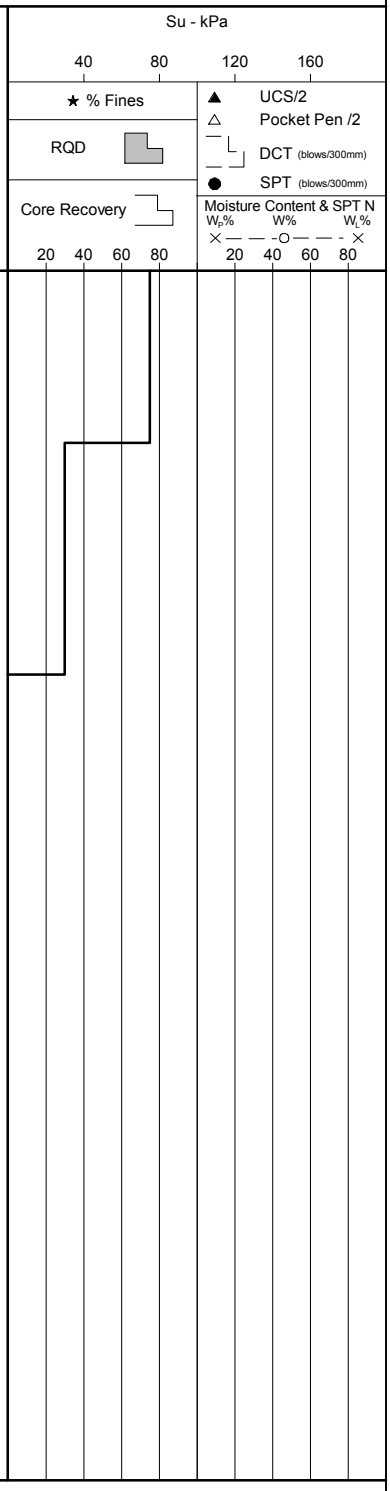
Drill Designation: Compact Roto Sonic
Drilling Contractor: Downrite Drilling
Drill Method: Sonic
Fluid: Water
Casing: 5.75" Matrix Thread **Cased To (m)**: 10.7
Depth To Rock (m): N/A
Depth To Water (m): N/A

Start Date: 27 Nov 17
Finish Date: 27 Nov 17
Final Depth of Hole (m): 10.7
Logged by: VPC
Reviewed by: LDM
Approved by: AB

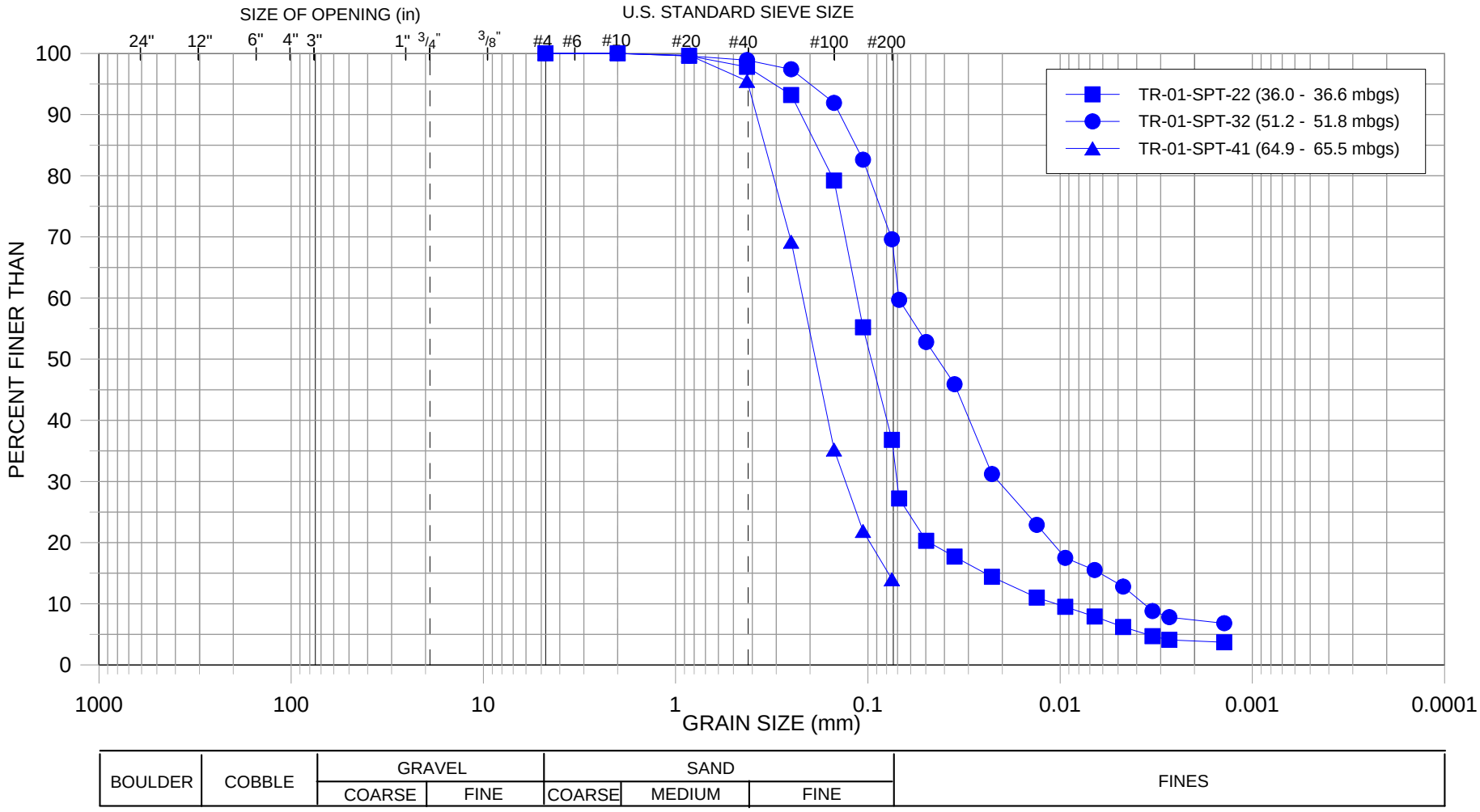
Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					9.1 m - Poor recovery due to granularity and saturation of soil, sample partially lost upon retrieval of core barrel	
10					End of Hole at 10.7 m.	

NOTES:
1. Sonic hole terminated at target depth.
2. The location of the water table was not measured during drilling as the sonic drilling method disturbs the natural moisture condition of the soil, and installation of casing prevents accurate measurement of the groundwater table.
3. Hole backfilled with drill cuttings and bentonite chips.
4. Soil structure and relative density/consistency assumed based on disturbed soil samples from sonic flights.
5. Sonic hole coordinates obtained with Garmin GPSMAP 62s handheld GPS, accuracy +/- 3 m. Ground elevation based on LiDAR (McElhanney, April 2014).

DRAFT



APPENDIX D
LABORATORY TEST RESULTS



NOTE:
1. Material classification plotted according to the Unified Soil Classification System (USCS).

SCALE:	NTS	DESIGNED:	SZ
DATE:	JUL 2018	CHECKED:	SAA
DRAWN:	SHA	APPROVED:	KSJ

DRAWING TO BE READ WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9 ", AND DATED JULY 2018.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: GRAIN SIZE ANALYSIS RESULTS - BH-BGC13-TR-01

PROJECT No.	DWG No.	REV.
0095-150	D-01	1

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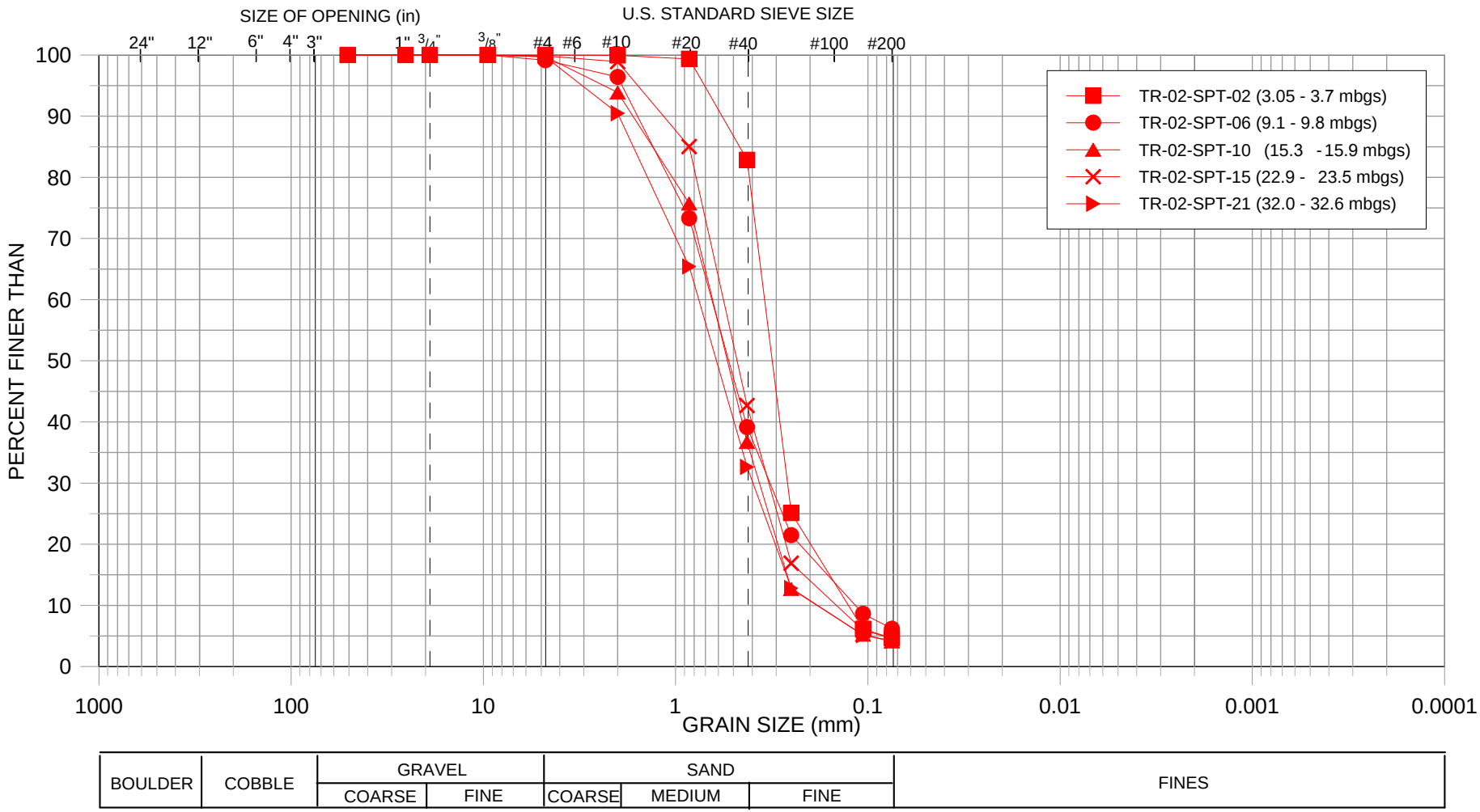

NOTE:
1.Material classification plotted according to the Unified Soil Classification System (USCS).

SCALE:	NTS	DESIGNED:	SZ
DATE:	JUL 2018	CHECKED:	SAA
DRAWN:	SHA	APPROVED:	KSJ

DRAWING TO BE READ WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9", AND DATED JULY 2018.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: GRAIN SIZE ANALYSIS RESULTS - BH-BGC14-TR-02

PROJECT No.	DWG No.	REV.
0095-150	D-02	1

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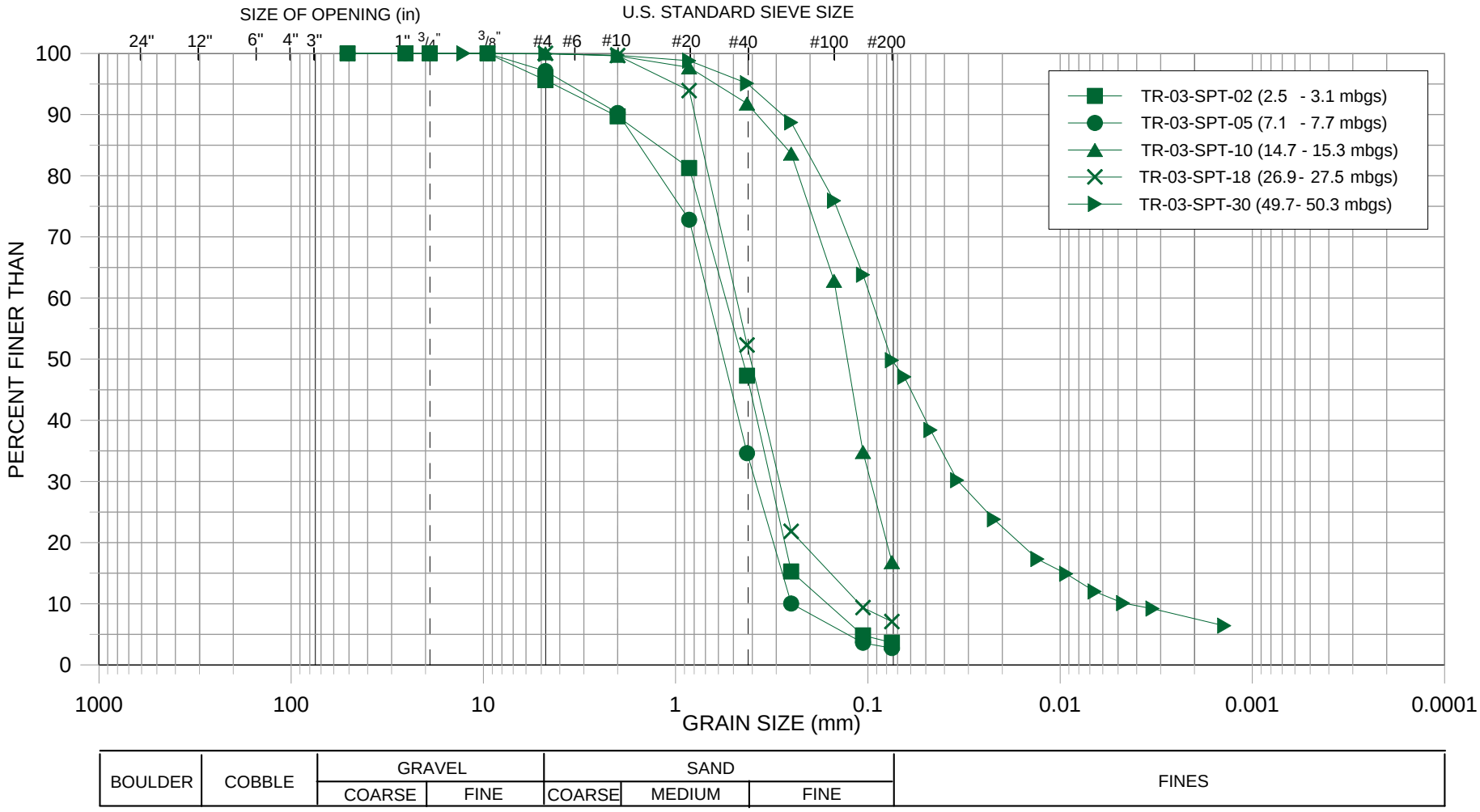

NOTE:
1. Material classification plotted according to the Unified Soil Classification System (USCS).

SCALE:	NTS	DESIGNED:	SZ
DATE:	JUL 2018	CHECKED:	SAA
DRAWN:	SHA	APPROVED:	KSJ

DRAWING TO BE READ WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9", AND DATED JULY 2018.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: GRAIN SIZE ANALYSIS RESULTS - BH-BGC14-TR-03

PROJECT No.	DWG No.	REV.
0095-150	D-03	1

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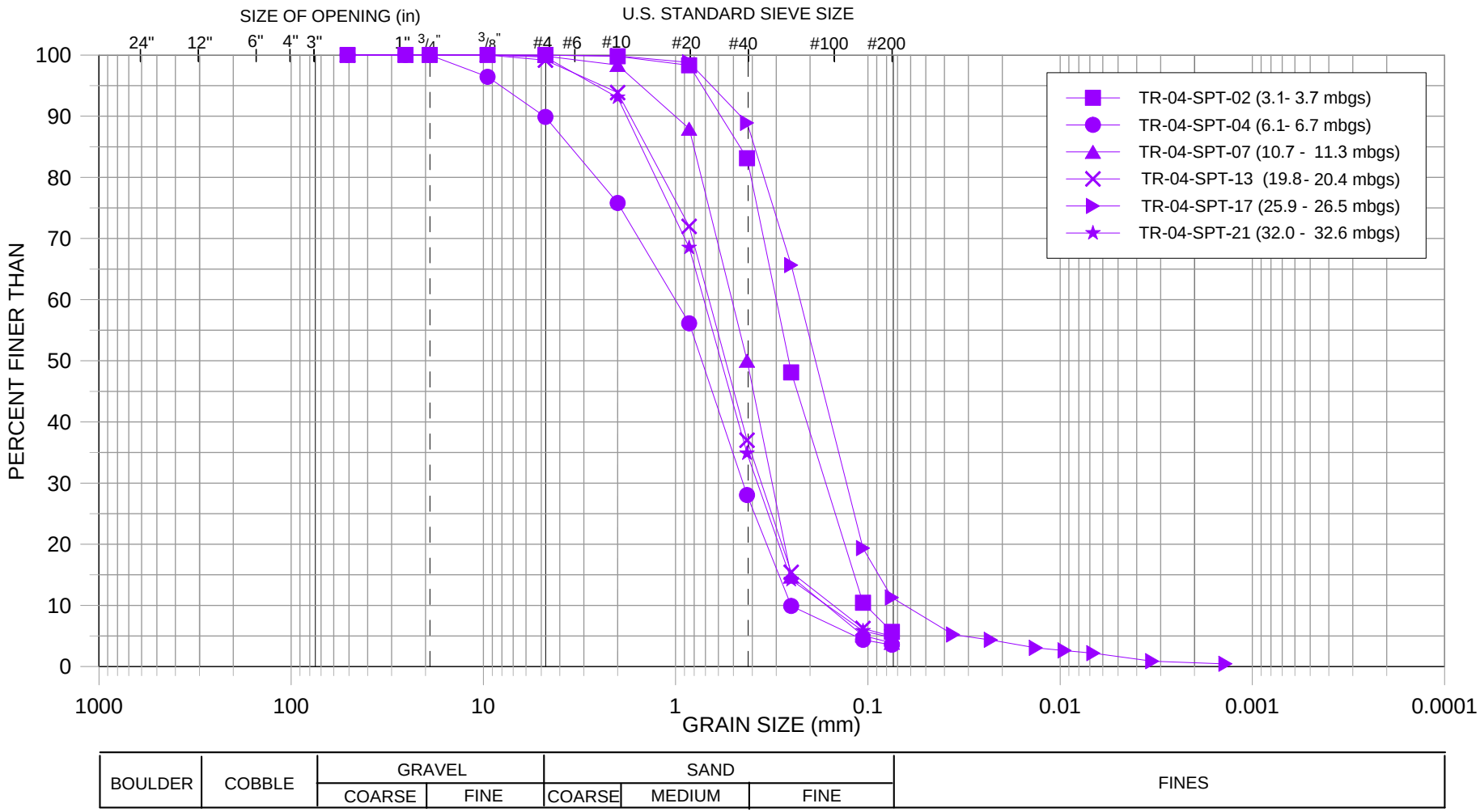


NOTE:
1. Material classification plotted according to the Unified Soil Classification System (USCS).

SCALE:	NTS	DESIGNED:	SZ
DATE:	JUL 2018	CHECKED:	SAA
DRAWN:	SHA	APPROVED:	KSJ

DRAWING TO BE READ WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9", AND DATED JULY 2018.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

TITLE: GRAIN SIZE ANALYSIS RESULTS - BH-BGC14-TR-04

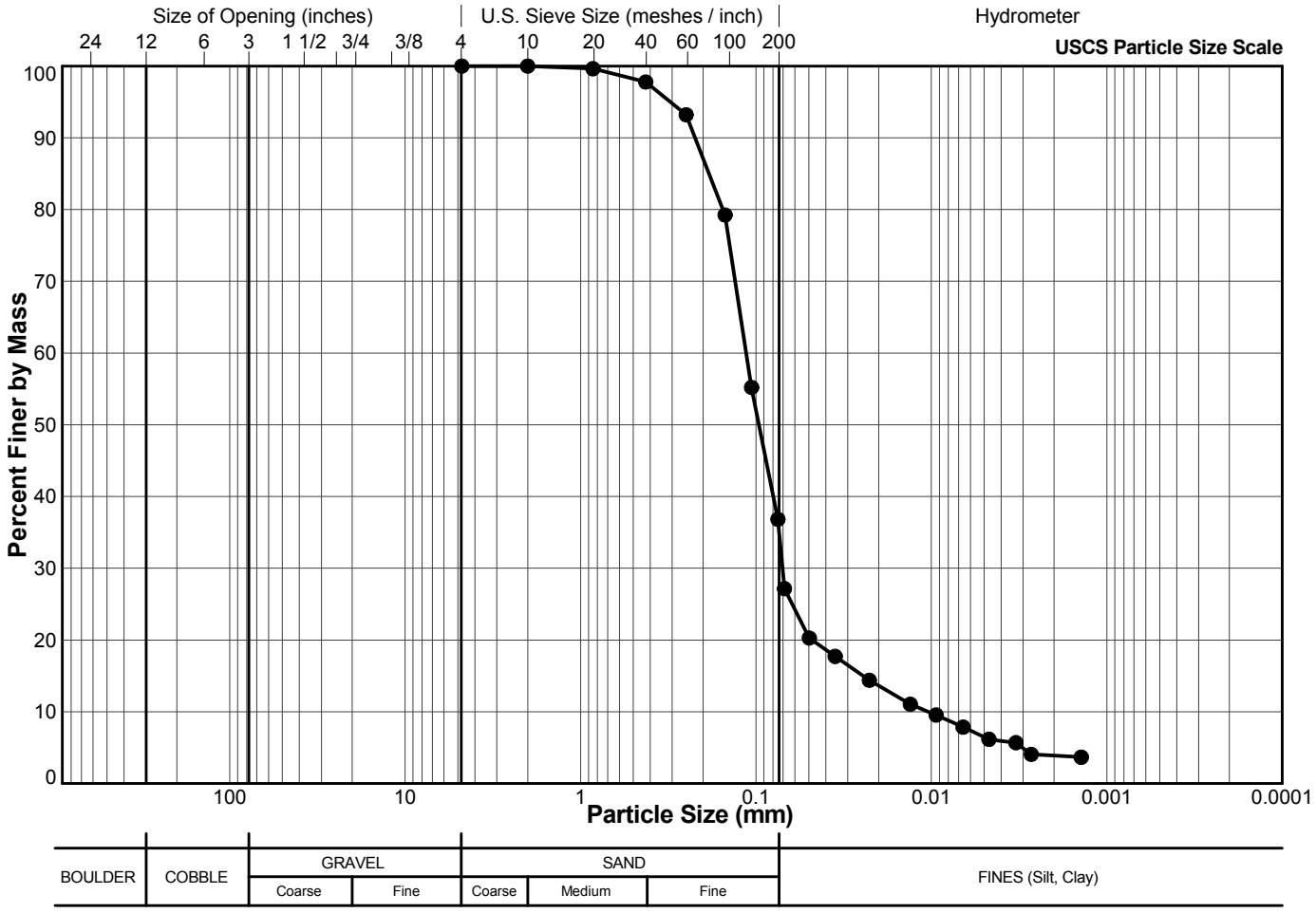
PROJECT No.	DWG No.	REV.
0095-150	D-04	1

N:\BGC\Projects\0095 Kinder Morgan\150 - TMEP Pipeline Project\04 HDD Assessment\lab data\Thompson River\GSA_01.29.2014_GR10_TR.grf

FIGURE 1: SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	BGC Engineering	**Sample Location:**	BH-BGC13-TR-1
Project:	BGC / Proj 0095-150-04 / TMEP	**Sample No.:**	SPT22
Location:	TMEP	**Depth Interval (m):**	35.97 to 36.58
Project No.:	13-1415-0029 **Phase:** 16000	**Lab Schedule No.:**	265



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
#4 US MESH	4.75		100.0
#10 US MESH	2		100.0
#20 US MESH	0.85		99.6
#40 US MESH	0.425		97.8
#60 US MESH	0.25		93.2
#100 US MESH	0.15		79.2
#140 US MESH	0.106		55.2
#200 US MESH	0.075		36.8
		0.0688	27.2
		0.0497	20.3
		0.0354	17.7
		0.0226	14.4
		0.0132	11.0
		0.0094	9.5
		0.0066	7.9
		0.0047	6.2
		0.0033	5.7
		0.0027	4.1
		0.0014	3.7

	OA	**12/4/2013**	**LP**	**12/18/2013**
	Tech	Date	Checked	Date

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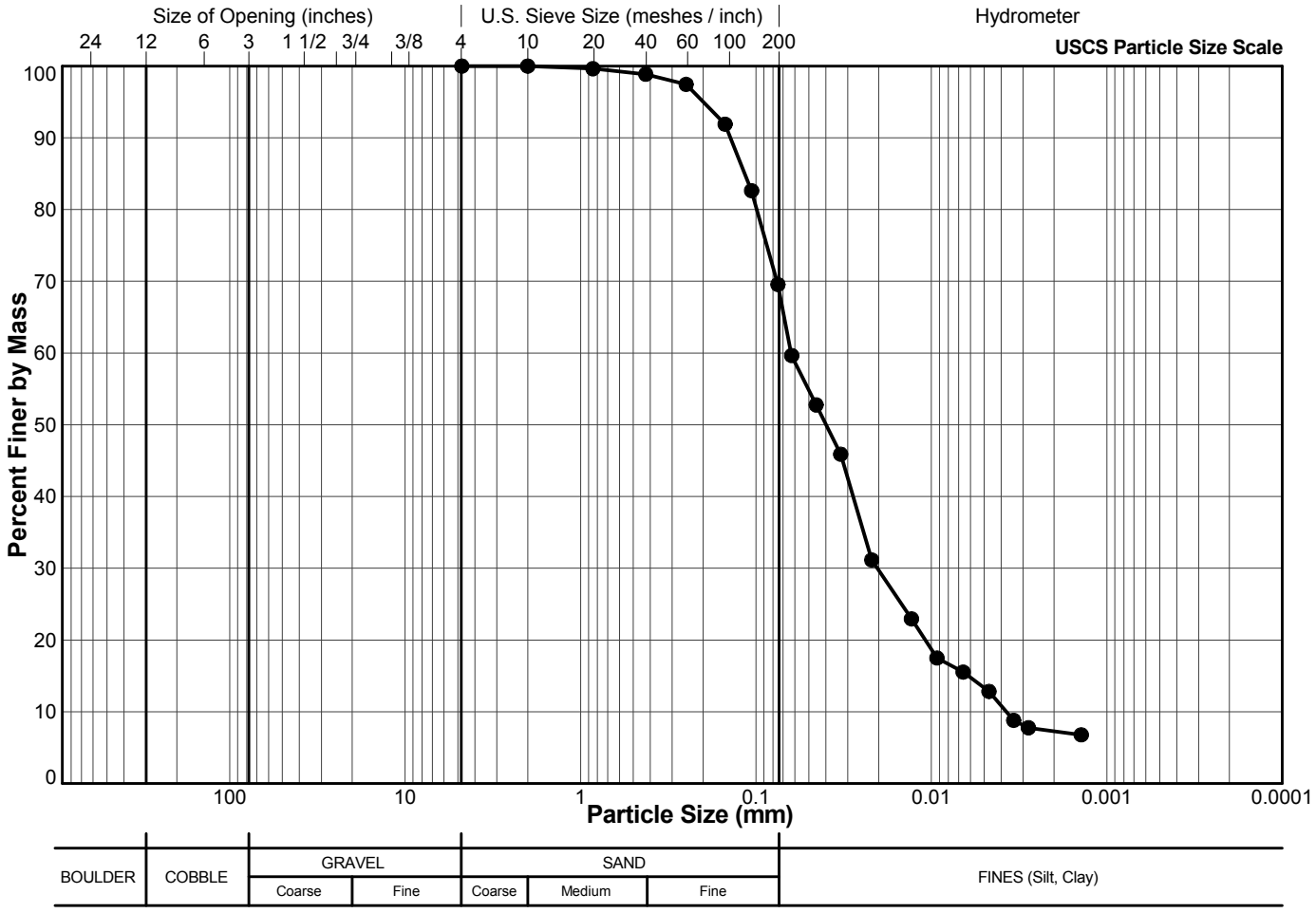
FIGURE 1: SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	BGC Engineering	**Sample Location:**	BH-BGC13-TR-1
Project:	BGC / Proj 0095-150-04 / TMEP	**Sample No.:**	SPT32
Location:	TMEP	**Depth Interval (m):**	51.21 to 51.82
Project No.:	13-1415-0029 **Phase:** 16000	**Lab Schedule No.:**	265



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
#4 US MESH	4.75		100.0
#10 US MESH	2		100.0
#20 US MESH	0.85		99.6
#40 US MESH	0.425		98.9
#60 US MESH	0.25		97.4
#100 US MESH	0.15		91.9
#140 US MESH	0.106		82.6
#200 US MESH	0.075		69.6
		0.0626	59.7
		0.0454	52.8
		0.0329	45.9
		0.0219	31.2
		0.0130	22.9
		0.0093	17.5
		0.0066	15.5
		0.0047	12.8
		0.0034	8.8
		0.0028	7.8
		0.0014	6.8

	OA	12/4/2013	LP	12/18/2013	
	Tech	Date	Checked	Date	

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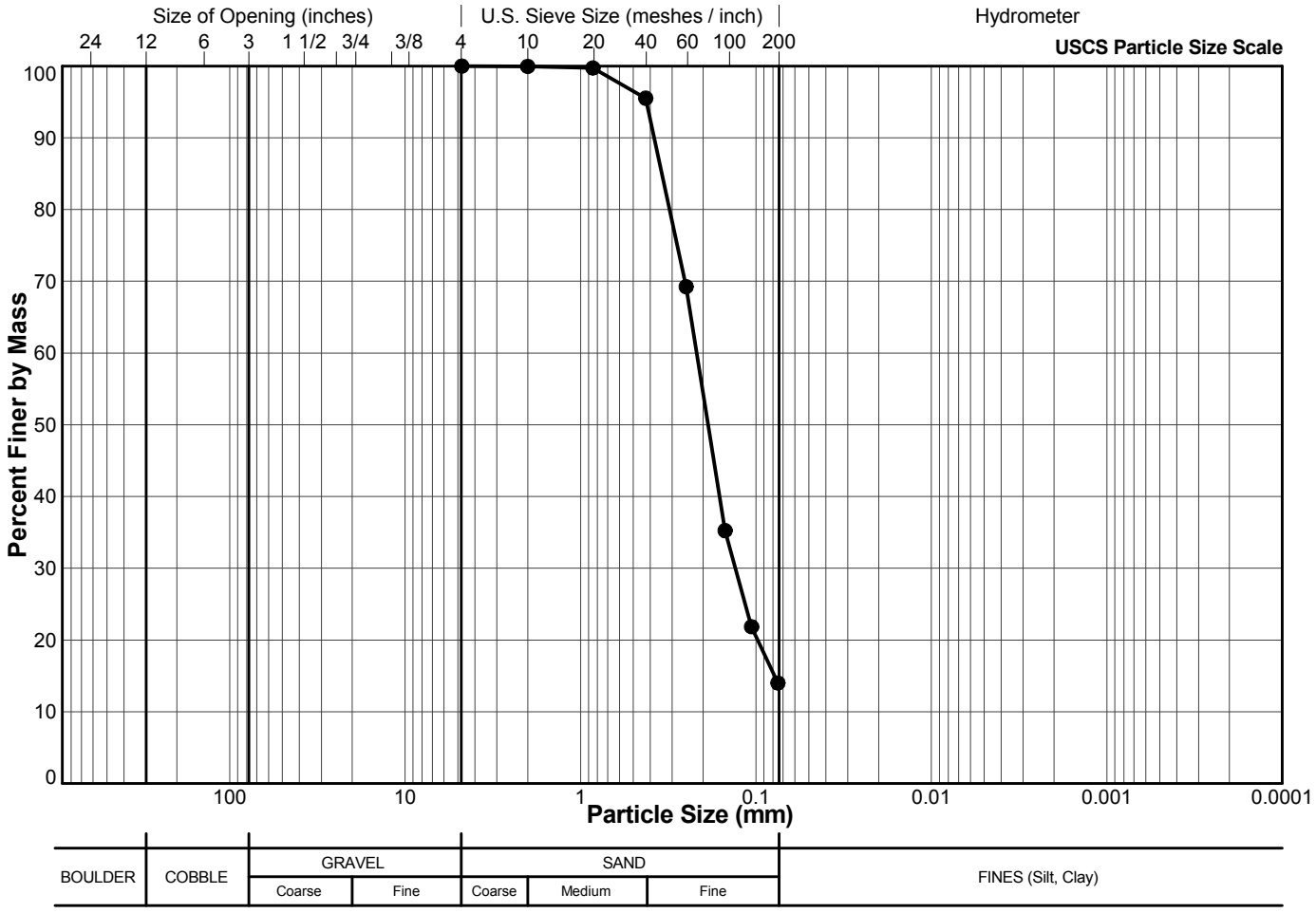
FIGURE 1: SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	BGC Engineering	**Sample Location:**	BH-BGC13-TR-1
Project:	BGC / Proj 0095-150-04 / TMEP	**Sample No.:**	SPT41
Location:	TMEP	**Depth Interval (m):**	64.92 to 65.53
Project No.:	13-1415-0029 **Phase:** 16000	**Lab Schedule No.:**	265



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
#4 US MESH	4.75		100.0
#10 US MESH	2		100.0
#20 US MESH	0.85		99.7
#40 US MESH	0.425		95.5
#60 US MESH	0.25		69.2
#100 US MESH	0.15		35.2
#140 US MESH	0.106		21.9
#200 US MESH	0.075		14.0

	OA	**12/4/2013**	**LP**	**12/18/2013**
	Tech	Date	Checked	Date

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WATER CONTENT DETERMINATION

Reference(s)
ASTM D 4959

Client:	BGC Engineering	**Project No.:** 13-1415-0029 **Phase:** 16000	
Project:	BGC / Proj 0095-150-04 / TMEP	**Lab Schedule No.:** 265	
Location:	TMEP		

Sample Location	Sample No.	Sample Interval		Water Content (%)
		Depth (m)	Bottom (m)	
BH-BGC13-FN-01	**SPT06**	8.53	9.14	**25.0**
BH-BGC13-FN-02	**SPT04**	5.48	6.10	**13.0**
BH-BGC13-FN-02	**SPT10**	14.02	14.65	**15.9**
BH-BGC13-NTC-01	**SPT07**	10.06	10.67	**34.6**
BH-BGC13-RFT-02	**SPT13**	19.20	19.81	**31.9**
BH-BGC13-TR-1	**SPT22**	35.97	36.58	**39.6**
BH-BGC13-TR-1	**SPT32**	51.21	51.82	**46.8**
BH-BGC13-TR-1	**SPT41**	64.92	65.53	**28.3**

	LP	12/18/2013
	Checked	Date

File:GINT_GAL_NATIONALIM Output Form:_LAB_WATER CONTENT (REPORT) Template:LOCALHOST: GINT_GAL_TEMPLATE_DEV Library:_GAL LIBRARY.GLB MMiller 12/19/13

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Specific Gravity of Soil Solids By Water Pycnometer

Reference: ASTM D854 -10

Project No.:	13-1415-0029 Phase 16000	**Borehole**	**BH-BGC13-TR-1**
Project:	BGC / PROJ 0095-150-04 / TMEP	**Depth (m)**	35.97-36.58
Location:	TMEP	**Sample Number:**	SPT 22
Client:	BGC Engineering	**Lab ID No:**	265

Visual Description:	**% Passing 4.75µm**	100.00
Silty SAND, brown.	**Excluded Material Description**	No excluded material

Specific Gravity of Fine Fraction Method B - Oven Dried Samples

		Trial 1	Trial 2
Flask Number		4	F
Air Removal Method	M_p	Vacuum	Vacuum
Mass of Flask (g)		172.68	169.33
Mass of Flask + Dry Soil (g)		253.02	249.08
Mass of Flask + Soil + Water (g)	$M_{\rho ws,t}$	721.9	717.98
Test Temperature (°C)	T_t	20	20.7
Mass of Flask + Water (g)	$M_{\rho w,t}$	671.09	667.66
Tare Number		5	M-6
Mass of Tare (g)		203.08	292.43
Mass of Tare + Dry Soil (g)		122.73	213.07
Mass of Oven Dry Soil (g)	M_S	80.35	79.36
Temperature Coefficient	K	1.00	1.00
Specific Gravity at Test Temperature	G_t	2.72	2.73
Specific Gravity at 20ºC	$G_{20ºC}$	2.72	2.73

AVERAGE SPECIFIC GRAVITY OF TRIALS	2.73

Specific Gravity of Coarse Fraction (ASTM C 127-07)

Percentage Retained on 4.75µm		
Mass of Sample in Water (g)		
Mass of Sample @ SSD (g)		
Mass of Oven Dry Sample (g)		
Bulk G (Oven Dry)	G_{OD}	
Bulk G (SSD)	G_{SSD}	
Apparent	G	
Absorption (%)	A	
Corrected Specific Gravity to 20°C	$G_{20ºC}$	

COMBINED SPECIFIC GRAVITY	$G_{avg\ @20ºC}$	

OA/MM	December 18, 2013	LP	December 18, 2013
TESTED BY	DATE	CHECKED BY	DATE

O:\Active_2013\1415\13-1415-0029 BGC Various Lab Testing\PHASE 16000 - TMEP Sch-265\WORKING FILES\SG\

** The test data given herein pertain to the sample provided only. This report constitutes a testing service only. Interpretation of the data can be provided upon request.*

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Specific Gravity of Soil Solids By Water Pycnometer

Reference: ASTM D854 -10

Project No.:	13-1415-0029 Phase 16000	**Borehole**	**BH-BGC-TR-1**
Project:	BGC / PROJ 0095-150-04 / TMEP	**Depth (m)**	51.21-51.82
Location:	TMEP	**Sample Number:**	SPT 32
Client:	BGC Engineering	**Lab ID No:**	265

Visual Description:	**% Passing 4.75µm**	100.00
Sandy SILT, drak grey/brown	**Excluded Material Description**	No excluded material

Specific Gravity of Fine Fraction Method B - Oven Dried Samples

		Trial 1	Trial 2
Flask Number		5	4
Air Removal Method	M_p	Vacuum	Vacuum
Mass of Flask (g)		174.78	172.68
Mass of Flask + Dry Soil (g)		254.57	251.83
Mass of Flask + Soil + Water (g)	$M_{\rho ws,t}$	723.63	720.51
Test Temperature (°C)	T_t	19.9	20.8
Mass of Flask + Water (g)	$M_{\rho w,t}$	673.12	671.10
Tare Number		m-6	#5
Mass of Tare (g)		292.83	201.26
Mass of Tare + Dry Soil (g)		213.1	122.63
Mass of Oven Dry Soil (g)	M_S	79.73	78.63
Temperature Coefficient	K	1.00	1.00
Specific Gravity at Test Temperature	G_t	2.73	2.69
Specific Gravity at 20ºC	$G_{20ºC}$	2.73	2.69

AVERAGE SPECIFIC GRAVITY OF TRIALS	2.71

Specific Gravity of Coarse Fraction (ASTM C 127-07)

Percentage Retained on 4.75µm		
Mass of Sample in Water (g)		
Mass of Sample @ SSD (g)		
Mass of Oven Dry Sample (g)		
Bulk G (Oven Dry)	G_{OD}	
Bulk G (SSD)	G_{SSD}	
Apparent	G	
Absorption (%)	A	
Corrected Specific Gravity to 20°C	$G_{20ºC}$	

COMBINED SPECIFIC GRAVITY	$G_{avg\ @20ºC}$	

OA/MM	December 18, 2013	LP	December 18, 2013
TESTED BY	DATE	CHECKED BY	DATE

O:\Active_2013\1415\13-1415-0029 BGC Various Lab Testing\PHASE 16000 - TMEP Sch-265\WORKING FILES\SG\

** The test data given herein pertain to the sample provided only. This report constitutes a testing service only. Interpretation of the data can be provided upon request.*

Golder Associates Ltd. - Burnaby Lab
#300 - 3811 North Fraser Way
Burnaby, B.C. Canada V5J 5J2

Specific Gravity of Soil Solids By Water Pycnometer

Reference: ASTM D854 -10

Project No.:	13-1415-0029 Phase 16000	**Borehole**	**BH-BGC13-TR-1**
Project:	BGC / PROJ 0095-150-04 / TMEP	**Depth (m)**	64.92-65.53
Location:	TMEP	**Sample Number:**	SPT 41
Client:	BGC Engineering	**Lab ID No:**	265

Visual Description:	**% Passing 4.75µm**	100.00
Fine to medium SAND with some silt, light brown.	**Excluded Material Description**	No excluded material

Specific Gravity of Fine Fraction Method B - Oven Dried Samples

		Trial 1	Trial 2
Flask Number		C	3
Air Removal Method	M_p	Vacuum	Vacuum
Mass of Flask (g)		167.95	173.85
Mass of Flask + Dry Soil (g)		267.66	272.93
Mass of Flask + Soil + Water (g)	$M_{\rho ws,t}$	728.78	735.52
Test Temperature (°C)	T_t	20	20.7
Mass of Flask + Water (g)	$M_{\rho w,t}$	666.04	672.20
Tare Number		M-7	G-2
Mass of Tare (g)		312.66	292.86
Mass of Tare + Dry Soil (g)		212.9	193.05
Mass of Oven Dry Soil (g)	M_S	99.76	99.81
Temperature Coefficient	K	1.00	1.00
Specific Gravity at Test Temperature	G_t	2.69	2.74
Specific Gravity at 20ºC	$G_{20ºC}$	2.69	2.73

AVERAGE SPECIFIC GRAVITY OF TRIALS	2.71

Specific Gravity of Coarse Fraction (ASTM C 127-07)

Percentage Retained on 4.75µm		
Mass of Sample in Water (g)		
Mass of Sample @ SSD (g)		
Mass of Oven Dry Sample (g)		
Bulk G (Oven Dry)	G_{OD}	
Bulk G (SSD)	G_{SSD}	
Apparent	G	
Absorption (%)	A	
Corrected Specific Gravity to 20°C	$G_{20ºC}$	

COMBINED SPECIFIC GRAVITY	$G_{avg\ @20ºC}$	

OA/MM	December 18, 2013	LP	December 18, 2013
TESTED BY	DATE	CHECKED BY	DATE

O:\Active_2013\1415\13-1415-0029 BGC Various Lab Testing\PHASE 16000 - TMEP Sch-265\WORKING FILES\SG\

** The test data given herein pertain to the sample provided only. This report constitutes a testing service only. Interpretation of the data can be provided upon request.*

BH ID	Sample ID	Water Content (%)
BH-BGC14-YAR-01	SPT-03	22.3
	SPT-04	25.8
	SPT-07A	35.9
	SPT-07B	34.3
	SPT-10	30.6
	SPT-14	34.2
	SPT-17	32.0
	SPT-19	35.1
	G1	24.1
	G2	43.8
BH-BGC14-VR-05-AH	#3	35.5
	#6	21.3
	#7	16.5
	#8	10.9
BH-BGC14-COQ-02	SPT-02	15.9
	SPT-04	18.9
	SPT-12	8.9

BH ID	Sample ID	Water Content (%)
BH-BGC14-TR-02	SPT-02	27.4
	SPT-06	26.3
	SPT-10	23.0
	SPT-15	22.0
	SPT-21	20.6
BH-BGC14-TR-03	SPT-02	21.9
	SPT-05	19.8
	SPT-18	22.2
BH-BGC14-TR-04	SPT-02	27.0
	SPT-04	22.3
	SPT-07	25.9
	SPT-13	20.9
	SPT-17	39.2
	SPT-21	19.9
BH-BGC14-MO-02	G2	13.6

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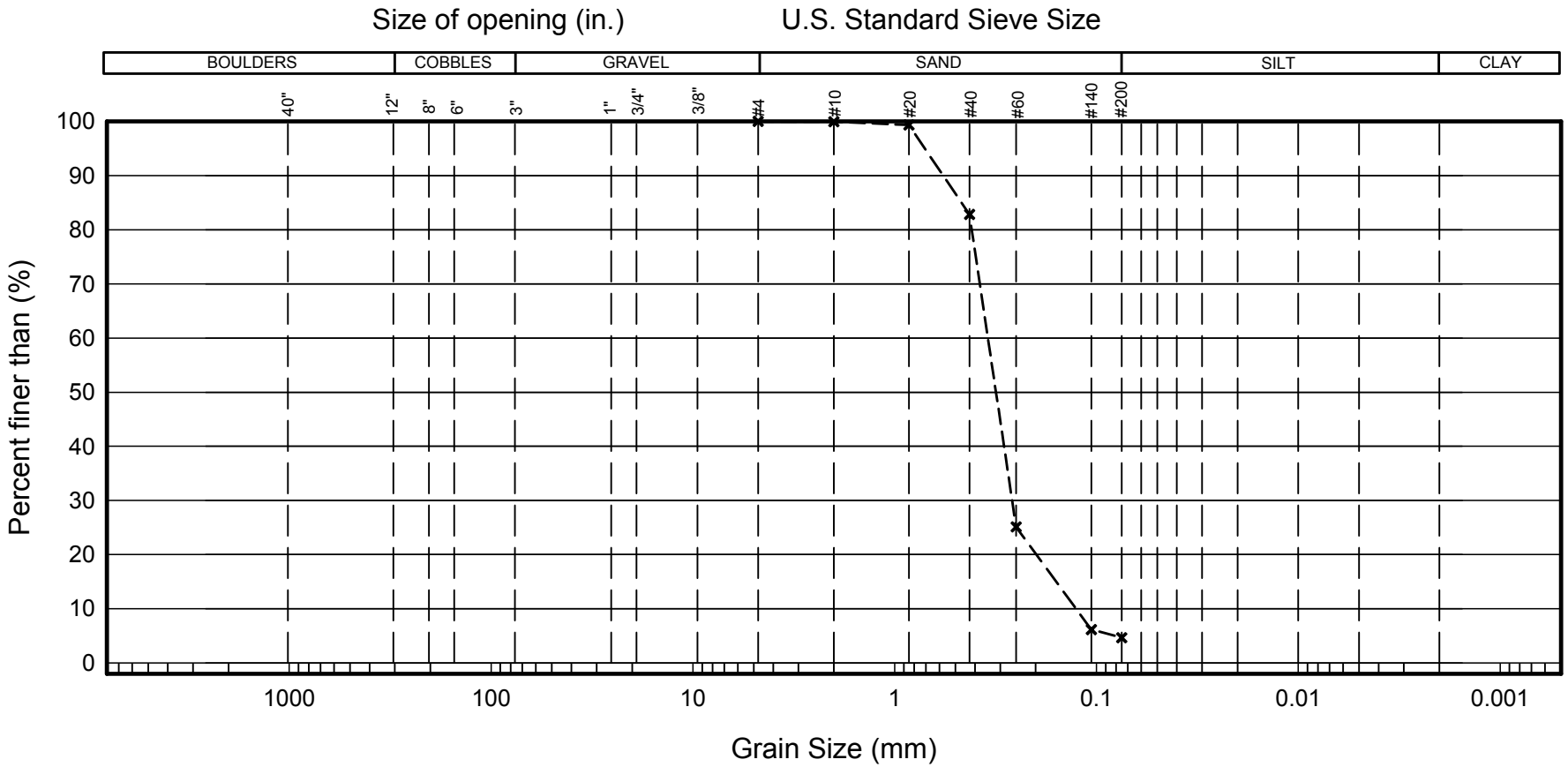

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-02 - Sample: SPT-02 - Depth 3.05 to 3.66m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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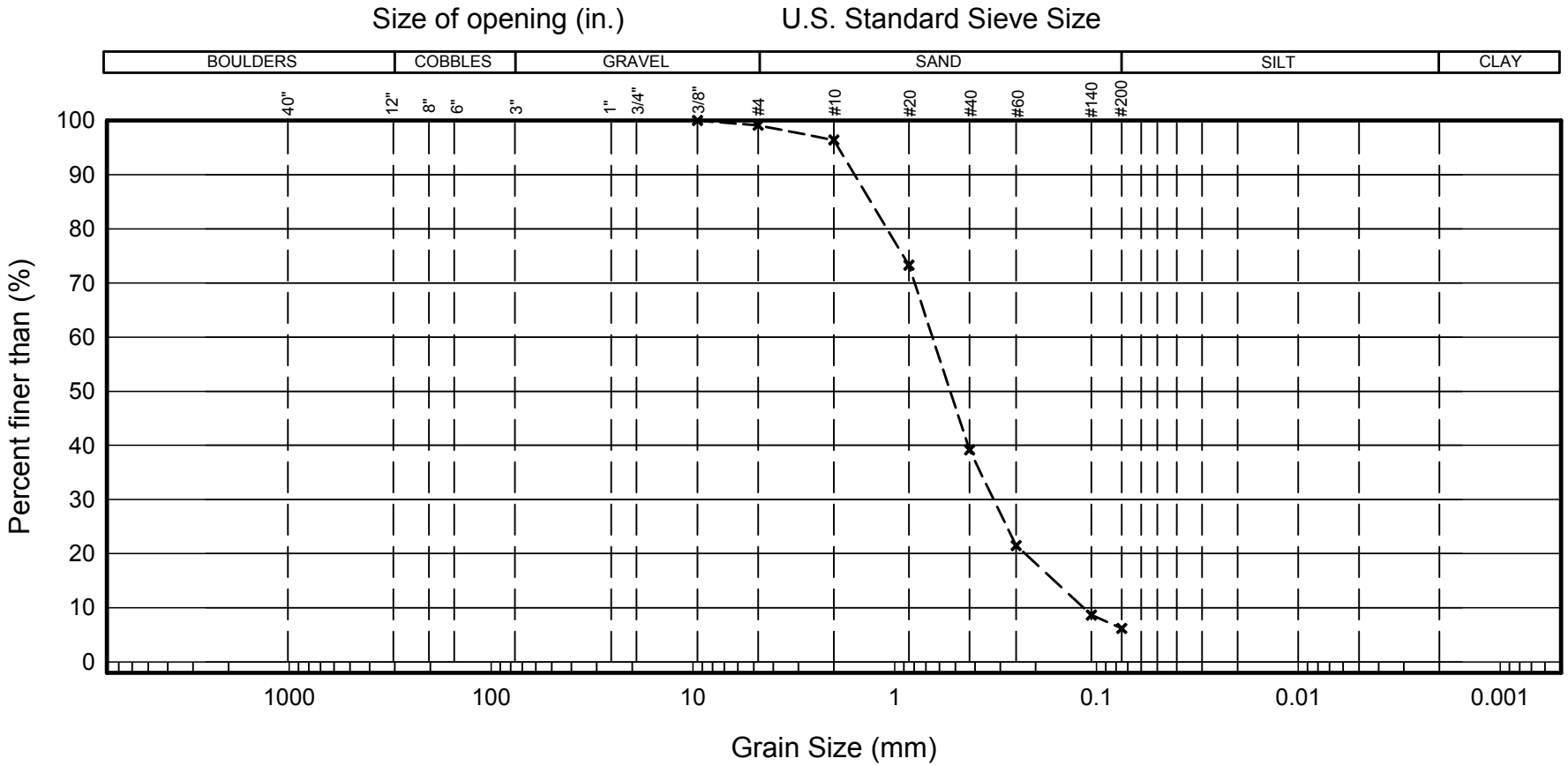

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-02 - Sample: SPT-06 - Depth 9.14 to 9.75m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

BGC ENGINEERING INC.
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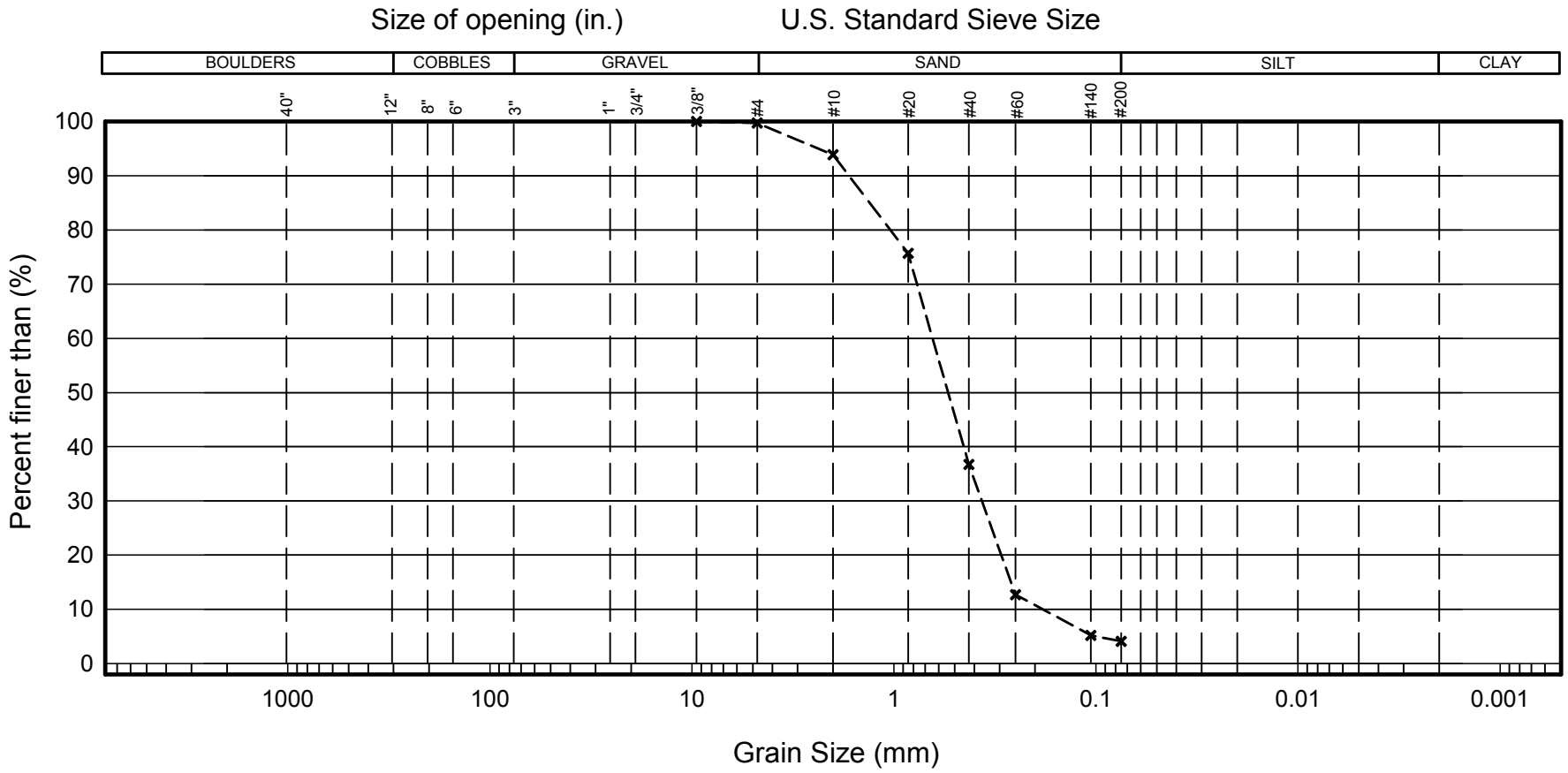

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-02 - Sample: SPT-10 - Depth 15.24 to 15.85m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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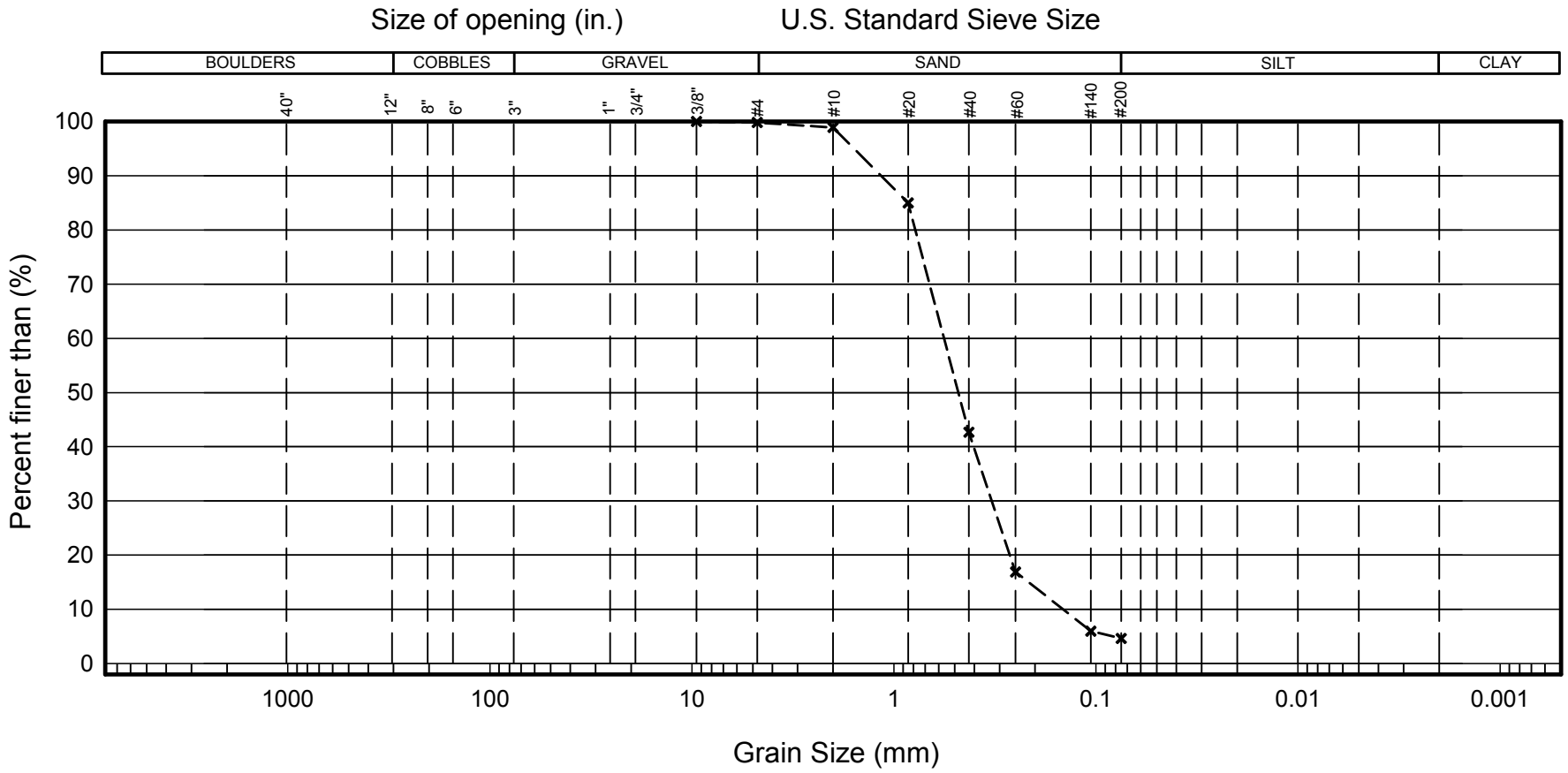


NOTES:

1. Lab analysis completed by DO, reviewed by SD.

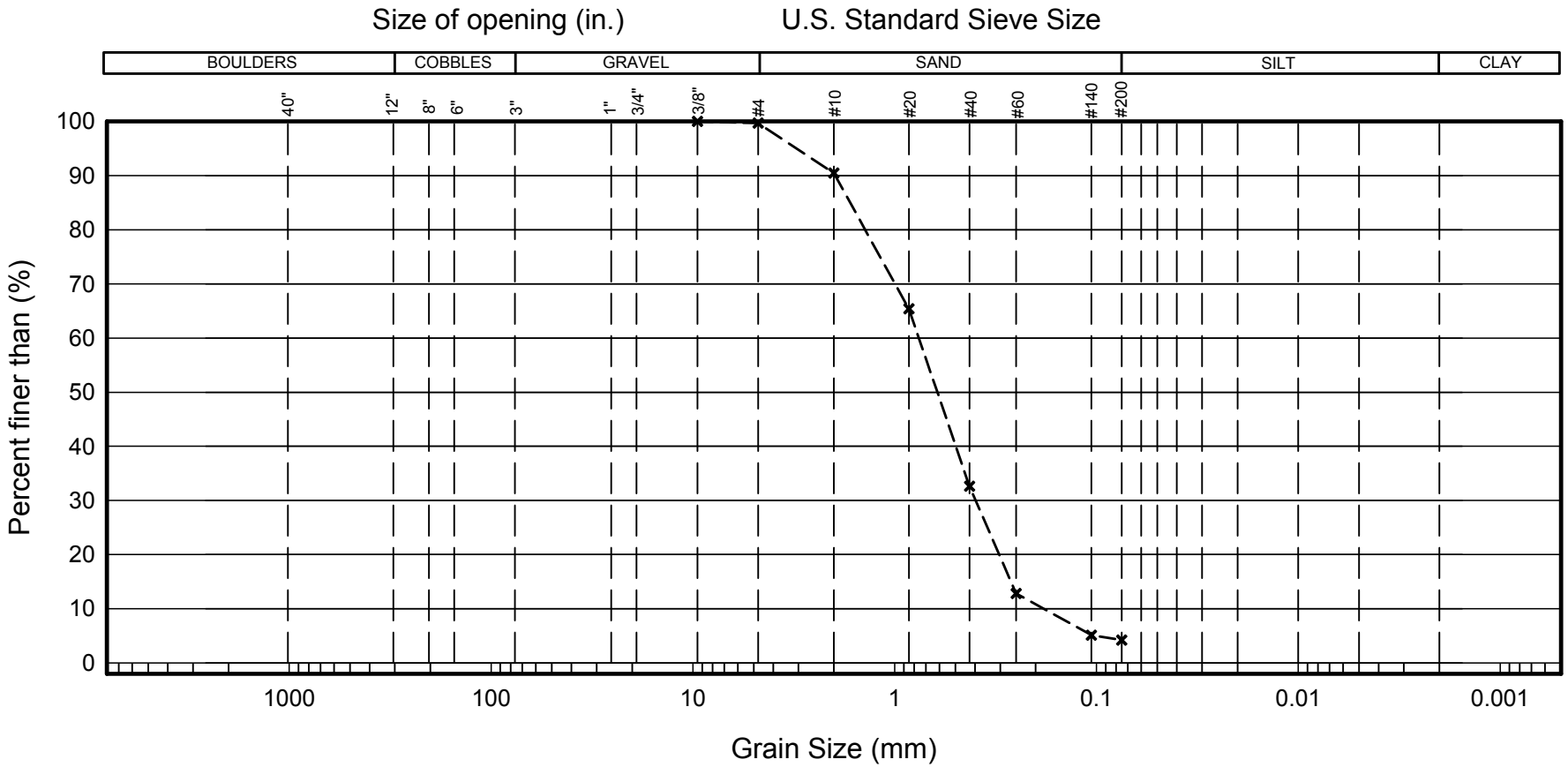
GRAIN SIZE ANALYSIS

BH-BGC14-TR-02 - Sample: SPT-15 - Depth 22.86 to 23.47m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY



NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-02 - Sample: SPT-21 - Depth 28.96 to 29.57m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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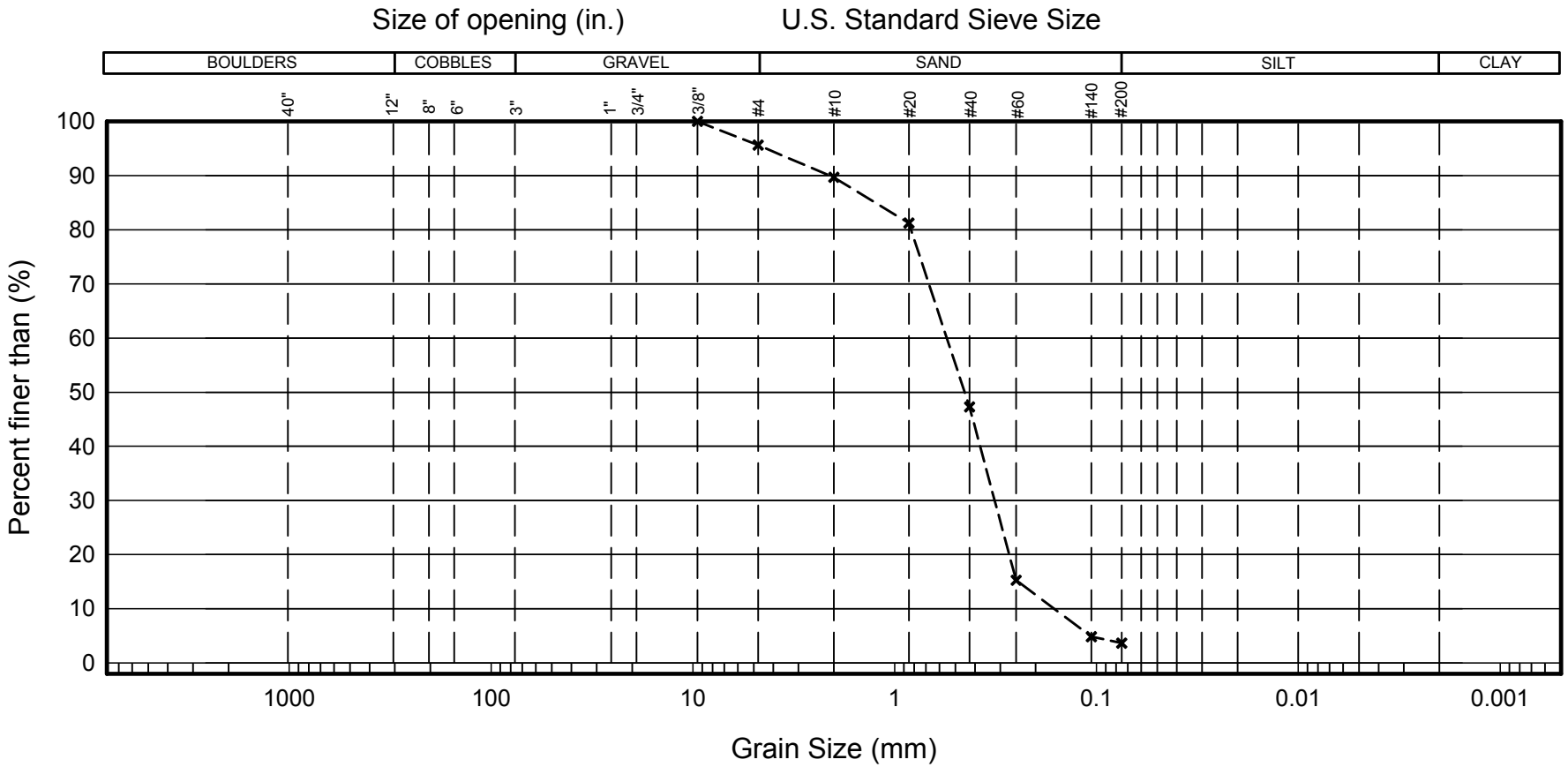

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-03 - Sample: SPT-02 - Depth 2.49 to 3.10m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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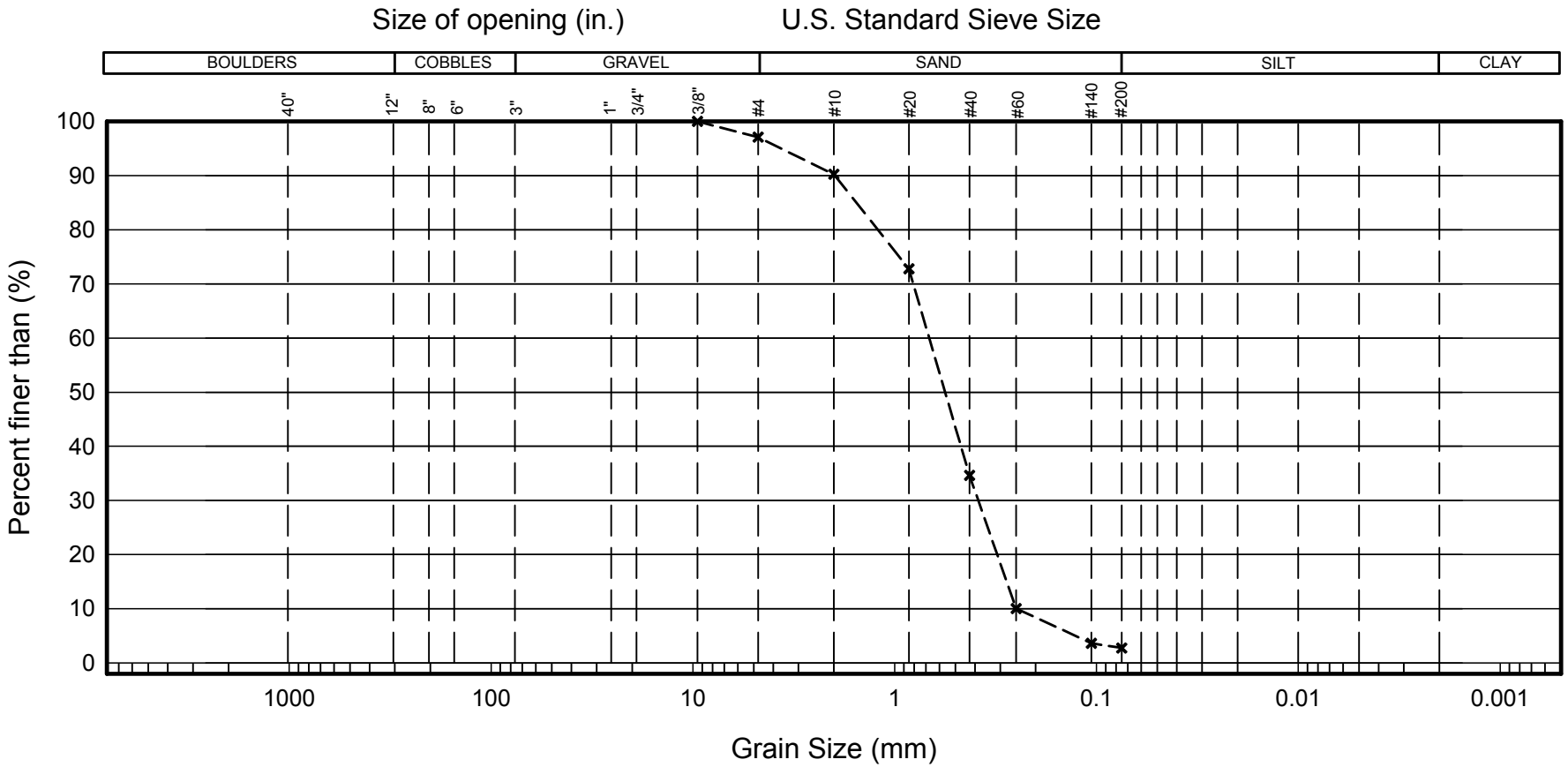


NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-03 - Sample: SPT-05 - Depth 7.06 to 7.67m

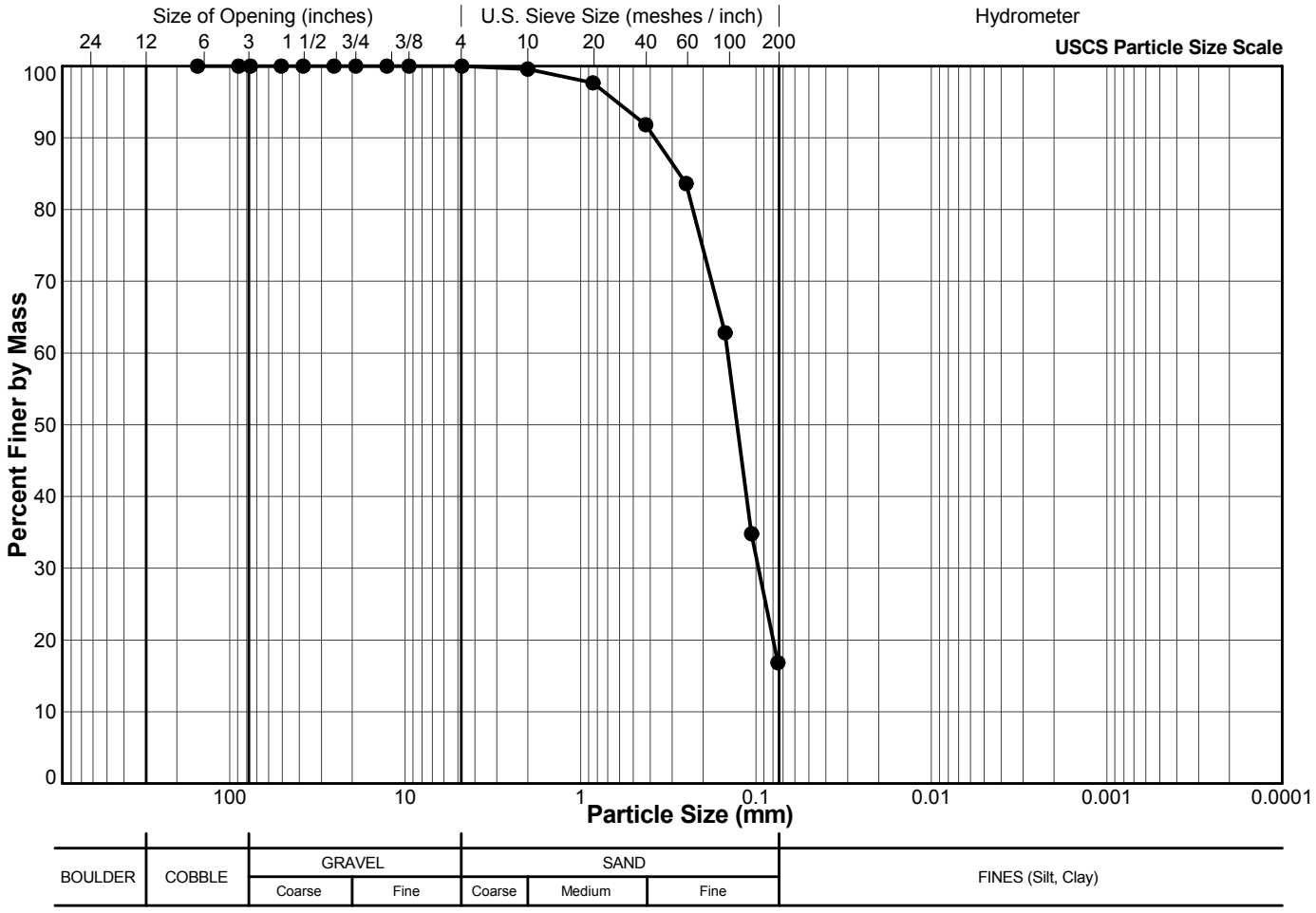
BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136, C117

Client:	BGC Engineering Inc.	**Sample Location:**	BH-BGC14-TR-03
Project:	Trans Mountain Expansion / Ref # 0095-150-14	**Sample No.:**	SPT 10
Location:	N/A	**Depth Interval (m):**	14.68 to 15.29
Project No.:	1408883 **Phase:** 2000	**Lab Schedule No.:**	449



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		100.0
#10 US MESH	2		99.6
#20 US MESH	0.85		97.7
#40 US MESH	0.425		91.8
#60 US MESH	0.25		83.6
#100 US MESH	0.15		62.8
#140 US MESH	0.106		34.8
#200 US MESH	0.075		16.8

	SJ	**12/18/2014**	**DN**	**12/23/2014**
	Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:648 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 12/23/14

Golder Associates Ltd.
300-3811 North Fraser Way Burnaby, British Columbia Canada V5J 5J2
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Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

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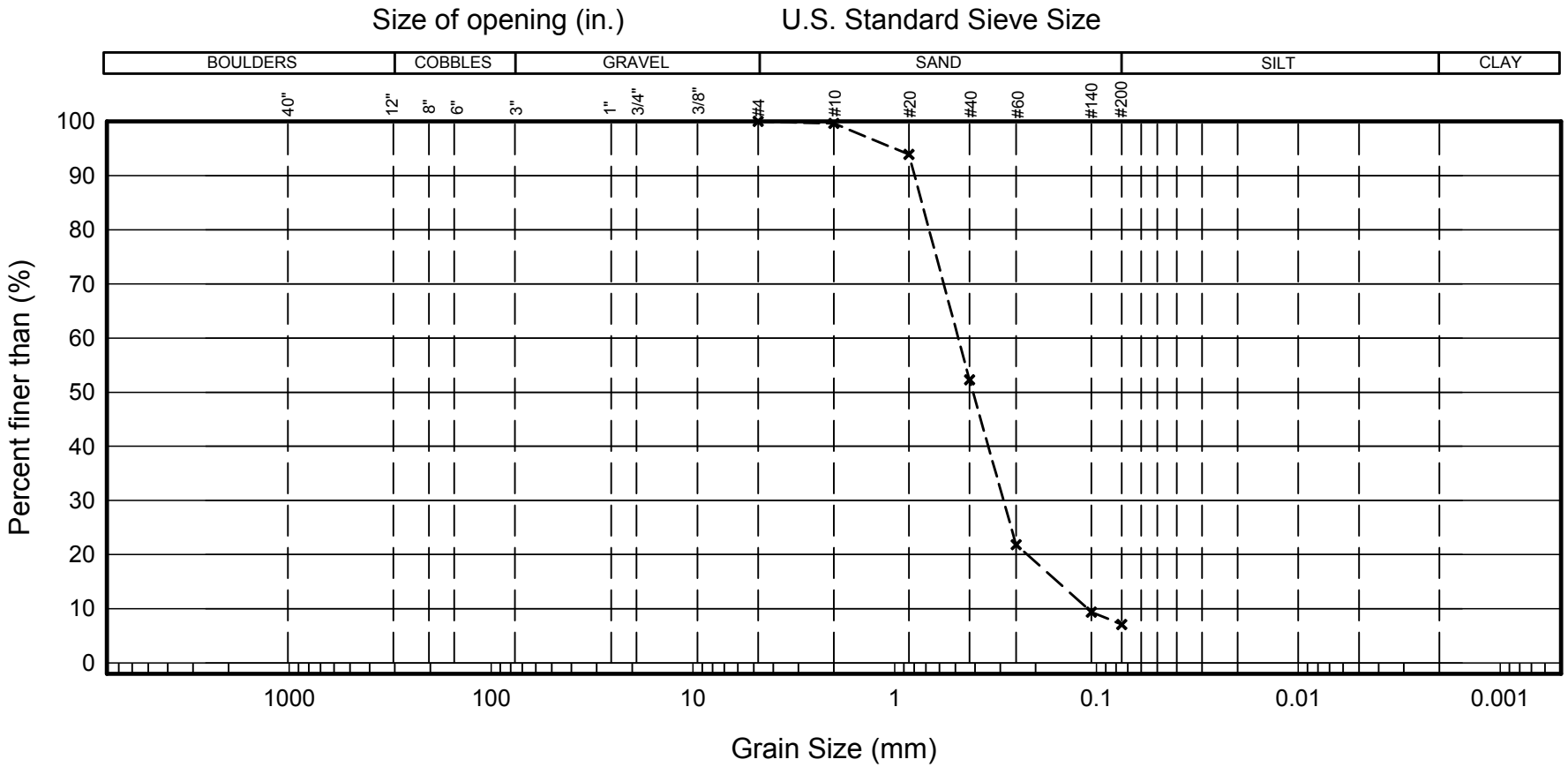


NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-03 - Sample: SPT-18 - Depth 26.87 to 27.48m

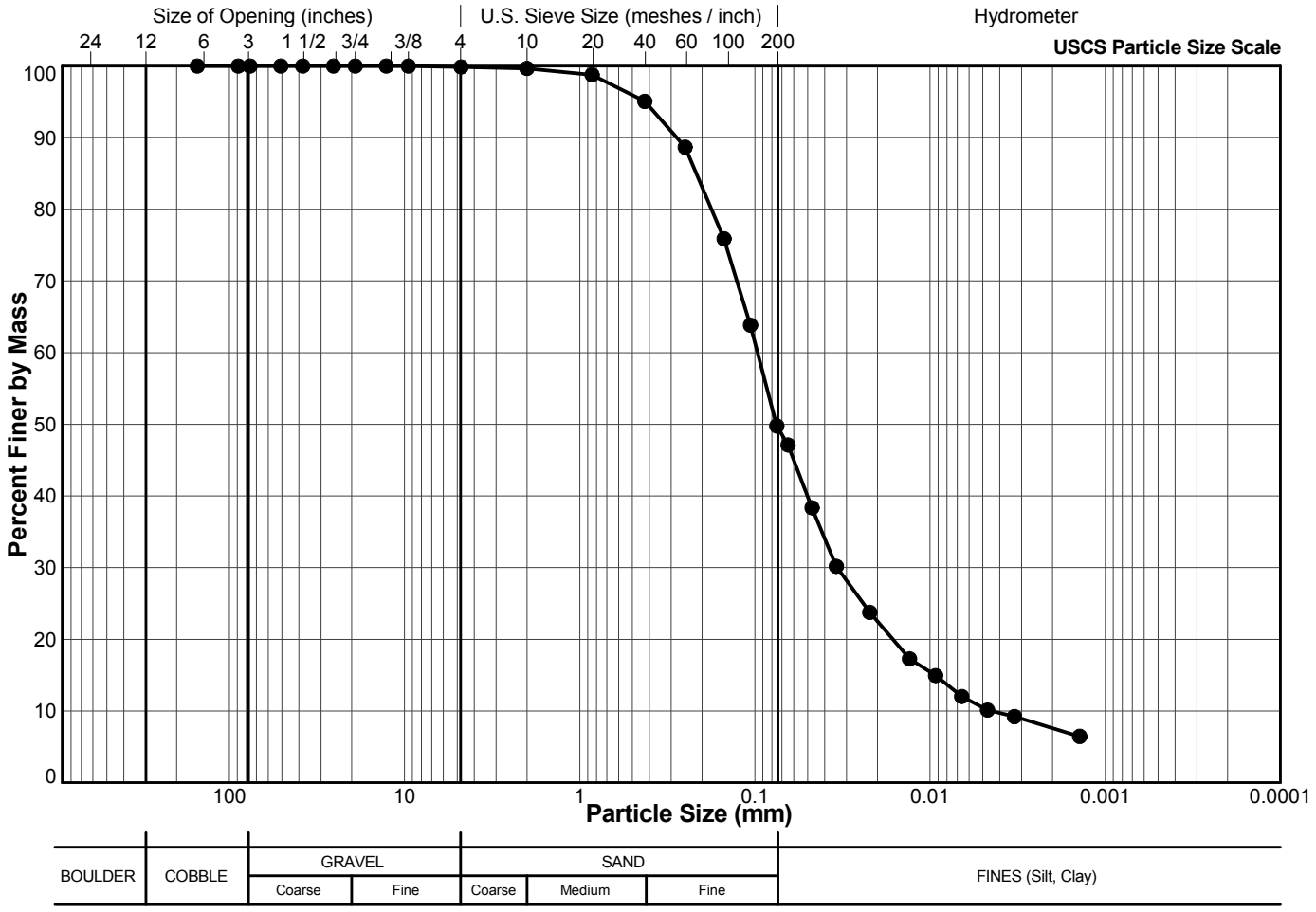
BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	BGC Engineering Inc.	**Sample Location:**	BH-BGC14-TR-03
Project:	Trans Mountain Expansion / Ref # 0095-150-14	**Sample No.:**	SPT 30
Location:	N/A	**Depth Interval (m):**	49.73 to 50.34
Project No.:	1408883 **Phase:** 2000	**Lab Schedule No.:**	449



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		99.9
#10 US MESH	2		99.7
#20 US MESH	0.85		98.8
#40 US MESH	0.425		95.1
#60 US MESH	0.25		88.7
#100 US MESH	0.15		75.9
#140 US MESH	0.106		63.8
#200 US MESH	0.075		49.8
		0.0647	47.1
		0.0472	38.4
		0.0343	30.2
		0.0221	23.8
		0.0131	17.3
		0.0093	14.9
		0.0066	12.0
		0.0047	10.1
		0.0033	9.2
		0.0014	6.4

	SJ/OA	**12/19/2014**	**DN**	**12/23/2014**
	Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:648 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 12/23/14

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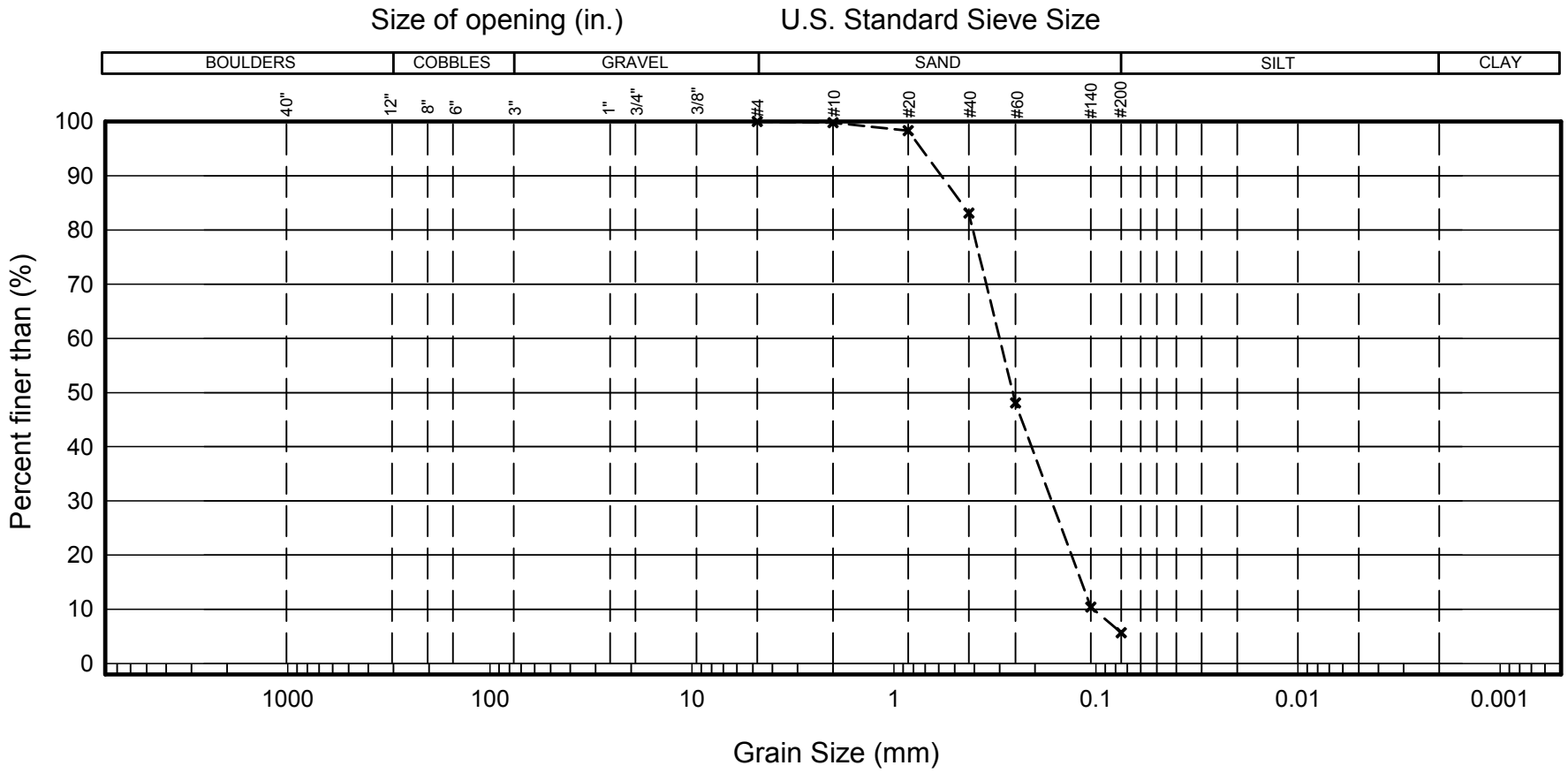

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-02 - Depth 3.05 to 3.66m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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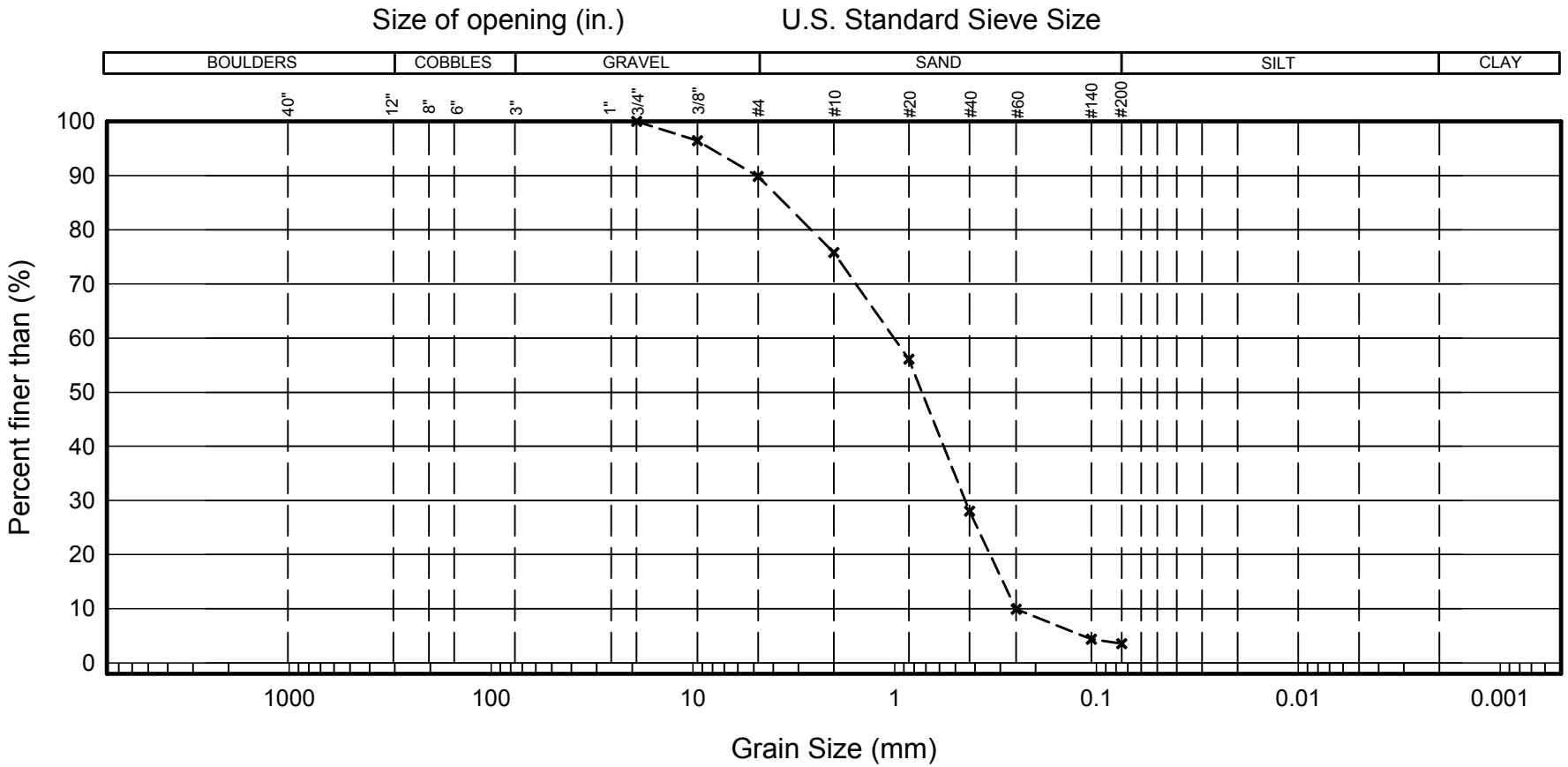

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-04 - Depth 6.10 to 6.71m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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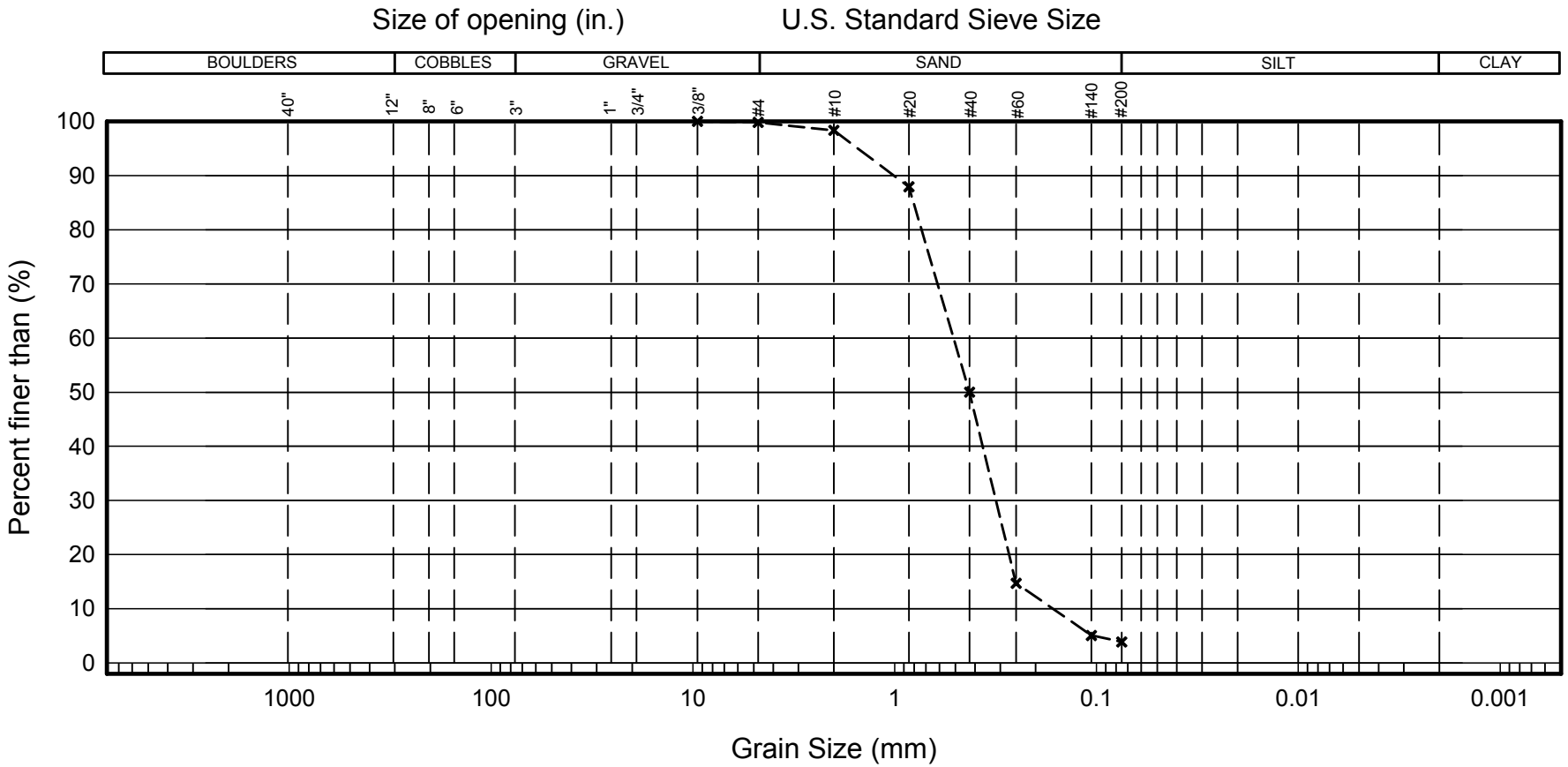

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-07 - Depth 10.67 to 11.28m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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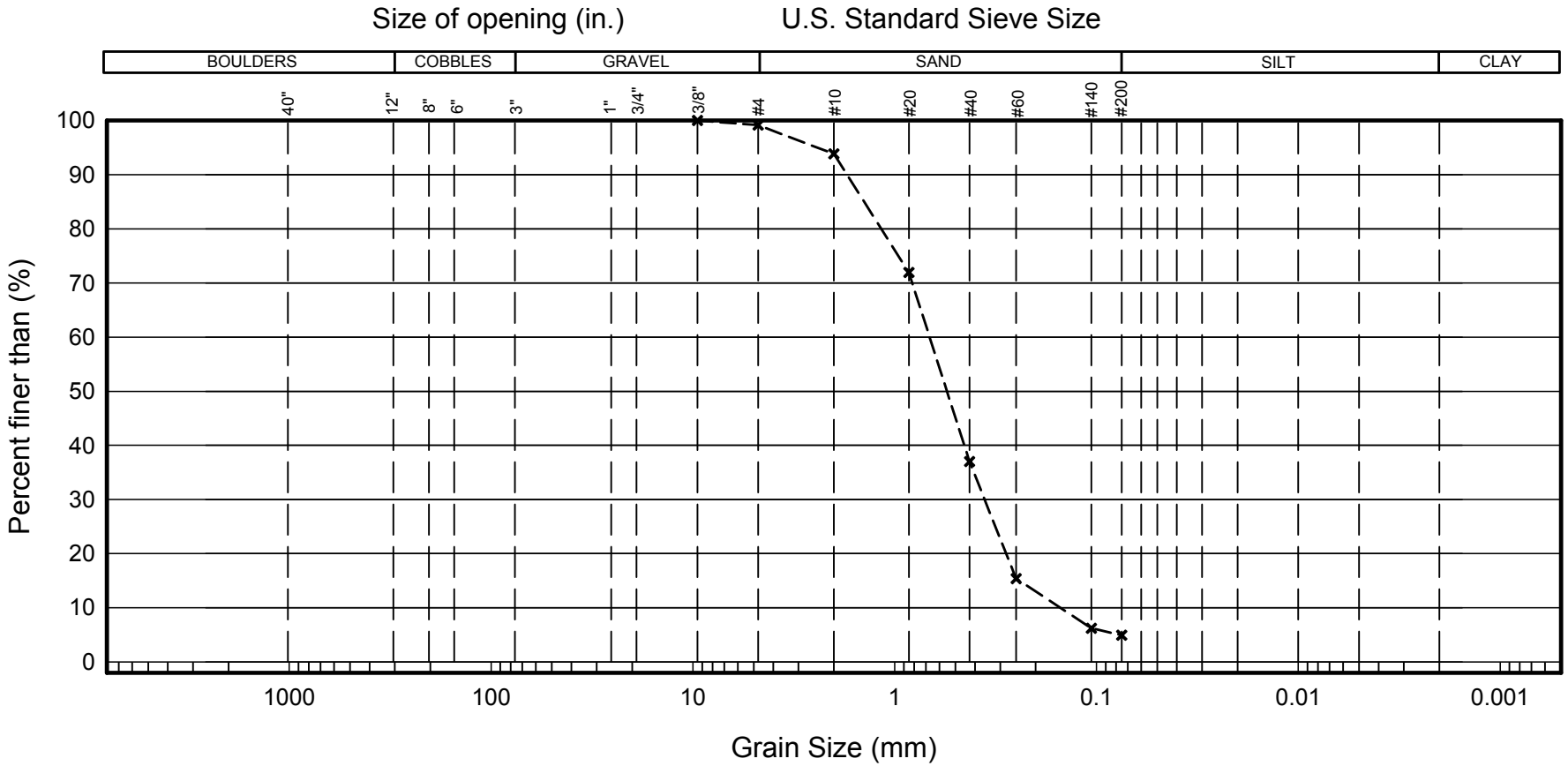

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-13 - Depth 19.81 to 20.42m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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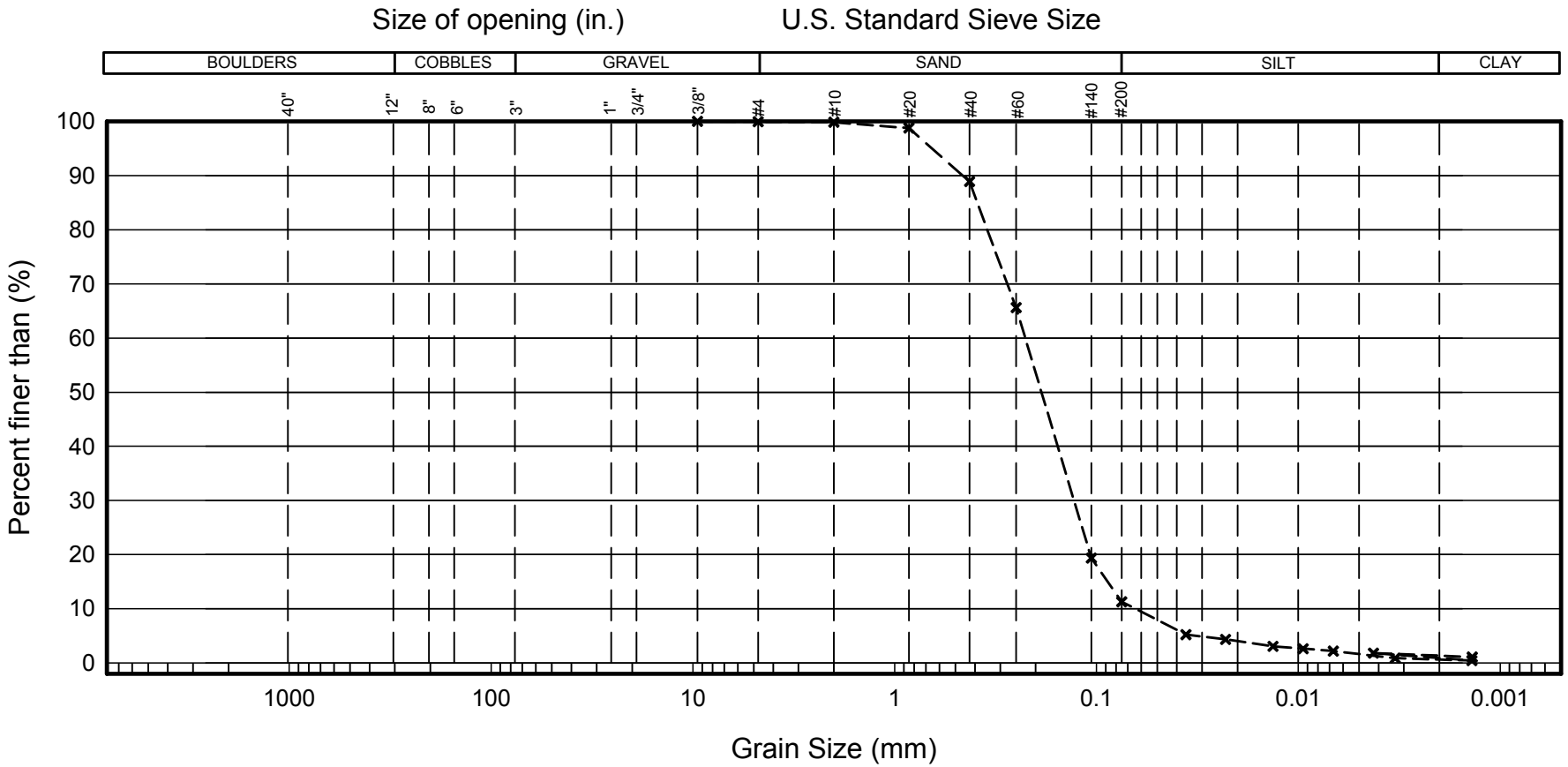

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-17 - Depth 25.91 to 26.52m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

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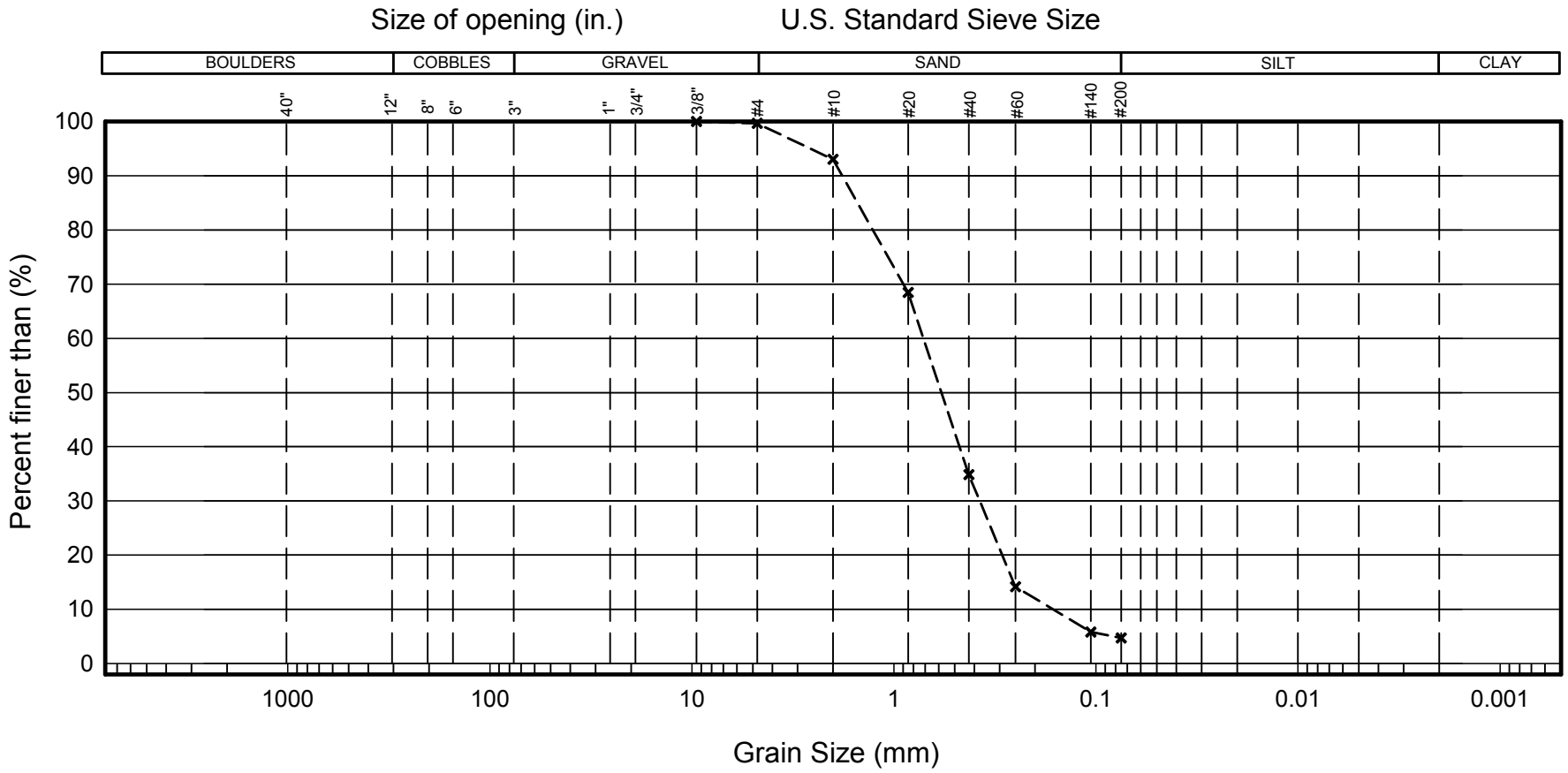

NOTES:

1. Lab analysis completed by DO, reviewed by SD.

GRAIN SIZE ANALYSIS

BH-BGC14-TR-04 - Sample: SPT-21 - Depth 32.00 to 32.61m

BGC Project No.: 0095150-13

TMEP - LIQUEFACTION ASSESSMENT

APPENDIX E
VIBRATING WIRE PIEZOMETER DOCUMENTATION

innovation in geotechnical instrumentation

RST Instruments Ltd., 11545 Kingston St., Maple Ridge, British Columbia, Canada V2X 0Z5
Tel: 604 540 1100 • Fax: 604 540 1005 • Toll Free: 1 800 665 5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

Calibration Record

Vibrating Wire Piezometer

Customer:		BGC Engineering Inc.
Model:		VW2100-0.35
Serial Number:		**VW31070**
Mfg Number:		1433250
Range:		350.0 kPa
Temperature:		23.3 °C
Barometric Pressure:		989.3 millibars
Work Order Number:		205661
Cable Length:		17 meters
Cable Markings:		682408 m - 682424 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 kΩ

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	8837	8837	8837	0.1	0.03	0.01
70.0	8205	8205	8205	69.9	-0.04	-0.04
140.0	7569	7569	7569	140.0	0.01	0.03
210.0	6935	6935	6935	210.0	0.00	0.02
280.0	6302	6302	6302	279.9	-0.04	-0.03
349.9	5666	5667	5667	350.0	0.03	0.01
			Max. Error (%):		0.04	0.04

Linear Calibration Factor:	**C.F.=**	**0.11036 kPa/B unit**
Regression Zero:	**At Calibration =**	**8838.0 B unit**
Temperature Correction Factor:	**Tk =**	**-0.1047 kPa/°C rise**

Polynomial Gage Factors (kPa) A: -4.9129E-08 B: -0.10965 C: 972.83

Pressure is calculated with the following equations:

Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$

Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	20-Nov-14	8823	20.5	1014.3

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = Hz^2 / 1000 ie: 1700Hz = 2890 B units

Technician: J. Chu Date: 20-Nov-14

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Applied Science Technologists and Technicians of British Columbia
22724
AL CULLEY
AScT

Document Number.: ELL0130K

MIG0106B

innovation in geotechnical instrumentation

RST Instruments Ltd., 11545 Kingston St., Maple Ridge, British Columbia, Canada V2X 0Z5
Tel: 604 540 1100 • Fax: 604 540 1005 • Toll Free: 1 800 665 5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

Calibration Record

Vibrating Wire Piezometer

Customer:		BGC Engineering Inc.
Model:		VW2100-0.35
Serial Number:		**VW31076**
Mfg Number:		1433369
Range:		350.0 kPa
Temperature:		23.6 °C
Barometric Pressure:		989.1 millibars
Work Order Number:		205661
Cable Length:		32 meters
Cable Markings:		682291 m - 682323 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 kΩ

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	8864	8865	8865	0.0	-0.01	-0.01
70.0	8224	8224	8224	70.1	0.02	0.01
140.0	7585	7585	7585	140.0	0.00	-0.01
210.0	6945	6945	6945	210.0	0.01	0.00
280.0	6306	6306	6306	280.0	-0.01	-0.01
349.9	5667	5667	5667	349.9	0.00	0.01
			Max. Error (%):		0.02	0.01

Linear Calibration Factor:	**C.F.=**	**0.10944 kPa/B unit**
Regression Zero:	**At Calibration =**	**8864.1 B unit**
Temperature Correction Factor:	**Tk =**	**-0.05141 kPa/°C rise**

Polynomial Gage Factors (kPa) A: 1.4027E-08 B: -0.10965 C: 970.84

Pressure is calculated with the following equations:
Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$
Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	20-Nov-14	8850	21.3	1014.3

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = $Hz^2 / 1000$ ie: 1700Hz = 2890 B units

Technician: Joshua Chung Date: 20-Nov-14

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

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AScT

Document Number: ELL0130K

MIG0106B

Trans Mountain Expansion Project

Feasibility Report for the Thompson River Crossing

TMEP Document # 01-13283-S5A-M002-PL-RPT-0004 R1

Rev No.	Prepared by/ Date	Reviewed by/ Date	Approved by/ Date	Reviewed by TMEP	Pages Revised	Issued Type
1	T. Miles 2019-12-12	J. Murphy 2019-12-12	H. Beaujot 2019-12-12	B Kochalt 2019-12-13	5	Issued for Use
0	P. Liang 2015-02-24	J. Murphy 2015-02-24	B. Osorio 2015-02-24	Tim Johnson 2015-02-24		Issued for Use

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1.0 INTRODUCTION

UniversalPegasus International (UPI) has been retained by Trans Mountain Canada Inc. (TMC) to undertake the routing and engineering design for the Trans Mountain Expansion Project (TMEP) pipeline. As part of this work, a number of watercourse crossings have been identified as potential candidates for a trenchless crossing methodology, specifically a Horizontal Directional Drill (HDD). This report evaluates the Thompson River Crossing (KP 842.9, SSEID5.8), with the intent of determining the feasibility of an HDD. The applicability of several other crossing methodologies has been considered in this study as well.

The purpose of this feasibility report is to evaluate existing information and the results of the geotechnical and geophysical investigations that have been completed at Thompson River for the TMEP, in order to provide an assessment of the feasibility of the HDD crossing methodology for this crossing.

Appendix A lists the abbreviations and acronyms used in this report.

2.0 SITE VISIT

Site visits and investigations were carried out at the Thompson River Crossing by BGC Engineering Inc. (BGC) in November 2013 and December 2014 to ascertain an understanding of the subsoil conditions at this site.

3.0 GEOTECHNICAL/GEOPHYSICAL INVESTIGATIONS

As part of the HDD feasibility evaluation process, BGC has completed geotechnical and geophysical investigations at several major river crossing locations, specifically to determine if an HDD could be a viable crossing methodology at these locations. BGC issued a preliminary Geotechnical HDD Feasibility Assessment report for the Thompson River Crossing in February 2015, and issued an updated version of the report in July 2018 to reflect the crossing alignment changes made during the engineering development process. From the hydrological data attached in Appendix B, *Mean Monthly Flows for Thompson River Crossing*, June is the month with the highest flow, and March is the month with the lowest flow. Daily streamflow records used in the calculation of monthly flow statistics are recorded by hydrometric stations that have been established and are operated across Canada by Water Survey Canada (WSC) to help understand and manage water resources.

4.0 REVIEW OF AVAILABLE WATERCOURSE CROSSING METHODOLOGIES

A number of watercourse crossing methodologies, including trenchless techniques (HDD, Direct Pipe®, Bore), isolated crossing technique and open cut are typically considered for crossing watercourses such as the Thompson River. These methodologies are described below.

4.1 Horizontal Directional Drill

Horizontal Directional Drilling is one of the most commonly accepted trenchless methods for a pipeline watercourse crossing. The method involves setting up an HDD drill rig and drilling a pilot hole with subsequent reaming passes to enlarge the borehole to an adequate diameter for pull-in of carrier pipe. The make-up section is typically fabricated in one piece, hydrostatically tested, and then pulled into the bore. Buoyancy water within the pipe is normally used to minimize pull forces for larger diameter pipes. The constructability of an HDD typically ranges from 400 m to 3,500 m in length for NPS 36 pipe. In some instances, the HDD methodology may also require a large diameter surface casing if sands or gravels are encountered near surface.

The feasibility of utilizing an HDD method is normally compromised where large boulders or deep deposits of gravel containing cobbles and boulders are encountered. Topography, geometry, and available workspace may also impact the feasibility of using an HDD.

Potential obstacles for HDD:

- Loss of drilling fluid circulation in a sand and gravel stratum;
- Pilot hole steering problems when encountering boulders, or if voids are present along the drill profile;
- Need for additional workspace for the pullback area;
- Unacceptable levels of induced settlement;
- Cobbles and boulders which may be present.

4.2 Direct Pipe®

The Direct Pipe® method involves attaching a Micro-Tunnel Boring Machine (MTBM) in front of the product pipe (or a casing). The MTBM and product pipe are then “thrust” into the ground using the Herrenknecht ‘thruster’. This technique can be utilized to tunnel through soft or hard ground below the water table. The excavated material is mixed with water or drilling mud in the micro-tunnelling cutting head and pumped back to

surface to be cleaned and reused, much like the HDD method. Gravel and cobbles which are able to enter the MTBM, are crushed and mixed with the drilling mud and then pumped back up to surface. Small to medium sized boulders that are able to enter the MTBM may also be broken down by disk cutters on the cutter head. Larger boulders that are unable to be broken down need to be pushed away from the bore alignment. Boring through large boulders or numerous boulders would not be feasible. This has been seen on a recent project North East of Hope, BC on a crossing of the Coquihalla River.

This methodology has length limitations of approximately 500 m for NPS 36 and 800 m for NPS 42. The size and number of boulders encountered also limits the feasibility of using this technique. The use of the Direct Pipe® method in Europe has been growing rapidly over the last 5 years. To date a number of relatively straight forward crossings, as well as some more challenging crossings, have been completed in Canada and the United States using this methodology.

Potential obstacles for Direct Pipe®:

- Quantity and size of boulders present along the drill path;
- Complicated entry pit setup; and
- Possibly requires additional geotechnical information.
- Length of crossing vs. Product pipe size
- Overly soft subsurface conditions leading to steering difficulties

4.3 Bore

This is a common crossing technique that utilizes a boring machine operating within an excavation to advance a casing pipe and auger beneath a road. Length is normally limited to a maximum of approximately 100 m but some contractors now state that advances in equipment capabilities can increase this maximum length limit. This technique is generally not ideal for watercourse crossing due to the difficulties with controlling water migration into the bell holes but is very well suited to road and rail crossings. Proper procedural criteria need to be maintained to minimize the formation of voids during the bore. Feasibility is generally assisted with geotechnical information.

Potential obstacles for Bored methodology:

- Large boulders which the boring equipment is not capable of handling
- High water table in coarse granular soils.

- Length of crossing
- High water table in cohesionless soils

4.4 Isolated Crossing Techniques

Isolated crossing techniques (which are in-stream bypass techniques) typically involve isolating the location of works from the water flow by the use of temporary dams or steel plates, and then diverting the water using a pump, flume, or by excavating a side channel. The dam and pump method generally works well for maximum flows up to approximately 1.2 to 1.4 m3/s for summer construction and up to approximately 1.0 m3/s for winter construction. The flume method works well for maximum flows up to approximately 8.0 m3/s (i.e. double super flume). After the crossing location is isolated the pipeline trench is excavated followed by pipe placement and backfill. The final steps include re-contouring the riverbed and restoration of the banks.

4.5 Open Cut

The Open Cut method involves excavating a trench through the watercourse (without isolation) to the required depth, installing the pipe and then backfilling. The final steps include re-contouring the riverbed and restoration of the banks. This method is best used when flows are at their lowest point.

Potential obstacles for Open Cut:

- Unexpected soil conditions within the riverbed;
- Lack of available workspace;
- Fisheries sensitivity; and
- Unanticipated high water conditions.

5.0 GEOTECHNICAL/GEOPHYSICAL PROGRAM

The Thompson River site has been investigated both geotechnically and geophysically by BGC. A total of four (4) geotechnical boreholes were drilled in November 2013 and December 2014 with one borehole on the northwest side of the crossing, one borehole in the river and two boreholes on the southeast side of the crossing. Borehole BH-BGC-TR-04 and BH-BGC-TR-02 were drilled within approximately 6 m of each other on the south bank of the river, offset approximately 31 m and 26 m west from the proposed HDD entry point, respectively. BH-BGC-TR-04 was drilled adjacent to BH-BGC-TR-02 to support the seismic liquefaction assessment for the pipeline.

Borehole BH-BGC13-TR-01 (Appendix C) is located on the northwest side of the crossing and is the closest borehole to the exit point. The borehole report shows that the surficial material is loose to compact sand up to a depth of 14 m. Beneath the top layer of sand, compact to dense interbedded sand and silt layers extend to a depth of 66 m. Following the interbedded sand and silt, the borehole encountered a very dense sand layer down to the termination point at 68.6 m. Water table was measured at a depth of 7.4 m below ground surface. Approximately 30% of drilling fluid circulation loss was reported at depths of 67 m to 68.6 m.

Borehole BH-BGC14-TR-02 (Appendix C) is located on the southeast side of the crossing and is close to the entry point. The surficial layer of loose sand extends to a depth of 11.8 m. Beneath the sand layer, the borehole encountered loose to compact interbedded sand and silt layers down to a depth of 27 m. Following the interbedded sand and silt units, a compact to dense sand layer extends to the termination point at 40.23 m. Water table was measured at a depth of 3.58 m below ground surface. Drilling fluid circulation losses were reported as follows: approximately 15% at a depth of 4.5 m, 20% at 6.7 m, 25% at 22.5 m and 35% at 30 m.

Borehole BH-BGC14-TR-03 (Appendix C) is located within the river channel, offset 25 m west from the proposed HDD alignment. The borehole log shows that the top layer of the riverbed is loose to compact sand up to a depth of 14 m. Beneath the top layer, a compact to dense interbedded sand and silt layer extends to a depth of 55.4 m. Following the interbedded sand and silt, the borehole encountered a very dense sand layer down to the termination point at 61m. No drilling fluid circulation loss was reported in this borehole.

Borehole BH-BGC14-TR-04 (Appendix C) is also located on the southeast bank of the crossing near the entry point. There is a loose to compact sand layer present from the ground surface to a depth of 25.8 m. Beneath the top layer, a compact interbedded sand and silt unit was encountered down to a depth of 27.1 m. Following the interbedded sand and silt, a dense sand layer extends to the termination point of 35.7 m. Water table was measured at a depth of 3.2 m below ground surface. Drilling fluid circulation losses were reported as follows: approximately 10% at a depth of 6.8 m and 15% at depths of 11 m to 23.5 m.

The soil strata are shown in the borehole logs located in Appendix C, and the interpreted geological section drawing is located in Appendix D.

The conclusion from the results of the geotechnical and geophysical investigations is that, from a geotechnical perspective, an HDD at this location is considered feasible but challenging due to possible fluid circulation losses.

6.0 CROSSING DESIGN

6.1 Primary Crossing Method - HDD Crossing Design

The proposed NPS 36 TMEP pipeline crosses Thompson River at about KP 842.9 where the distance between active channel river banks is approximately 600m. The proposed HDD alignment will run adjacent to two existing pipelines. The Thompson River Crossing is situated within the city limits of Kamloops, BC, just southeast of the Kamloops Airport. Pipeline alignment is from south to north at this crossing location and as such the Thompson River is almost perpendicular to the alignment and flowing in an east to west flow direction.

For the purposes of this report, an HDD crossing plan and profile drawing for the Thompson River was prepared and is included in this report as Appendix E. A hydrofracture analysis diagram is also presented in Appendix F.

The ground profile utilized in the design was derived from the survey drawing information dated January 20, 2017 and provided by Opus Stewart Weir. As shown in the HDD crossing plan and profile drawing M002-XD-00160, the drill path for the NPS 36 pipeline will be about 1366m long. The pipe will cross the river at a depth of approximately 45m below the bottom elevation of the river. This design profile has an entry angle of 12° and an exit angle of 10°. The setback from the river centre is about 837m on the northwest side and 520m to the southeast side. The exit point is near the Kamloops airport runway/taxiway, therefore, the southeast side has been selected as the entry point to minimize the construction activities at the airport. The exit point will be 1.9m higher than the entry point, and the make-up section of pipe is currently to be located on the northwest side of the crossing, but this will need further study due to very close proximity to air traffic.

1

There may be a requirement for casings on both the entry and exit. Casing, if required, is anticipated to have a minimum diameter of about 1,524mm OD (NPS 60) to accommodate the anticipated final ream size of 1,219mm (NPS 48).

The calculated pull force for the 914mm OD (NPS 36) pipe is estimated to be 3,870 kN (870,000 lbf) without buoyancy control, and 1,601 kN (360,000 lbf) by utilizing 100% buoyancy control. Based on the length and overall geometry of this crossing, we recommend a drill rig size of at least 4,003 kN (900,000 lbf). NPS 36 pipe is normally installed using buoyancy control to minimize the pull force.

1

The initial hydrofracture analysis (Appendix F) illustrates that this HDD crossing should be feasible at the depth shown.

Construction of the Thompson River Crossing may require a drilling schedule of about 10 weeks for the 914mm OD (NPS 36) pipe, excluding the time that may be required to install casings (if required). The duration is based on the HDD Contractor working twenty four (24) hours per day to complete the installation.

6.2 Contingency Crossing Method - Open Cut (Without Isolation) Crossing Design

In accordance with the Stage 2 watercourse evaluation process, the contingency crossing method for the Thompson River was determined to be an open cut (without isolation) crossing method with water quality monitoring. The preliminary contingency crossing drawing appears in Appendix G. The construction window for the contingency crossing method is currently planned to occur inside the least risk biological window.

7.0 RECOMMENDATIONS

Based on the geotechnical and geophysical information provided for this feasibility report, the following is recommended:

Thompson River is considered to be a suitable candidate for an HDD crossing method based on the results and recommendations included in the BGC Feasibility Assessment. The following difficulties may be encountered:

- Sloughing and hole collapse: Soils encountered during drilling were generally stable with minor sloughing, however coarser materials may be present and lead to hole collapse in some areas. If encountered, this can be mitigated via proper drill mud mixes or casing.

1

- Loss of drilling fluids: Loose, cohesionless coarse sands may be present and could cause circulation losses. If encountered, this can be mitigated via proper drill mud mixes or casing.
- Encountering cobbles or boulders: The presence of boulders or cobbles was not evident during the geotechnical drilling program, but large clasts may generally be encountered in fluvial/glaciofluvial deposits. If encountered, they could deflect the HDD borepath. Preparation for variable drilling conditions, use of casing, or altering the alignment may be considered.

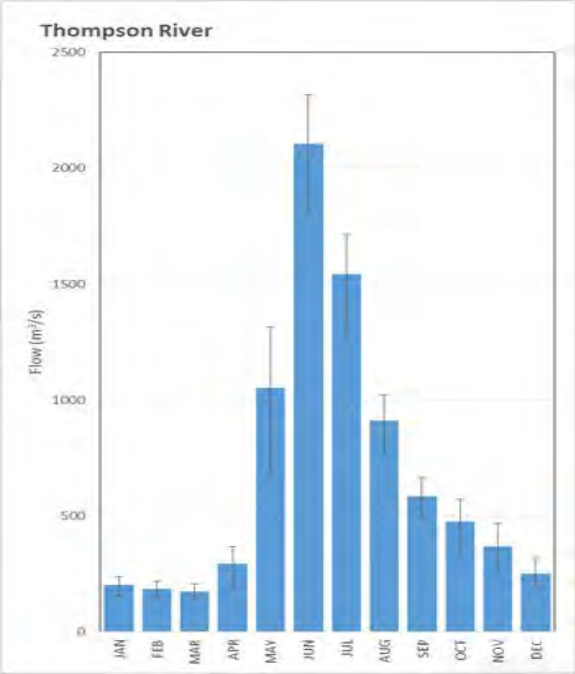
An open cut (without isolation) design aligned parallel to the existing TMPL is the proposed contingency crossing method.

Appendix A – Abbreviations and Acronyms

The following is a list of abbreviations and acronyms used in this report.

Term	Meaning
°	degree
%	percent
AK	Alternate Kilometre
BGC	BGC Engineering Inc.
DWG	Drawing
ERT	Electrical Resistivity Tomography
HDD	horizontal directional drill
KMC	Kinder Morgan Canada Inc.
kN	kilonewton
KPa	kilopascal
lbf	Pounds force
LiDAR	Light Detection and Ranging
m	metre
m^3/s	cubic metres per second
mm	millimetre
MTBM	micro-tunnel boring machine
NPS	nominal pipe size
OD	outside diameter
RK	Reference Kilometer
®	Registered Trademark Symbol
SPT	Standard Penetration Test
TMEP	Trans Mountain Expansion Project
TMPL	Trans Mountain Pipeline
UPI	UniversalPegasus International

Appendix B – Mean Monthly Flows for Thompson River



	Mean	Lower Quartile	Upper Quartile
	in m^3/s	in m^3/s	in m^3/s
JAN	202	155	240
FEB	186	147	219
MAR	174	142	208
APR	294	191	369
MAY	1052	684	1315
JUN	2104	1802	2316
JUL	1544	1257	1715
AUG	910	767	1023
SEP	585	490	664
OCT	475	323	571
NOV	371	256	469
DEC	251	194	317

Appendix C – Geotechnical Borehole Logs at Thompson River

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SM) Fine to medium, some silt, trace gravel, poorly graded, very loose to compact, maximum particle size = 40 mm, subrounded, brown, no odour, moist, weak cementation, heterogeneous, no foreign materials. [FLUVIAL]	
4		SPT-01			SPT 01 - Recovered 0.46 m (75%).	1 2 2
5						
6		SPT-02			SPT 02 - Recovered 0.46 m (75%). Changes to very loose.	0 1 1
7		SPT-03			SPT 03 - Recovered 0.41 m (67%). Changes to compact, grey.	4 5 7
8					Water depth measured at 7.4 m below ground surface on November 16, 2013 with the borehole at final depth of 68.6 metres below ground surface (mbgs) and casing to 2.7 mbgs.	

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
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Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SM) Fine to medium, some silt, trace gravel, poorly graded, loose to compact, maximum particle = 40 mm, subrounded, grey, no odour, moist, weak cementation, heterogeneous, no foreign materials. [FLUVIAL]	
9		SPT-04			SPT 04 - Recovered 0.38 m (62%).	6 5 6
10		SPT-05			SPT 05 - Recovered 0.48 m (79%). Changes to loose.	3 4 4
11						
12		SPT-06			SPT 06 - Recovered 0.41 m (67%).	5 5 5
13		SPT-07			SPT 07 - Recovered 0.43 m (70%).	4 4 5
14					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, loose, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm.	
15		SPT-08			SILT (ML) Some fine to medium sand, low plasticity, firm, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.53 m (87%).	2 2 4
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, stiff to very stiff, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT-09			SPT 09 - Recovered 0.41 m (67%). Sand changes to compact, silt changes to stiff.	7 8 6
17					SPT 10 - Recovered 0.51 m (84%). Silt changes to very stiff.	
18		SPT-10				6 7 10
19					SPT 11 - Recovered 0.51 m (84%). Silt changes to stiff.	
		SPT-11				6 6 7
20					SPT 12 - Recovered 0.53 m (87%). Silt changes to very stiff.	
21		SPT-12				5 8 8
22					SPT 13 - Recovered 0.36 m (59%). Silt changes to stiff.	
		SPT-13				6 6 8
23						
24					SPT 14 - Recovered 0.61 m (100%).	

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24		SPT-14			Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	9 8 7
25		SPT-15			SPT 15 - Recovered 0.51 m (84%).	8 7 9
26						
27		SPT-16			SPT 16 - Recovered 0.38 m (62%).	12 11 14
28						
29		SPT-17			SPT 17 - Recovered 0.33 m (54%). Sand changes to dense, silt changes to hard.	13 15 16
30		SPT-18			SPT 18 - Recovered 0.41 m (67%).	15 15 18
31						
32		SPT-19			SPT 19 - Recovered 0.43 m (70%).	10 15 20

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
33		SPT-20			SPT 20 - Recovered 0.58 m (95%). Sand changes to compact, silt changes to very stiff.	5 8 15
34						
35		SPT-21			SPT 21 - Recovered 0.46 m (75%).	2 10 11
36		SPT-22			SPT 22 - Recovered 0.58 m (95%). SAND (SM) 0.0% gravel, 63.2% sand, 36.8% fines.	7 10 12
37						
38		SPT-23			SPT 23 - Recovered 0.61 m (100%).	4 8 8
39		SPT-24			SPT 24 - Recovered 0.61 m (100%).	4 4 13
40						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

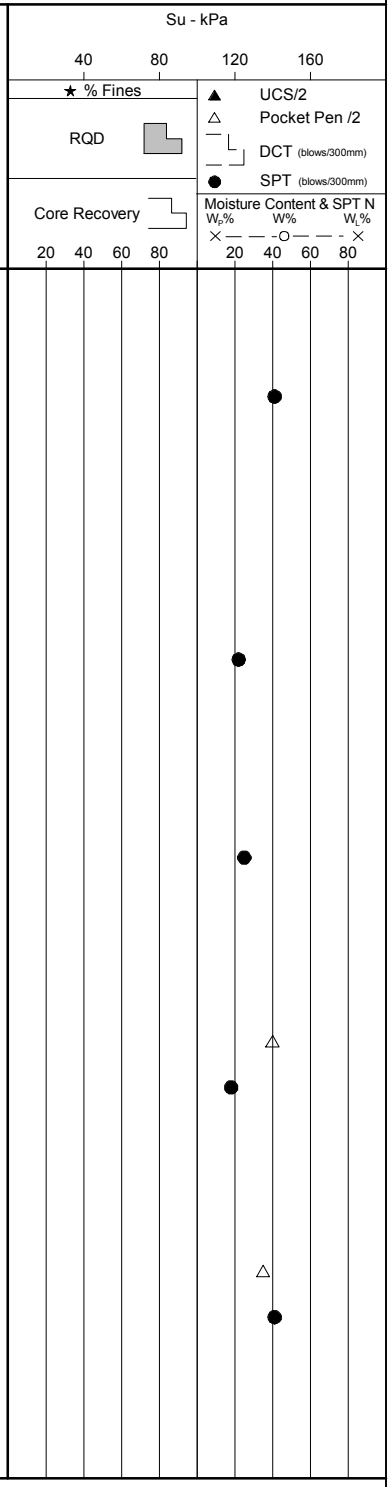
(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
40					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
41		SPT-25			SPT 25 - Recovered 0.56 m (92%). Sand changes to dense, silt changes to hard.	13 19 22
42		SPT-26			SPT 26 - Recovered 0.61 m (100%). Sand changes to compact, silt changes to very stiff.	4 9 13
43						
44		SPT-27			SPT 27 - Recovered 0.48 m (79%).	7 12 13
45		SPT-28			SPT 28 - Recovered 0.61 m (100%).	5 6 12
46						
47		SPT-29			SPT 29 - Recovered 0.56 m (92%). Sand changes to dense, silt changes to hard.	10 18 23
48						



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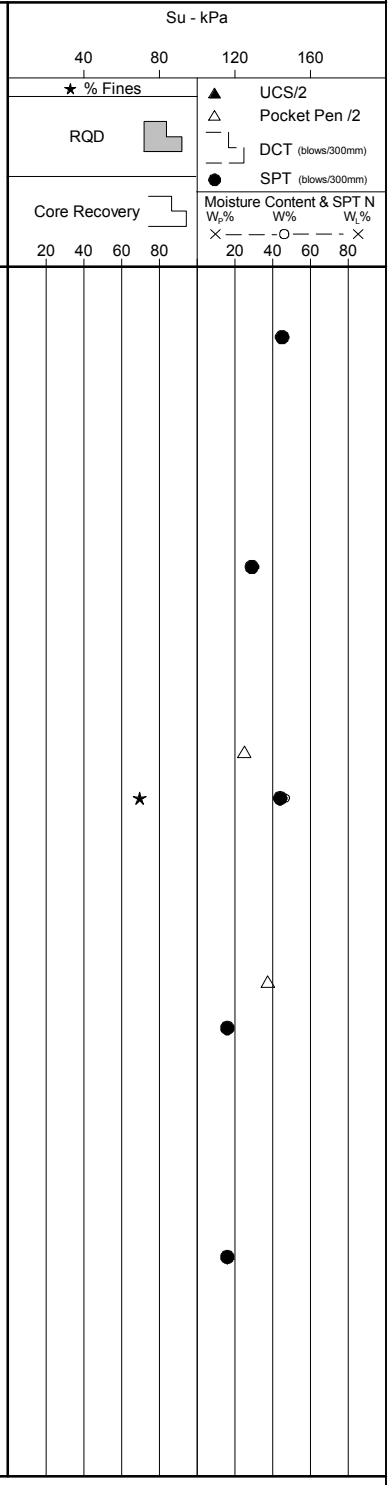
Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
48					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, compact to dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, very stiff to hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT-30			SPT 30 - Recovered 0.43 m (70%).	14 21 24
49						
		SPT-31			SPT 31 - Recovered 0.38 m (62%). Sand changes to compact, silt changes to very stiff.	13 13 16
50						
51						
		SPT-32			SPT 32 - Recovered 0.61 m (100%). Sand changes to dense, silt changes to hard. SILT (ML) 0% gravel, 30.3% sand, 69.6% fines.	7 16 28
52						
		SPT-33			SPT 33 - Recovered 0.61 m (100%). Sand changes to compact, silt changes to very stiff.	3 5 11
53						
54						
		SPT-34			SPT 34 - Recovered 0.61 m (100%).	3 4 12
55						
56						



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Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
56		SPT-35			SPT 35 - Recovered 0.61 m (100%). Sand changes to dense, silt changes to hard. Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, dense to very dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	20 23 23
57						
		SPT-36			SPT 36 - Recovered 0.38 m (62%). Sand changes to very dense.	26 26 27
58						
59		SPT-37			SPT 37 - Recovered 0.28 m (46%).	15 24 29
60						
		SPT-38			SPT 38 - Recovered 0.36 m (59%).	R
61						
62		SPT-39			SPT 39 - Recovered 0.36 m (59%).	20 35 40
63						
		SPT-40			SPT 40 - Recovered 0.48 m (79%).	10 26
64						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20, 40, 60, 80

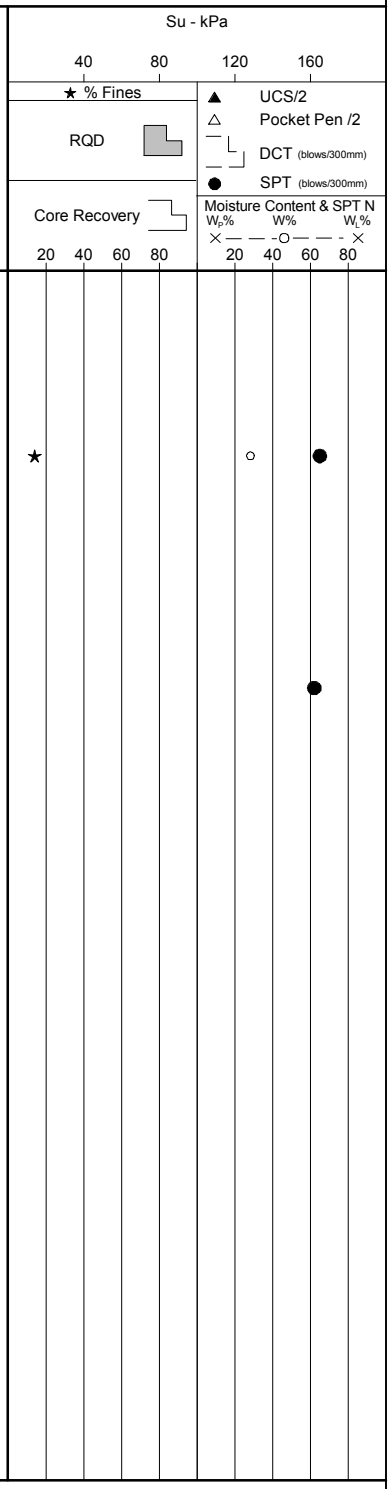
(Continued on next page)

Survey Method: Garmin GPSMAP 62s
Co-ordinates (m): 681,567E, 5,619,565N
Ground Elevation (m): 345.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: HWT **Cased To (m)**: 2.7
Depth To Rock (m):

Start Date: 11 Nov 13
Finish Date: 16 Nov 13
Final Depth of Hole (m): 68.6
Logged by: SW
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
64					Interbedded SAND and SILT: SAND (SM) Fine to medium, some silt, trace clay, poorly graded, very dense, subrounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace organics, peaty, layers < 10 mm. SILT (ML) Some fine to medium sand, low plasticity, hard, low sensitivity, grey, moist, laminated to stratified, moderate cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	28
65		SPT-41			SPT 41 - Recovered 0.36 m (59%). SAND (SM) 0.0% gravel, 86.0% sand, 14.0% fines.	21 30 35
66					SAND (SM) Fine to medium, some silt, poorly graded, very dense, maximum particle size = 2 mm, subrounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL]	
67		SPT-42			Zone of 30% drilling mud circulation loss begins. SPT 42 - Recovered 0.48 m (79%).	25 30 32
68		SPT-43			SPT 43 - Recovered 0.38 m (62%).	R
69					Borehole completed at target depth of 68.6 m. Borehole grouted to surface with bentonite grout. No instrumentation installed. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586.	
70					Pocket penetrometer tests conducted perpendicular to borehole axis. Tests were conducted on disturbed samples. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
71						
72						



Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
0				SAND (SP) Fine to medium, trace silt, trace gravel, fine to coarse, poorly graded, loose, maximum particle size = 30 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [FLUVIAL]		
1						
2		SPT 01		SPT 01 - Recovered 0.47 m (77%).	3 3 4	
3		SPT 02		SPT 02 - Recovered 0.34 m (56%). SAND (SP) 95.4% sand, 4.6% fines.	2 3 3	
4				Water level measured at 3.58 m below ground surface on December 8, 2014.		
5		SPT 03		4.5 m - 10 - Drilling mud circulation loss of 15% begins. SPT 03 - Recovered 0.38 m (66%).	3 4 5	
6		SPT 04		SPT 04 - Recovered 0.38 m (62%).	4 3 5	
7				From 6.7 - 69 m Drilling mud circulation loss increases to 20%. Possible gravel or coarse sand layer.		
8		SPT 05		SPT 05 - Recovered 0.36 m (59%).	3	

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
8				SAND (SP) Fine to coarse, trace silt, trace gravel, fine to medium, poorly graded, loose, maximum particle size = 30 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [FLUVIAL]	3 5	
9				9.0 m - Drilling mud circulation loss decreases to 0%.		
		SPT 06		SPT 06 - Recovered 0.37 m (61%). Sand changes to fine to coarse. SAND (SP) 0.9% gravel, 92.9% sand, 6.2% fines.	2 2 4	
10						
11		SPT 07		SPT 07 - Recovered 0.55 m (90%).	3 4 5	
12				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, loose, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses.		
		SPT 08			2 4 6	
13				SILT (ML) And sand, low plasticity, stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.52 m (85%).		
14		SPT 09		SPT 09 - Recovered 0.38 m (62%). Silt changes to firm.	3 3 3	
15						
		SPT 10		SPT 10 - Recovered 0.46 m (75%). Silt changes to stiff. SAND (SP) 0.3% gravel, 95.6% sand, 4.1% fines.	4 4 6	
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
RQD
DCT (blows/300mm)
● SPT (blows/300mm)
Core Recovery: 20, 40, 60, 80
Moisture Content & SPT N: W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
16				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, loose to compact, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses. SILT (ML) And sand, low plasticity, stiff to very stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]		
17		SPT 11		SPT 11 - Recovered 0.38 m (62%). Sand changes to compact.	6 7 8	
18		SPT 12		SPT 12 - Recovered 0.48 m (79%).	7 7 7	
19						
20		SPT 13		SPT 13 - Recovered 0.55 m (90%). Silt changes to very stiff.	7 11 13	
21						
22		SPT 14		SPT 14 - Recovered 0.42 m (69%).	7 8 8	
23		SPT 15		22.5 m - Drilling mud circulation loss increases to 25%. SPT 15 - Recovered 0.35 m (57%). SAND (SP) 0.2% gravel, 95.2% sand, 4.6% silt.	7 9 10	
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
24				Interbedded SAND and SILT SAND (SP) Fine to medium, trace silt, poorly graded, compact, maximum particle size = 2 mm, rounded, equidimensional, grey, no odour, moist, laminated to stratified, weak cementation, trace woody organics in lenses.		
		SPT 16			8 13 11	
25				SILT (ML) And sand, low plasticity, very stiff, grey, no odour, laminated to stratified, weak cementation, no foreign materials, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 16 - Recovered 0.52 m (87%).		
26		SPT 17		SPT 17 - Recovered 0.50 m (82%).	10 14 14	
27				SAND (SP) Fine to coarse, trace silt, poorly graded, dense, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL]		
		SPT 18		SPT 18 - Recovered 0.42 m (69%).	13 17 13	
28						
29		SPT 19		SPT 19 - Recovered 0.47 m (77%).	13 27 23	
30				30.0 m - Drilling mud circulation loss increases to 35%.		
		SPT 20		SPT 20 - Recovered 0.48 m (79%).	9 19 17	
31						
32						

Su - kPa: 40, 80, 120, 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
32		SPT 21		SAND (SP) Fine to coarse, trace silt, poorly graded, compact to dense, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL] SPT 21 - Recovered 0.43 m (70%). Changes to compact. SAND (SP) 0.3% gravel, 95.5% sand, 4.2% fines.	7 14 13	
33						
34		SPT 22		SPT 22 - Recovered 0.38 m (62%). Changes to dense.	10 15 16	
35		SPT 23		SPT 23 - Recovered 0.48 m (79%).	16 22 27	
36						
37		SPT 24		SPT 24 - Recovered 0.61 m (100%). Changes to some silt, compact.	8 12 17	
38		SPT 25		SPT 25 - Recovered 0.61 m (100%).	10 15 14	
39						
40		SPT 26		SPT 26 - Recovered 0.61 m (100%). Changes to dense.	17	

Su - kPa
40 80 120 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
RQD
DCT (blows/300mm)
● SPT (blows/300mm)
Core Recovery
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,724E, 5,618,733N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m): N/A

Start Date: 06 Dec 14
Finish Date: 07 Dec 14
Final Depth of Hole (m): 40.2
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description	SPT Blows per 150mm	Install Details
40				Borehole completed at target depth of 40.2 m below ground surface. Borehole grouted to surface with bentonite grout. Vibrating wire piezometers (Model VW2100-0.35) installed at 15.0 m and 30.0 m depth. VW31076 Installed at 30.0 m depth. VW31070 Installed at 15.0 m depth. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	19 20	
41						
42						
43						
44						
45						
46						
47						
48						

Su - kPa
40 80 120 160
★ % Fines
◆ Vane Field Peak
◇ Vane Field Remold
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
RQD
Core Recovery
20 40 60 80
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 15 mm, subrounded to subangular, brown to grey, no odour, moist, heterogeneous, weak cementation, visible muscovite and quartz, no foreign materials. [FLUVIAL]	
1		SPT01			SPT 01 - Recovered 0.34 m (56%).	3 3 3
					Groundwater level measured to be 1.38 m below ground surface on December 9, 2014.	
2						
		SPT02			SPT 02 - Recovered 0.35 m (57%). SAND (SP) 4.4% gravel, 92.0% sand, 3.6% fines.	2 1 3
3					2.95 m - Transition from brown to grey.	
4		SPT03			SPT 03 - Recovered 0.34 m (56%).	4 3 3
5						
		SPT04			SPT 04 - Recovered 0.30 m (49%).	2 2 2
6						
7		SPT05			SPT 05 - Recovered 0.32 m (52%). Maximum particle size decreases to 7 mm. SAND (SP) 2.9% gravel, 94.4 sand, 2.7% fines.	2 3 3
8						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 7 mm, subrounded to subangular, grey, no odour, moist, heterogeneous, weak cementation, visible muscovite and quartz, no foreign materials. [FLUVIAL]	
9		SPT06			SPT 06 - Recovered 0.32 m (52%).	3 3 4
10		SPT07			SPT 07 - Recovered 0.39 m (64%).	3 4 4
11						
12		SPT08			SPT 08 - Recovered 0.34 m (56%).	3 5 5
13		SPT09			SPT 09 - Recovered 0.37 m (61%). Changes to compact.	5 6 7
14					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	
15		SPT10			SILT (ML) Sandy,low plasticity, stiff, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 10 - Recovered 0.46 m (75%). SAND (SM) 0.0% gravel, 83.2% sand, 16.8% fines.	3 5 5
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, stiff to very stiff, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT11			SPT 11 - Recovered 0.46 m (75%).	4 5 5
17						
18		SPT12			SPT 12 - Recovered 0.32 m (52%). Silt changes to very stiff.	6 8 12
19						
		SPT13			SPT 13 - Recovered 0.28 m (46%). Changes to trace fine gravel.	10 14 16
20						
21		SPT14			SPT 14 - Recovered 0.40 m (66%).	10 12 14
22						
		SPT15			SPT 15 - Recovered 0.37 m (61%). Changes to no gravel.	8 12 16
23						
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24		SPT16			SPT 16 - Recovered 0.33 m (54%). Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact to dense, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	7 13 16
25		SPT17			SILT (ML) Sandy,low plasticity, very stiff to hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 17 - Recovered 0.49 m (80%). Sand changes to dense, silt changes to hard.	12 13 18
26						
27		SPT18			SPT 18 - Recovered 0.31 m (51%). Sand changes to compact, silt changes to very stiff. SAND (SP) 0.0% gravel, 92.9% sand, 7.1% fines.	9 12 15
28						
29						
30		SPT19			SPT 19 - Recovered 0.31 m (51%). Sand changes to dense, silt changes to hard.	11 18 27
31						
32						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact to dense, maximum particle size = 2 mm, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, very stiff to hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
33		SPT20			SPT 20 - Recovered 0.49 m (80%). Sand changes to compact, silt changes to very stiff.	10 14 15
34						
35						
36		SPT21			SPT 21 - Recovered 0.42 m (69%). Sand changes to dense, silt changes to hard.	17 21 29
37						
38		SPT22			SPT 22 - Recovered 0.35 m (57%).	18 19 20
39		SPT23			SPT 23 - Recovered 0.33 m (54%).	10 14 20
40						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
40					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, dense to very dense, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness.	
41		SPT24			SILT (ML) Sandy,low plasticity, hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 24 - Recovered 0.61 m (100%).	8 17 22
42		SPT25			SPT 25 - Recovered 0.57 m (93%).	9 14 24
43						
44		SPT26			SPT 26 - Recovered 0.29 m (48%). Sand changes to very dense.	16 26 30
45						
46		SPT27			SPT 27 - Recovered 0.47 m (77%). Sand changes to dense.	18 23 22
47		SPT28			SPT 28 Recovered 0.55 m (90%). Sand changes to very dense.	14 21 31
48						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
48					Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to and silt, poorly graded, dense to very dense, subrounded to rounded, grey, no odour, moist, laminated to stratified, weak cementation, visible muscovite and quartz, trace organics: woody, dark brown, flat, occur in layers 20 mm or less in thickness. SILT (ML) Sandy,low plasticity, hard, grey, no odour, drier than plastic limit, laminated to stratified, weak cementation, no dilatancy. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
		SPT29			SPT 29 - Recovered 0.53 m (87%). Sand changes to dense.	12 19 23
49						
		SPT30			SPT 30 - Recovered 0.62 m (101%). SAND (SM) 0.1% gravel, 50.1% sand, 49.8% fines.	13 18 21
50						
51						
		SPT31			SPT 31 - Recovered 0.68 m (111%).	11 15 21
52						
53		SPT32			SPT 32 - Recovered 0.62 m (101%).	11 21 24
54						
		SPT33			SPT 33 - Recovered 0.54 m (89%).	14 20 22
55						
56						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

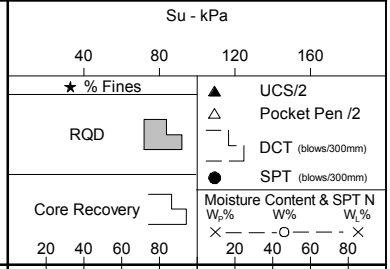
(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,624E, 5,619,120N
Ground Elevation (m): 342.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 700
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: N/A **Cased To (m)**:
Depth To Rock (m):

Start Date: 07 Dec 14
Finish Date: 09 Dec 14
Final Depth of Hole (m): 61.0
Logged by: SHA
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
56						
		SPT34			SAND (SM) Fine to medium, some silt, poorly graded, very dense, maximum particle size = 2 mm, subrounded to rounded, equidimensional to flat, grey, no odour, moist, heterogeneous, weak cementation, visible muscovite, no foreign materials. [FLUVIAL] SPT 34 - Recovered 0.43 m (70%).	20 28 33
57						
		SPT35			SPT 35 - Recovered 0.28 m (46%).	12 37 48
58						
59		SPT36			SPT 36 - Recovered 0.44 m (72%).	20 27 30
60						
		SPT37			SPT 37 - Recovered 0.28 m (46%).	20 31 36
61					Borehole completed at target depth of 61.0 m below ground surface. Borehole grouted to surface with bentonite grout. No instrumentation installed. SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586. Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
62						
63						
64						



Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [FLUVIAL]	
1						
2		SPT 01			SPT 01 - Recovered 0.46 m (75%).	3 2 2
3		SPT 02			SPT 02 - Recovered 0.49 m (80%). Lenses of sand have orange oxidation staining. SAND (SP) 0.0% gravel, 94.3% sand, 5.7% fines. Water level measured at 3.20 m below ground surface on December 10, 2014.	4 4 3
4						
5		SPT 03			SPT 03 - Recovered 0.50 m (82%).	4 3 4
6		SPT 04			SPT 04 - Recovered 0.32 m (52%). Changes to some fine gravel. SAND (SP) 10.1% gravel, 86.4% sand, 3.5% fines.	3 2 2
7					6.8 m - Thin layer (<10 cm) of 10% drilling fluid circulation loss.	
8		SPT 05			SPT 05 - Recovered 0.48 m (79%). Changes to trace fine gravel.	4

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					SAND (SP) Fine to medium, trace silt, trace fine gravel, poorly graded, loose, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [FLUVIAL]	5 5
9		SPT 06			SPT 06 - Recovered 0.38 m (62%).	5 5 3
10						
11		SPT 07			SPT 07 - Recovered 0.38 m (62%). SAND (SP) 0.2% gravel, 95.9% sand, 3.9% fines. Drilling fluid circulation loss of 15% begins; was resolved at 23.5 m depth with modification of drilling mud density.	3 3 4
12						
13		SPT 08			SAND (SP) Fine to medium, trace silt, poorly graded, loose to compact, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT] SPT 08 - Recovered 0.57 m (93%). Changes to no gravel.	4 4 3
14		SPT 09			SPT 09 - Recovered 0.52 m (85%).	5 4 4
15						
16		SPT 10			SPT 10 - Recovered 0.39 m (64%).	4 4 5

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16						
17		SPT 11			SPT 11 - Recovered 0.54 m (89%). Changes to compact.	6 7 8
18						
19		SPT 12			SPT 12 - Recovered 0.40 m (66%).	9 9 8
20		SPT 13			SPT 13 - Recovered 0.43 m (71%). SAND (SP) 0.8% gravel, 94.3% sand, 4.9% fines.	7 7 7
21						
22		SPT 14			SPT 14 - Recovered 0.37 m (61%).	8 8 8
23		SPT 15			SPT 15 - Recovered 0.38 m (62%).	7 7 7
24						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24					SAND (SP) Fine to medium, trace silt, poorly graded, compact, maximum particle size = 10 mm, rounded, equidimensional, grey, no odour, moist, heterogeneous, weak cementation, trace woody organics. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	
25		SPT 16			SPT 16 - Recovered 0.56 m (92%).	7 8 7
26		SPT 17			Interbedded SAND and SILT SAND (SP-SM) Fine to medium, trace to some silt, poorly graded, compact, maximum particle size = 4 mm, rounded, equidimensional, grey, faint organic odour, laminated to stratified, weak cementation, trace woody organics. SILT (ML) Sandy, low plasticity, very stiff, grey, faint organic odour, laminated to stratified, weak cementation, no foreign materials. [GLACIOLACUSTRINE - FRASER GLACIATION, KAMLOOPS DRIFT]	8 7 10
27					SPT 17 - Recovered 0.58 m (95%). SAND (SP-SM) 0.0% gravel, 88.7% sand, 11.3% fines.	
28		SPT 18			SAND (SP) Fine to coarse, trace silt, poorly graded, compact, maximum particle size = 4 mm, rounded, equidimensional, grey, no odour, wet, heterogeneous, weak cementation, no foreign materials. [GLACIOFLUVIAL] SPT 18 - Recovered 0.44 m (72%).	6 6 7
29		SPT 19			SPT 19 - Recovered 0.54 m (89%).	8 8 10
30						
31		SPT 20			SPT 20 - Recovered 0.53 m (87%).	9 10 11
32						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,722E, 5,618,732N
Ground Elevation (m): 343.0
Datum: NAD83 UTM Zone 10U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT 750
Drilling Contractor: Foundex Explorations
Drill Method: Mud Rotary
Fluid: Bentonite Mud
Casing: **Cased To (m)**:
Depth To Rock (m):

Start Date: 09 Dec 14
Finish Date: 10 Dec 14
Final Depth of Hole (m): 35.7
Logged by: ERM
Reviewed by: LDM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
32						
		SPT 21			SPT 21 - Recovered 0.38 m (62%). Changes to trace fine gravel. SAND (SP) 0.3% gravel, 95.0% sand, 4.7% fines.	7 7 8
33						
		SPT 22			SPT 22 - Recovered 0.68 m (111%). Changes to no gravel.	10 15 16
34						
35						
		SPT 23			SPT 23 - Recovered 0.51 m (84%).	10 13 11
36					Borehole completed at target depth of 35.7 m below ground surface. Borehole grouted to surface with bentonite grout. No instrumentation installed.	
					SPT Sampler Details: 60.1 cm in length, 5.1 cm diameter, driven by a 63 kg automatic trip hammer that was dropped 76 cm above the anvil. All SPT Sampling was carried out in accordance with ASTM D1586.	
37					Coordinates were recorded using a handheld GPS. Elevation based on LiDAR survey provided by Kinder Morgan and received on April 18, 2014.	
38						
39						
40						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

AUGER HOLE # AH-BGC16-CHW-01

Project: Trans Mountain Expansion Project
Project No.:0095-150-16

Reference #: TP 847.503 - 1
Location: T3810.0 & T3808.0, Chuwhels Station

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 681,779E; 5,618,597N
Ground Elevation (m): 342.6
Datum: NAD83 UTM Zone 10U

Drill Designation: Marl M5T
Drilling Contractor: Mobile Augers
Drill Method: 6" Solid Stem Auger
Auger Size: 6"
Depth to Water (m): 2.6

Drill Date: 07 Oct 16
Final Depth of Hole (m): 6.1
Logged by: YY
Reviewed by: LDM
Approved by: AJB

Depth (m)	Sample Type	Sample No.	Symbol	Lithologic Description
0				[ORGANICS] Topsoil, rootlets; brown, moist.
				CLAY (CL) And sand, silty, some gravel, low plasticity, soft to firm, brown, drier than plastic limit, no cementation, organic odour, mottled red and orange oxidation, scattered organics, slow to no dilatancy. Coarse fraction is subrounded, some angular, equidimensional, max observed particle size = 55 mm. [FLUVIAL]
1				
				1.4 m - Material becomes stiff. 1.5 m - Material grades to some clay, some gravel, near plastic limit. S1 (1.52 - 3.05 m) Laboratory analysis results: 15% gravel, 35% sand, 37% silt, 13% clay, moisture content 16.3%, fines classify as CL with LL = 29%, PI = 11%.
2		S1		
				CLAY (CL) Some silt, trace fine sand, trace gravel, low plasticity, stiff, grey, wetter than plastic limit, heterogeneous, no cementation, no odour, no weathering, no organics, no dilatancy. Coarse fraction is subangular to subrounded, equidimensional, max observed particle size = 55 mm. [GLACIOLACUSTRINE] 2.6 m - Interpreted water table. Material becomes wetter than plastic limit. 3.0 m - Material becomes grey mottled with brown weathering discolouration.
3				
		S2		GRAVEL (GC) Some clay, some silt, trace sand, well graded, dense, angular to subrounded, equidimensional, grey, wet, heterogeneous, no cementation, no odour, no weathering, no foreign materials, max observed particle size = 55 mm. Fine fraction is near plastic limit, low plasticity and no dilatancy. [TILL] 4.6 m - Material grades to and sand, clayey, trace silt, very dense.
4				
5				
6				End of hole at 6.1 m.
				NOTES: 1. Auger hole terminated at 6.1 m of 5.0 m target depth. DCPT-BGC16-CHW-01 encountered refusal at 4.9 m. 2. Water table interpreted at 2.6 m from increase in moisture content. 3. Hole backfilled with cuttings and bentonite chips. 4. Soil relative density/consistency estimated from auger drill action and DCPT completed at the same coordinates as AH-BGC16-CHW-01 prior to auger drilling. 5. Soil structure interpreted from disturbed soil samples obtained from auger flights. 6. Auger hole coordinates obtained with Garmin GPSMAP 62s handheld GPS, accuracy +/- 3 m. Ground elevation based on LiDAR (McElhanney, April 2014).
7				
8				

Su - kPa: 40, 80, 120, 160
VANE PEAK ◆ REMOLD ◇ FIELD ◆ LAB ■ □ ★ % Fines
Moisture Content: W_P% × 20 — W% ○ 40 — 60 — W_L% × 80

KINDER MORGAN (AUGER_FIGURE) KINDERMORGAN_AUGER.GDL BGC.GDT 4/13/17

DRILL HOLE # SD-BGC17-KLP-04

Reference Number: KP 0841.25
Location: Kamloops Airport, BC

Project No.: 0095-150-16

Survey Method: Handheld GPS
Co-ordinates (m): 681,529E, 5,620,694N
Ground Elevation (m): 344.1
Datum: NAD83 UTM ZONE 10U
Dip (degrees from horizontal): 90
Direction: N/A

Drill Designation: Compact Roto Sonic
Drilling Contractor: Downrite Drilling
Drill Method: Sonic
Fluid: Water
Casing: 5.75" Matrix Thread **Cased To (m)**: 10.7
Depth To Rock (m): N/A
Depth To Water (m): N/A

Start Date: 27 Nov 17
Finish Date: 27 Nov 17
Final Depth of Hole (m): 10.7
Logged by: VPC
Reviewed by: LDM
Approved by: AB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
0					ORGANICS, clayey, dark brown, very soft [TOPSOIL]
					SAND (SM) Fine to medium, and silt to silty, trace clay, well-graded, compact, equidimensional to flat, subrounded to subangular, grey, dry to wet, laminated, maximum particle size 1 mm, fines are low plasticity, medium to rapid dilatancy, moderate orange weathering discoloration, trace decomposed organics [FLUVIAL]
1					0.45 - 1.5 m - Silt, some fine sand, some clay, dry, trace organics
					1.7 m - Transitions from 'and' silt to silty, moist
2					
3					2.75 - 3.05 m - Orange weathering discoloration becomes intense
4					3.7 m - Becomes grey, moist, laminated to stratified, decomposed organics as layers up to 10 mm
					4.6 m - Becomes wet
5		S1			S1 (4.8 - 5.0 m) Laboratory analysis results: 0% gravel, 51.8% sand, 43.2% silt, 5% clay, moisture content 39.5%. Fines classify as NP.
6					
7					
8					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UCS/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

DRAFT

(Continued on next page)

Survey Method: Handheld GPS
Co-ordinates (m): 681,529E, 5,620,694N
Ground Elevation (m): 344.1
Datum: NAD83 UTM ZONE 10U
Dip (degrees from horizontal): 90
Direction: N/A

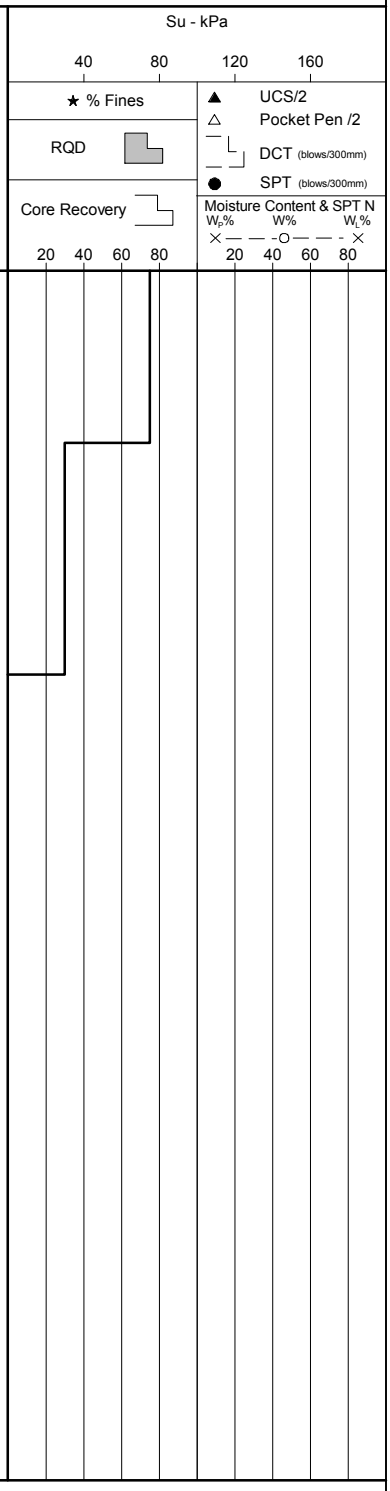
Drill Designation: Compact Roto Sonic
Drilling Contractor: Downrite Drilling
Drill Method: Sonic
Fluid: Water
Casing: 5.75" Matrix Thread **Cased To (m)**: 10.7
Depth To Rock (m): N/A
Depth To Water (m): N/A

Start Date: 27 Nov 17
Finish Date: 27 Nov 17
Final Depth of Hole (m): 10.7
Logged by: VPC
Reviewed by: LDM
Approved by: AB

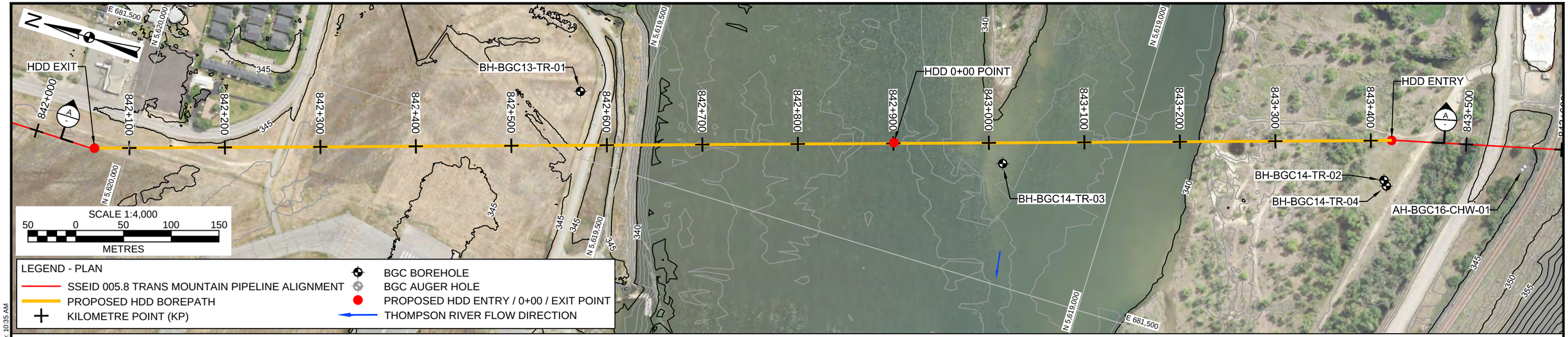
Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8					9.1 m - Poor recovery due to granularity and saturation of soil, sample partially lost upon retrieval of core barrel	
10					End of Hole at 10.7 m.	

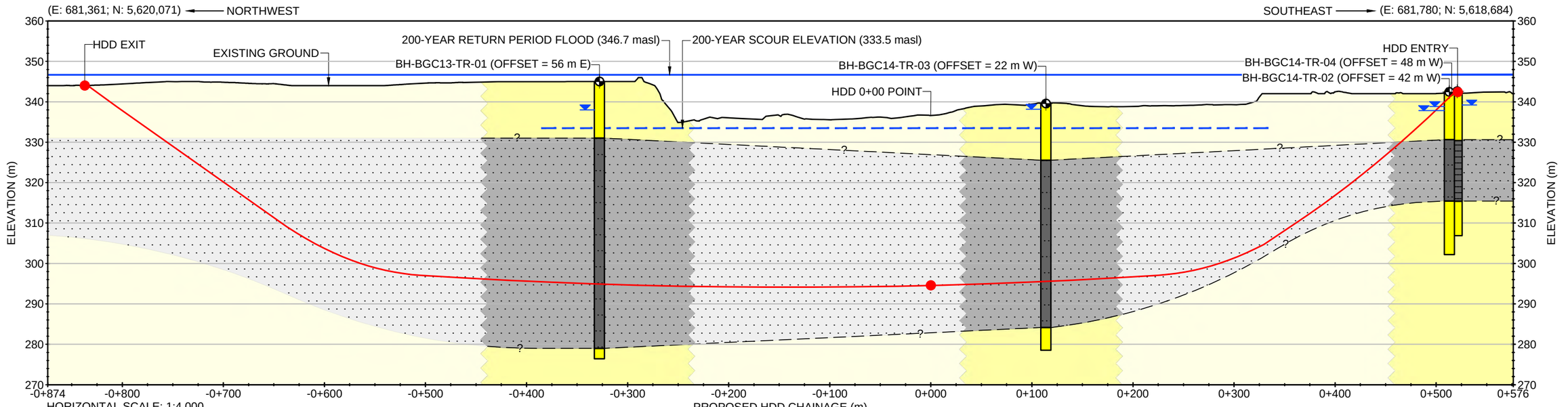
NOTES:
1. Sonic hole terminated at target depth.
2. The location of the water table was not measured during drilling as the sonic drilling method disturbs the natural moisture condition of the soil, and installation of casing prevents accurate measurement of the groundwater table.
3. Hole backfilled with drill cuttings and bentonite chips.
4. Soil structure and relative density/consistency assumed based on disturbed soil samples from sonic flights.
5. Sonic hole coordinates obtained with Garmin GPSMAP 62s handheld GPS, accuracy +/- 3 m. Ground elevation based on LiDAR (McElhanney, April 2014).

DRAFT



Appendix D – Interpreted Geological Section at Thompson River





HORIZONTAL SCALE: 1:4,000
VERTICAL SCALE: 1:1,000 (4x VERTICAL EXAGGERATION)

CROSS-SECTION A

CROSS-SECTION AT BEARING 162.7°

SCALE 1:4,000
50 0 50 100 150
METRES

GROUNDWATER OBSERVATIONS			
BOREHOLE	INFERRED WATER LEVEL (mbgs)	WATER LEVEL ELEVATION (masl)	COMMENTS
BH-BGC13-TR-01	7.4	337.6	OBSERVED IN OPEN HOLE WITH CASING AT 2.7 m DEPTH ON NOVEMBER 16, 2013
BH-BGC14-TR-02	3.6 / 4.6	338.4	RECORDED FROM VWPS INSTALLED AT 15.0 mbgs AND 20.0 mbgs, ON DECEMBER 8, 2014
BH-BGC14-TR-03	1.4	340.6	OBSERVED IN OPEN HOLE WITH NO CASING ON DECEMBER 9, 2014
BH-BGC14-TR-04	3.2	339.8	OBSERVED IN OPEN HOLE WITH NO CASING ON DECEMBER 9, 2014

BOREHOLE | INTERPRETED GEOLOGY | DESKTOP INTERPRETED GEOLOGY
FLUVIAL / GLACIOFLUVIAL SAND AND GRAVEL
GLACIOLACUSTRINE SILT AND SAND

LEGEND - CROSS-SECTION
PROPOSED HDD PROFILE
GROUND SURFACE (2014)
BGC BOREHOLE
PROPOSED HDD ENTRY / 0+00 / EXIT POINT
INFERRED WATER LEVEL
INFERRED GEOLOGICAL INTERFACE
200-YEAR RETURN PERIOD FLOOD
200-YEAR SCOUR ELEVATION

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9", AND DATED JULY 2018.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY UPI LTD., DATED SEPTEMBER 25, 2014. CONTOUR INTERVAL IS 1.0 m.
4. BATHYMETRIC SURVEY DATA PROVIDED BY OPUS STEWART WEIR, DATED JUNE 3, JUNE 24, JULY 19 TO 22, AND JULY 26, 2014.
5. IMAGE SOURCE: ESRI WORLD IMAGERY SERVER RETRIEVED FROM BING IMAGERY.
6. PROPOSED TMEP SSEID 005.8 PIPELINE ALIGNMENT PROVIDED BY KMC, DATED MAY 2018. PROPOSED HDD ALIGNMENT PROVIDED BY UPI, DRAWING NO. 01-13283-M002-XD00160-01 REV 2A, ISSUED APRIL 25, 2018.
7. PREDICTED 200 YEAR FLOOD LEVEL IS BASED ON A CROSS-SECTIONAL GEOMETRY ONLY AND MAY NOT REFLECT THE TRUE EXTENT OF OVERBANK FLOODING.
8. PROJECTION IS UTM NAD83 ZONE 10.
9. SPECIFIC OBSERVATIONS PERTAINING TO THE WATER LEVEL MEASUREMENTS ARE AVAILABLE IN THE REPORT.
10. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR
11. ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AS SUCH THIRD PARTIES' SOLE RISK.

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

SCALE:	1:4,000
DATE:	JUL 2018
DRAWN:	CR
CHECKED:	SAA
APPROVED:	KSJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - THOMPSON RIVER AT SSEID 005.8 KP 842.9

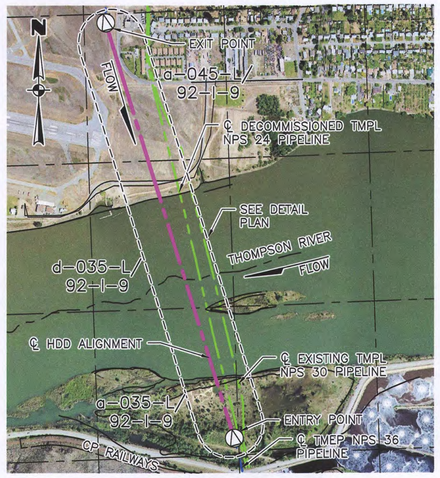
TITLE: INTERPRETED GEOLOGIC CROSS-SECTION

PROJECT No.: 0095-150

DWG No.: 02

T:\Geomatics\Projects\0095\CAD\Production\Report-Memo\20170720_GEOTECHNICAL_HDD_FEASIBILITY_ASSESSMENT_DRAWINGS\THOMPSON_RIVER_KP_812.9\02.dwg Layout: RM-B-SIZE Plot Date: Jul 3 18 Time: 10:35 AM

Appendix E – HDD Crossing Plan and Profile, Thompson River



LOCATION PLAN

SCALE 1:10000
a-035-L/92-I-9 – a-045-L/92-I-9
REGIONAL DISTRICT OF THOMPSON-NICOLA
NAD83 UTM ZONE 10N
APPROX. TMEP KP 842.9

GENERAL NOTES

A1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN. ALL ELEVATIONS ARE GEODETIC. ALL CHAINAGES ARE HORIZONTAL.

A2. DRAWING SCALES ARE ONLY CORRECT WHEN PLOTTED AT FULL SIZE (A1).

A3. ALL WORK IN CLOSE PROXIMITY TO POWER LINES MAY BE SUBJECT TO ELECTROSTATIC AND ELECTROMAGNETIC INDUCED VOLTAGES. CONTRACTOR SHALL BE RESPONSIBLE FOR MONITORING AND IMPLEMENTING MITIGATION PROCEDURES. CONTRACTOR SHALL IMPLEMENT THESE PRECAUTIONS AS WELL AS THOSE SPECIFIED BY TRANS MOUNTAIN REPRESENTATIVE.

A4. THE CONTRACTOR SHALL ENSURE THAT ALL UTILITIES ARE PROTECTED AND MAINTAINED THROUGH THE CONSTRUCTION PROCESS.

A5. THE CONTRACTOR SHALL ENSURE THAT COPIES OF THE CROSSING AGREEMENTS ARE KEPT ON SITE FOR THE FULL DURATION OF THE CONSTRUCTION ACTIVITIES. CONTRACTOR SHALL ADHERE TO ALL REQUIREMENTS OF THE CROSSING AGREEMENTS.

A6. SURVEYED BASE PLAN SHOWN ARE EXTRACTED FROM SURVEY DRAWINGS 37112-THOMPSONRIVERX-9219-WC-113-R2, DATED NOV. 24, 2014, AND 38290-BASE-9219L-R9 DATED JANUARY 20, 2017, PROVIDED BY OPUS STEWART WEIR LTD. (OSW). THE GROUND PROFILE IS GENERATED FROM LIDAR DATA SUPPLIED BY McELHANNEY LAND SURVEYS LTD. DATED 2008.

A7. CONSTRUCTION SHALL BE COMPLETED IN ACCORDANCE WITH CSA Z662 (CURRENT VERSION), AND THE MOST RECENT VERSIONS OF ALL PROVINCIAL AND FEDERAL REGULATIONS, ENVIRONMENTAL PROTECTION PLAN (EPP), CONTRACT DOCUMENTS, AND THE AUTHORITIES HAVING JURISDICTION.

A8. THE CONTRACTOR SHALL SUPPLY AND ADHERE TO THE CONTRACTOR SUPPLIED AND APPROVED DRILLING EXECUTION PLAN.

CONSTRUCTION NOTES

B1. CONSTRUCTION METHOD FOR THIS CROSSING IS THE HORIZONTAL DIRECTIONAL DRILL METHOD (HDD). FOR HDD CONSTRUCTION SPECIFICATIONS REFER TO THE CONTRACT DOCUMENTS.

B2. THE CONTRACTOR SHALL VERIFY ALL TOPOGRAPHICAL SURVEY INFORMATION AND CONFIRM THE DEPTH AND LOCATION OF ALL BURIED FACILITIES IN THE FIELD PRIOR TO CONSTRUCTION.

B3. THE CONTRACTOR SHALL SUPPLY A DRILL RIG WITH A MINIMUM OF 900,000 LBF (4,003 kN) PUSH/PULL WITH APPROPRIATE ASSOCIATED EQUIPMENT AS OUTLINED IN THE SPECIFICATIONS. THE THEORETICAL PULL FORCE FOR THIS CROSSING IS 870,000 LBF (3,870 kN) WITHOUT BUOYANCY CONTROL AND 360,000 LBF (1,601 kN) WITH 100% BUOYANCY CONTROL.

B4. THE CONTRACTOR SHALL SUPPLY AN ELECTRONIC DRILLING RECORDER (EDR) TO MONITOR AT A MINIMUM, TANK/PIT VOLUME, FLOW (PUMP AND RETURN), PRESSURE (ANNULAR/STANDPIPE), RATE OF PENETRATION, PUSH/PULL FORCE, ROTARY TORQUE, AND ROTATIONAL SPEED, PROVIDE THIS ELECTRONIC INFORMATION TO TRANS MOUNTAIN REPRESENTATIVE AND ALSO SUBMIT AS A PART OF THE AS-BUILT RECORDS REQUIRED AT THE END OF THE PROJECT.

B5. THE CONTRACTOR SHALL SUPPLY AND USE AN APPROVED ANNULAR PRESSURE TOOL WITH THE CONTRACTOR SUPPLIED ANNULAR PRESSURE MODEL.

B6. ALL EQUIPMENT SHALL BE SUPPLIED IN GOOD WORKING ORDER MAINTAINED AND SERVICED. ANY EQUIPMENT NOT OPERATIONAL OR FULFILLING THE REQUIREMENTS OUTLINED IN THE CONTRACT DOCUMENTS SHALL BE REPAIRED OR REPLACED.

B7. SURFACE CASING AT THIS CROSSING, IF REQUIRED TO ASSIST/SECURE DRILLING FLUID CIRCULATION OR TO PREVENT HOLE COLLAPSING NEAR THE SURFACE, SHOULD BE DETERMINED BY CONTRACTOR AND APPROVED BY TRANS MOUNTAIN REPRESENTATIVE.

B8. THE CONTRACTOR SHALL SUPPLY A CASING PLAN (IF REQUIRED) WHICH SHALL INCLUDE SIZE OF CASING, INSTALLATION METHOD, CLEANOUT PROCEDURE, REMOVAL PROCEDURE, AND A DESCRIPTION OF THE CENTRALIZING CASING TO BE USED. THE CASING SHALL BE SEALED IN A COMPETENT FORMATION.

B9. THE PILOT HOLE SHALL BE INSTALLED AS CLOSE AS PRACTICAL TO THE PROPOSED DESIGN DRILL PATH WITH THE DESIGN INFORMATION SHOWN ON THE DRAWING. HORIZONTAL DEVIATION GREATER THAN ±2.0 m SHALL BE APPROVED BY TRANS MOUNTAIN REPRESENTATIVE PRIOR TO COMPLETION OF DRILL. DRILL PATH VERTICAL DEVIATION SHALL BE WITHIN ±2.0 m RADIAL DISTANCE OF THE DESIGN DRILL PATH. UNDER NO CIRCUMSTANCES SHALL THE PIPELINE BE INSTALLED OUTSIDE THE LEGAL PIPELINE EASEMENT.

B10. MINIMUM DEPTH OF COVER TO BE THE GREATER OF THIS DRAWING OR AS SPECIFIED IN CROSSING AGREEMENTS.

B11. THE DESIGN RADIUS FOR THE CROSSING IS 1000.0m. THE PILOT HOLE SHALL ADHERE TO THE FOLLOWING TOLERANCES:
- THE SINGLE JOINT RADIUS SHALL NOT BE LESS THAN 600.0m
- THE THREE JOINTS RADIUS SHALL NOT BE LESS THAN 800.0m

B12. THE MAKE-UP SECTION WILL BE LIKELY PLACED ON EXIT SIDE.

B13. PRODUCT PIPE SHALL BE ADEQUATELY SUPPORTED AT ALL TIMES DURING THE PIPE PULL BACK SO AS TO PREVENT OVERSTRESSING THE PIPE AND TO PROTECT THE PIPE COATING.

B14. THE COMPOSITION OF THE DRILLING FLUID USED SHALL BE LIMITED TO BENTONITE, FRESH WATER AND IF REQUIRED, TRANS MOUNTAIN REPRESENTATIVE APPROVED NON-TOXIC ADDITIVES. DURING DRILLING OR PIPE PULL OPERATIONS, NO SUBSTANCE SHALL BE ADDED TO THE DRILLING FLUID WITHOUT THE WRITTEN AUTHORIZATION OF TRANS MOUNTAIN REPRESENTATIVE.

ENVIRONMENTAL NOTES

C1. DISPOSAL OF DRILLING FLUID AND CUTTINGS WILL BE CONDUCTED IN A MANNER THAT ADHERES TO BRITISH COLUMBIA OIL AND GAS HANDBOOK – DRILLING WASTE MANAGEMENT CHAPTER.

C2. TO MINIMIZE THE POTENTIAL FOR INADVERTENT FLUID RELEASE TO SURFACE, CONTRACTOR SHALL ENSURE THAT MUD PRESSURE IS KEPT TO THE MINIMUM REQUIREMENT FOR CUTTINGS RETURN AND FOR MAINTAINING A CLEAN HOLE AND IN ACCORDANCE WITH THE CONTRACTOR SUPPLIED ANNULAR PRESSURE MODEL.

C3. FRAC WALKS SHALL BE CONDUCTED EVERY 4 HOURS (AS A MINIMUM), OR IMMEDIATELY AFTER A LOSS OF FLUID EVENT.

C4. TURBIDITY MONITORING AND SAMPLING REGIME SHALL BE IN PLACE PRIOR TO ANY DRILLING ACTIVITIES UNDER THE JURISDICTION OF FISHERIES AND OCEANS CANADA (DFO).

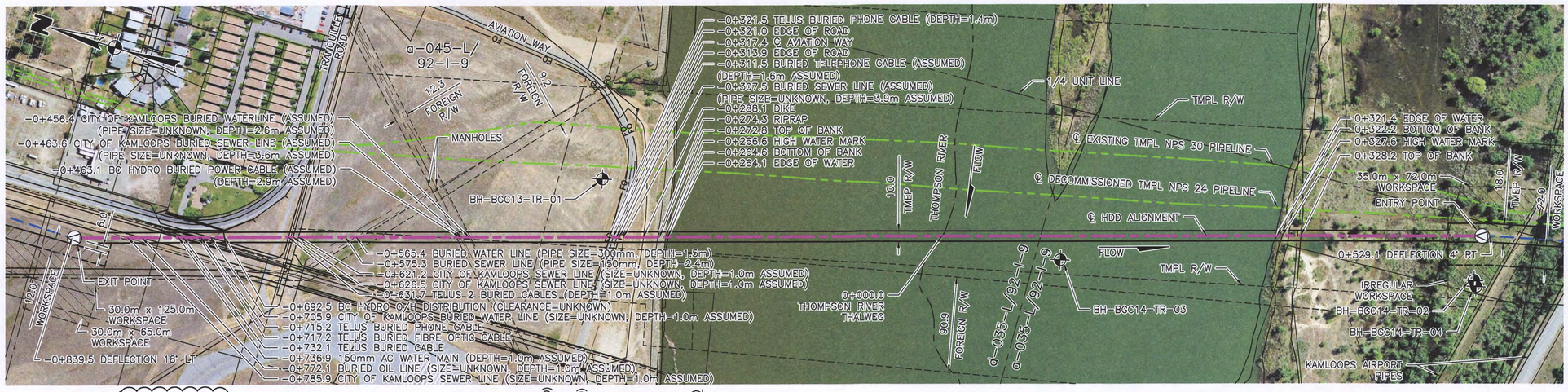
C5. SUITABLE EMERGENCY RESPONSE SPILL KITS ARE REQUIRED TO BE MAINTAINED ON SITE AT ALL TIMES.

GEOTECHNICAL INFORMATION

D1. GEOTECHNICAL BOREHOLE DATA ON THE DRAWING IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. FOR COMPLETE SOIL INFORMATION AND GROUNDWATER CONDITIONS, THE CONTRACTOR SHALL REFER TO GEOTECHNICAL DOCUMENT NO. 01-13283-S5A-0000-PL-RPT-0006 R0, FOR TRANS MOUNTAIN EXPANSION PROJECT – GEOTECHNICAL HDD FEASIBILITY ASSESSMENT THOMPSON RIVER AT SSEID 005.8 KP 842.9, DATED JULY 06, 2018. ALL GEOTECHNICAL INFORMATION PROVIDED BY BGC ENGINEERING INC. (4)

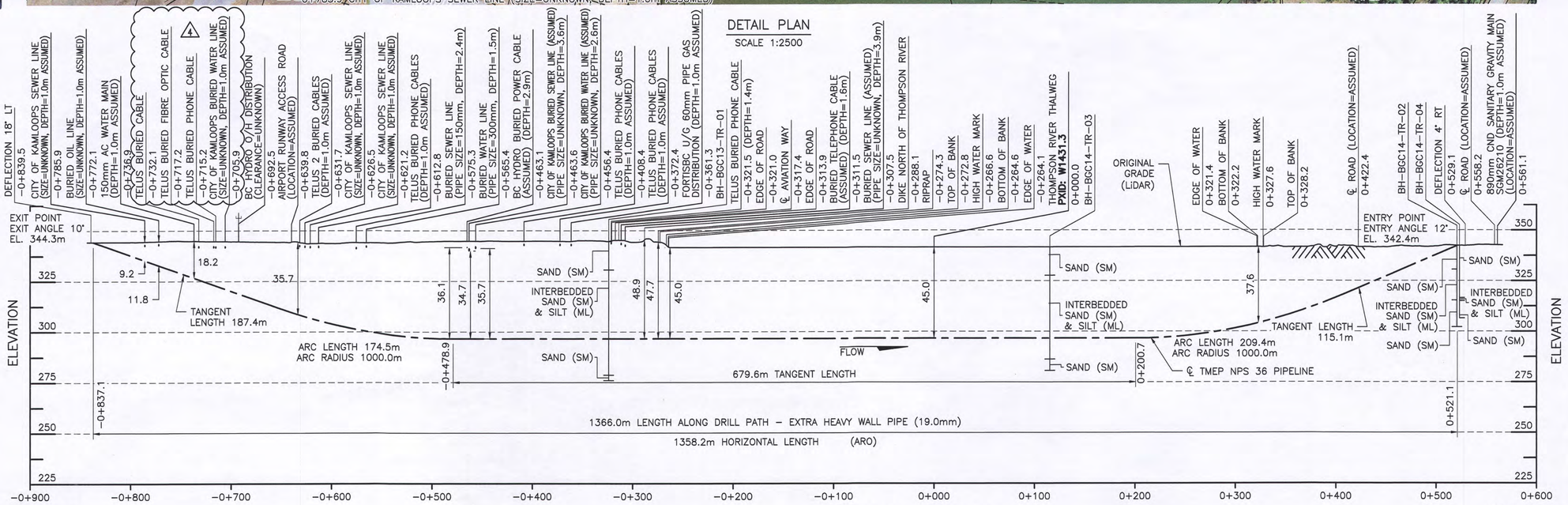
LEGEND

HDD ALIGNMENT
EXISTING TMPL PIPELINE
TMEP NPS 36 PIPELINE
BOREHOLE



DETAIL PLAN

SCALE 1:2500



PROFILE ALONG DITCHLINE

SCALES HORIZONTAL 1:2500 VERTICAL 1:1250

HDD FEATURE COORDINATES

(NAD83 UTM ZONE 10N)

	EASTING	NORTHING
ENTRY POINT	681767.0	5618737.9
0+000 POINT	681611.7	5619235.4
EXIT POINT	681362.2	5620034.5

BOREHOLE LOCATION

(NAD83 UTM ZONE 10N)

BOREHOLE	EASTING	NORTHING
BH-BGC13-TR-01	681567.0	5619565.0
BH-BGC14-TR-02	681724.0	5618733.0
BH-BGC14-TR-03	681624.0	5619120.0
BH-BGC14-TR-04	681719.0	5618729.0

PROJECT PIPE SPECIFICATIONS

PRODUCT	LOW VAPOUR PRESSURE (LVP) LIQUID HYDROCARBONS		
CLASS LOCATION DESIGNATION	N/A		
DESIGN PRESSURE	9,930 kPa		
MAXIMUM OPERATING PRESSURE	9,930 kPa		
MINIMUM TEST PRESSURE	12,413 kPa		
MINIMUM OPERATING TEMPERATURE	5 °C		
MAXIMUM OPERATING TEMPERATURE	38 °C		
PIPELINE DATA	CARRIER PIPE		
	LINE PIPE	HEAVY WALL PIPE	EXTRA HEAVY WALL PIPE
OUTSIDE DIAMETER OF PIPE (mm)	914.4 (NPS 36)	914.4 (NPS 36)	914.4 (NPS 36)
PIPE WALL THICKNESS (mm)	11.8	14.7	19.0
MINIMUM YIELD STRENGTH (MPa)	483	483	483
PIPE MATERIAL	STEEL, CSA Z245.1 (GRADE 483, CAT II)		
COATING	FUSION BOND EPOXY (FBE), ABRASION RESISTANT OVERCOAT (ARO)		
CATHODIC PROTECTION	IMPRESSED CURRENT		

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA

Feb. 14, 2019

THIS DRAWING IS PREPARED SOLELY FOR THE USE OF TRANS MOUNTAIN PIPELINE ULC, UPI PROJECTS CANADA LTD. ASSUMES NO LIABILITY TO ANY OTHER PARTY FOR ANY REPRESENTATIONS CONTAINED IN THIS DRAWING.

UniversalPegasus INTERNATIONAL
A Subsidiary of Huntington Ingalls Industries

UPI DWG. No.: 19731-505-HDW-00160-001

CLIENT ACCEPTANCE

NO.	DATE	REVISION	ACC
4	19/02/14	ISSUED FOR CONSTRUCTION, AFE 01-13283	

NO.	REFERENCE DRAWING TITLE	REFERENCE DRAWING NO.
2	PLANS AND PROFILES – THOMPSON RIVER	M002-XD0016002
1	ALIGNMENT SHEET	M002-PA0311301

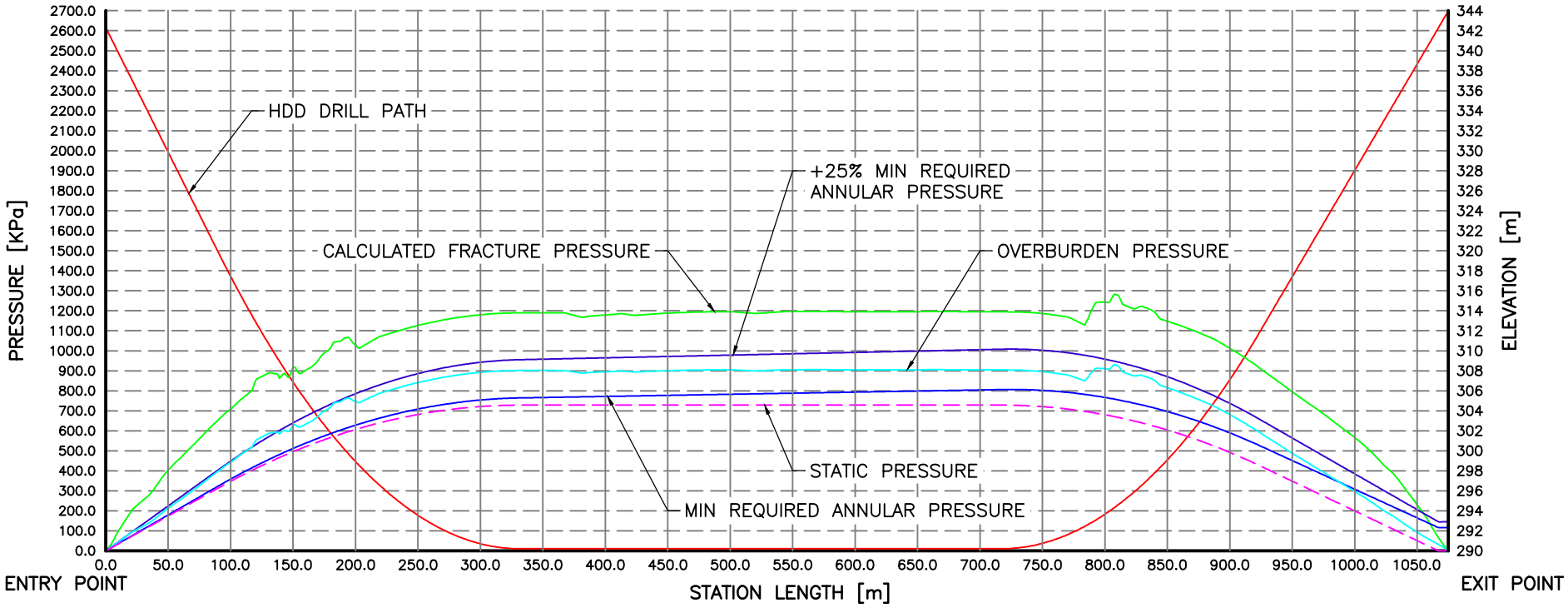
NO	DATE	REVISION	DRN	CHK	ENG	APPR
4	19/02/14	ISSUED FOR CONSTRUCTION, AFE 01-13283	BF			
3	18/05/24	ISSUED FOR CONSTRUCTION, AFE 01-13283	AL	RGR	MK	HB
2	17/07/25	ISSUED FOR CONSTRUCTION, AFE 01-13283	SAH	RGR	PL	JLM
1	17/07/06	ISSUED FOR CONSTRUCTION, AFE 01-13283	SAH	RGR	JM	JLM
0	17/04/04	ISSUED FOR CONSTRUCTION, AFE 01-13283	SAH	RGR	MK	AA

TRANS MOUNTAIN

DRAWN BY MF	TRANS MOUNTAIN EXPANSION PROJECT PLANS AND PROFILES		SHEET SIZE A1
CHECKED BY RGR			SCALE AS SHOWN
APPROVED BY BOM	THOMPSON RIVER d-035-L/92-I-9		DATE 14/10/06
PROJECT CODING AFE	DRAWING NUMBER FACILITY ID	DOCUMENT NO	SHT NO / REV
01-13283	M002	XD00160	01 / 4

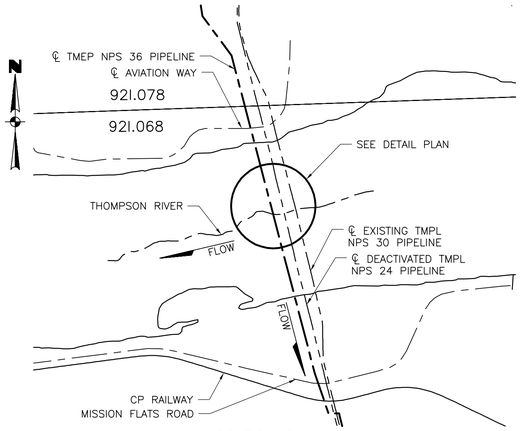
P:\19731 - Kinder Morgan TMX\81 Drafting\505 Pipeline Drawings\HDW - Horizontal Directional Drill\M002-XD0016001.dwg, 2/14/2019 11:04:38 AM, melanie.mcdonald

Appendix F – Hydrofracture Analysis, Thompson River



THOMPSON RIVER HDD CROSSING
ANNULAR PRESSURE CURVES

Appendix G – Preliminary Open Cut (Without Isolation) Crossing for Thompson River



LOCATION PLAN

SCALE 1:10000
BC 20K GRID: 92I.068
NAD83 UTM ZONE 10N

GENERAL NOTES

A1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN. ALL CHAINAGES ARE HORIZONTAL. ALL ELEVATIONS ARE GEODETIC.

A2. DRAWING SCALES ARE ONLY CORRECT WHEN PLOTTED AT FULL SIZE (A1).

A3. ALL WORK IN CLOSE PROXIMITY TO POWER LINES MAY BE SUBJECT TO ELECTROSTATIC AND ELECTROMAGNETIC INDUCED VOLTAGES. CONTRACTOR SHALL BE RESPONSIBLE FOR MONITORING AND IMPLEMENTING MITIGATION PROCEDURES. CONTRACTOR SHALL IMPLEMENT THESE PRECAUTIONS AS WELL AS THOSE SPECIFIED BY MANAGER.

A4. THE CONTRACTOR SHALL ENSURE THAT COPIES OF THE CROSSING AGREEMENTS ARE KEPT ON SITE FOR THE FULL DURATION OF THE CONSTRUCTION ACTIVITIES. CONTRACTOR SHALL ADHERE TO ALL REQUIREMENTS OF THE CROSSING AGREEMENTS.

CONSTRUCTION NOTES

B1. THE CROSSING SHALL BE CONSTRUCTED USING OPEN CUT (WITHOUT ISOLATION) CROSSING METHOD WITH WATER QUALITY MONITORING.

B2. THE CONTRACTOR SHALL VERIFY ALL TOPOGRAPHICAL SURVEY INFORMATION AND CONFIRM THE DEPTH AND LOCATION OF THE BURIED FACILITIES IN THE FIELD PRIOR TO CONSTRUCTION.

B3. THE MINIMUM DEPTH OF COVER SHOWN SHALL BE MAINTAINED FOR FULL DISTANCE BETWEEN THE SPECIFIED CHAINAGES AS SHOWN IN THE DRAWING. 'MINIMUM COVER' REFERS TO DISTANCE BETWEEN LOWEST POINT ON WATERCOURSE (THALWEG) TO TOP OF PIPE (T.O.P.) INCLUSIVE OF LAGGING, CONCRETE COATING, WEIGHTS, ETC.

B4. BACKFILLING SHALL IMMEDIATELY FOLLOW PIPE INSTALLATION USING NATIVE MATERIAL. STREAM BEDS SHALL BE GRADED TO CONFORM AS NEAR AS PRACTICABLE TO ORIGINAL PROFILES. BANKS SHALL BE GRADED TO ORIGINAL OR STABLE CONTOURS.

B5. REQUIREMENTS FOR BUOYANCY CONTROL AT CROSSING LOCATION WILL BE CONFIRMED BY MANAGER, IN ACCORDANCE WITH THE CONSTRUCTION SPECIFICATION, PRIOR TO INSTREAM ACTIVITIES.

B6. FINAL PLACEMENT OF DRAINS, DIVERSION BERMS, AND DITCH PLUGS SHALL BE DETERMINED BY MANAGER DURING CONSTRUCTION. ALL EXISTING DIVERSION BERMS SHALL BE EXTENDED, OR HERRINGBONED IF REQUIRED ACROSS THE RIGHT-OF-WAY.

B7. SPOIL SITES SHALL BE GRADED TO ENSURE WATER WILL NOT POND ON THE SURFACE OR BE TRAPPED BY THE SPOIL PILE.

B8. INSTALL TEMPORARY EROSION CONTROL MEASURES SUCH AS SILT FENCES AS NECESSARY TO CONSERVE SOIL DURING CONSTRUCTION AND TO PREVENT ANY SEDIMENTS FROM ENTERING THE WATERCOURSE.

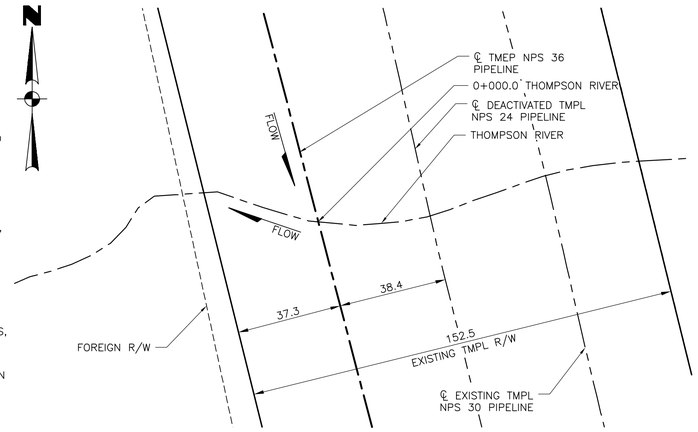
B9. WORK SHALL BE PLANNED TO KEEP TIME LENGTH OF INSTREAM ACTIVITY TO AN ABSOLUTE MINIMUM.

B10. CONSTRUCTION SHALL BE COMPLETED IN ACCORDANCE WITH CSA Z662 (CURRENT VERSION), ENVIRONMENTAL PROTECTION PLAN (EPP), CONTRACT DOCUMENTS, AND THE AUTHORITIES HAVING JURISDICTION.

SITE SPECIFIC NOTES

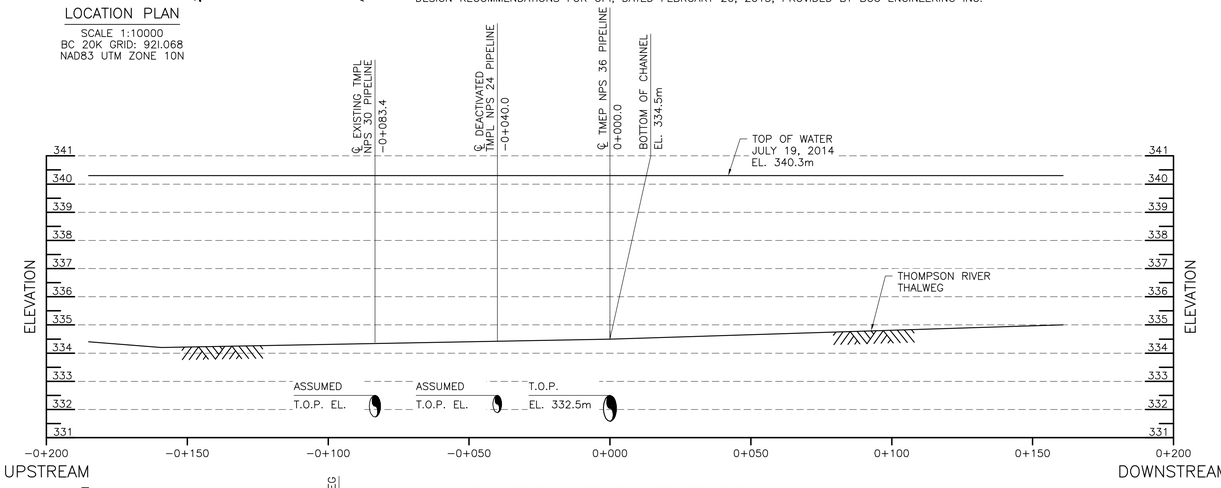
C1. SURVEYED BASE PLAN AND ELEVATIONS SHOWN ARE BASED ON SURVEY DRAWING DWG #, DATED DATE PROVIDED BY NAME. PIPELINE ALIGNMENT IS BASED ON CENTRELINE SSEID 001.

C2. HYDROTECHNICAL INFORMATION, SCOUR DEPTH, AND SET BACK DISTANCES ARE BASED ON TRANSMITTAL TITLED BGC-00373 WC CROSSINGS HDD CONTINGENCY DESIGN RECOMMENDATIONS FOR UPI, DATED FEBRUARY 20, 2015, PROVIDED BY BGC ENGINEERING INC.



DETAIL PLAN

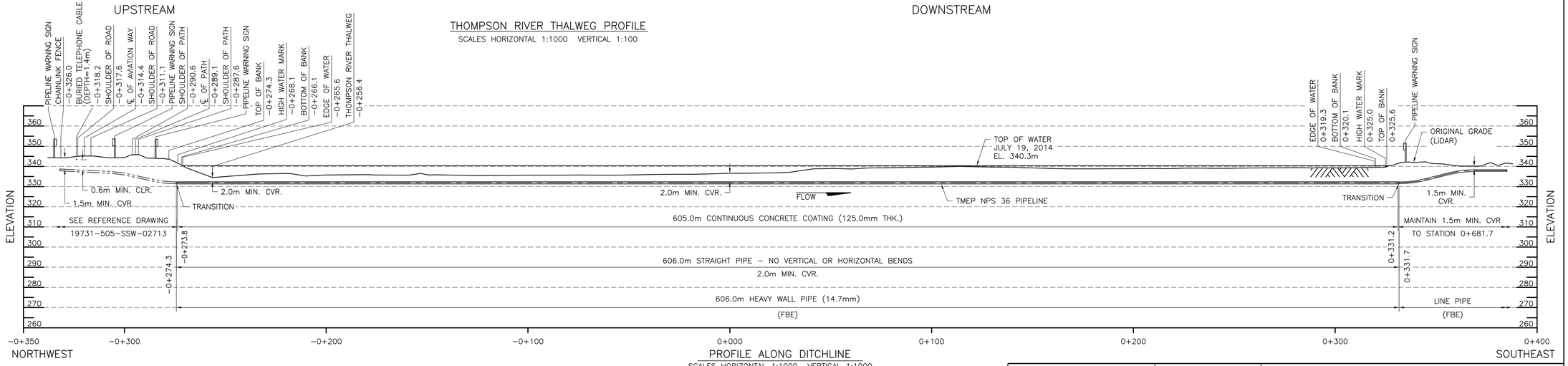
SCALE 1:1000



THOMPSON RIVER THALWEG PROFILE

SCALES HORIZONTAL 1:1000 VERTICAL 1:100

PIPE SPECIFICATIONS			
PRODUCT	LOW VAPOUR PRESSURE (LVP)		
CLASS LOCATION DESIGNATION	CLASS 1 (TO BE CONFIRMED)		
DESIGN PRESSURE	9,930 kPa		
MAXIMUM OPERATING PRESSURE	9,930 kPa		
MINIMUM TEST PRESSURE	12,413 kPa		
MINIMUM OPERATING TEMPERATURE	5°C		
MAXIMUM OPERATING TEMPERATURE	45°C		
PIPELINE DATA	CARRIER PIPE		CASING PIPE
	LINE PIPE	HEAVY WALL PIPE (14.7mm)	
OUTSIDE DIAMETER OF PIPE (mm)	914 (NPS 36)	914 (NPS 36)	N/A
PIPE WALL THICKNESS (mm)	11.8	14.7	N/A
MINIMUM YIELD STRENGTH (MPa)	483	483	N/A
PIPE MATERIAL	STEEL, CSA Z245.1 (GRADE 483, CAT II)		N/A
COATING	FUSION BOND EPOXY (FBE), ABRASION RESISTANT OVERCOAT (ARO)		N/A



PROFILE ALONG DITCHLINE

SCALES HORIZONTAL 1:1000 VERTICAL 1:1000

NOT FOR CONSTRUCTION

THIS DRAWING IS PREPARED SOLELY FOR THE USE OF TRANS MOUNTAIN PIPELINE ULC, UPI PROJECTS CANADA LTD. ASSUMES NO LIABILITY TO ANY OTHER PARTY FOR ANY REPRESENTATIONS CONTAINED IN THIS DRAWING.

UniversalPegasus INTERNATIONAL — A Subsidiary of Huntington Ingalls Industries

UPI DWG. No.: 19731-505-SSW-02715

TRANS MOUNTAIN

NO.	REFERENCE DRAWING TITLE	REFERENCE DRAWING NO.
2	ROAD CROSSING PLANS & PROFILES – AVIATION WAY RK 846.810	19731-505-SSW-02713
1	ALIGNMENT SHEET	19731-510-ALS-XXXXX

NO	DATE	REVISION	DRN	CHK	ENG	APPR
B	2015-02-24	ISSUED FOR NEB FILING	SB	RGR	BT	BOM
A	2014-12-30	ISSUED FOR REVIEW	MF	RGR	RS	BOM

DRAWN BY	MF
CHECKED BY	RGR
APPROVED BY	BOM

TRANS MOUNTAIN EXPANSION PROJECT
WATERCOURSE CROSSING PLANS & PROFILES
THOMPSON RIVER-CONTINGENCY PLAN
RK 846.820
BC 20K GRID: 92I.068

SHEET SIZE	A1
SCALE	AS SHOWN
DATE	14/11/04

PROJECT CODING	DRAWING NUMBER			
AFE	FACILITY ID	DOCUMENT NO	SHT NO	REV
	M002	XW-02715		B