Geotechnical Investigation
2045 Loseth Road

Prepared for:

City of Kelowna
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Attention: Rod MacLean, P.Eng.
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Prepared by:

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This is an electronic replica of the original signed and sealed report, provided for convenience. Westrek retains the original signed/sealed report on file and can provide an authenticated document if required.

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Table of Contents

List of Figures

Appendices

1 Introduction and Scope

Westrek Geotechnical Services Ltd. (Westrek) investigated several slope instabilities developing adjacent to the pump station along Loseth Road, near the corner with Sunrise Road, in Kelowna, BC. The purpose of the investigation was to assess slope stability, estimate the probability of a landslide and potential runout, and recommend methods to stabilize the slope.

The original scope of work was originally authorized by the Black Mountain Irrigation District (BMID) in a Client Service Agreement dated June 6, 2018. The City of Kelowna (the City) took over as lead authority for the project on December 3, 2018. The scope of consisted of:

- A review of available background information.
- A geotechnical subsurface investigation of the soils present on the slopes, in and around the observed movement.
- Installation and monitoring of slope inclinometers (SIs) and vibrating wire (VW) piezometers within several of the boreholes to measure slope displacement and groundwater pressure, respectively.
- A slope stability analysis to assess the mode and cause of the slope movement.
- Develop conceptual measures to stabilize the slope.

The services provided by Westrek are subject to the terms and conditions set out in the *Interpretation and Use of Study and Report and Limitations*, which is attached in Appendix A and incorporated herein by reference.

2 Investigation

2.1 Site Visit

Tim Smith, P.Geo., Eng.L., representing Westrek, conducted an initial site assessment on May 30, 2018, accompanied by Matt Cameron, P.Eng., with CTQ Consulting, and Kevin Burtsch and Toby Pike with BMID. A more thorough field assessment was conducted by Tim Smith and Eric McQuarrie, P.Eng., P.Geo., of Westrek on July 25, 2018. Visual observations and measurements were made of the terrain and drainage conditions, and the various areas of slope movement.

2.2 Background Documents

The following information was reviewed during this investigation:

- Environment Canada daily weather records for several weather stations in the Kelowna area.
- Environment Canada Climate Normals (1981 to 2010) for *Kelowna Airport*.
- *Surficial Geology of Kelowna.* Geological Survey of Canada. Open File 6146 (2009).
- *Geology of the Kelowna Tertiary Outlier.* BC Geological Survey. Preliminary Map 45. June 1981.
- Google Earth satellite imagery from 2002, 2004, 2005, 2006, 2009, 2012, 2015, 2016 & 2017.
- iKelowna Map Viewer [https://maps.kelowna.ca].
- *Kirschner Mountain Estates Loseth Road Plan/Profile – Sanitary and Storm*. *Dwg. No. PP001 Rev. No. 3.* As constructed January 5, 2005. City of Kelowna.

- *Geotechnical Investigation Proposed Subdivision, Garner Road Lot A, Section 13, Township 23, ODYD, Plan KAP48770 Kelowna, B.*C. Interior Testing Services Ltd. (ITSL) March 26, 2003.
- *Proposed Structural Fill Pumphouse, Kirschner Mountain Phase 1B*. Interior Testing Services Ltd. May 14, 2004.
- *Subdivision Development Kirschner Mountain Estates – Phase 1B and 2 Kelowna, B.C*. Interior Testing Services Ltd. May 18, 2004.
- *Daily Inspection Report No. 1 to 60. Kirschner Mt Estates Pump Station*. Agua Consulting Inc. (Agua) May 29, 2006 to October 19, 2006.
- *Proposed Pumphouse Kirschner Mountain Estates* – Phase 3. Interior Testing Services Ltd. June 6, 2006.
- *Proposed Multi-Family Development 2045 & 2062 Loseth Road, Kelowna, B.C*. Interior Testing Services Ltd. December 19, 2011.
- *Unnamed topographic plan showing pre-development contours reportedly from 2010.*

2.3 Drilling Investigation

Between August 3 and 19, 2018, thirteen bore holes were drilled using a track-mounted sonic drill rig supplied by Mud Bay Drilling. One bore hole was completed with a multidrill rig using ODEX methods.

- Bore holes BH18-01 and BH18-02 were drilled on the level area between the pump house and the slope.
- BH18-03 was drilled on the level paved area above the pump house.
- BH18-05, BH18-09, and BH18-10 were drilled along the northwest shoulder of Loseth Road;
- BH18-04, BH18-06, and BH18-08 were drilled within Loseth Road.
- BH18-11 and BH18-12 were drilled within the adjacent undeveloped lot at 2045 Loseth Road.
- BH18-13 and BH18-14 were drilled along the gravel trail midway along the slope.
- BH18-07 was eliminated because of the close proximity to underground services.

Twelve bore holes were terminated in bedrock, which ranged from 2.1 m depth in BH18-08, to 26.2 m depth in BH18-01. Two bore holes, BH18-13 and BH18-14, terminated in till at 10.7 and 8.5 m depth, respectively, without having encountered bedrock.

The sonic drill used 150 mm diameter casing to retrieve 100 mm diameter continuous core samples, logged in the field by Westrek. Selected samples were obtained for further testing, as described in Section 2.5. The soil consistency or density was determined in-situ by performing Dynamic Cone Penetration Tests (DCPTs) continuously through the fill in most of the boreholes. Standard Penetration Tests (SPTs) were conducted at 1.5 m intervals in BH18-13.

The drill rig was unable to access the base of the gully below the gravel trail; therefore, a test pit (TP18-15) was excavated instead. The test pit was dug with a Hitachi 210 excavator, provided and operated by BMID. The test pit advanced to practical refusal and terminated in till at 4.2 m depth.

The locations of the bore holes and test pit are shown on Drawing 01 in Appendix B, while the bore hole and test pit logs are included in Appendix C.

2.4 Instrumentation

Each bore hole was instrumented as summarized in Table 1 below.

Table 1: Summary of Borehole Instrumentation

Piezometer	Top of Hole Elev. (m)	Hole Depth (m)	Instrumentation
BH18-01	602.42	27.1	• Vibrating wire piezometer (#51703) • Slope inclinometer
BH18-02	602.14	18.0	• Vibrating wire piezometer (#51702) • Slope inclinometer
BH18-03	605.24	11.9	• Vibrating wire piezometer (#51704) • Slope inclinometer
BH18-04	606.29	5.8	• Vibrating wire piezometer (#51705) • Slope inclinometer
BH18-05	607.39	8.8	• Vibrating wire piezometer (#51711) • Slope inclinometer
BH18-06	607.99	5.8	• Vibrating wire piezometer (#51701) • Slope inclinometer
BH18-07	Not drilled due to underground utilities.		
BH18-08	609.4	2.1	• None
BH18-09	608.95	8.8	• Vibrating wire piezometer (#51708) • Slope inclinometer
BH18-10	611.7	5.8	• Slope inclinometer
BH18-11	610.15	14.0	• Vibrating wire piezometer (#51707) • Slope inclinometer
BH18-12	609.96	13.9	• Vibrating wire piezometer (#51709) • Slope inclinometer
BH18-13	588.96	10.7	• Vibrating wire piezometer (#51710) • Slope inclinometer
BH18-14	588.3	8.5	• None
TP18-15	573.1	4.4	• None

The piezometers are model VW2100 vibrating wire piezometers supplied by RST Instruments and all except BH18-09 are connected to a Model DT2011B single channel serial datalogger set to measure the piezometric pressure every 4 hours.

The slope inclinometers are 70 mm outside diameter PVC casing, also supplied by RST Instruments.

The initial reading of all instruments occurred on August 20, 2018 with subsequent measurements every week until October when the monitoring frequency was reduced to roughly every two weeks. The results to date are discussed in Section 6.

2.5 Laboratory Testing

A laboratory testing program was carried out to assist in characterizing the slope material and its engineering behaviour. Selected samples from the sonic bore holes and test pit were submitted for testing to Wood PLC's materials laboratory in Kamloops. The analyses carried out included fifty-six (56) moisture contents, seventeen (17) grain size distributions, including two (2) with hydrometer, and three (3) Atterberg limits.

The Atterberg limit testing yielded plasticity indices of 5.1 and 5.4 within the fill, indicating that the fines fraction (clay and silt) has low plasticity (CL-ML). The plasticity index in the colluvium in TP18-15 was 8.4%, which still classifies the soil as a CL.

The natural moisture contents of tested samples ranged from 4.2% in BH18-13 at 7.6 m depth to 21.2% in BH18-12 at 6.4 m depth.

The laboratory test results are provided in Appendix D and summarized on the bore hole logs.

3 Development History

The development history for the pump station site is summarized below based on information provided by BMID and the City; however, this information may not be complete.

- Loseth Road was constructed up to the intersection of Sunrise Court in 2004 (Loseth Road Plan Profile – as constructed).
- The pump station structural fill pad was placed and compacted up to the footing elevation from May 12 to May 21, 2004 (ITSL, May 14, 2004).
    - Specifications for the structural fill were maximum 300 mm lifts of silty sand and gravel, compacted to 95% modified Proctor dry density (ITSL, March 26, 2003).
    - A cursory review of the compaction testing results indicates the moisture content of the fill was well below optimum in several of the tests, despite having a modified Proctor result considerably higher than the target value. Given the moisture content results and variability of the fill, the validity of the Proctor Testing results are suspect and would need further review to confirm. Also, two separate Proctor values were used without explanation and the actual Proctor test results were unavailable for review.
    - It appears that compaction testing was only carried out on the structural fill beneath the building. No compaction test results were provided for the remainder of the fill pad.
    - The May 14, 2004 field memo states that "a 1H:1V splay for load spread is not practical. The existing stripped material has been stockpiled as a toe support for structural fill". It seems ITSL relied on a stockpile of stripped material to support the fillslope. The same memo states that "the slope will be graded to 1.5H:1V". Since this stockpile is no longer visible and the slope is much steeper than 1.5H:1V, either toe support was subsequently removed or it was buried within the fill as the fillslope was over-steepened.
    - Concerns regarding potential settlement of the fill, particularly if saturated, were noted in a memo from ITSL, dated May 18, 2004.

- The residence at 2001 Kloppenburg Court was constructed between 2003 and 2006. In 2006, an approximately 3 m high bench was present at the toe of the slope between the residence and the future location of the pump station (iKelowna Map Viewer).
- The pump station was constructed between June and October 2006 (Agua, 2006).
- During foundation preparation, the 2004 structural fill was exposed, and compaction testing was carried out at footing elevation. The foundation preparation was considered adequate for an allowable bearing pressure of 150 kPa (ITSL, June 6, 2006). Compaction testing results were not provided to us.
    - The field memo states that: "the existing fill slope appears well vegetated and stable at ± 1.5H:1V."
- The walking path extending from Kloppenburg Court appeared to be partially constructed in the 2009 City of Kelowna aerial photographs. No other information regarding construction of the walking trail was provided (iKelowna Map Viewer).
- Based on the City of Kelowna aerial photographs, the bench along the toe of the slope between the 2001 Kloppenburg Court residence and the pump station was removed and replaced with a stacked rock wall between 2012 and 2015 (iKelowna Map Viewer) (Figure 5). No additional information regarding this construction was provided to us.

The development history for the property at 2045 Loseth Road mainly involves placement of fill over various phases, as summarized below:

- The site was logged and much of the fill placed in summer of 2004 and November 2005. ITSL tested compaction of this material, although some of the fill placed in November 2005 was blasted rock (ITSL, December 19, 2011).
- The steep slope near the northeast end of the property was pushed out farther in 2006. The 2006 orthophoto or satellite image on iKelowna shows the slope formed by end-dumping waste soil (not rockfill) from the previous edge of slope. No compaction testing was reported during this phase of work.
    - ITSL's December 19, 2011 report post-dates this fill placements and states that the slope is stable at 1.25H:1V, but describes the slope as rockfill and does not provide any records showing that they inspected fill placement after November 2005.
- Additional filling began in 2009 closer to Loseth Road and working towards the southwest, continuing to 2017. No compaction testing was reported during this phase of work.
- The current stockpiles were placed in 2016 or 2017.

4 Site Conditions

4.1 Pump Station Area

Loseth Road climbs across the hill to the southwest while the hillslope has a northwesterly aspect. A pre-existing gully bisects the site and was completely filled in both at the pump station site and the upslope residential development. The pump station is constructed of reinforced concrete, built into a filled platform on the northwest side of the road. The asphalt paved access and the roof of the pump station are close to road grade while the filled platform steps 3 m down the slope to where the base of the pump station fully daylights (Photo 2).

The slope curves around the pump station, with both northwesterly and northerly aspects. The northwesterly slope (Figure 1, Cross-section A-A') is more than 60 m long, with the upper 12 m sloping between 80 and 90% (39 and 42°) (Photo 1). The slope forms a 2 to 3 m wide bench as part of the back yard at 2001 Kloppenburg Court. The slope then descends another 1.5 m onto the municipal trail, which is about 3 m wide, and then descends 5 to 6 m into the remnant gully. The gully slopes at 40% for another 10 m and then flattens to 20% towards Kloppenburg Road.

Photos 1 & 2: Gravel area and slope behind the pump station.

Immediately southwest of the pump station, the crest of the slope is located at the shoulder of the road where more tension cracks were observed. The slope below is approximately 18 m high sloping at 60% (31°) down to the gravel trail (Figure 2, Cross-section B-B').

The northerly slope (Figure 3, Cross-section C-C') descends 13 m into the backyard of 2001 Kloppenburg Court with an overall slope of 80 to 90% (39 to 42°). The toe of the slope was excavated in 2015 to install a pond. The lower 5 m was excavated steeper than 50° and supported by a single row of stacked boulders that have since failed (Photos 3 & 4). The City did not issue a building permit for this boulder-stack wall, and the wall thickness indicates that it was not engineered.

Tension cracks have formed in the gravel-surfaced platform at the rear of the pump station (Photo 2). The tension cracks are 2 to 3 m from the slope crest and 15 cm wide, with 10 to 15 cm of vertical displacement. The slope movement is also evident by bending of the top pole in the chain-link fence around the pump house compound and displacement between fence posts.

Although the greatest movement was observed close to the slope crest, at least 3 cm of vertical displacement is evident in the ground beneath the steel stairs leading to the pump station entrance, the concrete slab near the base of the stairs is cracked, and minor settlement cracks were noted in the concrete footing for the pump station. The above-ground transformer box adjacent to the pump station is not level. More noticeably, wide tension cracks were noted along the shoulder of Loseth Road, indicating that the slope has moved more than 15 cm.

Photo 3: The toe of the slope at 2001 Kloppenburg Court.

Photo 4: Setback of the house from the slope and failure of the boulder-stack wall.

4.2 2045 Loseth Road

The slope pulls farther away from Loseth Road southwest of the pump station, where a large relatively level area has been prepared for development. The ground surface has been capped with a blanket of granular material and several stockpiles of granular fill cover the area.

Here, the ground area has been obviously filled out, creating an over-steepened slope more than 20 m high or 30 m long. The overall slope angle is 80 to 85% (39 to 40°) but the lower 20 m slopes at close to 100% (45°) (Figure 4, Cross-section D-D′). Several wide tension cracks are located at various elevations, and the lower half of the slope is bulged, indicating slope movement.

The toe of the slope flattens to between 30 and 50% leading down to Kloppenburg Road. The area is undeveloped at this time and sparsely forested with conifer trees. The trees along the toe of the slope are more densely spaced, with some fill partially burying the base of the trunks.

Photo 5: Slope at 2045 Loseth Road.

Photos 6 & 7: Open tension cracks on slope.

5 Subsurface Conditions

5.1 Loseth Road

Boreholes BH18-03 to BH18-06 are located within Loseth Road or the outside shoulder.

The subsurface conditions beneath Loseth Road generally consists of loose fill placed over bedrock. The fill is predominantly sandy silt with some clay, trace gravel, and occasional cobbles and organic debris. The SPT blow counts in BH18-03 ranged from less than 5 blows/ft to more than 20. The wide range suggests either the fill was compacted in roughly 1 m lifts or the higher blow counts may be caused by cobbles or rubble in the fill rather than by soil density. Most of the blow counts below the upper 1 m in BH18-05 were less than 10 blows/ft, indicating poor compaction. Overall, the drill results indicate that the fill beneath the road is not select granular material and was not placed in proper lifts or compacted to meet municipal specifications.

The fill was placed directly over the natural colluvium, comprised of sandy silt with some clay and gravel. The colluvium ranged from 0.6 to 1.1 m thick and overlies bedrock at depths of 3.7 to 5.5 m along the inside edge of the road, and 7.9 to 11.0 m below the outside shoulder.

5.2 Pump Station

The pump station is located over a former gully that was filled in as part of the residential development. The southwest bank seems to have been bedrock-controlled while the northeast bank was comprised of till. Topographic data indicates that up to 15 m if fill was placed within the middle of the gully. Boreholes BH18-01 to BH18-02 are located at the crest of the slope adjacent to the pump station, but straddle the middle of the gully. BH18-03 is located in the road shoulder on the southeast side of the pump station, also within the filled-in gully.

All three boreholes found a thick layer of fill predominantly comprised of silty sand to sandy silt with some clay and trace gravel. The upper 3 to 5 m is mostly loose with some compact layers below 3 to 5 m depth. The base of the fill ranges from 9.9 m deep in BH18-03 to 11.4 m in BH18-01. Essentially the entire slope is comprised of poorly compacted clay/silt/sand fill.

While BH18-03 found the fill overlying 1.1 m of colluvium and then bedrock, the fill in BH18-01 and BH18-02 overlies 1.1 to 1.6 m of weathered till and then unweathered till. The till is mostly silty sand with some clay and a trace of gravel. The till was more difficult to drill through and is, therefore, inferred to be hard/dense.

The till overlies bedrock but the bedrock surface is quite variable. While the bedrock is 11 m deep in BH18-03, it deepens to 16.2 m in BH18-02 and 26.2 m in BH18-01. Both BH18-01 and BH18-02 are approximately 3 m lower in elevation than BH18-03, further steepening the slope in the bedrock. BH18-01 and BH18-02 are just 10 m apart with a 10 m difference in the bedrock elevation, indicating a roughly 1:1 slope to the bedrock in the north to northeasterly direction.

5.3 Slope Below Pump Station

BH18-01 and BH18-02 are located at the crest of the slope, next to the pump station while BH18-13 is located at mid-slope along the trail off of Kloppenburg Court, and Test Pit TP18-15 is near the toe of the slope closer to Kloppenburg Road. All are located directly over the filled in gully.

The thick fill identified in BH18-01 and BH18-02 was also found in BH18-13. The trail is constructed over 6.2 m of loose silty sand fill. The fill becomes compact below 5 m depth and then overlies dense sandy silt till. No bedrock was found to 10.7 m depth.

TP18-15, excavated more than 65 m downslope of the pump station, found 2.5 m of fill comprised of mostly sandy silt but containing a wide range of materials including boulders and household refuse. The fill overlies a thin veneer of silt/clay colluvium and then till at 4.2 m depth. Bedrock was not encountered. Seepage entered the test pit from within the colluvium below 3.8 m depth.

5.4 Slope to Southwest of Pump Station

BH18-05 and BH18-09 were drilled along the shoulder of the road southwest of the pump station while BH18-14 is located near the toe of the steep section, adjacent to the trail off of Kloppenburg Court.

BH18-05 and BH18-09 both found 7.2 to 7.5 m of fill overlying bedrock or a thin veneer of colluvium and then bedrock. Most of the fill is the same uncompacted mixture of clay/silt/sand although BH18-09 found a layer of blasted rockfill at 3.2 m depth, within the middle of the sandy silty fill.

BH18-14, at the toe of the slope, found just 0.6 m of fill overlying till. The hole was drilled to 8.5 m depth without finding bedrock; therefore, the lower slope is not bedrock-controlled.

5.5 2045 Loseth Road

Farther southwest, BH18-11 and BH18-12 were drilled about 3 m from the edge of the over-steepened fillslope and found 11 to 12.5 m of fill directly overlying weathered bedrock. The fill in BH18-12, closer to the pump station, is the same mixture of poorly compacted (or uncompacted) clay/silt/sand, although some layers of more gravelly fill were found in the upper 5 m.

BH18-11 found a thick layer of blasted rockfill between 2.7 and 8.2 m depth, overlying loose clayey sand fill. The DCPT had some difficulty penetrating the upper 1 m of rockfill, indicating the probable presence of at least one boulder. However, the DCPT readily penetrated the coarse rockfill below 3.8 m depth, with blowcounts between 20 and 50 blows/ft. Such blowcounts in sand indicate dense soil, but in blasted rockfill, the high blowcounts are likely the result of cobble-size clasts. The DCPT should not have been able to penetrate through a well compacted rockfill, indicating that even the rockfill in this area is poorly compacted.

The lateral extent of the rockfill is not known. Construction reports by ITSL indicate that blast rockfill was placed throughout much of this area, but it was found in only one of three bore holes. Regardless, the slope is certainly not comprised of a 3 m wide rockfill blanket as identified on some past geotechnical reports.

6 Monitoring Results

6.1 Piezometers

The piezometers were installed in August, after groundwater levels had begun to subside. As a result, only two of the ten vibrating wire piezometers have measured any groundwater pressure.

The piezometric data is summarized on Table 2 below while graphs showing the piezometric pressure versus date for the two piezometers that measured water pressures are provided in Appendix E.

Table 2: Summary of Piezometric Data

Piezometer	Top of Hole Elev. (m)	Tip Depth (m)	Tip Elev. (m)	Head (m)		Piezometric Elevation (m)	
				Min. (Date)	Max. (Date)	Min.	Max.
BH18-01	602.42	13.4	589.02	0.30 (Nov 4)	0.55 (Nov 12)	589.32	589.57
BH18-02	602.14	9.4	592.74	-	-	-	-
BH18-03	605.24	9.4	595.84	-	-	-	-
BH18-04	606.29	5.2	601.09	-	-	-	-
BH18-05	607.39	5.2	602.19	-	-	-	-
BH18-06	607.99	3.5	604.49	0.29 (Sep 16)	1.41 (Nov 1)	604.78	605.90
BH18-09	608.95	6.1	602.85	-	-	-	-
BH18-11	610.15	11.9	598.25	-	-	-	-
BH18-12	609.96	10.1	599.86	-	-	-	-
BH18-13	588.96	5.5	583.46	-	-	-	-

The piezometer in BH18-06 is just 3.5 m deep and situated 0.2 m above the bedrock surface. The piezometric pressure has ranged 1.15 m, between 0.29 m and 1.41 m above the piezometer tip. The piezometer tip is shallow and location directly above the bedrock surface; as a result, the piezometer responded rapidly to precipitation. The piezometric elevation was relatively uniform while the weather was dry from mid-August to September 21, declining slightly from 605.0 m to 604.8 m. The Kelowna Airport measured 14.1 mm of rainfall on September 21 causing the piezometric pressure to rise 0.59 m in less than one day. After this initial rain, even 2 mm/day of rainfall caused groundwater pressures to increase at least 0.5 m in a single day and then drop again over about 3 days. The more frequent rainfall from October 28 to November 3 caused a total rise of more than 1.0 m in groundwater elevation to 605.9 m, dropping to 605.5 m in a single day after the rain passed.

The piezometer in BH18-01 is 10 m deeper, situated below the bottom of the thick fill. The piezometric pressure has ranged just 0.25 m, between approximately 0.30 m and 0.55 m above the piezometer tip. Some of the variability is due to rainfall but with more than 10 m of silty clayey fill, surface water infiltration into the groundwater is relatively slow, thereby muting the

piezometric response. Comparing rainfall records for Kelowna Airport and the variations in piezometric pressures indicates a 5 to 10 day lag between rainfall and a rise in groundwater levels.

These two piezometers demonstrate the differences in response based on depth to bedrock and thickness of fill. The groundwater surface responds rapidly beneath Loseth Road where bedrock is shallow, while deeper bedrock and thicker silty soils downslope create a lag and dampens the magnitude of the response.

The rapid and exaggerated response in BH18-06 of roughly 0.5 m rise in groundwater pressure immediately following just a few millimetres of rainfall also suggests that shallow groundwater is concentrated in the infilled gully that crosses the site. Many of the houses upslope near the infilled gully are understood to be connected to in-ground stormwater disposal, which would also accelerate the groundwater response in the gully.

6.2 Slope Inclinometers

Noticeable slope movement occurred during the spring due to snowmelt and rainfall, but drilling did not occur until August. The base reading (to which all subsequent readings are compared) was made on August 20, during the dry season when groundwater levels had subsided. As a result, little movement has been detected by the slope inclinometers. Without definitive movement, the depth of the slip surface cannot be accurately located nor the magnitude of the landslide be determined.

Plots from the slope inclinometer (SI) measurements up to November 16, 2018 are included in Appendix E.

The SIs in BH18-01 and BH18-02 are both located in the fenced compound on the slope-side of the pump station, but they serve different purposes. BH18-02 is located on the slope-side of the tension crack, on the active landslide, where it can measure movement of the existing landslide mass. BH18-01 is located behind the tension crack, outside of the active landslide, in order to determine if the pump station is at risk.

BH18-01 has measured approximately 1 mm of movement extending down to 25 m depth but the movement is in the upslope direction, and there is equal movement across the slope (in the B-direction). The slope is only 13 m high and the base of the movement is slightly above the bedrock surface, well within the dense till. The movement cannot be caused by slope deformation and the fill has been in place too long for the movement to be caused by settlement. With just 1 mm of movement, it could be due to moisture variation in the clay till.

BH18-02 measured less than 2 mm of total movement in the downslope direction from August 20 to November 16. Up to 0.5 mm of movement occurred from 9 to 16 m depth. The base of the fill is at 10.8 m depth so most of this movement occurred within the till and is not related to slope movement. Another 1 mm of movement occurred within the fill above 9 m depth and half of that movement occurred within the upper 2 m. The movement to date is measurable but does not identify a definitive slip surface. The depth and magnitude of the landslide will likely not be measurable until spring 2019.

BH18-03 and BH18-04 measured less than 0.5 mm of movement and is more likely the result of moisture content variation in the soils.

BH18-05 measured less than 1 mm of horizontal movement down to 4 m depth, which is the base of the fill. The borehole is located in the shoulder of the road but behind the tension cracks in the fillslope below; therefore, the SI is not measuring the shallow surficial movement within the upper 2 m of the fillslope.

BH18-09 is similarly located as BH18-05 and measured less than 2 mm of horizontal movement to 8 m depth, which is the bottom of the fill. The SI is missing the surficial fillslope movement but still detecting creep extending the full depth of the fill.

BH18-11 and BH18-12 are located about 3 m back from the slope crest and, therefore, miss the surficial movement evident by the tension cracks. The SI in BH18-11 measures up to 2 mm of bending between 5 and 7.5 m depth, within the rockfill, but the movement resembles settlement rather than slope deformation. BH18-12 measures 2.5 mm of slope deformation down 5.5 m depth, combined with settlement between 3 and 5.5 m depth. The bore hole log shows loose fill at this depth.

BH18-13 is located in the trail at the base of the steep slope. It measured less than 1 mm of horizontal movement in the downslope direction with the base of the movement at 6 m depth, which is the base of the clayey sand fill. Although the movement is minor, it suggests that the landslide could extend downslope beyond BH18-13. The SI also measured 8 mm of lateral movement across the slope, peaking at 1.5 m depth, and with zero movement at the ground surface. The borehole encountered a boulder at 2 m depth and the inclinometer casing is being deformed by bending around the boulder.

Overall, the amount of landslide movement measured between August and November has been relatively minor. The landslide seems to have suspended movement seasonally, pending the next wet weather, particularly the spring snowmelt and rainfall.

7 Slope Stability Analyses

7.1 Methodology

2D limit equilibrium slope stability software (RocScience SLIDE 7.0) was used to estimate the stability of the slope under several conditions. Four cross-sections were created through the site, as shown in Figures 1 to 4. Subsurface conditions were interpolated between available borehole information and instrumentation readings.

The four cross-sections are shown on Drawing 01 and located as follows:

- Cross-section A-A' runs northwest, directly down the former gully from the pump station.
- Cross-section B-B' is located 21 m to the southeast of Cross-section A-A', with a similar orientation.
- Cross-section C-C' runs from the pump station directly northward down the slope to 2001 Kloppenburg Court.
- Cross-section D-D' is located on the slope below BH18-12, at 2045 Loseth Road.

The soil strength properties were estimated based on the in-situ test results from the SPTs and DCPTs. The soil properties used in the analyses are summarized in Table 1:

Table 3: Summary of Estimated Soil Strength Parameters

Soil Unit	Bulk Density (kN/m^3)	Cohesion (kPa)	Friction Angle (°)
Fill (N<10)	18	3	27
Fill (N>10)	19	3	29
Weathered Till	20	0	35
Clay Till	21	20	35
Toe Buttress (Engineered)	21	0	38
Angular Rock Fill	21	0	39

The slopes were modeled under various conditions to assess the present stability, causes of the instability, and design of possible mitigation measures.

7.1.1 Existing Conditions

The existing slope configuration was modeled using the measured piezometric pressures to test the soil parameters. Conditions were adjusted slightly to ensure the factor of safety was greater than 1.0 to reflect the existing conditions where the slope is marginally stable. Groundwater pressures were then raised by 2 m to represent anticipated peak groundwater conditions.

7.1.2 Causal Analyses

Section C-C' was first modeled with the apparent original slope configuration and then with the existing excavation at the toe, in order to assess the effects of the excavation on slope stability.

7.1.3 Mitigation

To assess various mitigation measures to improve slope stability, Cross-sections A-A' and C-C' were analyzed under the following scenarios:

a. Existing topography – as the base case.
b. Various configurations of toe buttresses and flattened slope angles.
c. With various spacings and types of soil nails.

Cross-section B-B' was also analyzed under Scenario (a) and (b), but not (c) (the soil nails).

Cross-section D-D' was analyzed under existing slope conditions and various flattened slopes.

All cases were analyzed with the piezometric level 2 m higher than measured to account for the estimated spring conditions.

The mitigation options using soil nails and Tecco mesh were also analyzed using Geobrugg's Ruvolum design software; however, this software only considered surficial slope movement up to 2.5 m deep.

7.2 Results

The results of the slope stability analyses are summarized on Table 3. The calculated factor of safety and the relative change in factor of safety from the base condition are both given. A slight change in the soil strength parameters can affect the absolute factor of safety but should have little impact on the relative change in factor of safety; therefore, the relative change in factor of safety is the better measurement of the effectiveness of the various mitigation measures.

The analysis concludes that the entire slope is just marginally stable under current conditions and can be destabilized by even a modest rise in groundwater pressures, which likely occurs each spring.

The toe excavation along Cross-section C-C' in 2015 reduced the factor of safety by 9%, which would be enough to destabilize a marginally stable slope. There is insufficient topographic data to determine the extent of the excavation along Cross-section A-A' or to analyze the impact on slope stability.

With respect to mitigation, a minimum factor of safety of 1.3 should be the objective for long-term stability. Where this is difficult to achieve, the higher the relative increase in factor of safety should provide greater assurance. Even an increase in factor of safety of 0.1 (or 10%) should significantly reduce slope movement while an increase of 0.2 (or 20%) should halt movement under most circumstances.

The results of the stability analysis with respect to existing conditions are discussed further in Section 8 while the results with respect to mitigation options are discussed in Section 10.

Table 3: Summary of Slope Stability Results

	Condition	Factor-of-Safety	Increase
Cross-section A-A'	Existing Conditions	1.00	-
	Existing slope configuration - piezometric level +2 m (Base Case)	0.99	-
	Toe Berm - 1.5H:1V Rockfill slope 2H:1V upper slope	1.05	+0.05
	Toe Buttress - two-tiered GRS wall	1.20	+0.21
	Toe Buttress - GRS with 2H:1V Slope	1.13	+0.13
	Toe Buttress - GRS wall with 1.5H:1V engineered slope. Mid-slope bench with 2H:1V upper slope.	1.14	+0.15
	Soil Nails and Tecco Mesh	1.39	+0.40
	Trim upper slope to flatten to 33° slope	1.07	+0.08
	Trim + fill to flatten to 28° slope	1.02	+0.02
Cross-section B-B'	Existing Conditions	1.04	-
	Existing slope configuration - piezometric level +2 m (Base Case)	1.03	-
	2H:1V Slope	1.18	+0.15
	1.5H:1V Toe Berm with 2H:1V Slope Above	1.30	+0.27
Cross-section C-C'	Pre-2016 Slope	1.16	-
	Existing slope configuration	1.07	-
	Existing slope configuration - piezometric level +2 m (Base Case)	1.07	-
	Rockfill Toe Buttress	1.28	+0.21
	GRS Toe Buttress	1.48	+0.41
	Soil Nails and Tecco Mesh R51N hollow core soil nails 6 m long @3.6 m spacing	1.56	+0.49
Cross-section D-D'	Existing Conditions	0.88	-
	Existing slope configuration - piezometric level +2 m (Base Case)	0.88	-
	Pullback to 30° (1.75H:1V) slope	1.14	+0.26
	Pullback to 27° (2H:1V) slope	1.23	+0.35
	Pullback to 25° (to existing ditch)	1.24	+0.36
	Re-build fill with 27° (2H:1V) slope	1.36	+0.48

8 Discussion of Results

8.1 Original Construction

8.1.1 Pump Station

Understanding of the technical causes of the slope instability is necessary to analyze mitigation measures. This analysis does not attribute blame or responsibility for the slope failure but merely the apparent factors that destabilized the slope. To assess responsibility, further review of the development history of this site would be needed, with more thorough construction records.

The in-situ SPT and DCPT data indicates that the fill beneath the slope and the roadway was poorly compacted during site grading for the subdivision. Almost the entire 15 m high embankment is comprised of non-select fill that is poorly compacted. The fill is a mixture of clay, silt and sand, which drains poorly compared to clean granular soils, retains moisture, and softens when wet. The fill has a low shear strength and is prone to settlement under an increase in load, and susceptible to slope movement.

This loose fill was found in all bore holes, including those along the crest of the slope and within Loseth Road; however, no bore holes were drilled within or immediately adjacent to the pump station. ITSL claims the fill beneath the pump station was compacted in lifts; however, compaction test reports indicate that only the fill directly within the building footprint was tested. ITSL admitted that a 1:1 splay beneath the footings was not possible and the fillslope abutted a loose stockpile of soil stripped from the site. Whether this loose stockpile was later incorporated into the fillslope is unknown, but the records seem to confirm that the soil within the fillslope was not placed in lifts and properly compacted.

Significant settlement likely occurred during and immediately after construction, merely under the weight of the fill itself, but the settlement would have been fairly uniform. The embankment was constructed long before the pump station; therefore, the primary settlement occurred before the pump station was in place.

The existing slope angles below the pump station are close to 1.1H:1V, too steep for well compacted granular fill, and far too steep for poorly compacted clay/silt/sand fill. Even if the fill was well compacted, the slope angles should not have been any steeper than 2H:1V. These slopes were all constructed much too steep and without adequate compaction or engineering.

This combination of unfavourable conditions creates the potential for a landslide in the fill and, considering the thickness of the fill, such failures could be fairly deep. The slope was just marginally stable when originally constructed circa 2006.

8.1.2 Adjacent Slope to Southwest

The slope southwest of the pump station easement flattens slightly near BH18-05 and BH18-09. While this slope is also just marginally stable, as evident by the tension cracks in the shoulder of the road, and the slight movement in the slope inclinometers, the slope is not as steep as the others and the factor of safety is slightly above 1.0. This slope is less likely to fail than the others and is more readily stabilized.

8.1.3 2045 Loseth Road

The development history raises several discrepancies between the construction records and the bore hole results. Based on the number of compaction tests and the apparent frequency of testing, it seems the fill was placed in 0.5 to 1 m thick lefts, but was still compacted and partly tested; however, the area of fill placement was not well documented. Most of the fill placement occurred in July to August 2004, up to 2 m below what was assumed to be final grade, although there is no elevation given or confirmation that the final development grade is the same as the existing grade. Fill placement resumed in the summer of 2005 but only a few compaction test results from November 2005 were included in the ITSL summary report (December 19, 2011). Some of the fill was reportedly blasted rockfill, but records do not indicate the lift thickness or method of compaction. The final fill placed in 2005 is referred to as "sand and gravel" but the only compaction tests provided are on the "final grade".

Substantial fill was placed at the north end of the property in 2006, including the locations of both BH18-11 and BH18-12; the previous crest was roughly 7 m southwest of BH18-11 (Google Earth). Some fill had previously been placed in this area but the grade was raised significantly in 2006. No records of inspections or testing were provided for the fill placed in 2006; therefore, this fill does not seem to have been compacted or tested.

Discrepancies regarding the slope angle and composition are apparent in the ITSL documents. The slopes were initially designed or intended to be 1.5H:1V (67% or 34°), with the houses set back behind a 2H:1V projection up from the toe of the slope. Later documents acknowledge that the slope is actually 1.25H:1V (80% or 39°) but is said to be comprised of blast rock fill for the outer 3 m of the fillslope (ITSL, December 19, 2011). This fill is referred to as "structural fill" implying that it was compacted, despite the fact that the fill was placed after the compaction tests in 2004 and 2005.

The actual slope at the north end of the property (Cross-section D-D') is 1.25H:1V overall but the lower 15 to 20 m of the slope is close to 1:1. The bore hole logs show that only a portion of the slope is comprised of blasted rock fill, which was not well compacted. Most of the fill is gravelly sand with a relatively high silt and clay content. The open tension cracks on the slope expose this same material, indicating that the outer 3 m of fill was not constructed of blasted rock fill, as stated, as was not well compacted.

This filled slope near BH18-11 and BH18-12 is highly over-steepened with a factor of safety less than 1.0 under normal conditions. The number of tension cracks and their widths support a factor of safety less than 1.0 and the slope is considered to be unstable.

The slope was constructed in this manner in 2006 and likely showed signs of movement for several years. The weight of the stockpiles added in the past two years would have further reduced stability, but the slope is simply far too steep for the loose, poor quality fill. The cause of this slope movement is simply poor construction.

8.2 Groundwater

Shallow groundwater levels typically peak in the spring, shortly after snowmelt; therefore, the increased slope movement during spring 2018 suggests that the movement is related to groundwater pressures. Groundwater levels would have also risen during each preceding spring, so slope movement would have been expected during each spring and possibly even after heavy rainfall any time of the year.

The slope at the north end of 2045 Loseth Road has several, extensive tension cracks and a large toe bulge, indicating that movement has been occurring for several years. As such, the over-steepened slope, poor soil conditions, and seasonal rise in groundwater levels may fully account for the movement on this slope.

The wide tension crack in the gravel yard behind the pump station and the bending of the fence reportedly initiated within the last few years. Some movement may have occurred earlier but gone unnoticed, but the movement seems to have at least accelerated over the past few years, with the most movement occurring in spring 2018. Higher than normal snow levels on Kirschner Mountain or higher than normal rainfall during spring 2018 could account for higher than normal groundwater levels; however, Environment Canada's weather data from the weather stations near Kelowna do not indicate such conditions. Therefore, with respect to the slope below the pump station, groundwater pressures seem to be a factor in stability of this slope, but the increased movement over the past few years must have another causal factor.

BMID reportedly pressure-tested the water mains and the City of Kelowna also checked their utilities in the vicinity of the site to confirm that they are not leaking, eliminating another potential source of additional groundwater.

8.3 Recent Changes to Slope

The toe of the slope at 2001 Kloppenburg Court was excavated in 2015 to install a small pond; a comparison of the 2012 and 2015 satellite images for the slope is provided in Figure 5. The excavation for the pond appears to have cut roughly 4 m into the toe of the bank, over-steepening the lower slope, removing toe support, and reducing the factor of safety by approximately 0.09. The timing of this excavation aligns with the reported initiation or acceleration of slope movement 2 to 3 years ago. This marginally stable slope became unstable and the movement in the northerly direction seems to have been directly caused by this toe excavation.

The base of the northwesterly slope was also altered in 2015 but it is less clear how much ground was excavated to create the landscaped panhandle between the toe of the steep slope and the trail. Prior to 2015, the slope between the pump station and the trail was fairly uniform. The landscaped panhandle is a level grassed area created by a combination of cut and fill. The amount of cut cannot be determined from the available information; therefore, the impact on slope stability is less certain.

9 Landslide Hazards & Risks

The probability of a landslide occurring has been rated based on both the slope stability analysis and the site observations. The criteria used for the probability ratings are provided in Table 4.

Table 4: Qualitative Landslide Probability Rating Criteria

	Rating	Criteria
Landslide Probability P(H) Under Static Conditions	Low	Factor of Safety > 1.3 under seasonal high groundwater conditions. No signs of slope movement or past landslides on the slopes below the property.
	Moderate	Factor of Safety between 1.1 and 1.3 under seasonal high groundwater conditions. Possibly signs of minor or small-scale slope movement but no signs of significant slope movement or past landslides.
	High	Factor of Safety < 1.1 under seasonal high groundwater conditions. Signs of significant slope movement or past landslides.
	Very High	Factor of Safety </= 1.0 under seasonal high groundwater conditions. Signs of significant slope movement or past landslides.
	Imminent	Factor of Safety < 1.0 under current groundwater conditions. Signs of significant active slope movement.

9.1 Pump Station

The soils directly beneath the pump station could not be investigated; however, compaction test results indicate that the fill beneath the pump station was compacted in lifts and, therefore, should be much denser than the loose fill found in BH18-01 and BH18-02. The slope stability model included better compaction of the fill beneath the pump station, which affects the results. Therefore, this analysis is predicated on compaction of the fill beneath the pump station. Still, the factor of safety with respect to a slope failure capable of directly reaching the pump station is less than 1.1, meaning the probability of a landslide affecting the pump station is high.

BH18-01 was located behind the tension crack to allow the slope inclinometer to measure any retrogression of the landslide that could pose a hazard to the pump station. It has not measured any movement since installation in August. BH18-02 is located on the slope-side of the tension crack, but has measured less than 1.5 mm of total movement, with less movement at depth. The SIs have not yet detected the actual slip surface; however, at this time, the slope movement does not appear to pose a direct hazard to the pump station. If the slope fails, the fence and part of the level platform behind the pump station would be lost, but the pump station should remain intact.

The pump station is at risk of settlement resulting from a slope failure. Significant settlement typically occurs behind the landslide headscarp, which could affect the concrete sidewalk at the entrance to the pump station, and possibly even the northwest wall of the building. Settlement resulting from a slope failure would be differential with greater movement along the northwest side of the building. The effects on the water infrastructure depend on the sensitivity of the pump facilities and are best analyzed by the City of Kelowna's or BMID's engineers.

9.2 Below the Pump Station

Both the north and northwest aspect slopes have a high to very high probability of failure. The thin rock wall at the toe has already failed but the greater hazard is a landslide extending from the crest of the fillslope near BH18-01 or BH18-02. Such a failure would likely be 10 to 12 m wide by 2 to 4 m thick, with a volume in the order of 500 m^3. The potential exists for deeper landslides, which would increase the volume. A longer landslide depletion zone is also possible in the northwest direction, creating a landslide volume exceeding 1,000 m^3.

The potential impacts of the landslide depend on the landslide runout, which can be influenced by several factors, most notably, the landslide volume and the fluidity or rheological properties of the slide debris. A simple means of estimating landslide runout is to predict the "angle of reach", measured from the crest of the slope to the toe of the runout. Based on the predicted landslide volume, the angle of reach could range from 17° to 27°. The gradation of the fill material and the fines content indicates that the fillslope is capable of static liquefaction and flow sliding, although most of the slope is above the groundwater table. A more likely range for the angle of reach is between 20° and 24°, which would yield the anticipated maximum and minimum landslide runout zones shown on Drawing 02.

With less than 7 m from the toe of the slope to the house at 2001 Kloppenburg Court, the predicted landslide runout would reach the middle of the house. Even a small slide on the north aspect slope would impact the house with sufficient force to cause both cosmetic and structural damage. Occupants of the adjacent rooms of the house would be at risk of serious harm.

A slide on the northwest aspect slope would overwhelm the gravel trail and possibly reach Kloppenburg Road. Based on the predicted angle of reach, the minimum runout distance would be within 10 m of the road while the maximum predicted runout could reach the far side of the road, where some mud could even enter the driveways on the opposite side and reach the houses. The main element at risk would be users on the trail at the time of the slide.

The probability of a landslide occurring is very high, but with little movement measured since August, the potential landslide is not considered to be imminent (as defined on Table 4). A rise in groundwater pressures in the spring could destabilize the slope fairly quickly, increasing the hazard rating from very high to imminent. The only noticeable signs of a pending landslide may be widening of the tension crack and movement measured in the slope inclinometers; however, there could be no warning if the movement occurs between readings.

Once the hazard is deemed imminent, the house at 2001 Kloppenburg Court should be evacuated and the adjacent trail closed. An evacuation order would restrict the mitigation options due to worker safety; therefore, delaying mitigation until the landslide becomes imminent can be problematic.

9.3 Adjacent Slope to Southwest

The slope on this adjacent property is steeper and has more tension cracks indicating greater movement to date and a very high probability of a landslide. The current rate measured in BH18-12 is approximately 1 mm/month, which does not suggest an imminent hazard at this time.

However, a rapid slope failure must be considered imminent each spring and possibly whenever heavy rainfall occurs.

The tension cracks are currently limited to the slope, although there are signs of settlement behind the slope crest. The most likely scenario would be a landslide 12 to 15 m wide by 2 to 3 m deep, with a volume in the order of 1,000 m^3; however, the potential exists for a much larger landslide.

The potential landslide would easily reach the gravel trail below; at present there are no houses between the trail and Kloppenburg Road. Using an angle of reach between 20 and 24°, the potential landslide would easily reach Kloppenburg Road and could directly impact on the houses opposite.

10 Mitigation Measures

The main mitigation measures considered for this project are:

i. Flattening the slope by pulling back or excavating the upper slope. This reduces the weight of soil in the upper part of the slope, thereby reducing the driving forces causing landslide movement.
ii. Constructing a toe buttress near the base of the slope, and flattening the slope above. This option increases the resisting forces supporting the slope.
iii. Reinforcing the unstable soil mass using soil nails and Tecco mesh.

Drainage measures were not considered at this stage because piezometric pressures are not high enough to achieve sufficient benefit from drainage and the groundwater table is expected to rise only 1 to 2 m over the till surface. Intercepting groundwater using horizontal drains would be challenging. Also, the benefits of drainage would be minor because the slope is over-steepened and just marginally stable without the seasonal rise in groundwater.

10.1 North Slope Below Pump Station

10.1.1 Toe Buttress

The most cost-effective means of stabilizing the north aspect slope would be to construct a toe buttress to replace the material excavated from the toe of the slope in 2015. The original fill slope was already too steep prior to excavation; therefore, the buttressed slope should be flattened to 2H:1V (27°). With between 5.3 and 7 m between the house and the toe of slope, the toe buttress must be constructed of either coarse blast rock or a geosynthetic reinforced soil (GRS) wall. Both options will reduce the distance between the toe of slope and the house.

A rockfill buttress, shown on Figure 6, would increase the factor of safety to 1.3, which should be considered the minimum tolerable factor of safety. The toe buttress base should be roughly 5 m wide, leaving less than 2 m between the toe of the buttress and the house. Since the lower 4 m of the buttress would be steepened to 1H:1V, rolling boulders could still pose a hazard. This hazard could be reduced by ensuring each surface boulder is well interlocked or by grouting or concreting the surface layer of rock.

A 3 m high GRS toe buttress wall, shown on Figure 7, should improve the factor of safety to almost 1.5 simply because of the geotextile reinforcement layers. A GRS wall would increase the

setback from the house to 3 m and would eliminate the hazard of loose boulders rolling down the slope.

10.1.2 Soil Nail & Mesh

A third option is to heavily reinforce the slope using soil nails and steel mesh, as shown on Figure 8. The analysis indicates that the following conceptual design should provide a factor of safety greater than 1.4.

- IBO R51N soil nails 8 m long, installed at an angle of 20° below horizontal, in a diamond pattern at a spacing of 2.5 m.
- Tecco Mesh G65/4, galvanized, with P66 plates.

The soil nail and mesh option will be much more costly than either buttress option but would preserve most of the slope in its current configuration. The failed toe would have to be reconstructed but should have just a minor impact on the spacing from the house to the slope.

10.2 Northwest Slope Below Pump Station

The same two options are also available for the northwest slope below the pump station; however, the thick fill within this former gully creates the potential for deeper and longer landslides, which affects the design of both the buttress and soil nails.

10.2.1 Toe Buttress

With 6 m of poorly compacted clay/silt/sand fill beneath the trail, a buttress constructed on the trail bench would increase the factor of safety just marginally because the slip surface can extend beneath the trail and into the gully below. The buttress must extend more than 20 m downslope of the trail, requiring significant earthworks. The buttress would also have to be excavated through the existing fill, which is 2.5 m thick in TP18-15, to bear directly on till.

A simple rockfill buttress constructed with a slope of 1.5H:1V (34°) is not thick enough and would only improve the factor of safety to 1.05 (from 1.00).

Constructing a 5.1 m high GRS buttress wall at the bottom of the slope and a 2H:1V slope for the full height up to the pump station would increase the factor of safety to 1.13. Steepening the lower slope above the GRS wall in order to allow the trail to be reconstructed at mid-slope results in a factor of safety of 1.14 and is shown on Figure 9.

The costs of fill placement across the upper slope could be reduced by constructing a shorter GRS wall at the crest, just outside of the current fence line surrounding the pump station. This option increases the factor of safety to 1.20 and is shown on Figure 10. This upper GRS wall would be founded on loose fill and, therefore, prone to future settlement. However, GRS walls with a flexible welded-wire facing are able to accommodate greater settlement than structural walls.

While none of the buttress options are able to reach a factor of safety greater than 1.2, they should be adequate to significantly reduce, if not halt, the slope movement. The factor of safety would not reach acceptable standards of stability for new construction, but may be acceptable for stabilization of an existing landslide.

10.2.2 Soil Nail & Mesh

Reinforcing the slope with soil nails and mesh requires longer soil nails and a tighter spacing than on the north-facing slope because of the length of slope and thickness of fill. The analysis indicates that the following conceptual design, shown on Figure 11, should provide a factor of safety greater than 1.3.

- IBO R51N soil nails 14 to 16 m long, installed at an angle of 20° below horizontal, in a diamond pattern at a spacing of 2.3 m.
- Tecco Mesh G65/4, galvanized, with P66 plates.

A factor of safety of 1.3 for the soil nail and mesh option does not imply that it is more stable than the factor of safety of 1.2 for the toe buttress option. The soil nail design carries greater uncertainties, particularly with respect to the grout penetration and bond within the fill, which could significantly affect stability. Therefore, the soil nail and mesh option warrants a higher factor of safety than the toe buttress option.

10.2.3 Pullback Options

Another option to flatten the slope would be to trim or pullback the upper slope 4 to 5 m from the existing crest to the edge of the concrete sidewalk at the entrance to the pump station. The slope could be flattened from its current 39° to 42° to approximately 33° or 1.5H:1V. This pullback would remove the fill that is currently failing, thereby preventing the development of an imminent hazard. The factor of safety with respect to deep-seated failure capable of impacting on the pump station, would increase 8% to 1.07, as shown on Figure 12.

The pullback is suitable for mitigating the imminent and short-term stability because it would be the quickest and least costly mitigation measure. The pullback also allows greater flexibility with respect to construction of a toe buttress without destabilizing the upper slope. The disadvantage of the pullback option is that the vehicular access to the back door of the pump station would be lost, although pedestrian access via the metal stairway would be maintained.

A work procedure and logistics, such as excavator access, truck access, whether the excavator bails material to the bottom of the slope or benches down from the top, must still be resolved.

The long-term objective should be a higher factor of safety closer to 1.2 plus equipment access to the back of the pump station. This pullback would be a necessary step in constructing the upper GRS wall and, therefore, could be used as a short-term solution prior to constructing the GRS buttress and upper wall option in Figure 10.

10.3 Adjacent Slope to Southwest

10.3.1 Toe Buttress

The slight draw in the slope immediately south of the pump station is not as steep as the adjacent slopes and can be readily stabilized by supporting the lower slope, just upslope of the trail. This draw will be partially filled as part of the mitigation along Cross-section A-A', flattening the slope to 2H:V. Placing fill upslope of the trail would increase the factor of safety to 1.18, as shown on Figure 13. Adding a larger toe buttress near the trail alignment, as shown on Figure 14, would

increase the factor of safety to 1.30, but the grades will depend on the final grades along Cross-section A-A' .

Mitigating the hazard along Cross-section B-B' should be relatively easy. By comparison, the large fill area to the southwest (Cross-section D-D') will require much greater effort to stabilize.

A toe buttress at Cross-section D-D' is not viable because the toe of the slope is right along property line and the slope is already over-steepened and unstable. The height and width of the toe buttress wall would require significant excavation into the slope, which would pose serious short-term hazards during construction. Essentially, the slope would have to be deconstructed from the top prior to constructing the toe buttress, which would result in almost complete reconstruction of the slope.

10.3.2 Soil Nails & Mesh

The large fillslope on the development site can be mitigated using soil nails and mesh, but the costs would be prohibitive considering that the land above is currently undeveloped.

10.3.3 Flatten the Slope

Since the property is still vacant, the easiest means of mitigating the slope hazard is to flatten it by excavating the crest back. Given the height of the slope, this requires more than a simple pullback or trimming; excavators will have to work the crest of the slope down in benches.

Flattening the slope to 1.75H:1V (30°) by trimming the crest of the slope back 9 m at Cross-section D-D', would increase the factor of safety to approximately 1.14 as shown on Figure 15. This level of stability would not be adequate for future residential development but should be adequate to prevent an imminent hazard from developing. This work should not be delayed until an imminent hazard develops because, at that time, the slope will be too unstable to safely allow equipment and trucks to operate.

Flattening the slope to an overall 2H:1V would trim the crest back 15 m but still only achieve a factor of safety of 1.23. If the property is to be developed for residential use, the poorly compacted fill should be completely removed and replaced in maximum 300 mm thick lifts, compacted to a minimum 95% standard Proctor density. The extent of the excavation will depend on if or where the structural fill that was reportedly placed and compacted in lifts is encountered. Encountering the blast rockfill would be even better, provided it was properly placed and compacted.

If the existing fill with a high fines content is to be used as an engineered fill, a drainage layer should be placed near the bottom of the fill and then at least every 5 m of fill height. This drainage layer should be comprised of free-draining granular material to prevent the build-up of groundwater pressures in the fill. Even if properly compacted and drained, the existing clay/silt/sand fill should be sloped no steeper than 2H:1V. Any steeper of a slope will require additional stabilization measures, such as GRS walls.

11 Recommendations

A detailed site survey is required prior to preliminary design of the mitigation measures and cost estimations. This survey should proceed immediately.

Preliminary cost estimates will depend on the preliminary designs; however, the soil nail option will invariably be the most expensive. This option is attractive if the land required to flatten the slope and construct the toe buttresses is unavailable or if the property owners are willing to pay the cost premium associated with the soil nail option. Otherwise, the recommended mitigation works include the following:

i. Construct a 3 m high GRS toe buttress wall at the base of the slope on 2001 Kloppenburg Court and then flatten the slope above to 2H:1V (see Figure 7). This work should proceed immediately due to the risks to the occupants of the house below.

ii. Flatten the northwest aspect slope at the rear of the pump house by pulling back the upper slope to 1.5H:1V as a temporary measure. This work should proceed before spring to mitigate the imminent hazard that is expected to develop.

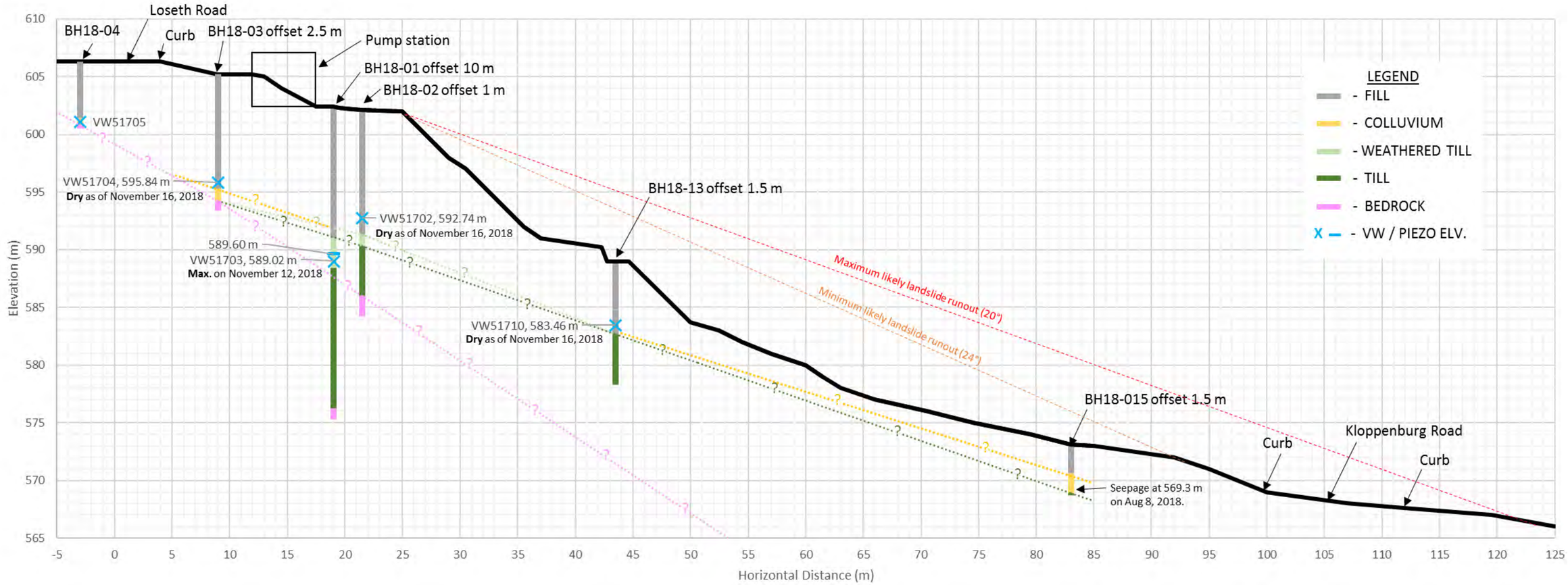
iii. A large GRS toe buttress wall should be constructed at the base of the slope, below the trail, and the slope flattened as shown on Figure 10.

iv. The upper slope at the rear of the pump house can then be reconstructed by supporting the upper slope behind a second GRS wall, also shown on Figure 10.

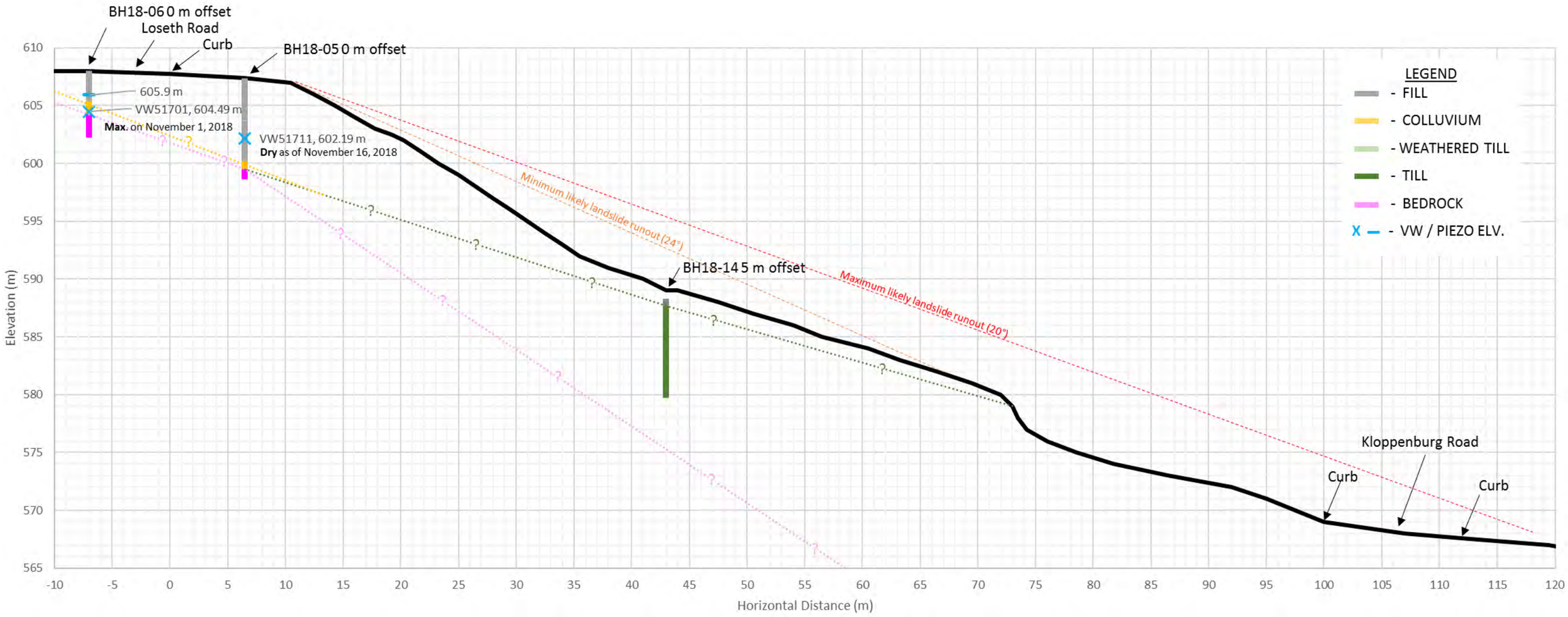
v. The large fillslope at 2045 Loseth Road should be flattened to no steeper than 1.75H:1V as part of the short-term mitigation measures. Considering the magnitude and effort of the earthworks required to flatten the slope, the property owners may choose to flatten the slope even farther to 2H:1V for long-term stability, depending on their development plans. However, a 1.75H:1V slope is considered the maximum slope angle that should be permitted by the City for the safety of those downslope.

12 Limitations

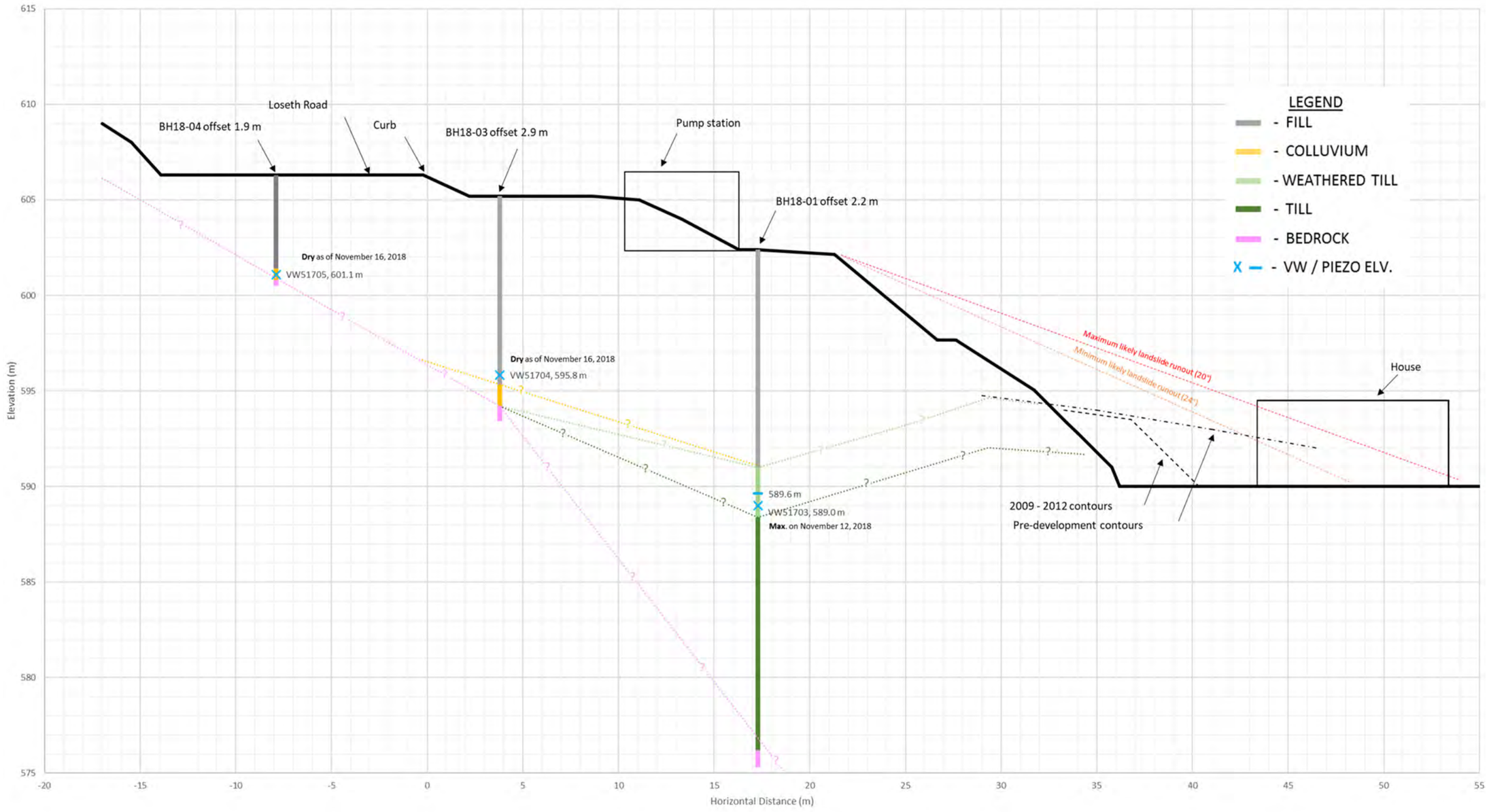
All of the analysis is based on preliminary cross-sections created using the available topographic data. The recommended slope angles, setbacks, wall heights, etc. are all dependent on these cross-sections and topographic data. A more accurate survey of the topography is needed prior to final design, which could affect the final wall heights, setbacks, and slope angles.



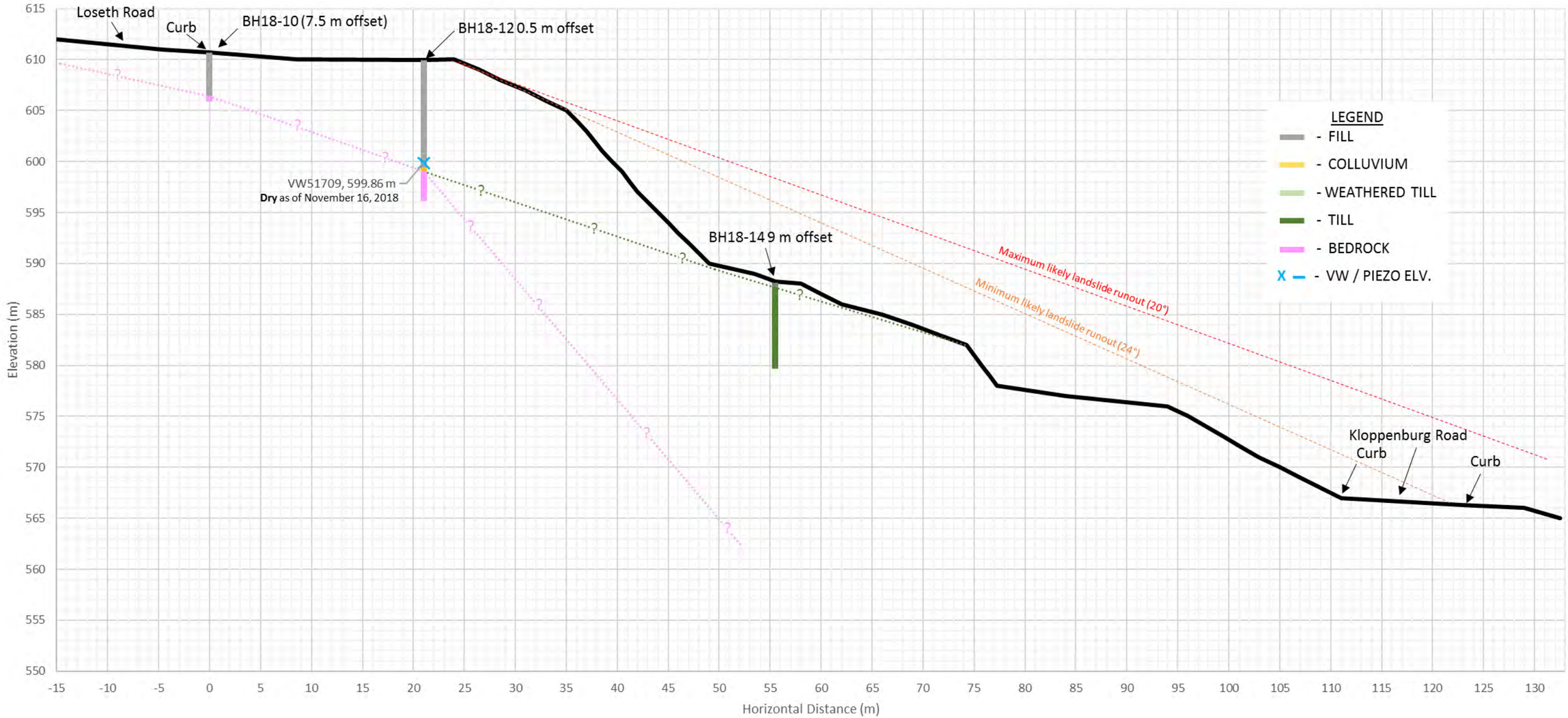
westrek geotechnical services ltd. *100 -1383 McGill Road, Kamloops, BC V2C 6K7*	Scale 1:350	**2045 LOSETH ROAD PUMP STATION** **CROSS-SECTION A-A'**	**FIGURE 1**
	December 19, 2018		
	Project: 018-253		



westrek geotechnical services ltd. 20th ANNIVERSARY *100 -1383 McGill Road, Kamloops, BC V2C 6K7*	Scale 1:350 December 19, 2018 Project: 018-253	**2045 LOSETH ROAD PUMP STATION** **CROSS-SECTION B-B'**	**FIGURE 2**



westrek geotechnical services ltd. *100 -1383 McGill Road, Kamloops, BC V2C 6K7*	Scale 1:200	**2045 LOSETH ROAD PUMP STATION**	**FIGURE 3**
	December 19, 2018	**CROSS-SECTION C-C'**	
	Project: 018-253		



westrek geotechnical services ltd. 20th ANNIVERSARY *100 -1383 McGill Road, Kamloops, BC V2C 6K7*	Scale 1:400 December 19, 2018 Project: 018-253	**2045 LOSETH ROAD PUMP STATION** **CROSS-SECTION D-D'**	**FIGURE 4**

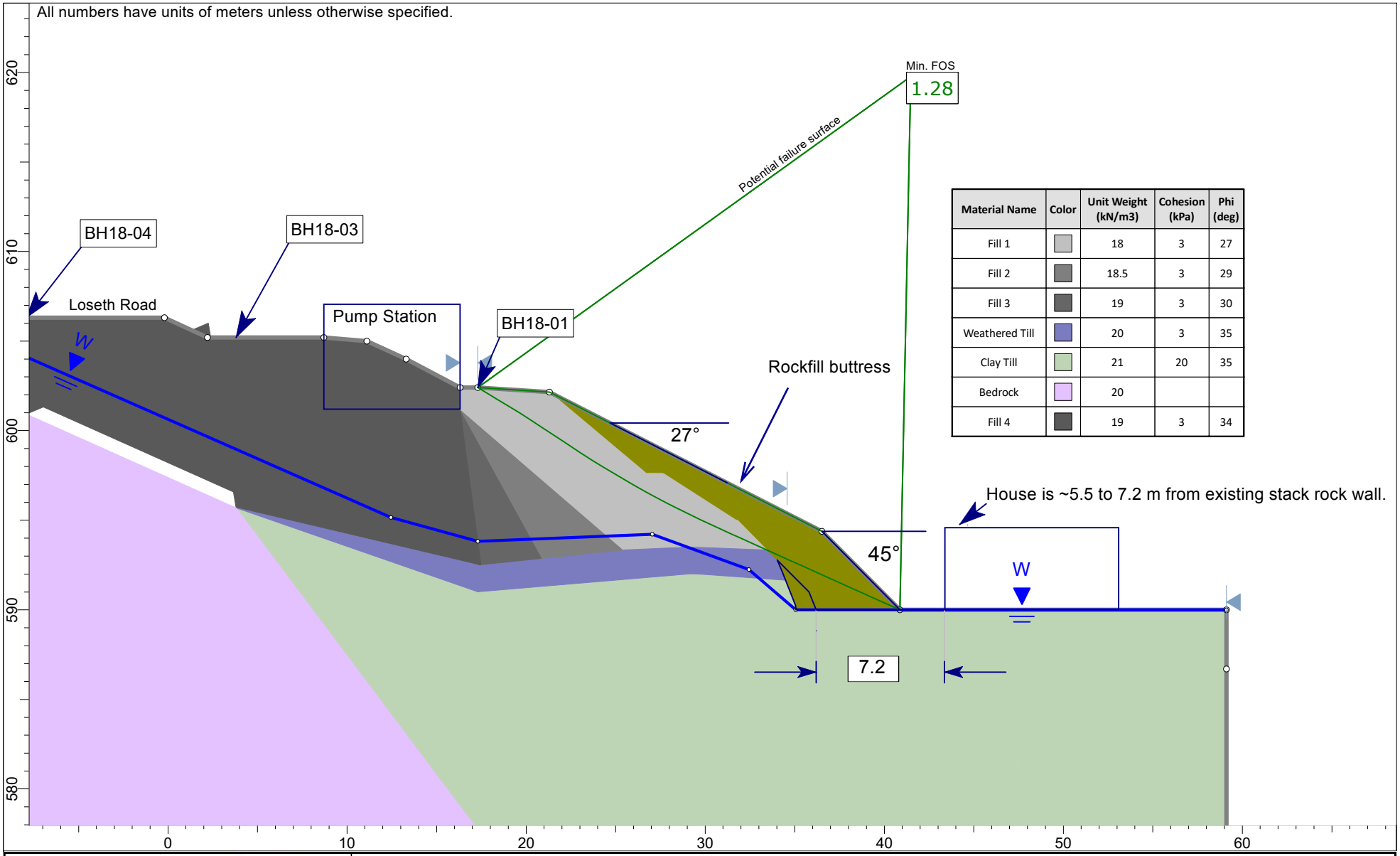
2012 satellite image of slope below the pump station.

2015 satellite image of slope below the pump station.

N

Satellite images from iKelowna map website.

westrek geotechnical services ltd.	**Comparison of the Slope in 2012 and 2015 2045 Loseth Road Pump Station**	City of Kelowna December 14, 2018 Project: 018-253	**FIGURE 5**



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Fill 4		19	3	34

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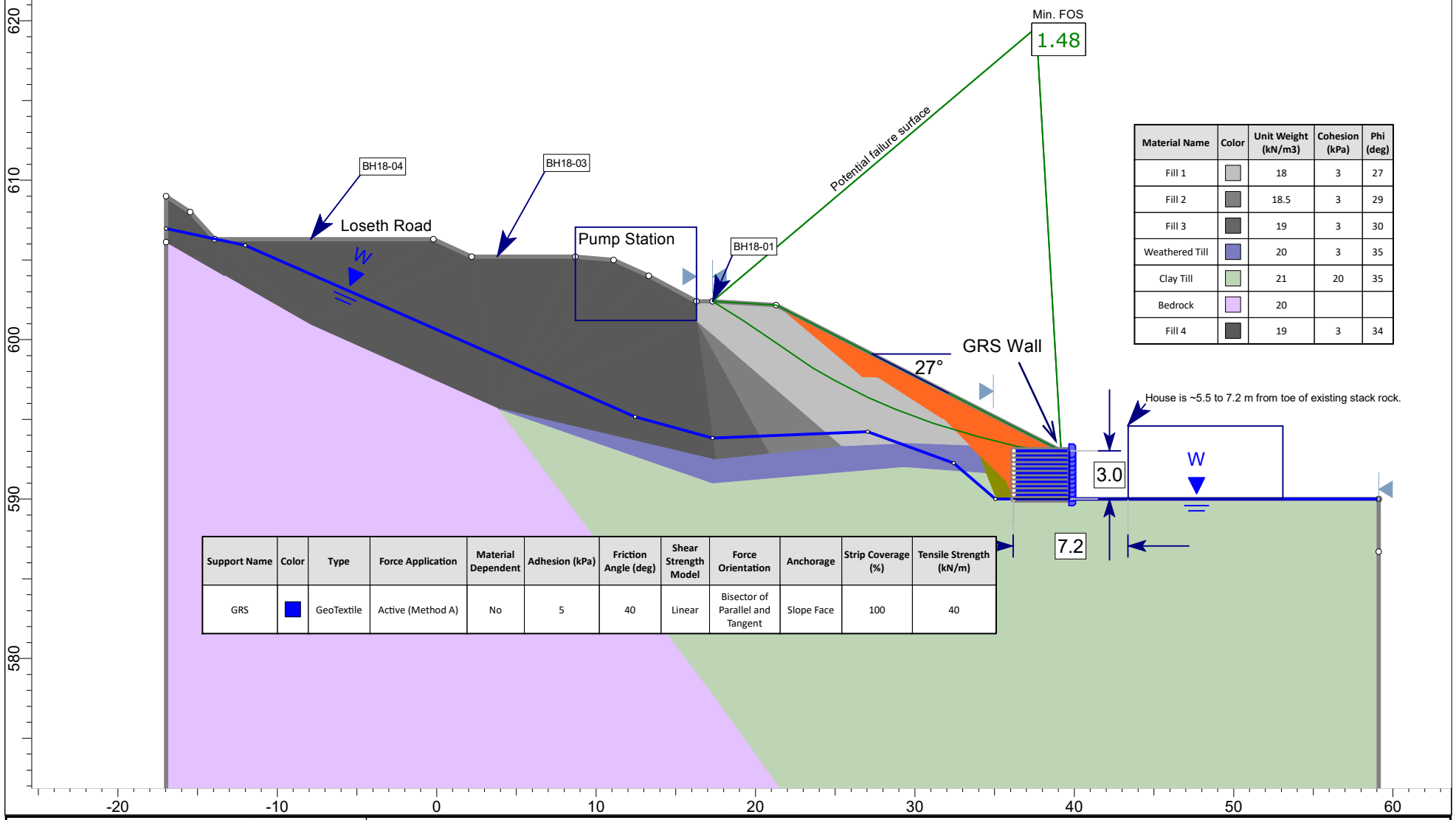
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section C-C' - Rockfill Buttress		
Drawn By JP	*Scale* 1:300	*Company*	Westrek Geotechnical Services Ltd.
Date 2018-12-19			**FIGURE 6**

All numbers have units of meters unless otherwise specified.



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Fill 4		19	3	34

Support Name	Color	Type	Force Application	Material Dependent	Adhesion (kPa)	Friction Angle (deg)	Shear Strength Model	Force Orientation	Anchorage	Strip Coverage (%)	Tensile Strength (kN/m)
GRS		GeoTextile	Active (Method A)	No	5	40	Linear	Bisector of Parallel and Tangent	Slope Face	100	40

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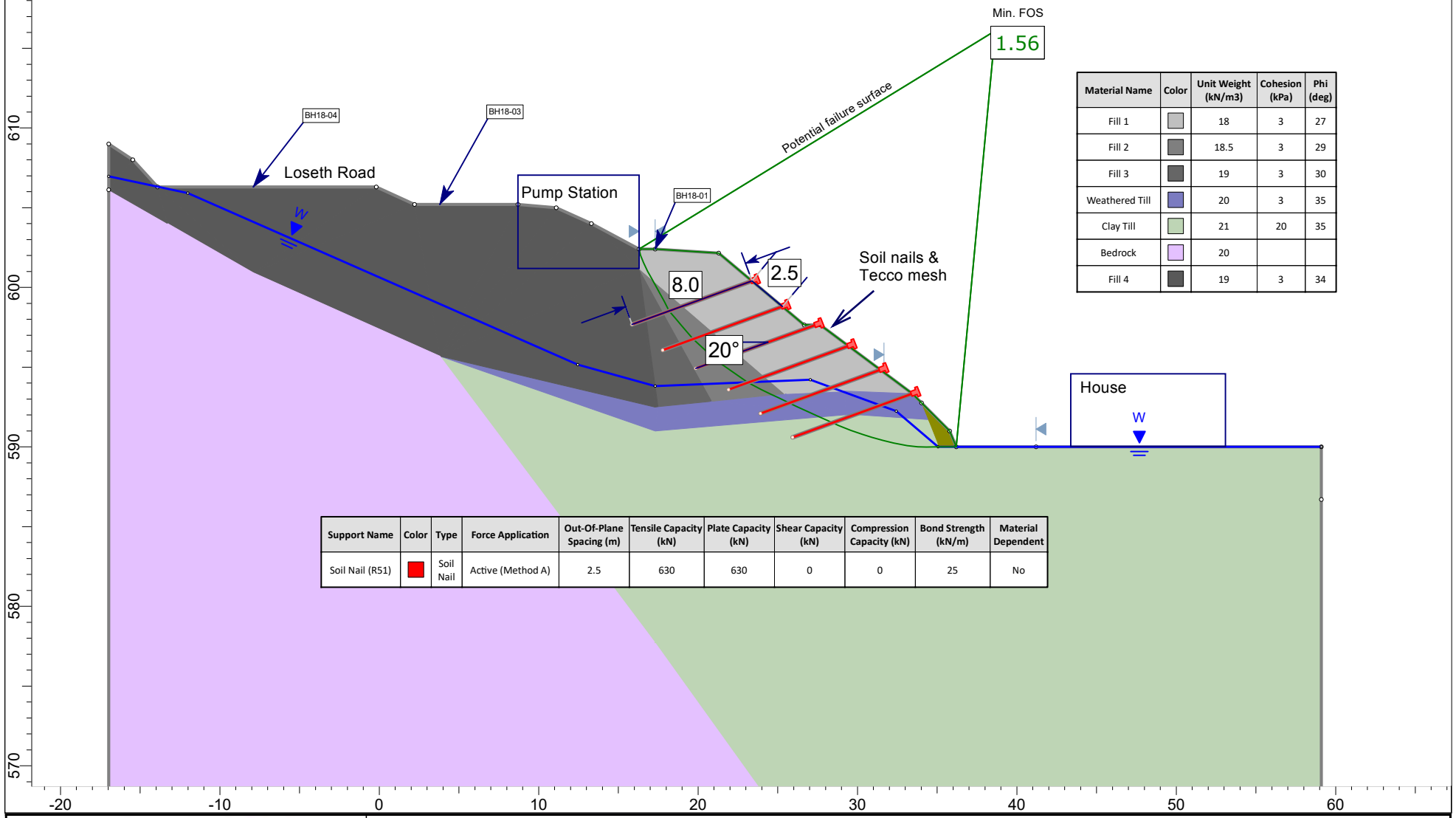
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section C-C' - GRS Toe Buttress Wall		
Drawn By JP	*Scale* 1:350	*Company*	Westrek Geotechnical Services Ltd.
Date 2018-12-19			**FIGURE 7**

All numbers have units of meters unless otherwise specified.



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Fill 4		19	3	34

Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Strength (kN/m)	Material Dependent
Soil Nail (R51)		Soil Nail	Active (Method A)	2.5	630	630	0	0	25	No

Project	2045 Loseth Road Pump Station		
Analysis Description	Section C-C' - Soil Nails and Tecco Mesh		
Drawn By JP	*Scale* 1:350	*Company*	Westrek Geotechnical Services Ltd.
Date 2018-12-19			**FIGURE 8**

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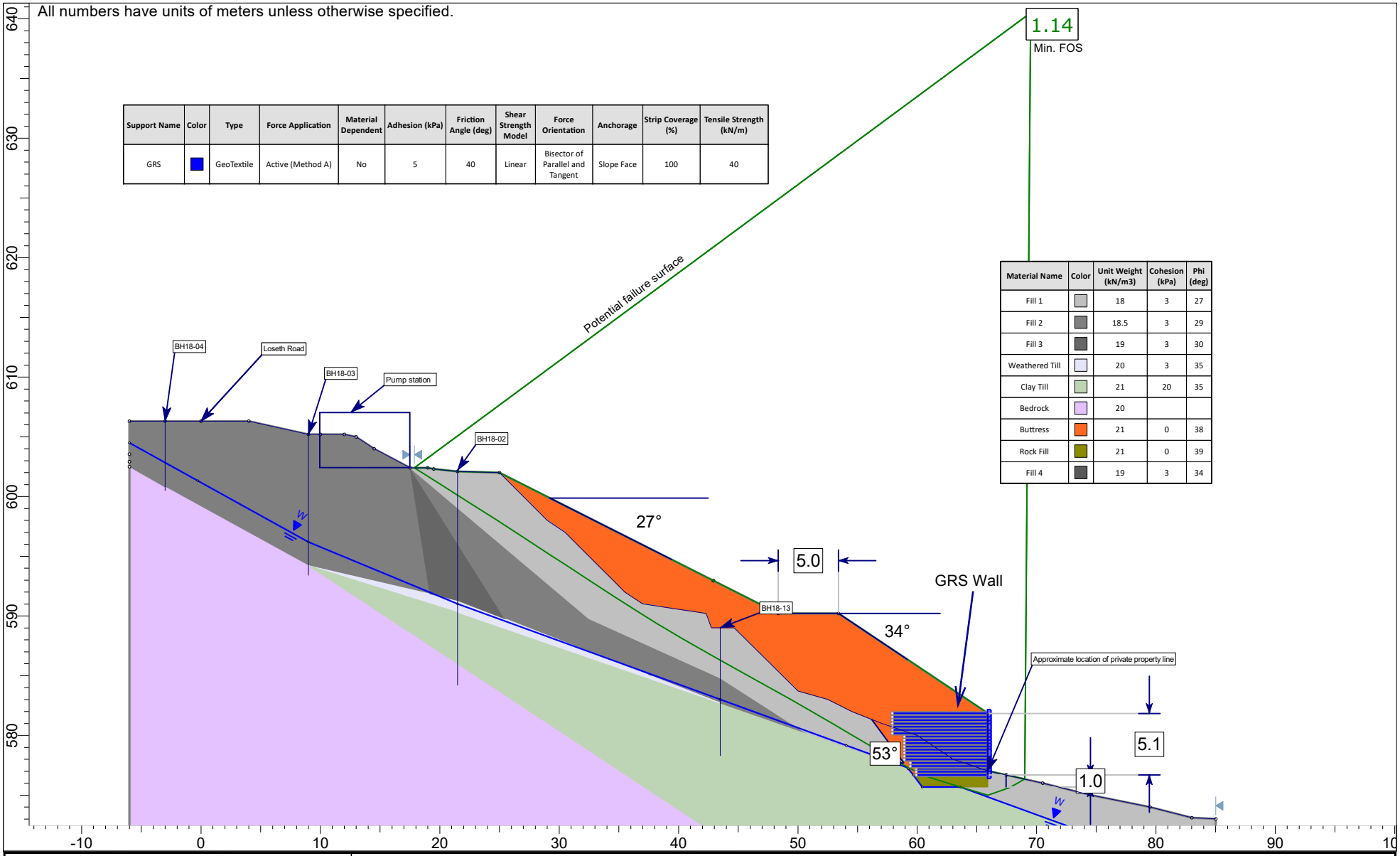
SLIDEINTERPRET 7.037

All numbers have units of meters unless otherwise specified.



Support Name	Color	Type	Force Application	Material Dependent	Adhesion (kPa)	Friction Angle (deg)	Shear Strength Model	Force Orientation	Anchorage	Strip Coverage (%)	Tensile Strength (kN/m)
GRS		GeoTextile	Active (Method A)	No	5	40	Linear	Bisector of Parallel and Tangent	Slope Face	100	40

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Buttress		21	0	38
Rock Fill		21	0	39
Fill 4		19	3	34

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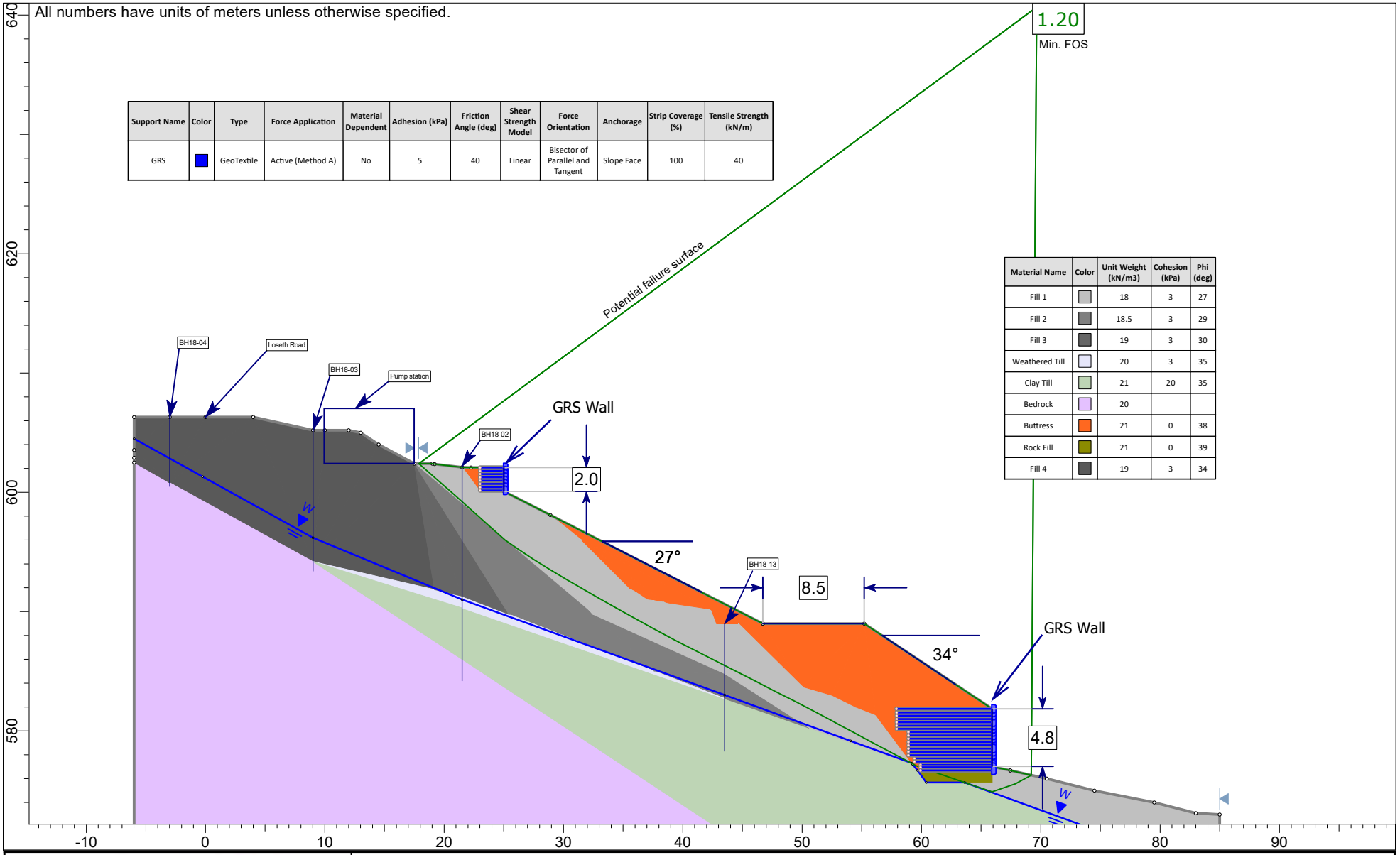
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section A-A' - GRS Toe Buttress with Benched Slope		
Drawn By	JP	*Scale* 1:450	*Company* Westrek Geotechnical Services Ltd.
Date	2018-12-19		**FIGURE 9**

All numbers have units of meters unless otherwise specified.



Support Name	Color	Type	Force Application	Material Dependent	Adhesion (kPa)	Friction Angle (deg)	Shear Strength Model	Force Orientation	Anchorage	Strip Coverage (%)	Tensile Strength (kN/m)
GRS		GeoTextile	Active (Method A)	No	5	40	Linear	Bisector of Parallel and Tangent	Slope Face	100	40

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Buttress		21	0	38
Rock Fill		21	0	39
Fill 4		19	3	34

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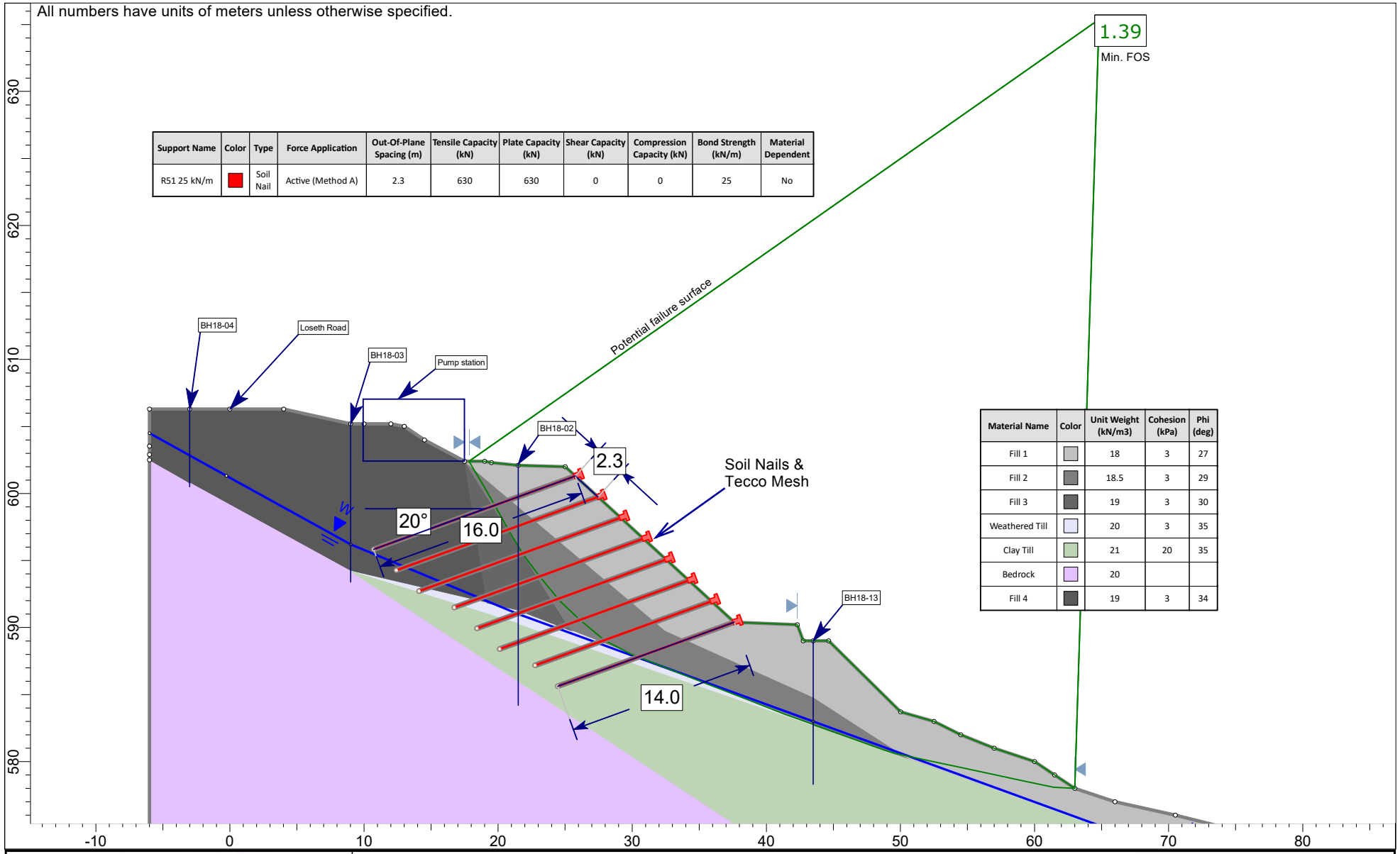
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section A-A' - GRS Toe Buttress + GRS Wall at Crest		
Drawn By JP	*Scale* 1:450	*Company*	Westrek Geotechnical Services Ltd.
Date 2018-12-19			**FIGURE 10**

All numbers have units of meters unless otherwise specified.



Support Name	Color	Type	Force Application	Out-Of-Plane Spacing (m)	Tensile Capacity (kN)	Plate Capacity (kN)	Shear Capacity (kN)	Compression Capacity (kN)	Bond Strength (kN/m)	Material Dependent
R51 25 kN/m		Soil Nail	Active (Method A)	2.3	630	630	0	0	25	No

Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		
Fill 4		19	3	34

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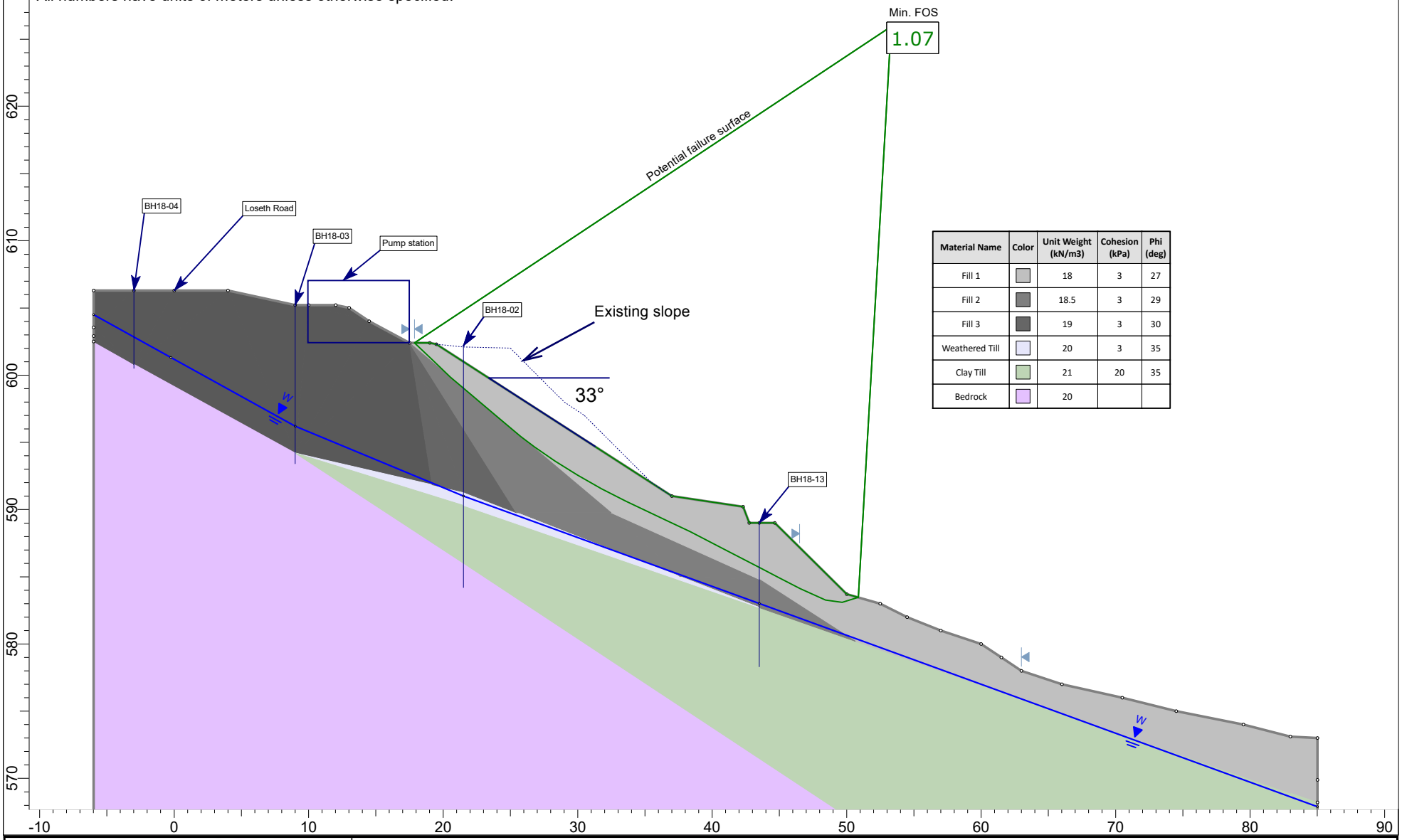
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section A-A' - Soil Nails and Tecco Mesh		
Drawn By	JP	*Scale* 1:400	*Company* Westrek Geotechnical Services Ltd.
Date	2018-12-19		**FIGURE 11**

All numbers have units of meters unless otherwise specified.



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	3	27
Fill 2		18.5	3	29
Fill 3		19	3	30
Weathered Till		20	3	35
Clay Till		21	20	35
Bedrock		20		

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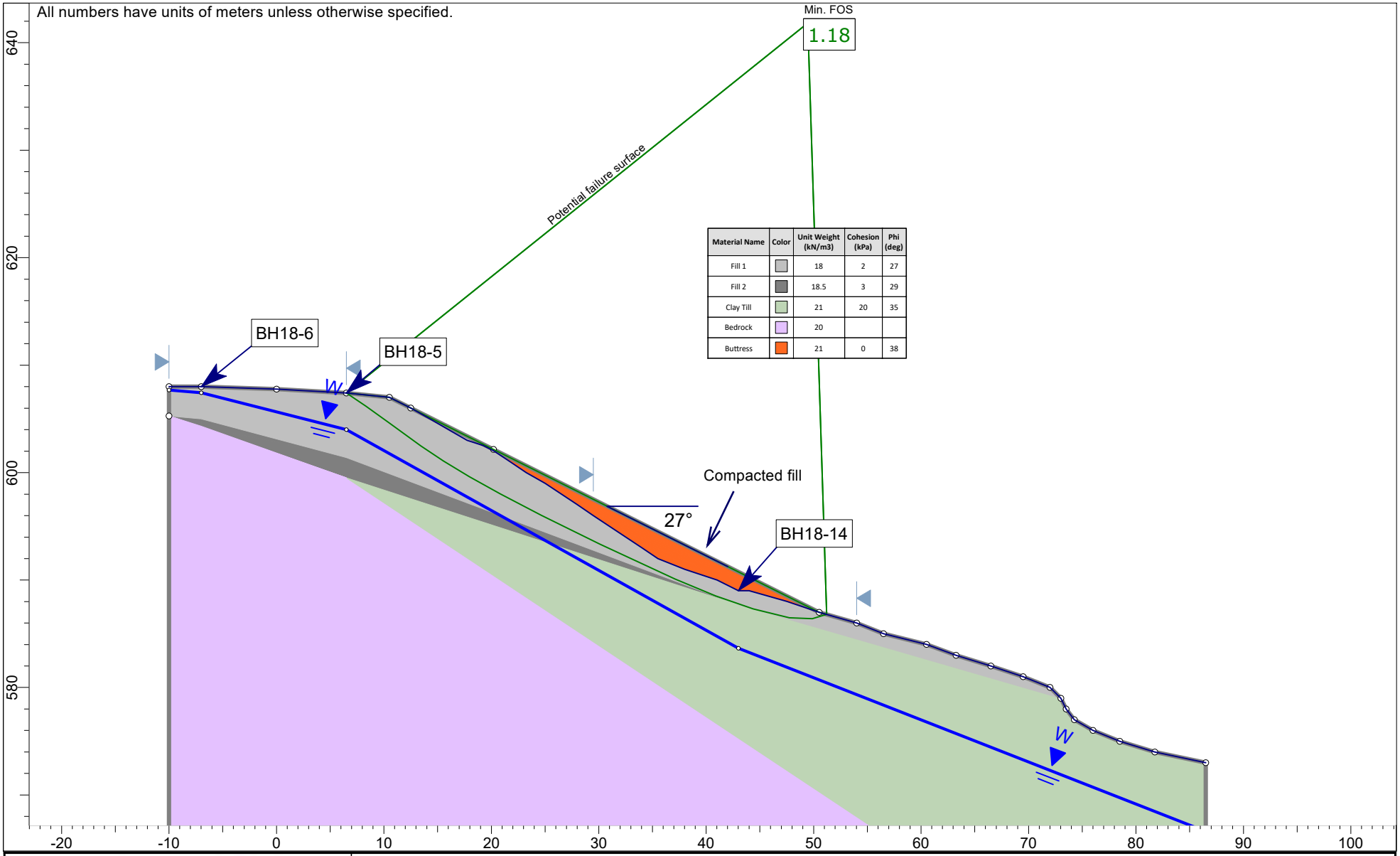
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station			
Analysis Description	Section A-A' Trim Slope to 33°			
Drawn By	JP	*Scale*	1:400	*Company* Westrek Geotechnical Services Ltd.
Date	2018-12-19			**FIGURE 12**



Project	2045 Loseth Road Pump Station		
Analysis Description	Section B-B - Fill Lower Slope at 2H:1V		
Drawn By JP	*Scale* 1:500	*Company* Westrek Geotechnical Services Ltd.	
Date 2018-12-19	**FIGURE 13**		

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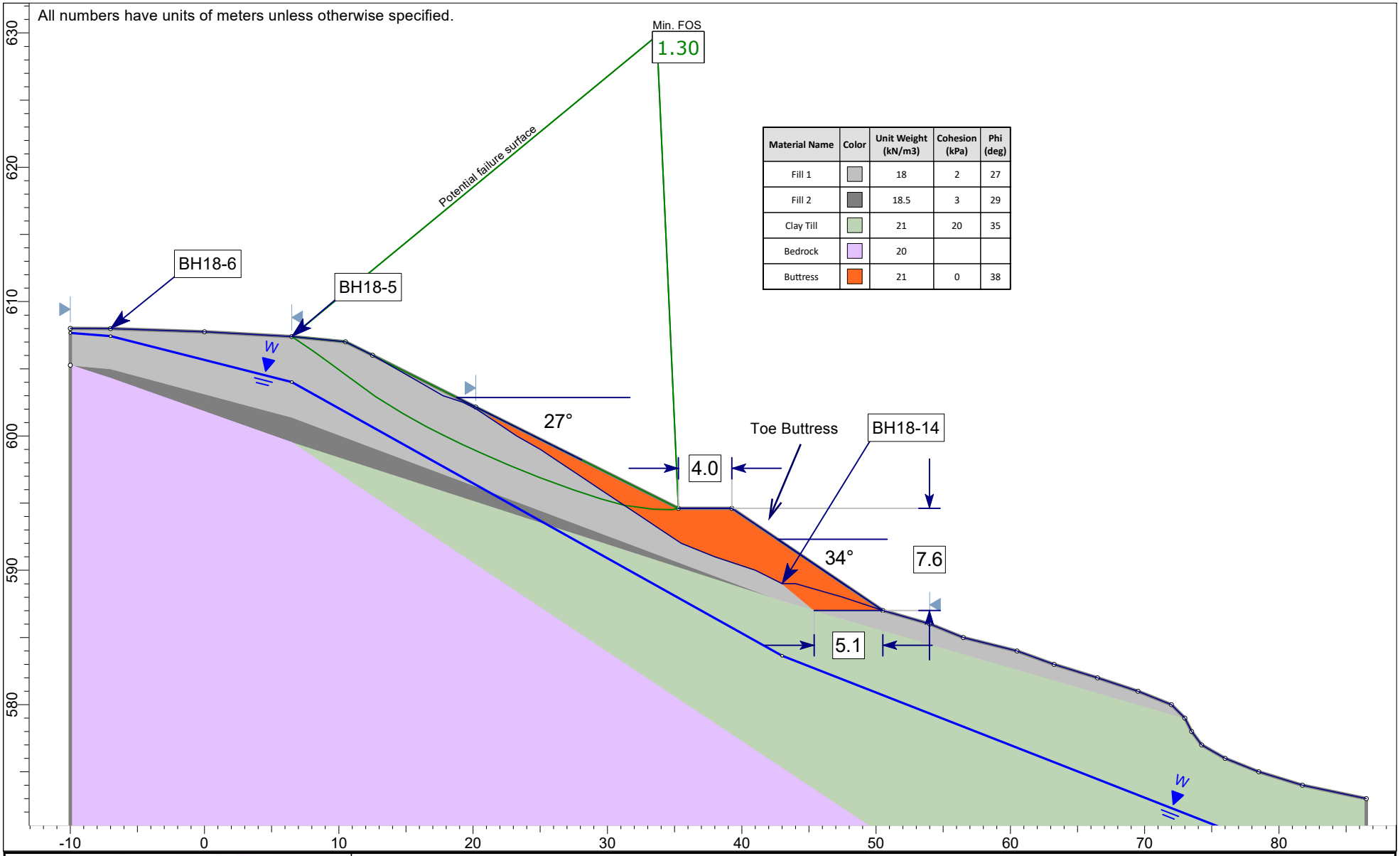
SLIDEINTERPRET 7.037



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Fill 1		18	2	27
Fill 2		18.5	3	29
Clay Till		21	20	35
Bedrock		20		
Buttress		21	0	38

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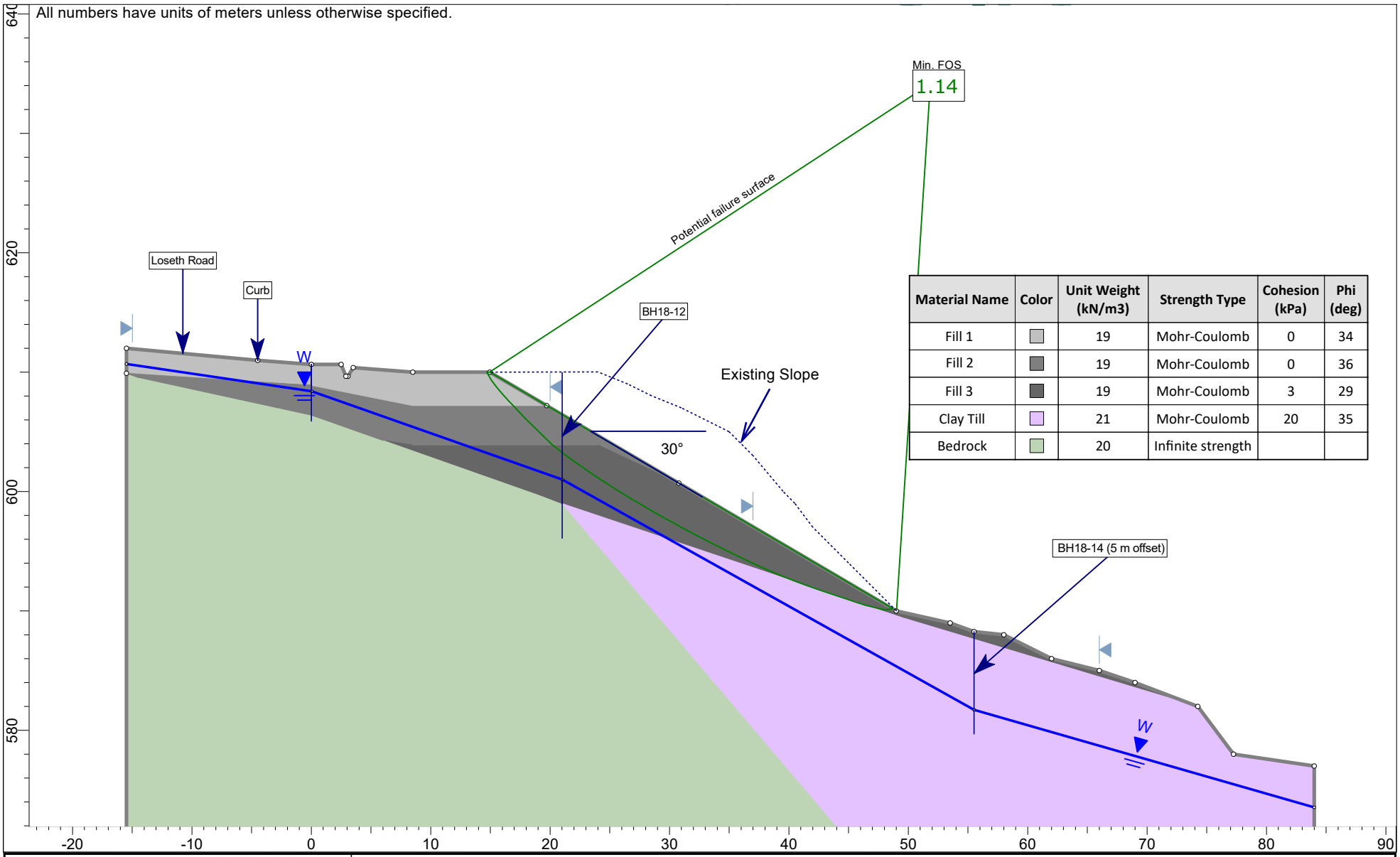
SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station		
Analysis Description	Section B-B' - Toe Buttress		
Drawn By	JP	*Scale* 1:400	*Company* Westrek Geotechnical Services Ltd.
Date	2018-12-19		**FIGURE 14**

All numbers have units of meters unless otherwise specified.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)
Fill 1		19	Mohr-Coulomb	0	34
Fill 2		19	Mohr-Coulomb	0	36
Fill 3		19	Mohr-Coulomb	3	29
Clay Till		21	Mohr-Coulomb	20	35
Bedrock		20	Infinite strength		

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SLIDEINTERPRET 7.037

Project	2045 Loseth Road Pump Station			
Analysis Description	Section D-D' - 1.75H:1V Pullback			
Drawn By	MS	*Scale*	1:450	*Company* Westrek Geotechnical Services Ltd.
Date	2018-12-19			**FIGURE 15**

APPENDIX A
INTERPRETATION AND USE OF STUDY AND REPORT AND LIMITATIONS

1. STANDARD OF CARE.

This study and Report have been prepared in accordance with generally accepted engineering and geoscience practices. No other warranty, express or implied, is made. Geological and geotechnical studies and reports do not include environmental consulting unless specifically stated in the report.

2. COMPLETE REPORT.

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF THE REPORT.

The Report has been prepared for the specific site, development, design objectives and purpose that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document are only valid to the extent that there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT.

The information and opinions expressed in the Report, or any document forming the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT. WE WILL CONSENT TO ANY REASONABLE REQUEST BY THE CLIENT TO APPROVE THE USE OF THIS REPORT BY OTHER PARTIES AS "APPROVED USERS". The contents of the Report remain our copyright property and we authorise only the Client and Approved Users to make copies of the Report only in such quantities as are reasonably necessary for the use of the Report by those parties. The Client and Approved Users may not give, lend, sell or otherwise make the Report or any portion thereof, available to any party without our written permission. Any uses, which a third party makes of the Report, or any portion of the Report, are the sole responsibility of such third parties. Westrek accepts no responsibility for damages suffered by any third party resulting from unauthorised use of the Report.

5. INTERPRETATION OF THE REPORT.

(i) Nature and Exactness of Soil and Description: Classification and identification of soils, rocks, geological units, and engineering estimates have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature and even comprehensive sampling and testing programs, implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilising the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarising such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and all persons making use of such documents or records should be aware of, and accept, this risk. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

(ii) Reliance on Provided information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations or fraudulent acts of any persons providing representations, information and instructions.

(iii) To avoid misunderstandings, Westrek should be retained to work with the other design professionals to explain relevant geotechnical findings and to review the adequacy of their plans and specifications relative to engineering issues. Further, Westrek should be retained to provide field reviews during the construction, consistent with generally accepted practices.

6. LIMITATIONS OF LIABILITY.

Westrek's liability will be limited as follows:

(a) In recognition of the relative risks and benefits of the Services to be provided to the Client by Westrek, the risks have been allocated such that the Client agrees, to the fullest extent permitted by law, to limit the liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for any and all claims, losses, costs, damages of any nature whatsoever or claims expenses from any cause or causes, whether arising in contract or tort including negligence, including legal fees and costs and disbursements (the "Claim"), so that the total aggregate liability of Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals:

i. if the Claim is satisfied by the re-performance of the Services proven to be in error, shall not exceed and shall be limited to the cost to Westrek in re-performing such Services; or

ii. if the Claim cannot be satisfied by the re-performance of the Services and:

1. if Westrek's professional liability insurance does not apply to the Claim, shall not exceed and shall be limited to Westrek's total fee for services rendered for this matter, whichever is the lesser amount. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such amount; or

2. if Westrek's professional liability insurance applies to the Claim, shall be limited to the coverage amount available under Westrek's professional liability insurance at the time of the Claim. The Client will indemnify and hold harmless Westrek from third party Claims that exceed such coverage amount. Westrek shall maintain professional liability insurance in the amount of $2,000,000 per occurrence, $2,000,000 in the aggregate, for a period of two (2) years from the date of substantial performance of the Services or earlier termination of this Agreement. If the Client wishes to increase the amount of such insurance coverage or duration of such policy or obtain other special or increased insurance coverage, Westrek will cooperate with the Client to obtain such coverage at the Client's expense.

It is intended that this limitation will apply to any and all liability or cause of action however alleged or arising, including negligence, unless otherwise prohibited by law. Notwithstanding the foregoing, it is expressly agreed that there shall be no claim whatsoever against Westrek, its officers, directors, partners, employees, shareholders, owners, subconsultants and principals for loss of income, profit or other consequential damages howsoever arising, including negligence, liability being limited to direct damages.

(b) Westrek is not responsible for any errors, omissions, mistakes or inaccuracies contained in information provided by the Client, including but not limited to the location of underground or buried services, and with respect to such information, Westrek may rely on it without having to verify or test that information. Further, Westrek is not responsible for any errors or omissions committed by persons, consultants or specialists retained directly by the Client and with respect to any information, documents or opinions provided by such persons, consultants or specialists, Westrek may rely on such information, documents or opinions without having to verify or test the same.

(c) Notwithstanding the provisions of the Limitation Act, R.S.B.C. 2012 c. 13, amendments thereto, or new legislation enacted in its place, Westrek's liability for any and all claims, including a Claim as defined herein, of the Client or any third party shall absolutely cease to exist after a period of two (2) years following the date of:

i. Substantial performance of the Services,

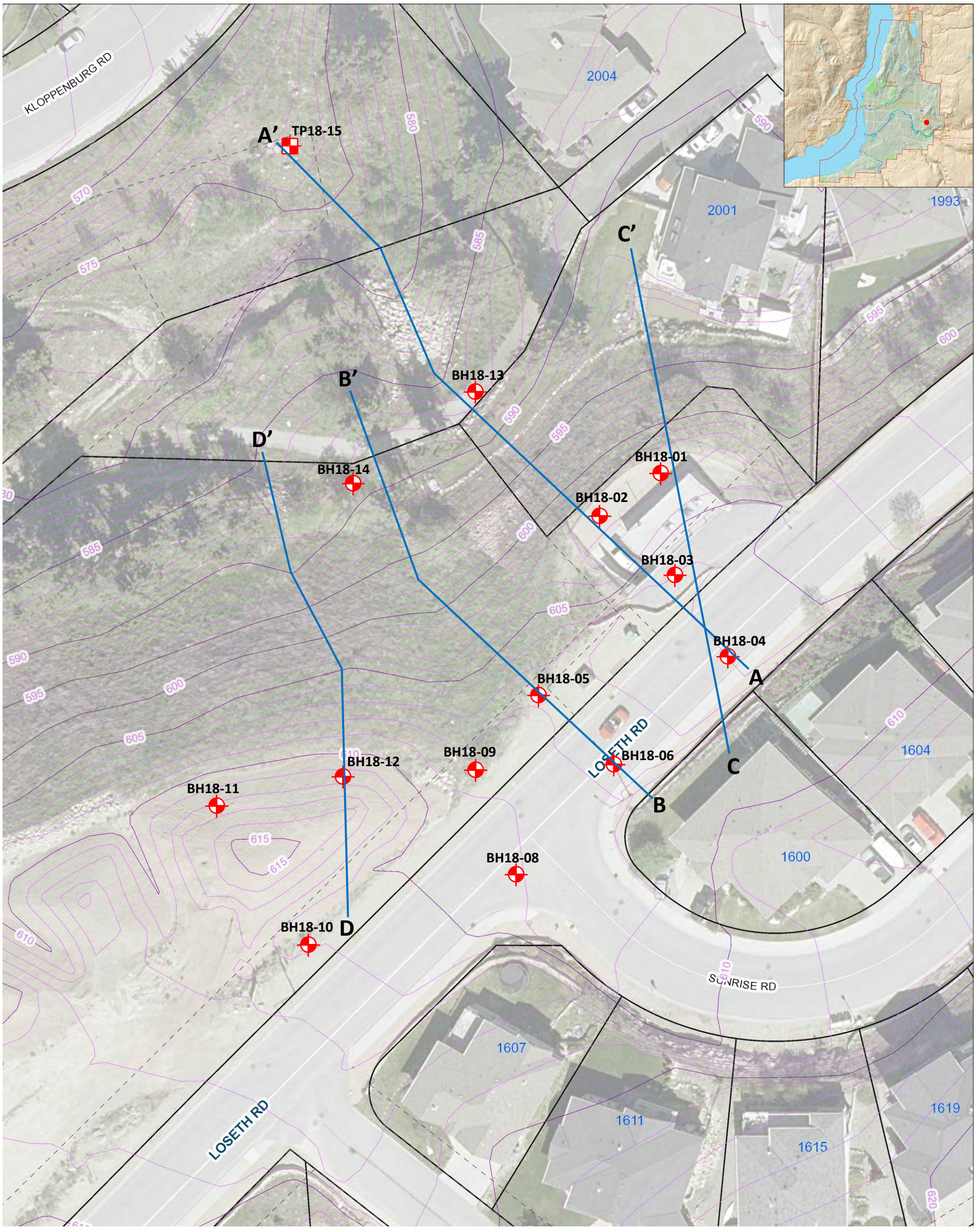
ii. Suspension or abandonment of the Services provided under this agreement, or

iii. Termination of Westrek's Services under the agreement,

whichever shall occur first, and following such period, the Client shall have no claim, including a Claim as defined herein, whatsoever against Westrek.

APPENDIX B

Drawing 01, Bore Hole Location Plan
Drawing 02, Potential Landslide Runout



LEGEND

- Borehole location
- Test-pit location
- Cross-section profile (D' – D)

N W E S

Map Source: City of Kelowna online mapping application

westrek geotechnical services ltd.
20th ANNIVERSARY
100 -1383 McGill Road, Kamloops, BC V2C 6K7

SCALE 1:500

December 7, 2018

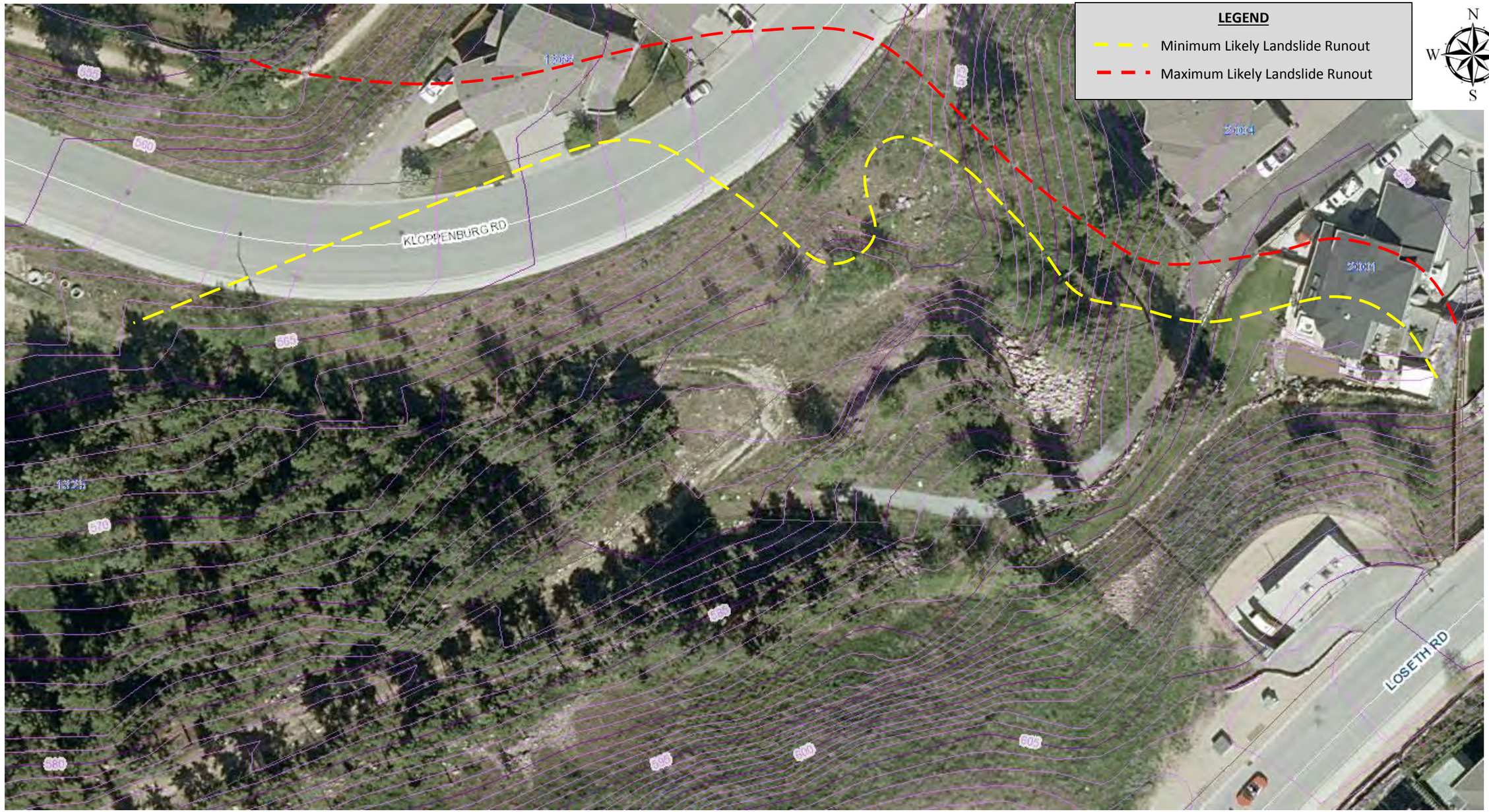
Project: 018-253

City of Kelowna

2045 Loseth Road Pump Station

Bore Hole Location Plan

DRAWING 01



Map Source: City of Kelowna online mapping application

westrek geotechnical services ltd. 20th ANNIVERSARY *100 -1383 McGill Road, Kamloops, BC V2C 6K7*	SCALE 1:500 December 18, 2018 Project: 018-253	**City of Kelowna** **2045 Loseth Road Pump Station** **Potential Landslide Runout**	**DRAWING 02**

APPENDIX C

Bore Hole Logs & Test Pit Log

RECORD OF BOREHOLE BH18-01

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330515.64E 5526037.92N | Elevation: 602.4 m [Survey]

Date Drilled: Aug 07-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m) Water Level
0	Sonic	(SM-SC) fine SANDY SILT some clay, trace gravel; loose, dry; brown-grey [FILL].					PLASTIC 10 20 30 40; M.C.; LIQUID BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80 VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160			602
1										601
2										600
3						01		W_n = 10.6%		599
4		...becomes trace cobbles, dry to moist, compact.		4.0 598.5						598
5						02		W_n = 13.7%		597
		...becomes dark grey with organics; moist to wet.		5.6 596.8		03				
6		(SM-SC) SILTY SAND some clay, trace gravel, trace organics; loose/soft to compact/stiff, dry; brown-grey [FILL].		5.8 596.6						596
7										595
8		...highly variable density; discontinuous pods of hard soil.		7.9 594.5		04		W_n = 10.4% May be chunks of hard till mixed in with fill.		594
9										593
10		...becomes loose to compact.		9.8 592.7						

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY.
THIS LOG IS THE SOLE PROPERTY OF WESTREK GEOTECHNICAL SERVICES LTD. AND CANNOT BE USED OR DUPLICATED IN ANYWAY WITHOUT EXPRESS WRITTEN PERMISSION.

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

WESTREK SOIL BOREHOLE LOG 018-098 BMID KIRSCHNER MOUNTAIN PUMP STATION SLIDE - NO PPEN.GPJ WGS SOIL LOG.GDT 18-12-20

RECORD OF BOREHOLE BH18-01

2045 Loseth Road Pump Station

City of Kelowna

Date Drilled: Aug 07-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

Project No.: 018-253

Co-ordinate: 11 330515.64E 5526037.92N

Elevation: 602.4 m [Survey]

SAMPLE TYPE: SPT SAMPLE; GRAB SAMPLE; SHELBY TUBE; CORE SAMPLE; NO RECOVERY

INSTALLATION: GROUT; BENTONITE; SAND; DRILL CUTTINGS; SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m) Water Level
10						05		W_n = 10.0% Sieve Analysis (10.0 m): Gravel = 13% Sand = 42% Fines = 45%		592
				10.4 592.1						
		(SP/GP) SAND and GRAVEL sub-angular to sub-rounded, some silt; dry to moist, compact; brown-grey [FILL].		10.8 591.6						
11		(ML) fine SANDY SILT some clay, trace gravel, sub-rounded to sub-angular, occasional cobbles; inferred compact, moist; brown-grey [FILL].		11.4 591.0		06		W_n = 10.6%		591
12		(SM) SILTY SAND some gravel, sub-rounded to sub-angular, trace clay, occasional cobbles; inferred compact, moist; medium brown [WEATHERED TILL].								590
13						07		W_n = 8.0% Sieve Analysis (12.9 m): Gravel = 21% Sand = 42% Fines = 37% VW piezometer installed at ~13.4 m depth.		589
14				14.0 588.4				Difficult drilling and high core expansion below.		588
		(SM) SILTY SAND some gravel, sub-rounded to sub-angular, trace clay, occasional cobbles; dense, moist; grey-brown [TILL].				08		W_n = 8.3%		
15	Sonic									587
16										586
17										585
18										584
19										583
20										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-01

2045 Loseth Road Pump Station

City of Kelowna

westrek geotechnical services ltd.

Project No.: 018-253 | Co-ordinate: 11 330515.64E 5526037.92N | Elevation: 602.4 m [Survey]

Date Drilled: Aug 07-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m) Water Level
20	Sonic					09		W_n = 10.0% Sieve Analysis (20.5 m): Gravel = 10% Sand = 51% Fines = 40%		582
21		...gravel and cobble content decreases slightly, below.		21.0 581.4						581
22										580
23										579
24										578
25										577
26										576
27		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		26.2 576.2						575
28		End of hole at 27.1 m (575.3 m) Notes: Piezometer max head elevation 589.6 m (November 12, 2018). Ground surface is 0.18 m above top of slope inclinometer casing.		27.1 575.3						574
29										573
30										

PLASTIC / M.C. / LIQUID: 10 20 30 40

BLOW COUNT [SPT] ◆ [DCPT] ▼: 20 40 60 80

VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗: 40 80 120 160

WESTREK SOIL BOREHOLE LOG 018-098 BMID KIRSCHNER MOUNTAIN PUMP STATION SLIDE - NO PPEN.GPJ WGS SOIL LOG.GDT 18-12-20

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-02

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330507.6E 5526032.91N | Elevation: 602.1 m [Survey]

Date Drilled: Aug 09-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	(ML) SILT some gravel, fine to coarse, angular, occasional cobbles and boulders; loose, moist; dark brown [FILL].		0.2 602.0			PLASTIC M.C. LIQUID 10 20 30 40 BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80 VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160			602
1		(SM) fine SANDY SILT trace to some clay, trace gravel, rounded to sub-angular; loose, moist; medium brown-grey, blocky [FILL].								601
2										600
3										599
4										598
5						01		W_n = 12.8% PL = 13.9% LL = 19.3% Sieve Analysis (4.7 m): Gravel = 8% Sand = 31% Silt = 51% Clay = 9%		597
6		...becomes occasional hard chunk, occasional cobble; very stiff/compact, moist; medium grey with light to medium brown mottling.		5.6 596.5						596
7		...becomes soft/loose, moist to wet; brown-grey.		6.6 595.6		02		W_n = 13.3%		595
8		...becomes trace sand and occasional cobbles; dense, moist; medium grey. ...becomes fewer cobbles and trace organics (bark); very dense, moist; dark blue-grey. ...increased sand and gravel content, occasional cobbles.		7.5 594.7 7.8 594.4 8.2 593.9		03 04 05		W_n = 11.0%		594
9										593
10		(SM) SILTY SAND some clay, trace fine gravel; variable loose to compact (firm to stiff), wet; medium grey [FILL].		9.3 592.8		06		VW piezometer installed at 9.4 m depth. W_n = 15.2% Sieve Analysis (9.5 m):		

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-02

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330507.6E 5526032.91N | Elevation: 602.1 m [Survey]

Date Drilled: Aug 09-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
10	Sonic	...becomes trace to some gravel, occasional cobbles; dense, dry to moist (variable); dark grey with brown mottling.		10.4 / 591.8				Gravel = 7% Sand = 49% Fines = 44%		592
11		(SM) SILTY SAND some clay, trace to some gravel, rounded to sub-angular, some cobbles; inferred very dense, dry; light brown to off-white [WEATHERED TILL].		10.8 / 591.3				Very difficult to drill below.		591
12		(SM) SILTY SAND trace to some clay, trace gravel, rounded to sub-angular, trace cobbles; inferred dense, dry to moist (variable); medium grey-brown [TILL].		11.9 / 590.3						590
13										589
14						07		W_n = 10.9% PL = 12.9% LL = 18.0% Sieve Analysis (13.8 m): Gravel = 9% Sand = 47% Silt = 35% Clay = 9%		588
15										587
16				16.2 / 586.0						586
17		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).								585
18				18.0 / 584.2						584
19		End of hole at 18.0 m (584.2 m) Notes: Piezometer was dry (August 27, 2018). Ground surface is 0.12m above top of slope inclinometer casing.								583
20										

PLASTIC / M.C. / LIQUID: 10 20 30 40

BLOW COUNT [SPT] ◆ [DCPT] ▼: 20 40 60 80

VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗: 40 80 120 160

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-03

2045 Loseth Road Pump Station

City of Kelowna

Date Drilled: Aug 07-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

Project No.: 018-253

Co-ordinate: 11 330517.38E 5526025.15N

Elevation: 605.2 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	ASPHALT		0.2 / 605.0						605
		(GP) GRAVEL 3-inch minus granular [ROAD BASE].								
		...becomes cobbly with sand and fines, wet.		0.6 / 604.6 0.8 / 604.4						
1		(SM-SC) sandy SILT fine-grained, some clay, trace gravel, sub-rounded; loose to compact, moist; medium brown to grey-brown [FILL].				01		W_n = 12.3% Sieve Analysis (1.4 m): Gravel = 5% Sand = 28% Fines = 67%		604
2										603
						02				
3										602
				3.4 / 601.9		03		W_n = 10.7%		
		... becomes trace to some gravel, sub-rounded to sub-angular, trace cobbles, trace organics (roots); dense; brown-grey.								
4										601
						04		W_n = 10.2%		
5										600
6		... slight medium brown mottling.		5.9 / 599.3		05		W_n = 11.3%		599
7										598
						06				
8										597
						07		W_n = 13.3%		
				8.8 / 596.4						
9		... becomes some gravel, trace cobbles, trace organics; loose, wet; dark grey with yellow-brown mottling.				01		N = 10		596
								VW piezometer installed at 9.4 m depth.		
						08		W_n = 12.6%		
10				9.9						

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-03

2045 Loseth Road Pump Station

City of Kelowna

Date Drilled: Aug 07-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

Project No.: 018-253

Co-ordinate: 11 330517.38E 5526025.15N

Elevation: 605.2 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
10	Sonic	(GM) sandy GRAVEL some silt, trace clay, trace cobbles; compact, moist to wet; medium brown with dark grey silty clay pods [COLLUVIUM].		595.3		09	PLASTIC M.C. LIQUID 10 20 30 40 BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80 VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160	W_n = 12.1% Sieve Analysis (10.3 m): Gravel = 37% Sand = 35% Fines = 28%		595
11		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		11.0 594.2						594
12		End of hole at 11.9 m (593.4 m) Notes: Piezometer was dry (August 27, 2018). Ground surface is 0.07m above top of slope inclinometer casing.		11.9 593.4						593
13										592
14										591
15										590
16										589
17										588
18										587
19										586
20										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-04

2045 Loseth Road Pump Station

City of Kelowna

Date Drilled: Aug 03-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

Project No.: 018-253

Co-ordinate: 11 330524.3E 5526014.39N

Elevation: 606.3 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	HVAC	ASPHALT		0.1 / 606.2						606
		(SM-SC) gravelly silty SAND fine-grained to coarse-grained, sub-rounded gravel, some clay; compact, moist; yellow-brown [FILL].								
1										605
2		ROCK FILL		1.8 / 604.5						604
		(CL-ML) sandy SILT dominantly fine-grained, some clay, trace gravel, sub-rounded to sub-angular; compact to dense, moist; grey-brown [FILL].		2.0 / 604.3		01				
3										603
4	Sonic					02		W_n = 11.0% Sieve Analysis (3.4 m): Gravel = 7% Sand = 30% Fines = 63%		602
		(CL-ML) clayey SILT trace sand, trace gravel, sub-rounded to sub-angular, occasional cobbles, trace organics; compact/very stiff, moist; medium grey with brown mottling [FILL].		4.1 / 602.2		03				
				4.6 / 601.7		04		W_n = 14.0%		
5		(SM-SC) gravelly SILTY SAND fine-grained to coarse-grained, sub-angular gravel, some clay, occasional cobbles, trace organics; loose to compact, moist to wet; dark blue-grey [FILL].		4.9 / 601.4		05 06 07		VW piezometer installed at 5.2 m depth. W_n = 15.1% Sieve Analysis (5.4 m): Gravel = 27% Sand = 40% Fines = 34%		601
		(SM-SC) gravelly SILTY SAND fine-grained to coarse-grained, sub-rounded to sub-angular gravel, some clay, trace organics; loose, moist; yellow-brown [COLLUVIUM].		5.5 / 600.8						
6		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		5.8 / 600.5						600
7		End of hole at 5.8 m (600.5 m) Notes: Piezometer was dry (August 27, 2018). Ground surface is 0.24m above top of slope inclinometer casing.								599
8										598
9										597
10										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-05

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330499.59E 5526009.41N | Elevation: 607.4 m [Survey]

Date Drilled: Aug 10-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	(SM-SC) silty SAND some clay, some gravel, angular to sub-rounded, occasional cobbles, trace to some organics; compact/stiff, dry; dark brown [FILL].					PLASTIC M.C. LIQUID 10 20 30 40 BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80 VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160	DCPT at 0.15m to 0.45m stuck on cobble.		607
1										606
2		...becomes very loose/soft, moist to wet.		1.8 605.6		01		GS-01 depth approximate due to poor recovery. W_n = 19.1%		605
3						02		W_n = 17.3%		604
4		(SM-ML) fine SANDY SILT some clay, trace gravel, fine, sub-rounded to sub-angular; loose/firm, moist; yellow-grey [FILL].		3.7 603.7		03		W_n = 14.3%		603
5								VW piezometer installed at 5.2 m depth.		602
6		...becomes some gravel; compact/stiff, dry to moist; medium grey with mild light brown mottling.		6.1 601.3						601
7						04		W_n = 11.2% Sieve Analysis (6.9 m): Gravel = 13% Sand = 34% Fines = 54%		600
8		(SM-SC) silty SAND some clay, trace gravel; compact/stiff, moist; light brown with rusty orange mottling [COLLUVIUM]. BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		7.2 600.2 7.9 599.5		05				599
9		End of hole at 8.8 m (598.6 m) Notes: Piezometer was dry (August 27, 2018). Ground surface is 0.1m above top of slope inclinometer casing.		8.8 598.6						598
10										

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N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

WESTREK SOIL BOREHOLE LOG 018-098 BMID KIRSCHNER MOUNTAIN PUMP STATION SLIDE - NO PPEN.GPJ WGS SOIL LOG.GDT 18-12-20

RECORD OF BOREHOLE BH18-06

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330509.53E 5526000.32N | Elevation: 608.0 m [Survey]

Date Drilled: Aug 03-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m) Water Level
0	Hydrovac	ASPHALT		0.1 / 607.9			PLASTIC 10 20 30 40; M.C.; LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160			
		(SM) gravelly silty SAND fine-grained to coarse-grained sand, fine to coarse gravel, sub-rounded; compact, moist; yellow-brown [FILL].								
1										607
2										606
				2.4 / 605.6						
		ROCK FILL		2.6 / 605.4						
3		(SM-GM) gravelly silty SAND fine-grained to coarse-grained sand, fine to coarse sub-rounded gravel; compact, moist; yellow-brown [COLLUVIUM].								605
	Sonic			3.7 / 604.3				VW piezometer installed at 3.5 m depth.		
4		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).								604
5										603
				5.8 / 602.2						
6		End of hole at 5.8 m (602.2 m) Notes: Piezometer max head elevation 605.9 m (November 1, 2018). Ground surface is 0.18 m above top of slope inclinometer casing.								602
7										601
8										600
9										599
10										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-08

2045 Loseth Road Pump Station

City of Kelowna

westrek geotechnical services ltd.

Project No.: 018-253 | Co-ordinate: 11 330496.57E 5525986.05N | Elevation: 609.4 m [Survey]

Date Drilled: Aug 03-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	Elevation (m)
0	Hydrovac	ASPHALT		0.1 / 609.3					609
		(SP/GP) SAND and GRAVEL fine-grained tocoarse-grained sand, sub-rounded gravel, trace to some fines, occasional cobbles; compact, moist; medium to dark brown [FILL].				01			
1		ROCK FILL		1.2 / 608.2					608
		(SM-ML) sandy SILT some clay, trace gravel, sub-angular to angular; loose to compact, moist; grey brown [FILL].		1.4 / 608.0		02			
2	DCPT	BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		2.1 / 607.4					607
		End of hole at 2.1 m (607.4 m)		2.1 / 607.3					
3									606
4									605
5									604
6									603
7									602
8									601
9									600
10									

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

WESTREK SOIL BOREHOLE LOG 018-098 BMID KIRSCHNER MOUNTAIN PUMP STATION SLIDE - NO PPEN.GPJ WGS SOIL LOG.GDT 18-12-20

RECORD OF BOREHOLE BH18-09

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330491.27E 5525999.77N | Elevation: 609.0 m [Survey]

Date Drilled: Aug 09-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	ROCK FILL angular rock from pad building.		0.3 608.6				DCPT results skewed from surface to about 1 m depth due to rocks.		609
1		(SM-GM) silty SAND some gravel, fine to coarse, angular to sub-rounded, trace to some clay, inferred occasional cobbles and boulders; inferred compact, dry; light brown [FILL].				01		W_n = 6.9%		608
2				2.4 606.5						607
3		(SM-SC) fine sandy SILT some clay, trace gravel, sub-angular to sub-rounded, trace cobbles; loose to compact (variable density), moist; brown-grey [FILL].		3.2 605.8						606
4		ROCK FILL angular		3.5 605.4		02		W_n = 13.4%		605
5		(SM-SC) fine sandy SILT trace to some clay, trace gravel, sub-angular to sub-rounded, trace cobbles; loose to compact / stiff to very stiff (variable density), moist; brown-grey [FILL].				03		W_n = 12.8%		604
6						04		VW piezometer installed at 6.1 m depth. W_n = 14.5% Variable density between 5.8 m and 6.9 m.		603
7		(SM-GM) silty SAND some clay, some gravel, angular to sub-rounded, some organics (roots); compact, moist to wet; dark black-grey [FILL].		6.9 602.1		05		Spongey.		602
8		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		7.5 601.5						601
9		End of hole at 8.8 m (600.1 m) Notes: Ground surface is 0.95 m below top of slope inclinometer casing.		8.8 600.1						600
10										

THIS LOG IS FOR GEOTECHNICAL PURPOSES ONLY.

N - Blow Count

Standard Penetration Test [SPT]: ASTM D1586

Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw

DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-10

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330469.61E 5525977.12N | Elevation: 611.7 m [Survey]

Date Drilled: Aug 10-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	(SM-GM) silty SAND some gravel, angular to sub-rounded, trace to some clay; compact, dry; light brown [FILL].				01				611
1										
		(SM-SC) fine sandy SILT some clay, trace gravel; loose to very dense (variable due to hard blocks); dry; brown-grey, blocky [FILL].		1.5 610.2		02		W_n = 8.1%		610
2		...boulder.		2.4 609.3						
		...becomes trace cobbles; compact to dense, moist; medium grey.		2.7 609.0						609
3										
4										608
						03		W_n = 12.9%		607
5				5.2 606.5						
		...becomes some organics; moist; dark black-grey.		5.3 606.4						606
6		BEDROCK Fresh to slightly weathered, brown-yellow, fine-grained, with silica veinlets, R5, DACITE (Kettle River Formation).		5.8 605.9						
		End of hole at 5.8 m (605.9 m) Notes: Ground surface is 0.78 m below top of slope inclinometer casing.								605
7										
										604
8										
										603
9										
										602
10										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-11
2045 Loseth Road Pump Station
City of Kelowna

Date Drilled: Aug 19-2018
Drill Type: Sonic
Driller: Mud Bay Drilling
Project No.: 018-253
Co-ordinate: 11 330457.98E 5525995.02N
Elevation: 610.1 m [Survey]

SAMPLE TYPE: SPT SAMPLE; GRAB SAMPLE; SHELBY TUBE; CORE SAMPLE; NO RECOVERY
INSTALLATION: GROUT; BENTONITE; SAND; DRILL CUTTINGS; SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	(SM-GM) gravelly SAND sub-rounded to sub-angular, some silt, trace clay; dense; brown [FILL].								610
1		...becomes compact.		1.5 608.6						609
2		(SM-SC) SILT and SAND some clay, some gravel; sub-angular to angular; compact, moist; brown [FILL].		2.1 608.0		01		W_n = 10.5%		608
3		ROCK FILL angular fragments up to 15 cm, local dacite lithology; light grey-orange.		2.7 607.4		02		>> Poor sample recovery.		607
4										606
5										605
6										604
7										603
8						03				602
		(SM-SC) fine sandy SILT some clay, trace gravel, sub-rounded to sub-angular; loose to compact, wet; brown [FILL].		8.2 601.9		04		W_n = 12.8%		
9		...becomes trace cobbles, sub-rounded to sub-angular; loose / firm.		8.8 601.3		05		W_n = 11.3%		601
10										

PLASTIC M.C. LIQUID
10 20 30 40
BLOW COUNT [SPT] ◆ [DCPT] ▼
20 40 60 80
VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗
40 80 120 160

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: jp
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-11

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330457.98E 5525995.02N | Elevation: 610.1 m [Survey]

Date Drilled: Aug 19-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
10	Sonic						PLASTIC M.C. LIQUID 10 20 30 40; BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160			600
11		...becomes loose to compact / firm to stiff.		11.0 / 599.2						599
		...becomes with angular fragments; wet; orange to light grey.		11.6 / 598.6						
12								VW piezometer installed at 11.9 m depth.		598
				12.5 / 597.7		06				
		WEATHERED BEDROCK Highly weathered, orange to light grey, fine-grained, clayey, dry, R1, DACITE (Kettle River Formation).		12.8 / 597.3		07				
13		BEDROCK Fresh to slightly weathered, light orange-grey, fine-grained, with silica veinlets, dry, R5, DACITE (Kettle River Formation).								597
14				14.0 / 596.1		087				596
		End of hole at 14.0 m (596.1 m) Notes: Ground surface is 0.1 m above top of slope inclinometer casing.								
15										595
16										594
17										593
18										592
19										591
20										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: jp
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-12
2045 Loseth Road Pump Station
City of Kelowna

Date Drilled: Aug 19-2018
Drill Type: Sonic
Driller: Mud Bay Drilling
Project No.: 018-253
Co-ordinate: 11 330474.1E 5525998.84N
Elevation: 610.0 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY
INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	Sonic	(GM-GC) gravelly SAND to SAND and GRAVEL sub-rounded to angular, some silt, some clay; loose to compact, moist; brown [FILL].								
1										609
2						01		W_n = 8.7% Sieve Analysis (2.3 m): Gravel = 47% Sand = 32% Fines = 21%		608
3		...becomes some angular to sub-angular blocks (max 6 cm); moist to wet.		2.7 607.2						607
4						02		W_n = 15.1%		606
5		...becomes loose.		5.0 605.0						605
6		(SM) silty SAND some gravel, fine, sub-rounded to sub-angular, some clay, trace organics (rootlets, pieces of wood, charcoal); loose, wet; dark brown, likely poorly stripped topsoil mixed with fill [FILL].		6.1 603.9		03		W_n = 21.2%		604
7										603
8										602
9		...becomes some organics (woody fragments up to 5 cm, roots, charcoal); loose, wet; dark brown-black.		9.1 600.8						601
10										

PLASTIC M.C. LIQUID: 10 20 30 40
BLOW COUNT [SPT] ◆ [DCPT] ▼: 20 40 60 80
VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗: 40 80 120 160

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: jp
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-12

2045 Loseth Road Pump Station

City of Kelowna

Date Drilled: Aug 19-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

Project No.: 018-253

Co-ordinate: 11 330474.1E 5525998.84N

Elevation: 610.0 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
10	Sonic	...becomes gravelly, sub-rounded to sub-angular, trace organics.		10.5 / 599.4		04		VW piezometer installed at 10.1 m depth. W_n = 20.5%		599
11		WEATHERED BEDROCK Highly weathered, brown-yellow, fine-grained, with silica veinlets, dry, R1, DACITE (Kettle River Formation).		11.0 / 599.0		05		W_n = 18.8%		
12						06				598
		BEDROCK Moderately weathered, orange to light grey, fine-grained, with silica veinlets, dry, R2, DACITE (Kettle River Formation).		12.2 / 597.8		01 07		N = 78		
13										597
		...becomes fresh, R5.		13.4 / 596.5		08				
				13.9 / 596.1		09				
14		End of hole at 13.9 m (596.1 m) Notes: Ground surface is 0.09 m above top of slope inclinometer casing.								596
15										595
16										594
17										593
18										592
19										591
20										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: jp
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-13
2045 Loseth Road Pump Station
City of Kelowna

Date Drilled: Aug 16-2018
Drill Type: ODEX
Driller: Mud Bay Drilling
Project No.: 018-253
Co-ordinate: 11 330491.59E 5526048.48N
Elevation: 589.0 m [Survey]

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY
INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
0	ODEX	(SC-SM) SILTY SAND fine-grained to medium-grained, some clay, trace gravel, angular; loose to compact, moist; medium to dark brown [FILL].					PLASTIC M.C. LIQUID 10 20 30 40 BLOW COUNT [SPT] ◆ [DCPT] ▼ 20 40 60 80 VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗ 40 80 120 160			
1										588
2		...boulder.		2.1 586.9		01	◆ ⊙	N = 21 W_n = 8.2% REC = 42% SPT for SS-01 had rock in shoe. Rock in bit from 2.1 m to 2.4 m but soil is soft.		587
		...inferred occasional cobbles, trace organics; loose, moist; brown-grey [FILL].		2.4 586.5						
3						02	◆ ⊙	N = 3 W_n = 15.9% Sieve Analysis (3.4 m): Gravel = 11% Sand = 41% Fines = 48% REC = 58%		586
4										585
5		...encountered cobble or small boulder midway into SPT.		4.9 584.1		03	◆ ⊙	N = 5 W_n = 20.3% REC = 50% VW piezometer installed at 5.5 m depth.		584
6				6.2 582.7						583
		(SM-GM) silty SAND some gravel, sub-rounded to sub-angular, trace to some clay, inferred occasional cobbles; dense, dry; medium brown [TILL].				04	⊙ ◆	N = 66 W_n = 7.0% Sieve Analysis (6.4 m): Gravel = 16% Sand = 47% Fines = 37% REC = 100%		
7										582
8						05	⊙	W_n = 4.2% REC = 67%		581
		...becomes trace gravel.		8.5 580.4						
9										580
						06		REC = 88%		
10										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-13

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330491.59E 5526048.48N | Elevation: 589.0 m [Survey]

Date Drilled: Aug 16-2018

Drill Type: ODEX

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	SLOPE INCLINOMETER	Elevation (m)
10	ODEX						PLASTIC M.C. LIQUID; 10 20 30 40; BLOW COUNT [SPT] ◆ [DCPT] ▼; 20 40 60 80; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗; 40 80 120 160			
11		End of hole at 10.7 m (578.3 m) Notes: Ground surface is 0.14 m above top of slope inclinometer casing.								578
12										577
13										576
14										575
15										574
16										573
17										572
18										571
19										570
20										

N - Blow Count
Standard Penetration Test [SPT]: ASTM D1586
Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw
DRAWN: ms/hkw

RECORD OF BOREHOLE BH18-14

2045 Loseth Road Pump Station

City of Kelowna

Project No.: 018-253 | Co-ordinate: 11 330475.43E 5526037.09N | Elevation: 588.3 m [Survey]

Date Drilled: Aug 11-2018

Drill Type: Sonic

Driller: Mud Bay Drilling

SAMPLE TYPE: SPT SAMPLE | GRAB SAMPLE | SHELBY TUBE | CORE SAMPLE | NO RECOVERY

INSTALLATION: GROUT | BENTONITE | SAND | DRILL CUTTINGS | SCREEN

Depth (m)	DRILLING METHOD	SOIL DESCRIPTION	SOIL SYMBOL	DEPTH (m) (ELEV.)	SAMPLE TYPE	SAMPLE NO	PLASTIC / M.C. / LIQUID; BLOW COUNT [SPT] ◆ [DCPT] ▼; VANE SHEAR (kPa) [Rig] ✖ [Pocket] ⊗	OTHER DATA	Elevation (m)
0	Sonic	TOPSOIL		0.2 / 588.1					588
		(SC-SM) SILTY SAND some clay, some gravel, angular, occasional cobbles, trace organics (rootlets); compact, dry; medium brown [FILL].		0.6 / 587.7		01		W_n = 7.5%	
1		(ML) fine sandy SILT some clay, trace sand, trace gravel, rounded to sub-angular, occasional cobbles and inferred boulders; compact to dense/hard, dry; medium grey [TILL].						Bouncing on cobbles between 0.8 m and 0.9 m.	587
2						02		W_n = 10.3%	586
3								>>	585
4						03		W_n = 8.8%	584
5						04		W_n = 11.7%	583
6						05			582
7						06		W_n = 7.2%	581
8						07			580
		End of hole at 8.5 m (579.7 m)		8.5 / 579.7					
9									579
10									

N - Blow Count

Standard Penetration Test [SPT]: ASTM D1586

Dynamic Cone Penetration Test [DCPT]: Number of blows using SPT energy to produce 300 mm of penetration of a 50 mm diameter cone.

LOGGED: hkw

DRAWN: ms/hkw

RECORD OF TEST PIT TP18-15
2045 Loseth Road Pump Station
City of Kelowna

westrek geotechnical services ltd.

Site Conditions:

Date Excavated: 2018-Aug-08
Equipment: Hitachi 210 excavator
Project No.: 018-253
Coordinates: 11 330467.35E 5526080.96N
Elevation: 1880.35 m [Survey]

PLASTIC M.C. LIQUID
20 40 60 80
■ DCPT RESISTANCE [PORTABLE] ■
20 40 60 80
◆ POCKET PEN. UCS (kPa) ◆
⊗ TORVANE UCS (kPa) ⊗
50 100 150 200

Depth (m)	DEPTH (m) (ELEV.)	SOIL DESCRIPTION	SOIL SYMBOL	SAMPLE	SAMPLE NO	OTHER DATA	Elevation (m)
0		TOPSOIL grass and roots					573
	0.2 572.9	(SM-SC) fine sandy SILT some clay, some gravel, sub-rounded, trace rootlet or small piece of wood; compact, dry; light brown [FILL].					
	0.5 572.6	... becomes dense.					
	0.7 572.4	... becomes occasional cobbles; medium brown, with rare charcoal.					
1							572
	1.6 571.5	... becomes some organics (roots); loose, moist; dark brown, spongey.					
	1.7 571.4	... garbage (household refuse) encountered.					
	1.8 571.3	... large boulders (up to 1.5 m) encountered during excavation.			1	W_n = 11.3%	
2							571
	2.5 570.6	(SM-SC) SILT and SAND some clay, trace gravel, trace organics; loose/firm, moist to wet; dark brown [COLLUVIUM].			2	W_n = 15.3% PL = 14.5% LL = 22.9% Sieve Analysis : Gravel = 8% Sand = 37% Fines = 54%	
3							570
	3.8 569.3	... seepage.					▼
4							569
	4.2 568.9	(SM-SC) SILT and SAND some clay, trace gravel, occasional cobbles and boulders; very dense, moist; grey [TILL].			3 4	W_n = 9.3% W_n = 8.1% Sieve Analysis : Gravel = 3% Sand = 40% Fines = 57%	
	4.4 (568.7)	End of hole at 4.4 m (568.7 m)					
5							

DCP Resistance
Number of blows of a 15 lb (6.8 kg) hammer dropped 10 inches (254 mm) to produce 1-3/4 inches (44 mm) of penetration of a 1.5 inch (38.1 mm) diameter, 45 degree cone.

LOGGED: hkw
DRAWN: hkw
Page 1 of 1

APPENDIX D

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

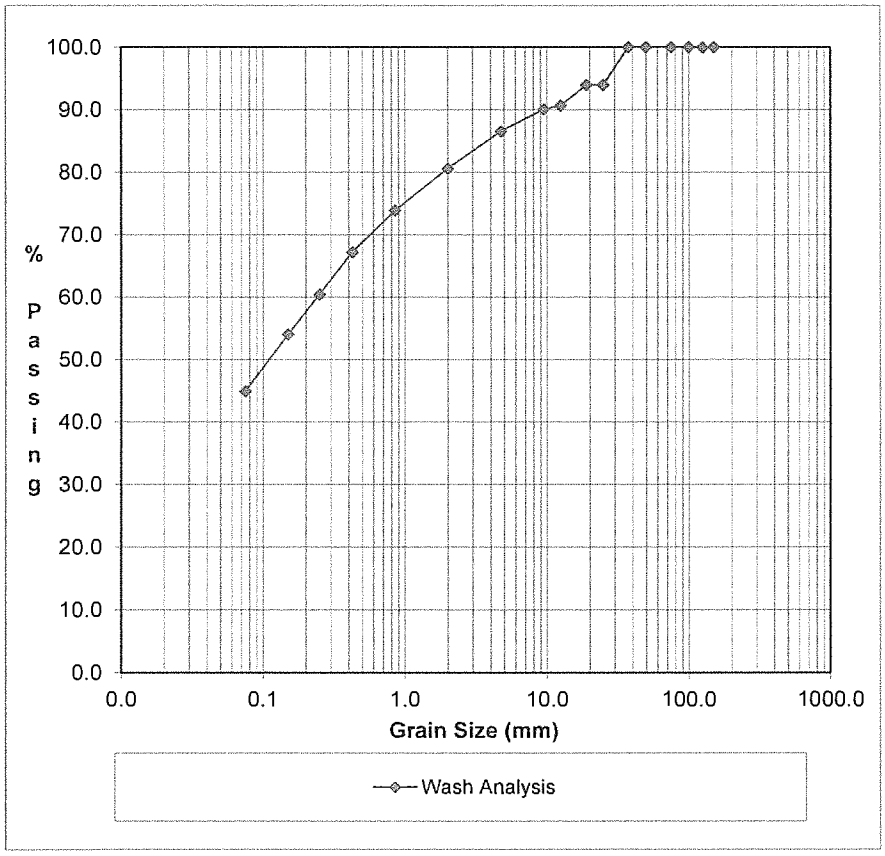
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 1
Date Rec'd: Aug 27, 2018

Source: BH 01 @ 32.5' - 33'
Grab Sample # 05
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	6.0	94.0		
19.0	0.0	94.0		
12.5	3.3	90.7		
9.5	0.6	90.1		
4.75	3.5	86.6		
2.000	5.9	80.6		
0.850	6.7	73.9		
0.425	6.7	67.2		
0.250	6.8	60.5		
0.150	6.5	54.0		
0.075	9.1	44.9		
PAN	44.9			

Sieve Mass (g): 949.5

Gravel	13.4 %
Sand	41.6 %
Fines	44.9 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

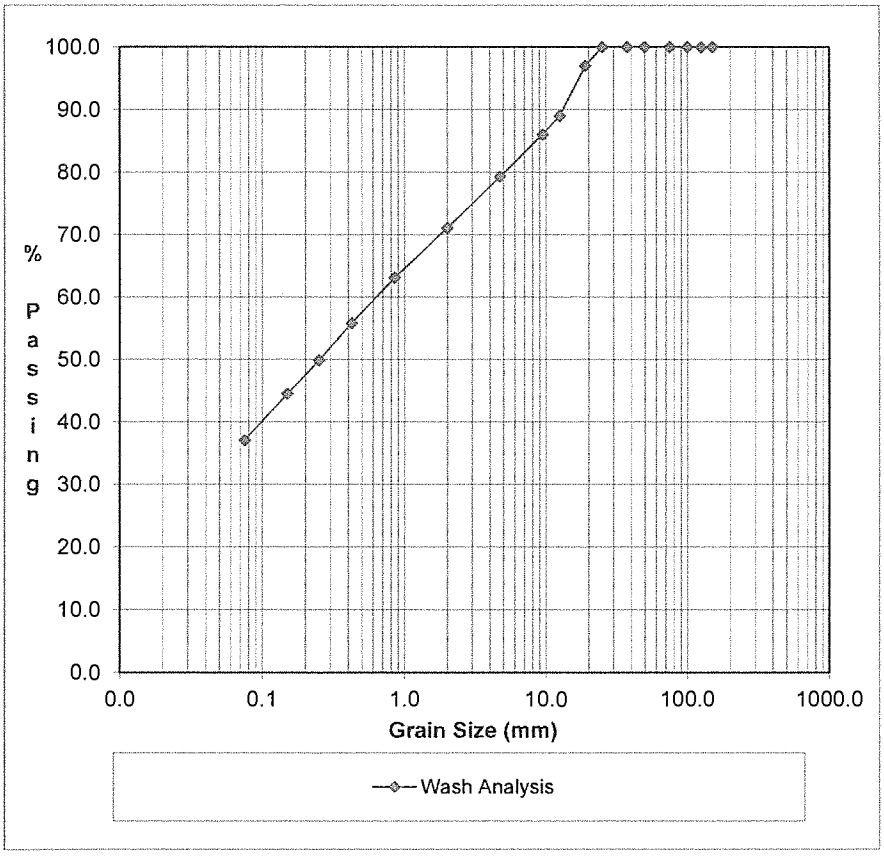
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 2
Date Rec'd: Aug 27, 2018

Source: BH 01 @ 42 - 42.5'
Grab Sample # 07
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis				
Sieve Size(mm)	Percent Retained	Percent Passing	Limits Upper	Limits Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	3.0	97.0		
12.5	8.0	89.0		
9.5	3.0	86.0		
4.75	6.7	79.3		
2.000	8.2	71.1		
0.850	8.0	63.1		
0.425	7.2	55.9		
0.250	6.0	49.8		
0.150	5.3	44.5		
0.075	7.5	37.0		
PAN	37.0			

Sieve Mass (g): 1030.9

Gravel	20.7 %
Sand	42.3 %
Fines	37.0 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

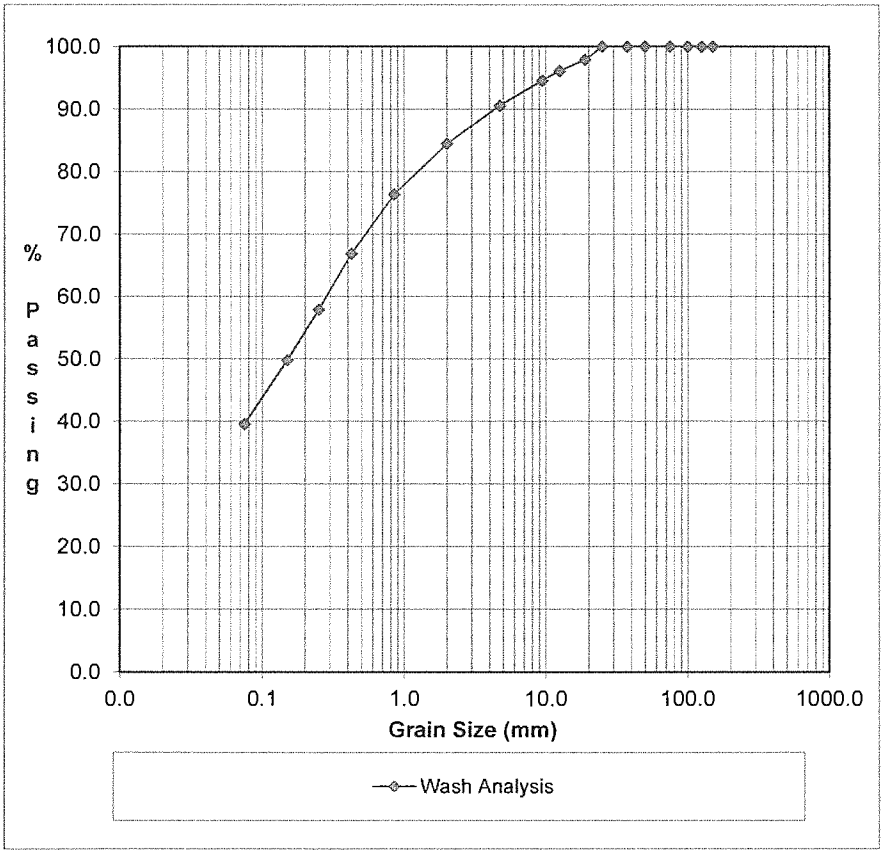
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 3
Date Rec'd: Aug 27, 2018

Source: BH 01 @ 67 - 67.5'
Grab Sample # 08
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	2.1	97.9		
12.5	1.8	96.1		
9.5	1.6	94.6		
4.75	4.0	90.5		
2.000	6.1	84.5		
0.850	8.1	76.4		
0.425	9.5	66.9		
0.250	9.0	57.9		
0.150	8.1	49.8		
0.075	10.3	39.5		
PAN	39.5			

Sieve Mass (g): 967.1

Gravel	9.5 %
Sand	51.0 %
Fines	39.5 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

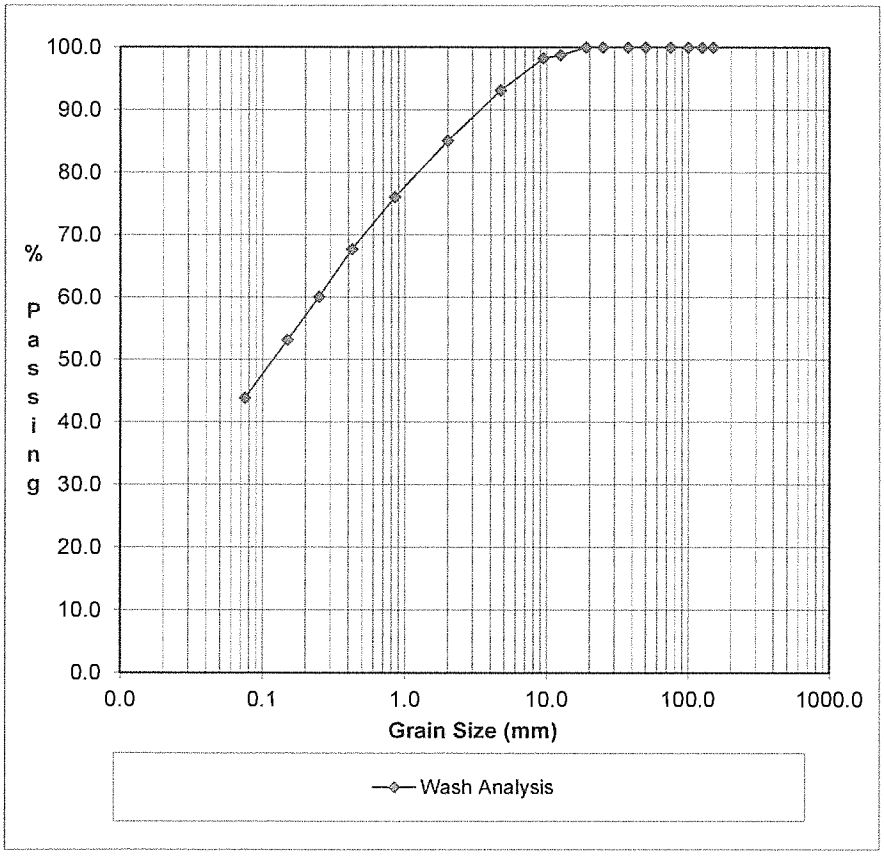
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 4
Date Rec'd: Aug 27, 2018

Source: BH 02 @ 31 - 31.5'
Grab Sample # 06
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	0.0	100.0		
12.5	1.3	98.7		
9.5	0.5	98.3		
4.75	5.2	93.1		
2.000	8.1	85.0		
0.850	9.0	76.1		
0.425	8.4	67.7		
0.250	7.6	60.1		
0.150	6.9	53.2		
0.075	9.4	43.8		
PAN	43.8			

Sieve Mass (g): 834.5

Gravel	6.9 %
Sand	49.3 %
Fines	43.8 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

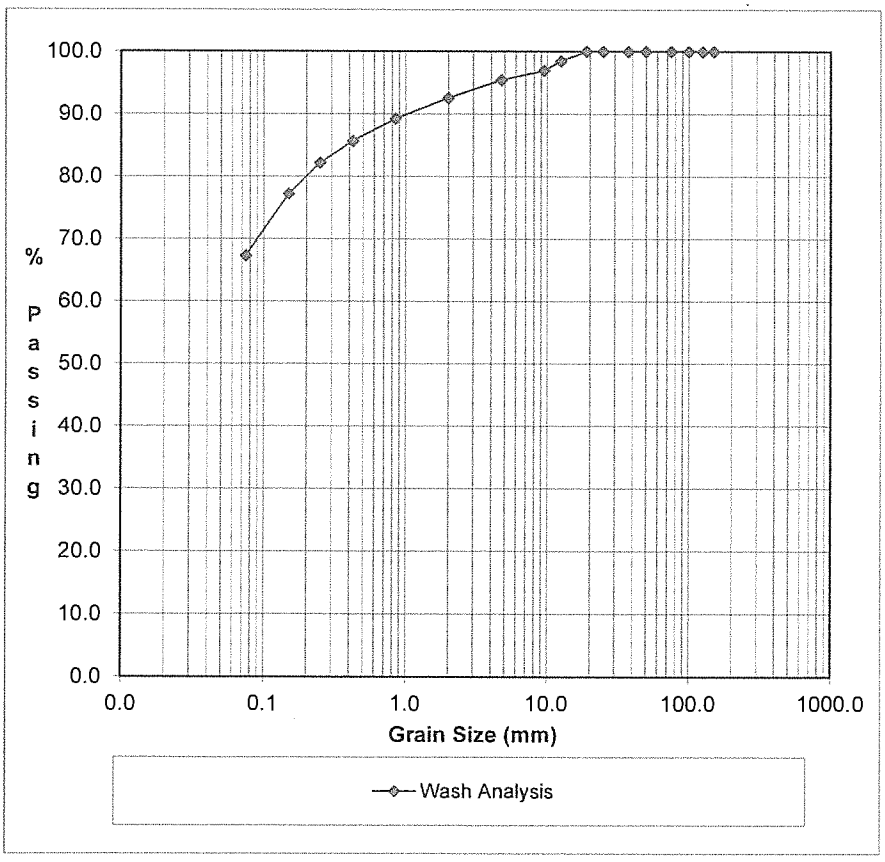
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 5
Date Rec'd: Aug 27, 2018

Source: BH 03 @ 4.5 - 5.0'
Grab Sample # 01
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	0.0	100.0		
12.5	1.5	98.5		
9.5	1.5	96.9		
4.75	1.5	95.4		
2.000	2.9	92.6		
0.850	3.4	89.2		
0.425	3.5	85.7		
0.250	3.6	82.1		
0.150	4.9	77.2		
0.075	9.9	67.3		
PAN	67.3			

Sieve Mass (g): 1440.9

Gravel	4.6 %
Sand	28.1 %
Fines	67.3 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

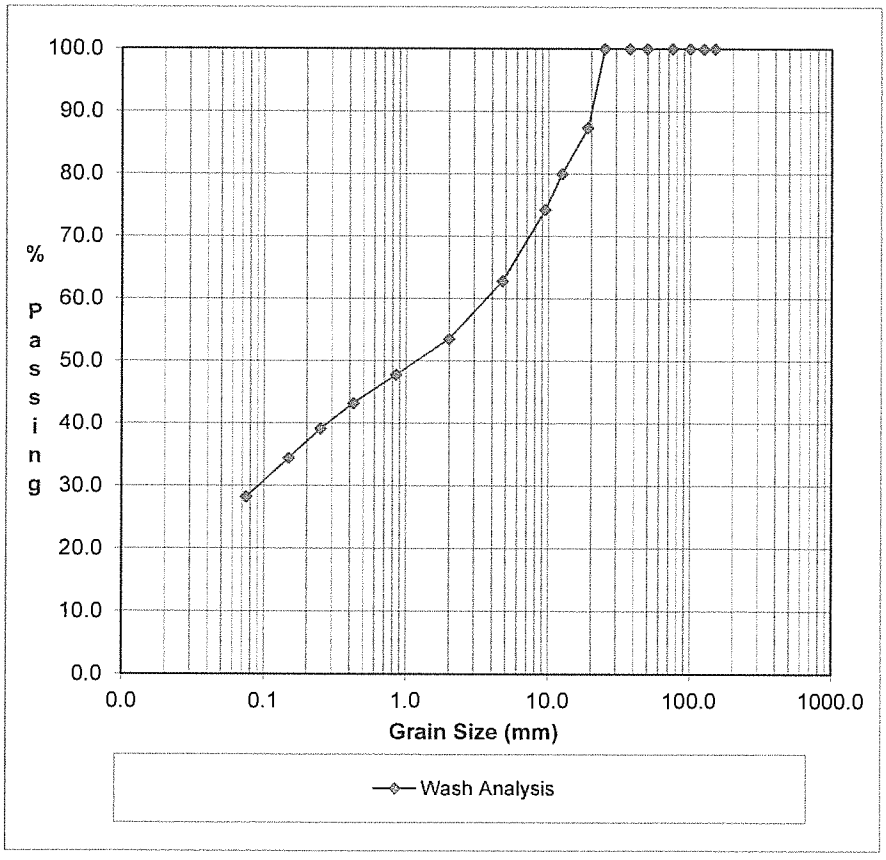
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 6
Date Rec'd: Aug 27, 2018

Source: BH 03 @ 33.5 - 34'
Grab Sample # 09
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	12.7	87.3		
12.5	7.4	80.0		
9.5	5.7	74.3		
4.75	11.4	62.8		
2.000	9.3	53.5		
0.850	5.8	47.7		
0.425	4.6	43.2		
0.250	4.1	39.1		
0.150	4.7	34.4		
0.075	6.2	28.2		
PAN	28.2			

Sieve Mass (g): 1199.6

Gravel	37.2 %
Sand	34.6 %
Fines	28.2 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

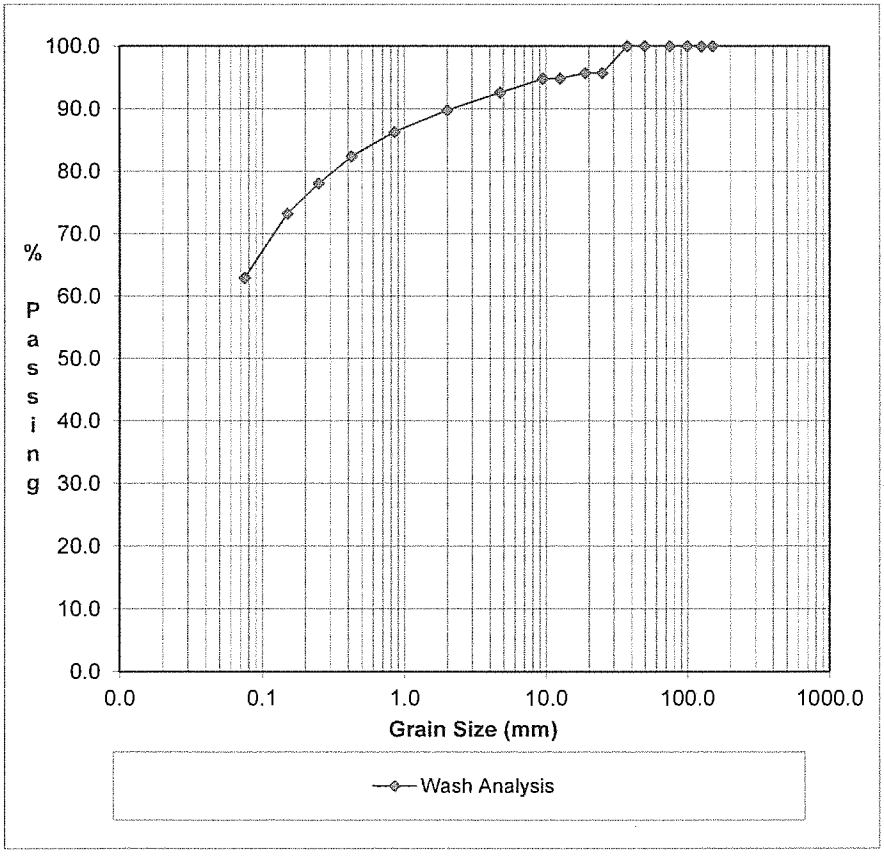
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 7
Date Rec'd: Aug 27, 2018

Source: BH 04 @ 11 - 11.5'
Grab Sample # 02
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis				
Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	4.3	95.7		
19.0	0.0	95.7		
12.5	0.8	94.9		
9.5	0.1	94.8		
4.75	2.2	92.6		
2.000	2.8	89.8		
0.850	3.5	86.3		
0.425	3.9	82.4		
0.250	4.3	78.1		
0.150	4.9	73.2		
0.075	10.3	62.9		
PAN	62.9			

Sieve Mass (g): 1717.8

Gravel	7.4 %
Sand	29.7 %
Fines	62.9 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

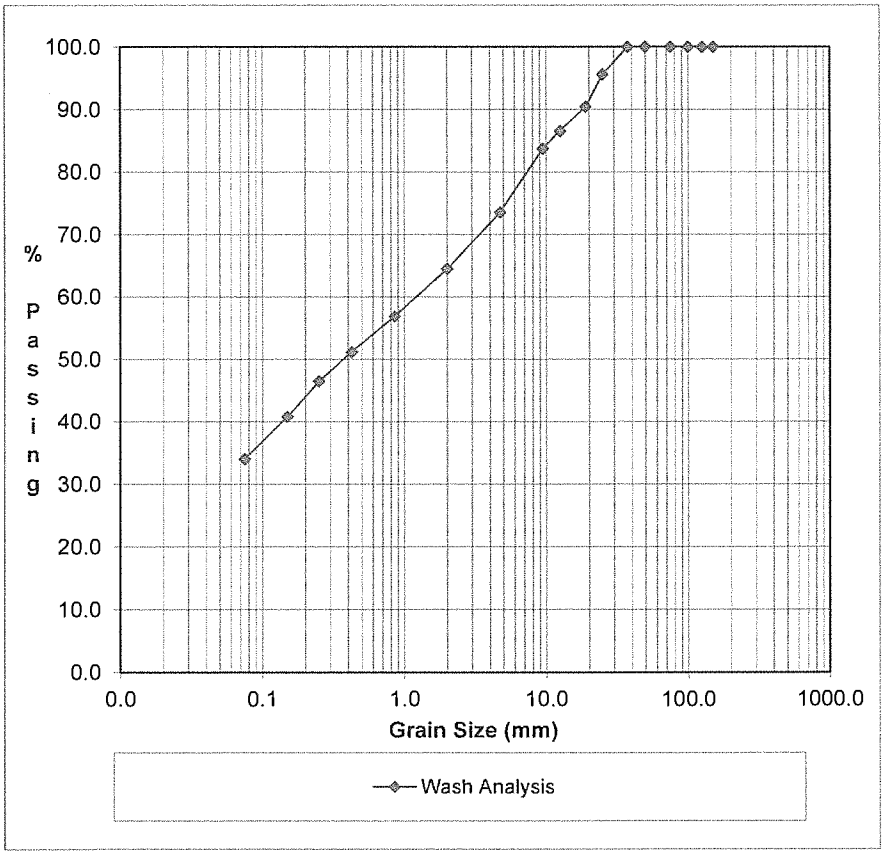
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 8
Date Rec'd: Aug 27, 2018

Source: BH 04 @ 17' 8" - 18'
Grab Sample # 07
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	4.4	95.6		
19.0	5.2	90.4		
12.5	3.8	86.6		
9.5	2.9	83.7		
4.75	10.2	73.5		
2.000	9.0	64.5		
0.850	7.6	56.9		
0.425	5.7	51.2		
0.250	4.7	46.4		
0.150	5.6	40.8		
0.075	6.8	34.0		
PAN	34.0			

Sieve Mass (g): 699.7

Gravel	26.5 %
Sand	39.5 %
Fines	34.0 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

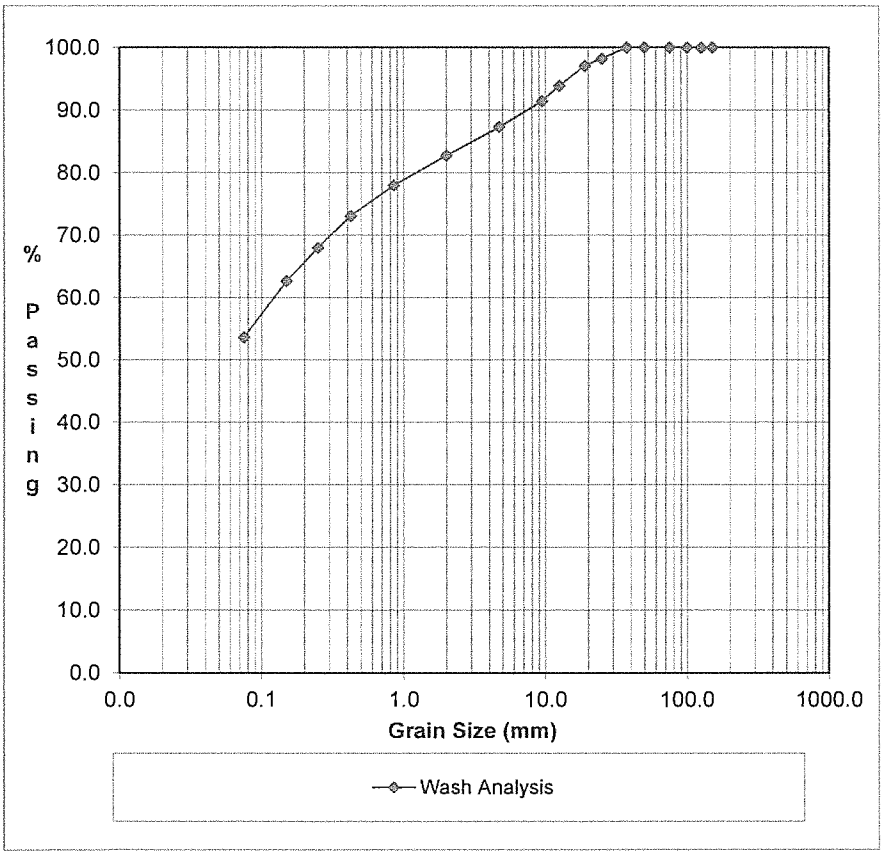
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 9
Date Rec'd: Aug 27, 2018

Source: BH 05 @ 22 - 23'
Grab Sample # 04
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	1.8	98.2		
19.0	1.1	97.1		
12.5	3.3	93.8		
9.5	2.4	91.4		
4.75	4.1	87.3		
2.000	4.6	82.7		
0.850	4.8	78.0		
0.425	4.9	73.1		
0.250	5.1	68.0		
0.150	5.3	62.6		
0.075	9.0	53.6		
PAN	53.6			

Sieve Mass (g): 1346.9

Gravel	12.7 %
Sand	33.7 %
Fines	53.6 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

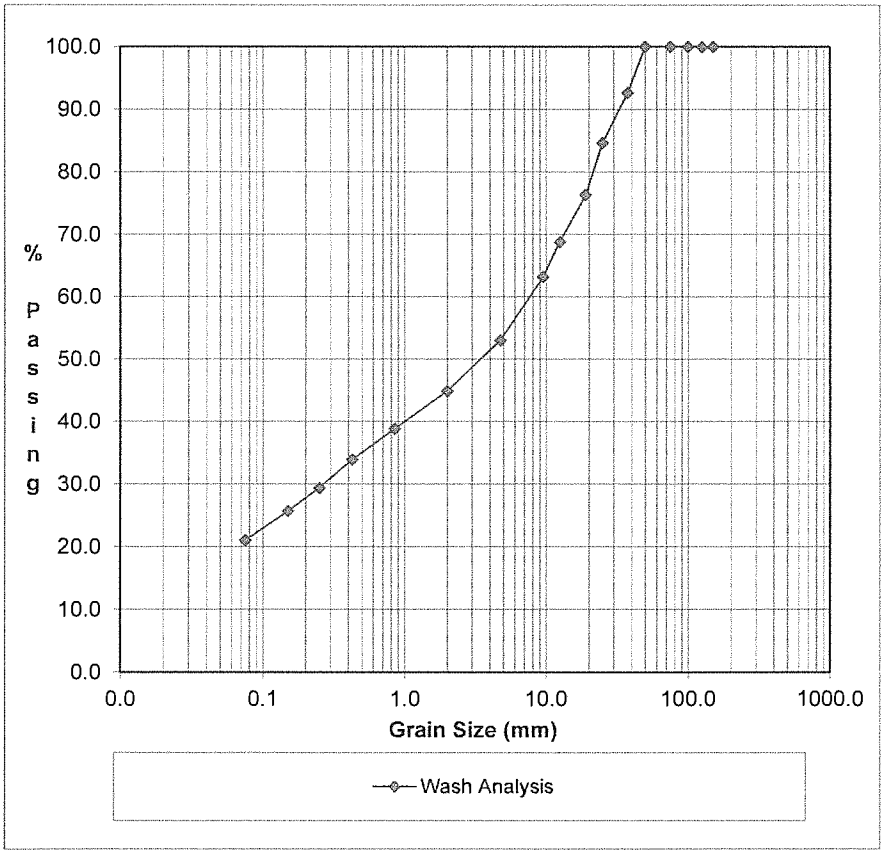
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 10
Date Rec'd: Aug 27, 2018

Source: BH 12 @ 7 - 8'
Grab Sample # 01
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	7.4	92.6		
25.0	8.0	84.6		
19.0	8.3	76.3		
12.5	7.5	68.8		
9.5	5.6	63.2		
4.75	10.2	53.0		
2.000	8.1	44.9		
0.850	6.0	38.9		
0.425	5.0	33.9		
0.250	4.5	29.4		
0.150	3.7	25.7		
0.075	4.7	21.0		
PAN	21.0			

Sieve Mass (g): 2362.1

Gravel	47.0 %
Sand	32.0 %
Fines	21.0 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

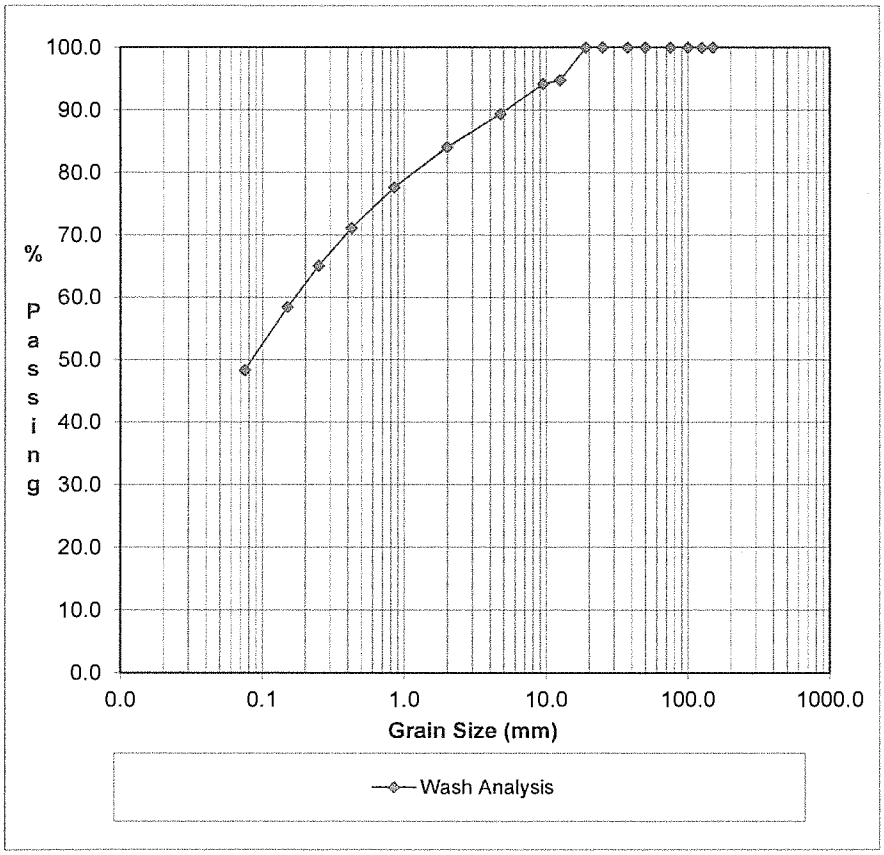
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 11
Date Rec'd: Aug 27, 2018

Source: BH 13 @ 10 - 12'
Split Spoon # 02
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	0.0	100.0		
12.5	5.3	94.7		
9.5	0.6	94.1		
4.75	4.8	89.4		
2.000	5.3	84.1		
0.850	6.4	77.7		
0.425	6.6	71.1		
0.250	6.0	65.1		
0.150	6.6	58.5		
0.075	10.1	48.3		
PAN	48.3			

Sieve Mass (g): 338.4

Gravel	10.6 %
Sand	41.0 %
Fines	48.3 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

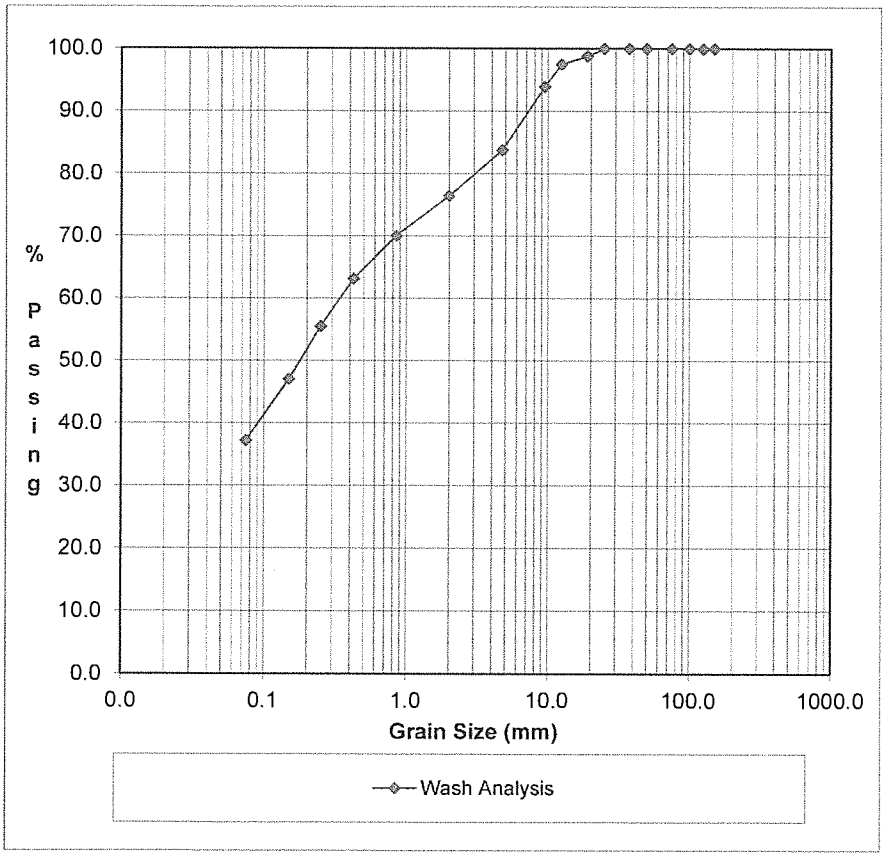
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 12
Date Rec'd: Aug 27, 2018

Source: BH 13 @ 20 - 22'
Split Spoon # 04
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	1.2	98.8		
12.5	1.3	97.5		
9.5	3.6	93.9		
4.75	10.1	83.8		
2.000	7.4	76.4		
0.850	6.4	70.0		
0.425	6.9	63.1		
0.250	7.6	55.5		
0.150	8.5	47.0		
0.075	9.8	37.2		
PAN	37.2			

Sieve Mass (g): 1139.4

Gravel	16.2 %
Sand	46.5 %
Fines	37.2 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

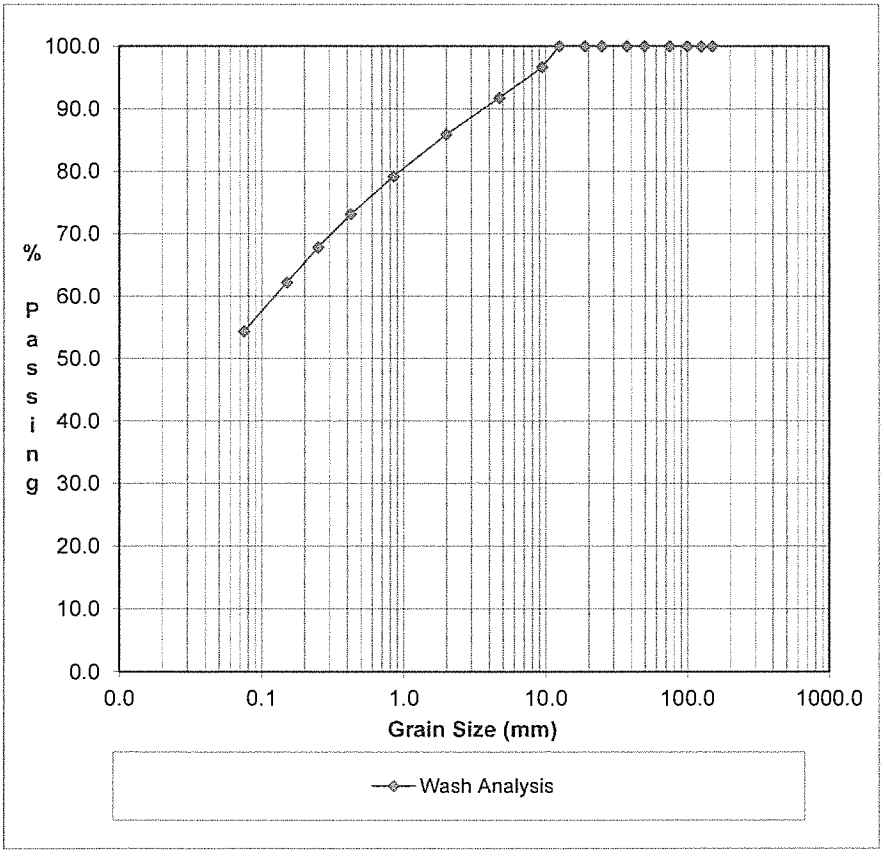
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 13
Date Rec'd: Aug 27, 2018

Source: TP 15 @ 2.6 - 2.7m
Grab Sample # 02
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	0.0	100.0		
12.5	0.0	100.0		
9.5	3.3	96.7		
4.75	4.9	91.7		
2.000	5.8	85.9		
0.850	6.7	79.2		
0.425	6.1	73.1		
0.250	5.3	67.9		
0.150	5.7	62.2		
0.075	7.8	54.4		
PAN	54.4			

Sieve Mass (g): 428.4

Gravel	8.3 %
Sand	37.3 %
Fines	54.4 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

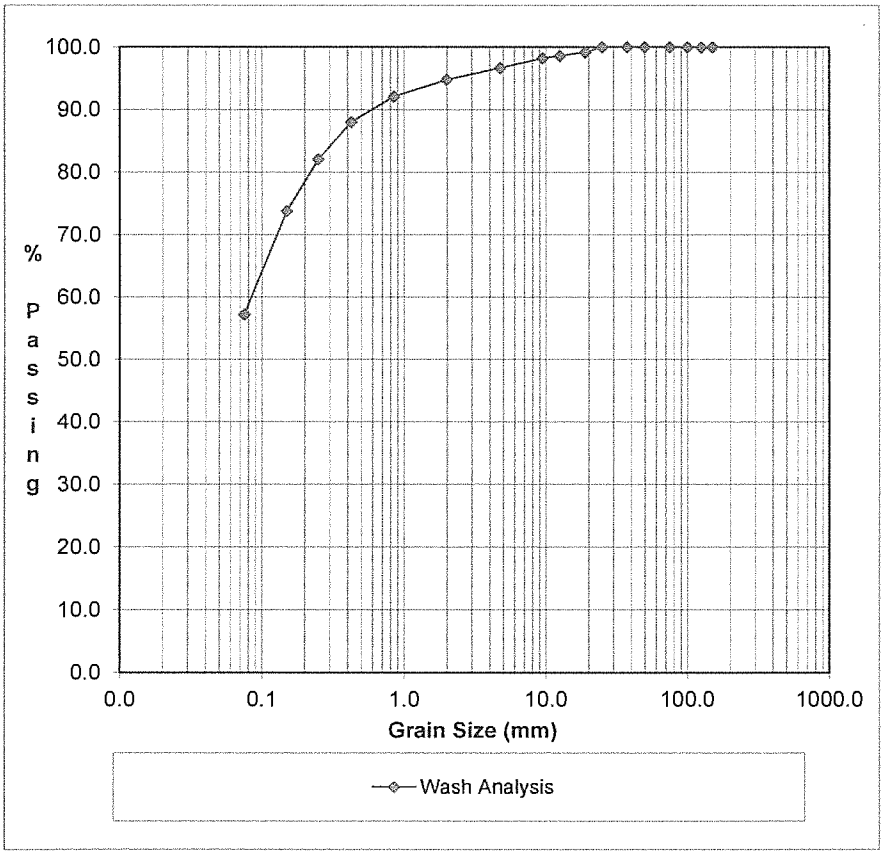
Project Name: Kirschner Mountain Pump Station

Project No:KX13690
Date: September 9, 2018

Test No.: 18 - 107 - 13
Date Rec'd: Aug 27, 2018

Source: TP 15 @ 4.3m
Grab Sample # 04
By: Client

Sample Type: Grab sample
Date Tested: Sept 1, 2018



Wash Sieve Analysis

Wash Sieve Analysis

Sieve Size(mm)	Percent Retained	Percent Passing	Limits	
			Upper	Lower
150.0	0.0	100.0		
125.0	0.0	100.0		
100.0	0.0	100.0		
75.0	0.0	100.0		
50.0	0.0	100.0		
37.5	0.0	100.0		
25.0	0.0	100.0		
19.0	0.8	99.2		
12.5	0.5	98.6		
9.5	0.4	98.2		
4.75	1.5	96.7		
2.000	1.9	94.8		
0.850	2.7	92.1		
0.425	4.1	88.0		
0.250	5.9	82.1		
0.150	8.3	73.8		
0.075	16.6	57.2		
PAN	57.2			

Sieve Mass (g): 1545.2

Gravel	3.3 %
Sand	39.5 %
Fines	57.2 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Shearer

MOISTURE CONTENT WORKSHEET

Project: KX13690
Lab 18- 107 - 1
Technician: B.Shearer
Date: Aug 30, 2018
Kirschner Mountain Pump Station

Hole No.	BH01 GS-01	BH01 GS-02	BH01 GS-04	BH01 GS-05	BH01 GS-06
Depth(Ft)	8-8.5'	16-16.5'	26-26.5'	32.5-33'	36-36.5'
Tare No.	1	2	3	4	5
Wt. Sple. Wet + Tare	575.6	752.4	712.1	1546.6	519.0
Wt. Sple. Dry + Tare	521.8	663.5	646.5	1451.4	470.8
Wt. Water	53.8	88.9	65.6	95.2	48.2
Tare Container	13.6	14.7	14.8	502.2	14.7
Wt. Dry Sample	508.2	648.8	631.7	949.2	456.1
Moist. Cont. %	10.6%	13.7%	10.4%	10.0%	10.6%
Hole No.	BH01 GS-07	BH01 GS-08	BH01 GS-09	BH02 GS-01	BH02 GS-02
Depth(Ft)	42-42.5'	48-48.5'	67-67.5'	15-16'	21.5-22'
Tare No.	6	7	8	9	10
Wt. Sple. Wet + Tare	1614.4	1548.6	531.5	635.6	734.8
Wt. Sple. Dry + Tare	1532.2	1468.3	484.5	565.3	650.1
Wt. Water	82.2	80.3	47.0	70.3	84.7
Tare Container	501.3	501.3	14.1	14.5	14.3
Wt. Dry Sample	1030.9	967.0	470.4	550.8	635.8
Moist. Cont. %	8.0%	8.3%	10.0%	12.8%	13.3%
Hole No.	BH02 GS-03	BH02 GS-06	BH02 GS-07	BH03 GS-01	BH03 GS-03
Depth(Ft)	24.5-25.5'	31-31.5'	45-45.5'	4.5-5.0'	4.5-5'
Tare No.	11	12	13	14	15
Wt. Sple. Wet + Tare	582.6	1461.2	197.1	2159.6	695.6
Wt. Sple. Dry + Tare	526.4	1334.3	179.1	1983.0	629.9
Wt. Water	56.2	126.9	18.0	176.6	65.7
Tare Container	14.6	499.7	14.3	542.0	15.2
Wt. Dry Sample	511.8	834.6	164.8	1441.0	614.7
Moist. Cont. %	11.0%	15.2%	10.9%	12.3%	10.7%
Hole No.	BH03 GS-04	BH03 GS-05	BH03 GS-07	BH03 GS-08	BH03 GS-09
Depth(Ft)	15-15.5'	20.5-21'	27-27.5'	31.5-32'	33.5-34'
Tare No.	16	17	18	19	20
Wt. Sple. Wet + Tare	495.0	697.6	540.0	758.9	1747.7
Wt. Sple. Dry + Tare	450.7	628.1	478.2	675.7	1603.0
Wt. Water	44.3	69.5	61.8	83.2	144.7
Tare Container	14.6	14.5	14.8	14.6	403.2
Wt. Dry Sample	436.1	613.6	463.4	661.1	1199.8
Moist. Cont. %	10.2%	11.3%	13.3%	12.6%	12.1%
Hole No.	BH04 GS-02	BH04 GS-04	BH04 GS-07		
Depth(Ft)	11-11.5'	15.5-16'	17.8-18'		
Tare No.	21	22	23		
Wt. Sple. Wet + Tare	2346.8	477.9	1214.8		
Wt. Sple. Dry + Tare	2157.3	420.9	1109.2		
Wt. Water	189.5	57.0	105.6		
Tare Container	439.5	14.7	409.2		
Wt. Dry Sample	1717.8	406.2	700.0		
Moist. Cont. %	11.0%	14.0%	15.1%		

MOISTURE CONTENT WORKSHEET

Project: KX13690
Lab 18- 107 - 1
Technician: B.Shearer
Date: Aug 30, 2018
Kirschner Mountain Pump Station

Hole No.	BH05 GS-01	BH05 GS-02	BH05 GS-03	BH05 GS-04	BH09 GS-01
Depth(Ft)	6-7'	9.5-10.5'	14-15'	22-23'	4-5'
Tare No.	24	25	26	27	28
Wt. Sple. Wet + Tare	376.8	495.6	694.7	1910.8	453.7
Wt. Sple. Dry + Tare	318.7	424.7	609.8	1759.6	425.5
Wt. Water	58.1	70.9	84.9	151.2	28.2
Tare Container	14.6	14.4	15.2	412.6	14.8
Wt. Dry Sample	304.1	410.3	594.6	1347.0	410.7
Moist. Cont. %	19.1%	17.3%	14.3%	11.2%	6.9%
Hole No.	BH09 GS-02	BH09 GS-03	BH09 GS-04	BH10 GS-02	BH10 GS-03
Depth(Ft)	12-13'	17.5-18.5'	20.5-21.5'	5.5-6'	15-15.5'
Tare No.	29	30	31	32	33
Wt. Sple. Wet + Tare	633.1	678.3	675.0	514.6	707.4
Wt. Sple. Dry + Tare	560.1	602.9	591.6	477.3	628.4
Wt. Water	73.0	75.4	83.4	37.3	79.0
Tare Container	14.6	14.6	14.7	14.6	14.8
Wt. Dry Sample	545.5	588.3	576.9	462.7	613.6
Moist. Cont. %	13.4%	12.8%	14.5%	8.1%	12.9%
Hole No.	BH11 GS-01	BH11 GS-04	BH11 GS-05	BH12 GS-01	BH12 GS-02
Depth(Ft)	7-8'	27-28'	30-31'	7-8'	11-12'
Tare No.	34	35	36	37	38
Wt. Sple. Wet + Tare	683.7	778.7	721.4	2988.8	663.9
Wt. Sple. Dry + Tare	620.4	692.1	649.5	2782.6	578.9
Wt. Water	63.3	86.6	71.9	206.2	85.0
Tare Container	14.7	14.8	14.7	420.4	14.8
Wt. Dry Sample	605.7	677.3	634.8	2362.2	564.1
Moist. Cont. %	10.5%	12.8%	11.3%	8.7%	15.1%
Hole No.	BH12 GS-3	BH12 GS-04	BH12 GS-05	BH13 SS-01	BH13 SS-02
Depth(Ft)	21-22'	33-34'	35-36'	5-7'	10-12'
Tare No.	39	40	41	42	43
Wt. Sple. Wet + Tare	604.1	635.5	685.4	251.0	806.8
Wt. Sple. Dry + Tare	501.0	529.8	579.2	233.0	753.1
Wt. Water	103.1	105.7	106.2	18.0	53.7
Tare Container	15.0	14.6	15.3	14.8	414.7
Wt. Dry Sample	486.0	515.2	563.9	218.2	338.4
Moist. Cont. %	21.2%	20.5%	18.8%	8.2%	15.9%
Hole No.	BH13 SS-03	BH13 SS-04	BH13 SS-05		
Depth(Ft)	15-17'	20-22'	25-27'		
Tare No.	44	45	46		
Wt. Sple. Wet + Tare	347.1	1757.1	603.5		
Wt. Sple. Dry + Tare	291.0	1677.3	579.7		
Wt. Water	56.1	79.8	23.8		
Tare Container	14.4	537.8	14.5		
Wt. Dry Sample	276.6	1139.5	565.2		
Moist. Cont. %	20.3%	7.0%	4.2%		

MOISTURE CONTENT WORKSHEET

Project: KX13690	
Lab 18- 107 - 1	
Technician: B.Shearer	
Date: Aug 30, 2018	
Kirschner Mountain Pump Station	

Hole No.	BH14 GS-01	BH14 GS-02	BH14 GS-03	BH14 GS-04	BH14 GS-06
Depth(Ft)	1-1.5'	6-7'	12-13'	17-18'	22-23'
Tare No.	47	48	49	50	51
Wt. Sple. Wet + Tare	670.1	478.7	597.2	1209.0	657.4
Wt. Sple. Dry + Tare	624.2	435.3	549.9	1083.7	614.3
Wt. Water	45.9	43.4	47.3	125.3	43.1
Tare Container	14.7	15.5	14.6	14.3	14.6
Wt. Dry Sample	609.5	419.8	535.3	1069.4	599.7
Moist. Cont. %	7.5%	10.3%	8.8%	11.7%	7.2%
Hole No.	TP15 GS-01	TP15 GS-02	TP15 GS-03	TP15 GS-04	
Depth(M)	1.7-1.8m	2.6-2.7m	4.2-4.3m	4.3m	
Tare No.	52	53	54	55	
Wt. Sple. Wet + Tare	237.6	1029.8	544.8	2217.8	
Wt. Sple. Dry + Tare	215.0	964.3	499.5	2092.2	
Wt. Water	22.6	65.5	45.3	125.6	
Tare Container	14.8	536.2	14.3	546.9	
Wt. Dry Sample	200.2	428.1	485.2	1545.3	
Moist. Cont. %	11.3%	15.3%	9.3%	8.1%	
Hole No.					
Depth(Ft)					
Tare No.					
Wt. Sple. Wet + Tare					
Wt. Sple. Dry + Tare					
Wt. Water					
Tare Container					
Wt. Dry Sample					
Moist. Cont. %					
Hole No.					
Depth(Ft)					
Tare No.					
Wt. Sple. Wet + Tare					
Wt. Sple. Dry + Tare					
Wt. Water					
Tare Container					
Wt. Dry Sample					
Moist. Cont. %					
Hole No.					
Depth(Ft)					
Tare No.					
Wt. Sple. Wet + Tare					
Wt. Sple. Dry + Tare					
Wt. Water					
Tare Container					
Wt. Dry Sample					
Moist. Cont. %					

ATTERBERG LIMITS

wood.

PROJECT : Westrek Geotechnical Services Ltd.
Project Number: KX13690
Lab : 18- 107- 1
Date: September 11, 2018

Sample ID: Kirschner Mountain Pump Station; BH18-02 @ 15-16'- GS 01
Technician: B. Shearer

Liquid Limit

Trial No.	1	2	3	
No. of Blows	33	24	20	
Tare ID:	1	2	3	
Mass Wet + Tare	101.04	92.71	95.62	
Mass Dry + Tare	93.53	86.44	88.83	
Mass Tare:	53.67	54.15	54.28	
Mass of Water:	7.51	6.27	6.79	
Dry Soil Mass:	39.86	32.29	34.55	
Moisture Content:	18.8%	19.4%	19.7%	
Liquid Limit:	19.6%	19.3%	19.1%	

Average Liquid Limit: 19.3%

Plastic Limit

Trial No.	4	5	6	
Tare ID:	1	2	3	
Mass Wet + Tare	62.97	62.78	61.67	
Mass Dry + Tare	61.83	61.71	60.73	
Mass Tare:	53.74	53.97	53.93	
Mass of Water:	1.14	1.07	0.94	
Dry Soil Mass:	8.09	7.74	6.80	
Moisture Content:	14.1%	13.8%	13.8%	

Average Plastic Limit: 13.9%

Plasticity Index: 5.4

ATTERBERG LIMITS

wood.

PROJECT : Westrek Geotechnical Services Ltd.
Project Number: KX13690
Lab : 18- 107- 2
Date: September 11, 2018

Sample ID: Kirschner Mountain Pump Station; BH18-02 @ 45-45.5'- GS 07
Technician: B. Shearer

Liquid Limit

Trial No.	1	2	3	
No. of Blows	30	27	21	
Tare ID:	1	2	3	
Mass Wet + Tare	99.48	95.65	93.33	
Mass Dry + Tare	92.70	89.16	87.35	
Mass Tare:	54.25	52.83	54.38	
Mass of Water:	6.78	6.49	5.98	
Dry Soil Mass:	38.45	36.33	32.97	
Moisture Content:	17.6%	17.9%	18.1%	
Liquid Limit:	18.1%	18.1%	17.7%	

Average Liquid Limit: 18.0%

Plastic Limit

Trial No.	4	5	6	
Tare ID:	1	2	3	
Mass Wet + Tare	62.70	62.80	63.58	
Mass Dry + Tare	61.69	61.79	62.50	
Mass Tare:	53.80	53.88	54.20	
Mass of Water:	1.01	1.01	1.08	
Dry Soil Mass:	7.89	7.91	8.30	
Moisture Content:	12.8%	12.8%	13.0%	

Average Plastic Limit: 12.9%

Plasticity Index: 5.1

ATTERBERG LIMITS

wood.

PROJECT : Westrek Geotechnical Services Ltd.
Project Number: KX13690
Lab : 18- 107-3
Date: September 11, 2018

Sample ID: Kirschner Mountain Pump Station; TP18-15 @ 2.6-2.7m - GS 02
Technician: B. Shearer

Liquid Limit

Trial No.	1	2	3	
No. of Blows	28	25	21	
Tare ID:	1	2	3	
Mass Wet + Tare	85.63	91.03	88.89	
Mass Dry + Tare	79.75	84.16	82.33	
Mass Tare:	53.55	54.24	54.24	
Mass of Water:	5.88	6.87	6.56	
Dry Soil Mass:	26.20	29.92	28.09	
Moisture Content:	22.4%	23.0%	23.4%	
Liquid Limit:	22.8%	23.0%	22.8%	

Average Liquid Limit: 22.9%

Plastic Limit

Trial No.	4	5	6	
Tare ID:	1	2	3	
Mass Wet + Tare	61.18	61.79	62.37	
Mass Dry + Tare	60.06	60.77	61.30	
Mass Tare:	52.40	53.69	53.93	
Mass of Water:	1.12	1.02	1.07	
Dry Soil Mass:	7.66	7.08	7.37	
Moisture Content:	14.6%	14.4%	14.5%	

Average Plastic Limit: 14.5%

Plasticity Index: 8.4

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

Project Name: Kirschner Mountain Pump House

OFFICE: Kamloops, BC
PROJECT: KX13690
DATE: September 11, 2018

TEST NO: 18-107-1

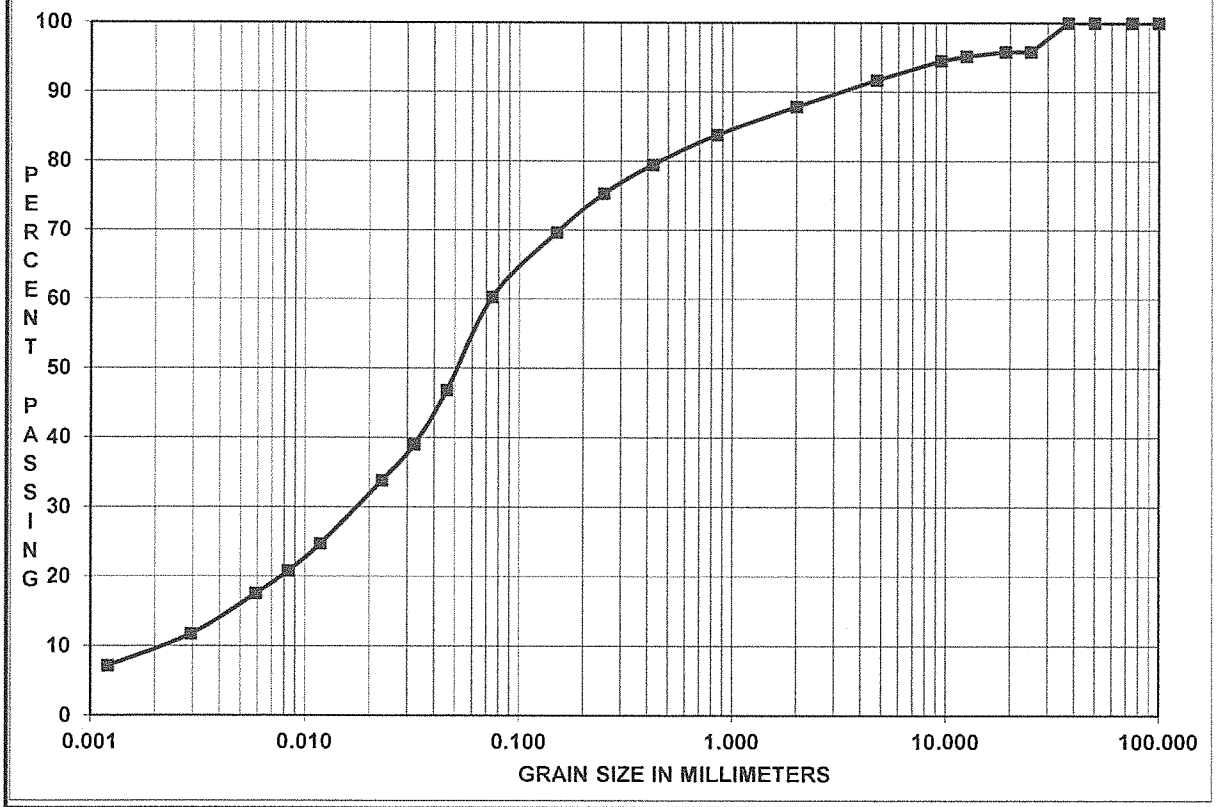
DATE Rec'd: August 27, 2018

DATE TESTED: Sept 9, 2018

SAMPLED BY: Client

SOURCE: BH18-02 @ 15 - 16' - GS01

SAMPLE TYPE: Grab Sample



SUMMARY

Grain size (mm)	Passing (%)
75.0	100.0
50.0	100.0
37.5	100.0
25.0	95.8
19.0	95.8
12.5	95.2
9.5	94.5
4.75	91.7
2.00	87.9
0.850	83.8
0.425	79.5
0.250	75.3
0.150	69.6
0.075	60.3
0.0459	46.8
0.0324	39.0
0.0229	33.8
0.0118	24.7
0.0084	20.8
0.0059	17.6
0.0030	11.7
0.0012	7.2

REMARKS:

GRAVEL	8.3%
SAND	31.4%
SILT	51.1%
CLAY	9.2%

TECHNICIAN: B. Shearer

GRAIN SIZE DISTRIBUTION

wood.

Westrek Geotechnical Services Ltd
101- 1383 McGill Road
Kamloops, BC
V2C 6K7

Attn: Jeffrey Pisio / Kevin Turner

Project Name: Kirschner Mountain Pump House

OFFICE: Kamloops, BC
PROJECT: KX13690
DATE: September 11, 2018

TEST NO: 18-107-2

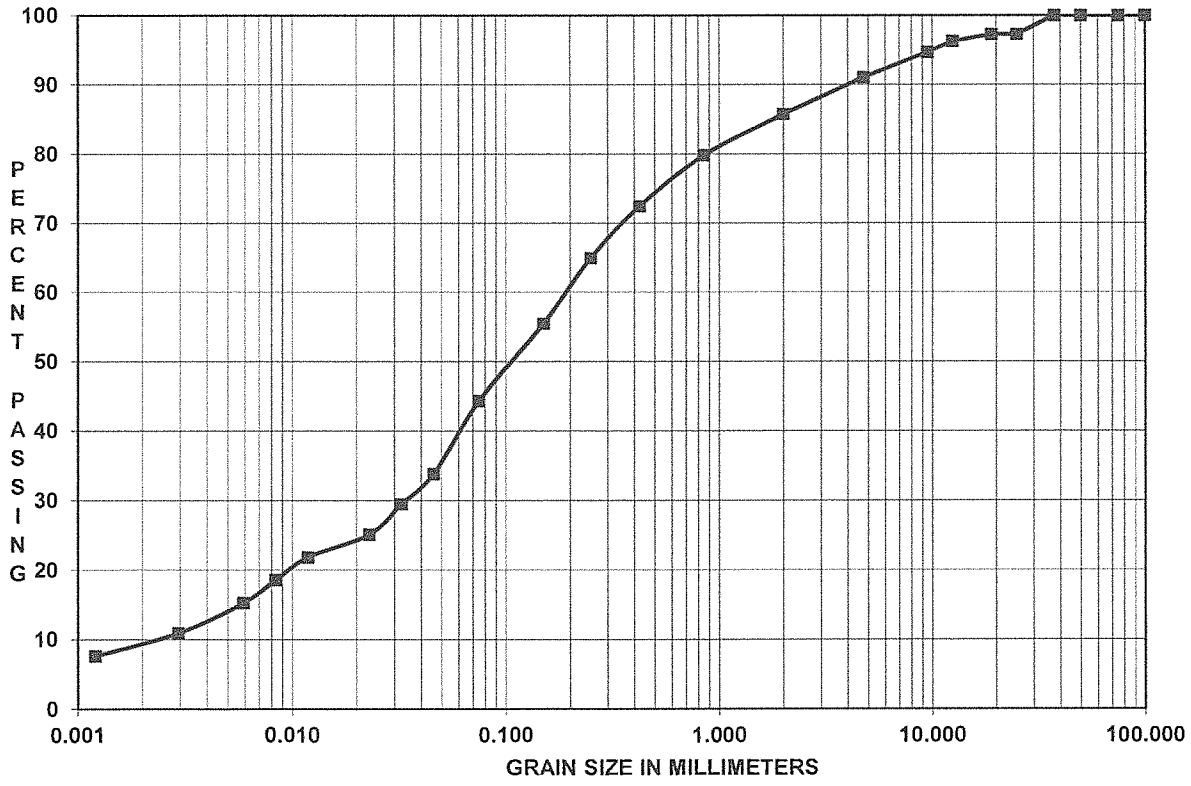
DATE Rec'd: August 27, 2018

DATE TESTED: Sept 9, 2018

SAMPLED BY: Client

SOURCE: BH18-02 @ 45 - 45.5' - GS07

SAMPLE TYPE: Grab Sample



SUMMARY

Grain size (mm)	Passing (%)
75.0	100.0
50.0	100.0
37.5	100.0
25.0	97.3
19.0	97.3
12.5	96.3
9.5	94.7
4.75	91.1
2.00	85.7
0.850	79.8
0.425	72.4
0.250	64.9
0.150	55.4
0.075	44.3
0.0459	33.8
0.0324	29.5
0.0229	25.1
0.0118	21.8
0.0084	18.5
0.0059	15.3
0.0030	10.9
0.0012	7.6

REMARKS:

GRAVEL	8.9%
SAND	46.8%
SILT	35.2%
CLAY	9.1%

TECHNICIAN: B. Shearer

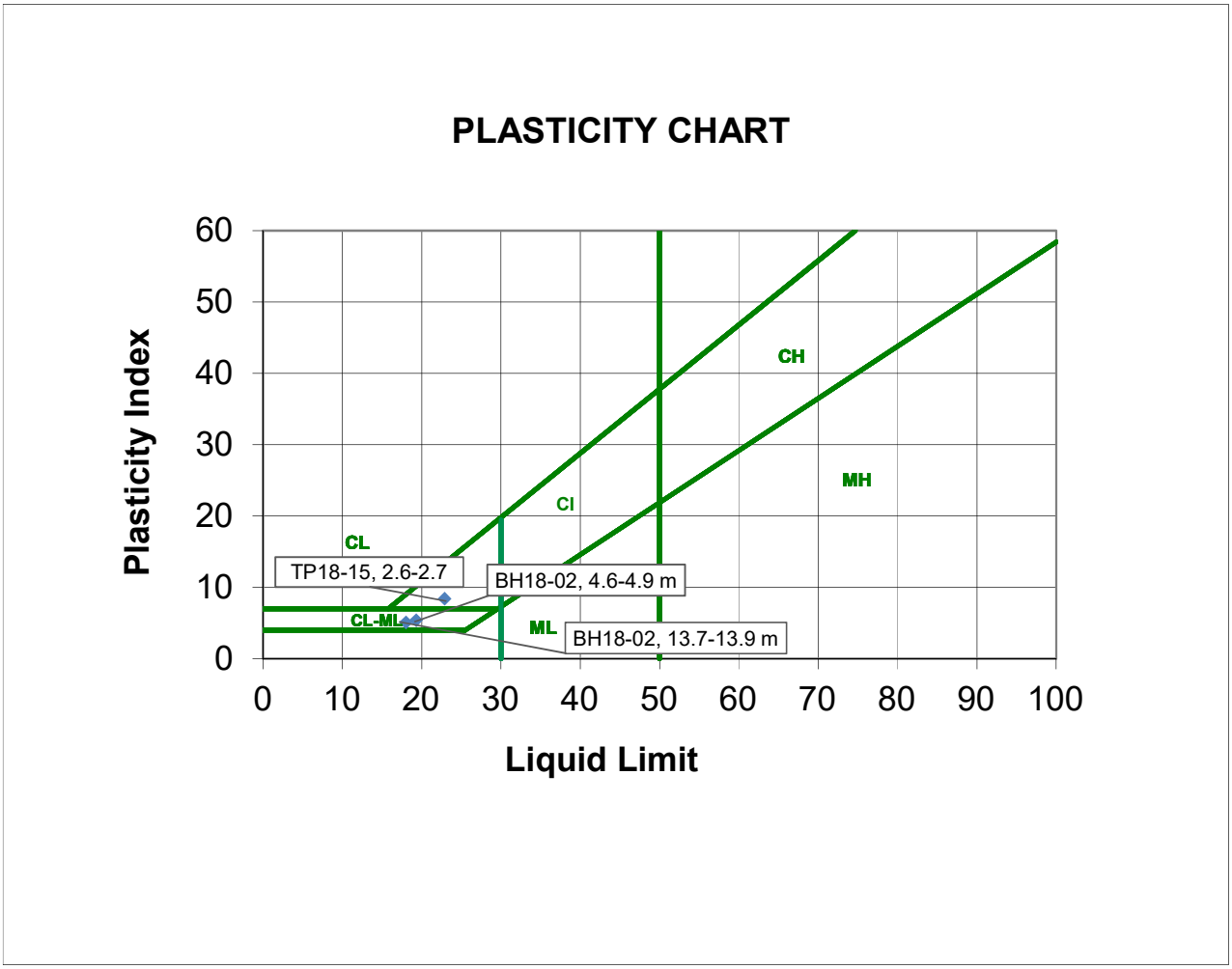
APPENDIX C

Atterberg Limits Testing Results

Project: City of Kelowna - 2045 Loseth Road Pump Station **Project:** 018-253

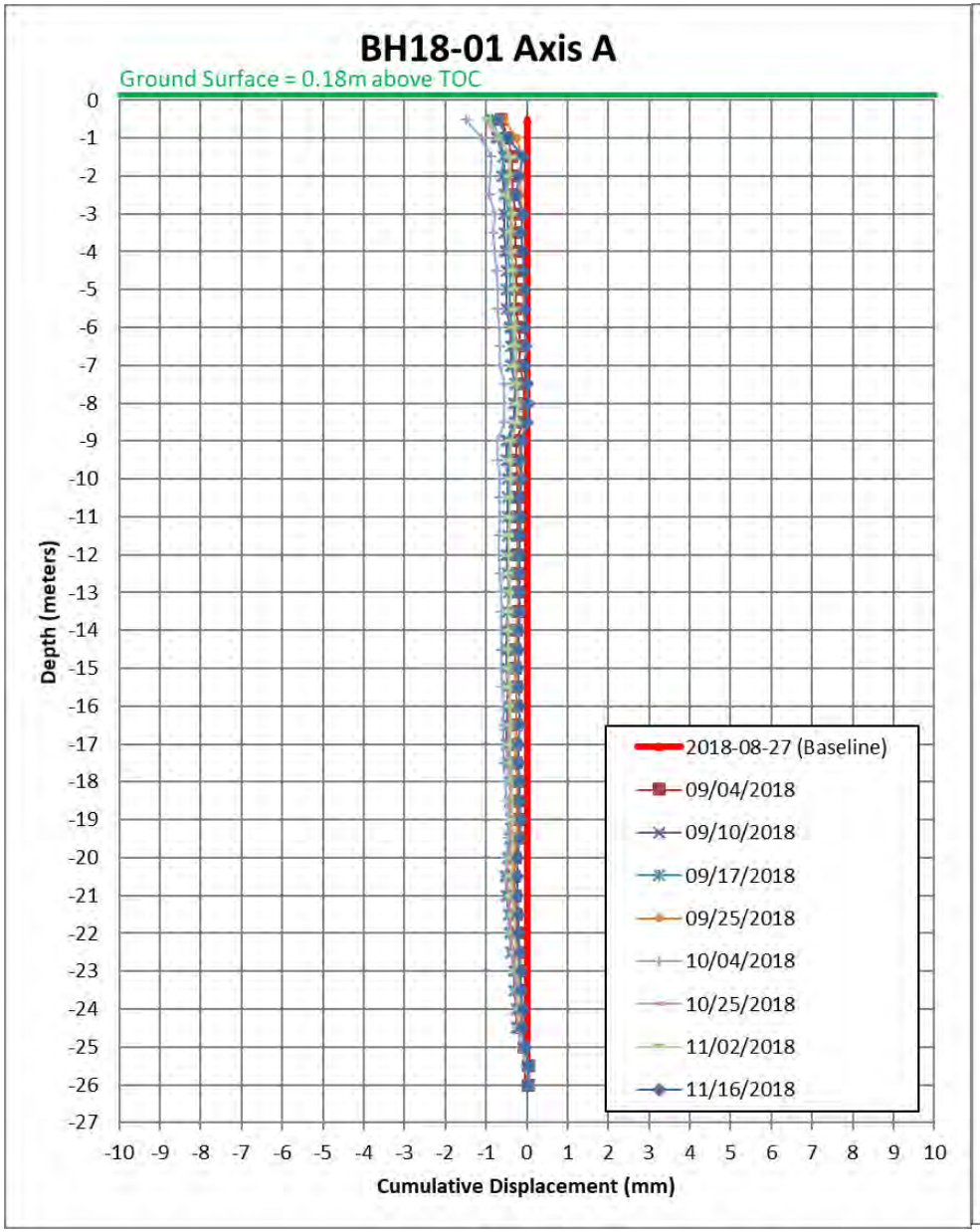
Sample Location					Particle Size Distribution										Index Parameters (%)						
Borehole	Sample	Top depth (ft)	Bottom depth (ft)	Depth (m)	Gravel	Sand	Silt	Clay	Fines	D10	D30	D60	CU	CC	W_N	LL	PL	PI	LI	Act.	USCS
BH18-02	GS-01	15	16	4.6-4.9 m											12.8	19.3	13.9	5.4	-0.20		CL-ML
BH18-02	GS-07	45	45.5	13.7-13.9 m											10.9	18.0	12.9	5.1	-0.39		CL-ML
TP18-15	GS-02	8.5	8.9	2.6-2.7 m											15.3	22.9	14.5	8.4	0.10		CL

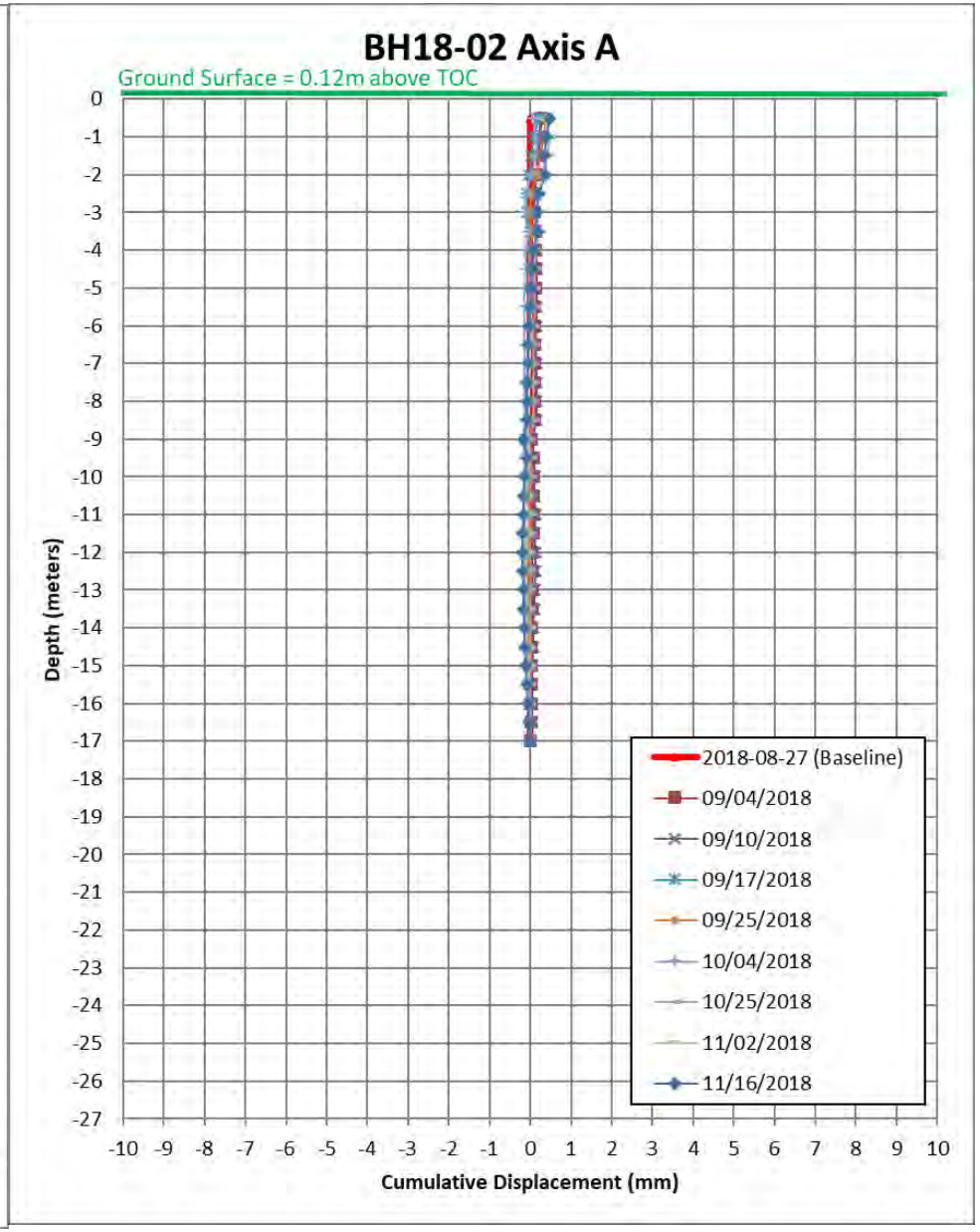
Remarks / Notes:



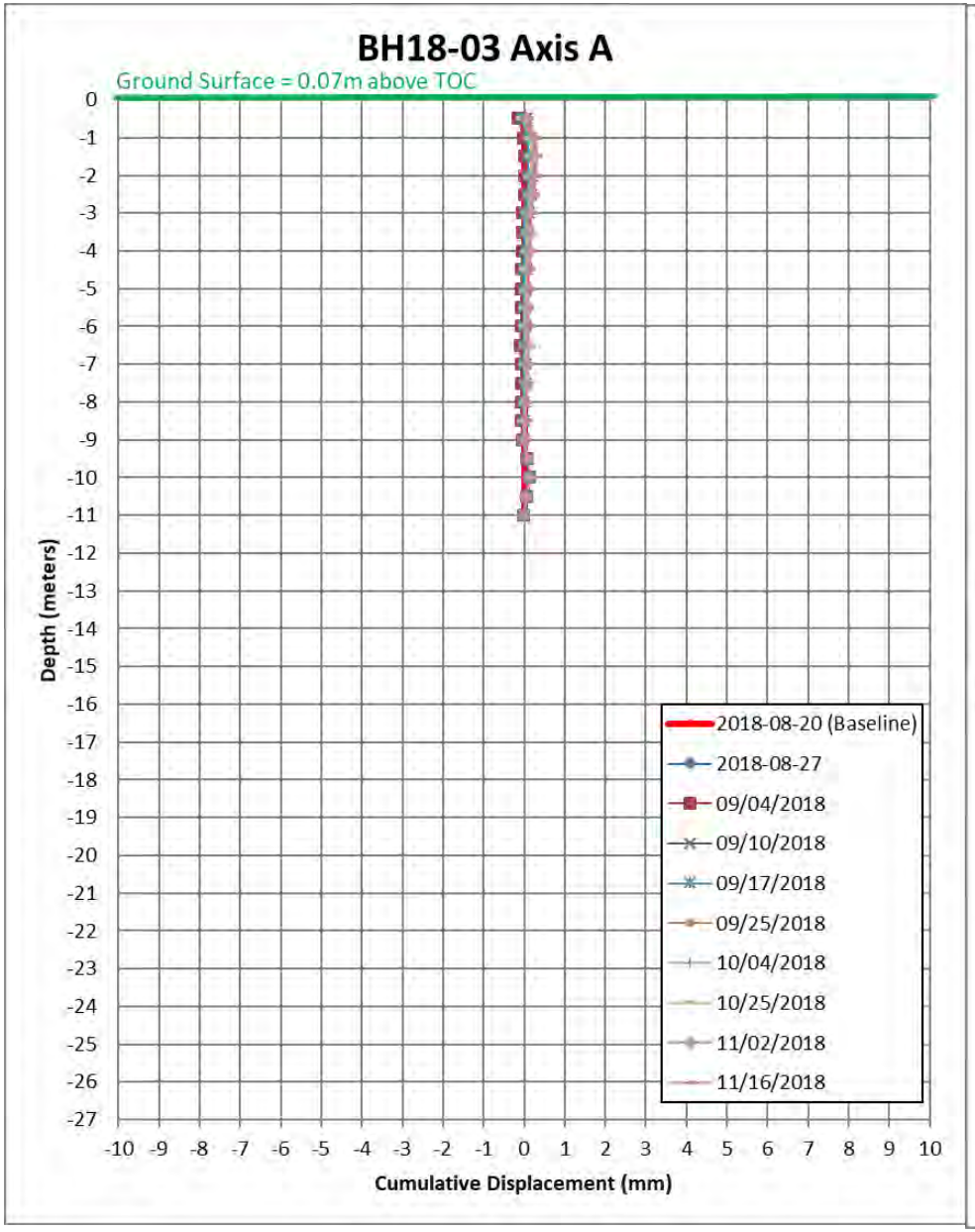
APPENDIX E

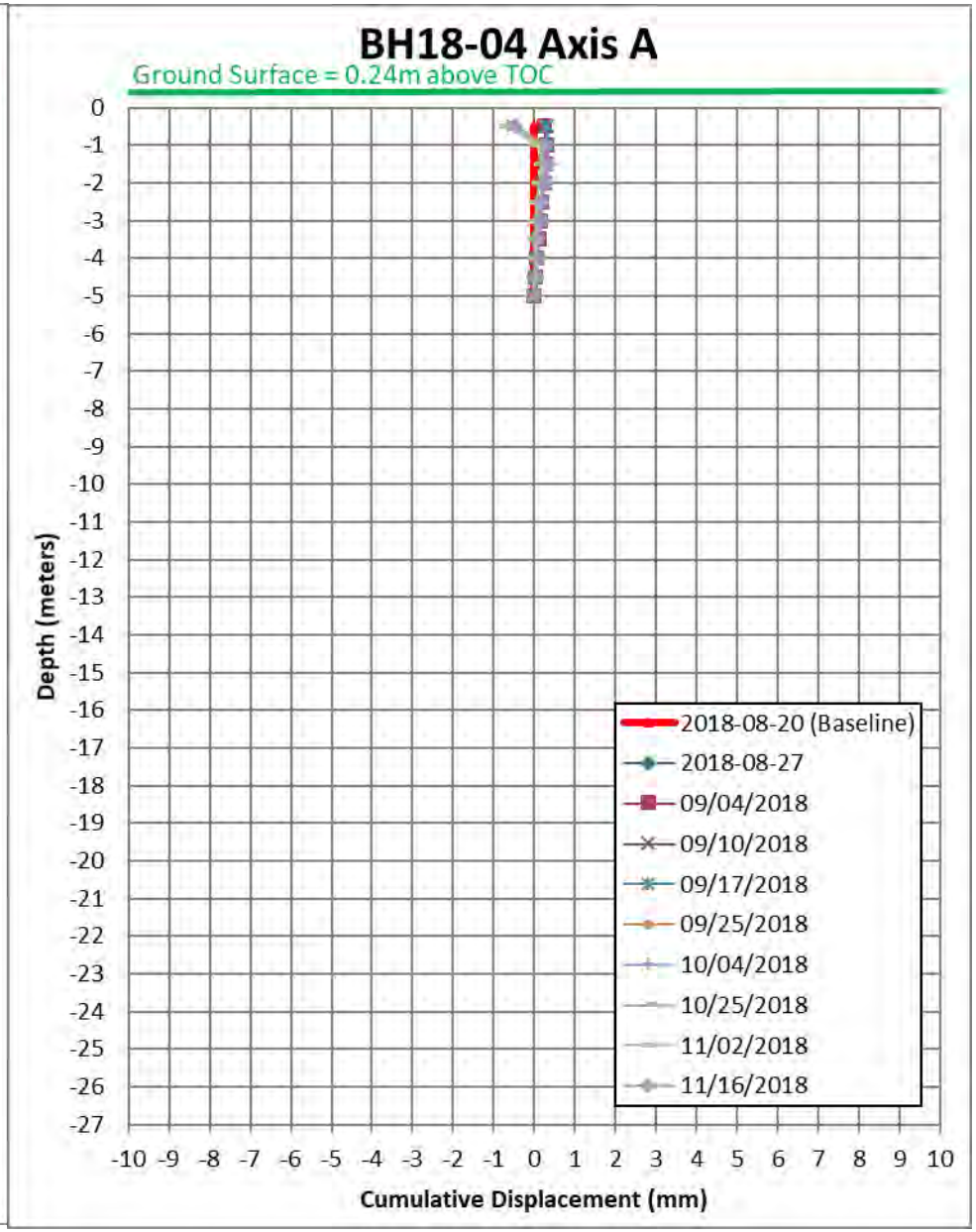
Slope Inclinometer and Piezometer Monitoring



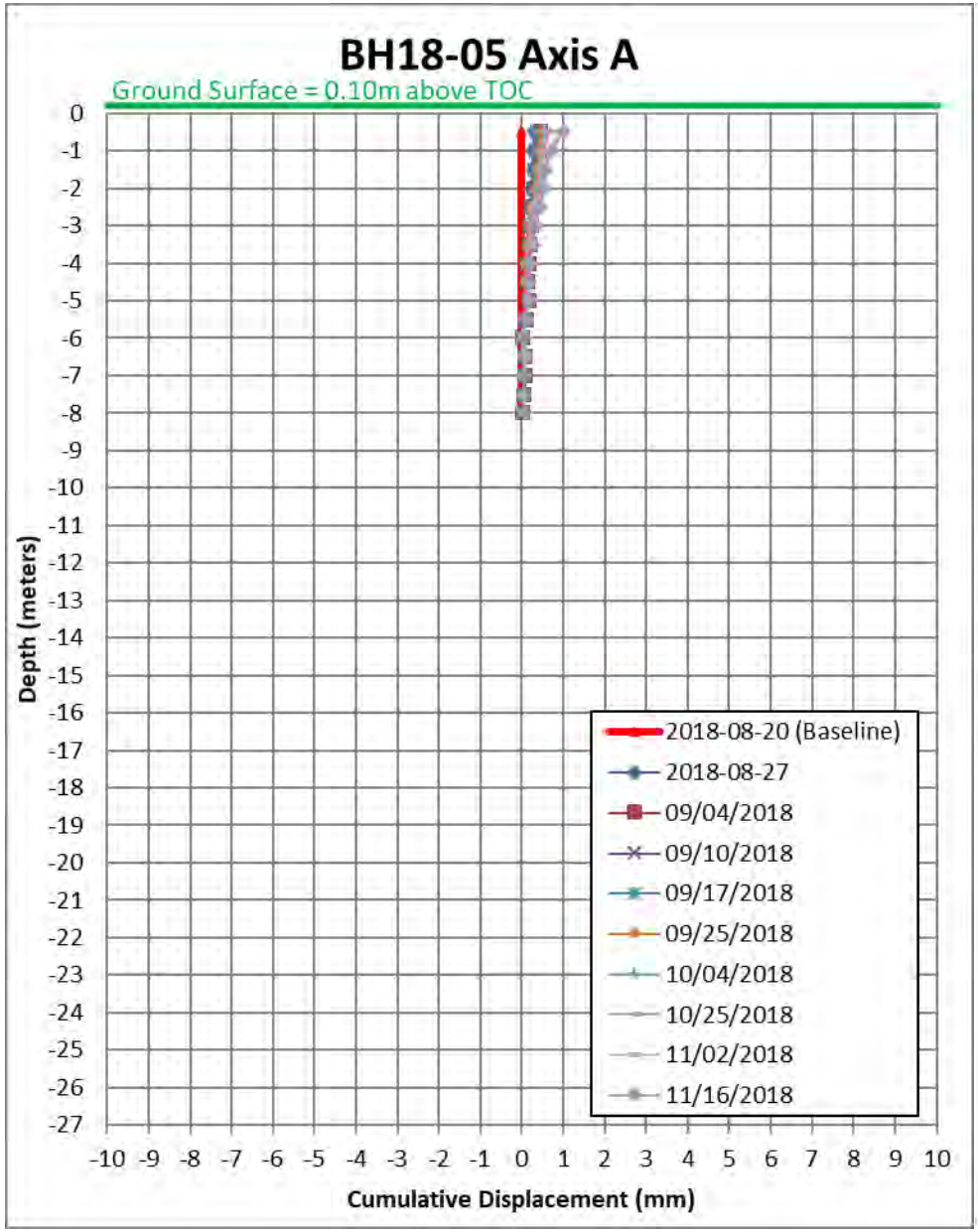


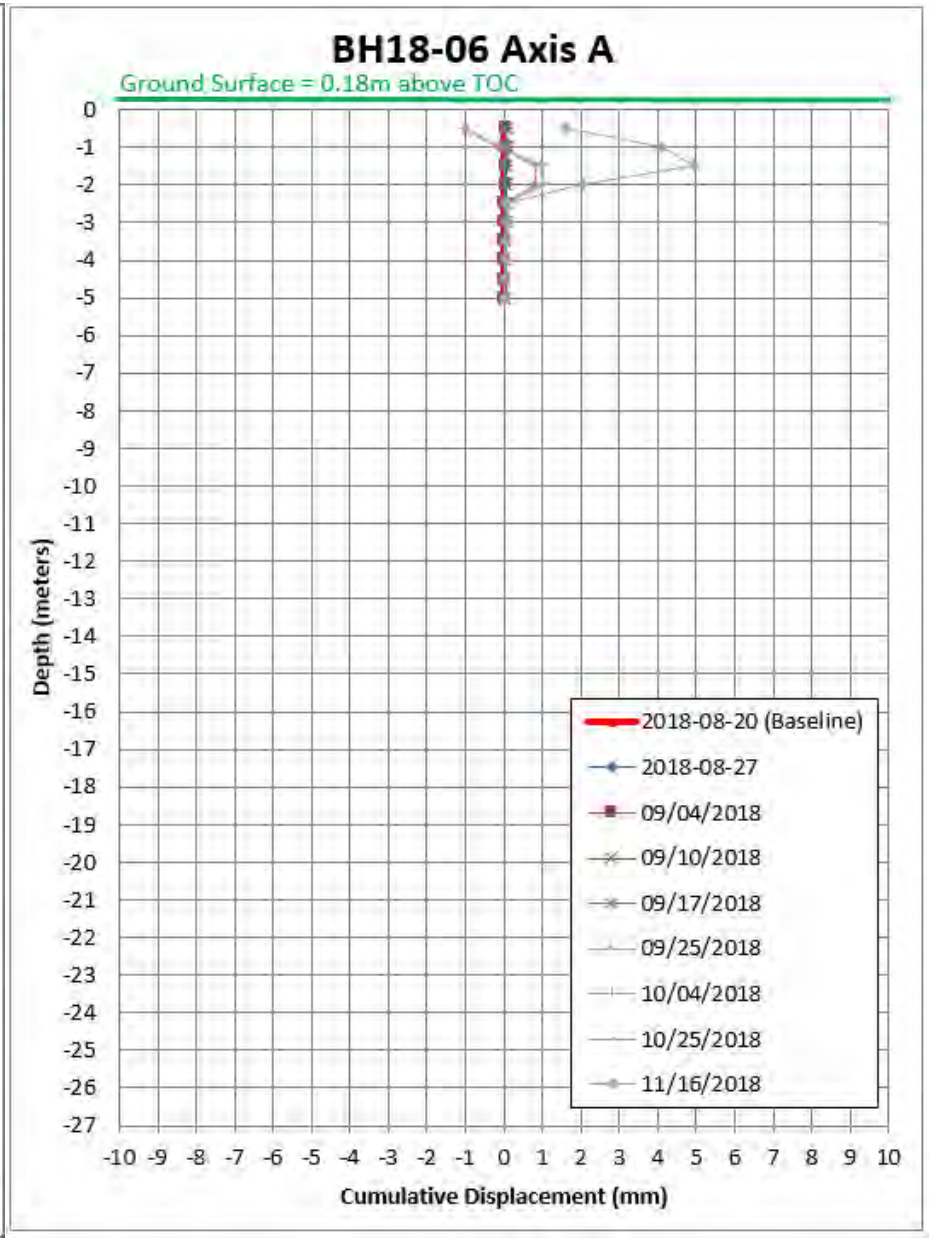
westrek geotechnical services ltd.	**BH18-01 and BH18-02 Slope Inclinometer Readings 2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 1**



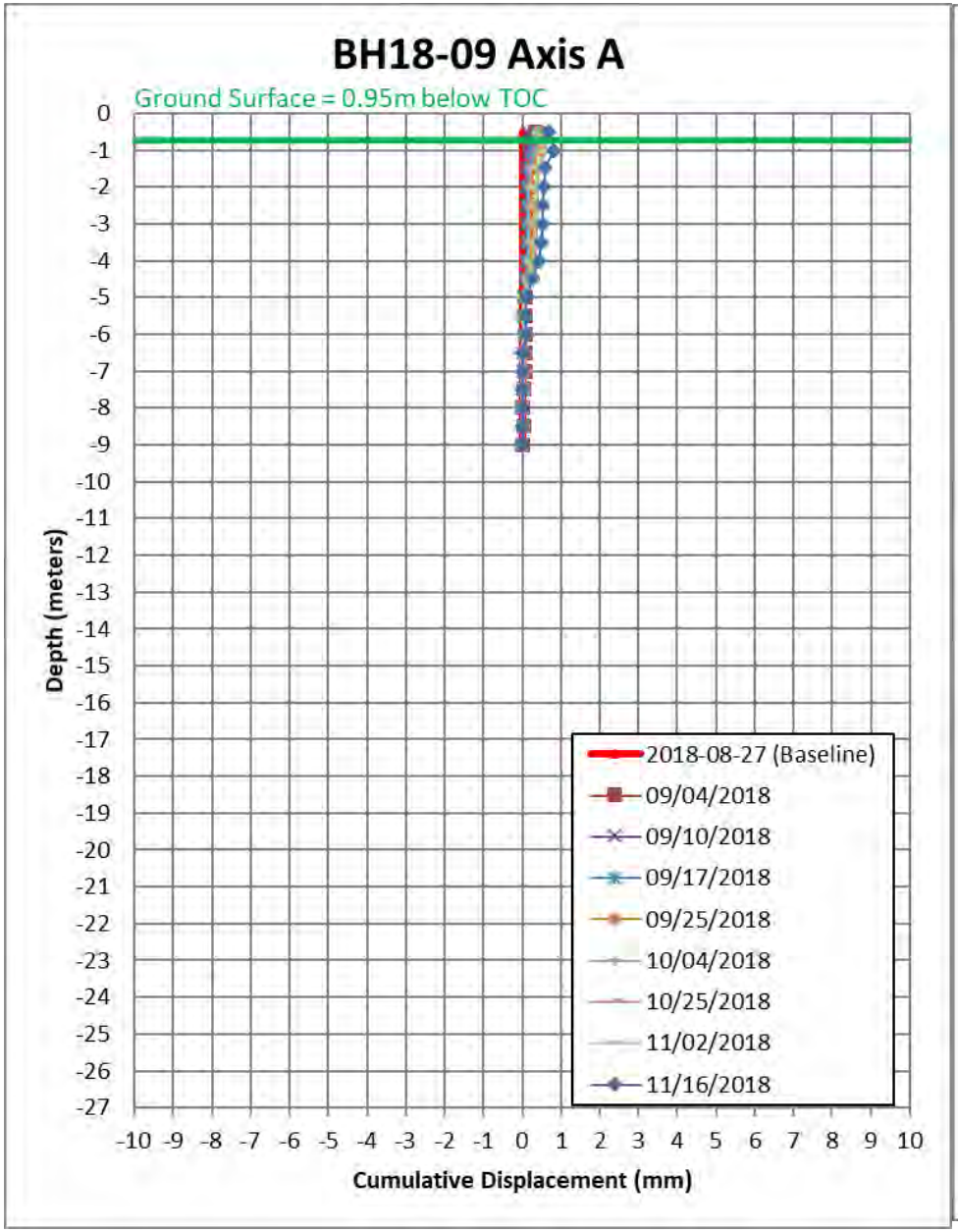


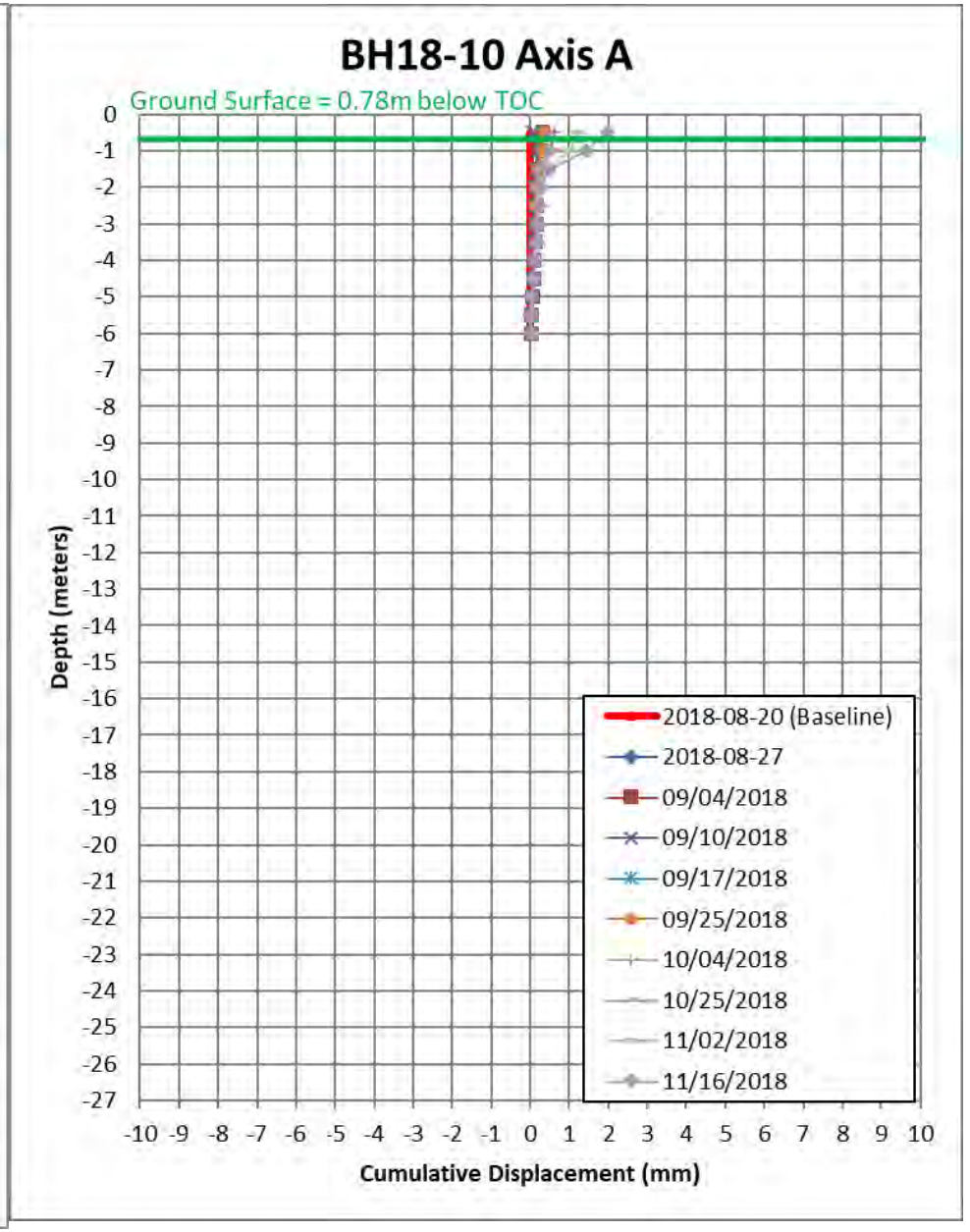
westrek geotechnical services ltd.	**BH18-03 and BH18-04 Slope Inclinometer Readings 2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 2**



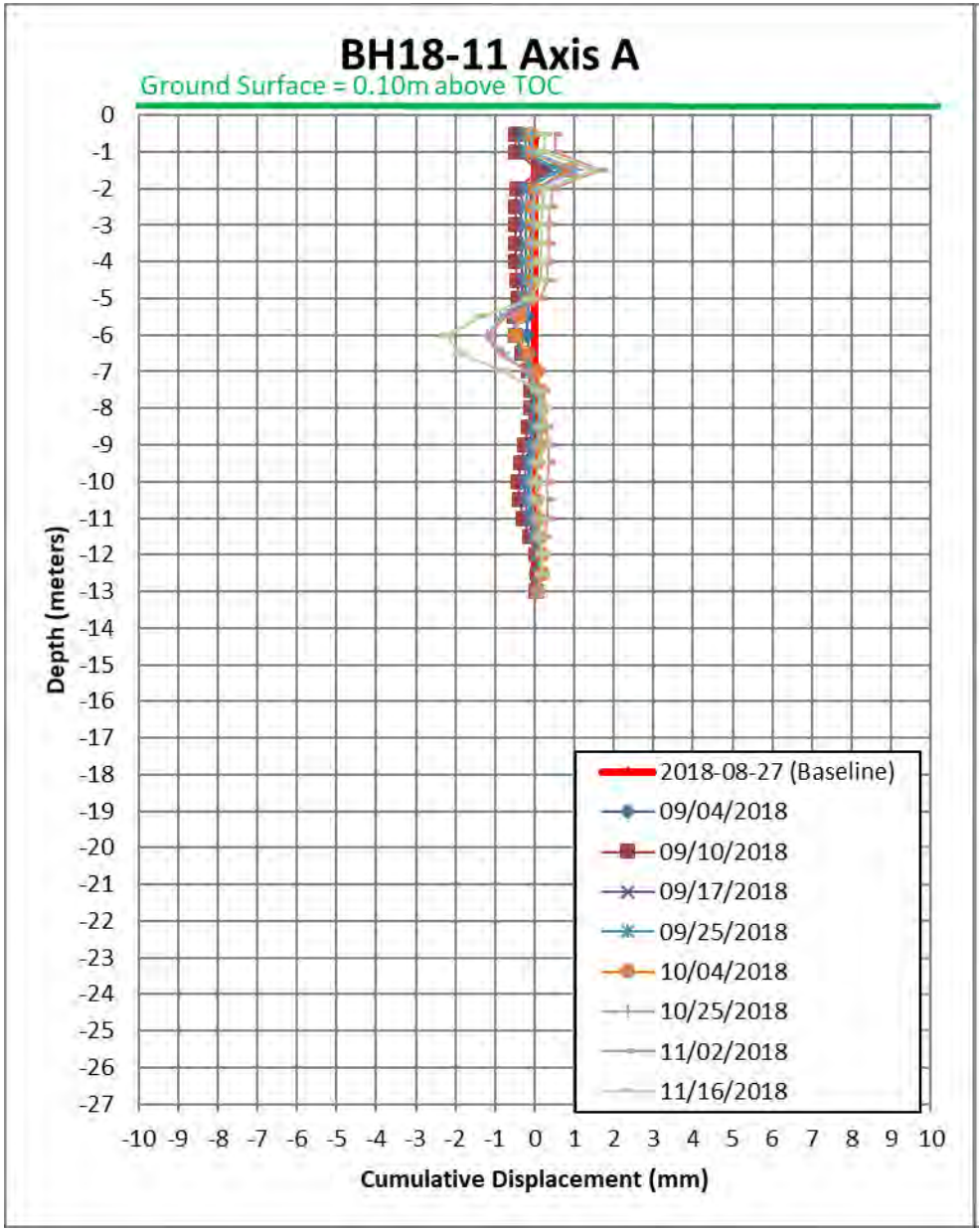


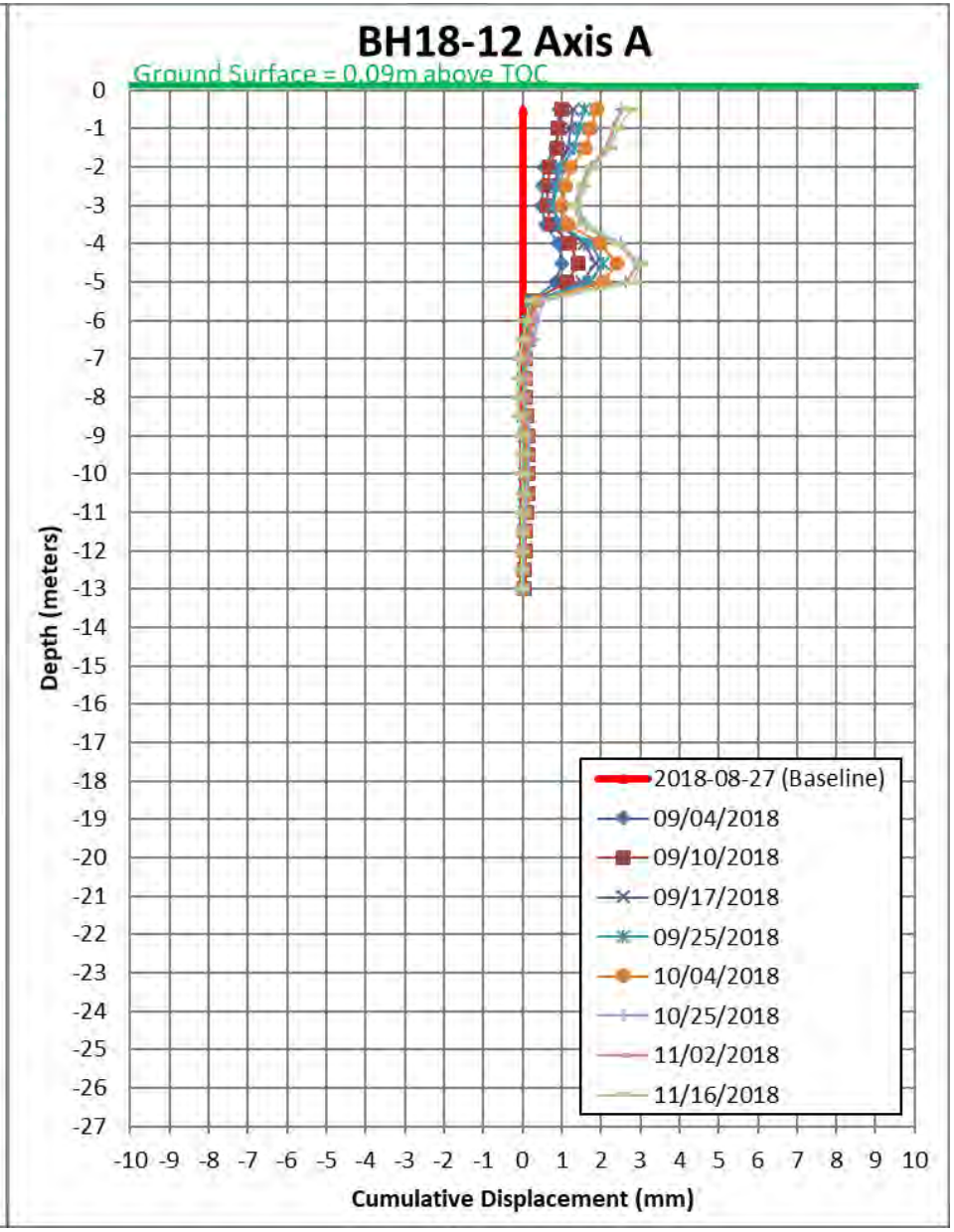
westrek geotechnical services ltd.	**BH18-05 and BH18-06 Slope Inclinometer Readings** **2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 3**



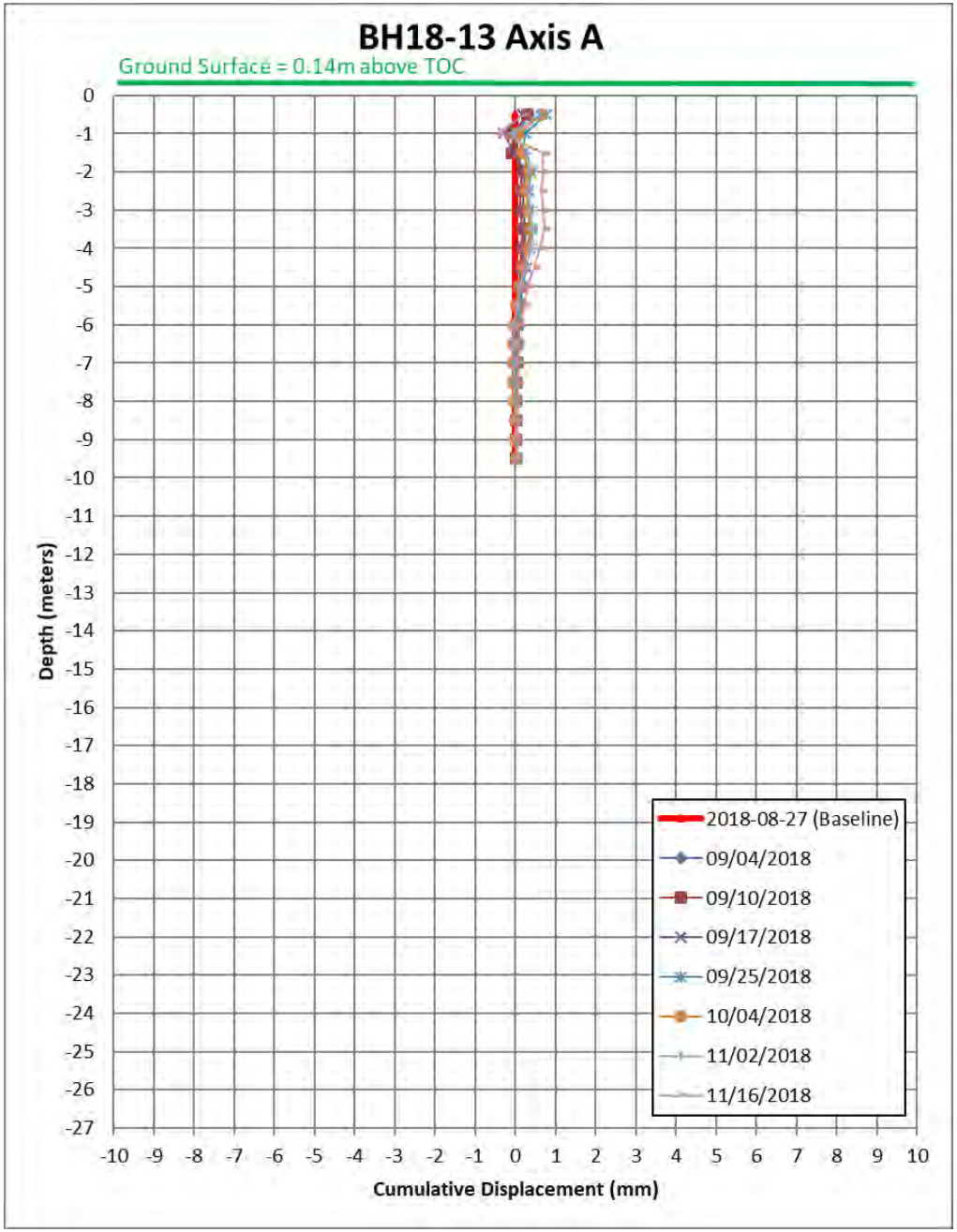


westrek geotechnical services ltd.	**BH18-09 and BH18-10 Slope Inclinometer Readings 2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 4**

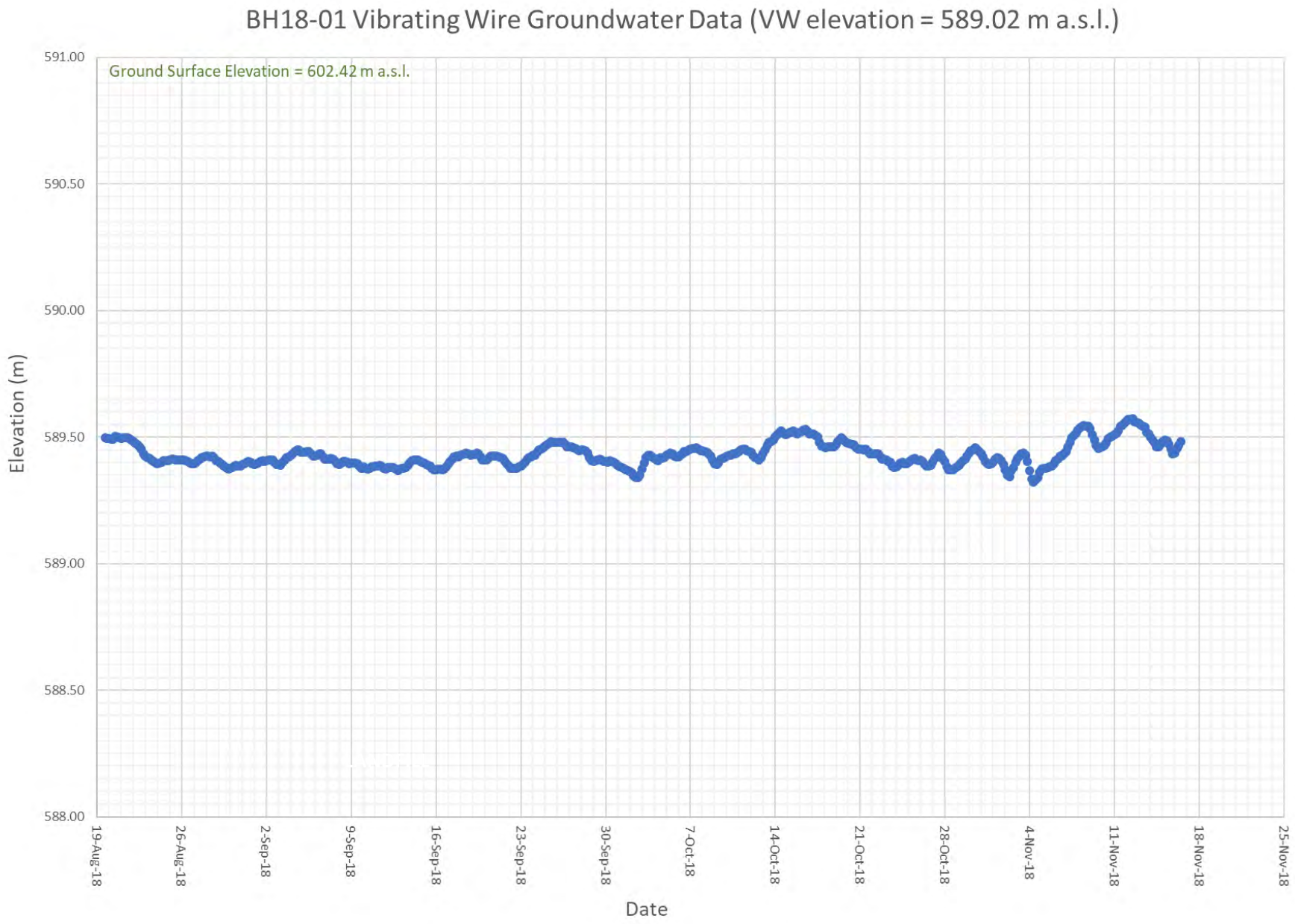




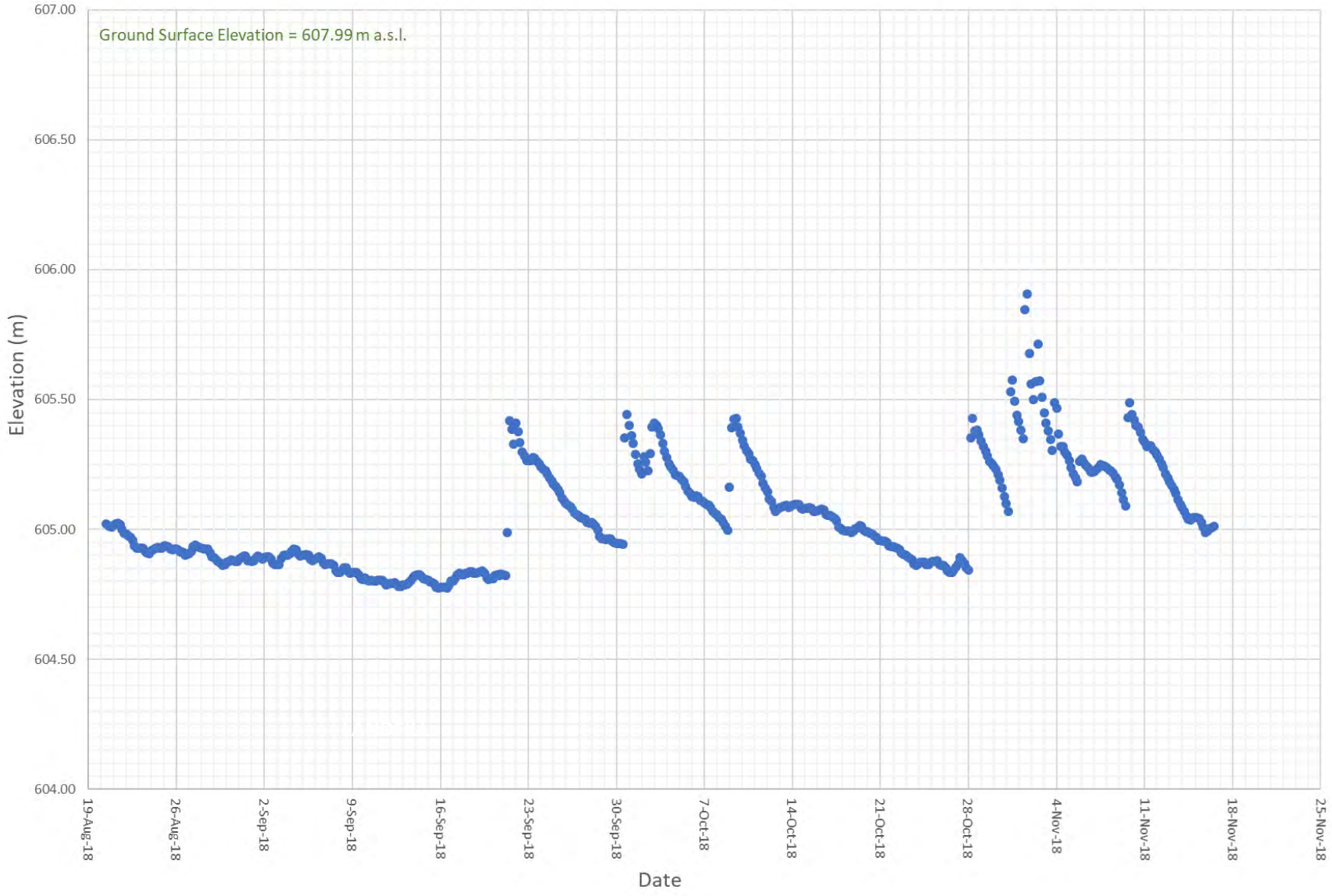
westrek geotechnical services ltd.	**BH18-11 and BH18-12 Slope Inclinometer Readings 2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 5**



westrek geotechnical services ltd.	**BH18-13 Slope Inclinometer Readings** **2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 6**



westrek geotechnical services ltd.	**BH18-01 Water Level Readings** **2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 7**



westrek geotechnical services ltd.	**BH18-06 Water Level Readings** **2045 Loseth Road Pump Station**	City of Kelowna December 7, 2018 Project: 018-253	**APPENDIX E - 8**