APPENDIX ‘D’

GEOTECHNICAL REPORTS

Morrison Hershfield

City of Winnipeg Branch 1 Aqueduct Underdrain Outfalls (RFP No. 512-2023) – Rue Plinguet Outfall Geotechnical Report

Prepared for:
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Project Number: 0035-129-00

Date: March 14, 2024

TREK GEOTECHNICAL
Quality Engineering | Valued Relationships

March 14, 2024 Our File No. 0035-129-00

Mr. Adam Braun, P.Eng.
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Winnipeg, MB R3Y 1G4

RE: City of Winnipeg Branch 1 Aqueduct Underdrain Outfalls (RFP No. 512-2023) – Rue Plinguet Outfall Geotechnical Report

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TREK Geotechnical Inc. is pleased to submit our final geotechnical investigation report for the above noted project. Please contact the undersigned should you have any questions.

Sincerely,

TREK Geotechnical Inc.
Per:

Michael Van Helden, Ph.D., P.Eng.
Senior Geotechnical Engineer

Encl.

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Revision History

Revision No.	Author	Issue Date	Description
0	MVH	Feb 28, 2024	Draft Final Report
1	MVH	March 14, 2024	Final Report

Authorization Signatures

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1.0 Introduction

The City of Winnipeg (COW) has identified structural issues with three Branch 1 Aqueduct underdrain outfalls and is planning to rehabilitate/replace the outfall drains. TREK Geotechnical Inc. (TREK) was retained by Morrison Hershfield (MHL) to provide geotechnical support for assessment and repairs to underdrain outfalls located at:

- Rue Notre Dame at Rue Maisonneuve on the Seine River;
- Rue Plinguet, west of McTavish Street on the Seine River; and
- Avenue Tache at Rue Messager on the Red River.

This report summarizes the results of the geotechnical assessment completed by TREK for the rehabilitation or replacement of the Branch 1 Aqueduct underdrain outfall at Rue Plinguet. The geotechnical assessment includes a review of existing information, sub-surface investigation, riverbank stability analysis, the development of preliminary design options for riverbank stability improvements, and provision of general recommendations for the design and construction of temporary excavations and shoring.

2.0 Site Conditions

TREK personnel (Michael Van Helden, P.Eng. and Reza Jamshidi Chenari, EIT) completed a site reconnaissance on November 29, 2023. The underdrain outfall pipe runs along the north side of Rue Plinguet before discharging into the Seine River just upstream of a 90-degree bend in the channel (Figure 01). The riverbank is generally grass-covered with sparse young and mature trees with a uniform gradient of about 5H:1V and a height of about 7 m. An over-steepened face along the river edge upstream and downstream of the outfall location related to shoreline erosion is visible (Photo 1). Although no active riverbank movements were noted within the outfall right-of-way, historical instabilities are evident upstream and downstream in particular coincident with the outside bend in the channel.

Discharge from a land drainage sewer (LDS) outfall south of the underdrain outfall pipe has created an erosion gully extending from the upper to lower bank areas (Photos 2 and 3). Beyond the slope crest, Plinguet Street terminates in a widened roadway area, and an access road to the adjacent cemetery to the north is located immediately adjacent to the bank crest (Photo 4). Photo 5 shows an overview of the site from an aerial drone perspective.

2.1 Site Survey

Three riverbank cross-sections were surveyed by Morrison Hershfield on January 8, 2024 at the locations shown on Figure 01. The cross sections showing the existing round surface from the MHL survey and LIDAR survey data are included on Figure 02 (cross section A and B) and Figure 03 (cross section C).

3.0 Sub-surface Information

A sub-surface investigation was completed under the supervision of TREK personnel to determine the soil stratigraphy and groundwater conditions at the site. Test Holes (TH) 24-01 and 24-02 were drilled at the locations shown on Figure 01 by Paddock Drilling Ltd. on January 8 and 9, 2024 using an Acker SS3 track-mounted drill rig equipped with 125 mm diameter solid stem and 200 mm hollow stem augers. TH 24-01 and 24-02 were drilled to power auger refusal at depths of 11.7 m and 17.6 m, respectively. Test hole locations were established using a hand-held GPS device and the ground surface elevation surveyed relative to a temporary benchmark (TBM) as shown on Figure 01.

A slope inclinometer (SI) casing was installed in TH24-01 to approximately 17.6 m below ground surface (bgs) and fully grouted to surface. A vibrating wire (VW) piezometer was installed at 9.2 m bgs in TH24-02. A standpipe piezometer (SP) was also installed in TH24-02 at 18.0 m bgs. TH24-02 was backfilled with sand around the standpipe tip, bentonite chips followed by cement/bentonite grout to surface (and surrounding the VW). Above-ground protective casings were installed for all instrumentation.

Sub-surface soils were visually classified based on the Unified Soil Classification System (USCS). Disturbed (auger cutting) samples were taken at regular intervals and relatively undisturbed (Shelby Tube) samples were collected at select depths. All samples retrieved during drilling were transported to TREK's testing laboratory in Winnipeg, Manitoba. Laboratory testing consisted of moisture content determination on all disturbed samples, bulk unit weight and unconfined compressive strength on Shelby tube samples, and Atterberg Limits on select samples. Laboratory testing results are included in Appendix B. The test hole logs include a description of the soil units encountered and other pertinent information such as groundwater and a summary of the laboratory testing results.

3.1 Soil stratigraphy

A brief description of the soil units encountered (in descending order from ground surface) in the two test holes is provided as follows. All interpretations of soil stratigraphy for the purposes of design should refer to the detailed information provided on the test hole logs.

TH 24-01 (lower bank)

The general soil stratigraphy in TH 24-01 consists of 0.6 m of topsoil, 2.8 m of firm to stiff clay fill, 1.5 m of loose and wet silt, 3.0 m of compact sand, and 3.7 m of compact and wet sand and gravel (possibly an ablation till). Dense silt till was encountered at 11.6 m bgs and power auger refusal was encountered at 11.7 m bgs.

TH 24-02 (top of bank)

The general soil stratigraphy in TH 24-02 consists of 0.6 m of topsoil, 2.5 m of firm to stiff clay fill, 7.9 m of silty clay that is firm to stiff becoming very soft below a depth of 7.9 m, 4.3 m of loose to compact (wet) sand, and 2.3 m of compact sand and gravel to the depth of exploration. Power auger refusal was encountered at 17.6 m bgs.

3.1.1 Groundwater and Sloughing Conditions

Seepage and sloughing was observed below 7.9 m in TH24-01 from sand and gravel, before switching to hollow stem augers. Seepage and sloughing could not be observed due to the drilling method used (hollow stem augers) for the remainder of TH24-01 and the entirety of TH24-02. Piezometric (groundwater) levels monitored after installation are summarized in Table 1.

Table 1. Measured Piezometric (Groundwater) Elevations

Test Hole	Instrument	Piezometric Elevation (m)	
		Feb 05, 2024	Feb 24, 2024
TH24-02	Vibrating Wire Piezometer (VW23-02)	224.66	224.83
	Standpipe Piezometer (SP23-02)	220.79	220.75

Measured groundwater elevations are short-term and should not be considered reflective of (static) elevations at the site which would require monitoring over an extended period of time to determine. It is important to recognize that groundwater conditions may vary seasonally, annually, or as a result of construction activities.

3.1.1 Slope Inclinometer Monitoring

A baseline reading of the SI was taken on February 05, 2024 to establish the initial profile of the SI pipe and a follow-up reading was completed on February 27, 2024. Monitoring results are included in Appendix B. No movement was measured over the brief monitoring period. Additional monitoring events are recommended after the spring 2024 flood, in the fall of 2024 (pre-drawdown) and the early winter of 2024 (post-drawdown).

4.0 Slope Stability Analysis

Slope stability analyses were conducted to assess the existing riverbank slope stability and provide recommendations for improvements to stability (if warranted) in conjunction with the outfall repairs. The analysis was conducted using a limit-equilibrium slope stability model (Slope/W) from the GeoStudio 2020 software package (Geo-Slope International Ltd.). The slope stability model used the Morgenstern-Price method of slices with the half-sine interslice force function to calculate factors of safety. Slip surfaces were identified using grid and radius methods. A static piezometric line was used to represent groundwater levels. The soil stratigraphy was based on information in THs 24-01 and 24-02 and the ground surface geometry was based on the MHL survey.

Assumed soil properties in Table 2 are based on measured values or in the absence of this information, using representative values based on TREK's experience. The clay strengths are assumed to be at a "fully softened" condition which we consider representative for a potential first time failure in Winnipeg riverbanks. Based on observed site conditions, we have assumed that there are no historical instabilities within the ROW that would warrant the use of lower (residual) strength properties.

Table 2. Soil Properties used in Slope Stability Analysis

Soil Description	Unit Weight (kN/m³)	Cohesion (kPa)	Friction Angle (degrees)
Clay Fill and Silty Clay	17	5	17
Riprap	21	0	45
Sand, Sand and Gravel, Silt Till	Impenetrable		

Analysis was conducted on cross-section B for short-term (extreme) and long-term (typical) groundwater conditions. The output of the slope stability analysis is presented as a factor of safety (FS) related to the stability of the slope along a particular slip surface. A factor of safety approaching unity (FS = 1.0) indicates that the slope is becoming unstable and differential shear movements are expected. As the factors of safety increase above unity, the likelihood of movements decreases. In general, slopes with a factor of safety greater than 1.3 under short-term (extreme) conditions and greater than 1.5 under long-term (normal) conditions are considered stable, although some minor creep may occur. In some cases, an increased factor of safety may be targeted for sensitive and critical infrastructure. Target factors of safety of 1.3 and 1.5 were selected for design under short and long-term conditions, and have been commonly used on other City of Winnipeg infrastructure projects. Short-term conditions were modelled with a nearly empty channel and a riverbank groundwater levels gently sloping up to Elev. 229.80 m (about 2.5 m below ground surface). Long-term conditions were modelled with a nearly empty channel and a riverbank groundwater level gently sloping up to Elev. 229.00 m (about 3.2 m below ground surface).

4.1 Analysis Results

4.1.1 *Existing Stability*

Table 3 summarizes the calculated factors of safety for the existing slope geometry, while the results are shown in the figures included in Appendix C (as referenced in the table). The estimated factors of safety for short and long-term conditions (1.27 and 1.48 respectfully) are within 2% of the respective targets (Figure C1 and C2) and are therefore considered acceptable.

Table 3. Slope Stability Analysis Results for Existing Conditions

Stability Case / Cross Section	Modelling Case	Groundwater Elevation (m)[1]	Channel Water Elevation (m)	Critical FS	Model Number (Appendix C)
Existing Condition / Cross Section B	Extreme Case	229.8	223.70	1.27	C1
	Normal Case	229.0		1.48	C2

4.1.2 Future Stability

Ongoing shoreline erosion can be expected to reduce the riverbank stability over time. Analysis was therefore carried out to evaluate the stability of the bank with the addition of riprap erosion protection at the toe. Thes results summarized in Table 4 show a marginal improvement to existing slope stability with a 0.6 m thick riprap blanket sub-cut below existing grades up to Elev. 226.0 m (Figures D1 and D2 respectively).

Table 4. Slope Stability Analysis Results for Riprap Blanket

Stability Case / Cross Section	Modelling Case	Groundwater Elevation (m)[1]	Channel Water Elevation (m)	Critical FS	Model Number (Appendix D)
Regrading and Riprap / Cross Section B	Extreme Case	229.8	223.70	1.31	D1
	Normal Case	229.0		1.51	D2

4.1.3 Recommendations

To prevent future shoreline erosion and the associated reduction in riverbank stability, TREK recommends the provision of erosion protection measures (riprap) during the outfall repair works. The riprap blanket should extend to the limits of the outfall right-of-way and ideally, 10 m upstream and downstream of the right-of-way limits. TREK's hydraulics engineers will complete a desktop assessment to determine riprap gradation and assess any adverse impact on channel geometry (a requirement of the necessary Waterways Permit).

5.0 Excavations and Shoring

We understand that a 9 m deep excavation will be required at the outfall manhole (within Plinguet Street) to facilitate the repairs. The outfall pipe will be installed using a combination of open-cut and directional drilling methods. As such, shoring will be required at the manhole location and open-cut excavations and/or shoring will be required near the outfall outlet to the river.

5.1 Temporary Excavations and Shoring

Based on the anticipated excavation depth and the sensitivity of surrounding structures to settlement (e.g. roadway, underground utilities), conventional shoring should be braced. Shoring will likely need to extend through the clay layer and into the sand / sand and gravel / silt till layers. Undrained soil conditions may govern design of the shoring in the short term and effective stress conditions should be considered for the long-term stability. Both undrained and drained soil conditions should be checked, and the more conservative condition used to design the shoring.

It is anticipated that the design of excavation slopes and temporary shoring will be the responsibility of the Contractor. Shoring designs or excavations will need to be designed and sealed by a professional engineer, and shop drawings should be reviewed by TREK prior to construction for review and comment.

The earth pressure distribution provided in Figure 03 can be used for braced shoring design, however the shoring designer should refer to the Canadian Foundation Engineering Manual (CFEM, 5th Edition, 2023) and the information provided on the test hole logs for consideration of the layered soil profile in design. The apparent earth pressure distribution shown on Figure 03 can be used for temporary braced shoring design in soft to firm clay and is not applicable for unsupported (cantilevered) shoring. The effect of any surcharge loads must be added to the force on the wall in addition to the calculated earth pressures. The appropriate earth pressure condition should be used to calculate the lateral earth pressure due to surcharge loads. Suggested soil parameters for use in shoring design are provided in Table 5, however it is the Contractor’s responsibility to review the test hole logs and confirm the selection of soil parameters for design.

Table 5. Engineering Properties for Soil

Material	Depth Below Site Grade in Upper Bank	Undrained Shear Strength	Effective Cohesion	Effective Friction Angle	Saturated Unit Weight	Effective Unit Weight	Earth Pressure Coefficients (Rankine[1])		
	(m)	(kPa)	(kPa)	(degrees)	(kN/m^3)	(kN/m^3)	Ko	Ka	Kp
Clay Fill	0 – 3.0	50	5	25	17.5	7.7	0.60	0.40	2.5
Clay	3.0 – 7.9	45	5	25	17.0	7.2	0.60	0.40	2.5
	7.9 – 11.0	15	5	20	16.0	6.2	0.66	0.49	2.0
Sand	11.0 – 15.4	n/a	0	33	20.0	10.2	0.46	0.30	3.4
Sand and Gravel	15.4 – 16.8	n/a	0	35	20.0	10.2	0.43	0.27	3.7
Silt Till	Below 16.8	n/a	0	30	20.0	10.2	0.50	0.33	3.0

Note 1: The effective stress earth pressure coefficients assume the magnitude of wall rotation is sufficient to develop the full earth pressure. The values should be reduced to suit the allowable wall rotation. Refer to Section 20.2.5 of the Canadian Foundation Engineering Manual (5th Edition 2023).

Ground movements behind the shoring and associated settlement are largely unavoidable. The amount of movement cannot be predicted with a high degree of accuracy as it is as much a function of the excavation procedures and workmanship as it is of theoretical considerations. In this regard, good contact between the retaining wall or timber lagging and retained soil should be maintained throughout the construction process. Free-draining sand fill should be used to fill in any voids behind the wall.

The proposed excavation base at 9 m depth is expected to terminate just above the clay-sand interface (± 11 m depth below ground surface) within very soft clay. A groundwater level in the clay at ground surface should be assumed for shoring design. Measured groundwater levels in the sand were at or near the clay-sand interface (± 11 m depth below ground surface) during the winter monitoring period and therefore, seepage into the excavation can likely be managed using conventional sump pits and pumping. However, groundwater levels can be expected to fluctuate with the level of the Seine River and may be higher during the summer months and during flood periods. Construction of the proposed works in the winter months (November to February) will reduce the risk of higher groundwater levels and the need for more extensive dewatering measures such as well point systems to address base heave.

Excavation base stability should be assessed based on equation 20.15 of the CFEM (5th Edition) as follows:

$$FS_b = \frac{N_b s_u}{\gamma H + q}$$

Where:

FS_b	is the factor of safety against base stability;
N_b	is the stability factor dependent upon the geometry of the excavation; a value of 9 should be used for excavations extending to between 8 to 10 m;
s_u	is the undrained shear strength of soil below the base of the excavation; a value of 15 kPa should be used for this site;
γ	is the unit weight of soil above the base of the excavation – refer to Table 5
H	is the depth of excavation (m)
q	is the surface surcharge load (kPa)

In the case of soft clays underlying the base of an excavation where FS_b is smaller than 2, substantial deformations of the excavation support, base and surrounding ground may occur. Where FS_b is less than 1.5, the depth of penetration of the support system should extend below the base of the excavation. Shoring that needs to extend below the depth of excavation should be designed in accordance with Chapter 20 of the CFEM (5th Edition).

A monitoring program should be established to record the performance of the shoring system from the onset of installation to removal. The monitoring program should include top of pile surveys as a minimum to measure and track lateral movement of the shoring with time. The vertical profile of soldier piles could be monitored using slope inclinometer casing and measurement of earth pressures acting on the shoring and groundwater pressure measurements could also be considered if deemed important by the shoring designer.

6.0 Closure

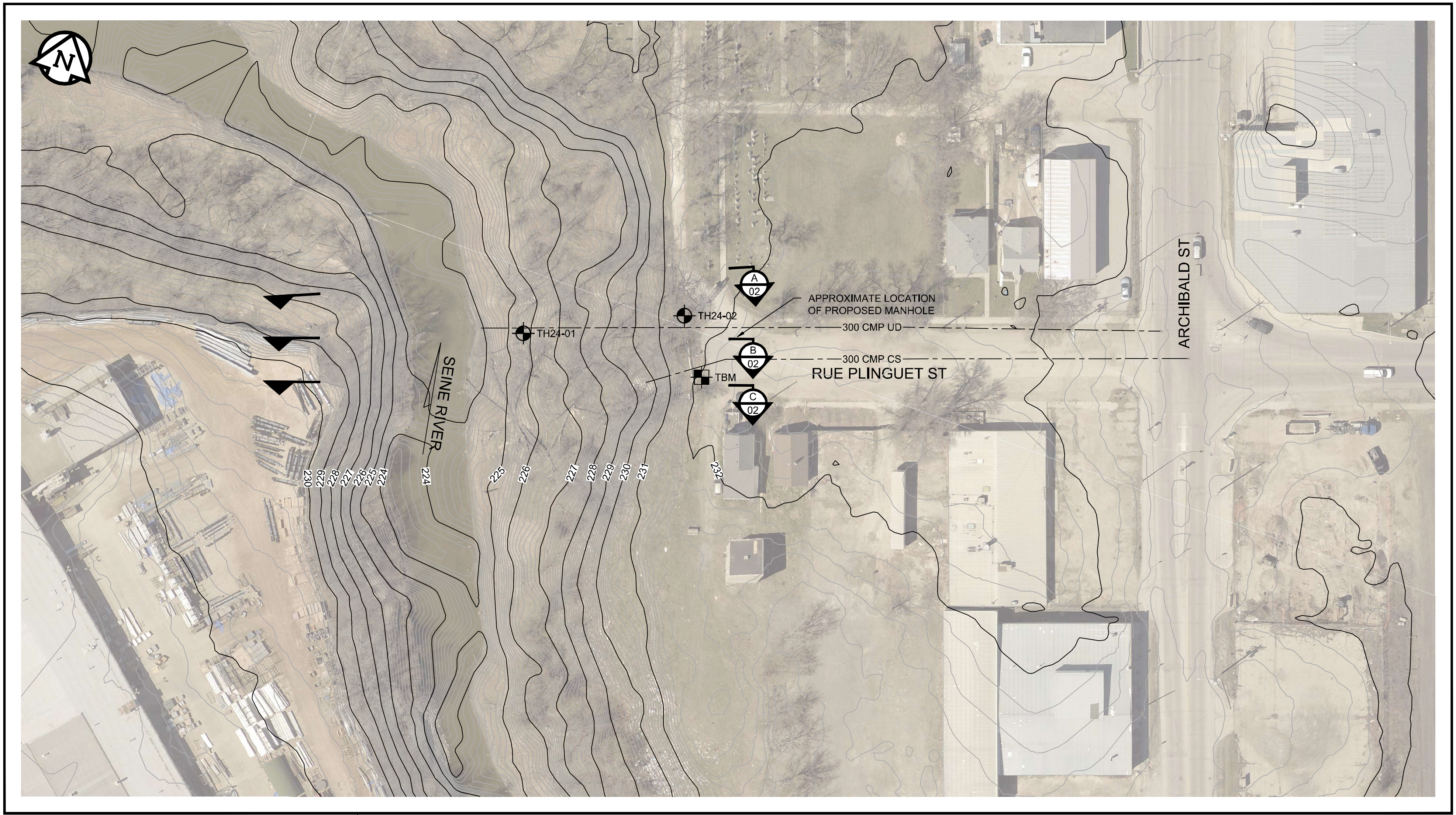
The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation and laboratory testing). Soil conditions are natural deposits that can be highly variable across a site. If sub-surface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work or standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of Morrison Hershfield (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

Figures

0035 129 00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls Rue Plinguet Site



0 10 20 30 m
SCALE = 1 : 750 (279 mm x 432 mm)

LEGEND:
- ⯐ TEST HOLE (TREK, 2024)
- ▚ TEMPORARY BENCHMARK
- EXISTING MAJOR CONTOUR (1.0 m INTERVAL)
- EXISTING MINOR CONTOUR (0.125 m INTERVAL)

NOTES:
1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).
2. CONTOURS FROM 2020 LIDAR.

Figure 01
Site Plan

Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 2024-02-26 Branch 1 Aqueduct 0_C 0035-129-00.dwg, 2024-02-26 3:06:54 PM

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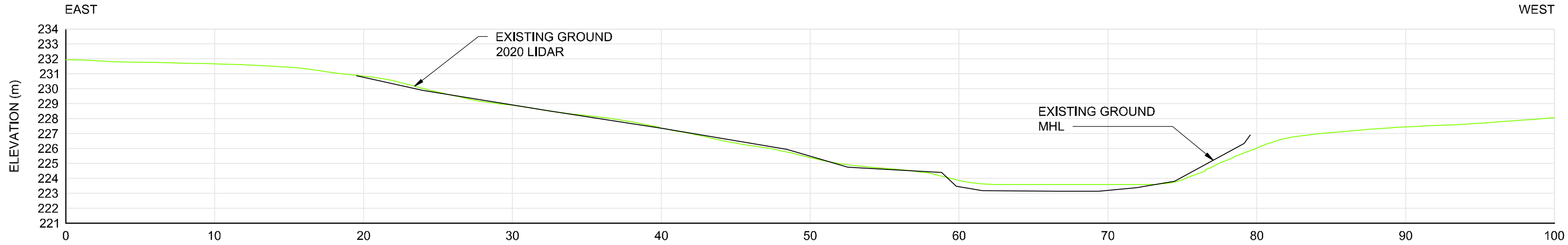
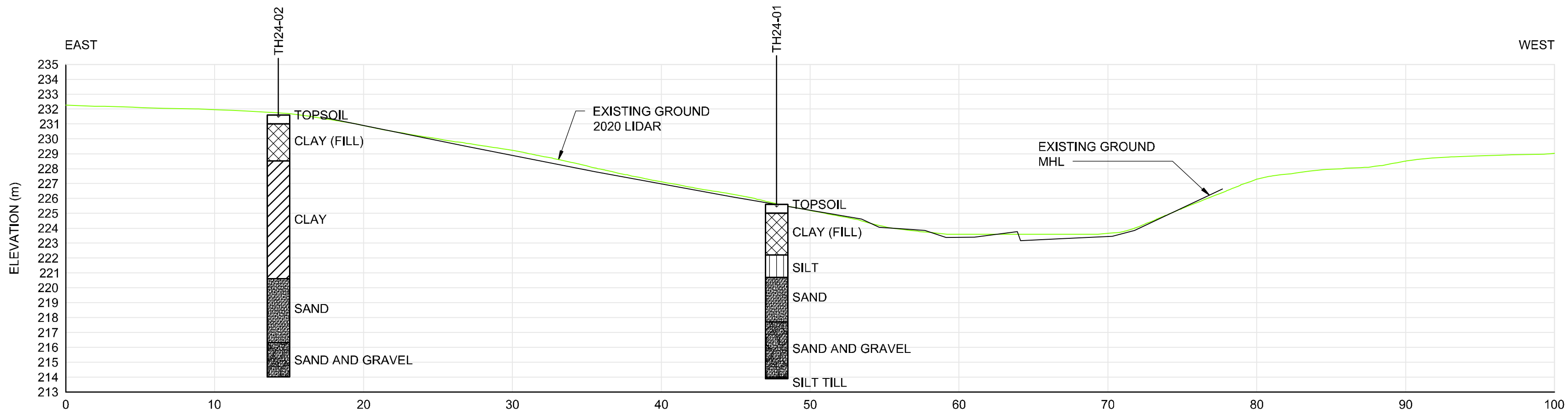
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls Rue Plinguet Site



CROSS SECTION A



CROSS SECTION B

Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 02 2024-02-26 Branch 1 Aqueduct 0_D 0035-129-00.dwg, 2024-02-26 3:03:27 PM

0 5 10 15 m
SCALE = 1 : 300 (279 mm x 432 mm)

LEGEND:

NOTES:

Figure 02
Cross Sections A & B

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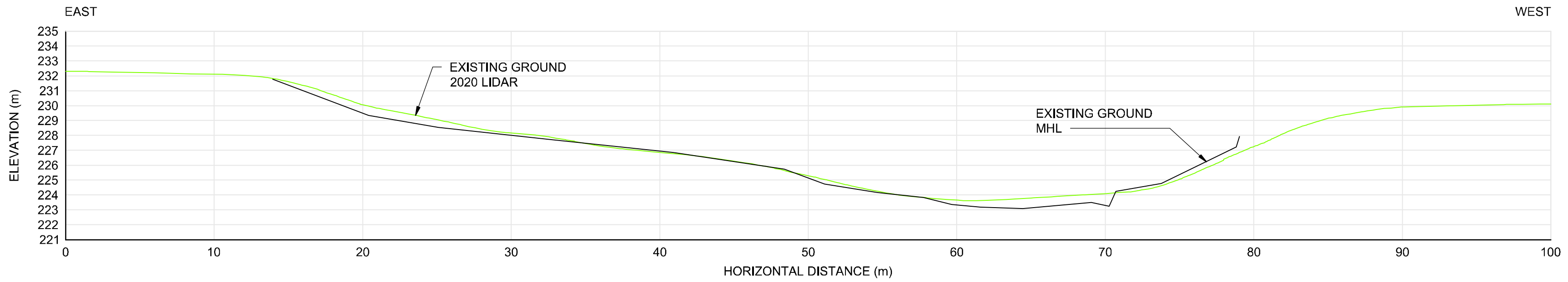
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls Rue Plinguet Site



CROSS SECTION C

0 5 10 15 m
SCALE = 1 : 300 (279 mm x 432 mm)

LEGEND:

NOTES:

Figure 03
Cross Section C

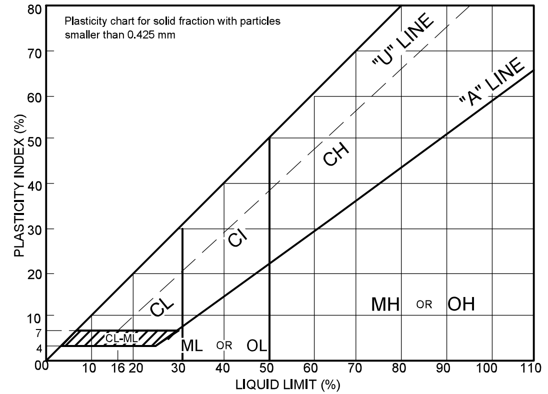
Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 02 2024-02-26 Branch 1 Aqueduct 0_D 0035-129-00.dwg, 2024-02-26 3:02:17 PM

Test Hole Logs

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the Unified Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classification	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent....... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	◌	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	◌	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	⁘	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	░	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart  		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	▤	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▮	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▨	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size: ASTM Sieve sizes	Particle Size: mm
Sand	Coarse	#10 to #4	2.00 to 4.75
	Medium	#40 to #10	0.425 to 2.00
	Fine	#200 to #40	0.075 to 0.425
Silt or Clay		< #200	< 0.075

Material		Particle Size: ASTM Sieve Sizes	Particle Size: mm
Boulders		> 12 in.	> 300
Cobbles		3 in. to 12 in.	75 to 300
Gravel	Coarse	3/4 in. to 3 in.	19 to 75
	Fine	#4 to 3/4 in.	4.75 to 19

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols.
For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	◌	Cobbles
░	Concrete	▦	Limestone Bedrock	●	Boulders and Cobbles
▩	Fill	☰	Cemented Shale	▥	Silt Till
		▤	Non-Cemented Shale	▨	Clay Till

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD- Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength

VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling

▼ Water Level at End of Drilling

▼ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent
with *	with silt, with sand	> 35 percent

* Used when the material is classified based on behaviour as a cohesive material

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

Test Hole TH24-01

1 of 1

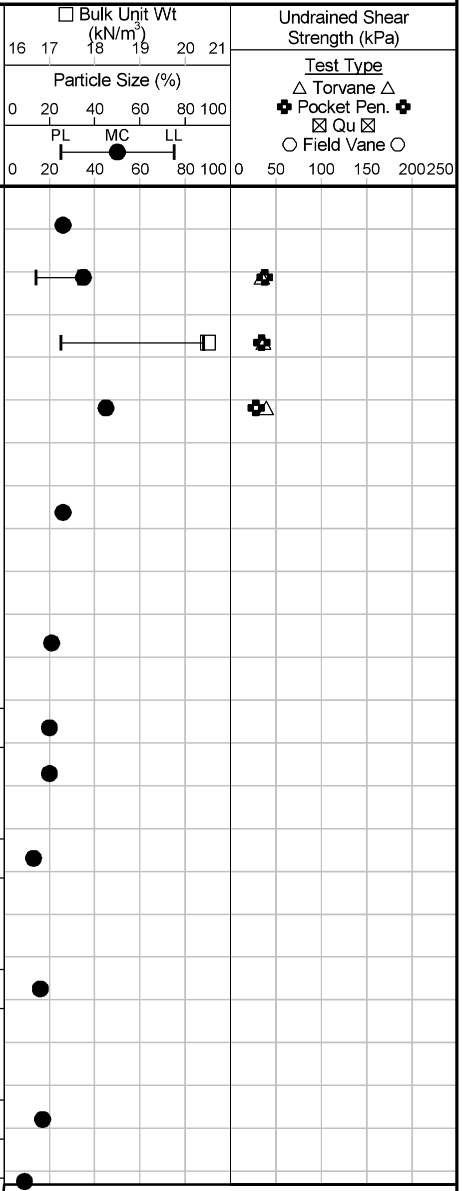
Client: Morrison Hershfield
Project Number: 0035-129-00
Project Name: Branch 1 Aqueduct Underdrain - Rue Plinguet Outfall
Location: UTM N-5528387, E-636055
Contractor: Paddock Drilling Ltd.
Ground Elevation: 225.69 m (geodetic)
Method: 125 mm SSA and 200 mm HSA
Date Drilled: January 8, 2024 - January 9, 2024

Sample Type: ◪ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ⧗ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ◌ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▩ Cement ▨ Drill Cuttings ⁘ Filter Pack Sand ⁘ Grout ▩ Slough

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)
	0	TOPSOIL, silty, trace to some sand, trace clay - dark brown, moist	◪	G01	
225.1		CLAY (FILL) - silty, some sand - brown - moist, stiff, high plasticity	◪	G02	
		- below 1.5 m, light brown, firm	▮	T03	
			◪	G04	
222.3		SILT - trace clay, trace sand, trace oxidation - light brown - moist, loose, no to low plasticity	◪	G05	
220.8		SAND -trace silt - light gray - moist, compact, poorly graded, fine sand	◪	G06	
			☒	SS07	32
		- trace gravel below 6.7 m	◪	G08	
			☒	SS09	15
217.8		SAND AND GRAVEL - trace silt - light brown, wet, compact			
		- well graded fine sand to fine gravel below 9.1 m	☒	SS10	42
		- trace coarse gravel below 10.7 m	☒	SS11	28
214.1		SILT (TILL) - trace gravel, trace sand, trace clay, brown, moist, dense	☒	SS12	50 / 76mm
214.0		END OF TEST HOLE AT 11.67 m IN SILT (TILL)			



Notes:
1) Seepage and sloughing observed below 7.9 m in SAND AND GRAVEL. Test hole open to 7.9 m after drilling to 9.1 m with solid stem augers. Switched to hollow stem augers below 9.1 m depth.
2) Seepage and sloughing could not be observed during drilling with hollow stem augers.
3) Power auger refusal at 11.67 m depth.
4) Water level hollow stem augers at 2.5 m below ground surface 5 minutes after drilling.

Logged By: Michael Van Helden
Reviewed By:
Project Engineer: Michael Van Helden

Sub-Surface Log

Test Hole TH24-02

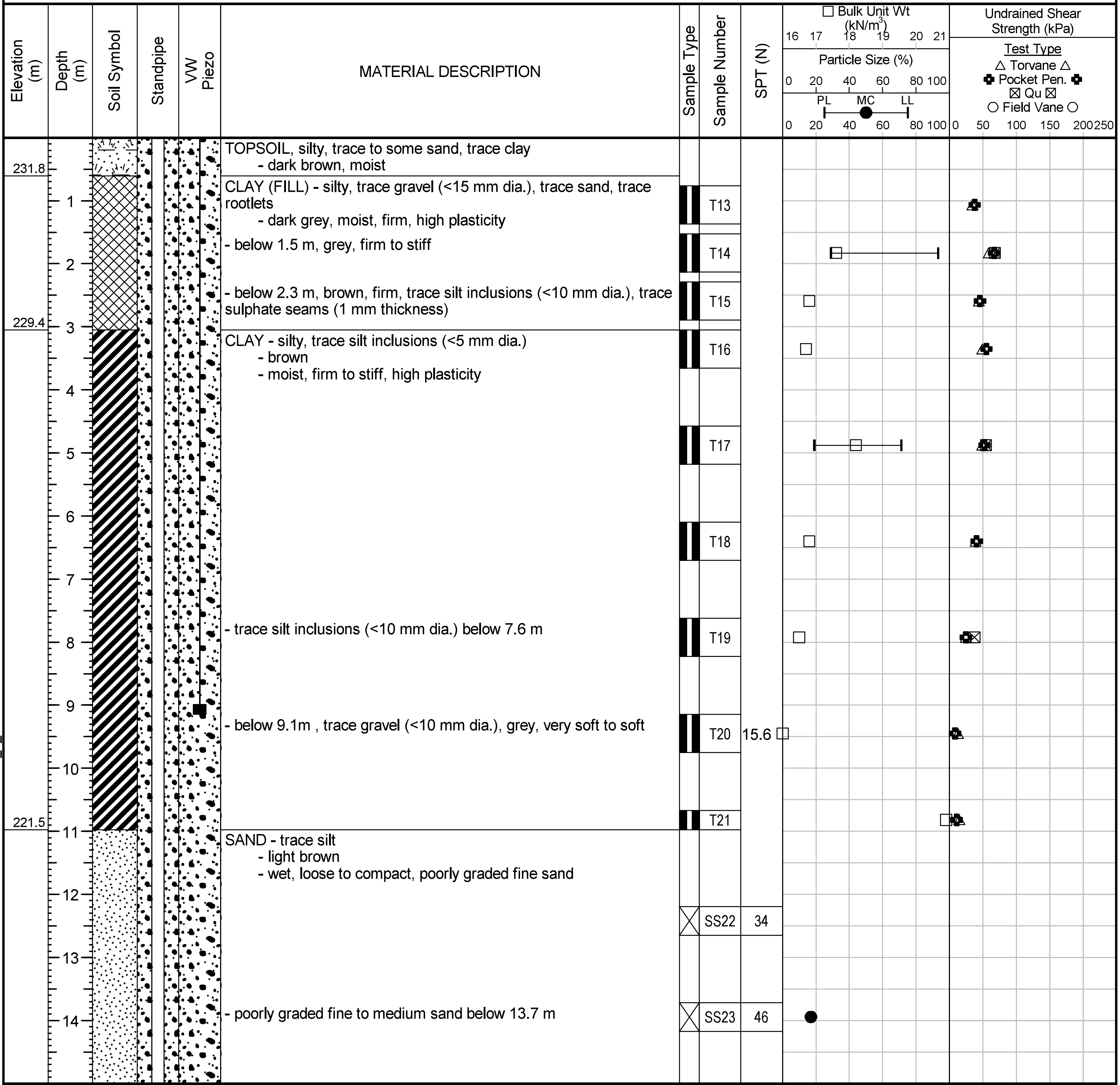
1 of 2

Client: Morrison Hershfield
Project Name: Branch 1 Aqueduct Underdrain - Rue Plinguet Outfall
Contractor: Paddock Drilling Ltd.
Method: 170 mm Hollow Stem Auger, Mobile B59 Track Mount
Project Number: 0035-129-00
Location: UTM N-5528408, E-636089
Ground Elevation: 232.45 m (geodetic)
Date Drilled: January 9, 2024 - January 10, 2024

Sample Type: ◩ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ⧓ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ░ Sand ▓ Gravel ▢ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▩ Cement ▨ Drill Cuttings ░ Filter Pack Sand ▒ Grout ▦ Slough

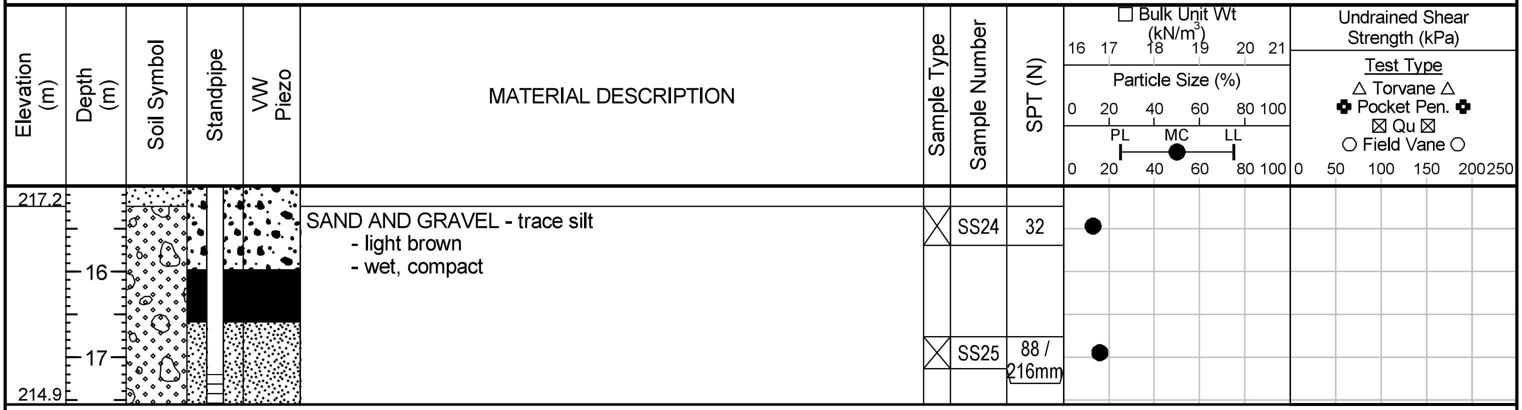


Elevation (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)
	TOPSOIL, silty, trace to some sand, trace clay - dark brown, moist			
231.8	CLAY (FILL) - silty, trace gravel (<15 mm dia.), trace sand, trace rootlets - dark grey, moist, firm, high plasticity	▮	T13	
	- below 1.5 m, grey, firm to stiff	▮	T14	
	- below 2.3 m, brown, firm, trace silt inclusions (<10 mm dia.), trace sulphate seams (1 mm thickness)	▮	T15	
229.4	CLAY - silty, trace silt inclusions (<5 mm dia.) - brown - moist, firm to stiff, high plasticity	▮	T16	
		▮	T17	
		▮	T18	
	- trace silt inclusions (<10 mm dia.) below 7.6 m	▮	T19	
	- below 9.1m , trace gravel (<10 mm dia.), grey, very soft to soft	▮	T20	15.6
		▮	T21	
221.5	SAND - trace silt - light brown - wet, loose to compact, poorly graded fine sand			
		☒	SS22	34
	- poorly graded fine to medium sand below 13.7 m	☒	SS23	46

Logged By: Michael Van Helden
Reviewed By:
Project Engineer: Michael Van Helden

Sub-Surface Log

Test Hole TH24-02



SAND AND GRAVEL - trace silt
- light brown
- wet, compact

END OF TEST HOLE AT 17.6 m IN SILT (TILL)
Notes:
1) Power auger refusal at 17.6 m depth.
2) Seepage and sloughing could not be observed due to the drlling method used (hollow stem augers).
3) Water level in hollow stem augers at 17.6 m depth before installing piezometers.
4) SP24-02 installed in test hole with 0.75 m stickup.
5) No water in SP24-02 5 m after installation.

Logged By: Michael Van Helden **Reviewed By:** ______ **Project Engineer:** Michael Van Helden

Appendix A

Photos of Site Reconnaissance

Photo 1 – Shoreline looking downstream from outfall location

Photo 2 – LDS Outfall in upper bank and erosion gully extending down slope

Photo 3 – Erosion gully extending in mid and lower bank areas

Photo 4 – Cemetery entrance in upper bank area

Photo 5 – Aerial drone view of site looking north

Appendix B

Laboratory Testing Results

TREK
GEOTECHNICAL Quality Engineering | Valued Relationships

MEMORANDUM

Date	February 28, 2024
To	Reza Jamshidi Chenari, TREK Geotechnical
From	Angela Fidler-Kliewer, TREK Geotechnical
Project No.	0035-129-00
Project	Branch 1 Aqueduct Underdrain Outfalls
Subject	Laboratory Testing Results – Lab Req. R24-017 - Reissue 2
Distribution	Michael Van Helden

Attached are the reissued laboratory testing results for the above noted project. The testing included moisture content determinations, Atterberg Limits, and unconfined compressive strength and related testing on Shelby tube samples.

Regards,

Angela Fidler-Kliewer, C.Tech.

Attach.

Review Control:

Prepared By: KF	*Reviewed By: AFK*	*Checked By:* NJF

JC

TREK GEOTECHNICAL

LABORATORY REQUISITION

CLIENT Morrison Hershfield

PROJECT NAME Branch 1 Aqueduct Underdrain Outfalls

PROJECT NO: 0035-129-00

FIELD TECHNICIAN: Michael Van Helden

TEST HOLE NUMBER	SAMPLE NUMBER	DEPTH OF SAMPLE (ft)	TARE NUMBER (LAB USE ONLY)	MOISTURE	VISUAL CLASS.	ATTERBERG LIMITS	HYDROMETER	GRADATION	STD. PROCTOR	UNCONFINED AND AUXILLARY TESTS	S.T.V. (Visual				Soil Description/Comments
TH24-01	G01	1.0 - 2.0		X											
TH24-01	G02	3.0 - 4.0		X											
TH24-01	T03	5.0 - 7.0		X	X	X				/					UNABLE TO DO QU MIKE IS AWARE
TH24-01	G04	8.0 - 9.0		X											
TH24-01	G05	12.0 - 13.0		X											
TH24-01	G06	17.0 - 18.0		X											
TH24-01	SS07	20.0 - 21.5		X											
TH24-01	G08	22.0 - 23.0		X											
TH24-01	SS09	25.0 - 26.5		X											
TH24-01	SS10	30.0 - 31.5		X											
TH24-01	SS11	35.0 - 36.5		X											
TH24-01	SS12	38.0 - 38.3		X											
TH24-02	T13	2.5 - 4.5		X							X				UNABLE TO DO AJ AND BULK (FRACTURED)
TH24-02	T14	5.0 - 7.0		X	X	X				X					
TH24-02	T15	7.5 - 9.5		/							X				
TH24-02	T16	10.0 - 12.0		X							X				
TH24-02	T17	15.0 - 17.0		X	X	/				X					
TH24-02	T18	20.0 - 22.0		X							X				
TH24-02	T19	25.0 - 27.0		X						X					
TH24-02	T20	30.0 - 32.0		X							X				
TH24-02	T21	35.0 - 37.0		X	X					/					UNABLE TO DO QU (TOO SHORT)
TH24-02	SS22	40.0 - 41.5		X											
TH24-02	SS23	45.0 - 46.5		X											
TH24-02	SS24	50.0 - 51.5		X											
TH24-02	SS25	55.0 - 56.2		X											

REQUESTED BY: Reza ~~Michael Van Helden~~

REPORT TO: MVH / RJC

REQUISITION DATE: Jan. 31 2024

DATE REQUIRED:

COMMENTS:

REQUISITION NO. R24-017

PAGE 1 OF 1

TREK LABORATORY REQUISITION LOGS 2024-01-08 BRANCH 1 AQUEDUCT 0_A RJ 0035-129-00.GPJ TREK GEOTECHNICAL.GDT 10/1/24

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www.trekgeotechnical.ca
1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report
ASTM D2216-98

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Sample Date	08-Jan-24
Test Date	01-Feb-24
Technician	CK

Test Hole	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01
Depth (m)	0.3 - 0.6	0.9 - 1.2	2.4 - 2.7	3.7 - 4.0	5.2 - 5.5	6.1 - 6.6
Sample #	G01	G02	G04	G05	G06	SS07
Tare ID	B6	B10	B11	B13	B14	B15
Mass of tare	6.7	6.7	6.7	6.8	6.8	6.7
Mass wet + tare	268.7	281.8	251.2	260.3	272.0	275.4
Mass dry + tare	214.4	210.6	175.6	208.4	225.4	231.2
Mass water	54.3	71.2	75.6	51.9	46.6	44.2
Mass dry soil	207.7	203.9	168.9	201.6	218.6	224.5
Moisture %	26.1%	34.9%	44.8%	25.7%	21.3%	19.7%

Test Hole	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01	TH24-02
Depth (m)	6.7 - 7.0	7.6 - 8.1	9.1 - 9.6	10.7 - 11.1	11.6 - 11.7	13.7 - 14.2
Sample #	G08	SS09	SS10	SS11	SS12	SS23
Tare ID	B20	B26	B25	B24	B18	B23
Mass of tare	6.6	6.7	6.7	6.7	6.7	6.7
Mass wet + tare	259.2	278.2	255.0	259.7	252.3	258.6
Mass dry + tare	217.6	246.2	220.2	222.8	213.0	222.8
Mass water	41.6	32.0	34.8	36.9	39.3	35.8
Mass dry soil	211.0	239.5	213.5	216.1	206.3	216.1
Moisture %	19.7%	13.4%	16.3%	17.1%	19.0%	16.6%

Test Hole	TH24-02	TH24-02				
Depth (m)	15.2 - 15.7	16.8 - 17.1				
Sample #	SS24	SS25				
Tare ID	B16	B22				
Mass of tare	6.7	6.8				
Mass wet + tare	276.6	269.1				
Mass dry + tare	246.0	232.8				
Mass water	30.6	36.3				
Mass dry soil	239.3	226.0				
Moisture %	12.8%	16.1%				

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Atterberg Limits
ASTM D4318-10e1

CERTIFIED BY CCIL Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

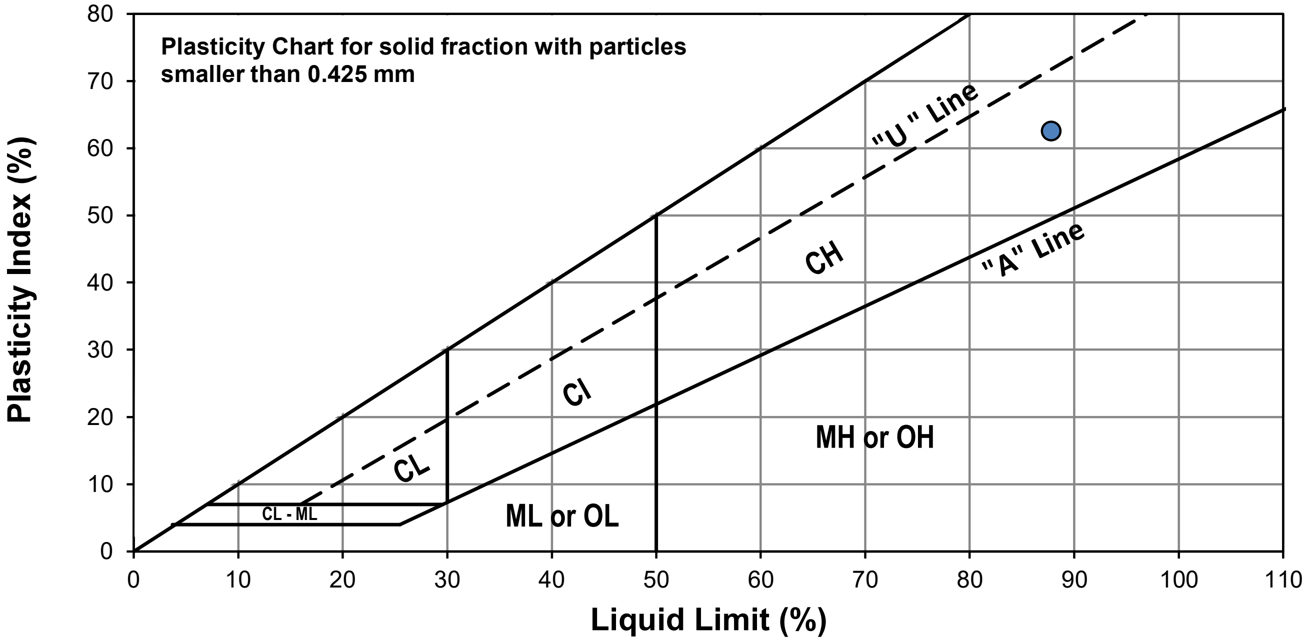
Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Test Hole TH24-01
Sample # T03
Depth (m) 2.0 - 2.1
Sample Date 08-Jan-24
Test Date 05-Feb-24
Technician DS

Liquid Limit	88
Plastic Limit	25
Plasticity Index	63

Liquid Limit

Trial #	1	2	3		
Number of Blows (N)	18	26	35		
Mass Tare (g)	14.032	13.711	14.053		
Mass Wet Soil + Tare (g)	21.121	21.820	23.529		
Mass Dry Soil + Tare (g)	17.756	18.038	19.170		
Mass Water (g)	3.365	3.782	4.359		
Mass Dry Soil (g)	3.724	4.327	5.117		
Moisture Content (%)	90.360	87.405	85.187		



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)	14.184	14.179			
Mass Wet Soil + Tare (g)	22.789	22.432			
Mass Dry Soil + Tare (g)	21.068	20.759			
Mass Water (g)	1.721	1.673			
Mass Dry Soil (g)	6.884	6.580			
Moisture Content (%)	25.000	25.426			

Note: Additional information recorded/measured for this test is available upon request.

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Atterberg Limits
ASTM D4318-10e1

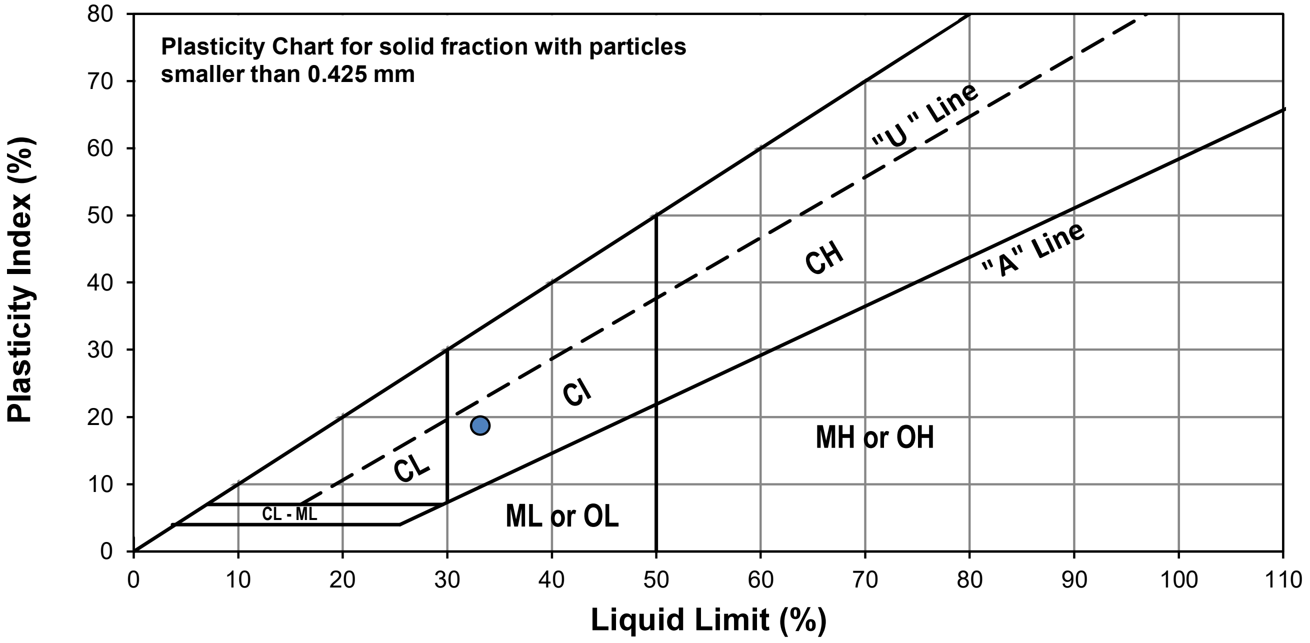
Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Test Hole TH24-01
Sample # T03
Depth (m) 1.9 - 2.0
Sample Date 08-Jan-24
Test Date 05-Feb-24
Technician KM

Liquid Limit	33
Plastic Limit	14
Plasticity Index	19

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	16	21	32		
Mass Tare (g)	14.261	13.987	14.201		
Mass Wet Soil + Tare (g)	27.621	27.057	27.840		
Mass Dry Soil + Tare (g)	24.203	23.763	24.497		
Mass Water (g)	3.418	3.294	3.343		
Mass Dry Soil (g)	9.942	9.776	10.296		
Moisture Content (%)	34.379	33.695	32.469		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	13.836	13.956			
Mass Wet Soil + Tare (g)	24.226	23.705			
Mass Dry Soil + Tare (g)	22.903	22.485			
Mass Water (g)	1.323	1.220			
Mass Dry Soil (g)	9.067	8.529			
Moisture Content (%)	14.591	14.304			

Note: Additional information recorded/measured for this test is available upon request.

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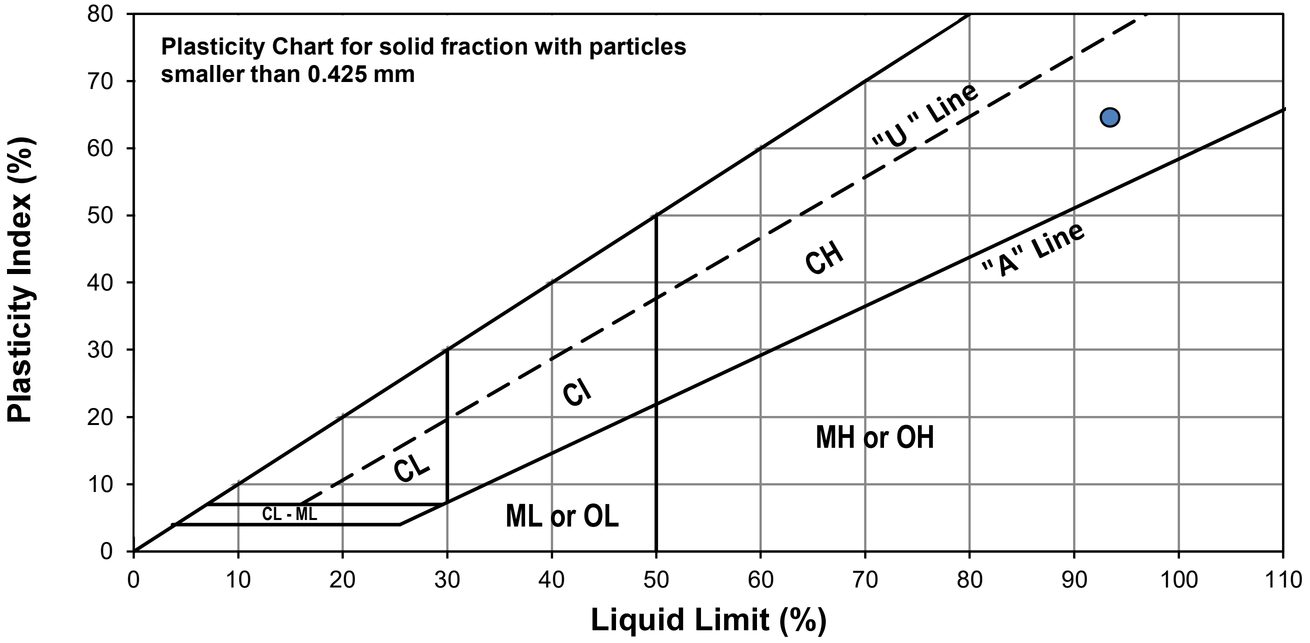
Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Test Hole TH24-02
Sample # T14
Depth (m) 1.5 - 2.1
Sample Date 08-Jan-24
Test Date 05-Feb-24
Technician KM

Liquid Limit	93
Plastic Limit	29
Plasticity Index	65

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	17	23	34		
Mass Tare (g)	14.271	13.980	14.205		
Mass Wet Soil + Tare (g)	27.701	26.380	26.927		
Mass Dry Soil + Tare (g)	21.058	20.360	20.905		
Mass Water (g)	6.643	6.020	6.022		
Mass Dry Soil (g)	6.787	6.380	6.700		
Moisture Content (%)	97.878	94.357	89.881		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.193	14.112			
Mass Wet Soil + Tare (g)	23.801	23.546			
Mass Dry Soil + Tare (g)	21.654	21.429			
Mass Water (g)	2.147	2.117			
Mass Dry Soil (g)	7.461	7.317			
Moisture Content (%)	28.776	28.933			

Note: Additional information recorded/measured for this test is available upon request.

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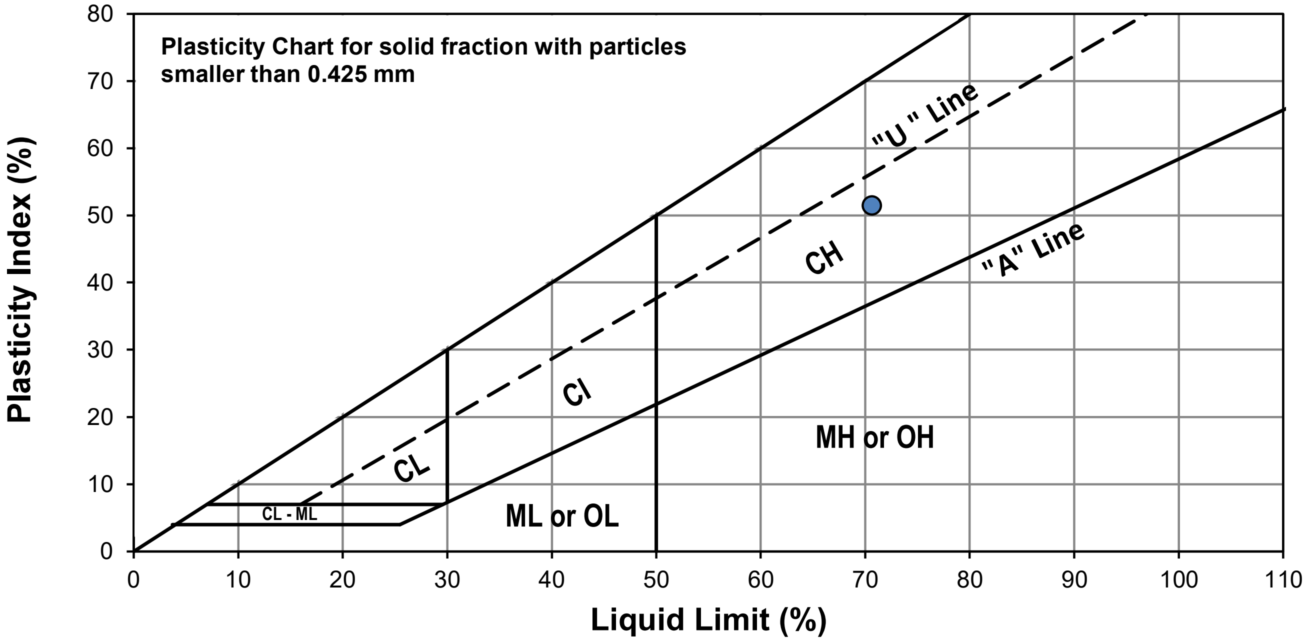
Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Test Hole TH24-02
Sample # T17
Depth (m) 4.6 - 5.2
Sample Date 09-Jan-24
Test Date 07-Feb-24
Technician DS

Liquid Limit	71
Plastic Limit	19
Plasticity Index	51

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	16	24	34		
Mass Tare (g)	14.085	14.170	13.704		
Mass Wet Soil + Tare (g)	23.861	23.584	22.318		
Mass Dry Soil + Tare (g)	19.715	19.688	18.808		
Mass Water (g)	4.146	3.896	3.510		
Mass Dry Soil (g)	5.630	5.518	5.104		
Moisture Content (%)	73.641	70.605	68.770		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	13.986	13.895			
Mass Wet Soil + Tare (g)	21.828	22.150			
Mass Dry Soil + Tare (g)	20.564	20.828			
Mass Water (g)	1.264	1.322			
Mass Dry Soil (g)	6.578	6.933			
Moisture Content (%)	19.216	19.068			

Note: Additional information recorded/measured for this test is available upon request.

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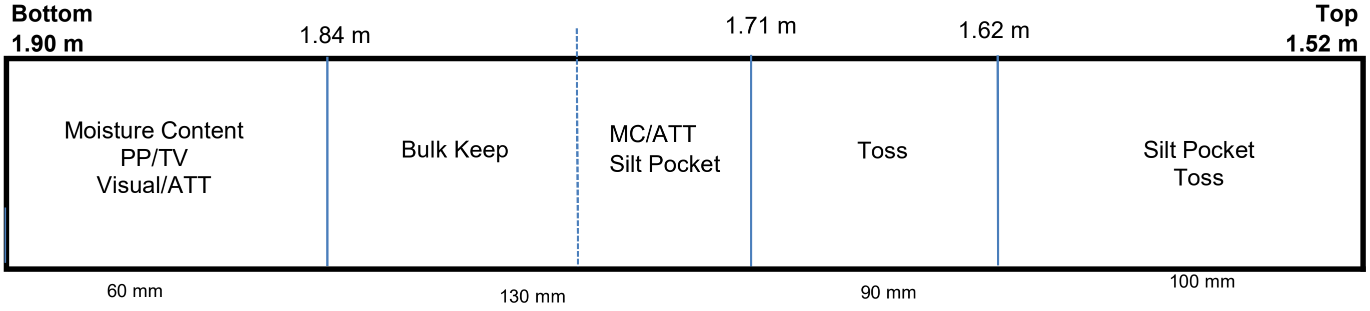
Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls

Test Hole	TH24-01
Sample #	T03
Depth (m)	1.5 - 2.1
Sample Date	08-Jan-24
Test Date	01-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 380



Visual Classification

Material	CLAY
Composition	silty
Color	light brown
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.35
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	34.3

Pocket Penetrometer

Reading	**1**	0.60
	2	0.70
	3	0.60
	Average	0.63
Undrained Shear Strength (kPa)		31.1

Moisture Content

	Clay	**Silt**
Tare ID	M43	AB69
Mass tare (g)	7.0	6.8
Mass wet + tare (g)	375.2	386.4
Mass dry + tare (g)	258.0	311.8
Moisture %	46.7%	24.5%

Unit Weight

Bulk Weight (g)		1019.3	-
Length (mm)	**1**	121.48	-
	2	121.14	-
	3	121.93	-
	4	121.64	-
Average Length (m)		0.122	-
Diam. (mm)	**1**	70.56	-
	2	71.22	-
	3	71.91	-
	4	72.42	-
Average Diameter (m)		0.072	-
Volume (m^3)		4.88E-04	-
Bulk Unit Weight (kN/m^3)		20.5	-
Bulk Unit Weight (pcf)		130.3	-
Dry Unit Weight (kN/m^3)		14.0	-
Dry Unit Weight (pcf)		88.8	-

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Tel: 204.975.9433 Fax: 204.975.9435

Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T13
Depth (m)	0.8 - 1.4
Sample Date	09-Jan-24
Test Date	05-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 240

Bottom **1.00 m**	0.86 m	**Top** **0.76 m**
Moisture Content PP/TV		Keep
140 mm		100 mm

Visual Classification

Material	CLAY
Composition	silty
trace gravel (<15mm diam.)	
trace sand	
trace organics (rootlets)	
Color	dark grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.35
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	34.3

Pocket Penetrometer

Reading	**1**	0.80
	2	0.80
	3	0.70
	Average	0.77
Undrained Shear Strength (kPa)		37.6

Moisture Content

Tare ID	M02
Mass tare (g)	6.8
Mass wet + tare (g)	350.4
Mass dry + tare (g)	269.8
Moisture %	30.6%

Unit Weight

Bulk Weight (g)		-
Length (mm)	**1**	-
	2	-
	3	-
	4	-
Average Length (m)		-
Diam. (mm)	**1**	-
	2	-
	3	-
	4	-
Average Diameter (m)		-
Volume (m^3)		-
Bulk Unit Weight (kN/m^3)		-
Bulk Unit Weight (pcf)		-
Dry Unit Weight (kN/m^3)		-
Dry Unit Weight (pcf)		-

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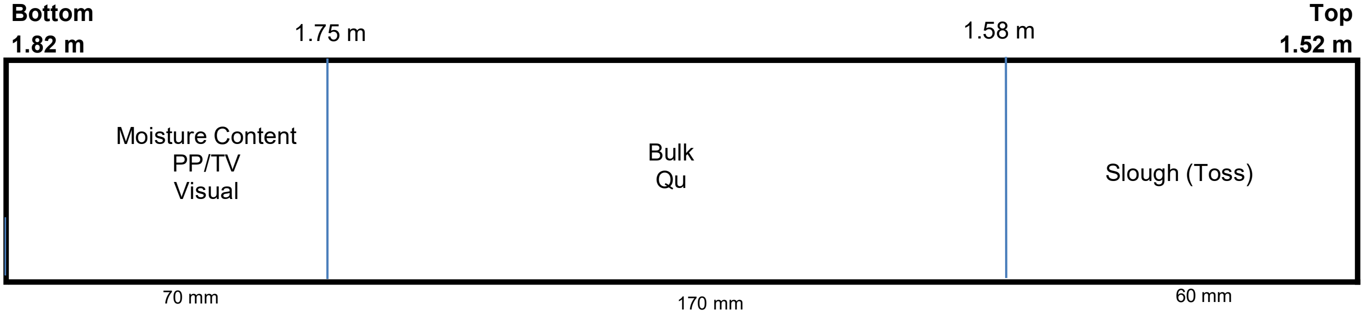
Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T14
Depth (m)	1.5 - 2.1
Sample Date	09-Jan-24
Test Date	01-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 300



Visual Classification

Material	CLAY
Composition	silty
Color	grey
Moisture	moist
Consistency	firm to stiff
Plasticity	high plasticity
Structure	blocky
Gradation	-

Torvane

Reading	0.60
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	58.8

Pocket Penetrometer

Reading	**1**	1.40
	2	1.30
	3	1.40
	Average	1.37
Undrained Shear Strength (kPa)		67.0

Moisture Content

Tare ID	M93
Mass tare (g)	6.8
Mass wet + tare (g)	435.4
Mass dry + tare (g)	305.2
Moisture %	43.6%

Unit Weight

Bulk Weight (g)		1104.2
Length (mm)	**1**	149.50
	2	149.73
	3	149.42
	4	149.39
Average Length (m)		0.150
Diam. (mm)	**1**	72.33
	2	72.46
	3	72.44
	4	72.66
Average Diameter (m)		0.072
Volume (m^3)		6.17E-04
Bulk Unit Weight (kN/m^3)		17.6
Bulk Unit Weight (pcf)		111.8
Dry Unit Weight (kN/m^3)		12.2
Dry Unit Weight (pcf)		77.8

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Unconfined Compressive Strength

ASTM D2166

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls

Test Hole	TH24-02
Sample #	T14
Depth (m)	1.5 - 2.1
Sample Date	09-Jan-24
Test Date	01-Feb-24
Technician	AD

Unconfined Strength

	kPa	**ksf**
Max q_u	67.9	1.4
Max S_u	33.9	0.7

Specimen Data

Description CLAY - silty, grey, moist, firm to stiff, high plasticity, blocky

Length	149.5	(mm)	**Moisture %**	44%	
Diameter	72.5	(mm)	**Bulk Unit Wt.**	17.6	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	12.2	(kN/m^3)
Initial Area	0.00413	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.60	58.8	1.23
Vane Size		
m	67.0	1.40

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	1.40	68.7	1.43
	1.30	63.8	1.33
	1.40	68.7	1.43
Average	**1.37**	**67.0**	**1.40**

Failure Geometry

Sketch:

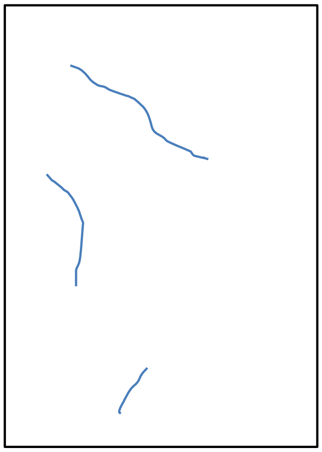


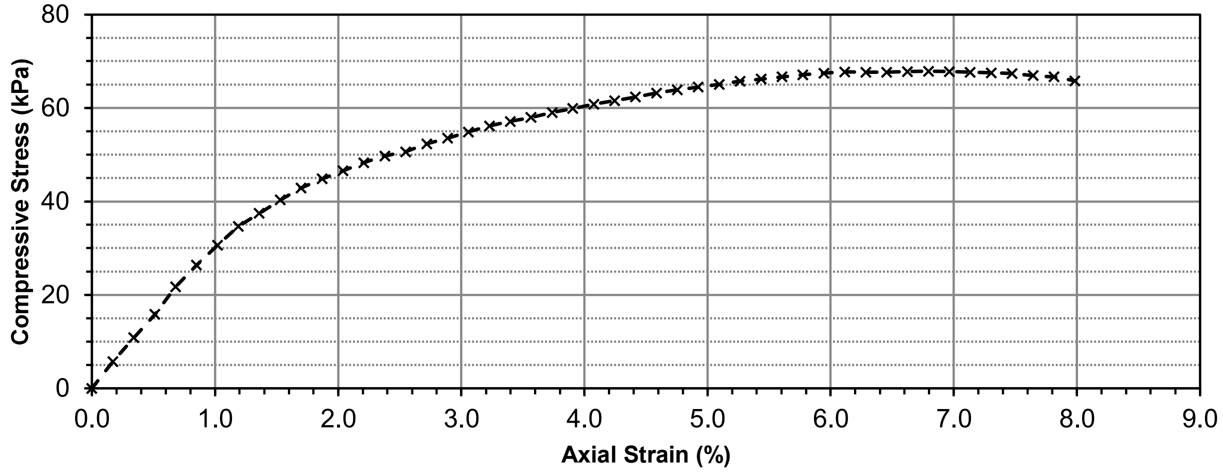
Photo:

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0.82	0.0000	0.00	0.004125	0.0	0.00	0.00
10	1.29	0.2540	0.17	0.004132	23.7	5.73	2.87
20	1.71	0.5080	0.34	0.004139	44.9	10.84	5.42
30	2.12	0.7620	0.51	0.004146	65.5	15.80	7.90
40	2.61	1.0160	0.68	0.004153	90.2	21.72	10.86
50	3.00	1.2700	0.85	0.004160	109.9	26.41	13.21
60	3.35	1.5240	1.02	0.004168	127.5	30.60	15.30
70	3.69	1.7780	1.19	0.004175	144.7	34.65	17.33
80	3.93	2.0320	1.36	0.004182	156.8	37.48	18.74
90	4.17	2.2860	1.53	0.004189	168.9	40.31	20.15
100	4.39	2.5400	1.70	0.004196	179.9	42.88	21.44
110	4.56	2.7940	1.87	0.004204	188.5	44.84	22.42
120	4.71	3.0480	2.04	0.004211	196.1	46.56	23.28
130	4.86	3.3020	2.21	0.004218	203.6	48.27	24.14
140	4.99	3.5560	2.38	0.004226	210.2	49.74	24.87
150	5.07	3.8100	2.55	0.004233	214.2	50.61	25.30
160	5.22	4.0640	2.72	0.004240	221.8	52.30	26.15
170	5.33	4.3180	2.89	0.004248	227.3	53.51	26.76
180	5.45	4.5720	3.06	0.004255	233.4	54.84	27.42
190	5.57	4.8260	3.23	0.004263	239.4	56.16	28.08
200	5.66	5.0800	3.40	0.004270	244.0	57.13	28.56
210	5.74	5.3340	3.57	0.004278	248.0	57.97	28.99
220	5.84	5.5880	3.74	0.004285	253.0	59.04	29.52
230	5.92	5.8420	3.91	0.004293	257.1	59.88	29.94

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	6.01	6.0960	4.08	0.004300	261.6	60.83	30.41
250	6.08	6.3500	4.25	0.004308	265.1	61.54	30.77
260	6.16	6.6040	4.42	0.004316	269.2	62.37	31.18
270	6.24	6.8580	4.59	0.004323	273.2	63.19	31.59
280	6.31	7.1120	4.76	0.004331	276.7	63.89	31.94
290	6.37	7.3660	4.93	0.004339	279.7	64.47	32.24
300	6.43	7.6200	5.10	0.004347	282.8	65.05	32.53
310	6.50	7.8740	5.27	0.004354	286.3	65.75	32.87
320	6.55	8.1280	5.44	0.004362	288.8	66.21	33.10
330	6.60	8.3820	5.61	0.004370	291.3	66.66	33.33
340	6.65	8.6360	5.78	0.004378	293.8	67.12	33.56
350	6.69	8.8900	5.95	0.004386	295.9	67.46	33.73
360	6.72	9.1440	6.12	0.004394	297.4	67.68	33.84
370	6.73	9.3980	6.29	0.004402	297.9	67.67	33.84
380	6.74	9.6520	6.46	0.004410	298.4	67.66	33.83
390	6.76	9.9060	6.63	0.004418	299.4	67.77	33.88
400	6.78	10.1600	6.80	0.004426	300.4	67.87	33.94
410	6.78	10.4140	6.97	0.004434	300.4	67.75	33.88
420	6.78	10.6680	7.14	0.004442	300.4	67.63	33.81
430	6.78	10.9220	7.31	0.004450	300.4	67.50	33.75
440	6.78	11.1760	7.48	0.004458	300.4	67.38	33.69
450	6.75	11.4300	7.64	0.004467	298.9	66.92	33.46
460	6.74	11.6840	7.81	0.004475	298.4	66.68	33.34
470	6.67	11.9380	7.98	0.004483	294.9	65.77	32.89

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T15
Depth (m)	2.3 - 2.9
Sample Date	09-Jan-24
Test Date	06-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 530

Bottom **2.82 m** | 2.74 m | 2.57 m | 2.40 m | **Top** **2.29 m**

Moisture Content PP/TV	Bulk	Keep	Toss
80 mm	170 mm	170 mm	110 mm

Visual Classification

Material	CLAY
Composition	silty

trace silt inclusions (<10mm diam.)

trace precipitates (sulphate seams, 1mm thick)

Color	brown
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	blocky
Gradation	-

Torvane

Reading	0.45
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	44.1

Pocket Penetrometer

Reading	**1**	0.90
	2	1.00
	3	0.90
	Average	0.93
Undrained Shear Strength (kPa)		45.8

Moisture Content

Tare ID	K16
Mass tare (g)	6.8
Mass wet + tare (g)	316.0
Mass dry + tare (g)	216.6
Moisture %	47.4%

Unit Weight

Bulk Weight (g)		1055.2
Length (mm)	**1**	150.40
	2	150.31
	3	149.89
	4	149.93
Average Length (m)		0.150
Diam. (mm)	**1**	72.61
	2	72.62
	3	72.63
	4	71.17
Average Diameter (m)		0.072
Volume (m^3)		6.16E-04
Bulk Unit Weight (kN/m^3)		16.8
Bulk Unit Weight (pcf)		107.0
Dry Unit Weight (kN/m^3)		11.4
Dry Unit Weight (pcf)		72.6

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T16
Depth (m)	3.0 - 3.7
Sample Date	09-Jan-24
Test Date	06-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 500

Bottom **3.55 m**	3.45 m	3.28 m	3.11 m	**Top** **3.05 m**

Moisture Content PP/TV Visual	Bulk	Keep	Toss
100 mm	170 mm	170 mm	60 mm

Visual Classification

Material	CLAY
Composition	silty

trace silt inclusions (<5mm diam.)

Color	brown
Moisture	moist
Consistency	firm to stiff
Plasticity	high plasticity
Structure	laminated (brown and grey clay, 4mm thick)
Gradation	-

Torvane

Reading	0.50
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	49.0

Pocket Penetrometer

Reading	**1**	1.10
	2	1.20
	3	1.10
	Average	1.13
Undrained Shear Strength (kPa)		55.6

Moisture Content

Tare ID	M54
Mass tare (g)	6.8
Mass wet + tare (g)	281.4
Mass dry + tare (g)	192.6
Moisture %	47.8%

Unit Weight

Bulk Weight (g)		1024.4
Length (mm)	**1**	147.26
	2	147.40
	3	147.41
	4	147.02
Average Length (m)		0.147
Diam. (mm)	**1**	71.50
	2	72.09
	3	72.48
	4	72.05
Average Diameter (m)		0.072
Volume (m^3)		6.00E-04
Bulk Unit Weight (kN/m^3)		16.7
Bulk Unit Weight (pcf)		106.6
Dry Unit Weight (kN/m^3)		11.3
Dry Unit Weight (pcf)		72.1

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T17
Depth (m)	4.6 - 5.2
Sample Date	09-Jan-24
Test Date	02-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 590

Bottom **5.16 m**	5.06 m	4.89 m	4.72 m	**Top** **4.57 m**

Moisture Content PP/TV Visual/ATT	Bulk/Qu	Keep	Toss
100 mm	170 mm	170 mm	150 mm

Visual Classification

Material	CLAY
Composition	silty

trace silt inclusions (<10mm diam.)
trace gravel (<15mm diam.)
trace sand

Color	brown
Moisture	moist
Consistency	firm to stiff
Plasticity	high plasticity
Structure	blocky
Gradation	-

Torvane

Reading	0.50
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	49.0

Pocket Penetrometer

Reading	**1**	1.10
	2	1.10
	3	1.00
	Average	1.07
Undrained Shear Strength (kPa)		52.3

Moisture Content

Tare ID	E27
Mass tare (g)	8.6
Mass wet + tare (g)	423.6
Mass dry + tare (g)	311.6
Moisture %	37.0%

Unit Weight

Bulk Weight (g)		1147.2
Length (mm)	**1**	149.85
	2	149.57
	3	149.80
	4	149.82
Average Length (m)		0.150
Diam. (mm)	**1**	73.36
	2	72.14
	3	72.85
	4	71.60
Average Diameter (m)		0.072
Volume (m^3)		6.18E-04
Bulk Unit Weight (kN/m^3)		18.2
Bulk Unit Weight (pcf)		115.9
Dry Unit Weight (kN/m^3)		13.3
Dry Unit Weight (pcf)		84.6

Unconfined Compressive Strength

ASTM D2166

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls

Test Hole	TH24-02
Sample #	T17
Depth (m)	4.6 - 5.2
Sample Date	09-Jan-24
Test Date	06-Feb-24
Technician	AD

Unconfined Strength

	kPa	ksf
Max q_u	54.6	1.1
Max S_u	27.3	0.6

Specimen Data

Description CLAY - silty, trace silt inclusions (<10mm diam.), trace gravel (<15mm diam.), trace sand, brown, moist, firm to stiff, high plasticity, blocky

Length	149.8	(mm)	**Moisture %**	37%	
Diameter	72.5	(mm)	**Bulk Unit Wt.**	18.2	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	13.3	(kN/m^3)
Initial Area	0.00413	(m^2)	**Liquid Limit**	71	
Load Rate	1.00	(%/min)	**Plastic Limit**	19	
			Plasticity Index	51	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.50	49.0	1.02
Vane Size		
m	52.3	1.09

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	1.10	54.0	1.13
	1.10	54.0	1.13
	1.00	49.1	1.02
Average	**1.07**	**52.3**	**1.09**

Failure Geometry

Sketch:

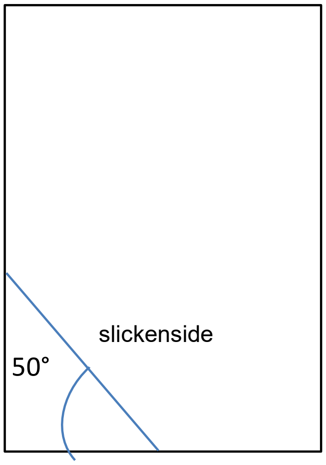


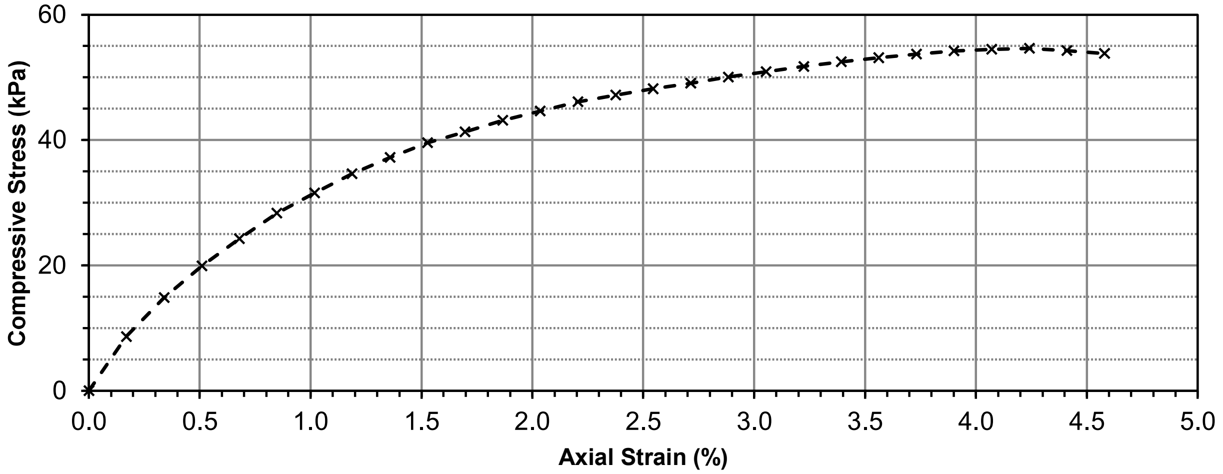
Photo:

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0.88	0.0000	0.00	0.004127	0.0	0.00	0.00
10	1.59	0.2540	0.17	0.004134	35.8	8.66	4.33
20	2.10	0.5080	0.34	0.004141	61.5	14.85	7.42
30	2.52	0.7620	0.51	0.004148	82.7	19.93	9.96
40	2.88	1.0160	0.68	0.004155	100.8	24.26	12.13
50	3.22	1.2700	0.85	0.004162	117.9	28.34	14.17
60	3.49	1.5240	1.02	0.004169	131.6	31.55	15.78
70	3.75	1.7780	1.19	0.004176	144.7	34.64	17.32
80	3.97	2.0320	1.36	0.004184	155.7	37.23	18.61
90	4.17	2.2860	1.53	0.004191	165.8	39.57	19.78
100	4.32	2.5400	1.70	0.004198	173.4	41.30	20.65
110	4.48	2.7940	1.87	0.004205	181.5	43.15	21.57
120	4.61	3.0480	2.04	0.004213	188.0	44.63	22.31
130	4.74	3.3020	2.20	0.004220	194.6	46.10	23.05
140	4.84	3.5560	2.37	0.004227	199.6	47.22	23.61
150	4.93	3.8100	2.54	0.004235	204.1	48.21	24.10
160	5.01	4.0640	2.71	0.004242	208.2	49.07	24.54
170	5.10	4.3180	2.88	0.004249	212.7	50.05	25.03
180	5.18	4.5720	3.05	0.004257	216.7	50.91	25.46
190	5.26	4.8260	3.22	0.004264	220.8	51.77	25.89
200	5.33	5.0800	3.39	0.004272	224.3	52.51	26.25
210	5.39	5.3340	3.56	0.004279	227.3	53.12	26.56
220	5.45	5.5880	3.73	0.004287	230.3	53.73	26.87
230	5.50	5.8420	3.90	0.004294	232.9	54.23	27.11

Unconfined Compressive Strength

ASTM D2166

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	5.53	6.0960	4.07	0.004302	234.4	54.48	27.24
250	5.55	6.3500	4.24	0.004310	235.4	54.62	27.31
260	5.53	6.6040	4.41	0.004317	234.4	54.29	27.14
270	5.50	6.8580	4.58	0.004325	232.9	53.84	26.92

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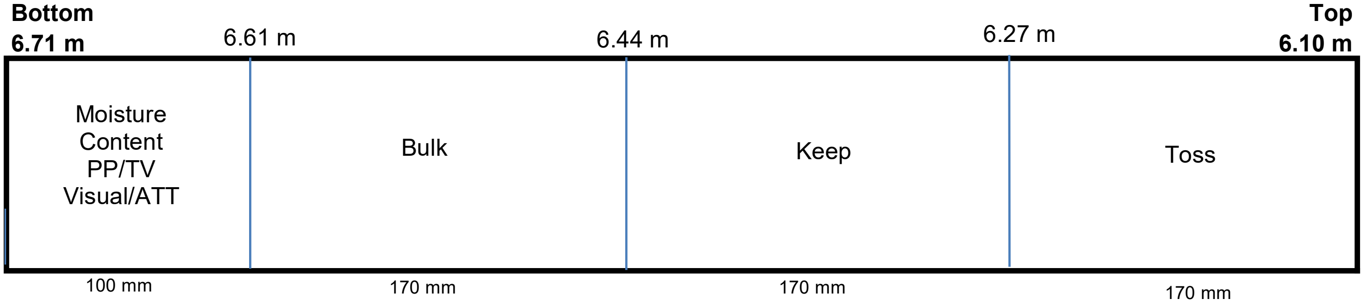
Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T18
Depth (m)	6.1 - 6.7
Sample Date	09-Jan-24
Test Date	02-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 610



Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<5mm diam.)	
trace gravel (<15mm diam.)	
Color	brown
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.40
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	39.2

Pocket Penetrometer

Reading	**1**	0.80
	2	0.90
	3	0.80
	Average	0.83
Undrained Shear Strength (kPa)		40.9

Moisture Content

Tare ID	AB69
Mass tare (g)	6.8
Mass wet + tare (g)	300.2
Mass dry + tare (g)	202.2
Moisture %	50.2%

Unit Weight

Bulk Weight (g)		1008.6
Length (mm)	**1**	146.99
	2	147.32
	3	146.97
	4	146.78
Average Length (m)		0.147
Diam. (mm)	**1**	71.04
	2	71.42
	3	71.33
	4	71.52
Average Diameter (m)		0.071
Volume (m^3)		5.87E-04
Bulk Unit Weight (kN/m^3)		16.8
Bulk Unit Weight (pcf)		107.2
Dry Unit Weight (kN/m^3)		11.2
Dry Unit Weight (pcf)		71.4

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T19
Depth (m)	7.6 - 8.2
Sample Date	09-Jan-24
Test Date	02-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 610

Bottom **8.23 m**	8.19 m	8.02 m	7.92 m	7.75 m	**Top** **7.62 m**

Toss	Keep	Moisture Content PP/TV Visual	Bulk/Qu	Toss
40 mm	170 mm	100 mm	170 mm	130 mm

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<10mm diam.)	
Color	brown
Moisture	moist
Consistency	soft
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.25
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	24.5

Pocket Penetrometer

Reading	**1**	0.50
	2	0.50
	3	0.50
	Average	0.50
Undrained Shear Strength (kPa)		24.5

Moisture Content

Tare ID	M57
Mass tare (g)	6.8
Mass wet + tare (g)	304.0
Mass dry + tare (g)	196.8
Moisture %	56.4%

Unit Weight

Bulk Weight (g)		1017.9
Length (mm)	**1**	150.18
	2	150.70
	3	150.60
	4	150.29
Average Length (m)		0.150
Diam. (mm)	**1**	70.90
	2	71.79
	3	71.79
	4	72.15
Average Diameter (m)		0.072
Volume (m^3)		6.07E-04
Bulk Unit Weight (kN/m^3)		16.5
Bulk Unit Weight (pcf)		104.7
Dry Unit Weight (kN/m^3)		10.5
Dry Unit Weight (pcf)		67.0

TREK GEOTECHNICAL
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Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Test Hole TH24-02
Sample # T19
Depth (m) 7.6 - 8.2
Sample Date 09-Jan-24
Test Date 06-Feb-24
Technician AD

Unconfined Strength

	kPa	ksf
Max q_u	37.2	0.8
Max S_u	18.6	0.4

Specimen Data

Description CLAY - silty, trace silt inclusions (<10mm diam.), brown, moist, soft, high plasticity

Length	150.4	(mm)	**Moisture %**	56%	
Diameter	71.7	(mm)	**Bulk Unit Wt.**	16.5	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	10.5	(kN/m^3)
Initial Area	0.00403	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.25	24.5	0.51
Vane Size		
m	24.5	0.51

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.50	24.5	0.51
	0.50	24.5	0.51
Average	**0.50**	**24.5**	**0.51**

Failure Geometry

Sketch:

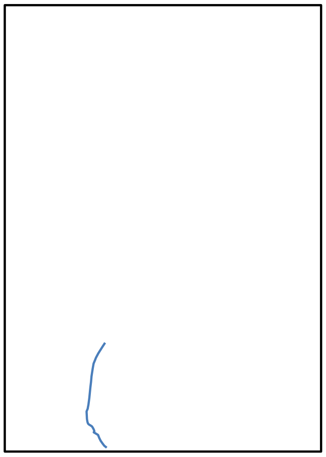


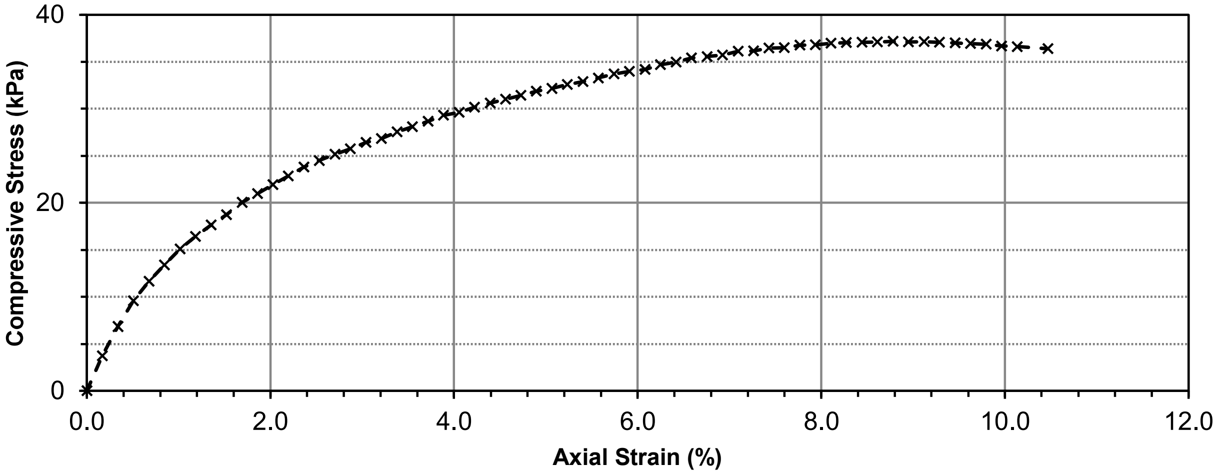
Photo:

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0.71	0.0000	0.00	0.004033	0.0	0.00	0.00
10	1.01	0.2540	0.17	0.004040	15.1	3.74	1.87
20	1.26	0.5080	0.34	0.004047	27.7	6.85	3.43
30	1.48	0.7620	0.51	0.004053	38.8	9.57	4.79
40	1.65	1.0160	0.68	0.004060	47.4	11.67	5.83
50	1.79	1.2700	0.84	0.004067	54.4	13.38	6.69
60	1.93	1.5240	1.01	0.004074	61.5	15.09	7.55
70	2.04	1.7780	1.18	0.004081	67.0	16.43	8.21
80	2.14	2.0320	1.35	0.004088	72.1	17.63	8.82
90	2.23	2.2860	1.52	0.004095	76.6	18.71	9.35
100	2.34	2.5400	1.69	0.004102	82.2	20.03	10.01
110	2.42	2.7940	1.86	0.004109	86.2	20.97	10.49
120	2.50	3.0480	2.03	0.004116	90.2	21.92	10.96
130	2.58	3.3020	2.19	0.004123	94.3	22.86	11.43
140	2.66	3.5560	2.36	0.004130	98.3	23.80	11.90
150	2.72	3.8100	2.53	0.004138	101.3	24.48	12.24
160	2.78	4.0640	2.70	0.004145	104.3	25.17	12.59
170	2.83	4.3180	2.87	0.004152	106.9	25.74	12.87
180	2.89	4.5720	3.04	0.004159	109.9	26.42	13.21
190	2.93	4.8260	3.21	0.004167	111.9	26.86	13.43
200	2.99	5.0800	3.38	0.004174	114.9	27.53	13.77
210	3.04	5.3340	3.55	0.004181	117.4	28.09	14.04
220	3.09	5.5880	3.71	0.004188	120.0	28.64	14.32
230	3.15	5.8420	3.88	0.004196	123.0	29.31	14.66

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-129-00
Client Morrison Hershfield
Project Branch 1 Aqueduct Underdrain Outfalls

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	3.18	6.0960	4.05	0.004203	124.5	29.62	14.81
250	3.23	6.3500	4.22	0.004211	127.0	30.17	15.08
260	3.27	6.6040	4.39	0.004218	129.0	30.59	15.30
270	3.31	6.8580	4.56	0.004225	131.0	31.01	15.51
280	3.35	7.1120	4.73	0.004233	133.1	31.44	15.72
290	3.39	7.3660	4.90	0.004240	135.1	31.85	15.93
300	3.42	7.6200	5.07	0.004248	136.6	32.15	16.08
310	3.46	7.8740	5.23	0.004256	138.6	32.57	16.29
320	3.49	8.1280	5.40	0.004263	140.1	32.87	16.43
330	3.53	8.3820	5.57	0.004271	142.1	33.28	16.64
340	3.57	8.6360	5.74	0.004278	144.2	33.69	16.85
350	3.60	8.8900	5.91	0.004286	145.7	33.99	16.99
360	3.62	9.1440	6.08	0.004294	146.7	34.16	17.08
370	3.67	9.3980	6.25	0.004302	149.2	34.68	17.34
380	3.70	9.6520	6.42	0.004309	150.7	34.97	17.49
390	3.74	9.9060	6.58	0.004317	152.7	35.38	17.69
400	3.76	10.1600	6.75	0.004325	153.7	35.54	17.77
410	3.78	10.4140	6.92	0.004333	154.7	35.71	17.86
420	3.82	10.6680	7.09	0.004341	156.8	36.11	18.06
430	3.83	10.9220	7.26	0.004349	157.3	36.16	18.08
440	3.86	11.1760	7.43	0.004356	158.8	36.44	18.22
450	3.87	11.4300	7.60	0.004364	159.3	36.49	18.25
460	3.90	11.6840	7.77	0.004372	160.8	36.77	18.39
470	3.91	11.9380	7.94	0.004380	161.3	36.82	18.41
480	3.93	12.1920	8.10	0.004389	162.3	36.98	18.49
490	3.94	12.4460	8.27	0.004397	162.8	37.03	18.51
500	3.95	12.7000	8.44	0.004405	163.3	37.08	18.54
510	3.96	12.9540	8.61	0.004413	163.8	37.12	18.56
520	3.97	13.2080	8.78	0.004421	164.3	37.17	18.58
530	3.97	13.4620	8.95	0.004429	164.3	37.10	18.55
540	3.98	13.7160	9.12	0.004437	164.8	37.14	18.57
550	3.98	13.9700	9.29	0.004446	164.8	37.07	18.54
560	3.98	14.2240	9.45	0.004454	164.8	37.00	18.50
570	3.98	14.4780	9.62	0.004462	164.8	36.94	18.47
580	3.98	14.7320	9.79	0.004471	164.8	36.87	18.43
590	3.97	14.9860	9.96	0.004479	164.3	36.69	18.34
600	3.97	15.2400	10.13	0.004487	164.3	36.62	18.31
620	3.96	15.7480	10.47	0.004504	163.8	36.37	18.18

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T20
Depth (m)	9.1 - 9.8
Sample Date	09-Jan-24
Test Date	05-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 600

Bottom
9.74 m 9.64 m 9.54 m 9.37 m 9.20 m **Top**
9.14 m

Toss	Moisture Content PP/TV Visual	Bulk	Keep	Toss
100 mm	100 mm	170 mm	170 mm	60 mm

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<5mm diam.)	
trace gravel (<10mm diam.)	
Color	grey
Moisture	moist
Consistency	v.soft to soft
Plasticity	high plasticity
Structure	blocky
Gradation	-

Torvane

Reading	0.65
Vane Size (s,m,l)	l
Undrained Shear Strength (kPa)	12.7

Pocket Penetrometer

		base size	
Reading	**1**	l	2.70
	2	l	2.70
	3	l	2.70
	Average		2.70
Undrained Shear Strength (kPa)			8.3

Moisture Content

Tare ID	AC33
Mass tare (g)	6.6
Mass wet + tare (g)	319.2
Mass dry + tare (g)	202.8
Moisture %	59.3%

Unit Weight

Bulk Weight (g)		987.6
Length (mm)	**1**	148.56
	2	148.81
	3	149.19
	4	149.05
Average Length (m)		0.149
Diam. (mm)	**1**	72.75
	2	73.19
	3	72.77
	4	72.40
Average Diameter (m)		0.073
Volume (m^3)		6.19E-04
Bulk Unit Weight (kN/m^3)		15.6
Bulk Unit Weight (pcf)		99.5
Dry Unit Weight (kN/m^3)		9.8
Dry Unit Weight (pcf)		62.5

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Shelby Tube Visual

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Branch 1 Aqueduct Underdrain Outfalls
Test Hole	TH24-02
Sample #	T21
Depth (m)	10.7 - 11.3
Sample Date	09-Jan-24
Test Date	05-Feb-24
Technician	AD

Tube Extraction

Recovery (mm) 170

Bottom **10.84 m**	10.74 m	**Top** **10.67 m**
Bulk		Moisture Content PP/TV Visual
100 mm		70 mm

Visual Classification

Material	CLAY
Composition	silty
trace sand seams (3mm thick)	
Color	grey
Moisture	moist
Consistency	v. soft to soft
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.75
Vane Size (s,m,l)	l
Undrained Shear Strength (kPa)	14.7

Pocket Penetrometer

		base size	
Reading	**1**	l	3.50
(large)	**2**	l	3.50
	3	l	3.50
	Average		3.50
Undrained Shear Strength (kPa)			10.7

Moisture Content

Tare ID	M90
Mass tare (g)	6.8
Mass wet + tare (g)	363.2
Mass dry + tare (g)	267.6
Moisture %	36.7%

Unit Weight

Bulk Weight (g)		682.2
Length (mm)	**1**	80.69
	2	80.85
	3	80.56
	4	79.99
Average Length (m)		0.081
Diam. (mm)	**1**	71.45
	2	71.08
	3	71.53
	4	70.45
Average Diameter (m)		0.071
Volume (m^3)		3.20E-04
Bulk Unit Weight (kN/m^3)		20.9
Bulk Unit Weight (pcf)		133.1
Dry Unit Weight (kN/m^3)		15.3
Dry Unit Weight (pcf)		97.4

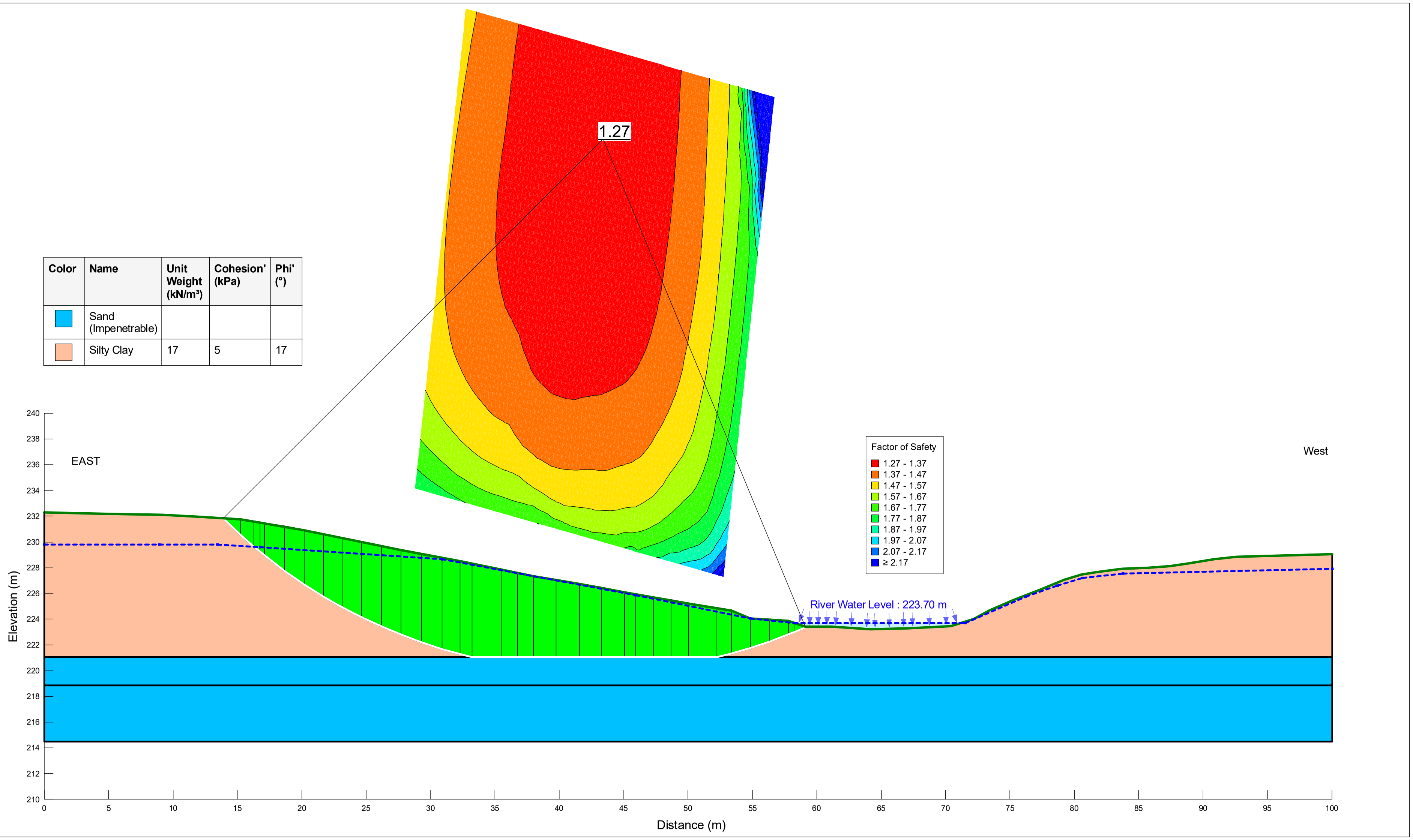
Appendix C

Slope Stability Analysis Outputs for Existing Conditions

0035-129-00

Morrison Hershfield

Branch 1 Aqueduct Underdrain Outfalls



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟦	Sand (Impenetrable)			
🟧	Silty Clay	17	5	17

Tabloid (279mm x 432mm)

SAVED: 2024-02-02 09:36:58 AM

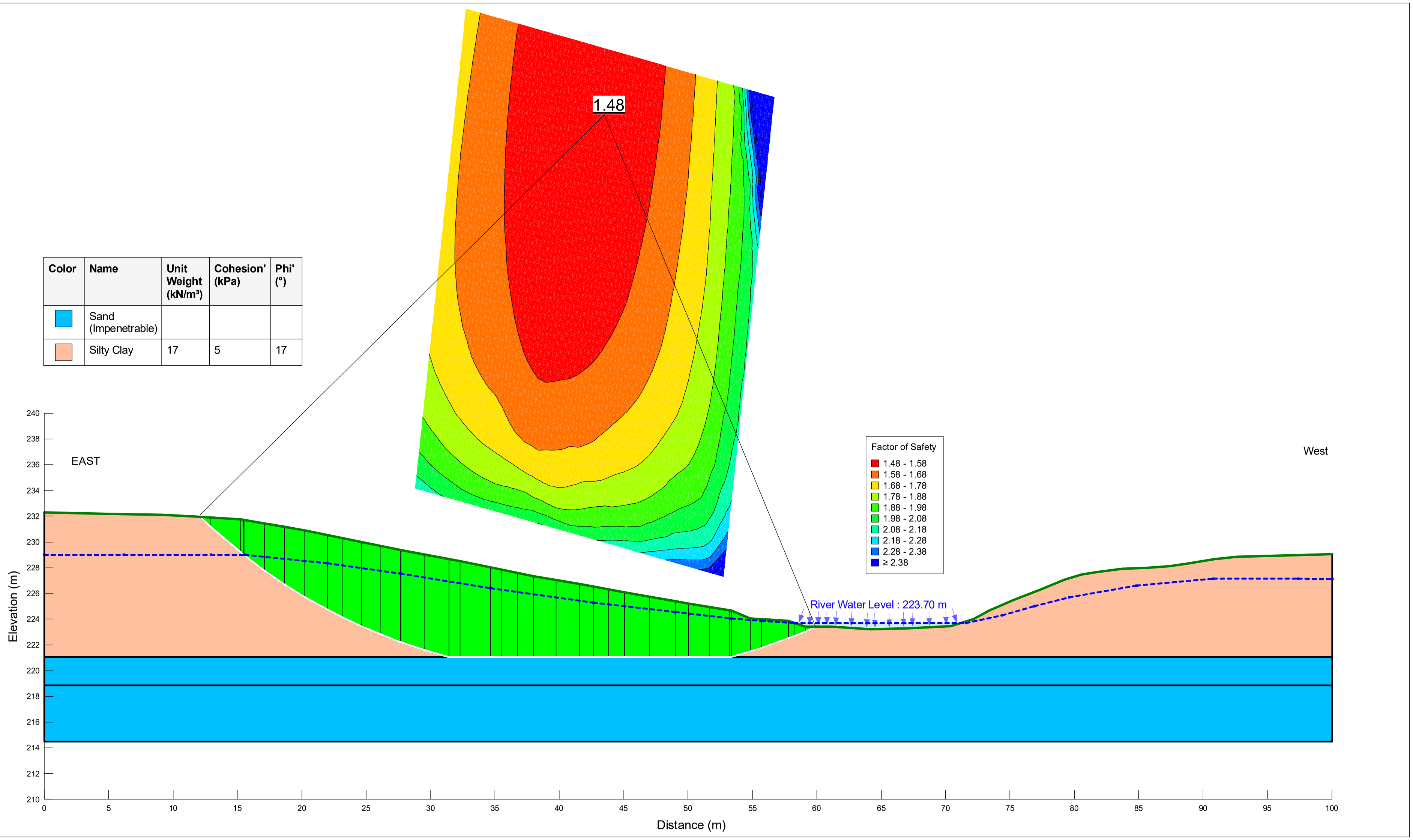
SCALE: 1:285 (279mm x 432mm)

FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\MOD02- Extreme condition.gsz

Figure C1

Extreme Condition

0035-129-00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟦	Sand (Impenetrable)			
🟧	Silty Clay	17	5	17

Factor of Safety
- 🟥 1.48 - 1.58
- 🟧 1.58 - 1.68
- 🟨 1.68 - 1.78
- 🟩 1.78 - 1.88
- 🟩 1.88 - 1.98
- 🟩 1.98 - 2.08
- 🟩 2.08 - 2.18
- 🟦 2.18 - 2.28
- 🟦 2.28 - 2.38
- 🟦 ≥ 2.38

Tabloid (279mm x 432mm)

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SCALE: 1:285 (279mm x 432mm)

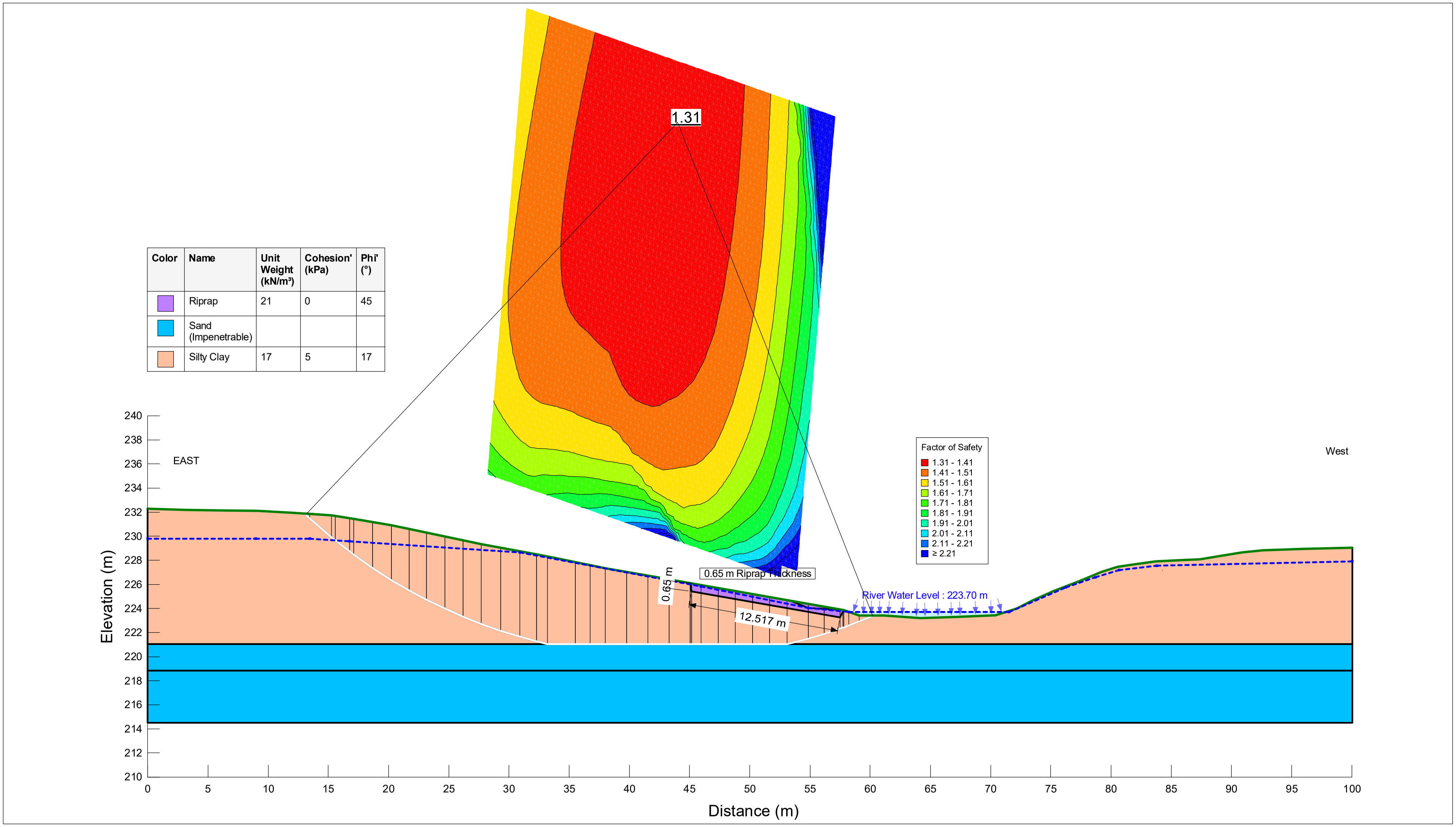
FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\MOD01- Normal condition.gsz

Figure C2
Normal Condition

Appendix D

Slope Stability Analysis Outputs for Regrading and Riprap

0035-129-00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟪	Riprap	21	0	45
🟦	Sand (Impenetrable)			
🟧	Silty Clay	17	5	17

Tabloid (279mm x 432mm)

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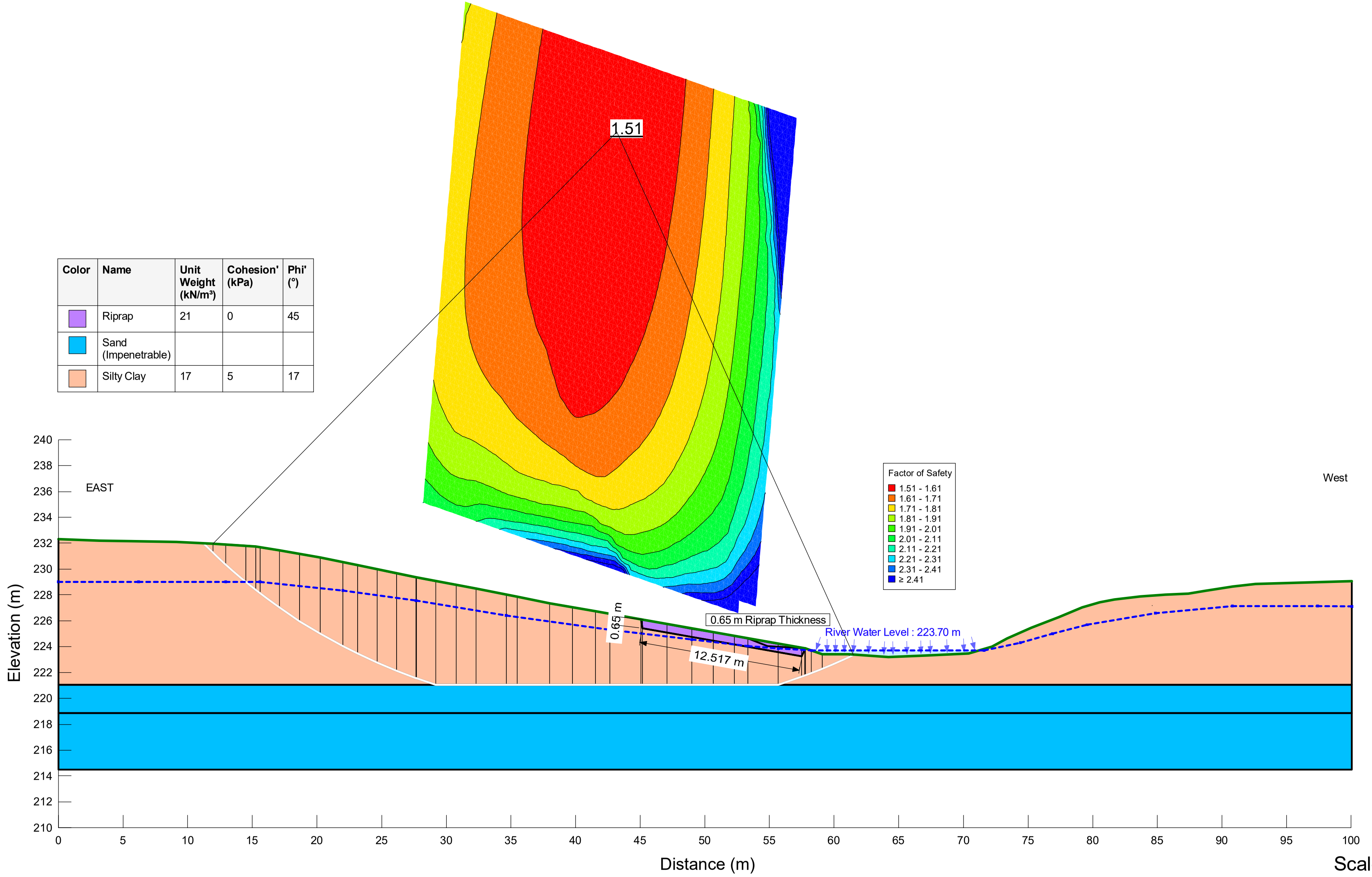
SCALE: 1:300 (279mm x 432mm)

FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\MOD03- Extreme condition - Regrading and Riprap.gsz

Figure D1

Extreme Condition
Regrading and Riprap

0035-129-00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟪	Riprap	21	0	45
🟦	Sand (Impenetrable)			
🟧	Silty Clay	17	5	17

Tabloid (279mm x 432mm)

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SCALE: 1:301 (279mm x 432mm)

FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\MOD05- Normal condition - Regrading and Riprap.gsz

Figure D2

Normal Condition
Regrading and Riprap

Quality Engineering | Valued Relationships

Morrison Hershfield

City of Winnipeg Branch 1 Aqueduct Underdrain Outfalls (RFP No. 512-2023) – Avenue Tache Outfall Geotechnical Report

Prepared for:
Mr. Adam Braun, P.Eng.
Senior Municipal Engineer
Morrison Hershfield
9 Scurfield Blvd #1
Winnipeg, MB R3Y 1G4

Project Number: 0035-129-00

Date: August 29, 2024

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

August 29, 2024 Our File No. 0035-129-00

Mr. Adam Braun, P.Eng.
Senior Municipal Engineer
Morrison Hershfield
9 Scurfield Blvd #1
Winnipeg, MB R3Y 1G4

RE: City of Winnipeg Branch 1 Aqueduct Underdrain Outfalls (RFP No. 512-2023) – Avenue Tache Outfall Geotechnical Report

---

TREK Geotechnical Inc. is pleased to submit our final geotechnical investigation report for the above noted project. Please contact the undersigned should you have any questions.

Sincerely,

TREK Geotechnical Inc.
Per:

Michael Van Helden, Ph.D., P.Eng.
Senior Geotechnical Engineer

Encl.

Revision History

Revision No.	Author	Issue Date	Description
0	RJC	July 22, 2024	Draft Report
1	MVH	August 29, 2024	Final Report

Authorization Signatures

Prepared By:

2024/08/29
M. J.
VAN HELDEN
Member
24729

Michael Van Helden Ph.D., P.Eng
Senior Geotechnical Engineer

Reviewed By:

ENGINEERS
GEOSCIENTISTS
MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877

Ken Skaftfeld M.Sc., P.Eng.
Senior Geotechnical Engineer

Table of Contents

List of Tables

List of Appendices

1.0 Introduction

The City of Winnipeg (COW) has identified structural issues with three Branch 1 Aqueduct underdrain outfalls and is planning to rehabilitate/replace the outfall drains. The repairs are expected to include a combination of trenchless pipe installation, open-cut excavations and pipe installation, and a manhole replacement. TREK Geotechnical Inc. (TREK) was retained by Morrison Hershfield (MHL) to provide geotechnical support for assessment and repairs to underdrain outfalls located at:

- Rue Notre Dame at Rue Maisonneuve on the Seine River;
- Rue Plinguet, west of McTavish Street on the Seine River; and
- Avenue Tache at Rue Messager on the Red River.

This report summarizes the results of the geotechnical assessment completed by TREK for the rehabilitation or replacement of the Branch 1 Aqueduct underdrain outfall at Avenue Tache. The geotechnical assessment includes a review of existing information, sub-surface investigation, riverbank stability analysis, the development of preliminary design options for riverbank stability improvements, and provision of general recommendations for the design and construction of temporary excavations and shoring.

2.0 Site Conditions

TREK personnel (Michael Van Helden, P.Eng. and Reza Jamshidi Chenari, P.Eng.) completed a site reconnaissance on November 29, 2023. Photos from the site reconnaissance are attached in Appendix A.

The underdrain outfall pipe runs north along Avenue Tache crossing the intersection with Rue Messager before crossing an upland area green space to the outlet at a tight inside bend of the Red River (Figure 01). The uplands between the top of bank and Rue Messager is flat, and grass covered with young and mature trees along the riverbank crest (Photo 1). The riverbank is about 7 m high and sloped at about 2.5H:1V. No active riverbank movements were noted within the outfall right-of-way, although some evidence of shoreline erosion was noted. We understand from MHL that the outfall outlet is buried under a thick layer of river sediment, suggesting the lower bank may be subject to aggradation, at least under normal flow conditions, and may experience net erosion only during large flood events.

2.1 Site Survey

Riverbank cross-sections were surveyed by Morrison Hershfield on January 8, 2024 at the locations shown on Figure 01. The cross sections showing the existing ground surface from the MHL survey and available LIDAR survey data are included on Figure 02 (cross section A and B).

3.0 Sub-surface Information

A sub-surface investigation was completed under the supervision of TREK personnel to determine the soil stratigraphy and groundwater conditions at the site. Test Holes (TH) 24-01 and 24-01A were drilled at the locations shown on Figure 01 by Paddock Drilling Ltd. on April 19, 2024, and April 22, 2024, using a B57 track-mounted drill rig equipped with 125 mm diameter solid stem and 170 mm hollow stem augers. TH 24-01 was drilled to the depth of 9.1 m and abandoned due to machine breakdown. On April 22, 2024, TH 24-01A was drilled to power auger refusal at a depth of 15.2 m immediately adjacent to the original test hole. Test hole locations were established using a hand-held GPS device and the ground surface elevation surveyed relative to a temporary benchmark (TBM) as shown on Figure 01. The geodetic elevation for the TBM was provided by MHL.

A vibrating wire (VW) and standpipe (SP) piezometer were installed in TH24-01A at 7.6 m and 15.0 m below ground surface (bgs) respectively. TH24-01 was backfilled with auger cuttings and bentonite chips. TH24-01A was backfilled with sand around the standpipe tip followed by a bentonite chip seal and cement/bentonite grout to surface (and surrounding the VW piezometer). An above-ground protective casing was installed on TH 24-01A.

Sub-surface soils were visually classified based on the Unified Soil Classification System (USCS). Disturbed (auger cutting) samples were taken at regular intervals and relatively undisturbed (Shelby Tube) samples were collected at select depths. All samples retrieved during drilling were transported to TREK's testing laboratory in Winnipeg, Manitoba. Laboratory testing consisted of moisture content determination on all disturbed samples, bulk unit weight and unconfined compressive strength on Shelby tube samples, and Atterberg Limits on select samples. Laboratory testing results are included in Appendix B. The test hole logs include a description of the soil units encountered and other pertinent information such as groundwater and a summary of the laboratory testing results.

3.1 Soil stratigraphy

A brief description of the soil units encountered (in descending order from ground surface) in the two test holes is provided as follows. All interpretations of soil stratigraphy for the purposes of design should refer to the detailed information provided on the test hole logs.

The general soil stratigraphy consists of 0.1 m of topsoil, 1.5 m of firm clay fill, and alternating layers of clay, silt and sand alluvium to 12.5 m bgs. The alluvium ranges from loose sand containing trace silt, to high plastic silty clay containing trace sand. Loose to compact silt till, becoming dense below 15.2 m bgs, was encountered below the alluvium and power auger refusal was encountered at 15.3 m bgs.

3.1.1 Groundwater and Sloughing Conditions

A water level 6.1 m bgs was measured in TH 24-01 immediately after drilling, however, the source and depth could not be determined. Seepage from sand below 9.1 m was observed in TH24-01A before switching from solid to hollow stem augers, however, seepage and sloughing conditions could not be observed beyond this depth due to the drilling method used (hollow stem augers). Sand blowup was observed below 12.2 m and 13.7 m bgs during drilling. Measured groundwater elevations are short-term and should not be considered reflective of (static) elevations at the site which would require monitoring over an extended period of time to determine. It is important to recognize that groundwater conditions may vary seasonally, annually, or as a result of construction activities.

Piezometric (groundwater) levels monitored after installation are summarized in Table 1.

Table 1. Measured Piezometric (Groundwater) Elevations

Test Hole	Instrument	Piezometric Elevation (m)		
		Immediately after installation	April 25, 2024	May 24, 2024
TH24-01A	Vibrating Wire Piezometer (VW24-01)	224.91	224.77	224.87
	Standpipe Piezometer (SP24-01)	217.59	218.05	220.96
	Water Level Logger (SP24-01)	-	218.15	221.12

4.0 Slope Stability Analysis

Slope stability analyses were conducted to assess the existing riverbank slope stability and provide recommendations for improvements to stability (if warranted) in conjunction with the outfall repairs. The analysis was conducted using a limit-equilibrium slope stability model (Slope/W) from the GeoStudio 2020 software package (Geo-Slope International Ltd.). The slope stability model used the Morgenstern-Price method of slices with the half-sine interslice force function to calculate factors of safety. Slip surfaces were identified using grid and radius methods. A static piezometric line was used to represent groundwater levels based on the measured levels. The soil stratigraphy was based on TREK's test holes and the ground surface geometry was based on the MHL survey.

Assumed soil properties in Table 2 are based on measured values or in the absence of this information, using representative values based on TREK's experience. The silty clay (alluvium) strengths are considered a composite of the various constituent layers of high plastic clay and loose silty sand. Based on observed site conditions, we have assumed that there are no historical instabilities within the ROW that would warrant the use of lower (residual) strength properties.

Table 2. Soil Properties used in Slope Stability Analysis

Soil Description	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (degrees)
Clay Fill and Silty Clay / Sand (Alluvium)	17	4	27
Silt Till	22	5	30

Analysis was conducted on cross-section A. The output of the slope stability analysis is presented as a factor of safety (FS) related to the stability of the slope along a particular slip surface. A factor of safety approaching unity (FS = 1.0) indicates that the slope is becoming unstable and differential shear movements are expected. As the factors of safety increase above unity, the likelihood of movements decreases. Target factors of safety of 1.3 and 1.5 were selected for design under short-term (extreme) and long-term (typical) conditions and have been commonly used on other City of Winnipeg infrastructure projects. Short-term conditions were modelled with the Regulated Summer River Level (RSRL) of 223.75 m and a riverbank groundwater level steeply rising up to Elev. 224.87 m (about 5.0 m below ground surface). Long-term conditions were modelled with a minimum river water level (223.75 m) and a riverbank groundwater level gently rising up to Elev. 224.87 m (about 5.0 m below ground surface).

4.1 Analysis Results

Figures C1 and C2 show the analysis results for the short-term and long-term cases, respectively, which are summarized in Table 3. The offset distance from the riverbank crest where all potential slip surfaces meet or exceed the target factors of safety is 9 m and 5 m for long-term and short-term cases, respectively. The proposed underdrain manhole should therefore be located 9 m or greater from the riverbank crest as shown on Figure 01.

Table 3. Slope Stability Analysis Results for Existing Conditions

Stability Case / Cross Section	Condition	Critical (Minimum) FS	Development Setback Distance (m)	Development Target FS	Model Number (Appendix C)
Existing Condition / Cross Section A	Long-term	1.29	9 m	1.5	C1
	Short-term	1.24	5 m	1.3	C2

5.0 Excavations and Shoring

We understand that a deep excavation will be required at the outfall manhole to facilitate the repairs. The outfall pipe will be installed using a combination of open-cut and directional drilling methods. Shoring will be required at the manhole location and open-cut excavations and/or shoring will be required between the manhole and outlet at the river.

5.1 Temporary Excavations and Shoring

Based on the anticipated excavation depth and the sensitivity of surrounding structures to settlement (e.g. roadway, underground utilities), conventional shoring should be braced. Shoring will likely need to extend through the alluvium layer and into the silt till layer. Undrained soil conditions may govern design of the shoring in the short term and effective stress conditions should be considered for the long-term stability. Both undrained and drained soil conditions should be checked, and the more conservative condition used to design the shoring.

It is anticipated that the design of excavation slopes and temporary shoring will be the responsibility of the Contractor. Shoring designs or excavations will need to be designed and sealed by a professional engineer, and shop drawings should be reviewed by TREK prior to construction for review and comment.

The earth pressure distribution provided in Figure 03 can be used for braced shoring design, however the shoring designer should refer to the Canadian Foundation Engineering Manual (CFEM, 5th Edition, 2023) and the information provided on the test hole logs for consideration of the layered soil profile in design. The apparent earth pressure distribution shown on Figure 03 can be used for temporary braced shoring design in soft to firm clay and is not applicable for unsupported (cantilevered) shoring. The effect of any surcharge loads must be added to the force on the wall in addition to the calculated earth pressures. The appropriate earth pressure condition should be used to calculate the lateral earth pressure due to surcharge loads. Suggested soil parameters for use in shoring design are provided in Table 4, however it is the Contractor's responsibility to review the test hole logs and confirm the selection of soil parameters for design.

Table 4. Engineering Properties for Soil

Material	**Depth Below Site Grade in Upper Bank**	**Undrained Shear Strength**	**Effective Cohesion**	**Effective Friction Angle**	**Saturated Unit Weight**	**Effective Unit Weight**	**Earth Pressure Coefficients (Rankine[1])**		
	(m)	(kPa)	(kPa)	(degrees)	(kN/m³)	(kN/m³)	K_0	K_a	K_p
Clay Fill	0 – 1.5	50	5	25	17.5	7.7	0.58	0.70	1.73
Clay and Sand Alluvium	1.5 – 12.5	30	3	27	18.0	8.2	0.55	0.38	2.66
Silt Till	Below 12.5	n/a	0	30	20.0	10.2	0.50	0.67	2.00

Note 1: The effective stress earth pressure coefficients assume the magnitude of wall rotation is sufficient to develop the full earth pressure. The values should be reduced to suit the allowable wall rotation. Refer to Section 20.2.5 of the Canadian Foundation Engineering Manual (5th Edition 2023).

Ground movements behind the shoring and associated settlement are largely unavoidable. The amount of movement cannot be predicted with a high degree of accuracy as it is as much a function of the excavation procedures and workmanship as it is of theoretical considerations. In this regard, good contact between the retaining wall or timber lagging and retained soil should be maintained throughout the construction process. Free-draining sand fill should be used to fill in any voids behind the wall.

The proposed excavation base at approximately 9 m depth is expected to terminate approximately 3.5 m above silt till. A groundwater level i at ground surface in the alluvium should be assumed for shoring design due to the potential for perched groundwater levels. Measured groundwater levels in the alluvium were approximately 1.5 m higher than the anticipated excavation base, therefore seepage into the excavation should be expected but likely can be managed using conventional sump pits and pumping. However, groundwater levels can be expected to fluctuate with the level of the Red River and may be higher during the summer months and during flood periods. Construction of the proposed works in the winter months (November to February) will reduce the risk of higher groundwater levels and the need for more extensive dewatering measures such as well point systems. Groundwater levels in the till are below the base of the excavation (during non-flood periods) and therefore base heave is not anticipated to be an issue.

Excavation base stability can be assessed based on equation 20.15 of the CFEM (5th Edition) as follows:

$$FS_b = \frac{N_b s_u}{\gamma H + q}$$

Where:

FS_b	is the factor of safety against base stability;
N_b	is the stability factor dependent upon the geometry of the excavation; a value of 5.2 should be used for excavations extending to between 8 to 10 m with no penetration of the excavation supports below the base of the excavation;
s_u	is the undrained shear strength of soil below the base of the excavation; a value of 30 kPa should be used for this site;
γ	is the unit weight of soil above the base of the excavation – refer to Table 4
H	is the depth of excavation (m)
q	is the surface surcharge load (kPa)

In the case of soft clays underlying the base of an excavation where FS_b is smaller than 2, substantial deformations of the excavation support, base and surrounding ground may occur. Where FS_b is less than 1.5, the depth of penetration of the support system should extend below the base of the excavation. Shoring that needs to extend below the depth of excavation should be designed in accordance with Chapter 20 of the CFEM (5th Edition).

A monitoring program should be established to record the performance of the shoring system from the onset of installation to removal. The monitoring program should include top of pile surveys as a minimum to measure and track lateral movement of the shoring with time. The vertical profile of soldier piles could be monitored using slope inclinometer casings or shape arrays and measurement of earth pressures acting on the shoring and groundwater pressure measurements could also be considered if deemed important by the shoring designer.

6.0 Closure

The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation and laboratory testing). Soil conditions are natural deposits that can be highly variable across a site. If sub-surface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work or standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

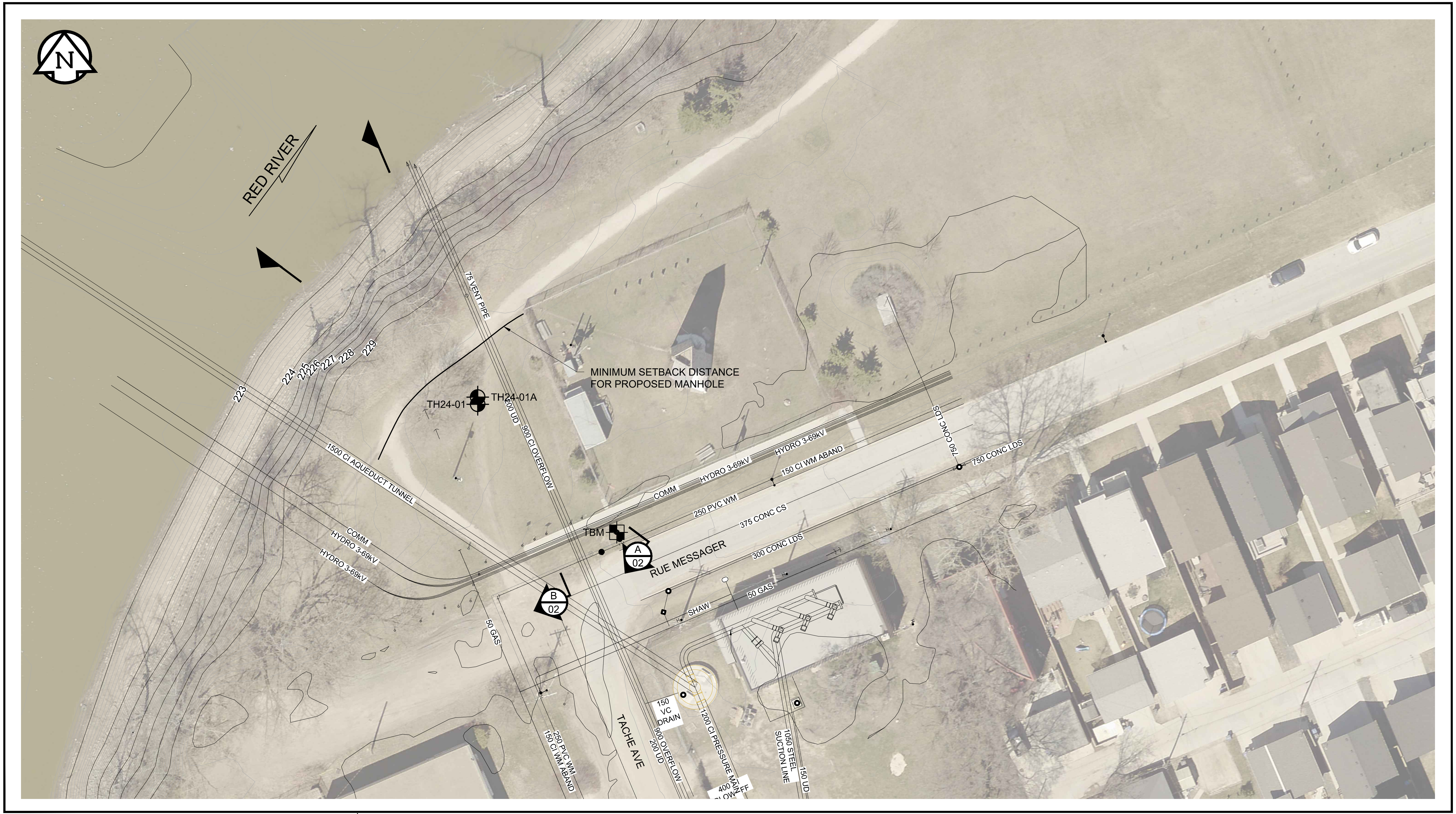
This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of Morrison Hershfield (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

Figures

TREK GEOTECHNICAL

0035 129 00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls Tache Site

Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 01 2024-07-22 Branch 1 Aqueduct Tache 0_A 0035-129-00.dwg, 2024-07-22 2:04:42 PM



0 5 10 15 20 25 m
SCALE = 1 : 500 (279 mm x 432 mm)

LEGEND:

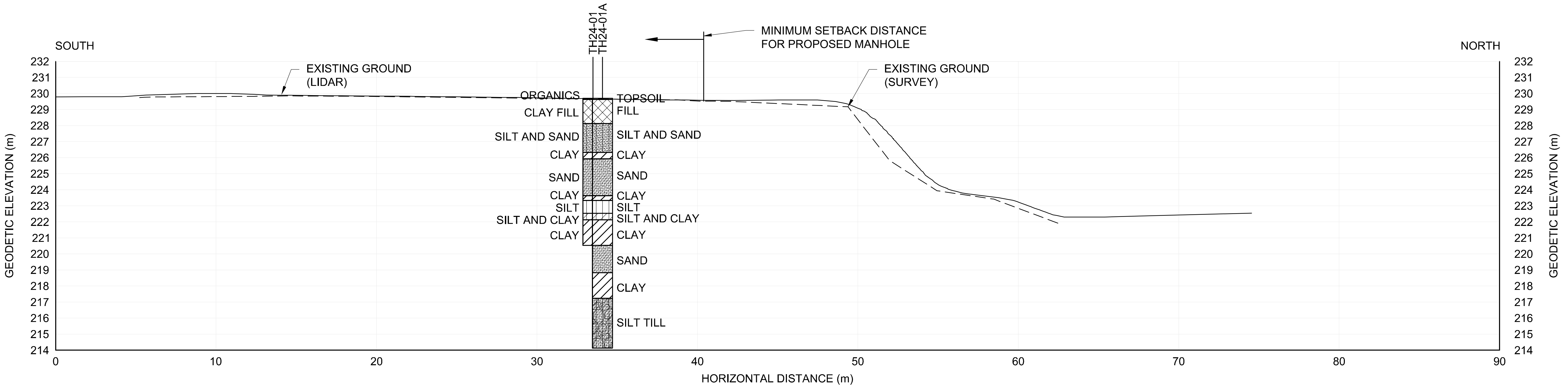
- TEST HOLE (TREK, 2024)
- TEMPORARY BENCHMARK
- EXISTING MAJOR CONTOUR (1.0 m INTERVAL)
- EXISTING MINOR CONTOUR (0.125 m INTERVAL)

NOTES:

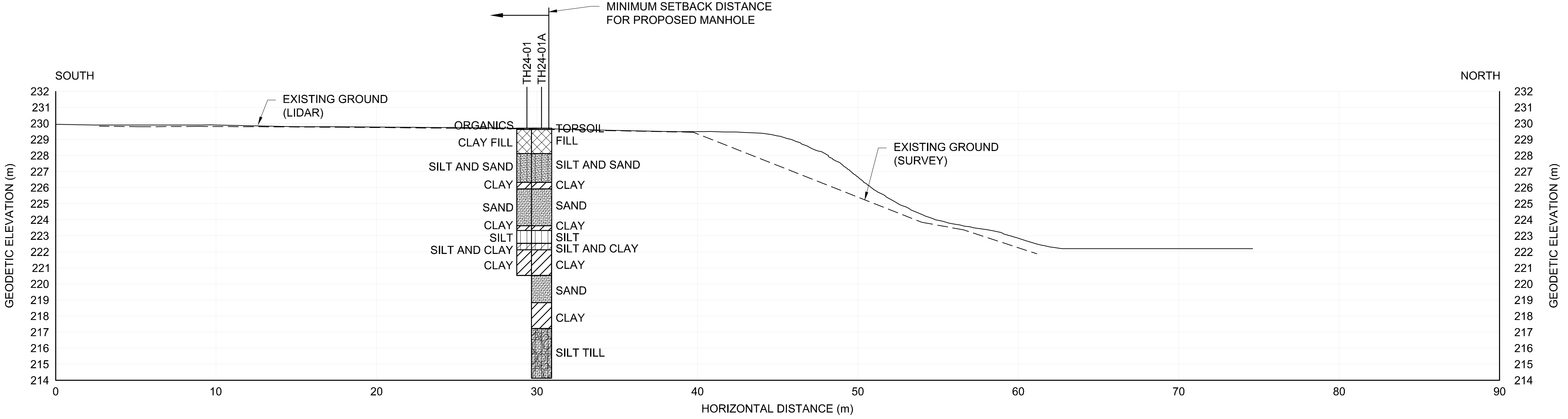
1. AERIAL IMAGERY FROM CITY OF WINNIPEG (2021).
2. CONTOURS FROM 2020 LIDAR.

Figure 01
Site Plan

Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 02 2024-07-22 Branch 1 Aqueduct Tache 0_A 0035-129-00.dwg, 2024-07-22 1:33:17 PM



CROSS SECTION A



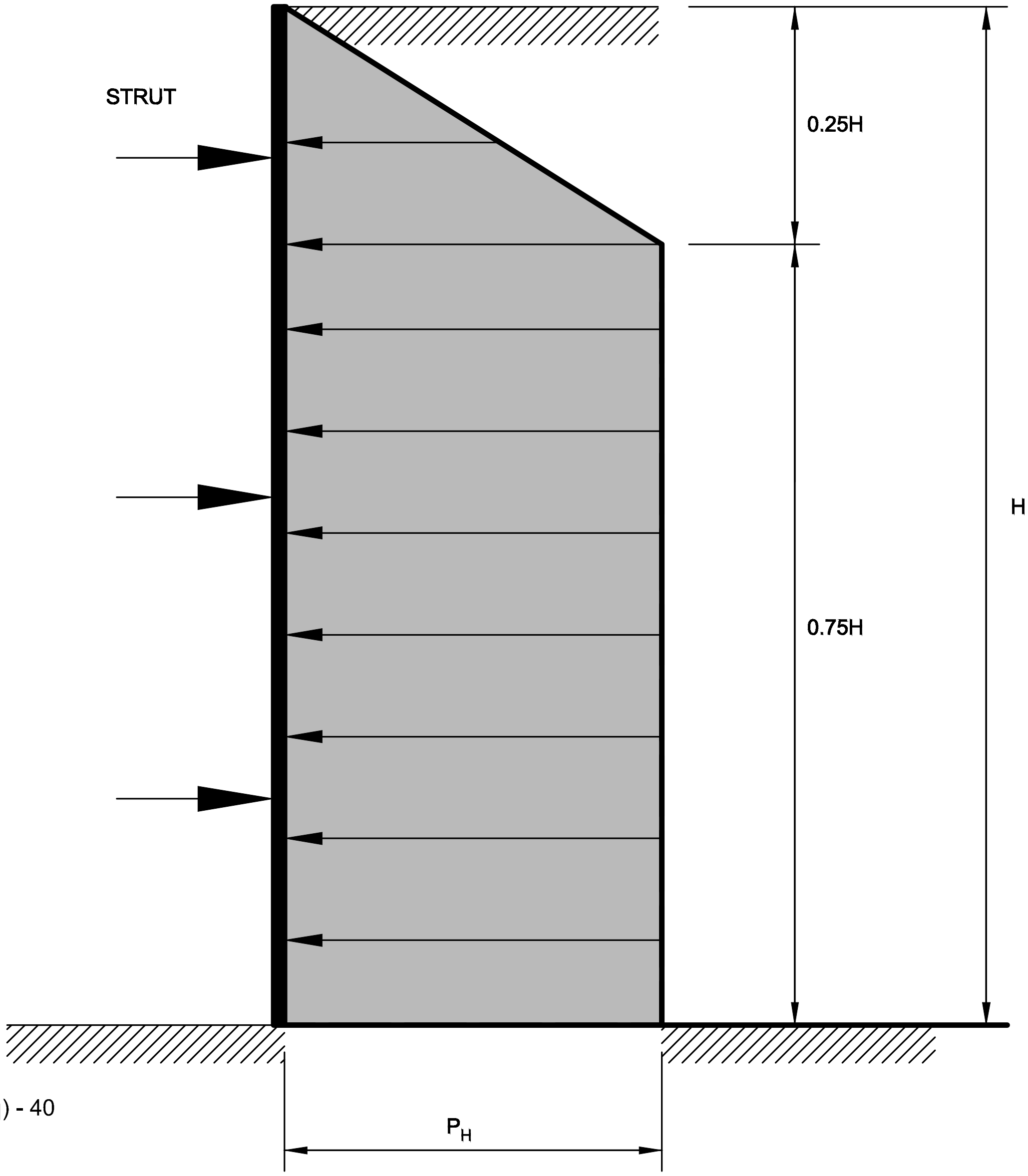
CROSS SECTION B

0 5 10 15 m
SCALE = 1 : 250 (279 mm x 432 mm)

LEGEND:

NOTES:

Figure 02
Cross Sections A & B



$P_H = (\gamma H + q) - 40$

WHERE:
P_H = LATERAL EARTH PRESSURE (kPa)
H = DEPTH OF EXCAVATION (m)
γ = BULK SOIL UNIT WEIGHT (17.0 kN/m³)
q = SURFACE SURCHARGE LOAD (kPa)

Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\Fig 03 2024-07-22 Branch 1 Aqueduct Tache 0_A 0020-056-00.dwg, 2024-07-22 1:08:55 PM (11.00 Inches)

Figure 03
Apparent Temporary Lateral Earth Pressure Distribution
Braced Excavation in Soft to Firm Clay

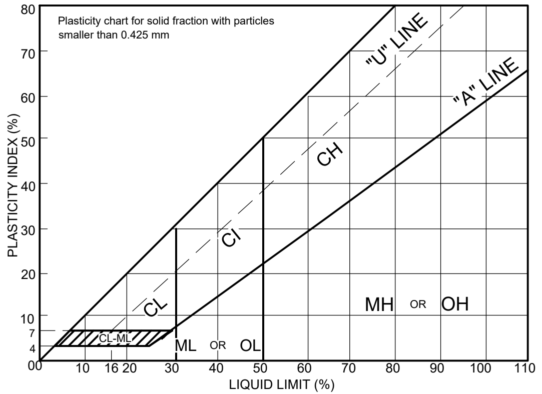
Test Hole Logs

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the Unified Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classi-fication	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	▚	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent....... GW, GP, SW, SP More than 12 percent....... GM, GC, SM, SC 6 to 12 percent....... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	▢	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	▢	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	⁘	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	░	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	☰	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▥	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▨	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size: ASTM Sieve sizes	Particle Size: mm
Sand	Coarse	#10 to #4	2.00 to 4.75
	Medium	#40 to #10	0.425 to 2.00
	Fine	#200 to #40	0.075 to 0.425
Silt or Clay		< #200	< 0.075
Boulders		> 12 in.	> 300
Cobbles		3 in. to 12 in.	75 to 300
Gravel	Coarse	3/4 in. to 3 in.	19 to 75
	Fine	#4 to 3/4 in.	4.75 to 19

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	▢	Cobbles
⁖	Concrete	⊞	Limestone Bedrock	▚	Boulders and Cobbles
▩	Fill	☰	Cemented Shale	▥	Silt Till
		▤	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength

VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling
▼ Water Level at End of Drilling
▼ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent
with *	with silt, with sand	> 35 percent

* Used when the material is classified based on behaviour as a cohesive material

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

Test Hole TH24-01

1 of 1

Client: Morrison Hershfield

Project Number: 0035-129-00

Project Name: Branch 1 Aqueduct - Tache

Location: UTM-14U, 5529019 m N, 634346 m E

Contractor: Paddock Drilling Ltd.

Ground Elevation: 98.97 m

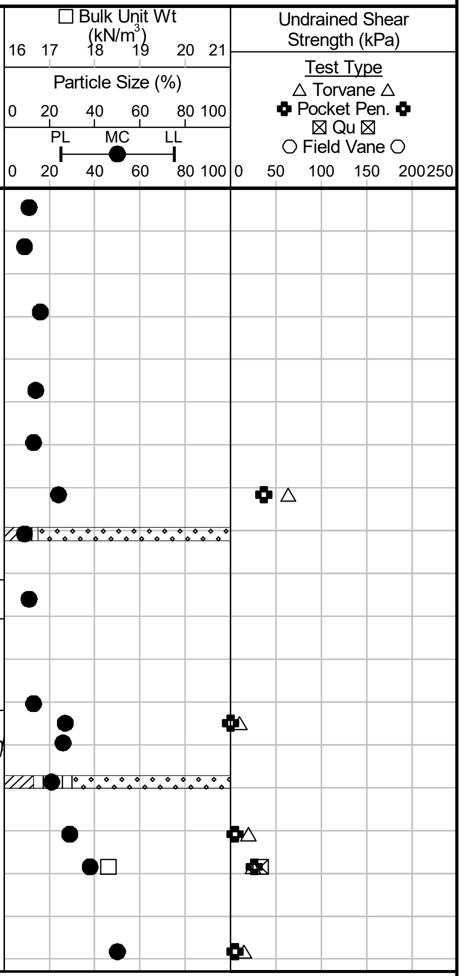
Method: 125 mm Solid Stem Auger, B57 Track Mounted Rig

Date Drilled: April 19, 2024

Sample Type: ◢ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) / SPT ⧓ Split Barrel (SB) / LPT ▯ Core (C)

Particle Size Legend: ▦ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ◌ Cobbles ■ Boulders

Elevation (m)	MATERIAL DESCRIPTION	Sample Number	SPT (N)
98.9	ORGANICS - trace sand, black, loose, grass, trace rootlets	G01	
	CLAY (FILL) - silty, trace sand, trace gravel (<20 mm dia.) - brown - moist, firm - high plasticity	G02	
97.4	SAND AND SILT - trace clay, trace rootlets - brown - moist, loose - low to no plasticity - poorly graded, fine sand - subangular to subrounded	G03 G04 G05	
95.6	CLAY - silty, dark brown, moist, stiff, high plasticity	G06	
95.2	SAND - trace silt - brown - moist, loose - poorly graded, fine sand - subangular to subrounded	G07 S08 G09	 7
92.9 ▼	CLAY - silty, trace sand, brown, moist, soft, medium to high plasticity	S10A	7 / 152mm
92.6	SILT - trace clay, some fine sand, brown, moist, loose	S10B G11	
91.8	SILT AND CLAY - trace gravel (<10 mm dia.), brown, moist, soft, intermediate plasticity	G12	
91.4	CLAY - silty, trace gravel (<15 mm dia.) - brown, moist, soft, high plasticity - trace silt inclusions (<10 mm dia.) - grey below 8.7 m	T13 G14	
89.8			



END OF TEST HOLE AT 9.1 m CLAY

Notes:

1. End of test hole at 9.1 m depth due to machine breakdown.
2. Seepage and sloughing observed at 7.6 m depth.
3. Test hole open to 8.5 m depth immediately after drilling.
4. Water level at 6.1 m depth immediately after drilling.
5. Test hole backfilled with auger cuttings and bentonite.

Logged By: Jason Wong

Reviewed By: Ken Skaftfeld

Project Engineer: Michael Van Helden

Test Hole TH24-01A

1 of 2

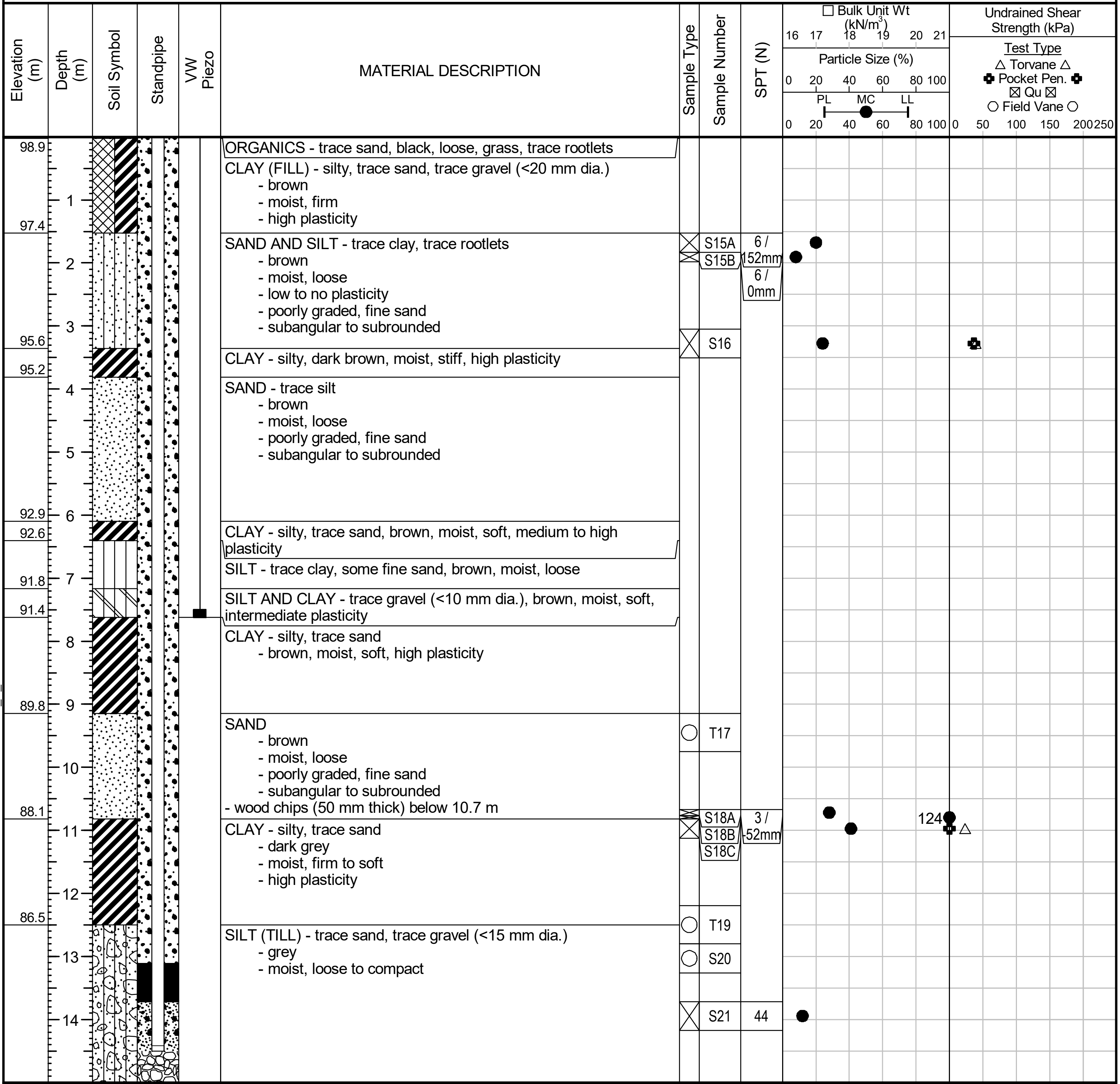
Sub-Surface Log

Client:	Morrison Hershfield	**Project Number:**	0035-129-00
Project Name:	Branch 1 Aqueduct - Tache	**Location:**	UTM-14U, 5529020 m N, 634346 m E
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	98.97 m
Method:	125 mm SSA / 170 mm HSA, B57 Track Mounted Rig	**Date Drilled:**	April 22, 2024

Sample Type: Grab (G) · Shelby Tube (T) · Split Spoon (SS) / SPT · Split Barrel (SB) / LPT · Core (C)

Particle Size Legend: Fines · Clay · Silt · Sand · Gravel · Cobbles · Boulders

Backfill Legend: Bentonite · Cement · Drill Cuttings · Filter Pack Sand · Grout · Slough



Elevation (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)
98.9	ORGANICS - trace sand, black, loose, grass, trace rootlets			
	CLAY (FILL) - silty, trace sand, trace gravel (<20 mm dia.) - brown - moist, firm - high plasticity			
97.4	SAND AND SILT - trace clay, trace rootlets - brown - moist, loose - low to no plasticity - poorly graded, fine sand - subangular to subrounded	SS SS SS	S15A S15B S16	6 / 152mm 6 / 0mm
95.6	CLAY - silty, dark brown, moist, stiff, high plasticity			
95.2	SAND - trace silt - brown - moist, loose - poorly graded, fine sand - subangular to subrounded			
92.9	CLAY - silty, trace sand, brown, moist, soft, medium to high plasticity			
92.6	SILT - trace clay, some fine sand, brown, moist, loose			
91.8	SILT AND CLAY - trace gravel (<10 mm dia.), brown, moist, soft, intermediate plasticity			
91.4	CLAY - silty, trace sand - brown, moist, soft, high plasticity			
89.8	SAND - brown - moist, loose - poorly graded, fine sand - subangular to subrounded - wood chips (50 mm thick) below 10.7 m	T	T17	
88.1	CLAY - silty, trace sand - dark grey - moist, firm to soft - high plasticity	SB SS	S18A S18B S18C	3 / -52mm
86.5	SILT (TILL) - trace sand, trace gravel (<15 mm dia.) - grey - moist, loose to compact	T T SS	T19 S20 S21	44

Logged By: Jason Wong **Reviewed By:** Ken Skaftfeld **Project Engineer:** Michael Van Helden

Sub-Surface Log

Test Hole TH24-01A

2 of 2

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	VW Piezo	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)	☐ Bulk Unit Wt (kN/m^3) 16 17 18 19 20 21 Particle Size (%) 0 20 40 60 80 100 PL MC LL 0 20 40 60 80 100	Undrained Shear Strength (kPa) Test Type △ Torvane △ ✚ Pocket Pen. ✚ ☒ Qu ☒ ○ Field Vane ○ 0 50 100 150 200 250
83.4					- dense below 15.2 m	☒	S22	50 / 128mm	●	

END OF TEST HOLE AT 15.3 m IN SILT (TILL)

Notes:

1. Power auger refusal at 15.3 m depth.
2. Seepage observed below 9.1 m depth during drilling.
3. Sloughing not observed due to method of drilling (Hollow Stem Augers)
4. Sand blowup observed below 12.2 m and 13.7 m depth.
5. Standpipe SP24-01 installed in test hole.
6. VW24-01 (VW130062) installed at 7.6 m below ground surface.
7. Test hole backfilled with sand, bentonite, and grout.
8. Soil stratigraphy above 9.1 m was copied from TH24-01.
9. Water level - 13.2 m below top of pipe on April 22, 2024 at 16:30.
   Water level - 12.7 m below top of pipe on April 25, 2024 at 10:15.

Logged By: Jason Wong **Reviewed By:** Ken Skaftfeld **Project Engineer:** Michael Van Helden

Appendix A

Photos of Site Reconnaissance

Photo 1 – Upper bank area along outfall alignment

Photo 2 – Riverbank crest at outfall

Appendix B

Laboratory Testing Results

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

MEMORANDUM

Date	April 29, 2024
To	Jason Wong, TREK Geotechnical
From	Angela Fidler-Kliewer, TREK Geotechnical
Project No.	0035-129-00
Project	Tache-Branch 1 Aqueduct
Subject	Laboratory Testing Results – Lab Req. R24-134
Distribution	Michael Van Helden

Attached are the laboratory testing results for the above noted project. The testing included moisture content determinations, particle size distribution (Hydrometer method), and unconfined compressive strength and related testing on a Shelby tube sample.

Regards,

Angela Fidler-Kliewer, C.Tech.

Attach.

Review Control:

Prepared By: *KF*	*Reviewed By:* AFK	*Checked By:* NJF

TREK GEOTECHNICAL

BC / JC (UCT)

Lab Requisition

TREK GEOTECHNICAL
1712 St. James Street
Winnipeg, Manitoba R3H 0L3
T 204.975.9433 F 204.975.9435

PROJECT: Tache - Branch 1 Aqueduct PROJECT NO: 0035-129-00

CLIENT: Morrison Hershfield FIELD TECHNICIAN: Jason Wong

TEST HOLE NUMBER	SAMPLE NUMBER	Sample Start Depth (ft)	Sample End Depth (ft)		MOISTURE	VISUAL CLASS.	ATTERBERG LIMITS	HYDROMETER	GRADATION	STD. PROCTOR	UNCONFINED AND AUXILLARY TESTS	SULPHATE			Soil Description/ Comments
TH24-01	G1	0.5	1.0		X										Clay (Fill)
TH24-01	G2	2.0	2.5		X										Clay (Fill)
TH24-01	G3	4.5	5.0		X										Clay (Fill)
TH24-01	G4	7.5	8.0		X										Sand and Silt
TH24-01	G5	9.5	10.0		X										Sand and Silt
TH24-01	G6	11.5	12.0		X										Clay
TH24-01	G7	13.0	13.5		X			X							Sand
TH24-01	S8	15.0	16.5		X										Sand
TH24-01	G9	19.5	20.0		X										Sand
TH24-01	S10A	20.0	21.0		X										Clay
TH24-01	S10B	21.0	21.5		X										Sand and Silt
TH24-01	G11	22.5	23.0		X			X							Silt
TH24-01	G12	24.5	25.0		X										Silt and Clay
TH24-01	T13	25.0	27.0								X				Clay
TH24-01	G14	29.0	29.5		X										Clay
TH24-02	S15A	5.0	6.0		X										Clay (Fill)
TH24-02	S15B	6.0	6.5		X										Sand
TH24-02	S16	10.0	11.5		X										Clay
~~TH24-02~~	~~T17~~	~~30.0~~	~~32.0~~												~~No Recovery~~
TH24-02	S18A	35.0	35.3		X										Sand
TH24-02	S18B	35.3	35.5		X										Wood Chips?
TH24-02	S18C	35.5	36.5		X										Clay
~~TH24-02~~	~~T19~~	~~40.0~~	~~42.0~~												~~No Recovery~~
~~TH24-02~~	~~S20~~	~~42.0~~	~~43.5~~												~~No Recovery~~
TH24-02	S21	45.0	46.5		X										Silt (Till)
TH24-02	S22	50.0	50.9		X										Silt (Till)

REQUESTED BY: JW REPORT TO: JW / MVH

REQUISTION DATE: 23-Apr-24 DATE REQUIRED:

COMMENTS:

REQUISITION NO.
R24-134

SHEET ____ OF ____

TREK GEOTECHNICAL
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Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report
ASTM D2216-98

Project No. 0035-129-00
Client Morrison Hershfield
Project Tache-Branch 1 Aqueduct

Sample Date 22-Apr-24
Test Date 23-Apr-24
Technician BC

Test Hole	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01
Depth (m)	0.2 - 0.3	0.6 - 0.8	1.4 - 1.5	2.3 - 2.4	2.9 - 3.0	3.5 - 3.7
Sample #	G1	G2	G3	G4	G5	G6
Tare ID	F18	E15	B10	B5	M36	M16
Mass of tare	6.8	6.8	6.6	6.6	7.0	6.8
Mass wet + tare	226.6	223.6	235.8	222.8	231.2	232.6
Mass dry + tare	204.2	204.9	204.9	196.6	206.1	189.7
Mass water	22.4	18.7	30.9	26.2	25.1	42.9
Mass dry soil	197.4	198.1	198.3	190.0	199.1	182.9
Moisture %	11.3%	9.4%	15.6%	13.8%	12.6%	23.5%

Test Hole	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01	TH24-01
Depth (m)	4.0 - 4.1	4.6 - 5.0	5.9 - 6.1	6.1 - 6.4	6.4 - 6.6	6.9 - 7.0
Sample #	G7	S8	G9	S10A	S10B	G11
Tare ID	B15	M91	E63	J74	J59	D35
Mass of tare	6.6	7.0	7.0	7.0	7.2	6.8
Mass wet + tare	438.8	199.0	222.4	202.2	123.0	427.2
Mass dry + tare	402.4	180.2	197.6	160.7	99.0	353.1
Mass water	36.4	18.8	24.8	41.5	24.0	74.1
Mass dry soil	395.8	173.2	190.6	153.7	91.8	346.3
Moisture %	9.2%	10.9%	13.0%	27.0%	26.1%	21.4%

Test Hole	TH24-01	TH24-01	TH24-02	TH24-02	TH24-02	TH24-02
Depth (m)	7.5 - 7.6	8.8 - 9.0	1.5 - 1.8	1.8 - 2.0	3.0 - 3.5	10.7 - 10.8
Sample #	G12	G14	S15A	S15B	S16	S18A
Tare ID	E86	P05	M32	E76	M20	M09
Mass of tare	7.2	7.0	6.8	6.8	7.0	7.0
Mass wet + tare	227.2	238.6	199.8	188.0	236.6	241.8
Mass dry + tare	177.8	161.7	167.3	174.7	192.0	190.8
Mass water	49.4	76.9	32.5	13.3	44.6	51.0
Mass dry soil	170.6	154.7	160.5	167.9	185.0	183.8
Moisture %	29.0%	49.7%	20.2%	7.9%	24.1%	27.7%

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Moisture Content Report
ASTM D2216-98

Project No. 0035-129-00
Client Morrison Hershfield
Project Tache-Branch 1 Aqueduct

Sample Date 22-Apr-24
Test Date 23-Apr-24
Technician BC

Test Hole	TH24-02	TH24-02	TH24-02	TH24-02		
Depth (m)	10.8 - 10.8	10.8 - 11.1	13.7 - 14.2	15.2 - 15.5		
Sample #	S18B	S18C	S21	S22		
Tare ID	Q13	E56	Q6	Q20		
Mass of tare	6.6	6.8	6.8	7.0		
Mass wet + tare	67.2	236.2	214.2	254.0		
Mass dry + tare	33.6	169.9	191.8	232.1		
Mass water	33.6	66.3	22.4	21.9		
Mass dry soil	27.0	163.1	185.0	225.1		
Moisture %	124.4%	40.6%	12.1%	9.7%		

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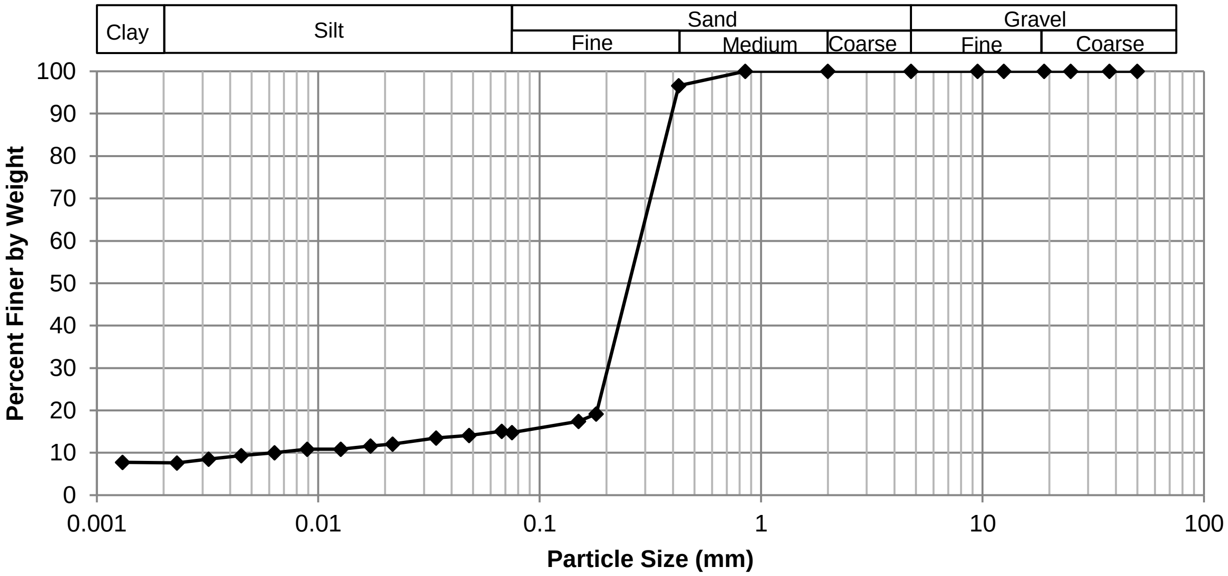
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Tache-Branch 1 Aqueduct
Test Hole	TH24-01
Sample #	G7
Depth (m)	4.0 - 4.1
Sample Date	22-Apr-24
Test Date	25-Apr-24
Technician	DS

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Gravel	0.0%
Sand	85.2%
Silt	7.1%
Clay	7.7%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	14.79
37.5	100.00	2.00	100.00	0.0675	15.05
25.0	100.00	0.850	99.98	0.0480	14.11
19.0	100.00	0.425	96.64	0.0341	13.49
12.5	100.00	0.180	19.17	0.0217	12.08
9.50	100.00	0.150	17.40	0.0172	11.61
4.75	100.00	0.075	14.79	0.0126	10.83
				0.0089	10.83
				0.0063	10.05
				0.0045	9.30
				0.0032	8.52
				0.0023	7.61
				0.0013	7.78

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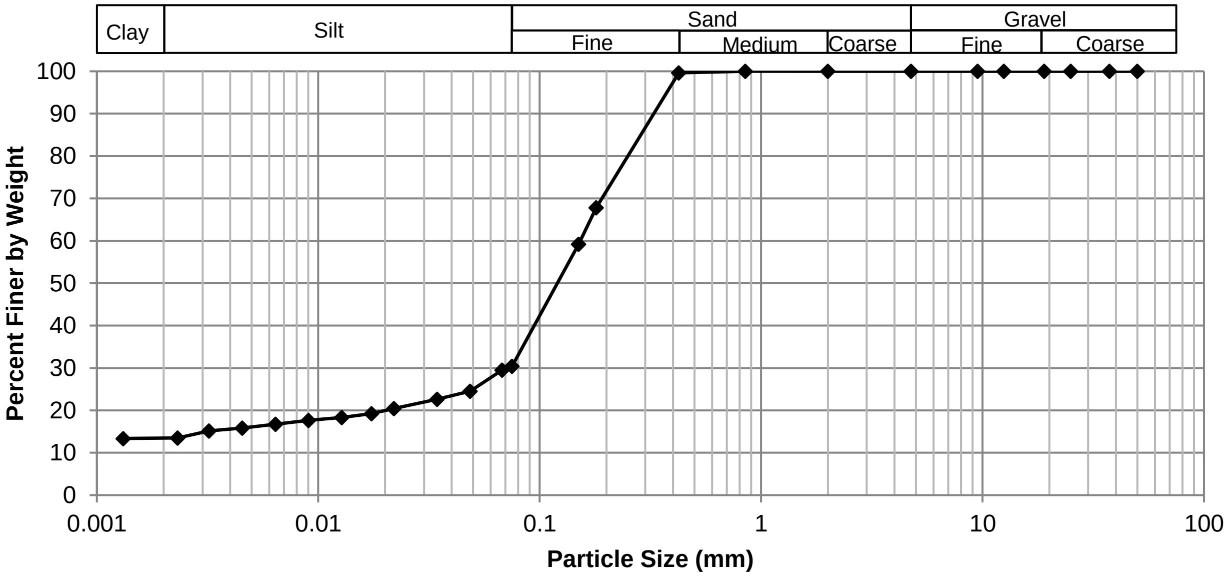
Grain Size Analysis (Hydrometer Method)
AASHTO T 88

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Project No.	0035-129-00
Client	Morrison Hershfield
Project	Tache-Branch 1 Aqueduct
Test Hole	TH24-01
Sample #	G11
Depth (m)	6.9 - 7.0
Sample Date	22-Apr-24
Test Date	25-Apr-24
Technician	DS

Gravel	0.0%
Sand	69.6%
Silt	17.0%
Clay	13.4%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	100.00	0.0750	30.42
37.5	100.00	2.00	100.00	0.0676	29.55
25.0	100.00	0.850	100.00	0.0485	24.54
19.0	100.00	0.425	99.62	0.0345	22.67
12.5	100.00	0.180	67.82	0.0220	20.48
9.50	100.00	0.150	59.20	0.0174	19.23
4.75	100.00	0.075	30.42	0.0128	18.29
				0.0090	17.67
				0.0064	16.73
				0.0045	15.83
				0.0032	15.13
				0.0023	13.46
				0.0013	13.37

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Shelby Tube Visual

Project No.	0035-119-00
Client	Morrison Hershfield
Project	Tache-Branch 1 Aueduct
Test Hole	TH24-01
Sample #	T13
Depth (m)	7.6 - 8.2
Sample Date	19-Apr-24
Test Date	23-Apr-24
Technician	KM

Tube Extraction

Recovery (mm) 610

Bottom **Top**

8.23 m 8.14 m 7.98 m 7.81 m **7.62 m**

Moisture Content PP/TV Visual	Keep	Qu Bulk	Toss
90 mm	160 mm	170 mm	190 mm

Visual Classification

Material	CLAy
Composition	silty
trace silt inclusions (<10mm, diam.)	
trace gravel (<15mm, diam.)	
Color	grey
Moisture	moist
Consistency	soft
Plasticity	high plasitcity
Structure	-
Gradation	-

Torvane

Reading	0.25
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	24.5

Pocket Penetrometer

Reading	**1**	0.50
	2	0.60
	3	0.50
	Average	0.53
Undrained Shear Strength (kPa)		26.2

Moisture Content

Tare ID	w10
Mass tare (g)	8.4
Mass wet + tare (g)	268.8
Mass dry + tare (g)	197.6
Moisture %	37.6%

Unit Weight

Bulk Weight (g)		1140.9
Length (mm)	**1**	146.48
	2	146.52
	3	146.58
	4	146.74
Average Length (m)		0.147
Diam. (mm)	**1**	72.26
	2	73.52
	3	72.83
	4	73.00
Average Diameter (m)		0.073
Volume (m^3)		6.12E-04
Bulk Unit Weight (kN/m^3)		18.3
Bulk Unit Weight (pcf)		116.4
Dry Unit Weight (kN/m^3)		13.3
Dry Unit Weight (pcf)		84.6

Unconfined Compressive Strength

ASTM D2166

Project No.	0035-119-00
Client	Morrison Hershfield
Project	Tache-Branch 1 Aueduct
Test Hole	TH24-01
Sample #	T13
Depth (m)	7.6 - 8.2
Sample Date	19-Apr-24
Test Date	23-Apr-24
Technician	KM

Unconfined Strength

	kPa	ksf
Max q_u	66.2	1.4
Max S_u	33.1	0.7

Specimen Data

Description CLAy - silty, trace silt inclusions (<10mm, diam.), trace gravel (<15mm, diam.), grey, moist, soft, high plasitcity

Length	146.6	(mm)	**Moisture %**	38%	
Diameter	72.9	(mm)	**Bulk Unit Wt.**	18.3	(kN/m^3)
L/D Ratio	2.0		**Dry Unit Wt.**	13.3	(kN/m^3)
Initial Area	0.00417	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.25	24.5	0.51
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	0.50	24.5	0.51
	0.60	29.4	0.61
	0.50	24.5	0.51
Average	**0.53**	**26.2**	**0.55**

Failure Geometry

Sketch:

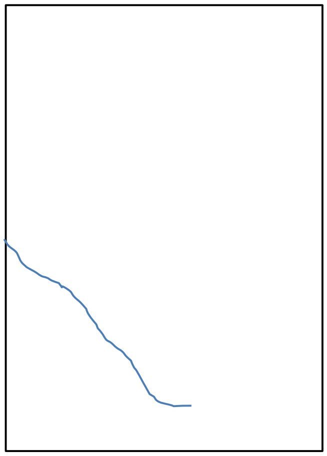
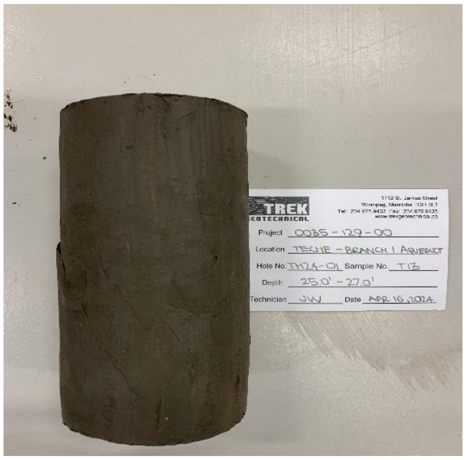


Photo:

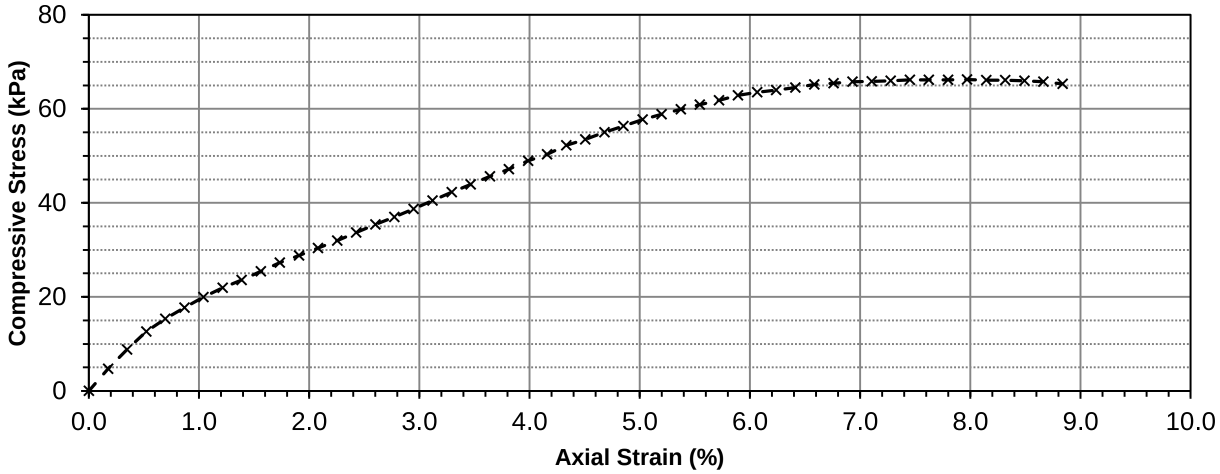


Unconfined Compressive Strength

ASTM D2166

Project No. 0035-119-00
Client Morrison Hershfield
Project Tache-Branch 1 Aueduct

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0.82	0.0000	0.00	0.004174	0.0	0.00	0.00
10	1.21	0.2540	0.17	0.004181	19.7	4.70	2.35
20	1.55	0.5080	0.35	0.004189	36.8	8.78	4.39
30	1.87	0.7620	0.52	0.004196	52.9	12.61	6.31
40	2.10	1.0160	0.69	0.004203	64.5	15.35	7.67
50	2.30	1.2700	0.87	0.004211	74.6	17.72	8.86
60	2.49	1.5240	1.04	0.004218	84.2	19.96	9.98
70	2.66	1.7780	1.21	0.004225	92.7	21.95	10.97
80	2.80	2.0320	1.39	0.004233	99.8	23.58	11.79
90	2.96	2.2860	1.56	0.004240	107.9	25.44	12.72
100	3.12	2.5400	1.73	0.004248	115.9	27.29	13.65
110	3.25	2.7940	1.91	0.004255	122.5	28.78	14.39
120	3.39	3.0480	2.08	0.004263	129.5	30.39	15.19
130	3.53	3.3020	2.25	0.004270	136.6	31.99	15.99
140	3.68	3.5560	2.43	0.004278	144.2	33.70	16.85
150	3.83	3.8100	2.60	0.004286	151.7	35.40	17.70
160	3.97	4.0640	2.77	0.004293	158.8	36.98	18.49
170	4.12	4.3180	2.95	0.004301	166.3	38.67	19.34
180	4.28	4.5720	3.12	0.004309	174.4	40.48	20.24
190	4.44	4.8260	3.29	0.004316	182.5	42.27	21.14
200	4.59	5.0800	3.47	0.004324	190.0	43.94	21.97
210	4.74	5.3340	3.64	0.004332	197.6	45.61	22.81
220	4.88	5.5880	3.81	0.004340	204.6	47.15	23.58
230	5.04	5.8420	3.99	0.004347	212.7	48.92	24.46

Unconfined Compressive Strength

ASTM D2166

Project No. 0035-119-00
Client Morrison Hershfield
Project Tache-Branch 1 Aueduct

Unconfined Compression Test Data (cont'd)

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
240	5.17	6.0960	4.16	0.004355	219.3	50.34	25.17
250	5.34	6.3500	4.33	0.004363	227.8	52.21	26.11
260	5.46	6.6040	4.51	0.004371	233.9	53.50	26.75
270	5.60	6.8580	4.68	0.004379	240.9	55.02	27.51
280	5.72	7.1120	4.85	0.004387	247.0	56.30	28.15
290	5.85	7.3660	5.03	0.004395	253.5	57.68	28.84
300	5.96	7.6200	5.20	0.004403	259.1	58.84	29.42
310	6.06	7.8740	5.37	0.004411	264.1	59.87	29.94
320	6.16	8.1280	5.55	0.004419	269.2	60.90	30.45
330	6.25	8.3820	5.72	0.004427	273.7	61.82	30.91
340	6.35	8.6360	5.89	0.004436	278.7	62.84	31.42
350	6.42	8.8900	6.06	0.004444	282.3	63.52	31.76
360	6.47	9.1440	6.24	0.004452	284.8	63.97	31.98
370	6.53	9.3980	6.41	0.004460	287.8	64.53	32.26
380	6.60	9.6520	6.58	0.004468	291.3	65.20	32.60
390	6.63	9.9060	6.76	0.004477	292.8	65.41	32.71
400	6.67	10.1600	6.93	0.004485	294.9	65.74	32.87
410	6.69	10.4140	7.10	0.004493	295.9	65.84	32.92
420	6.71	10.6680	7.28	0.004502	296.9	65.94	32.97
430	6.74	10.9220	7.45	0.004510	298.4	66.16	33.08
440	6.75	11.1760	7.62	0.004519	298.9	66.14	33.07
450	6.76	11.4300	7.80	0.004527	299.4	66.13	33.07
460	6.78	11.6840	7.97	0.004536	300.4	66.23	33.11
470	6.78	11.9380	8.14	0.004544	300.4	66.10	33.05
480	6.79	12.1920	8.32	0.004553	300.9	66.09	33.05
490	6.79	12.4460	8.49	0.004562	300.9	65.97	32.98
500	6.78	12.7000	8.66	0.004570	300.4	65.73	32.87
510	6.75	12.9540	8.84	0.004579	298.9	65.28	32.64

Appendix C

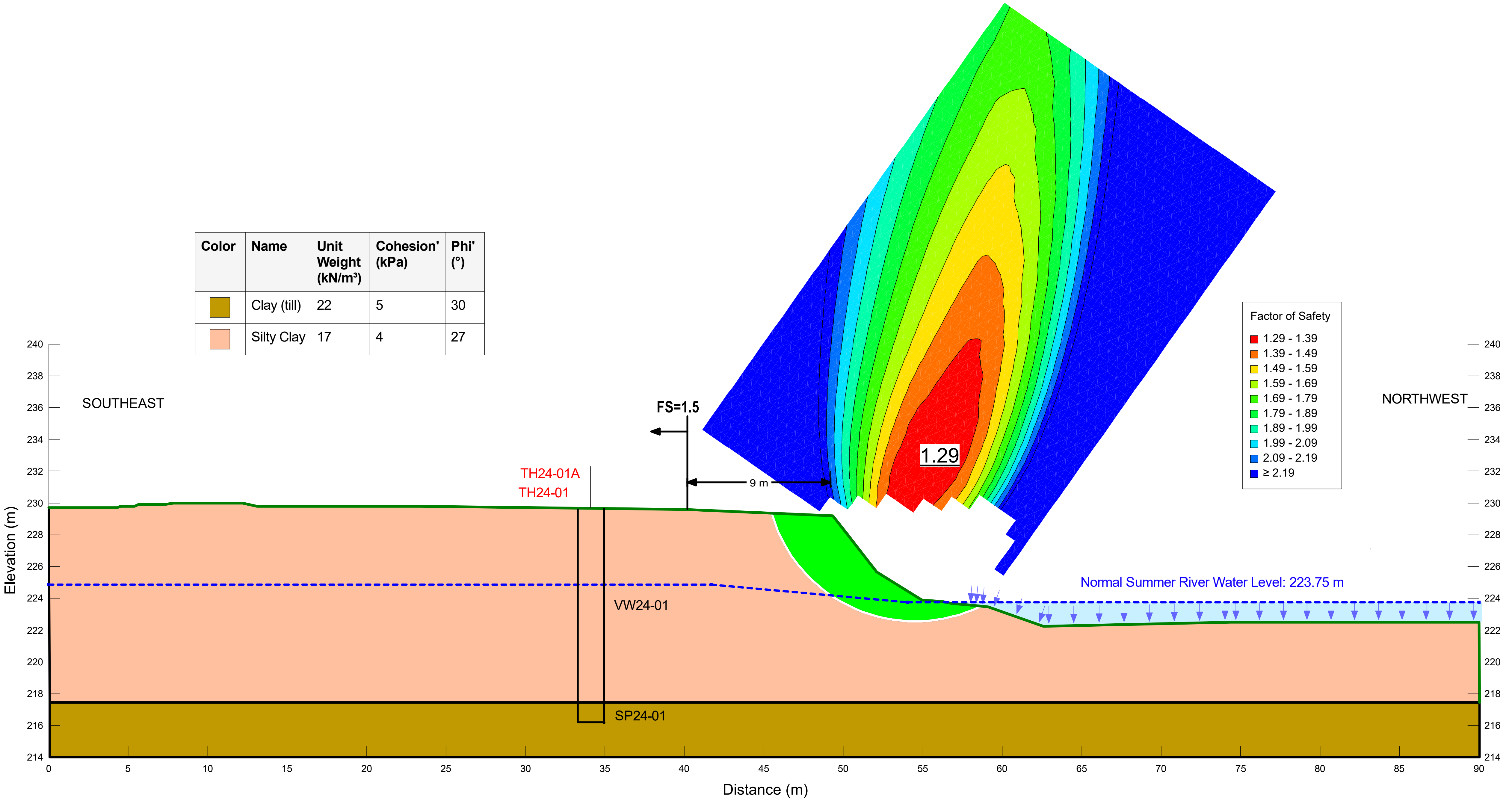
Slope Stability Analysis Results

0035-129-00
Morrison Hershfield
Branch 1 Aqueduct Underdrain Outfalls: TACHE

Tabloid (279mm x 432mm)

SAVED: 2024-07-04 04:14:58 PM

SCALE: 1:285 (279mm x 432mm)



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Clay (till)	22	5	30
🟧	Silty Clay	17	4	27

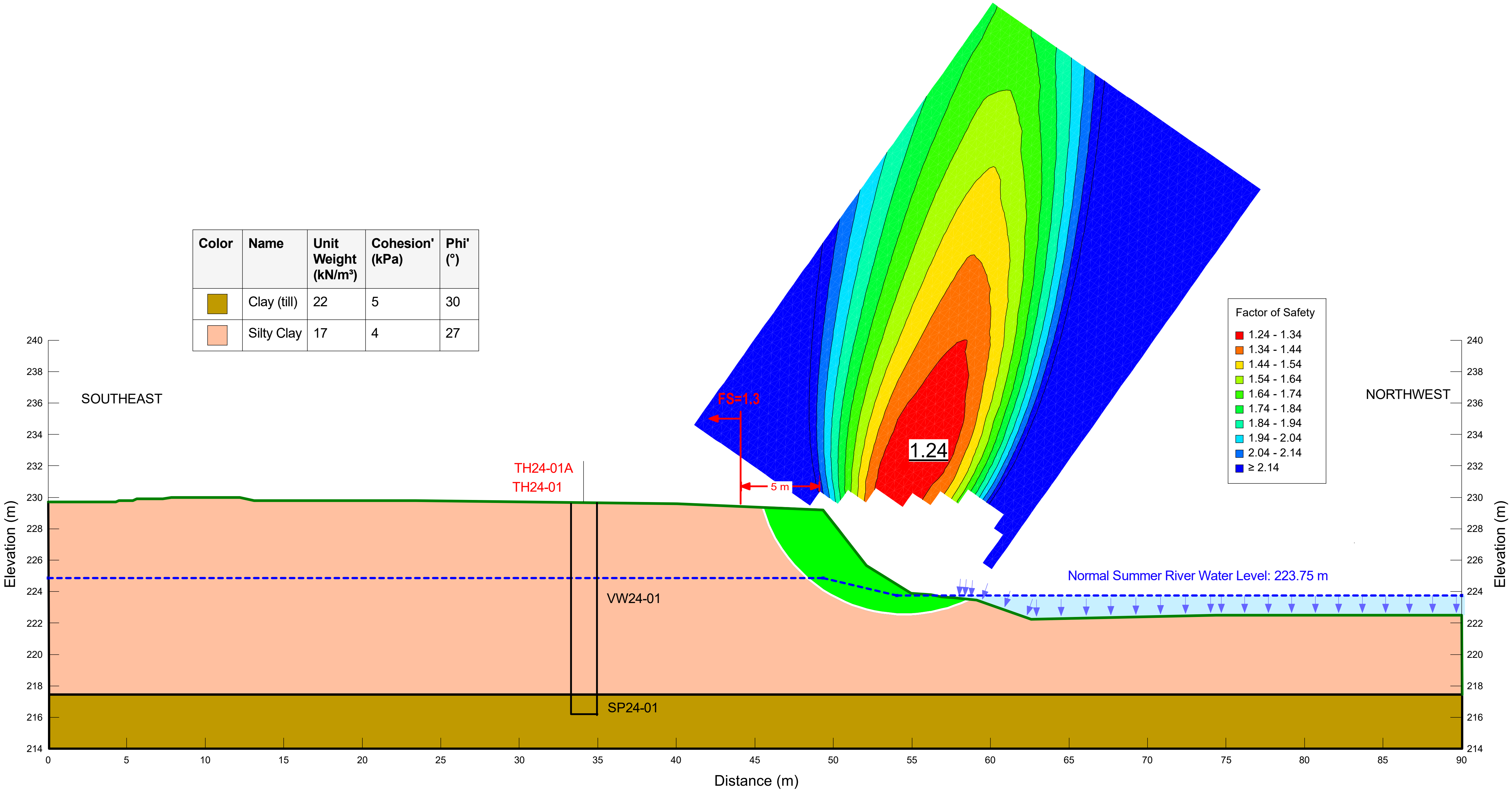
FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\TACHE\M001_2020.gsz

Figure C1
Normal Condition

Tabloid (279mm x 432mm)

SAVED: 2024-07-04 04:14:58 PM

SCALE: 1:285 (279mm x 432mm)



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Clay (till)	22	5	30
🟧	Silty Clay	17	4	27

FILE PATH: Z:\Projects\0035 Morrison Hershfield\0035 129 00 Branch 1 Aqueduct Underdrain Outfalls\2 Design\2.7 Modelling\TACHE\M001_2020.gsz

Figure C2
Critical Condition

Technical Memo

Project/File: 133600064 Date: September 20, 2024

Reference: Branch 1 Aqueduct Underdrain Outfall Repairs – Rue Notre Dame Underdrain Outfall – Existing Geotechnical Bore Hole Logs

Attached are all bore hole logs and cross sections showing soil stratigraphy for the Rue Notre Dame Underdrain Outfall site made available to Stantec.

The bore hole logs are as follows:

- SI-17-02
- SI-17-03
- SI-17-04
- SI-17-05

The cross section shows the stratigraphy for the following bore holes:

- SI-97-04
- SI-97-05
- SI-97-06
- SI-98-07
- SI-08-19
- SI-09-22

KGS GROUP

SUMMARY LOG

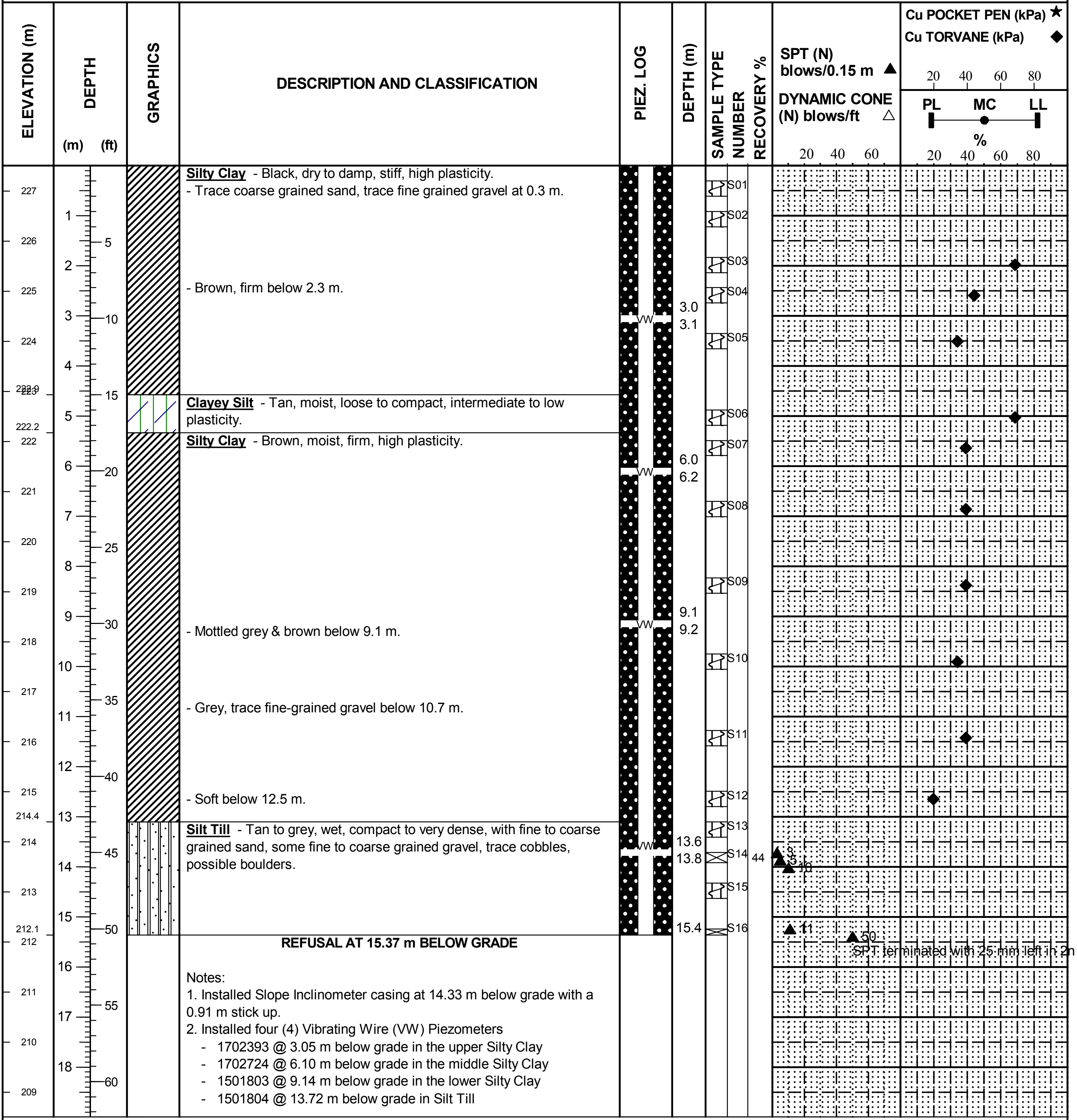
REFERENCE NO.

HOLE NO.
SI17-02

SHEET 1 of 1

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Seine River Aqueduct
SITE Seine River Aqueduct
LOCATION Mid Bank in Bush
DRILLING METHOD Track Mounted Rig B54X

JOB NO. **17-0107-008**
GROUND ELEV. **227.51 m**
TOP OF CASING ELEV. **228.54 m**
WATER ELEV.
DATE DRILLED **9/19/2017**
UTM (m) N **635,621**
E **5,528,893**



Silty Clay - Black, dry to damp, stiff, high plasticity.
- Trace coarse grained sand, trace fine grained gravel at 0.3 m.
- Brown, firm below 2.3 m.

Clayey Silt - Tan, moist, loose to compact, intermediate to low plasticity.

Silty Clay - Brown, moist, firm, high plasticity.
- Mottled grey & brown below 9.1 m.
- Grey, trace fine-grained gravel below 10.7 m.
- Soft below 12.5 m.

Silt Till - Tan to grey, wet, compact to very dense, with fine to coarse grained sand, some fine to coarse grained gravel, trace cobbles, possible boulders.

REFUSAL AT 15.37 m BELOW GRADE

Notes:
1. Installed Slope Inclinometer casing at 14.33 m below grade with a 0.91 m stick up.
2. Installed four (4) Vibrating Wire (VW) Piezometers
   - 1702393 @ 3.05 m below grade in the upper Silty Clay
   - 1702724 @ 6.10 m below grade in the middle Silty Clay
   - 1501803 @ 9.14 m below grade in the lower Silty Clay
   - 1501804 @ 13.72 m below grade in Silt Till

SAMPLE TYPE ⌇ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	D. FLYNN	DEA	10/5/17

KGS GROUP

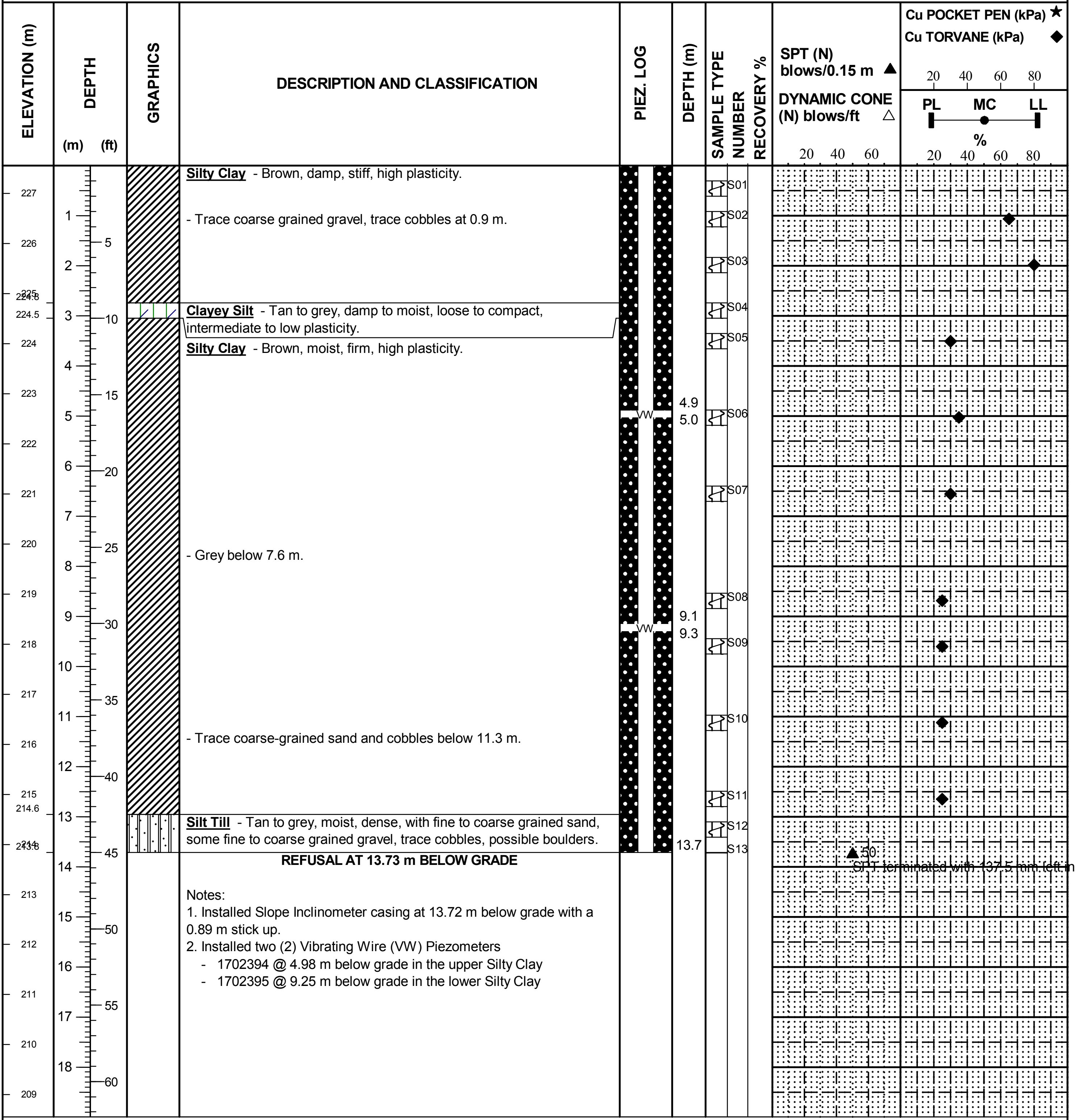
SUMMARY LOG

REFERENCE NO.

HOLE NO.
SI17-03

SHEET 1 of 1

CLIENT	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT	JOB NO.	17-0107-008
PROJECT	Seine River Aqueduct	GROUND ELEV.	227.55 m
		TOP OF CASING ELEV.	228.50 m
SITE	Seine River Aqueduct	WATER ELEV.	
LOCATION	Mid Bank Grassy Slope	DATE DRILLED	9/19/2017
		UTM (m)	N 635,600 E 5,528,873
DRILLING METHOD	Track Mounted Rig B54X		



DESCRIPTION AND CLASSIFICATION

Silty Clay - Brown, damp, stiff, high plasticity.

- Trace coarse grained gravel, trace cobbles at 0.9 m.

Clayey Silt - Tan to grey, damp to moist, loose to compact, intermediate to low plasticity.

Silty Clay - Brown, moist, firm, high plasticity.

- Grey below 7.6 m.

- Trace coarse-grained sand and cobbles below 11.3 m.

Silt Till - Tan to grey, moist, dense, with fine to coarse grained sand, some fine to coarse grained gravel, trace cobbles, possible boulders.

REFUSAL AT 13.73 m BELOW GRADE

Notes:
1. Installed Slope Inclinometer casing at 13.72 m below grade with a 0.89 m stick up.
2. Installed two (2) Vibrating Wire (VW) Piezometers
   - 1702394 @ 4.98 m below grade in the upper Silty Clay
   - 1702395 @ 9.25 m below grade in the lower Silty Clay

SAMPLE TYPE ▨ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	D. FLYNN	DEA	10/5/17

KGS GROUP

SUMMARY LOG

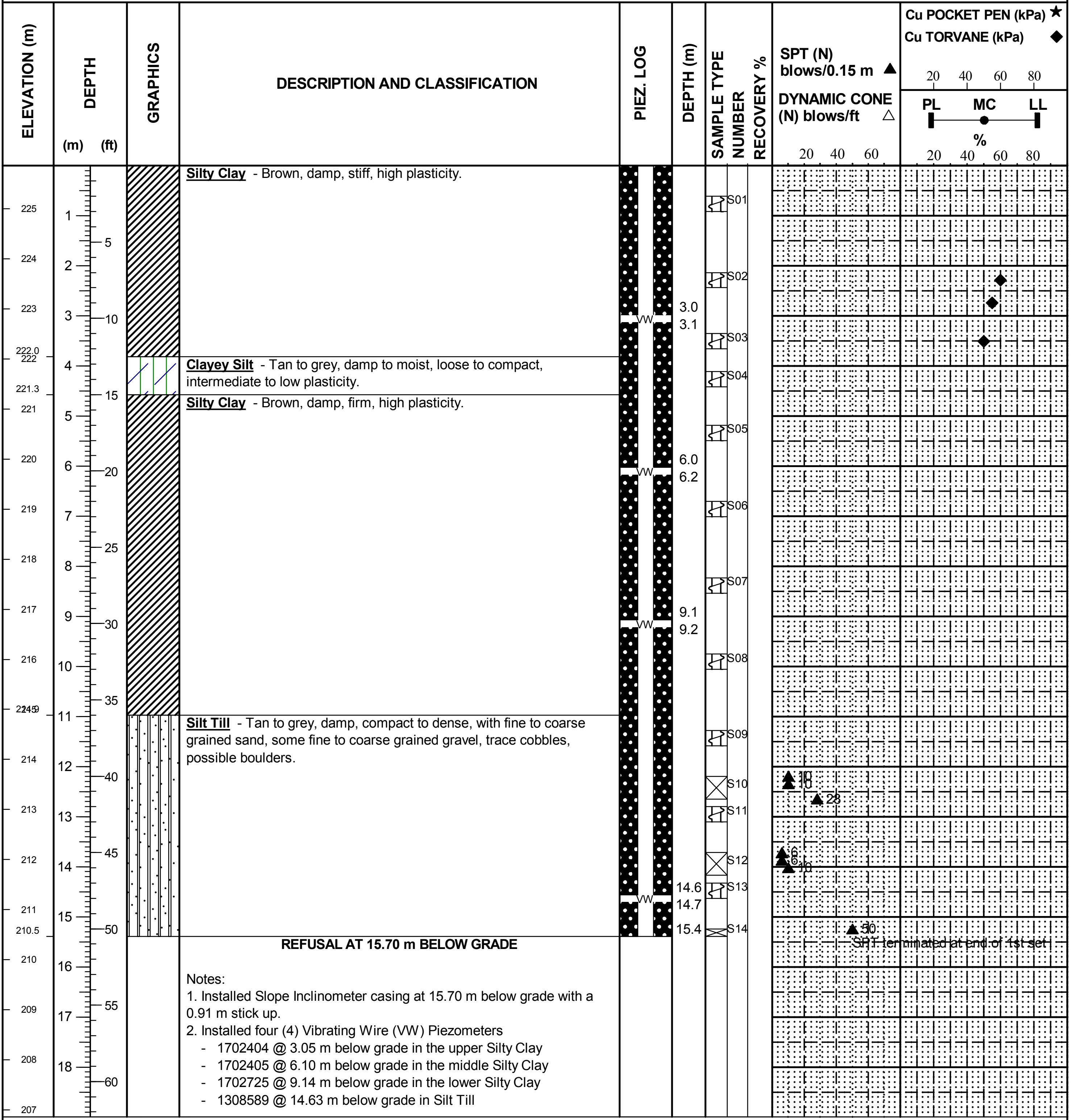
REFERENCE NO.

HOLE NO.
SI17-04

SHEET 1 of 1

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Seine River Aqueduct
SITE Seine River Aqueduct
LOCATION Lower Bank in Bush
DRILLING METHOD Track Mounted Rig B54X

JOB NO. 17-0107-008
GROUND ELEV. 225.86 m
TOP OF CASING ELEV. 226.81 m
WATER ELEV.
DATE DRILLED 9/19/2017
UTM (m) N 635,586 E 5,528,862



Silty Clay - Brown, damp, stiff, high plasticity.

Clayey Silt - Tan to grey, damp to moist, loose to compact, intermediate to low plasticity.

Silty Clay - Brown, damp, firm, high plasticity.

Silt Till - Tan to grey, damp, compact to dense, with fine to coarse grained sand, some fine to coarse grained gravel, trace cobbles, possible boulders.

REFUSAL AT 15.70 m BELOW GRADE

Notes:
1. Installed Slope Inclinometer casing at 15.70 m below grade with a 0.91 m stick up.
2. Installed four (4) Vibrating Wire (VW) Piezometers
    - 1702404 @ 3.05 m below grade in the upper Silty Clay
    - 1702405 @ 6.10 m below grade in the middle Silty Clay
    - 1702725 @ 9.14 m below grade in the lower Silty Clay
    - 1308589 @ 14.63 m below grade in Silt Till

SAMPLE TYPE ⊞ Auger Grab ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	10/5/17

KGS GROUP

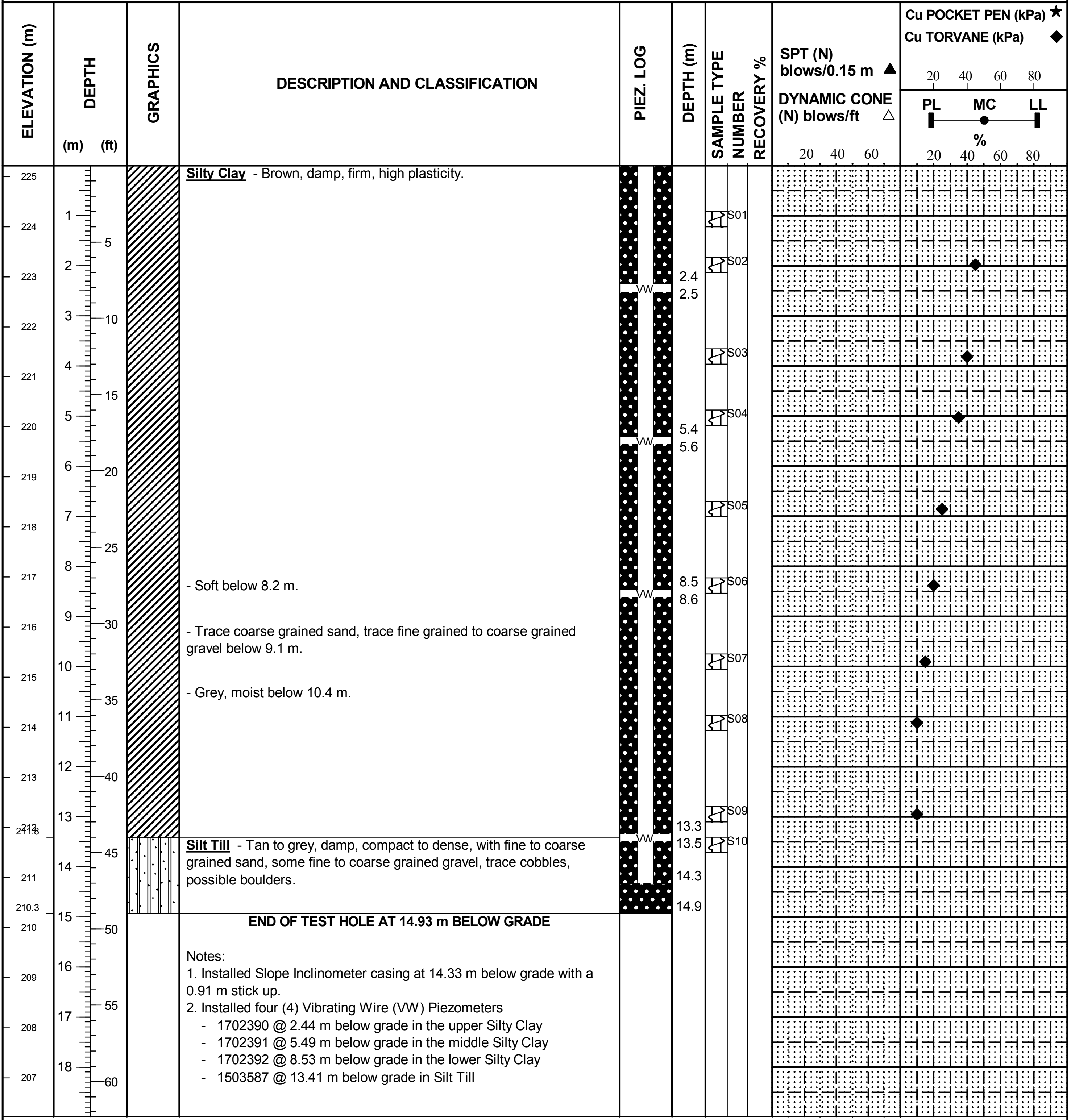
SUMMARY LOG

REFERENCE NO.

HOLE NO. **SI17-05**

SHEET 1 of 1

CLIENT	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT	JOB NO.	17-0107-008
PROJECT	Seine River Aqueduct	GROUND ELEV.	225.22 m
		TOP OF CASING ELEV.	226.20 m
SITE	Seine River Aqueduct	WATER ELEV.	
LOCATION	Lower Bank in Bush	DATE DRILLED	9/18/2017
		UTM (m)	N 635,571
DRILLING METHOD	Track Mounted Geoprobe 7822DT		E 5,528,852



Silty Clay - Brown, damp, firm, high plasticity.

- Soft below 8.2 m.

- Trace coarse grained sand, trace fine grained to coarse grained gravel below 9.1 m.

- Grey, moist below 10.4 m.

Silt Till - Tan to grey, damp, compact to dense, with fine to coarse grained sand, some fine to coarse grained gravel, trace cobbles, possible boulders.

END OF TEST HOLE AT 14.93 m BELOW GRADE

Notes:

1. Installed Slope Inclinometer casing at 14.33 m below grade with a 0.91 m stick up.
2. Installed four (4) Vibrating Wire (VW) Piezometers
    - 1702390 @ 2.44 m below grade in the upper Silty Clay
    - 1702391 @ 5.49 m below grade in the middle Silty Clay
    - 1702392 @ 8.53 m below grade in the lower Silty Clay
    - 1503587 @ 13.41 m below grade in Silt Till

SAMPLE TYPE ⍂ Auger Grab

CONTRACTOR	INSPECTOR	APPROVED	DATE
Maple Leaf Drilling Ltd.	K. HAMILTON	DEA	10/5/17

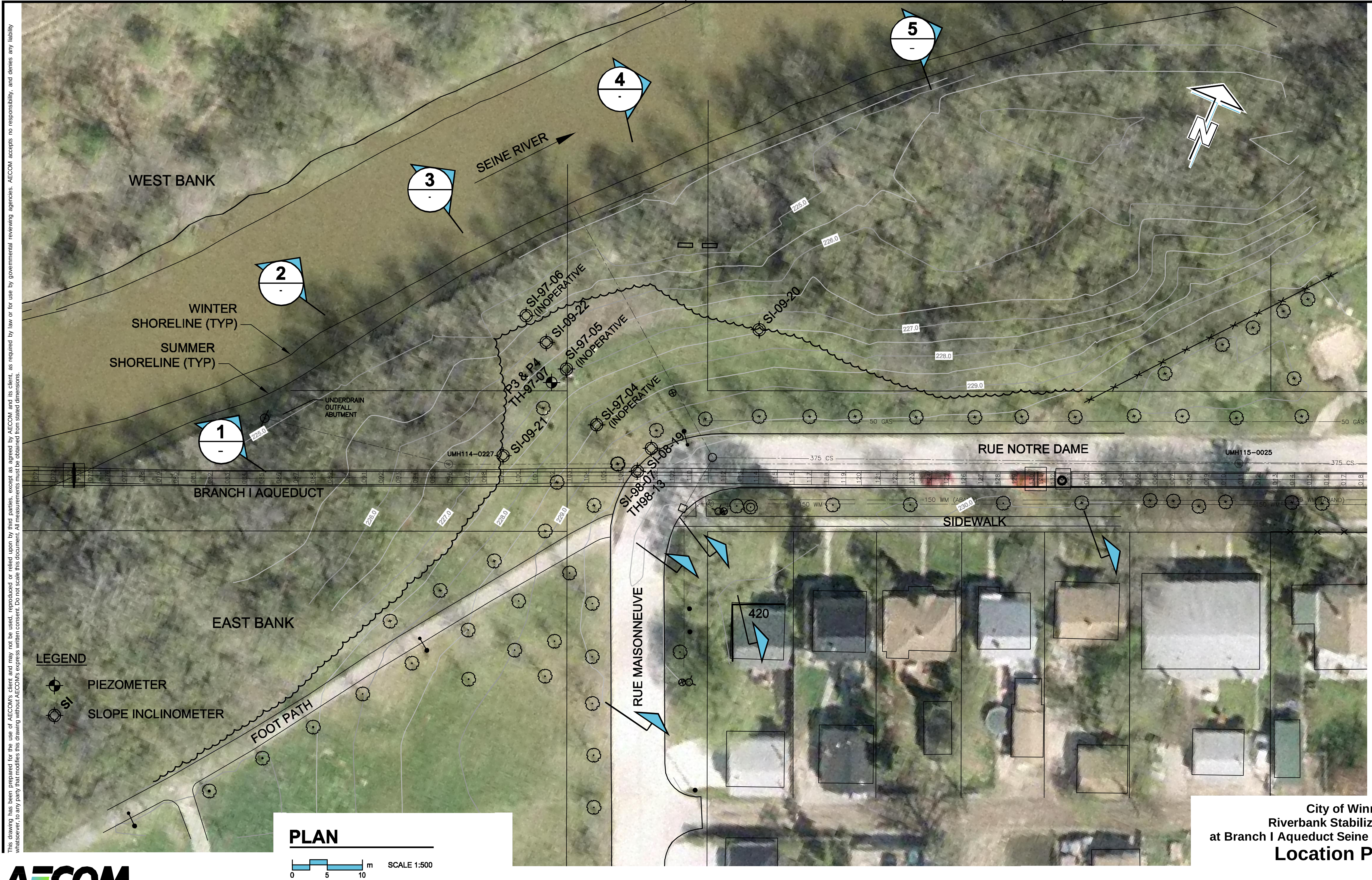
B SIZE 11" x 17" (279.4mm x 431.8mm)

PLOT: 10/09/14 3:09:45 PM

Saved By: cloustonc

ISS/REV: A

AECOM FILE NAME: D265-237-00_02-B-F001_RX.dwg



PLAN

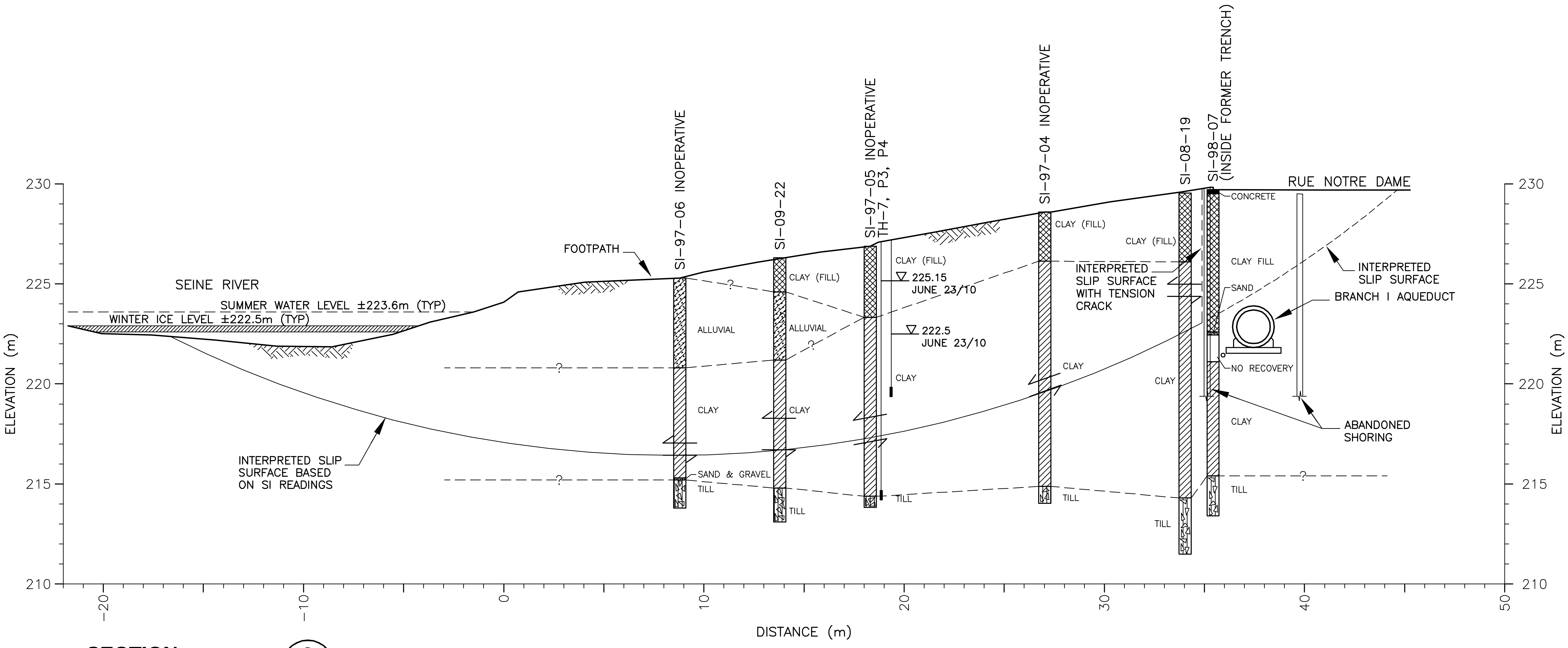
SCALE 1:500

AECOM

City of Winnipeg
Riverbank Stabilization
at Branch I Aqueduct Seine River

Location Plan

Drawing - 01



SECTION 3
01

0 2 4 m SCALE 1:200

LEGEND

▩ FILL	▩ SAND & GRAVEL	⇆ ZONE OF DETECTED MOVEMENT
▥ SILT	▨ CLAY (ALLUVIUM)	
▨ CLAY	▩ TILL	
░ SAND	■ CONCRETE	

AECOM

City of Winnipeg
Riverbank Stabilization
at Branch I Aqueduct Seine River

East Bank
Cross Section 3
Drawing - 02