APPENDIX A – GEOTECHNICAL INVESTIGATION REPORT

Burrows Avenue Outfall Gate Chamber Upgrades
Geotechnical Investigation Report

Prepared for:
Mr. Mark Baker, P.Eng.
MPE Engineering Ltd.
125 Higgins Avenue
Winnipeg, MB, R3B 0B6

Project Number: 0512 001 00

Date: July 5, 2019

July 5, 2019 Our File No. 0512 001 00

Mr. Mark Baker, P.Eng
MPE Engineering Ltd.
125 Higgins Avenue
Winnipeg, MB, R3B 0B6

RE: Burrows Avenue Outfall Gate Chamber Upgrades
Geotechnical Investigation Report

TREK Geotechnical Inc. is pleased to submit our Final Report for the geotechnical investigation 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	BT	July 5, 2019	Final Report

Authorization Signatures

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ENGINEERS
GEOSCIENTISTS
MANITOBA
Certificate of Authorization
TREK GEOTECHNICAL INC.
No. 4877 Date: July 5, 2019

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1.0 Introduction

This report summarizes the results of the geotechnical investigation completed by TREK Geotechnical Inc. (TREK) for the proposed outfall gate chamber upgrades at Burrows Avenue in Winnipeg, Manitoba. The terms of reference for the investigation are included in our proposal to Mr. Mark Baker, P.Eng. of MPE Engineering Ltd. (MPE) dated February 26, 2019. The scope of work includes a geotechnical sub-surface investigation, installation and monitoring of a standpipe piezometer, laboratory testing and the provision of geotechnical/hydrogeological recommendations for design and construction of the proposed upgrades. Other considerations such as lateral earth pressures for permanent walls and temporary shoring are also included in this report. This report will provide supporting documentation for a City of Winnipeg Waterways permit application for site development.

2.0 Background and Site Conditions

The existing chamber is located approximately 35 m west from the top of bank of the Red River at an outside bend of the river as shown on Figure 01. The riverbank slope generally extends from the river level (at El. 223.6 m±) at approximately 11H:1V (Horizontal to Vertical) to El.225.7m± becoming steeper to El.230.2 m± at approximately 6H:1V. The steeper portion of riverbank is vegetated with grass. TREK understands that stabilization measures (rockfill columns and riprap) have previously been constructed in this area.

The proposed upgrades will include a new cell to accommodate a new flap gate and the construction of a second new cell to accommodate a pump out chamber. The existing chamber will be left in place and modified, with existing gate and appurtenances to be replaced. The proposed works will involve excavation below the existing chamber invert in order to facilitate the construction of the new cell.

3.0 Field Program

3.1 Site Survey

A topographic survey at the site was performed by Eng-Tech Consulting Ltd. on behalf of MPE on May 13, 2019, however test hole drilling was not yet completed at the time of the survey. Test hole location and site features within riverbank area (top of bank, toe of bank, river level, etc) were surveyed by TREK on June 18, 2019.

3.2 Subsurface Investigation

A subsurface investigation was undertaken on May 28, 2019 under the supervision of TREK personnel to determine the soil stratigraphy and groundwater conditions at the site. One test hole (TH19-01) was drilled approximately 9 m west from the west edge of the existing gate chamber and 1.3 m south from the north median curb. The test hole was drilled using an Acker MP5-T track-mounted drill rig equipped with 125 mm diameter solid stem augers to 16.5 m depth below ground surface. A standpipe (SP-01) was installed in the test hole at 16.2 m depth below ground surface. The test hole was backfilled with sand to 11.9 m depth and a combination of bentonite and auger cuttings to ground surface. The location of the test hole is shown on Figure 01.

Subsurface soils observed during drilling were visually classified based on the Unified Soil Classification System (USCS). Samples retrieved during drilling included disturbed auger cuttings, split spoon and relatively undisturbed Shelby tube samples. All samples retrieved during drilling were transported to TREK's testing laboratory in Winnipeg, Manitoba. Laboratory testing consisted of moisture contents on all samples, Atterberg limit on silt and select clay samples, grain size analysis (hydrometer method) on select silt (till) samples and unconfined compressive testing were performed on select Shelby tube samples. Laboratory testing results are included in Appendix A.

A brief description of the soil stratigraphy and groundwater conditions encountered during drilling is provided in the following sections. All interpretations of soil stratigraphy for the purposes of design should refer to the detailed information provided on the attached test hole logs.

3.2.1 *Soil Stratigraphy*

The soil stratigraphy in descending order consists of organic clay (topsoil), silt, silty clay and silt (till). The organic clay (topsoil) is 0.5 m thick in TH19-01, is moist, very stiff and of high plasticity. A 0.9 m thick layer of silt was encountered beneath the topsoil, and is moist, firm and of low plasticity. Silty clay was encountered at 1.4 m depth below ground surface and extended to 13.7 m depth below ground surface. The silty clay is moist, firm to stiff becoming soft to firm with depth and of high plasticity. The silt (till) was observed beneath the silty clay and extended to the depth of power auger refusal at 16.5 m below ground surface. The silt (till) is moist below 13.9 m depth below ground surface, is dense and becoming very dense with depth.

3.2.2 *Groundwater and Sloughing Conditions*

Seepage was observed in silt (till) between 13.7 m and 13.9 m depth below ground surface. A standpipe SP-01 was installed within silt (till). Table 1 summarizes the water level monitoring results in SP-01 as well as river level elevation at the site.

Table 1 SP-01 Monitoring Results

Date (year 2019)	Elevation (m)	
	SP-01	River
May 28	216.55	n/a
June 18	223.85	223.58
June 25	223.99	223.70

Sloughing was encountered between 13.7 m and 15.2 m depth below ground surface.

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

4.0 Riverbank Stability and Waterways Permit

The proposed upgrading works are not expected to negatively impact the existing riverbank stability as there will be no increase in loading at the top of the bank in the vicinity of the gate chamber. However, staging areas, material stockpiles and equipment storage during construction should be limited to approved areas relative to riverbank stability. Without a detailed assessment of riverbank stability, we recommend that staging of the work be limited to the extent of Burrows Avenue pavement, and any material stockpiles be situated west of the gate chamber location.

A Waterways Permit from the City of Winnipeg is required to carry out the work. It is expected that conditions of the permit are likely to include the stockpiling of materials well away from the top of bank and written right-of-access from any adjacent property owners where access may be required. It will also be necessary to restore any access or egress routes in the same or better condition than before construction. The Waterway Permit application should therefore include any proposed access and egress routes and stockpile locations.

5.0 Excavations and Shoring

It is understood that an excavation depth of about 11.5 m is required to construct the new gate chamber and that shoring for the excavation will be required.

5.1 Temporary Excavations

Based on the above excavation depth, conventional shoring will need to be braced or tied back. The earth pressure distribution provided in Figure 02 can be used for shoring design. An undrained shear strength of 30 kPa for the clay can be used for the design of shoring and the determination of an adequate factor of safety against toe instabilities. The undrained shear strengths were selected based on the measured undrained shear strength profile from all test types. 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.

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 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 lagging. Additional recommendations can be provided should infrastructure sensitive to settlement exist in close proximity to the excavation.

It is anticipated that the design of excavation slopes and temporary shoring will be the responsibility of the Contractor. Shoring designs or excavations greater than 3 m in height will need to be designed and sealed by a professional engineer and reviewed by TREK Geotechnical prior to construction to confirm the parameters and soil conditions used in design are consistent with the recommendations provided herein.

5.2 Groundwater Considerations

The lacustrine clay is underlain by a layer of till under confined groundwater pressures. As a result, the potential for base heave and/or groundwater seepage into excavations must be considered. If base heave occurs causing hydraulic fracturing of the clay, there exists a potential for groundwater seepage into the excavation. This event could be sudden and catastrophic in nature. In this regard, sufficient resisting forces are required to counteract groundwater pressures. The resisting forces are a function of the thickness and unit weight of the clay above the till and, to a lesser degree, shoring dimensions.

An adequate factor of safety against base heave is achieved when the groundwater level in the till is at or below El. 221.3 m for the proposed excavation depth (El. 220.8 m) and the excavation dimensions from the preliminary design. In comparison, a groundwater elevation of 223.9 m was measured in the till in June 2019. As described in Section 3.2.2 it is anticipated that water levels in the till fluctuate with river levels however this cannot be confirmed at this time. If this is the case, the groundwater levels in the till may be closer to El. 222.0 m during the winter when construction is anticipated, however this elevation is still higher than the groundwater level necessary to achieve an adequate factor of safety. It must also be recognized that groundwater levels are likely to increase during spring freshet before returning to normal summer levels. With a regulated summer river level of El. 223.7 m, the groundwater level in the till may approach El. 224 m. This range of levels is summarized in the Preliminary Desktop Hydrogeological Assessment report attached in Appendix B from W.L. Gibbons and Associates for the current project.

The current and future groundwater levels in the till are higher than the level necessary to maintain an adequate level of stability against base heave. In this regard, relief wells to depressurize the till and/or bedrock are required to achieve an adequate factor of safety against basal heave. Depressurization of the till for this type of project in Winnipeg is typically achieved by installing pumping wells into either the till or underlying bedrock. The number of wells and rate of water flow required to lower the water table can be highly variable as it depends on the quality of the bedrock as well as the permeability and thickness of the till (both till and bedrock are known to be highly variable in Winnipeg). The well(s) should be able to maintain the recommended safe groundwater elevation for the length of time the excavation is open and be able to accommodate fluctuations in groundwater elevations. It is important to note that even with an adequate factor of safety against base heave, the potential for seepage into the excavation exists when the groundwater elevation is above the base of the excavation. Should this occur, it will be necessary to dewater the excavation and/or lower the groundwater to an elevation lower than the base. The number and size of wells necessary to lower groundwater levels will depend on the permeability and thickness of the till or bedrock which can be highly variable.

Based on the anticipated need for depressurization of the till we recommend that a pump test be performed by a qualified hydrogeologist to determine the necessary pumping requirements. As a part of this test, groundwater quality should be evaluated to determine if it is acceptable to discharge directly into the river. The results of the pump test should be included in the tender package for the project as permitting and dewatering are expected to be the responsibility of the contractor.

The recommended safe groundwater elevation is a function of excavation depth and shoring dimensions and should be re-calculated for any base elevation other than El. 220.8 m or if there are changes in shoring dimensions. As it appears likely that the till daylights into the river channel at this location, depressurization of the till may require significant effort. The effort required will primarily be a function of the till permeability which can also be highly variable.

Alternatively, a tremied concrete plug at the base of the excavation can be poured prior to dewatering the excavation, instead of depressurizing the till and/or bedrock. This type of approach should be used only if an adequate seal to the shoring can be achieved, if the thickness of the tremied concrete plug is feasible, and where the shoring will be left in place. In some cases, the thickness of the tremie plug can be significant and may not be constructible. In our experience, this technique has been most successful where secant pile walls are used as shoring, which can be incorporated into the permanent chamber walls if desired. Additional recommendations for a tremie plug design can be provided, if required.

5.3 Earth Pressures Against New Gate Chamber

TREK understands that the gate chamber excavation outside of the structure is to be backfilled for its full depth (D) using Type 2 fill (as per City of Winnipeg Specification CW2030) compacted to at least 95% Standard Proctor Maximum Dry Density (SPMDD). It is also our understanding that the distance between the shoring and the gate chamber walls will be approximately one metre. It should be recognized that lateral earth pressures induced by compaction against rigid structural walls may be greater than the at-rest pressure and earth pressure coefficients of 1.0 or higher are possible. The earth pressure coefficient is difficult to predict as it depends on several factors including the type, geometry and moisture content of the backfill material and the compactive effort applied. In this regard, it is generally recommended to lightly compact (in the order of 92% of SPMDD) the backfill in close proximity to buried walls unless a higher degree of compaction is necessary *e.g.* for pipe bedding or where minimizing surface settlement is required. Compensation for any settlement can be made in the final grading to provide positive drainage away from the structure. We estimate that backfill compacted in this manner (lightly) will ultimately settle by a maximum of about 2% of the fill depth. For the upper 0.6 m, clay backfill soils should be used to create a low-permeability cap.

Based on the limited space available between the shoring and structure, lateral pressures against the gate chamber are expected to be governed by the properties of the surrounding clay soil. We recommend that a small vibratory plate compactor or flood tamping be used for compaction. If this is the case, then earth pressures against the wall can be calculated using a triangular pressure distribution according to the following equation:

$$\mathbf{P = k_0 \gamma D}$$

Where P = lateral earth pressure at depth D (kPa)
k_0 = at-rest earth pressure coefficient (0.7)
γ = unit weight (17 kN/m^3)
D = depth from surface to the point of the pressure calculation (m)

Lateral earth pressures from surcharge loads (if applicable), or for heavy compaction equipment (if used) should be accounted for in design, TREK can provide recommendations for loading should they be needed. If drainage is not provided at the base of the gate chamber, the buoyant soil unit weight should be used and hydrostatic water pressure added assuming a water level coincident with the ground surface. The shoring geometry, backfill types and compaction methods should be reviewed during final design.

6.0 Foundations

Structures of this nature are often supported by a raft foundation buried deep into the soil where part (or all) of the loads may be compensated by the weight of removed soil. Based on the design elevation from the preliminary design (El. 220.8 m), foundation soils are expected to consist of soft to firm lacustrine clays. For a raft slab bearing at El. 220.8 m, we recommend ULS and SLS bearing capacities of 280 kPa and 250 kPa, respectively. For unfactored bearing pressures less than the SLS bearing capacity, settlement is expected to consist primarily of elastic recompression (due to the weight of soil removed) and be less than 25mm. Should such settlement not be acceptable, a deep foundation system consisting of either cast-in-place or driven piles could be considered. Aside from consolidation settlement, vertical displacements of the structure can occur if changes in the moisture content of the clay occur during construction, in this case drying. Measures to minimize the drying potential, for example a mud slab, should be considered. Uplift (buoyant) forces acting against the access chamber should also be considered in design and a groundwater level at existing ground surface should be used.

7.0 Closure

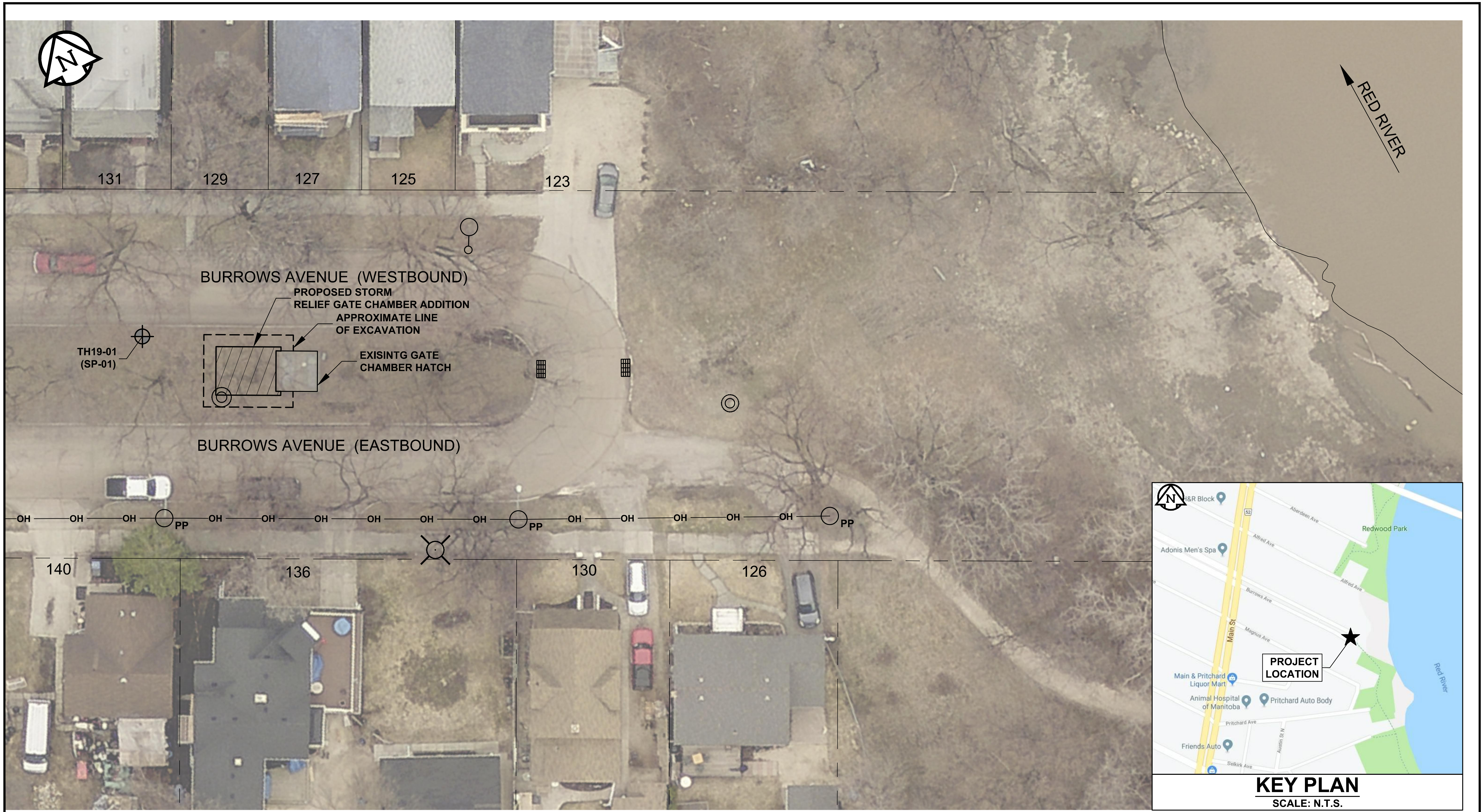
The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation and laboratory testing). Soil conditions are natural deposits that can be highly variable across a site. If subsurface 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 the MPE Engineering Ltd. (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

0512 001 00
MPE Engineering Ltd.
Burrows Avenue Outfall Gate Chamber Upgrades



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

LEGEND:

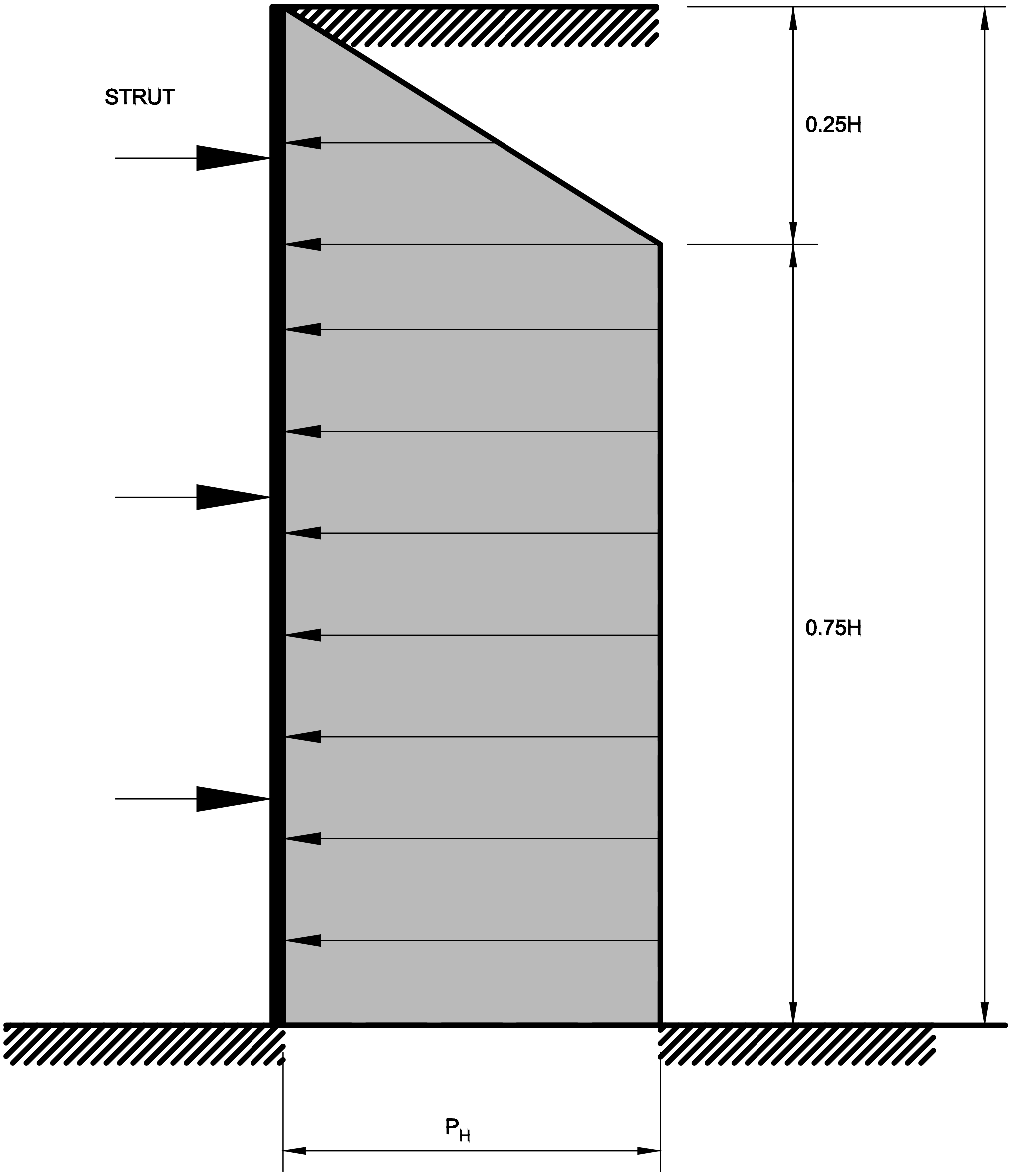
⊕ TEST HOLE (TREK, MAY 2019)
EXISTING FIRE HYDRANT
◎ EXISTING MANHOLE
○—○ EXISTING LIGHTPOST
○ PP EXISTING HYDRO POLE
▦ EXISTING SEWER GRATE
— — — EXISTING PROPERTY LINE
—OH—OH— EXISTING OVERHEAD POWER LINE

NOTES:

1. AERIAL IMAGE FROM CITY OF WINNIPEG 2016

Figure 01
TEST HOLE LOCATION PLAN

Z:\Projects\0512 MPE Engineering\0512 001 00 Burrows Outfall Gate Chambers Upgrades\3 Survey and Dwg\3.4 CAD\3.4.3 Working Folder\FIG 01_19-07-04_BURROWS OUTFALL_0_C_DW_0512-001-00.dwg, 7/4/2019 2:37:43 PM
ANSI full bleed B (11.00 x 17.00 Inches)



$P_H = \gamma H - m\, 4\, S_u$

WHERE:
P_H = LATERAL EARTH PRESSURE (kPa)
H = DEPTH OF EXCAVATION (m)
γ = BULK SOIL UNIT WEIGHT (17.7 kN/m³)
m = 0.4
S_u = UNDRAINED SHEAR STRENGTH (30 kPa)

NOTE:

- ADD SURFACE LOAD SURCHARGE IF APPLICABLE

Figure 02

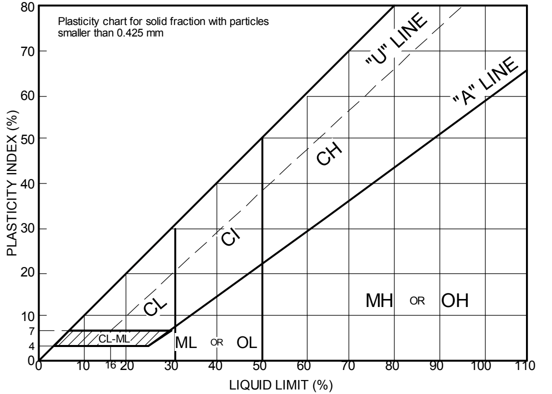
Lateral Earth Pressure Distribution
Braced Excavation in Clay

Test Hole Logs

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United 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 mm	Particle Size ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

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

* 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

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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

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

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Sub-Surface Log

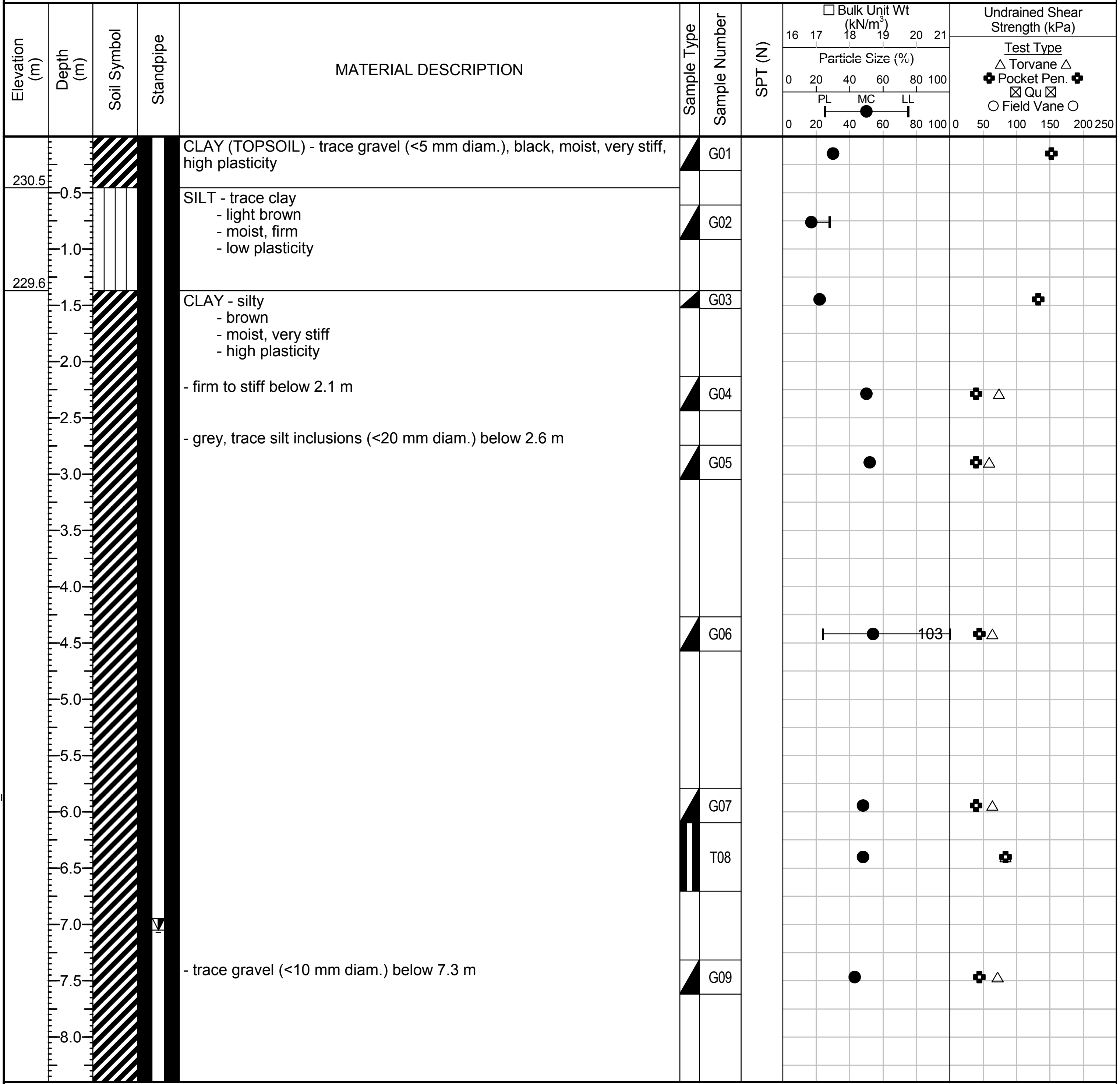
Test Hole TH19-01

Client: MPE Engineering
Project Name: Burrows Outfall Gate Chambers Upgrades
Contractor: Maple Leaf Drilling Ltd.
Method: Acker MP5-T Track Mount
Project Number: 0512-001-00
Location: UTM N-5530749.532, E-634309.703
Ground Elevation: 230.98 m
Date Drilled: May 28, 2019

Sample Type: ◩ Grab (G) ▮ Shelby Tube (T) ⊠ Split Spoon (SS) ⧗ Split Barrel (SB) ▯ Core (C)

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

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



MATERIAL DESCRIPTION

CLAY (TOPSOIL) - trace gravel (<5 mm diam.), black, moist, very stiff, high plasticity

SILT - trace clay
- light brown
- moist, firm
- low plasticity

CLAY - silty
- brown
- moist, very stiff
- high plasticity

- firm to stiff below 2.1 m

- grey, trace silt inclusions (<20 mm diam.) below 2.6 m

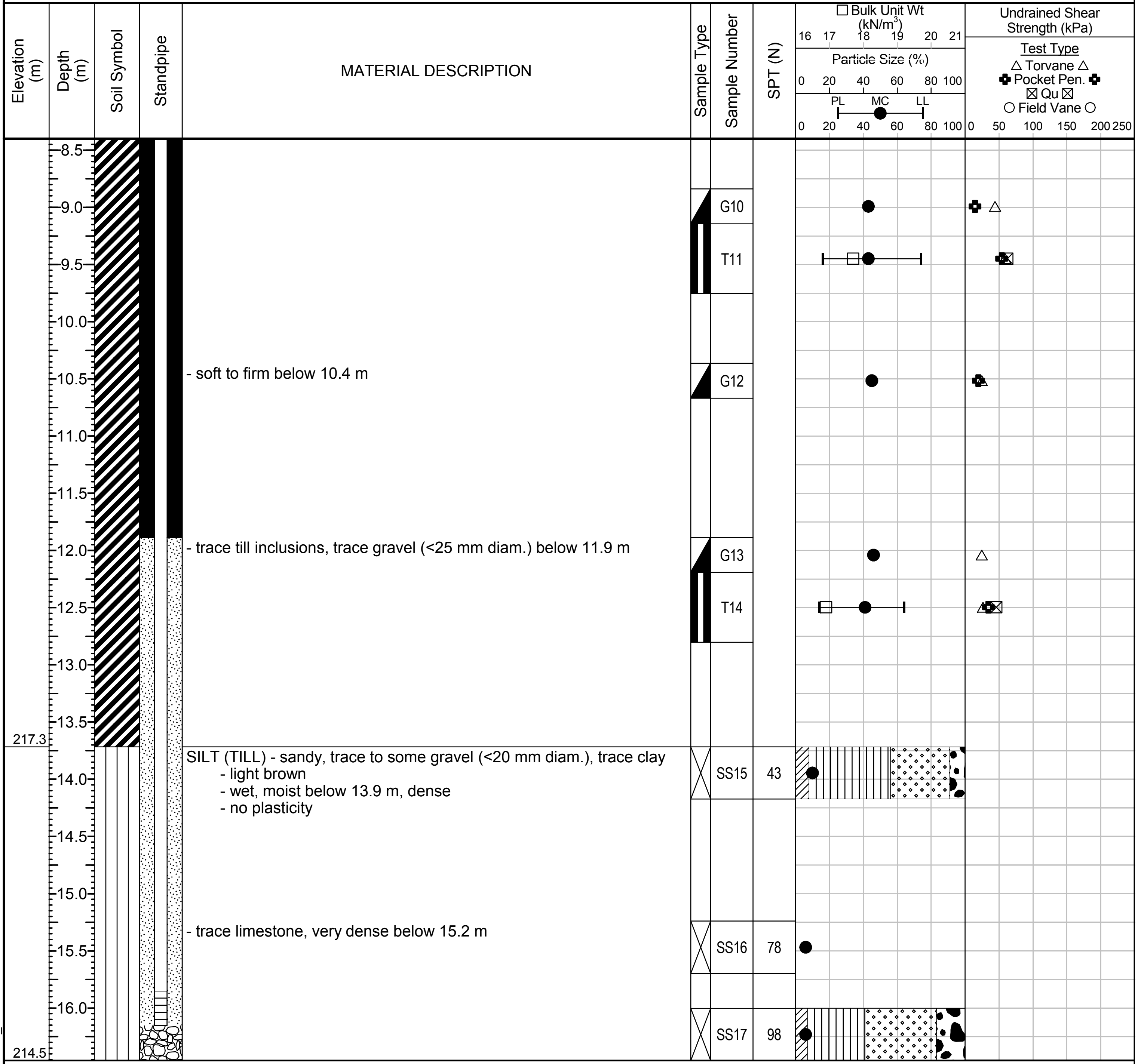
- trace gravel (<10 mm diam.) below 7.3 m

Logged By: Micha Roemer **Reviewed By:** Kent Bannister **Project Engineer:** Michael Van Helden

Sub-Surface Log

Test Hole TH19-01

2 of 2



- soft to firm below 10.4 m

- trace till inclusions, trace gravel (<25 mm diam.) below 11.9 m

SILT (TILL) - sandy, trace to some gravel (<20 mm diam.), trace clay
- light brown
- wet, moist below 13.9 m, dense
- no plasticity

- trace limestone, very dense below 15.2 m

G10	
T11	
G12	
G13	
T14	
SS15	43
SS16	78
SS17	98

POWER AUGER REFUSAL AT 16.5 m DEPTH IN SILT (TILL)

Notes:
1. Seepage between 13.7 m and 13.9 m below ground surface in SILT (TILL).
2. Sloughing between 13.7 m and 15.2 m below ground surface in SILT (TILL).
3. Test hole open to 16.0 m immediately after completion of drilling.
4. Standpipe SP-01 installed in SILT (TILL) at 16.2 m depth below ground surface.
5. Test hole backfilled with sand from 16.2 m to 11.9 m and combination of bentonite and auger cuttings from 11.9 m to ground surface.
6. Water level below ground surface in SP-01 at 14.4 m (fifteen minutes after SP-01 installation) and at 7.1 m (June 18, 2019)

Logged By: Micha Roemer **Reviewed By:** Kent Bannister **Project Engineer:** Michael Van Helden

Appendix A

Laboratory Testing Results

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

MEMORANDUM

Date	June 18, 2019
To	Micha Roemer, TREK Geotechnical
From	Angela Fidler-Kliewer, TREK Geotechnical
Project No.	0512-001-00
Project	Burrows Outfall Gate Chambers Upgrades
Subject	Laboratory Testing Results – Lab Req. R19-116
Distribution	Michael Van Helden

Attached are the laboratory testing results for the above noted project. The testing included moisture content determinations, Atterberg limits, particle size distribution (Hydrometer method) and unconfined compression tests with related testing on Shelby tube samples.

Regards,

Angela Fidler-Kliewer, C.Tech.

Attach.

Review Control:

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

LABORATORY REQUISITION

CLIENT MPE Engineering

PROJECT NAME Burrows Outfall Gate Chambers Upgrades

PROJECT NO: 0512-001-00

FIELD TECHNICIAN: Micha Roemer

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					Soil Description/Comments
TH19-01	G01	0.0 - 1.0		X											
TH19-01	G02	2.0 - 3.0		X		X									
TH19-01	G03	4.5 - 5.0		X											
TH19-01	G04	7.0 - 8.0		X											
TH19-01	G05	9.0 - 10.0		X											
TH19-01	G06	14.0 - 15.0		X		X									
TH19-01	G07	19.0 - 20.0		X											
TH19-01	T08	20.0 - 22.0		X											
TH19-01	G09	24.0 - 25.0		X											
TH19-01	G10	29.0 - 30.0		X											
TH19-01	T11	30.0 - 32.0		X		X				X					
TH19-01	G12	34.0 - 35.0		X											
TH19-01	G13	39.0 - 40.0		X											
TH19-01	T14	40.0 - 42.0		X		X				X					
TH19-01	SS15	45.0 - 46.5		X			X								
TH19-01	SS16	50.0 - 51.5		X											
TH19-01	SS17	52.5 - 54.0		X			X								

REQUESTED BY: Micha Roemer

REQUISITION DATE: Jun 7/19

COMMENTS:

REPORT TO: MR, MVH

DATE REQUIRED: Jun 14/19

REQUISITION NO. R19-116

PAGE 1 OF 1

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Moisture Content Report
ASTM D2216-10

Project No. 0512-001-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Sample Date 28-May-19
Test Date 7-Jun-19
Technician AD

Test Hole	TH19-01	TH19-01	TH19-01	TH19-01	TH19-01	TH19-01
Depth (m)	0.0 - 0.3	0.6 - 0.9	1.4 - 1.5	2.1 - 2.4	2.7 - 3.0	4.3 - 4.6
Sample #	G01	G02	G03	G04	G05	G06
Tare ID	AB53	K29	Z104	F153	A107	D45
Mass of tare	6.8	8.2	8.4	8.4	8.4	8.4
Mass wet + tare	165.4	347.4	172.8	184.6	164.0	315.2
Mass dry + tare	128.4	298.0	143.0	125.6	110.6	208.0
Mass water	37.0	49.4	29.8	59.0	53.4	107.2
Mass dry soil	121.6	289.8	134.6	117.2	102.2	199.6
Moisture %	30.4%	17.0%	22.1%	50.3%	52.3%	53.7%

Test Hole	TH19-01	TH19-01	TH19-01	TH19-01	TH19-01	TH19-01
Depth (m)	5.8 - 6.1	6.1 - 6.7	7.3 - 7.6	8.8 - 9.1	10.4 - 10.7	11.9 - 12.2
Sample #	G07	T08	G09	G10	G12	G13
Tare ID	AB54	AB47	W83	N62	C18	W86
Mass of tare	6.4	6.8	8.4	8.2	8.4	8.4
Mass wet + tare	216.9	306.9	239.6	176.6	169.2	166.8
Mass dry + tare	148.4	209.2	170.2	126.2	119.4	117.2
Mass water	68.5	97.7	69.4	50.4	49.8	49.6
Mass dry soil	142.0	202.4	161.8	118.0	111.0	108.8
Moisture %	48.2%	48.3%	42.9%	42.7%	44.9%	45.6%

Test Hole	TH19-01	TH19-01	TH19-01			
Depth (m)	13.7 - 14.2	15.2 - 15.7	16.0 - 16.5			
Sample #	SS15	SS16	SS17			
Tare ID	F6	F144	A19			
Mass of tare	8.6	8.6	8.8			
Mass wet + tare	327.0	120.0	325.8			
Mass dry + tare	297.6	113.6	307.0			
Mass water	29.4	6.4	18.8			
Mass dry soil	289.0	105.0	298.2			
Moisture %	10.2%	6.1%	6.3%			

Atterberg Limits
ASTM D4318-10e1

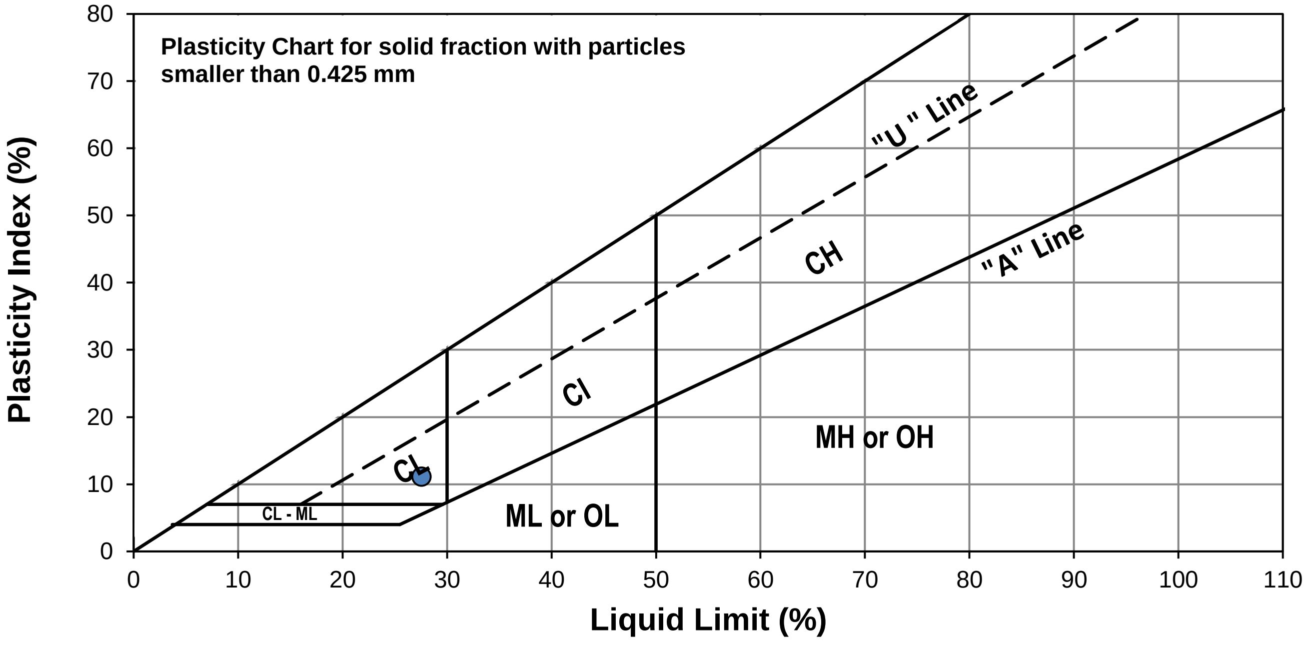
Project No. 0512-001-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Test Hole TH19-01
Sample # G02
Depth (m) 0.6 - 0.9
Sample Date 28-May-19
Test Date 12-Jun-19
Technician AD/NM

Liquid Limit	28
Plastic Limit	16
Plasticity Index	11

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	18	26	35		
Mass Wet Soil + Tare (g)	26.426	23.307	23.497		
Mass Dry Soil + Tare (g)	23.649	21.317	21.510		
Mass Tare (g)	14.074	14.037	13.890		
Mass Water (g)	2.777	1.990	1.987		
Mass Dry Soil (g)	9.575	7.280	7.620		
Moisture Content (%)	29.003	27.335	26.076		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.171	14.305			
Mass Wet Soil + Tare (g)	21.750	22.176			
Mass Dry Soil + Tare (g)	20.664	21.082			
Mass Water (g)	1.086	1.094			
Mass Dry Soil (g)	6.493	6.777			
Moisture Content (%)	16.726	16.143			

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Atterberg Limits
ASTM D4318-10e1

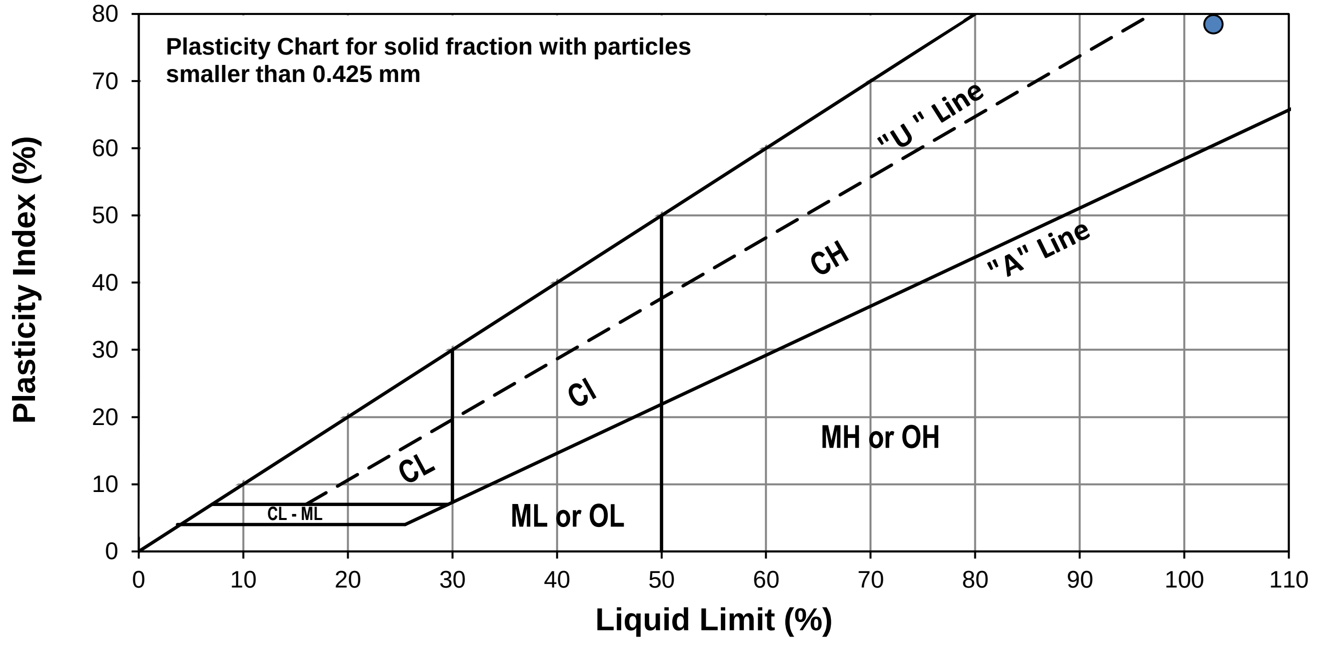
Project No. 0512-001-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Test Hole TH19-01
Sample # G06
Depth (m) 4.3 - 4.6
Sample Date 28-May-19
Test Date 12-Jun-19
Technician AD

Liquid Limit	103
Plastic Limit	24
Plasticity Index	78

Liquid Limit

Trial #	1	2	3		
Number of Blows (N)	15	24	30		
Mass Wet Soil + Tare (g)	21.226	21.991	23.760		
Mass Dry Soil + Tare (g)	17.588	18.020	18.930		
Mass Tare (g)	14.238	14.183	14.125		
Mass Water (g)	3.638	3.971	4.830		
Mass Dry Soil (g)	3.350	3.837	4.805		
Moisture Content (%)	108.597	103.492	100.520		



Plastic Limit

Trial #	1	2	3	4	5
Mass Tare (g)	14.222	13.967			
Mass Wet Soil + Tare (g)	17.967	18.036			
Mass Dry Soil + Tare (g)	17.229	17.246			
Mass Water (g)	0.738	0.790			
Mass Dry Soil (g)	3.007	3.279			
Moisture Content (%)	24.543	24.093			

Atterberg Limits
ASTM D4318-10e1

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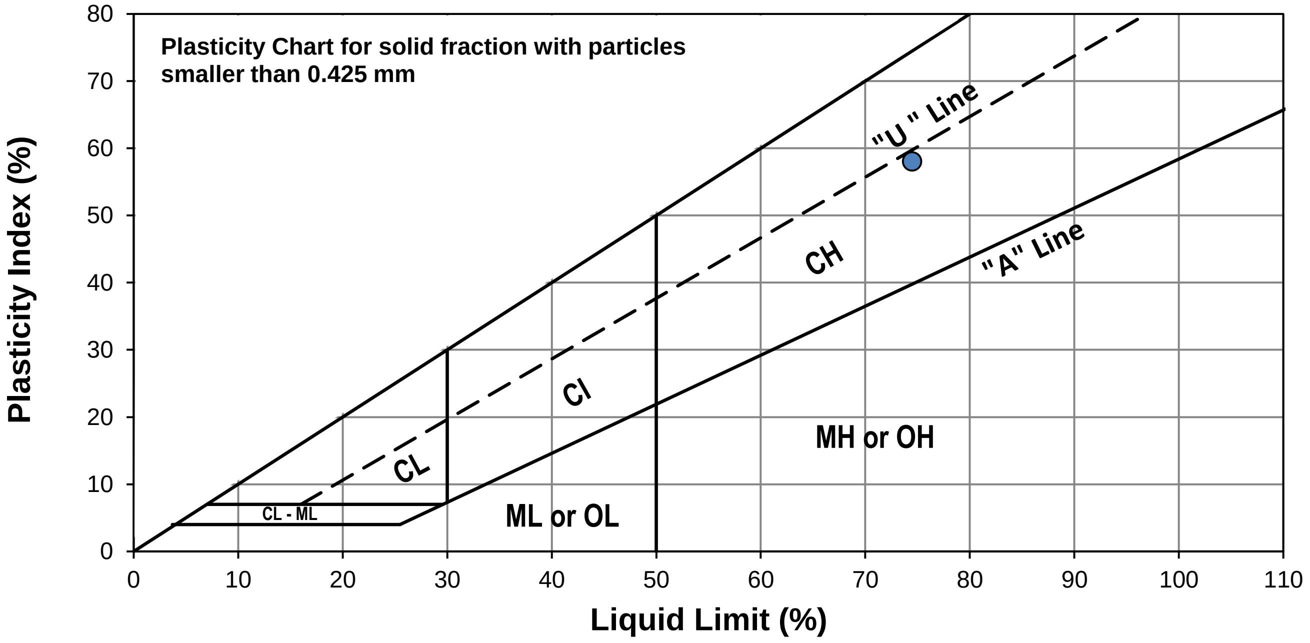
For specific tests as listed on www.ccil.com

Project No.	0512-001-00
Client	MPE Engineering
Project	Burrows Outfall Gate Chambers Upgrades
Test Hole	TH19-01
Sample #	T11
Depth (m)	9.1 - 9.8
Sample Date	28-May-19
Test Date	13-Jun-19
Technician	AD

Liquid Limit	74
Plastic Limit	16
Plasticity Index	58

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	16	20	31		
Mass Wet Soil + Tare (g)	22.060	23.075	22.557		
Mass Dry Soil + Tare (g)	18.576	19.268	19.023		
Mass Tare (g)	14.126	14.294	14.153		
Mass Water (g)	3.484	3.807	3.534		
Mass Dry Soil (g)	4.450	4.974	4.870		
Moisture Content (%)	78.292	76.538	72.567		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.155	14.029			
Mass Wet Soil + Tare (g)	18.877	18.061			
Mass Dry Soil + Tare (g)	18.196	17.504			
Mass Water (g)	0.681	0.557			
Mass Dry Soil (g)	4.041	3.475			
Moisture Content (%)	16.852	16.029			

Atterberg Limits
ASTM D4318-10e1

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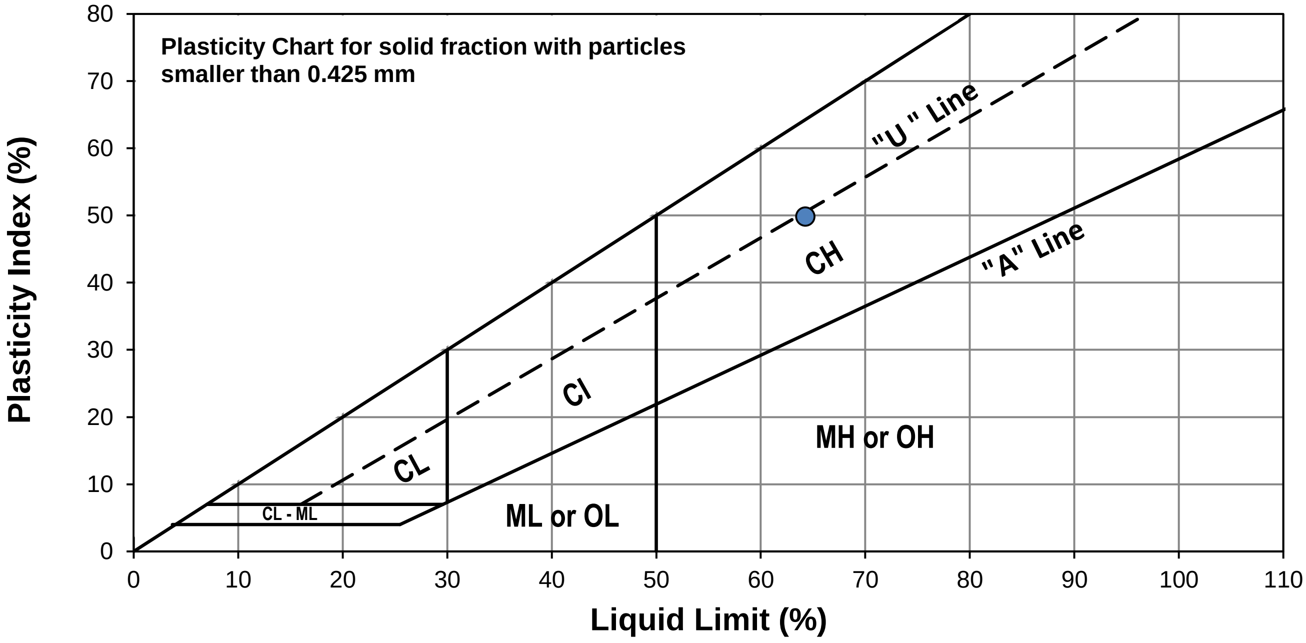
Project No.	0512-001-00
Client	MPE Engineering
Project	Burrows Outfall Gate Chambers Upgrades
Test Hole	TH19-01
Sample #	T14
Depth (m)	12.2 - 12.8
Sample Date	28-May-19
Test Date	13-Jun-19
Technician	AD

Liquid Limit	64
Plastic Limit	14
Plasticity Index	50

Liquid Limit

Trial #	**1**	**2**	**3**		
Number of Blows (N)	19	24	32		
Mass Wet Soil + Tare (g)	24.868	23.285	24.862		
Mass Dry Soil + Tare (g)	20.573	19.628	20.714		
Mass Tare (g)	14.131	13.999	14.005		
Mass Water (g)	4.295	3.657	4.148		
Mass Dry Soil (g)	6.442	5.629	6.709		
Moisture Content (%)	66.672	64.967	61.827		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Tare (g)	14.241	14.165			
Mass Wet Soil + Tare (g)	19.303	18.315			
Mass Dry Soil + Tare (g)	18.649	17.802			
Mass Water (g)	0.654	0.513			
Mass Dry Soil (g)	4.408	3.637			
Moisture Content (%)	14.837	14.105			

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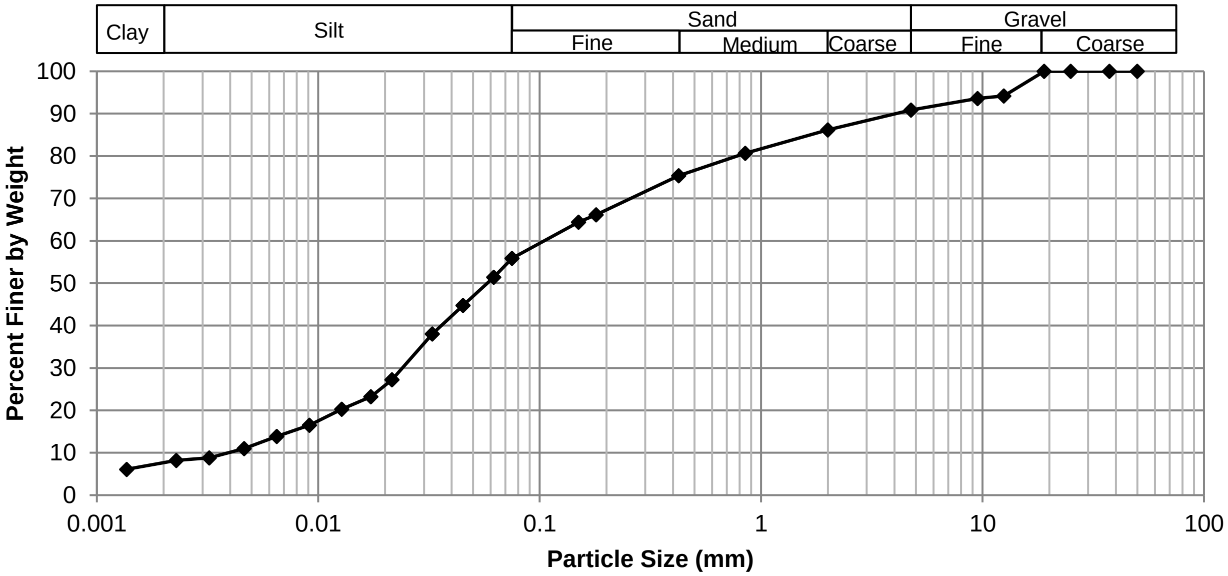
Grain Size Analysis (Hydrometer Method)
ASTM D422

Project No. 0512-001-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Test Hole TH19-01
Sample # SS15
Depth (m) 13.7 - 14.2
Sample Date 28-May-19
Test Date 10-Jun-19
Technician AD

Gravel	9.1%
Sand	35.0%
Silt	48.4%
Clay	7.5%

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	90.89	0.0750	55.88
37.5	100.00	2.00	86.15	0.0620	51.44
25.0	100.00	0.850	80.68	0.0451	44.77
19.0	100.00	0.425	75.36	0.0327	38.03
12.5	94.17	0.180	66.18	0.0216	27.26
9.50	93.60	0.150	64.42	0.0173	23.22
4.75	90.89	0.075	55.88	0.0128	20.26
				0.0091	16.49
				0.0065	13.86
				0.0046	11.02
				0.0032	8.79
				0.0023	8.24
				0.0014	6.12

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Grain Size Analysis (Hydrometer Method)
ASTM D422

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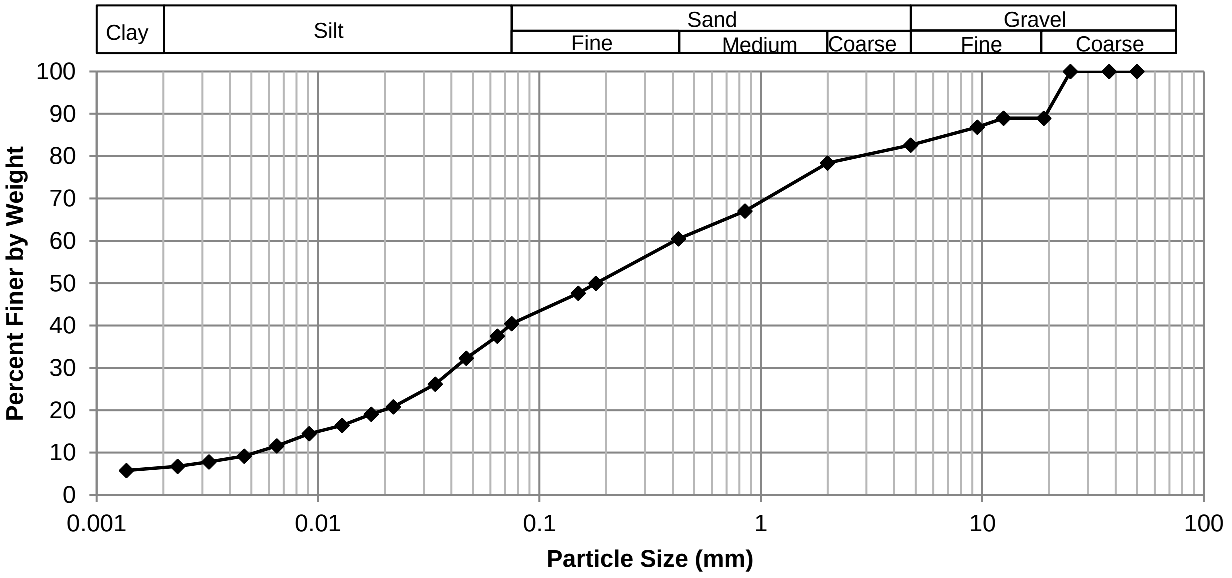
Project No.	0512-001-00
Client	MPE Engineering
Project	Burrows Outfall Gate Chambers Upgrades
Test Hole	TH19-01
Sample #	SS17
Depth (m)	16.0 - 16.5
Sample Date	28-May-19
Test Date	10-Jun-19
Technician	AD/SB

Gravel	17.4%
Sand	42.1%
Silt	34.0%
Clay	6.5%

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	82.63	0.0750	40.49
37.5	100.00	2.00	78.37	0.0647	37.49
25.0	100.00	0.850	67.05	0.0468	32.34
19.0	88.97	0.425	60.50	0.0339	26.21
12.5	88.97	0.180	49.98	0.0219	20.82
9.50	86.85	0.150	47.62	0.0174	19.11
4.75	82.63	0.075	40.49	0.0129	16.41
				0.0091	14.50
				0.0065	11.60
				0.0046	9.19
				0.0032	7.85
				0.0023	6.80
				0.0014	5.79

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Shelby Tube Visual

Project No. 0512-001-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Test Hole TH19-01
Sample # T11
Depth (m) 9.1 - 9.8
Sample Date 28-May-19
Test Date 10-Jun-19
Technician AD

Tube Extraction

Recovery (mm) 700 (overpush)

Bottom - 9.8 m	9.75 m	9.56 m	9.39 m	9.29 m **Top - 9.1 m**
Toss	Keep	Qu Bulk	Moisture Content Visual PP/TV	Toss
90 mm	190 mm	170 mm	100 mm	150 mm

Visual Classification

Material	CLAY
Composition	silty
trace gravel (<20 mm diam.)	
trace silt inclusions (<10 mm diam.)	
trace coarse sand	
Color	dark grey
Moisture	moist
Consistency	stiff
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.70
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	68.7

Pocket Penetrometer

Reading	**1**	1.30
	2	1.30
	3	1.40
	Average	1.33
Undrained Shear Strength (kPa)		65.4

Moisture Content

Tare ID	E38
Mass tare (g)	8.4
Mass wet + tare (g)	378.8
Mass dry + tare (g)	267.8
Moisture %	42.8%

Unit Weight

Bulk Weight (g)		1111.4
Length (mm)	**1**	151.52
	2	152.20
	3	152.56
	4	151.83
Average Length (m)		0.152
Diam. (mm)	**1**	71.65
	2	71.96
	3	71.49
	4	71.96
Average Diameter (m)		0.072
Volume (m^3)		6.15E-04
Bulk Unit Weight (kN/m^3)		17.7
Bulk Unit Weight (pcf)		112.8
Dry Unit Weight (kN/m^3)		12.4
Dry Unit Weight (pcf)		79.0

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Unconfined Compressive Strength

ASTM D2166

Project No.	0493-002-00
Client	MPE Engineering
Project	Burrows Outfall Gate Chambers Upgrades

Test Hole	TH19-01
Sample #	T11
Depth (m)	9.1 - 9.8
Sample Date	28-May-19
Test Date	10-Jun-19
Technician	AD

Unconfined Strength

	kPa	ksf
Max q_u	124.4	2.6
Max S_u	62.2	1.3

Specimen Data

Description CLAY - silty, trace gravel (<20 mm diam.), trace silt inclusions (<10 mm diam.), trace coarse sand , dark grey, moist, stiff, high plasticity

Length	152.0	(mm)
Diameter	71.8	(mm)
L/D Ratio	2.1	
Initial Area	0.00404	(m^2)
Load Rate	1.00	(%/min)

Moisture %	43%	
Bulk Unit Wt.	17.7	(kN/m^3)
Dry Unit Wt.	12.4	(kN/m^3)
Liquid Limit	-	
Plastic Limit	-	
Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.70	68.7	1.43
Vane Size		
m		

Pocket Penetrometer

	Reading	**Undrained Shear Strength**	
	tsf	**kPa**	**ksf**
	1.30	63.8	1.33
	1.30	63.8	1.33
	1.40	68.7	1.43
Average	**1.33**	**65.4**	**1.37**

Failure Geometry

Sketch:

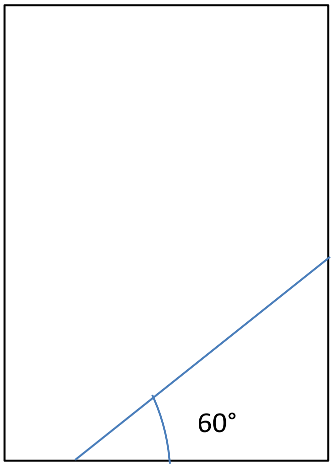


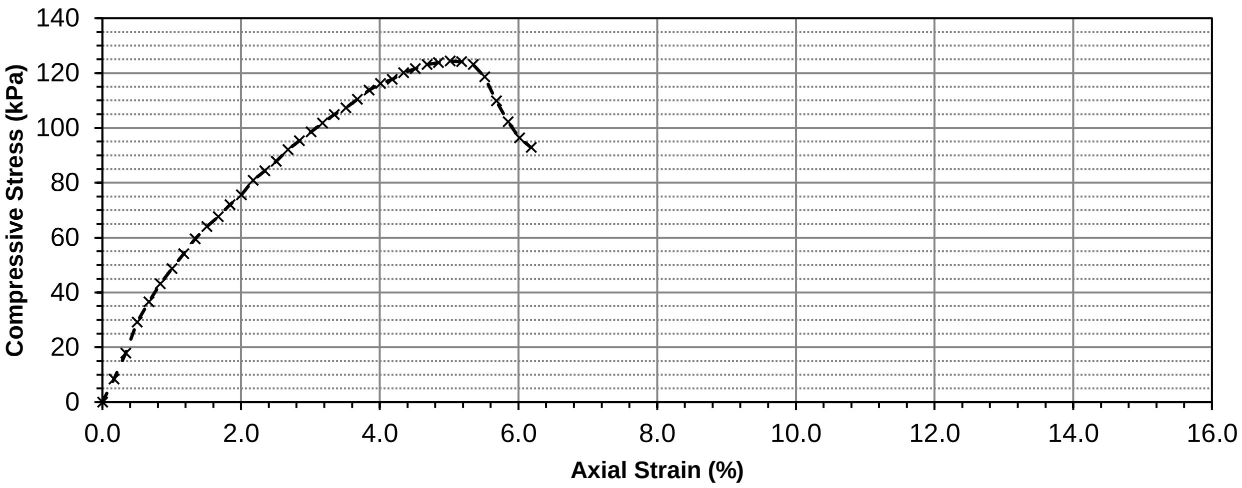
Photo:

Unconfined Compressive Strength

ASTM D2166

Project No. 0493-002-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

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	0.0000	0.00	0.004045	0.0	0.00	0.00
10	9	0.2540	0.17	0.004052	34.1	8.40	4.20
20	19	0.5080	0.33	0.004059	72.3	17.82	8.91
30	31	0.7620	0.50	0.004065	118.3	29.09	14.55
40	39	1.0160	0.67	0.004072	148.9	36.56	18.28
50	46	1.2700	0.84	0.004079	175.7	43.07	21.54
60	52	1.5240	1.00	0.004086	198.6	48.59	24.30
70	58	1.7780	1.17	0.004093	221.2	54.05	27.02
80	64	2.0320	1.34	0.004100	243.9	59.48	29.74
90	69	2.2860	1.50	0.004107	262.7	63.98	31.99
100	73	2.5400	1.67	0.004114	277.8	67.54	33.77
110	78	2.7940	1.84	0.004121	296.6	71.98	35.99
120	82	3.0480	2.00	0.004128	311.6	75.48	37.74
130	88	3.3020	2.17	0.004135	334.0	80.78	40.39
140	92	3.5560	2.34	0.004142	349.0	84.26	42.13
150	96	3.8100	2.51	0.004149	363.9	87.72	43.86
160	101	4.0640	2.67	0.004156	382.4	92.02	46.01
170	105	4.3180	2.84	0.004163	396.6	95.25	47.63
180	109	4.5720	3.01	0.004170	410.7	98.48	49.24
190	113	4.8260	3.17	0.004178	424.8	101.69	50.84
200	117	5.0800	3.34	0.004185	438.9	104.89	52.44
210	120	5.3340	3.51	0.004192	449.5	107.24	53.62
220	124	5.5880	3.68	0.004199	463.7	110.41	55.21
230	128	5.8420	3.84	0.004207	478.2	113.68	56.84

Unconfined Compressive Strength

ASTM D2166

Project No. 0493-002-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

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	131	6.0960	4.01	0.004214	489.2	116.09	58.05
250	133	6.3500	4.18	0.004221	496.5	117.63	58.81
260	136	6.6040	4.34	0.004229	507.5	120.03	60.01
270	138	6.8580	4.51	0.004236	514.9	121.55	60.77
280	140	7.1120	4.68	0.004243	522.2	123.06	61.53
290	141	7.3660	4.85	0.004251	525.9	123.71	61.86
300	142	7.6200	5.01	0.004258	529.6	124.36	62.18
310	142	7.8740	5.18	0.004266	529.6	124.14	62.07
320	141	8.1280	5.35	0.004273	525.9	123.06	61.53
330	136	8.3820	5.51	0.004281	507.5	118.56	59.28
340	126	8.6360	5.68	0.004289	470.9	109.80	54.90
350	117	8.8900	5.85	0.004296	438.9	102.17	51.09
360	110	9.1440	6.01	0.004304	414.2	96.24	48.12
370	106	9.3980	6.18	0.004311	400.1	92.80	46.40

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

Shelby Tube Visual

Project No.	0512-001-00
Client	MPE Engineering
Project	Burrows Outfall Gate Chambers Upgrades
Test Hole	TH19-01
Sample #	T14
Depth (m)	12.2 - 12.8
Sample Date	28-May-19
Test Date	11-Jun-19
Technician	AD

Tube Extraction

Recovery (mm) 710 (overpush)

Bottom - 12.9 m — **Top - 12.2 m**

	12.84 m	12.67 m	12.50 m	12.39 m
Toss	Keep	Qu Bulk	Moisture Content Visual PP/TV	Toss
60 mm	170 mm	170 mm	110 mm	200 mm

Visual Classification

Material	CLAY
Composition	silty
trace gravel (<20 mm diam.)	
trace silt inclusions (<15 mm diam.)	
Color	dark grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	-
Gradation	-

Moisture Content

Tare ID	E38
Mass tare (g)	8.6
Mass wet + tare (g)	460
Mass dry + tare (g)	329.8
Moisture %	40.5%

Unit Weight

Bulk Weight (g)		1044.9
Length (mm)	**1**	150.13
	2	150.03
	3	149.88
	4	150.19
Average Length (m)		0.150
Diam. (mm)	**1**	71.62
	2	71.53
	3	72.03
	4	72.09
Average Diameter (m)		0.072
Volume (m^3)		6.08E-04
Bulk Unit Weight (kN/m^3)		16.9
Bulk Unit Weight (pcf)		107.3
Dry Unit Weight (kN/m^3)		12.0
Dry Unit Weight (pcf)		76.4

Torvane

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

Pocket Penetrometer

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

TREK GEOTECHNICAL
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1712 St. James Street
Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Unconfined Compressive Strength
ASTM D2166

Project No. 0493-002-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

Test Hole TH19-01
Sample # T14
Depth (m) 12.2 - 12.8
Sample Date 28-May-19
Test Date 11-Jun-19
Technician AD

Unconfined Strength

	kPa	ksf
Max q_u	91.7	1.9
Max S_u	45.9	1.0

Specimen Data

Description CLAY - silty, trace gravel (<20 mm diam.), trace silt inclusions (<15 mm diam.), dark grey, moist, firm, high plasticity

Length	150.1	(mm)	**Moisture %**	41%	
Diameter	71.8	(mm)	**Bulk Unit Wt.**	16.9	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	12.0	(kN/m^3)
Initial Area	0.00405	(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
0.35	34.3	0.72
Vane Size		
m		

Pocket Penetrometer

	Reading	Undrained Shear Strength	
	tsf	kPa	ksf
	0.70	34.3	0.72
	0.80	39.2	0.82
	0.80	39.2	0.82
Average	**0.77**	**37.6**	**0.79**

Failure Geometry

Sketch:

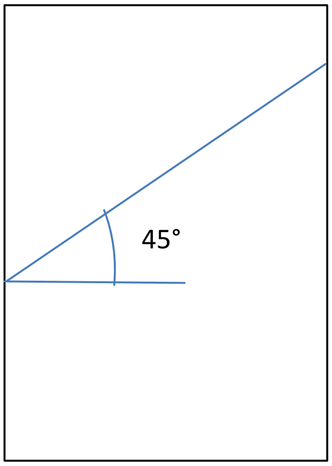


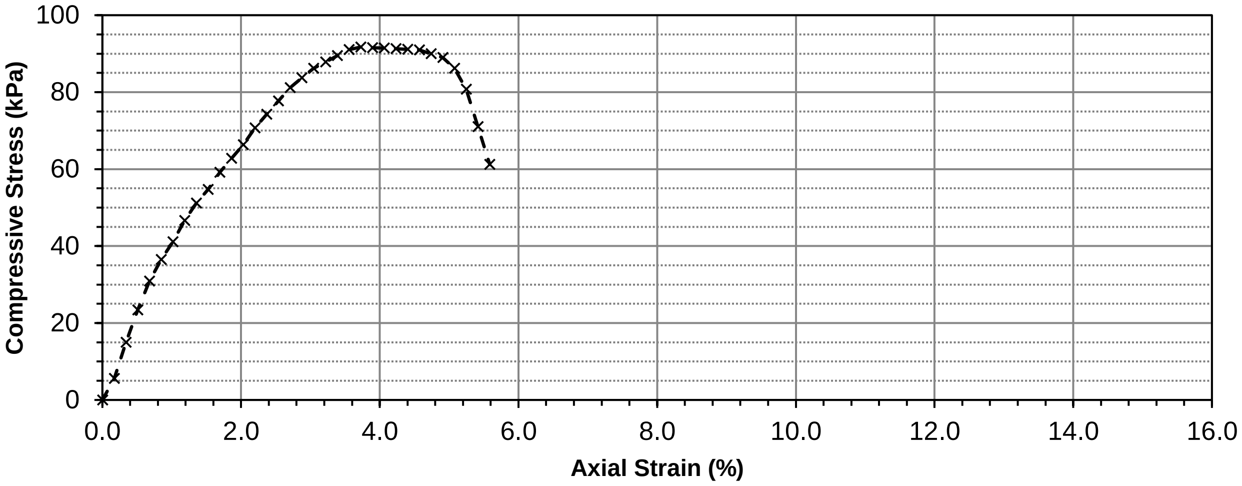
Photo:

Unconfined Compressive Strength

ASTM D2166

Project No. 0493-002-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

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	0.0000	0.00	0.004051	0.0	0.00	0.00
10	6	0.2540	0.17	0.004058	22.6	5.56	2.78
20	16	0.5080	0.34	0.004065	60.8	14.97	7.49
30	25	0.7620	0.51	0.004072	95.3	23.41	11.70
40	33	1.0160	0.68	0.004079	125.9	30.88	15.44
50	39	1.2700	0.85	0.004085	148.9	36.44	18.22
60	44	1.5240	1.02	0.004092	168.0	41.06	20.53
70	50	1.7780	1.18	0.004099	191.0	46.59	23.30
80	55	2.0320	1.35	0.004106	209.9	51.11	25.55
90	59	2.2860	1.52	0.004114	225.0	54.69	27.35
100	64	2.5400	1.69	0.004121	243.9	59.18	29.59
110	68	2.7940	1.86	0.004128	259.0	62.74	31.37
120	72	3.0480	2.03	0.004135	274.1	66.28	33.14
130	77	3.3020	2.20	0.004142	292.9	70.71	35.35
140	81	3.5560	2.37	0.004149	307.8	74.19	37.10
150	85	3.8100	2.54	0.004156	322.8	77.66	38.83
160	89	4.0640	2.71	0.004164	337.8	81.12	40.56
170	92	4.3180	2.88	0.004171	349.0	83.67	41.83
180	95	4.5720	3.05	0.004178	360.2	86.21	43.10
190	97	4.8260	3.22	0.004185	367.7	87.85	43.92
200	99	5.0800	3.39	0.004193	375.2	89.48	44.74
210	101	5.3340	3.55	0.004200	382.4	91.05	45.53
220	102	5.5880	3.72	0.004208	386.0	91.73	45.87
230	102	5.8420	3.89	0.004215	386.0	91.57	45.78

Unconfined Compressive Strength

ASTM D2166

Project No. 0493-002-00
Client MPE Engineering
Project Burrows Outfall Gate Chambers Upgrades

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	102	6.0960	4.06	0.004222	386.0	91.41	45.70
250	102	6.3500	4.23	0.004230	386.0	91.25	45.62
260	102	6.6040	4.40	0.004237	386.0	91.09	45.54
270	102	6.8580	4.57	0.004245	386.0	90.92	45.46
280	101	7.1120	4.74	0.004252	382.4	89.93	44.97
290	100	7.3660	4.91	0.004260	378.9	88.94	44.47
300	97	7.6200	5.08	0.004268	367.7	86.16	43.08
310	91	7.8740	5.25	0.004275	345.2	80.75	40.38
320	80	8.1280	5.42	0.004283	304.1	71.00	35.50
330	69	8.3820	5.59	0.004291	262.7	61.24	30.62

Appendix B

Preliminary Desktop Hydrogeological Report

W.L. Gibbons & Associates Inc.
64 St. Andrew Road Winnipeg, MB R2M 3H6

July 5, 2019 File: Burrows Outfall

Trek Geotechnical Inc.
1712 St. James Street
Winnipeg, MB R3H 0L3

Attention: Mr. Michael Van Helden, P.Eng.

Dear Mr. Van Helden:

RE: City of Winnipeg Burrows Outfall Gate Chamber
Potential Bedrock Groundwater Concerns
Preliminary Desktop Hydrogeologic Assessment

W.L. Gibbons & Associates Inc. (WLG) is pleased to provide the following report documenting the results of the preliminary desktop assessment of the hydrogeology relative to potential bedrock groundwater impacts during the construction of proposed upgrades to the Burrows Avenue Outfall Gate Chamber. Based on discussions with Trek personnel and other information provided by Trek, the following is the current understanding of the situation:

- Based on MMM Group Figure No. 3.02 entitled "Conceptual Gate Chamber Designs For Storm Relief Sewer Systems – Borrows Avenue Storm Relief Gate Chamber – Concrete Details" (dated March 30, 2015), it is understood that grade elevation at this site is at approximately 230.755 m (top of gate chamber concrete), and that the base of the concrete in the gate chamber will be at approximately 220.815 m. This indicates that an excavation to at least a depth of approximately 10.0 meters is required.
- A single auger test hole to refusal in till at a depth of 16.5 meters was drilled by Trek Geotechnical. A piezometer was installed in this test hole with the screen at a depth of 16.2 meters, within the till. A copy of the test hole log is included in Appendix A.
- Trek Geotechnical also provided the results of the monitoring of groundwater levels in the till piezometer on three dates, and the river level at the site on June 18 and 25, 2019.

Activities completed as part of this work program include the following:

- Review of the available published information on the hydrogeology of the area, including the geotechnical test hole logs completed by Trek personnel.
- Data assessment and reporting.

1.0 Regional Setting

Based on published information for the City of Winnipeg (Baracos et al, 1983), the subsurface geology in the area of the proposed gate chamber site consists of clay to a depth of approximately 12.5 to 18.3 meters, followed by up to 12.2 meters of glacial till. The bedrock beneath the site consists of brecciated dolomitic mudstone of the Lower Fort Garry Member of the Red River Formation, followed by mottled dolomitic limestone of the Selkirk Member.

Groundwater in significant quantities is found within the upper fractured bedrock, commonly referred to as the Carbonate Aquifer. This assessment is primarily concerned with the potential impacts associated with the groundwater in the upper aquifer zone, as this groundwater pressure is acting directly on the base of the overburden profile.

The provincial government maintains a network of groundwater level monitoring stations across the city. There are no long term groundwater level monitoring stations proximate to the Burrows Outfall Chamber site. Therefore, information from monitoring stations located west (OJ-025, McPhilips and Logan), east (OJ-009, Lagimodiere and Cordite), north (OJ-159, NEWPCC) of the site have been compiled and are included in Appendix B. The locations of these monitoring wells is shown on Figure 1. The following assessment of the regional bedrock groundwater pressure trends is based on this regional information and an extrapolation to the area of the Burrows site. Based on this information, the following is noted:

- Groundwater flow in the Carbonate Aquifer is towards the Red River (Figures 1 and 2), the natural point of discharge. Based on published provincial information from 2006 (Figures 1 and 2), the groundwater levels in the Burrows area are approximately 1.5 meters higher in winter than in summer. This seasonal trend in groundwater levels is reasonably typical in Winnipeg with lower levels in summer due to the consumptive use of groundwater for geothermal cooling. However, as is discussed in Section 2.0, proximate to the rivers, groundwater levels can respond to the annual fall drawdown in river levels, resulting in lower groundwater levels. The nature of the river to groundwater hydraulic connection is variable and needs to be established for each site.
- Groundwater levels in the bedrock aquifer have been rising since the 1970's (see Groundwater Stations OJ-009 and OJ-025, Appendix B). This rise is attributed to an overall decline in the consumptive use of groundwater in the Winnipeg area which is resulting in a gradual return of groundwater levels towards the natural predevelopment levels. Over the period of 1970 to 2009 (Figure 3), groundwater levels have risen by 4 to 5 meters in the Burrows Outfall area. This rise in groundwater levels has resulted in an increasing frequency of encountering bedrock groundwater issues during construction in Winnipeg.
- The highest groundwater levels were recorded in the spring of 2011 at all stations (Appendix B). This significant rise in groundwater levels coincides with the overall high precipitation and flooding that occurred in the early part of that year. Since the spring of 2011, groundwater levels have been declining and are currently in the range of 1 to 2 meters below that historic 2011 high.

- At Groundwater Station G05OJ159, a cyclic decline in groundwater levels occurs every summer. This decline is likely the result of the operation of a consumptive geothermal cooling system proximate to that monitoring station and is not indicative of overall trends in groundwater levels. The monitoring data from stations OJ-009 and OJ-025 is more indicative of the natural changes in groundwater levels over time.
- Long term groundwater levels records from the Carbonate Aquifer are not available for the immediate Burrows Outfall area. Therefore it is necessary to use the information from other groundwater monitoring stations to infer what the likely range of groundwater levels are at the Burrows site. A cursory assessment of this information suggests that the groundwater levels in the Burrows area likely range from 223 to 225 meters. Site specific groundwater level monitoring information is required to verify what the actual groundwater levels in the Carbonate Aquifer will be, particularly during the construction period.

Groundwater flow in the bedrock aquifer occurs within the fractures and joint sets in the rock. The size, extent and interconnectivity of these openings in the rock determine the degree of transmissivity (ie: the ability to transmit water) of the aquifer. As the transmissivity is a function of the degree of fracturing, the transmissivity and the well yield can vary substantially over short distances. Published maps of the transmissivity distribution in the area (Baracos et al, 1983) indicate that the transmissivity in the Burrows site area ranges from 1.4×10^{-4} to 1.4×10^{-3} m^2/s (1,000 to 10,000 USgpd/ft). This estimate of transmissivity is based on published regional information and it is reasonable to expect higher or lower transmissivities can be encountered at specific sites depending on the degree of fracturing of the bedrock. Site specific investigations are strongly recommended prior to design and tender to obtain the transmissivity estimate needed for design of a groundwater control system.

2.0 Site Specific Investigations

Site specific investigations at the Burrows Outfall site are limited to a single auger test hole completed by Trek Geotechnical. The test hole was drilled to auger refusal at a depth of 16.5 meters. The indicated soil profile consists of clay to a depth of 13.7 meters followed by silt till. The silt till is at least 2.8 meters thick at this site. Seepage and sloughing were observed in the silt till.

Trek Geotechnical provided the results of groundwater level monitoring in the piezometer installed in the tills on the day of the drilling and on June 18 and 25, 2019. This information is compiled on Figure 4, with the measured surface water level in the river at the site on June 18 and 25, 2019 and the Red River water levels at James Street. The initial water level reading on May 28, 2019 of approximately 216.5 meters was taken shortly after the piezometer was installed and it is considered very likely that groundwater levels had not yet stabilized in that piezometer. On June 18, 2019, the groundwater level in the piezometer was approximately 223.85 meters, and on June 25, 2019, the groundwater level in the piezometer was approximately 223.99 meters. The information indicates that groundwater pressures in the silt till was stabilizing at approximately 224.0 meters.

The limited water level monitoring information for this site suggests that the groundwater levels are slightly higher than the coinciding river levels and that a weak gradient towards the river may exist at this site. Such an observation of a potential hydraulic connection with the river is consistent with past observations at other sites in Winnipeg, and is consistent with expectations that the river is the natural point of discharge for a significant portion of the groundwater in the Carbonate Aquifer. At this stage, there is insufficient information to assess the degree of hydraulic connection between the river and the aquifer and how this may affect potential future needs to depressurize the aquifer to allow construction to proceed.

Per information provided by Trek Geotechnical, it is understood that the average winter water level (ice) in the river at Burrows is 222.08 meters, and that this level can rise in some winters to 224.08 meters (1% event). Assuming future studies confirm that there is a hydraulic connection between the river and the groundwater, it is reasonable to expect that the groundwater level in the winter (during the assumed period of construction) may be at approximately 222 meters, but could be as high as approximately 224 meters. Therefore, for preliminary design purposes, it should be assumed that there may be approximately 1.2 to 3.2 meters of excess groundwater pressure above the assumed base of excavation of 220.815 meters (base of concrete). The assessment of the need for groundwater depressurization during construction is the responsibility of geotechnical and other project personnel. If it is determined that groundwater depressurization is required, a hydrogeologic investigation should be conducted to obtain the information needed by the contractor to design a groundwater control system.

3.0 Existing Groundwater Users

As part of this desktop hydrogeologic assessment, an attempt was made to obtain preliminary information on potential groundwater users in the Burrows Outfall area. The provincial GWDRILL database containing the Driller's Reports for wells drilled within the province, and the Water Use Licensing Section database of existing licensed groundwater users within the area were reviewed. The search of the GWDRILL database identified at least 7 well records within 1.6 kms of the site that may be active water wells. The closest indicated water user is a geothermal system located at Austin and Euclid at a distance of 0.5 kms from the site. The status of these wells is unknown and will need to be verified before any groundwater control activities are undertaken to ensure existing groundwater users are not adversely impacted.

4.0 Conclusion and Recommendations

The results of this preliminary desktop assessment of the hydrogeology at the Burrows Outfall site has found that groundwater levels in the bedrock aquifer may be in the range of 223 to 225 meters, based on long term regional groundwater monitoring data. The limited site specific information to data indicates that groundwater levels may have been stabilizing in the 224.0 meter range, and that this groundwater level was slightly higher than the corresponding river level. This suggests that a hydraulic connection between the river and the aquifer may exist at this site, and that groundwater levels may respond to changing river levels. Further monitoring and hydrogeologic investigations are required to confirm these preliminary conclusions.

If future studies confirm that the hydraulic connection exists and that groundwater levels respond to changing river levels, it should be assumed for preliminary design purposes, that there may be approximately 1.2 to 3.2 meters of excess groundwater pressure above the assumed base of excavation of 220.815 meters (base of concrete). The assessment of the need for groundwater depressurization during construction is the responsibility of geotechnical and other project personnel.

If it is determined that groundwater depressurization is required, a hydrogeologic investigation should be conducted to obtain the information needed by the contractor to design a groundwater control system. The recommended hydrogeologic investigation program would include the following:

- The installation of a 125 mm diameter test well in the bedrock aquifer, a 50 mm diameter monitoring well in the bedrock aquifer, and the completion of a pumping test. During the pumping test, groundwater level changes in both the bedrock and till should be monitored to determine if the two are hydraulically connected. In addition, field tests of the discharge water quality should be completed to determine if any water quality changes occur that may indicate a hydraulic connection with the river.
- A monitoring program should be implemented that includes the digital recording of groundwater levels in both the till and any bedrock monitoring wells to monitor changes in levels over time, especially relative to any changes in the river levels over time.
- The information from this site specific testing should be assessed relative to the transmissivity of the aquifer, and the range of pumping rates that will likely be required to achieve the required level of groundwater depressurization.
- In addition to this site specific testing, an inventory of potential third party wells in the area of influence should be completed, a mitigation plan prepared in the event of adverse impacts, and approvals obtained from the provincial regulator to allow groundwater control activities to be completed during construction.

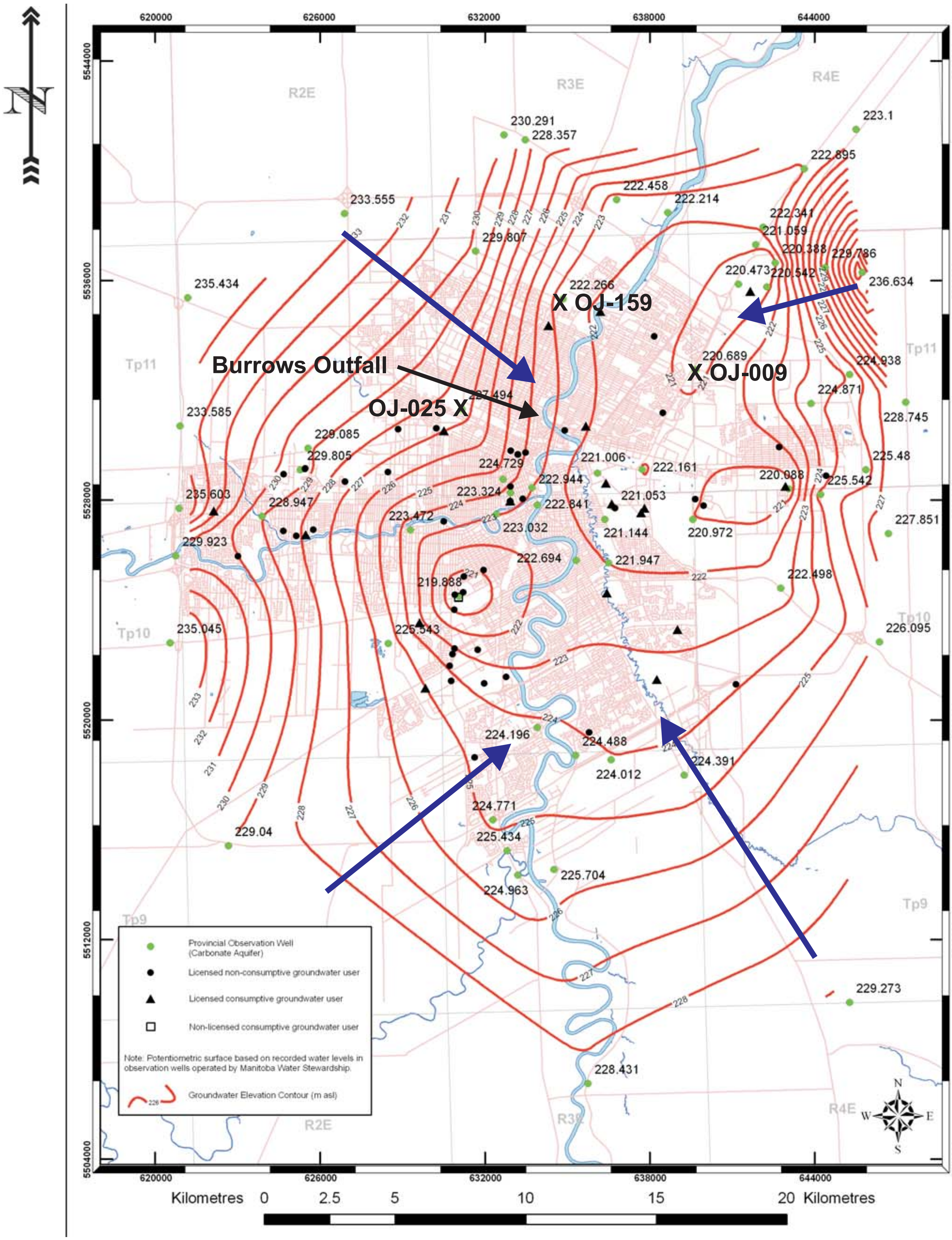
We trust that the preceding meets your requirements. If you have any questions or require further information, please contact the undersigned.

Sincerely,

PROVINCE OF MANITOBA
S. J.
WIECEK
REGISTERED PROFESSIONAL ENGINEER

Steve Wiecek, P.Geo., P.Eng.
Senior Geologic Engineer
swiecek@mts.net

APEGM
Certificate of Authorization
W. L. Gibbons and Associates Inc.
No. 4415 Date: 05/07/2019



→ - Groundwater Flow Direction

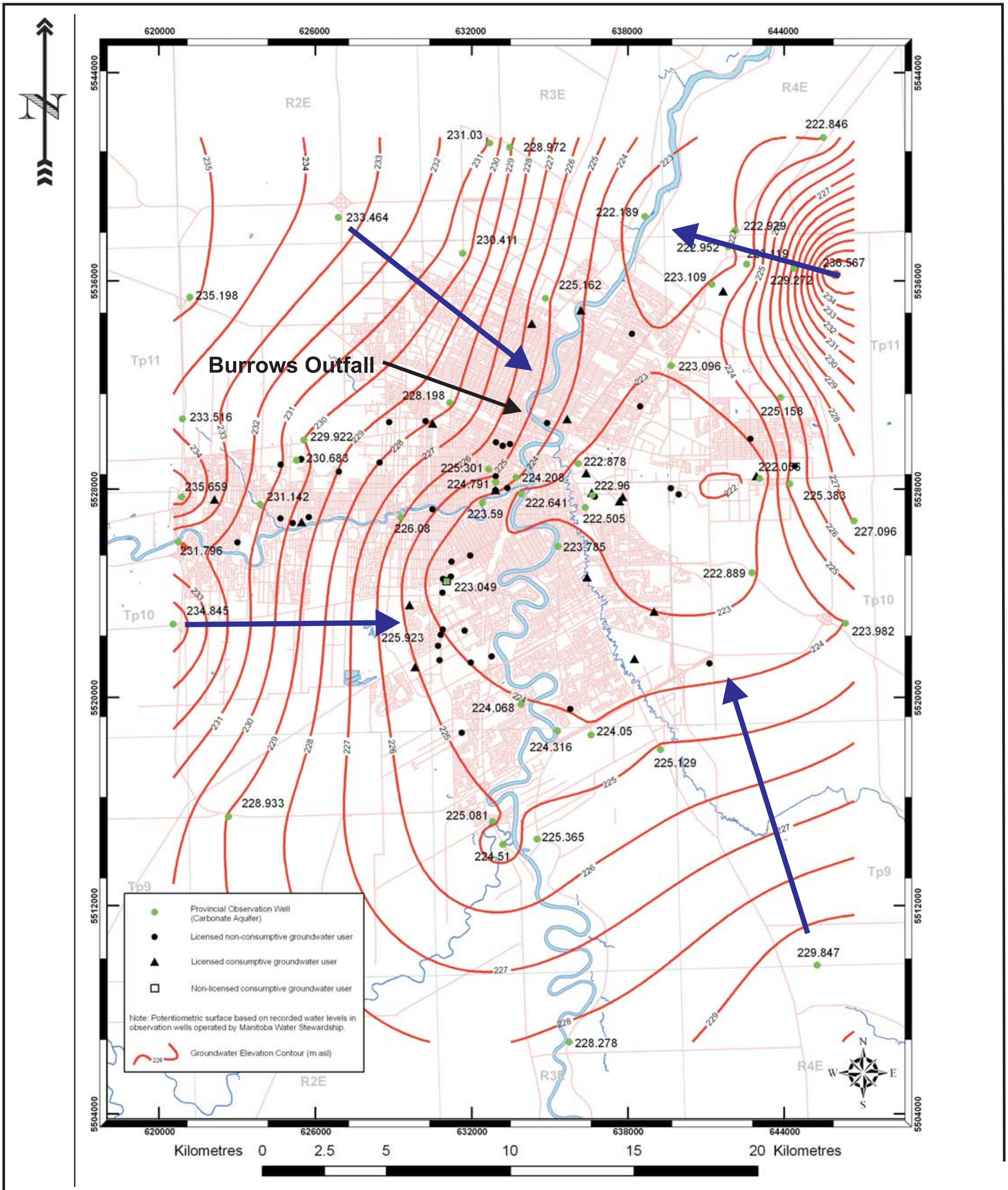
City of Winnipeg
Burrows Outfall Gate Chamber

Summer Groundwater Levels

Figure No. 1

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/19



→ **- Groundwater Flow Direction**

City of Winnipeg
Burrows Outfall Gate Chamber

Winter Groundwater Levels

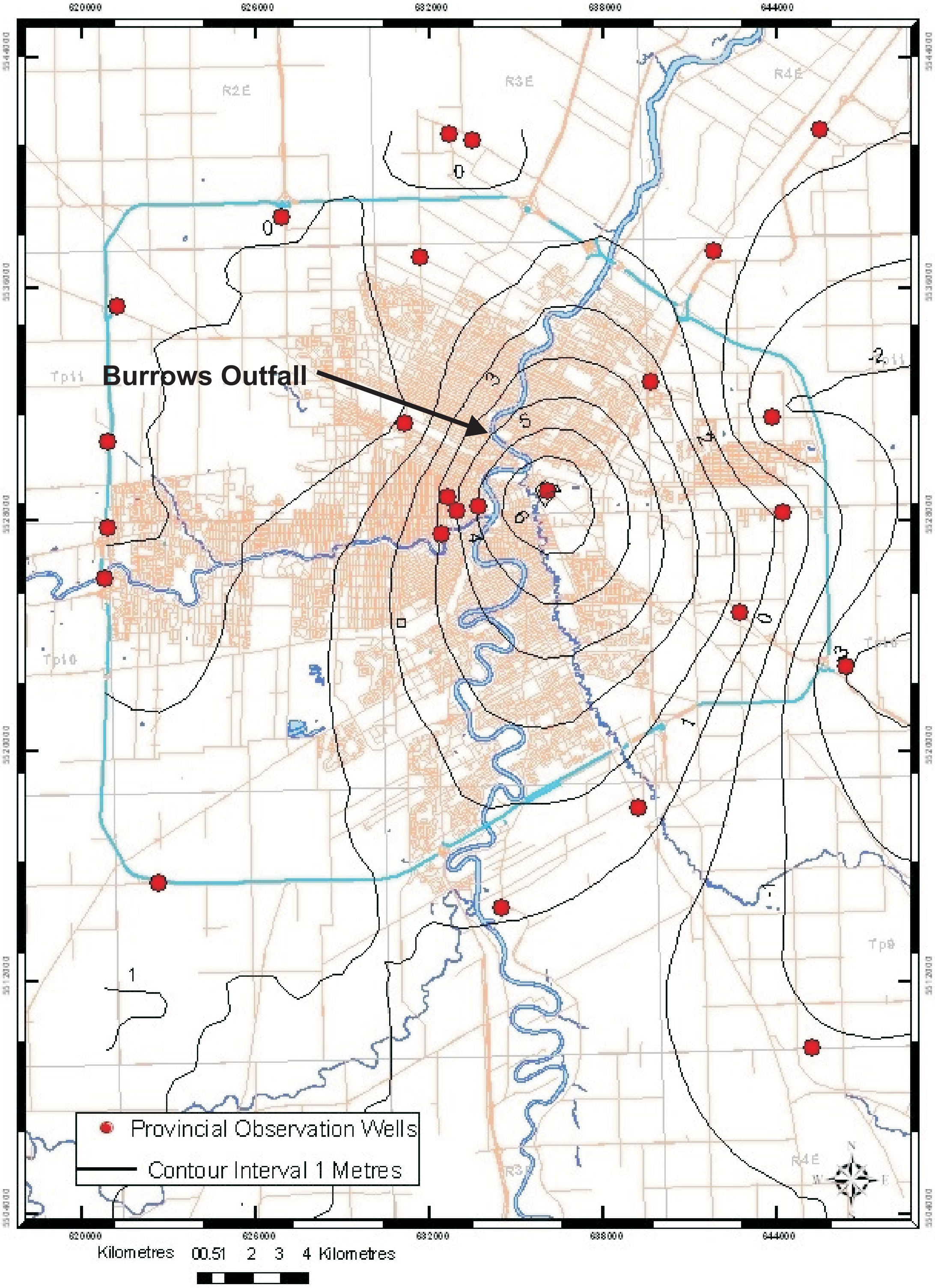
Figure No. 2

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/19

Carbonate Aquifer Potentiometric Surface
Winnipeg Area

Water Level Difference Spring 2009 & 1970



UTM NAD83, Zone 14

Groundwater Management Section
November, 2010

Manitoba
Water Stewardship

City of Winnipeg
Burrows Outfall Gate Chamber

Groundwater Level Changes

Figure No. 3

W. L. GIBBONS & ASSOC. INC.
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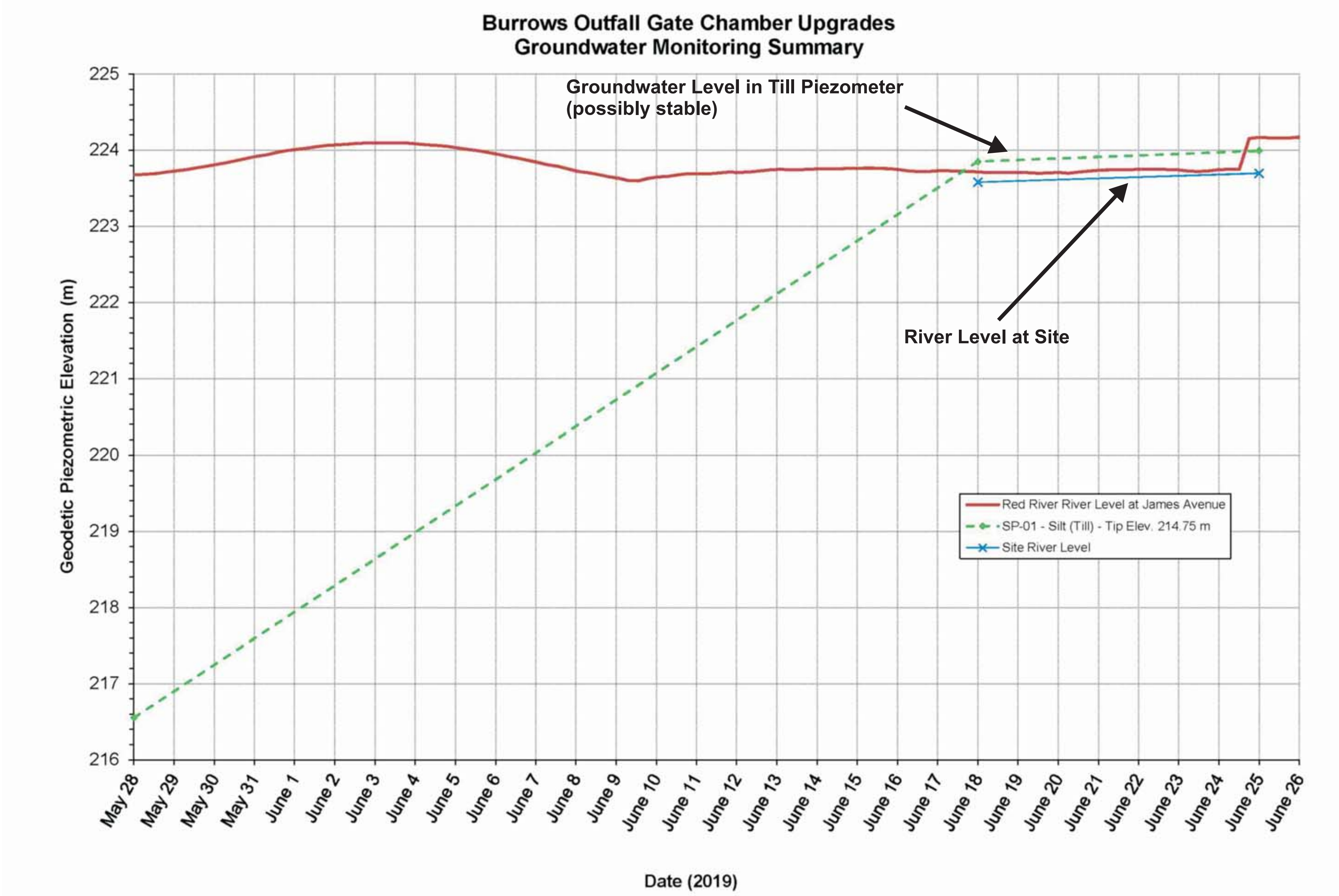
Designed By: BW
Approved By: SW
Date: 06/19



Data Source: Trek Geothechnical

W. L. GIBBONS & ASSOC. INC.

HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/19

City of Winnipeg
Burrows Outfall Gate Chamber
Groundwater Monitoring
Figure No. 4

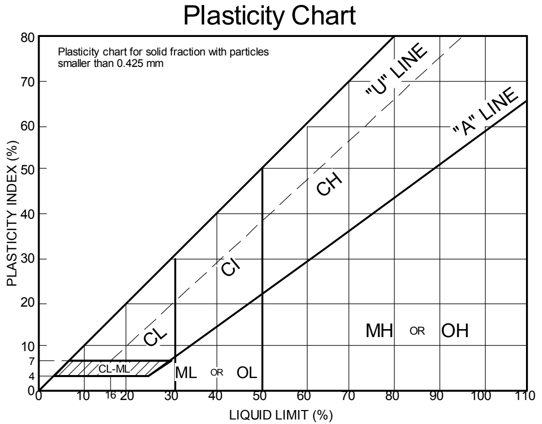
Appendix A
Test Hole Log

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United 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			
			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 mm	Particle Size ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

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

* 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

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 TH19-01

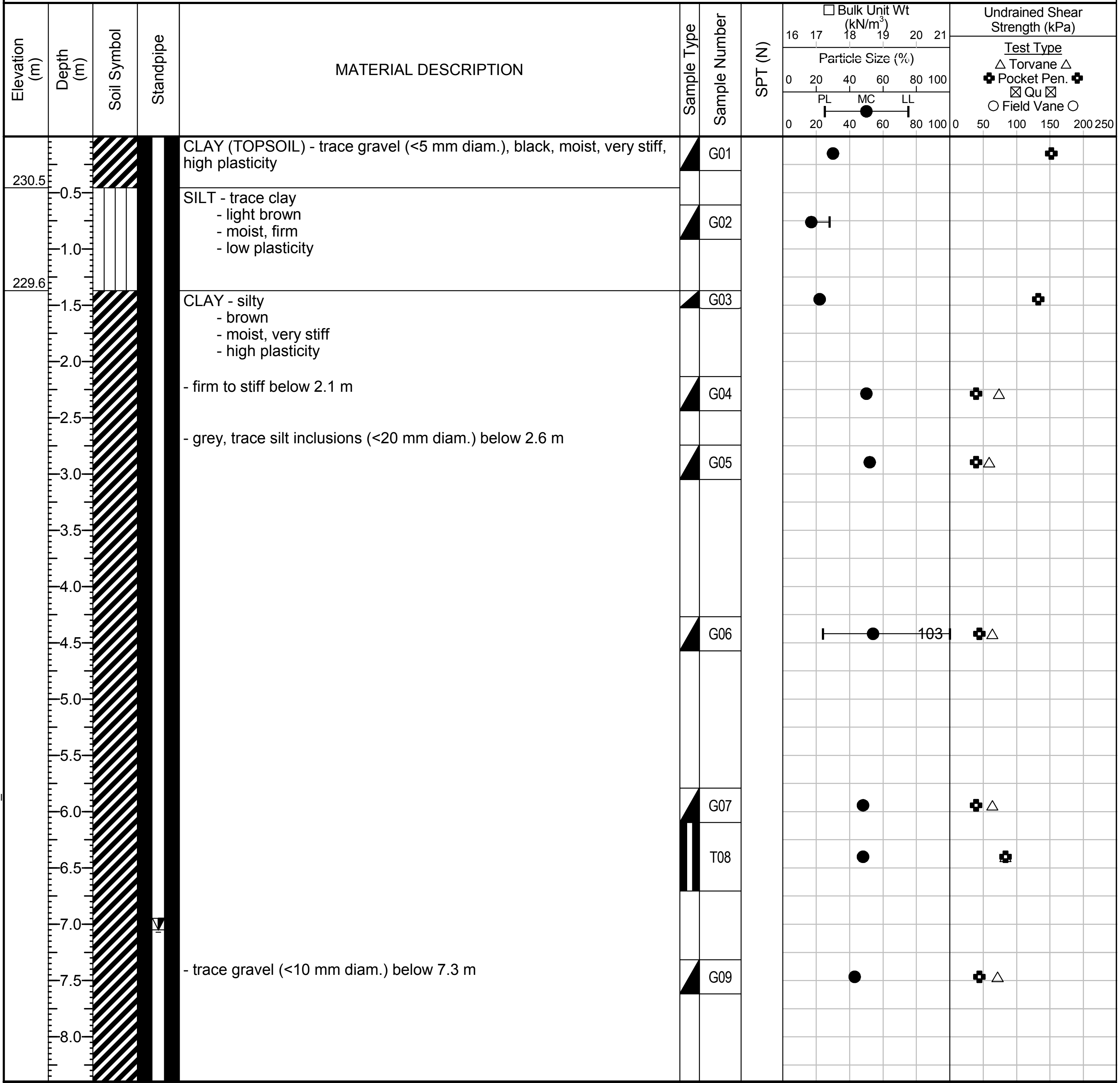
1 of 2

Client: MPE Engineering
Project Name: Burrows Outfall Gate Chambers Upgrades
Contractor: Maple Leaf Drilling Ltd.
Method: Acker MP5-T Track Mount
Project Number: 0512-001-00
Location: UTM N-5530749.532, E-634309.703
Ground Elevation: 230.98 m
Date Drilled: May 28, 2019

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

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

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



CLAY (TOPSOIL) - trace gravel (<5 mm diam.), black, moist, very stiff, high plasticity

SILT - trace clay
- light brown
- moist, firm
- low plasticity

CLAY - silty
- brown
- moist, very stiff
- high plasticity

- firm to stiff below 2.1 m

- grey, trace silt inclusions (<20 mm diam.) below 2.6 m

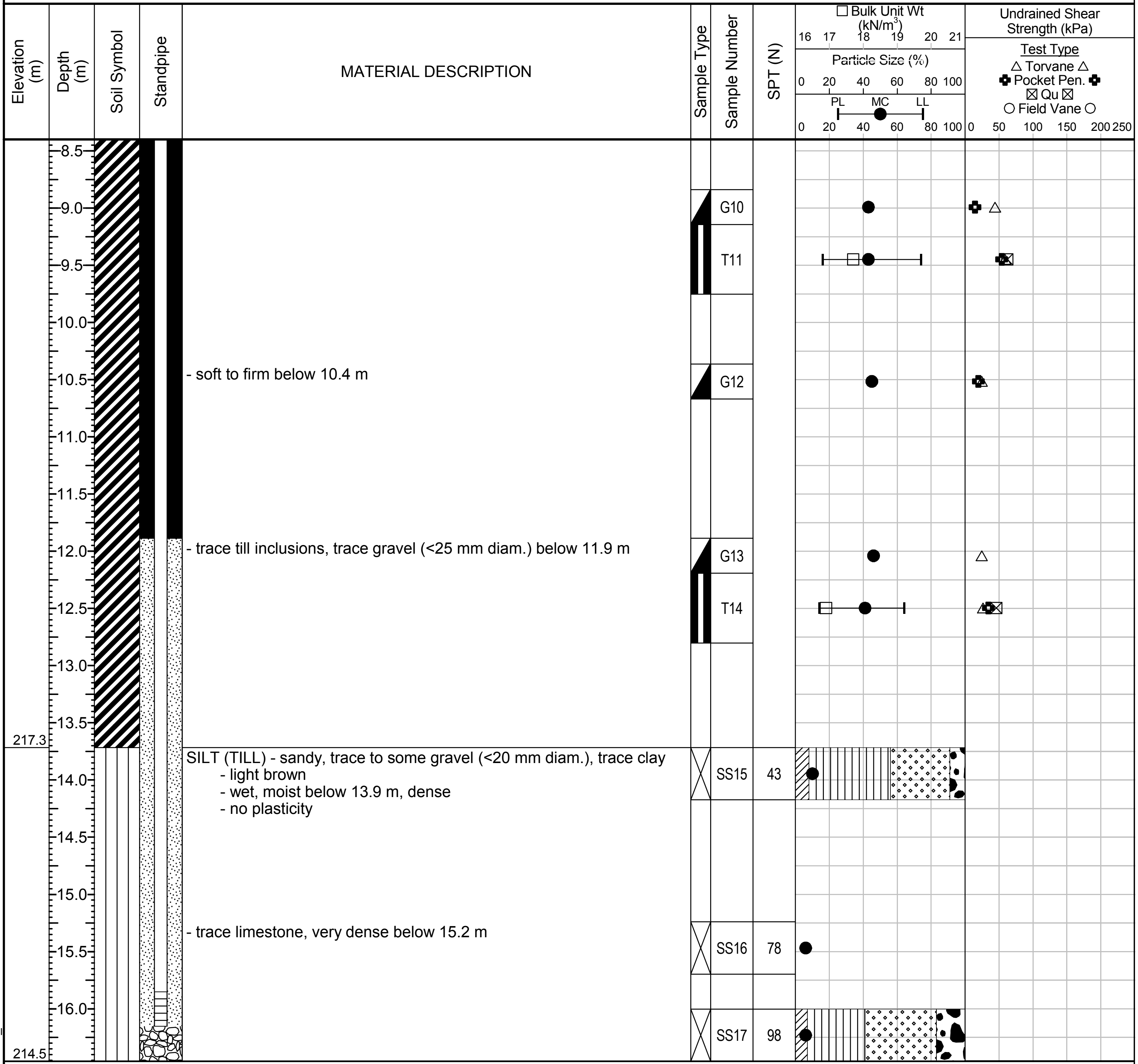
- trace gravel (<10 mm diam.) below 7.3 m

G01
G02
G03
G04
G05
G06
G07
T08
G09

Logged By: Micha Roemer **Reviewed By:** Kent Bannister **Project Engineer:** Michael Van Helden

Sub-Surface Log

Test Hole TH19-01



- soft to firm below 10.4 m

- trace till inclusions, trace gravel (<25 mm diam.) below 11.9 m

SILT (TILL) - sandy, trace to some gravel (<20 mm diam.), trace clay
- light brown
- wet, moist below 13.9 m, dense
- no plasticity

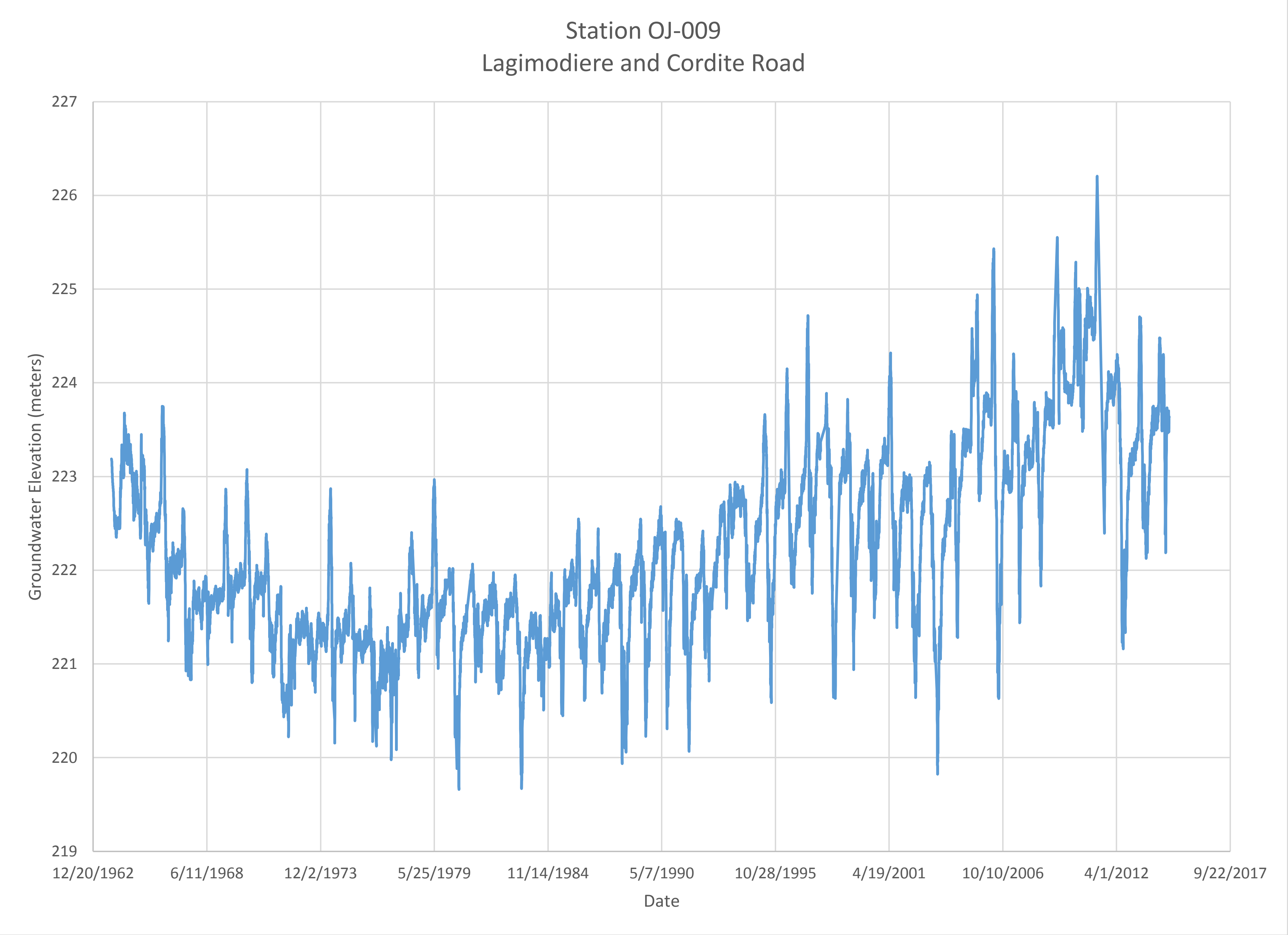
- trace limestone, very dense below 15.2 m

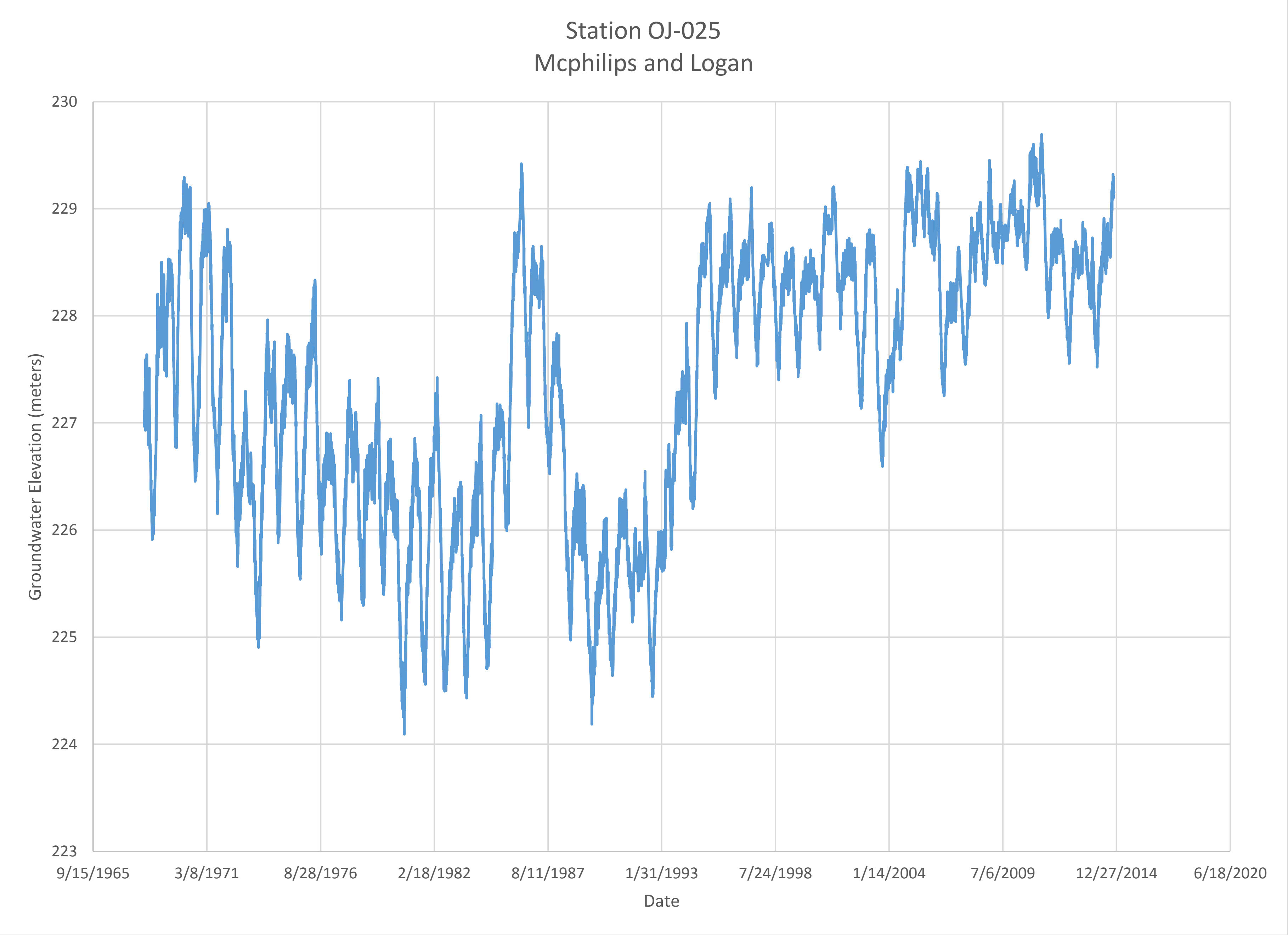
POWER AUGER REFUSAL AT 16.5 m DEPTH IN SILT (TILL)

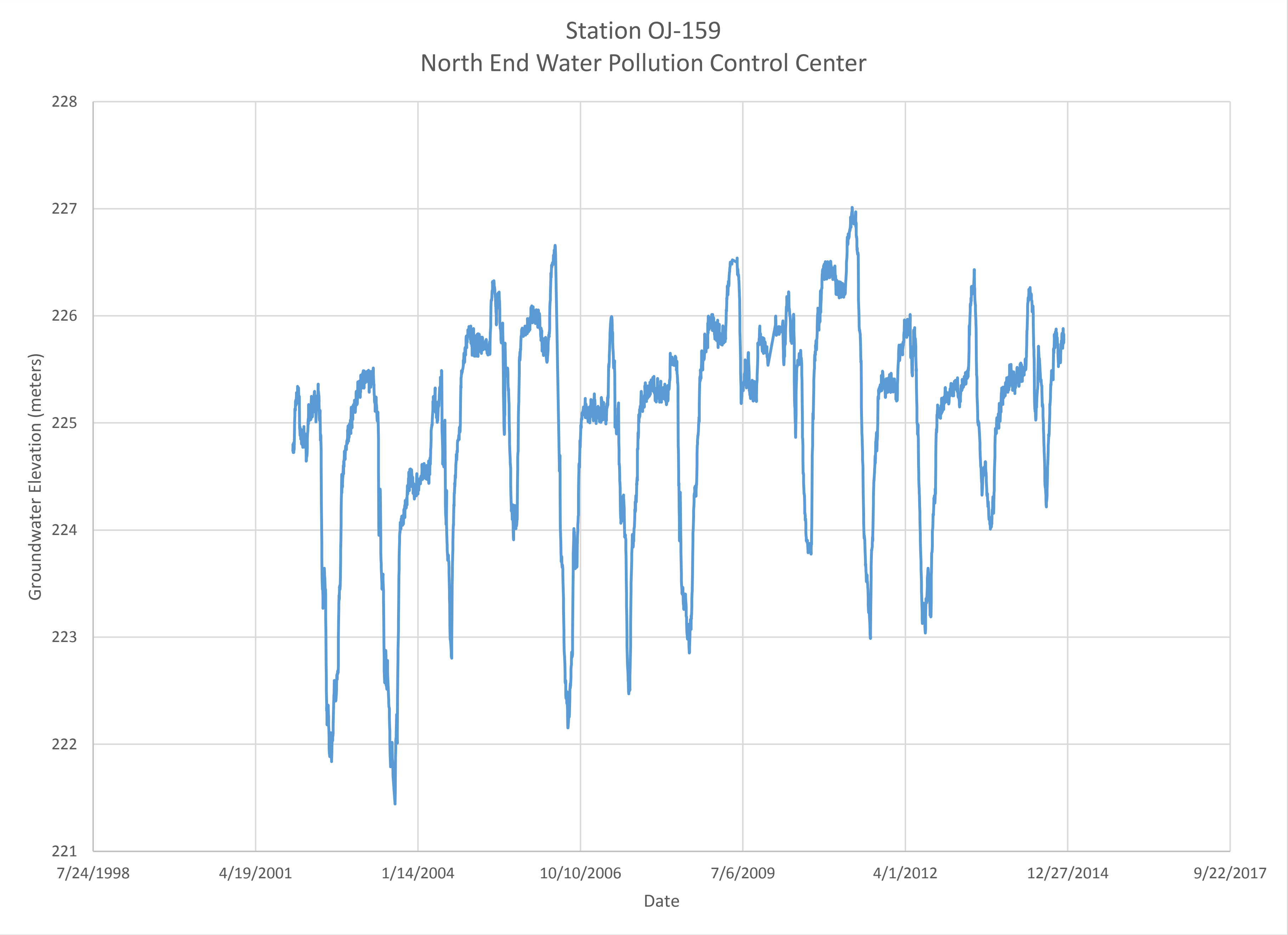
Notes:
1. Seepage between 13.7 m and 13.9 m below ground surface in SILT (TILL).
2. Sloughing between 13.7 m and 15.2 m below ground surface in SILT (TILL).
3. Test hole open to 16.0 m immediately after completion of drilling.
4. Standpipe SP-01 installed in SILT (TILL) at 16.2 m depth below ground surface.
5. Test hole backfilled with sand from 16.2 m to 11.9 m and combination of bentonite and auger cuttings from 11.9 m to ground surface.
6. Water level below ground surface in SP-01 at 14.4 m (fifteen minutes after SP-01 installation) and at 7.1 m (June 18, 2019)

Logged By: Micha Roemer **Reviewed By:** Kent Bannister **Project Engineer:** Michael Van Helden

Appendix B
Historic Groundwater Levels


Station OJ-009
Lagimodiere and Cordite Road
Groundwater Elevation (meters)
227
226
225
224
223
222
221
220
219
12/20/1962
6/11/1968
12/2/1973
5/25/1979
11/14/1984
5/7/1990
10/28/1995
4/19/2001
10/10/2006
4/1/2012
9/22/2017
Date


Station OJ-025
Mcphilips and Logan
Groundwater Elevation (meters)
230
229
228
227
226
225
224
223
9/15/1965
3/8/1971
8/28/1976
2/18/1982
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
6/18/2020
Date


Station OJ-159
North End Water Pollution Control Center
Groundwater Elevation (meters)
228
227
226
225
224
223
222
221
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
Date