APPENDIX E – SOILS INVESTIGATION REPORT AND TEST HOLE LOGS

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Memorandum

To	Marvin McDonald	Page	1
CC	Barry Biswanger		
Subject	Midtown Feedermain Bridge - Geotechnical Investigation		
From	Omer Eissa, Faris Khalil		
Date	November 6, 2012	Project Number	60256129 (403.19.2)

1. Introduction

This memorandum summarizes the results of the geotechnical field program and provides geotechnical assessment for the observed instability at the south bank of the Midtown Feedermain Bridge crossing the Assiniboine River. The Midtown Feedermain is a 900 mm diameter pipe extending over a single span steel truss bridge supported by two piers located on the North and South banks of the Assiniboine River. It is understood the bridge has reached its service life and the City of Winnipeg is considering rehabilitation of the existing bridge and treatment options to control the impact of the observed slope instabilities at the south bank of the subject structure.

In support of the geotechnical considerations provided in the AECOM report “Midtown Feedermain and Bridge Report”, dated July 2010, AECOM completed a field program to investigate the subsurface conditions within the river channel. The objectives of the investigation are primarily to assess the feasibility of off bridge installation of the Feedermain pipe and to supplement available subsurface information in support of stability assessment of the south pier of the bridge. A total of four (4) test holes were drilled slightly upstream of the existing bridge to investigate the subsurface conditions in the river channel. The locations of the test holes in relation to the bridge and the encountered soil profile at each test hole are presented on Drawing 01, Appendix A. Individual test hole details are outlined in Table 01 below.

2. Site Condition

The Feedermain Bridge is located in the City of Winnipeg, Manitoba. It crosses the Assiniboine River in a north to south direction, south of the junction of Aubrey Road and Palmerston Avenue. The river is approximately 80 meters wide at the bridge crossing. A detailed visual inspection of the site was carried out on January 2012. The findings of the visual inspection are documented in the AECOM “Midtown Feedermain Bridge Riverbank Re-Assessment Report” dated February 6th, 2012. The inspection revealed visible signs of slope instabilities along the south bank of the river in the vicinity of and immediately downstream the south pier of the bridge. Multiple soil mass slumps and an array of tension cracks and head scarps were observed manifesting typical retrogressive slope failure along the south bank. A head scarp in the order of 700 mm high and tension cracks approximately 300 mm wide were also visually identified extending along the crest of the bank. The slope movements have been monitored periodically since July 2010 using slope indicator (SI) readings. The results of the monitoring are presented in the attached Appendix C. With the exception of the tension crack in the vicinity of the south pier on the east side, Photo 01, no major movements have been detected in the SI readings since the aforementioned reassessment report dated February 6th, 2012.

Photo 01: Tension Crack in the Vicinity of the South Pier (looking west).

3. 2012 Field Investigation

The test hole drilling program was completed between May 22nd to May 25th, 2012 using a barge mounted ACKER SS drill rig capable of soil sampling and rock coring. The drill rig and barge were supplied and operated by Paddock Drilling Limited. Four (4) test holes were advanced in the vicinity of the existing bridge. Test hole details including location and depth are provided in Table 01.

Standard penetration tests (SPTs) were performed at regular intervals within the overburden soils, from which disturbed samples were obtained. Rock cores were retrieved from three of the test holes. All soils observed during drilling were logged and visually classified on site by AECOM personnel. Soil and rock samples recovered were transported to AECOM's Materials Testing Laboratory in Winnipeg for further visual examination and testing.

Table-01: Test Hole Details

Test hole ID	Coordinates (UTM, Zone 14)	Approximate Location	Depth (m)	Termination Condition
TH12-01	631084 E, 5526520 N	7 m upstream of existing bridge, 2 m South of North bank	10.7	0.6 m into bedrock
TH12-02	631060 E, 5526466 N	1 m upstream of existing bridge 5 m North of South bank	9.6	Terminated in dense till
TH12-03	631070 E, 5526485 N	1 m upstream of existing bridge 25 m North of South bank	8.8	0.9 m into bedrock
TH12-04	631080 E, 5526508 N	1 m upstream of existing bridge 15 m south of North Bank	8.9	1.2 m into bedrock

Laboratory testing included the determination of moisture contents on all soil samples. A detailed test hole log has been prepared for each test hole to record the description and the relative position of the various soil and bedrock strata, location of samples obtained, field and laboratory test results and other pertinent information. The test hole logs are provided in Appendix B.

4. Soil Profile

The general subsurface profile in descending order is:

- Water column (River)
- Alluvial clay (only in TH12-011,TH12-02)
- Alluvial sand
- Clay till
- Silt/Sand Till
- Bedrock

These units are described separately as follows:

Water

Drilling from a barge, water was encountered in all test holes to depths ranging from 1.2 m to 3.6 m.

Alluvial Clay

Alluvial clay was encountered at the river bed in TH12-01 and TH12-02 located in close proximity to the river north and south banks, respectively. Alluvial clay was not encountered towards the centre of the river channel in TH12-03 and TH12-04. The clay layer contains organics at the surface, some silt, and trace to some gravel. The clay is wet to moist, grey, of soft consistency and exhibits high plasticity. Moisture contents in the clay layer range from 6 to 13 percent.

Alluvial Sand

Alluvial sand was encountered at the river bed in TH12-03 and TH12-04 located close to the centre of the channel. The sand contains some organics, some roots, trace amounts of silt and trace amounts of fine gravel. The sand layer is dark grey, wet, poorly graded and is loose to compact. Cobbles were encountered within the sand layer in TH12-03. Moisture contents in the sand layer range from 8 to 11 percent.

Clay Till

Clay till was encountered in TH12-01 and TH12-02 below the alluvial clay. The layer extends from depths 3.9 to 4.9 m and 4.9 to 6.1 m in TH12-01 and TH12-02, respectively. The clay till is silty contains some sand and trace gravel. The layer is wet, brown, of firm consistency and exhibits low plasticity. Moisture contents in the till range from 13 to 15 percent.

Silt and Sand Till

Silt and Sand till was encountered below the clay till in TH12-01 and TH12-02 and below the alluvial sand in TH12-03 and TH12-04. It generally consists of sand, silt, some angular to sub-angular gravel and contains occasional limestone and granite boulders below 6 meters from the water surface. The layer is grey, moist, and compact to dense. Moisture content in the till range from 7 to 14 percent.

Bedrock

Where the drilling advanced below the till, Limestone/Dolomite bedrock was encountered beneath the till. The bedrock is fine grained and slightly foliated with occasional clay filled seams. Core recovery within the bedrock was in the range of 90%. Rock Quality Designation (RQD) ranges from 57 to 79 percent. No core samples were tested for uniaxial compressive strength.

5. Subsurface Pipe Installation

The in-water investigation indicated relatively shallow bedrock overlaid by dense till containing large diameter boulders which is expected to present construction challenges and costly trench/trenchless pipe installation conditions. Consultation within the project team concluded that an underground pipe crossing is no longer a feasible alternative. The remainder of this memorandum discusses the stability of the riverbank at the existing south pier.

6. Stability Assessment

6.1 Design Objectives and Site Limitations

The primary objective of the stability assessment is to provide more protection to the south pier of the existing Feedermain Bridge by developing measures to improve the stability at the south riverbank. Consistent with acceptable engineering practice, a design objective factor of safety (FS) of 1.5 was adopted for this project. Both global and local slip surfaces were investigated. For this report, global slip surface is defined as a slip surface engaging the bridge pier footing. Local slip surface is defined as a slip surface at least 1 m deep impacting the river bank without directly impacting the bridge pier. It is important to note that although a local slip surface doesn't directly engage the bridge pier, it may lead to retrogressive slope instabilities that may ultimately affect the bridge structure.

The stability assessment takes into account the main site restrictions which are:

- Limited space due to right of way restrictions.
- Limited headroom under the existing Bridge.
- Avoid hydraulic impact to the river channel.

6.2 Stability Analysis

The geometry used in the stability analysis is based on recent channel soundings and riverbank survey. Current and previous geotechnical investigation and local knowledge of alluvial deposit boundaries were used to develop a model for soil profile. Review of available monitoring results for the Assiniboine River water level in the vicinity of the site was used to establish a range of river water level considered in the analysis. The depth of the observed subsurface displacement from SI monitoring and the approximate location of the tension crack observed at ground surface in the vicinity of south pier (discussed in section 2) were used in conjunction with back analysis to confirm the operating strength parameters within the zone where the slip failure and subsurface movements are interpreted. Results from previous back analysis completed by AECOM (July 2010) were also reviewed. A set of soil strength parameters of (c = 0 and φ=18) for alluvial clay deposit is determined to be corresponding to a calculated factor of safety range from 0.95 to 1.08 . A FS near 1.0 is indicative of a condition of imminent instability which is considered, based on the available information and observations, representative for the condition at site. The selected soil strength parameters are provided in Table 02.

Table 02 – Soil Strength Parameters Used in the Stability Analysis

Material	Unit Weight (kN/m^3)	Cohesion (kPa)	Angle of Internal Friction (°)
Alluvial Clay	17	0	18
Lacustrine Clay	17	5	14
Till	21	0	35
Riprap	21	0	35
Rock fill	21	0	45

The analysis was completed to determine the stability improvement using the following stabilization measures:

1. Crest unloading and bank regrading.
2. Installation of shear key (rock columns)
3. Installation of riprap blanket (Slope stability and erosion protection)

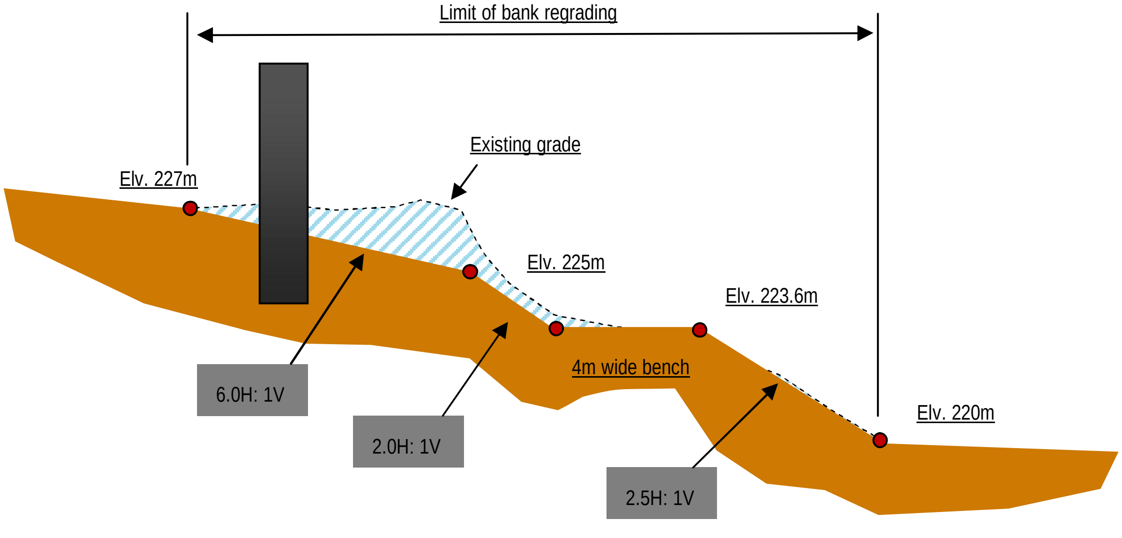
Summary of the analysis results is provided in Table 03 and presented graphically in Appendix C.

Table 03 – Summary of the Results of Stability Analysis

Case	**Calculated FS**	
	Global Slip Surface	Local Slip Surface
Existing Condition	1.08	0.95
Slope Regrade	1.21	1.08
Slope Regrade + Shear Key	1.67	1.41
Slope Regrade + Shear Key + Riprap	1.68	1.53

As a first step, the analysis models geometric modifications by regrading the south riverbank to unload some of the crest load and introduce flatter slope without adverse hydraulic impact on the river channel. The regrading concept took into account the necessity to maintain adequate soil cover over the existing buried pipe located south of the pier. The regrading resulted in improvements of approximately 12 percent to the calculated FS of the critical global slip surface but less than the design objective of 1.5. The configuration of the regrading work is schematically illustrated on Figure 01.

Figure 01: Schematic of the proposed regrading work at the south riverbank (not to scale)



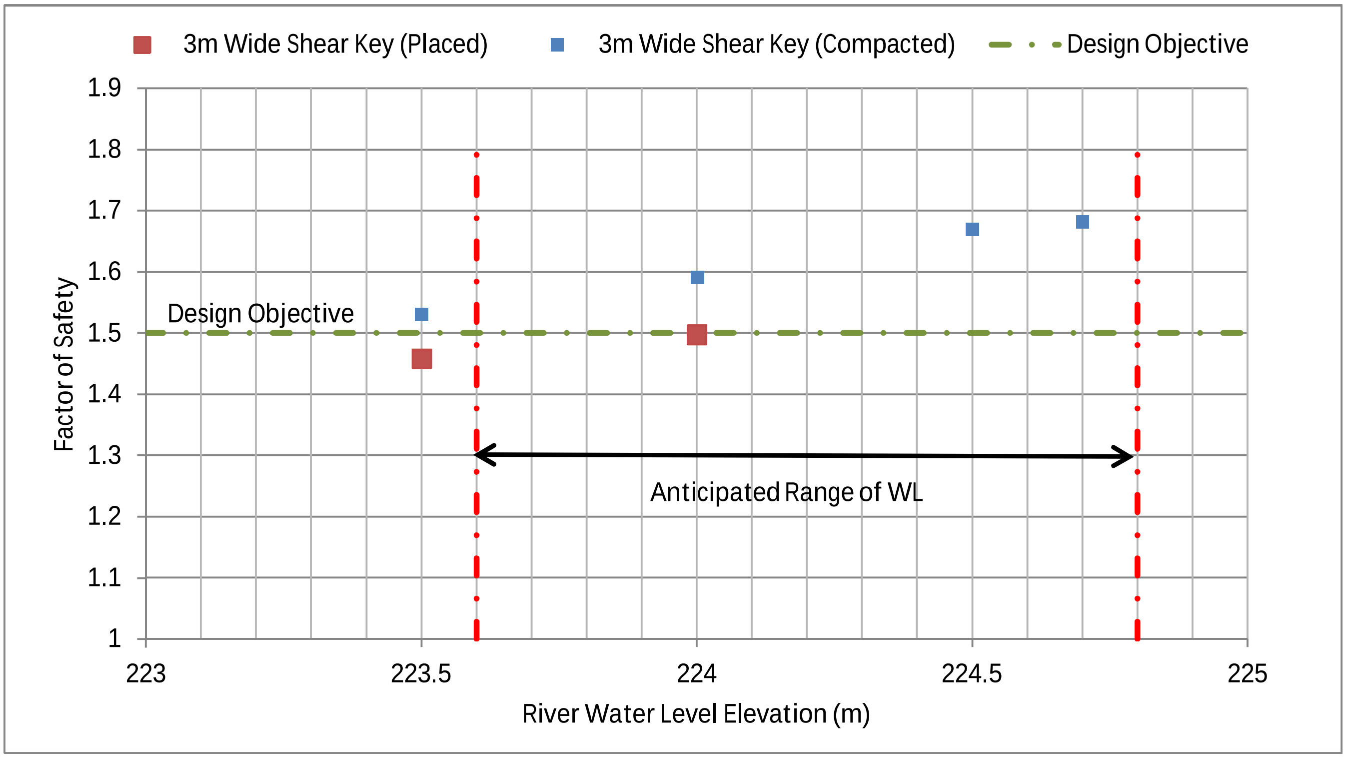
To improve the stability for the global slip surface, shear key in addition to bank regrading were incorporated into the model. The analysis optimized the depth, width and location of the shear key to attain the design objective. The analysis indicates that a three meter wide shear key or an equivalent configuration of rock columns will be required to satisfy FS of 1.5 for the global slip surface. Instabilities of the local slip surfaces down slope of the shear key due to the increased soil weight at the location of the shear key required an additional measure to address this concern. A 0.6 m layer of riprap was incorporated into the model to address the local instabilities and provide an erosion protection layer. The analysis results indicate that a combination of riverbank regrading, installation of rock columns and riprap layer will be required to achieve the design objective FS of 1.5 for both global and local slip surfaces.

The shear key was modelled to extend from just below the ground surface and into the silt/sand till. An optimization process was used to convert the required width of the shear key to an equivalent configuration of rock columns on the basis of the required area per metre run of the model. The process took into account the diameter of rock columns and the center to center spacing. Based on discussion with local contractors, the most economical configuration was determined to be two staggered rows of 2.1 m diameter of rock columns spaced at 2.7 m center to center. Rock columns are large diameter holes filled with150 mm crushed limestone fill and have been used successfully in riverbank stabilization works in the Winnipeg area. The densification of the rock fill is achieved using vibrofloat techniques. The rock fill was modelled using strength parameters of (c=0 and φ= 45). The selected friction angle is considered conservative based on the results of measured values for rock fill.

The limited headroom under the bridge presents construction challenges and imposes restrictions on the type and size of the construction equipment that can be used in this area. Therefore modifications to the rock columns configuration and construction method will be required for this short length (approximately 6 m along the river bank). The rock columns configuration will consists of 4 rows of 1.2 m diameter at 1.8 m c/c spacing. Vibrofloat densification will not be possible and the only feasible densification is from self weight, dumping effect and possibly by auger tamping. To investigation this change in rock fill placement method, stability analysis was completed using a lower friction angle (φ= 40) for the rock fill. The calculated FS corresponding to this condition was determined to be practically satisfying the design objective as presented on Figure 02. It is our assessment that this FS represent a conservative estimate at this location considering the three dimensional effect from the stabilized areas to the east and west and the positive contribution from the south pier pile foundation which has not been incorporated in the model.

A sensitivity analysis of calculated FS with respect to the river water level was conducted to verify acceptable FS over the range of anticipated river water level. Based on available historical monitoring data, the water level in the Assiniboine River at the bridge location generally ranges from an ice level of approximately 223.6 m to a normal summer level of 224.7. The results of the sensitivity analysis are presented on Figure 02 indicating acceptable FS over the anticipated range of river water level.

Figure 02:Factor of Safety vs. River Water Elevation



7. Recommendations

Based on the results of the stability assessment the following measures are recommended to protect the south pier of the Feedermain Bridge:

- Grade the riverbank to a configuration as illustrated on Figure 01 and shown on Drawing D-12241 in Appendix A.
- Install 16 number of 2.1 m diameter and 22 number of 1.2 m diameter rock columns at the location and configuration shown on Drawing D-12241 in Appendix A. The rock columns should extend at least 1m into the till layer. The smaller diameter rock columns will be limited to the area under the bridge structure.
- Place 0.6m thick rip rap layer class 350 on the slope face as shown on Drawing D-12241 in Appendix A.
- The area subjected to the proposed improvement is defined by two 45 degrees lines starting from a line 3m south of the existing south pier. Therefore part of the proposed work will be in private properties. The stability of the riverbank for the private properties is beyond the scope of this work.
- Special considerations should be given to the sequencing of augured holes to minimize the influence of the recently placed material on adjacent open holes.
- Access to the site and construction activities will likely utilize the land easement along the vacated north extension of Waverly Street north of Wellington Crescent.

- The installation of rock columns is expected to be more efficient during winter months, although slope regarding is less efficient in that time period due to frozen ground. Therefore, provision of follow up maintenance and reshape works should be allowed in project schedule and budget.

8. Closure

The findings and recommendations of this memorandum were based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions between the test hole locations. If conditions are encountered that appear to be different from those shown by the test holes drilled at this site and described in this report, or if the assumptions stated herein are not in keeping with the design, this office should be notified in order that the recommendations can be reviewed and adjusted, if necessary.

Soil conditions, by their nature, can be highly variable across a site. The placement of fill and prior construction activities on a site can contribute to the variability especially near surface soil conditions. A contingency should be included in the construction budget to allow for the possibility of variation in soil conditions, which may result in modification of the design and construction procedures.

Submitted by:

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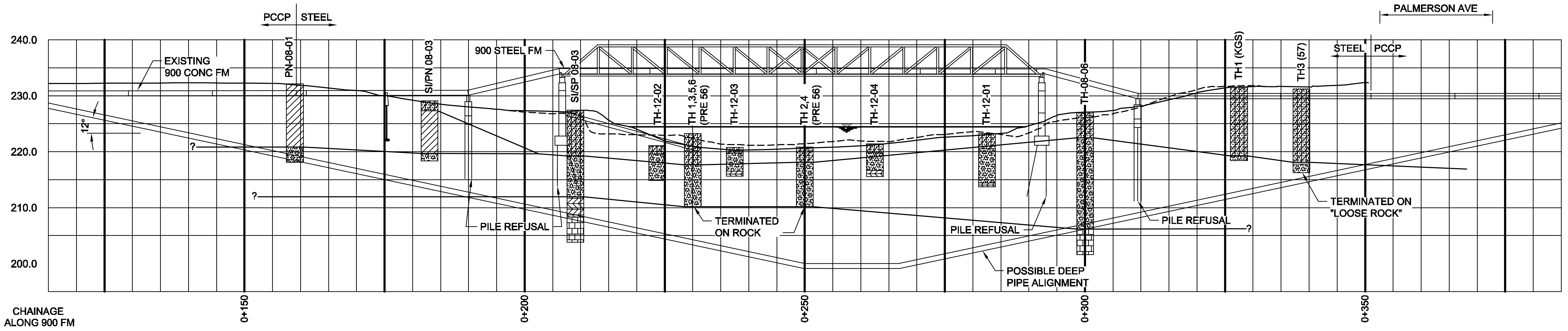
Geotechnical Engineer-in-Training
OE:dh

Reviewed by:

Faris Khalil, M.Sc., P.Eng.
Manager, Geotechnical Engineering

Appendix A

Drawings



0 7.5 15 22.5 m SCALE 1:750

LEGEND

▩ ALLUVIAL, CLAY, SILT, SAND	▨ BEDROCK, BROKEN
▨ LACUSTRINE CLAY	▦ BEDROCK, SOUND
▩ SAND, GRAVEL, BOULDERS AND TILL	—— EXISTING GROUND PROFILE
	– – – 1956 GROUND PROFILE

The City of Winnipeg, Public Works Department
Midtown Feedermain at Assiniboine River

Geotechnical Investigation

Drawing - 01

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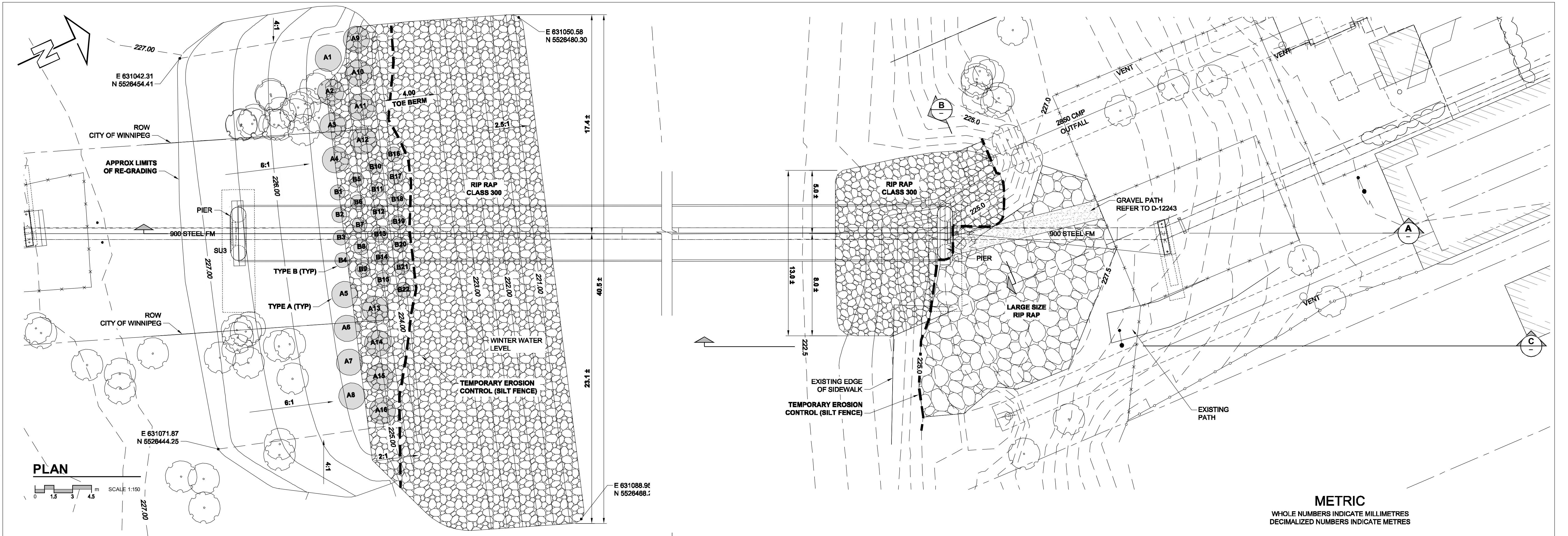

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WHOLE NUMBERS INDICATE MILLIMETRES
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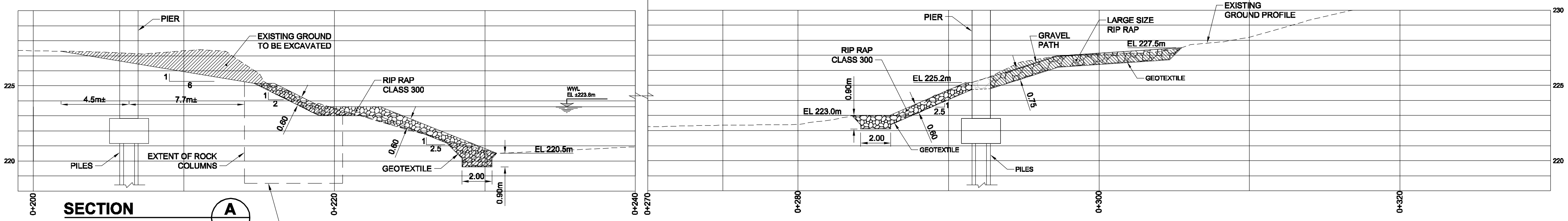

SECTION A

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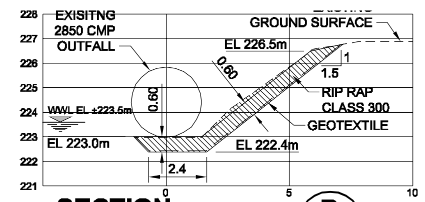
THRU CENTRE OF PIERS

ROCK COLUMNS TO EXTEND 1.0 MINIMUM INTO COMPETENT TILL OR AS DETERMINED BY THE ENGINEER



SECTION B

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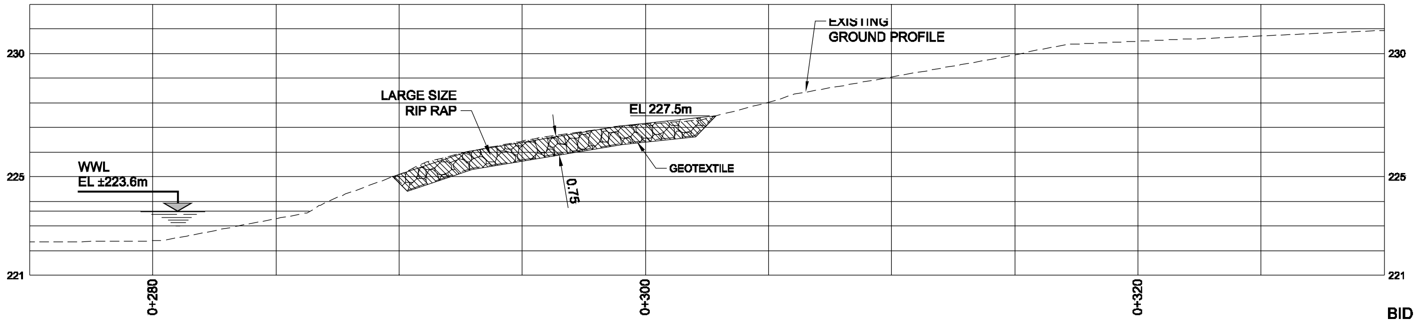
NORTH OF PIER
ON NORTH BANK OF ASSINIBOINE RIVER

LEGEND

- - - - EXISTING GROUND PROFILE
- ──── PROPOSED GROUND PROFILE
- ──── GEOTEXTILE
- ▬ ▬ ▬ TEMPORARY EROSION CONTROL
- ▨ EXISTING GROUND TO BE EXCAVATED
- ▦ RIP RAP CLASS 300
- ▦ LARGE SIZE RIP RAP (600 - 750mm)
- ▩ CLAY FILL



SECTION C

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BID OPPORTUNITY NO. 830-2012

NOTES:
1. NO WORK SHALL BE PERFORMED IN PRIVATE PROPERTY WITHOUT THE APPROVAL OF THE CONTRACT ADMINISTRATOR.
2. TYPE 'B' ROCK COLUMNS WILL BE INSTALLED UNDER THE EXISTING BRIDGE. THE HEADROOM BELOW THE BRIDGE IS 6.3m±.
3. 300 COMPACTED CLAY PLUG SHALL BE PLACED ABOVE ROCK COLUMN AREA AS SPECIFIED.
4. REFER TO SUBSURFACE PROFILE (DWG No. D-12240) AND AECOM TEST HOLE LOGS FOR SUBSURFACE CONDITIONS.
5. REFER TO REVEGETATION PLAN DRAWINGS FOR SITE RESTORATION & SITE REVEGETATION.

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AECOM REVIEW | DRFT CHK

LOCATION APPROVED
UNDERGROUND STRUCTURES

SUPR. U/G STRUCTURES COMMITTEE   DATE

NOTE:
LOCATION OF UNDERGROUND STRUCTURES AS SHOWN ARE BASED ON THE BEST INFORMATION AVAILABLE. BUT NO GUARANTEE IS GIVEN THAT ALL EXISTING UTILITIES ARE SHOWN OR THAT THE GIVEN LOCATIONS ARE EXACT. CONFIRMATION OF EXISTENCE AND EXACT LOCATION OF ALL SERVICES MUST BE OBTAINED FROM THE INDIVIDUAL UTILITIES BEFORE PROCEEDING WITH CONSTRUCTION.

NO.	REVISIONS	YY/MM/DD	BY
1	RE-ISSUED FOR CONSTRUCTION	12/10/24	CLC
0	ISSUED FOR CONSTRUCTION	11/05/09	LVJ

AECOM

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Winnipeg

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

REHABILITATION / REPLACEMENT OF THE
MID TOWN FEEDERMAIN AT THE
ASSINIBOINE RIVER

GEOTECHNICAL
EROSION PROTECTION PLAN AND CROSS-SECTIONS

SHEET 16 OF 19

CITY DRAWING NUMBER
D-12241
REV 1

Appendix B

Test Hole Logs

AECOM Canada Ltd.

GENERAL STATEMENT

NORMAL VARIABILITY OF SUBSURFACE CONDITIONS

The scope of the investigation presented herein is limited to an investigation of the subsurface conditions as to suitability for the proposed project. This report has been prepared to aid in the evaluation of the site and to assist the engineer in the design of the facilities. Our description of the project represents our understanding of the significant aspects of the project relevant to the design and construction of earth work, foundations and similar. In the event of any changes in the basic design or location of the structures as outlined in this report or plan, we should be given the opportunity to review the changes and to modify or reaffirm in writing the conclusions and recommendations of this report.

The analysis and recommendations presented in this report are based on the data obtained from the borings and test pit excavations made at the locations indicated on the site plans and from other information discussed herein. This report is based on the assumption that the subsurface conditions everywhere are not significantly different from those disclosed by the borings and excavations. However, variations in soil conditions may exist between the excavations and, also, general groundwater levels and conditions may fluctuate from time to time. The nature and extent of the variations may not become evident until construction. If subsurface conditions differ from those encountered in the exploratory borings and excavations, are observed or encountered during construction, or appear to be present beneath or beyond excavations, we should be advised at once so that we can observe and review these conditions and reconsider our recommendations where necessary.

Since it is possible for conditions to vary from those assumed in the analysis and upon which our conclusions and recommendations are based, a contingency fund should be included in the construction budget to allow for the possibility of variations which may result in modification of the design and construction procedures.

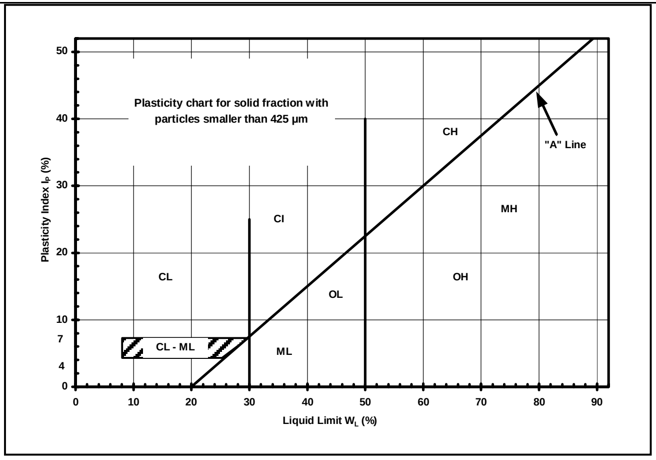
In order to observe compliance with the design concepts, specifications or recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated, we recommend that all construction operations dealing with earth work and the foundations be observed by an experienced soils engineer. We can be retained to provide these services for you during construction. In addition, we can be retained to review the plans and specifications that have been prepared to check for substantial conformance with the conclusions and recommendations contained in our report.

EXPLANATION OF FIELD & LABORATORY TEST DATA

Description				AECOM Log Symbols	USCS Classification	Laboratory Classification Criteria			
						Fines (%)	Grading	Plasticity	Notes
COARSE GRAINED SOILS	GRAVELS (More than 50% of coarse fraction of gravel size)	CLEAN GRAVELS (Little or no fines)	Well graded gravels, sandy gravels, with little or no fines	◬	GW	0-5	$C_U > 4$ $1 < C_C < 3$		Dual symbols if 5-12% fines. Dual symbols if above "A" line and $4<W_P<7$ $C_U = \frac{D_{60}}{D_{10}}$ $C_C = \frac{(D_{30})^2}{D_{10} x D_{60}}$
			Poorly graded gravels, sandy gravels, with little or no fines	▲	GP	0-5	Not satisfying GW requirements		
		DIRTY GRAVELS (With some fines)	Silty gravels, silty sandy gravels	▥	GM	> 12		Atterberg limits below "A" line or $W_P<4$	
			Clayey gravels, clayey sandy gravels	▨	GC	> 12		Atterberg limits above "A" line or $W_P<7$	
	SANDS (More than 50% of coarse fraction of sand size)	CLEAN SANDS (Little or no fines)	Well graded sands, gravelly sands, with little or no fines	⁘	SW	0-5	$C_U > 6$ $1 < C_C < 3$		
			Poorly graded sands, gravelly sands, with little or no fines	○	SP	0-5	Not satisfying SW requirements		
		DIRTY SANDS (With some fines)	Silty sands, sand-silt mixtures	▥	SM	> 12		Atterberg limits below "A" line or $W_P<4$	
			Clayey sands, sand-clay mixtures	▨	SC	> 12		Atterberg limits above "A" line or $W_P<7$	
FINE GRAINED SOILS	SILTS (Below 'A' line negligible organic content)	$W_L<50$	Inorganic silts, silty or clayey fine sands, with slight plasticity	▥	ML			Classification is Based upon Plasticity Chart	
		$W_L>50$	Inorganic silts of high plasticity	▥	MH				
	CLAYS (Above 'A' line negligible organic content)	$W_L<30$	Inorganic clays, silty clays, sandy clays of low plasticity, lean clays	▨	CL				
		$30<W_L<50$	Inorganic clays and silty clays of medium plasticity	▨	CI				
		$W_L>50$	Inorganic clays of high plasticity, fat clays	▨	CH				
	ORGANIC SILTS & CLAYS (Below 'A' line)	$W_L<50$	Organic silts and organic silty clays of low plasticity	┆	OL				
		$W_L>50$	Organic clays of high plasticity	▨	OH				
HIGHLY ORGAINIC SOILS			Peat and other highly organic soils	〰	Pt	Von Post Classification Limit		Strong colour or odour, and often fibrous texture	

■	Asphalt	⁘	Till			AECOM
⁘	Concrete	▩	Bedrock (Undifferentiated)			
▩	Fill	▦	Bedrock (Limestone)			

When the above classification terms are used in this report or test hole logs, the designated fractions may be visually estimated and not measured.



FRACTION		SEIVE SIZE (mm)		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
		Passing	Retained	Percent	Identifier
Gravel	Coarse	76	19	35-50	and
	Fine	19	4.75		
Sand	Coarse	4.75	2.00	20-35	“y” or “ey” *
	Medium	2.00	0.425		
	Fine	0.425	0.075	10-20	some
Silt (non-plastic) or Clay (plastic)		< 0.075 mm		1-10	trace

* for example: gravelly, sandy clayey, silty

Definition of Oversize Material

COBBLES: 76mm to 300mm diameter
BOULDERS: >300mm diameter

LEGEND OF SYMBOLS

Laboratory and field tests are identified as follows:

q_u - undrained shear strength (kPa) derived from unconfined compression testing.

T_v - undrained shear strength (kPa) measured using a torvane

pp - undrained shear strength (kPa) measured using a pocket penetrometer.

L_v - undrained shear strength (kPa) measured using a lab vane.

F_v - undrained shear strength (kPa) measured using a field vane.

γ - bulk unit weight (kN/m^3).

SPT - Standard Penetration Test. Recorded as number of blows (N) from a 63.5 kg hammer dropped 0.76 m (free fall) which is required to drive a 51 mm O.D. Raymond type sampler 0.30 m into the soil.

DPPT - Drive Point Pentrometer Test. Recorded as number of blows from a 63.5 kg hammer dropped 0.76 m (free fall) which is required to drive a 50 mm drive point 0.30 m into the soil.

w - moisture content (W_L, W_P)

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

Su (kPa)	**CONSISTENCY**
<12	very soft
12 – 25	soft
25 – 50	medium or firm
50 – 100	stiff
100 – 200	very stiff
200	hard

The resistance (N) of a non-cohesive soil can be related to compactness condition as follows

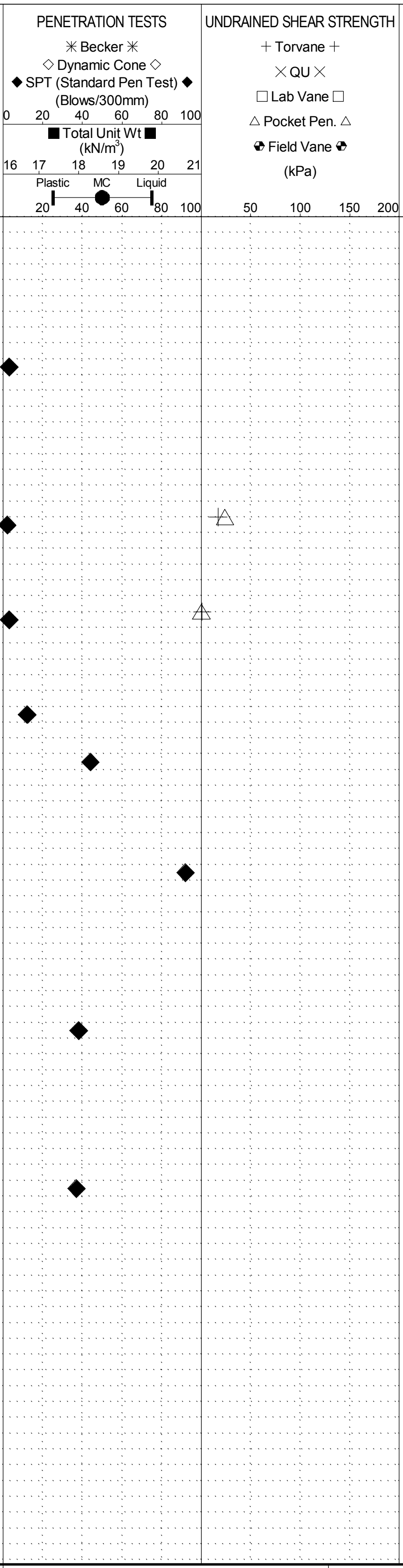
N – BLOWS/0.30 m	**COMPACTNESS**
0 - 4	very loose
4 - 10	loose
10 - 30	compact
30 - 50	dense
50	very dense

PROJECT: Mid Town Feedermain at Assiniboine River	CLIENT: City of Winnipeg	TESTHOLE NO: **TH12-01**
LOCATION: 631084 E, 5526520 N, 7 m upstream of existing bridge, 2 m south of north bank		PROJECT NO.: 60256129
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, HQ Coring	ELEVATION (m): 224.45

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◸ NO RECOVERY ▮ CORE

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
0	- Water					224
1.35	ORGANICS - riverbed sediments, rootmat, roots - dark grey, wet, very soft	☒	S1	3	- 2, 2, 1 blows	223
2	CLAY (Alluvial) - trace to some organics, some silt, trace gravel (angular/subangular, <20 mm) - intermittent sand seams (<25 mm) - grey, moist, soft - high plasticity	☒	S2	2	- 1, 1, 1 blows	221
		☒	S3	3	- 1, 1, 2 blows	
4	CLAY (Putty Till), silty, some sand, trace gravel - brown, wet, firm - non-plastic	☒	S4A	12	- 4, 3, 9 blows	220
5	SILT (Till) - sandy, some gravel - grey, moist, compact to dense - non-plastic - high SPT resistance on suspected boulder/cobbles	☒	S4B	44	- 6, 5, 39 blows	219
		▮	C1		Recovery = 30%	
6	SAND (Till) - silty, some gravel (angular/sub angular < 20 mm) - grey, moist, compact to dense	☒	S5	92	- 20, 42, 50/25 mm blows	218
7	- 150 mm dia boulder - 220 mm dia boulder - 80 mm dia boulder	▮	C2		Recovery = 42%	217
8		☒	S6	38	- 11, 17, 21 blows	216
8.5	Cobble (Till) - gravelly, some sand - angular/sub-angular (< 40 mm dia)	▮	C3		Recovery = 0%	
9.5		☒	S7	37	- 13, 20, 17 blows	215
		▮	C3A		Recovery = 75%	
10	BEDROCK - bedrock contact zone, limestone/dolomite, fine grained	▮	C3B		Recovery = 90%, RQD = 72%	214

END OF TEST HOLE at 10.7 m in BEDROCK
Notes:
1) 150 mm casing used upto 3.35 m below riverbed
2) HQ coring was used to advance the test hole
3) No sloughing observed in the test holes
4) The test hole was grouted to the riverbed upon completion



LOGGED BY: Omer Eissa	COMPLETION DEPTH: 3.25 m
REVIEWED BY: Faris Khalil	COMPLETION DATE: 5/22/11
PROJECT ENGINEER: Faris Khalil	Page 1 of 1

PROJECT: Mid Town Feedermain at Assiniboine River	CLIENT: City of Winnipeg	TESTHOLE NO: **TH12-02**
LOCATION: 631060 E, 5526466 N, 1 m upstream of existing bridge, 5 m north of south bank		PROJECT NO.: 60256129
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, HQ Coring	ELEVATION (m): 224.45

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ⊠ SPLIT SPOON ☰ BULK ◺ NO RECOVERY ▌ CORE

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS
Water				
CLAY (Alluvial)- trace to some organics, some silt, trace gravel (angular/subangular, <20 mm) - intermittent sand seams (<25 mm) - grey, wet to moist, soft - high plasticity	⊠	S8	2	- 1, 1, 1 blows
	⊠	S9	5	- 3, 2, 3 blows
CLAY (Putty Till), silty, some sand, trace gravel - brown, wet, firm - non-plastic	⊠	S10	8	- 2, 4, 4 blows
SILT (Till) - sandy, some gravel - grey, wet, compact to dense - high SPT resistance on suspected boulder/cobbles	⊠	S11	30	- 6, 7, 23 blows
- 440 mm dia granite boulder - sandy below 7.0 m	▌	C4		Recovery = 43%
	⊠	S12	8	- 4, 4, 4 blows
- 160 mm dia boulder - 80 mm dia boulder - 40 mm dia boulder - gravelly below 8.5 m - angular/sub-angular (< 40 mm dia)	▌	C5		Recovery = 30%
	⊠	S13	16	- 7, 8, 8 blows

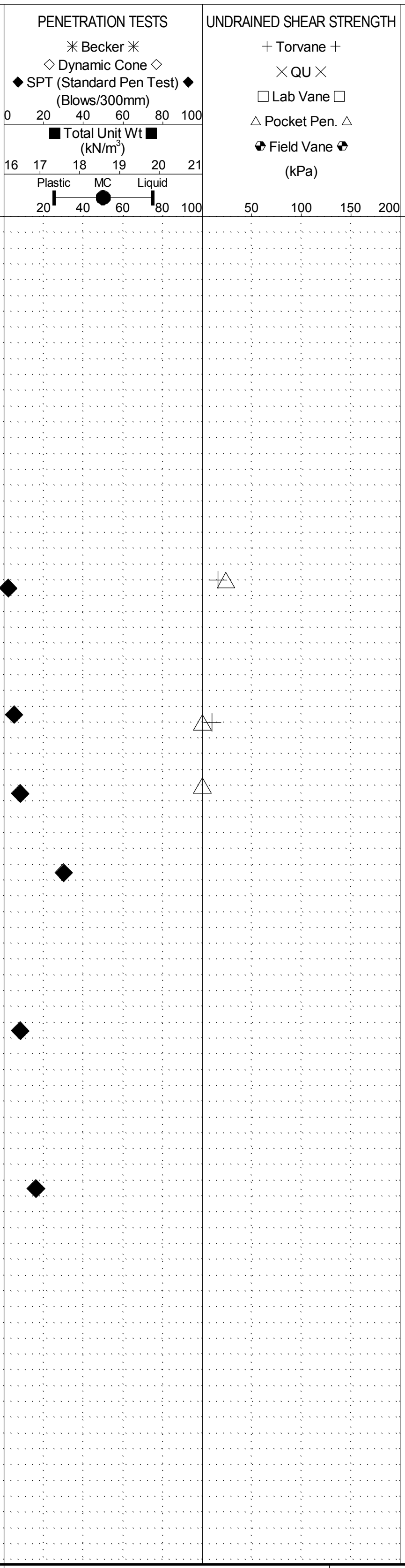
END OF TEST HOLE at 9.6 m in TILL

Notes:

1) 150 mm casing used upto 2.65 m below riverbed
2) HQ coring was used to advance the test hole
3) No sloughing observed in the test holes
4) The test hole was grouted to the riverbed upon completion

DEPTH (m): 0 1 2 3 4 5 6 7 8 9 10 11 12 13

ELEVATION: 224 223 222 221 220 219 218 217 216 215 214 213 212



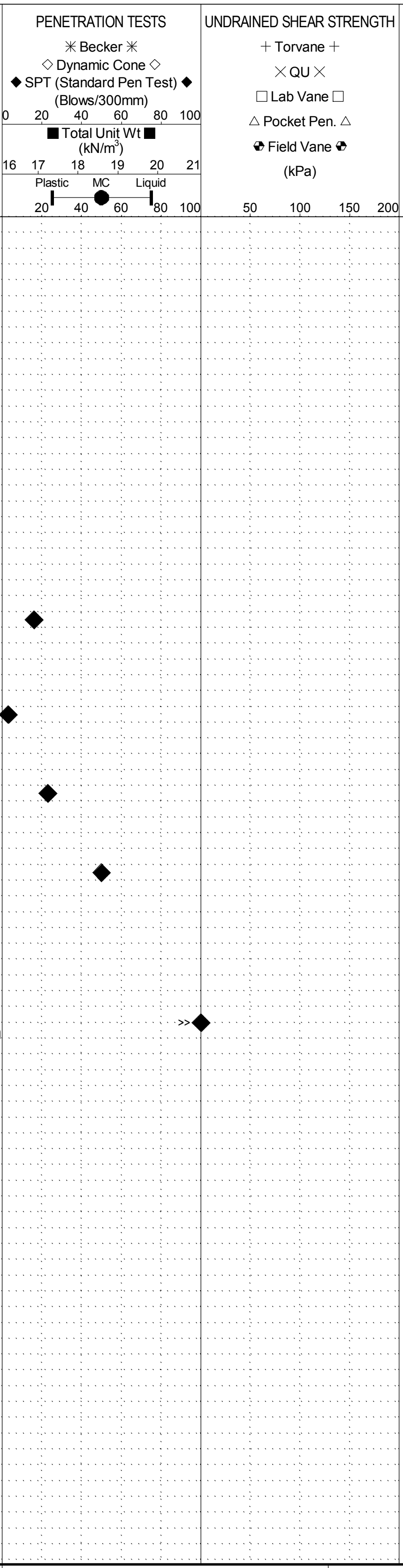
LOGGED BY: Omer Eissa	COMPLETION DEPTH: 2.93 m
REVIEWED BY: Faris Khalil	COMPLETION DATE: 5/23/11
PROJECT ENGINEER: Faris Khalil	Page 1 of 1

AECOM

PROJECT: Mid Town Feedermain at Assiniboine River	CLIENT: City of Winnipeg	TESTHOLE NO: **TH12-03**
LOCATION: 631070 E, 5526485 N, 1 m upstream of existing bridge, 25 m north of south bank		PROJECT NO.: 60256129
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, HQ Coring	ELEVATION (m): 224.45

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◩ NO RECOVERY ▮ CORE

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
0 1 2 3		- WATER					224 223 222 221
4		SAND (Alluvial)- trace silt, trace gravel - dark grey, wet, compact - poorly/uniform graded - some cobbles below 4.4 m	☒	S14	16	- 10, 7, 9 blows	220
5 6		SILT (Till) - sandy, some gravel (angular/sub-angular < 40 mm) - grey, moist, compact - coarse sand seam <25 mm	☒ ☒	S15 S16	3 23	- 3, 1, 2 blows - 7, 8, 15 blows	219
7		SAND (Till) - silt, some gravel (angular/sub angular < 20 mm) - grey, moist, compact to dense - occasional limestone/granite boulders (130 mm - 270 mm)	☒ ▮ ☒	S17 C7 S18	50 50/ 102mm	- 25, 26, 24 blows Recovery = 40% - 50 blows/ 75 mm	218 217
8		BEDROCK - bedrock contact zone - limestone/dolomite - fine grained, clay filled seam (<60 mm)	▮	C8		Recovery = 96%, RQD = 57%	216
9 10 11 12 13		END OF TEST HOLE at 8.8 m in BEDROCK Notes: 1) 150 mm casing used up to 3.35 m below riverbed 2) HQ coring was used to advance the test hole 3) No sloughing observed in the test holes 4) The test hole was grouted to the riverbed upon completion					215 214 213 212



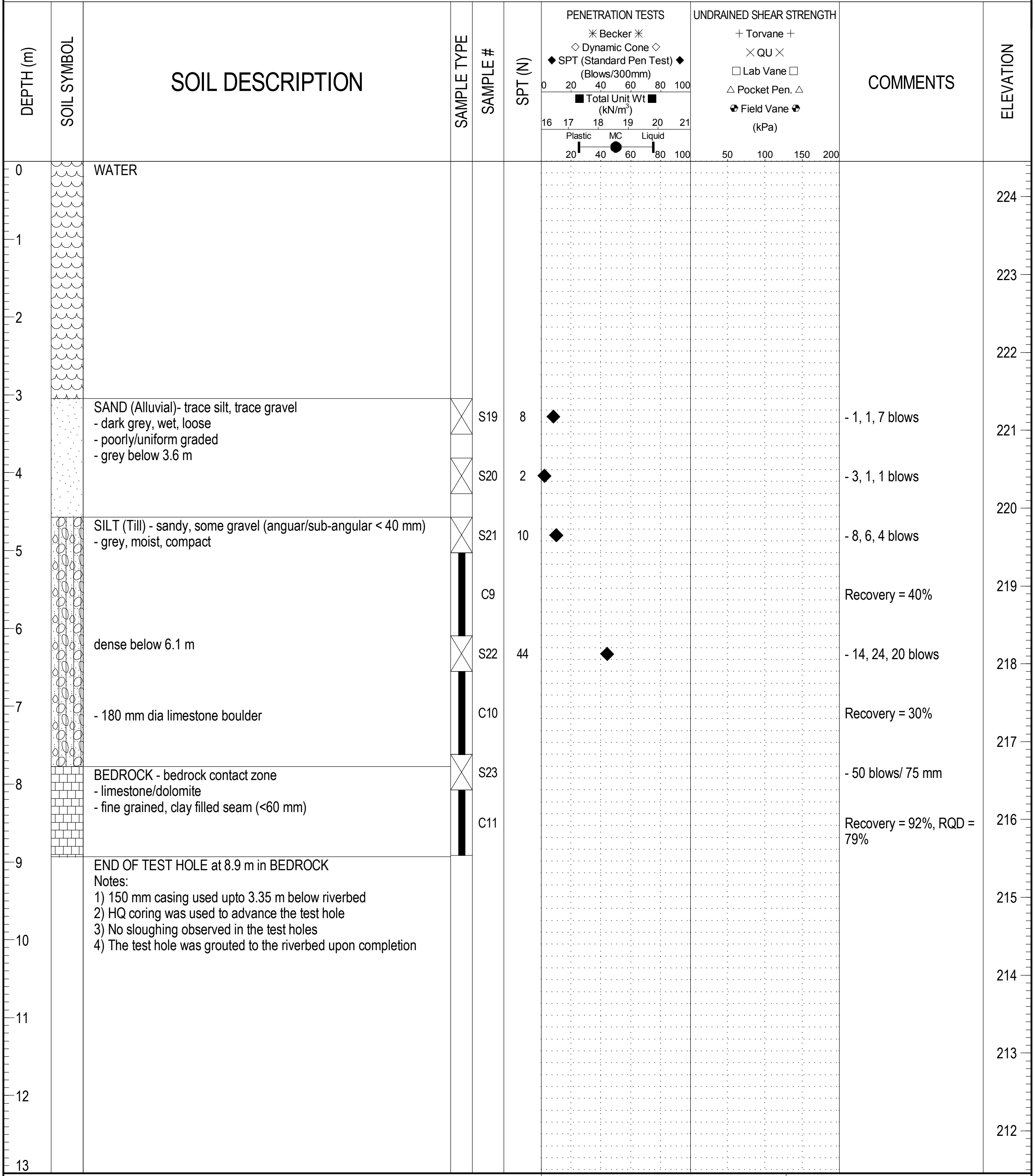
LOGGED BY: Omer Eissa	COMPLETION DEPTH: 2.68 m
REVIEWED BY: Faris Khalil	COMPLETION DATE: 5/24/11
PROJECT ENGINEER: Faris Khalil	Page 1 of 1

AECOM

PROJECT: Mid Town Feedermain at Assiniboine River
CLIENT: City of Winnipeg
TESTHOLE NO: **TH12-04**
LOCATION: 631080 E, 5526508 N, 2 m upstream of existing bridge, 25 m south of north bank
PROJECT NO.: 60256129
CONTRACTOR: Paddock Drilling Ltd.
METHOD: Acker ASS, HQ Coring
ELEVATION (m): 224.45

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◸ NO RECOVERY ▌ CORE

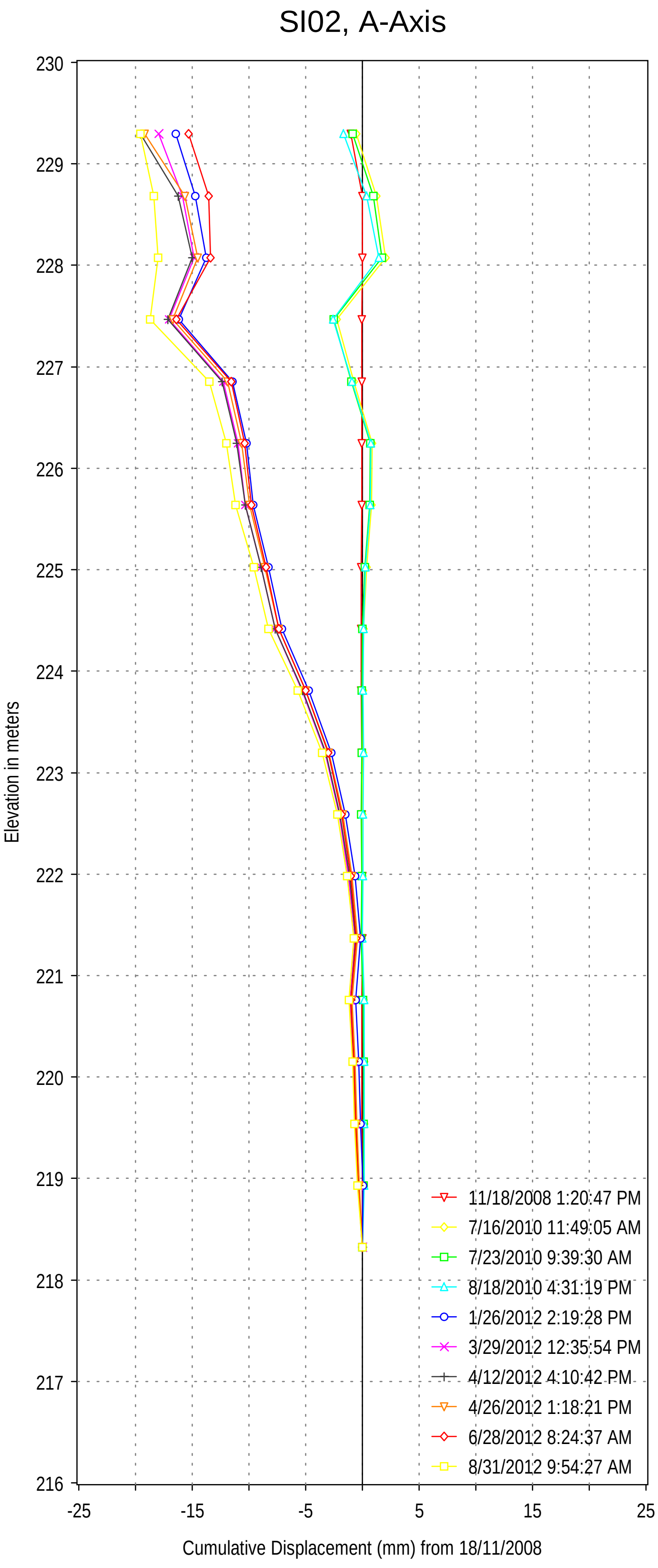
SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS
WATER				
SAND (Alluvial)- trace silt, trace gravel - dark grey, wet, loose - poorly/uniform graded - grey below 3.6 m	☒	S19	8	- 1, 1, 7 blows
	☒	S20	2	- 3, 1, 1 blows
SILT (Till) - sandy, some gravel (anguar/sub-angular < 40 mm) - grey, moist, compact	☒	S21	10	- 8, 6, 4 blows
	▌	C9		Recovery = 40%
dense below 6.1 m	☒	S22	44	- 14, 24, 20 blows
- 180 mm dia limestone boulder	▌	C10		Recovery = 30%
BEDROCK - bedrock contact zone - limestone/dolomite - fine grained, clay filled seam (<60 mm)	☒	S23		- 50 blows/ 75 mm
	▌	C11		Recovery = 92%, RQD = 79%
END OF TEST HOLE at 8.9 m in BEDROCK Notes: 1) 150 mm casing used upto 3.35 m below riverbed 2) HQ coring was used to advance the test hole 3) No sloughing observed in the test holes 4) The test hole was grouted to the riverbed upon completion				

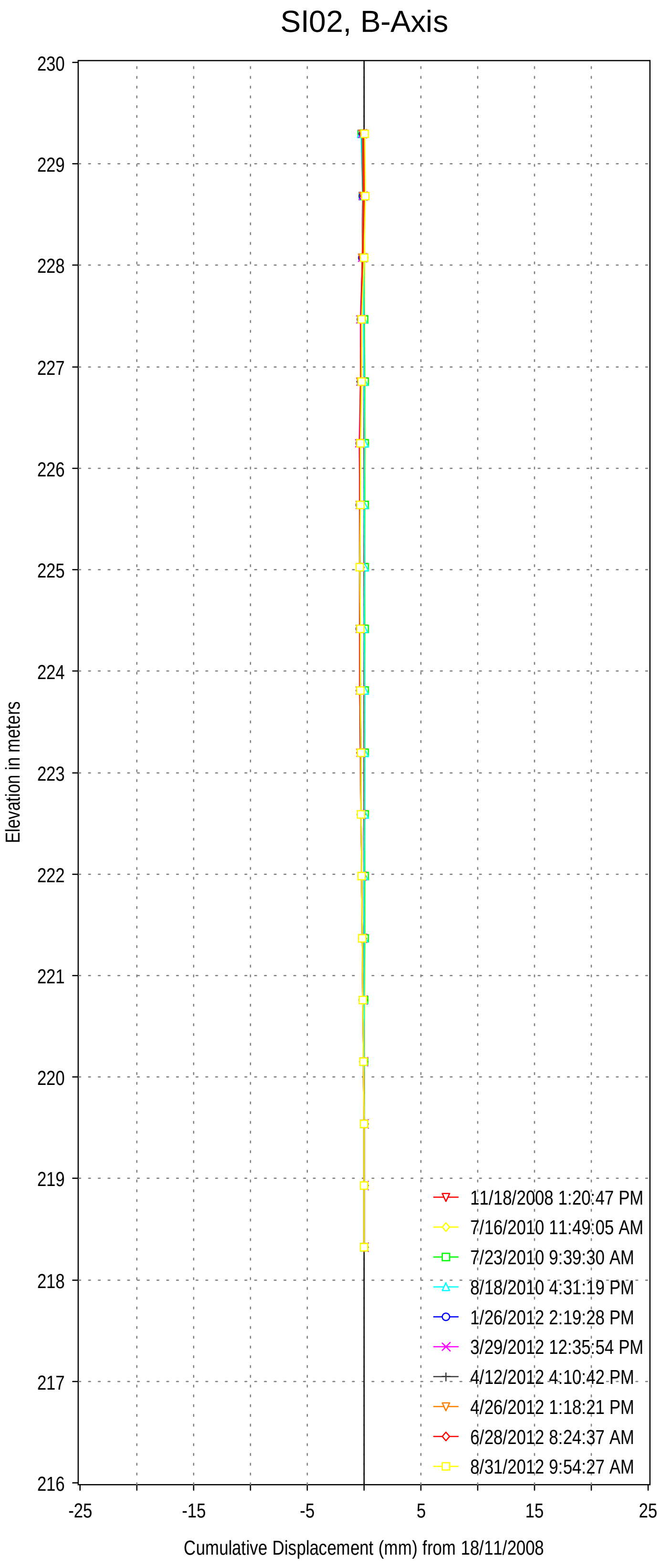


LOGGED BY: Omer Eissa
COMPLETION DEPTH: 2.71 m
REVIEWED BY: Faris Khalil
COMPLETION DATE: 5/24/11
PROJECT ENGINEER: Faris Khalil

Appendix C

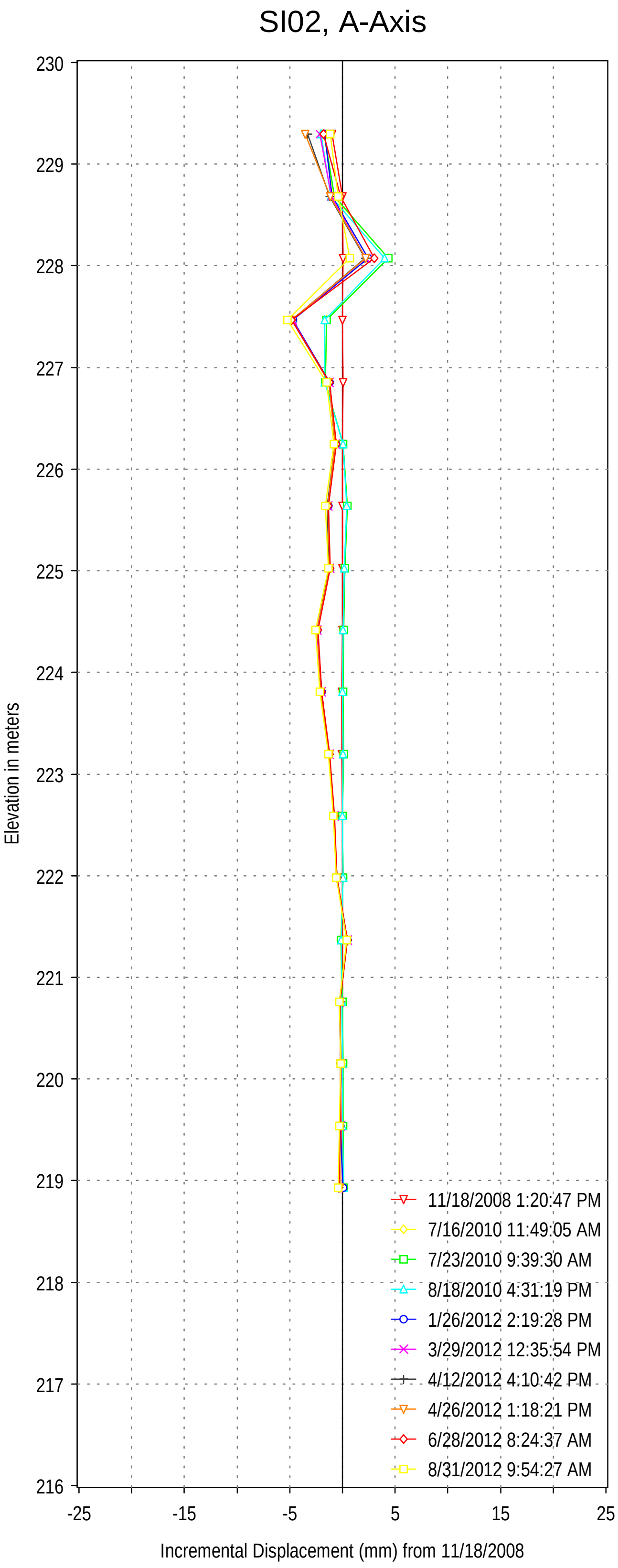
Stability Analysis Results

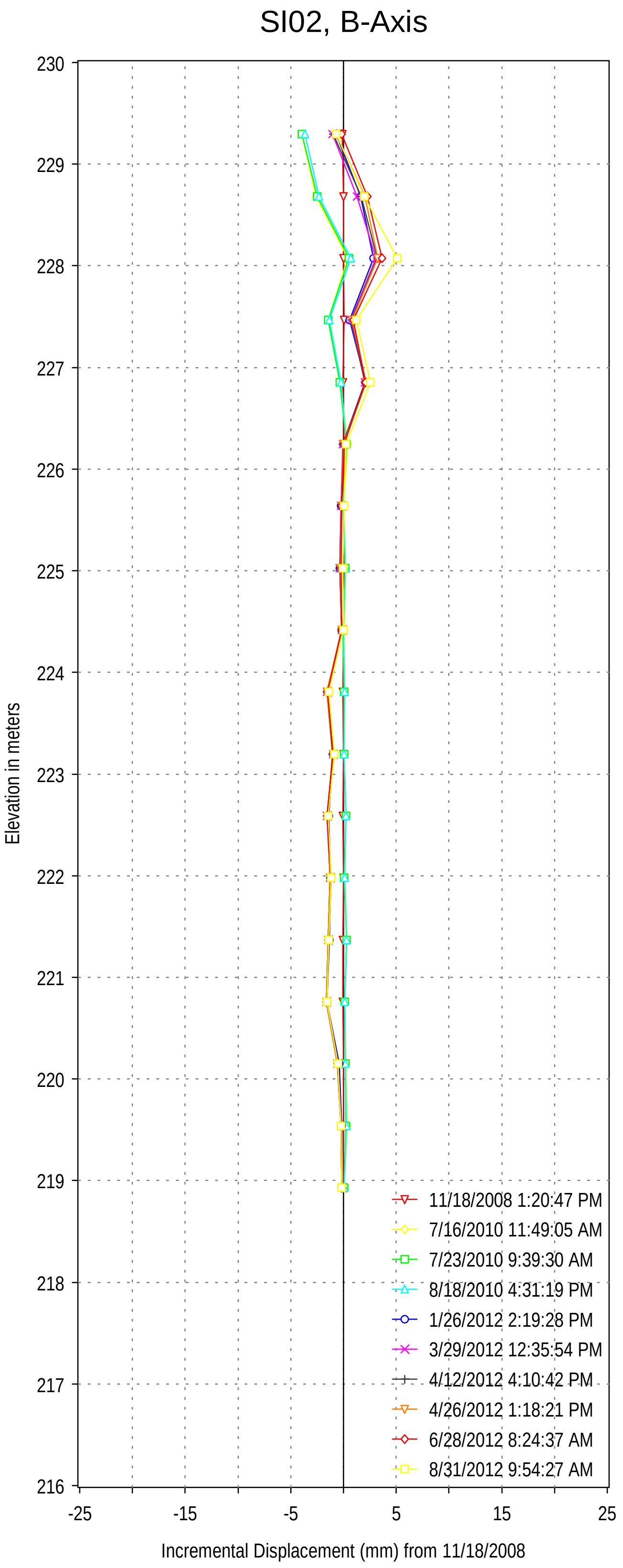




Midtown Feedermain South Bank
SI08-02
Ground Surface at Elev. 229.1 m
Cumulative Displacement

AECOM

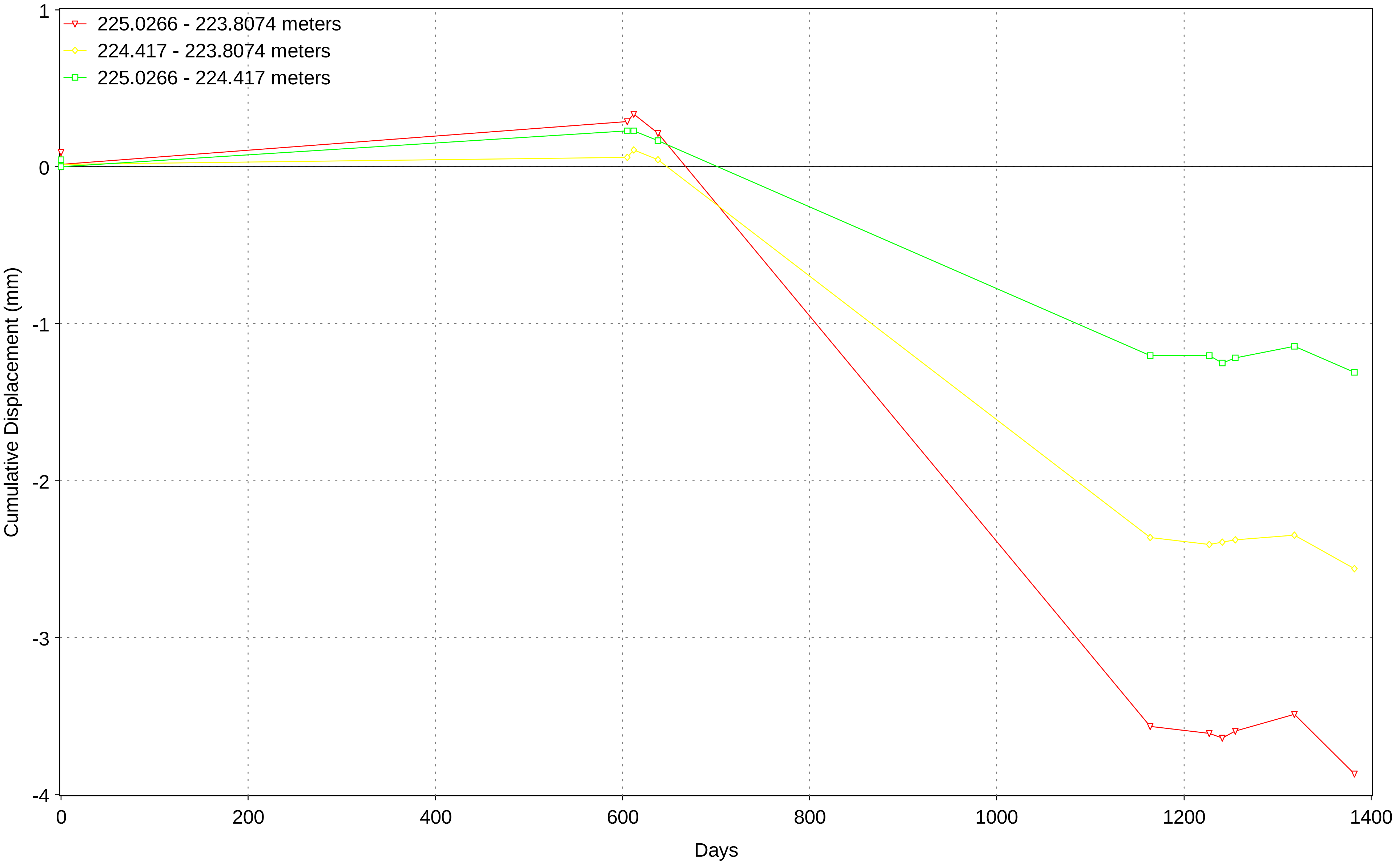

SI02, A-Axis


SI02, B-Axis

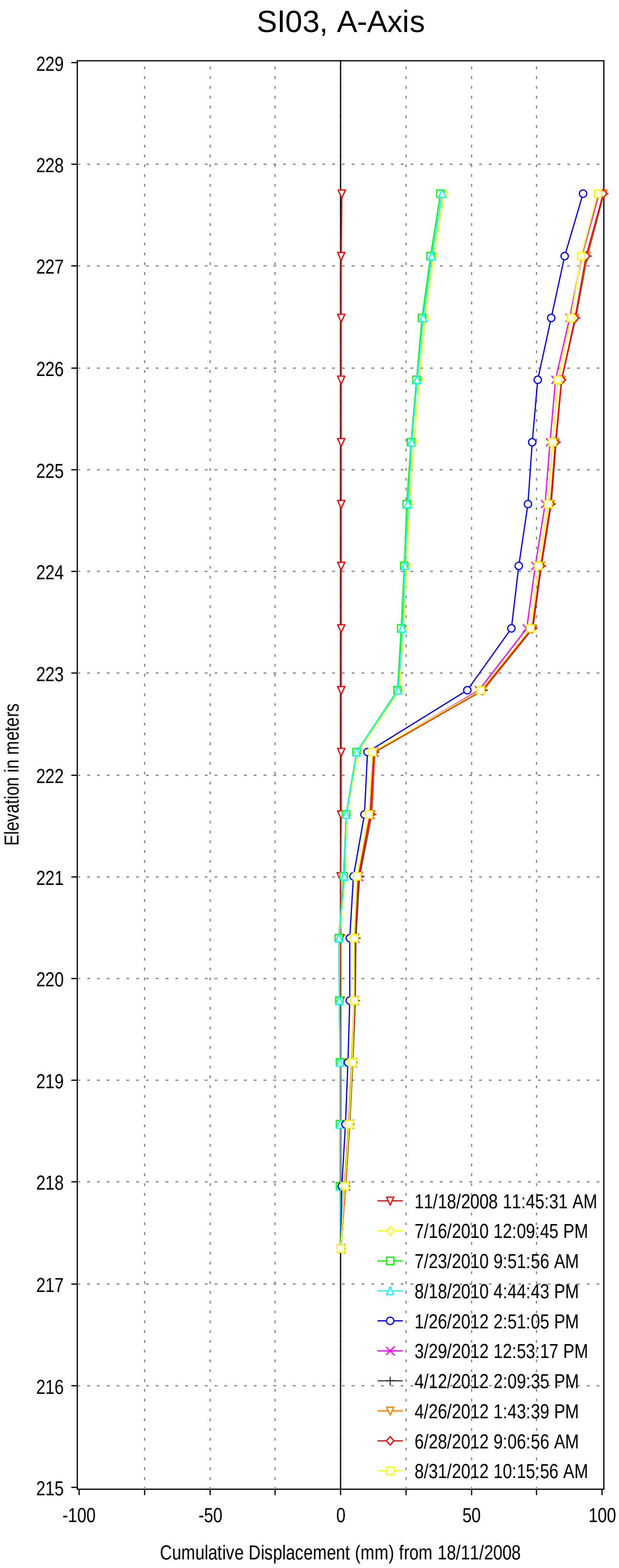
Midtown Feedermain South Bank
SI08-02
Ground Surface at Elev. 229.1
Incremental Displacement

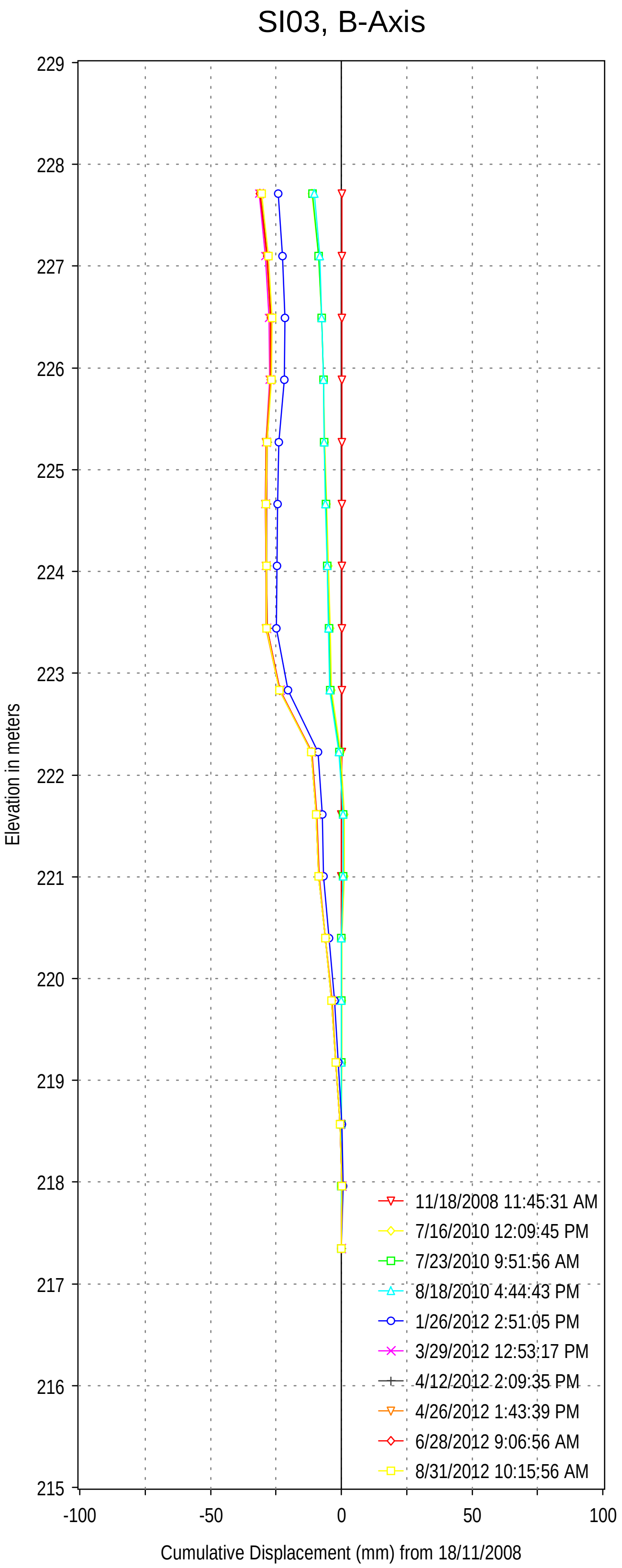
AECOM

MIDTWN SI02, A-Axis



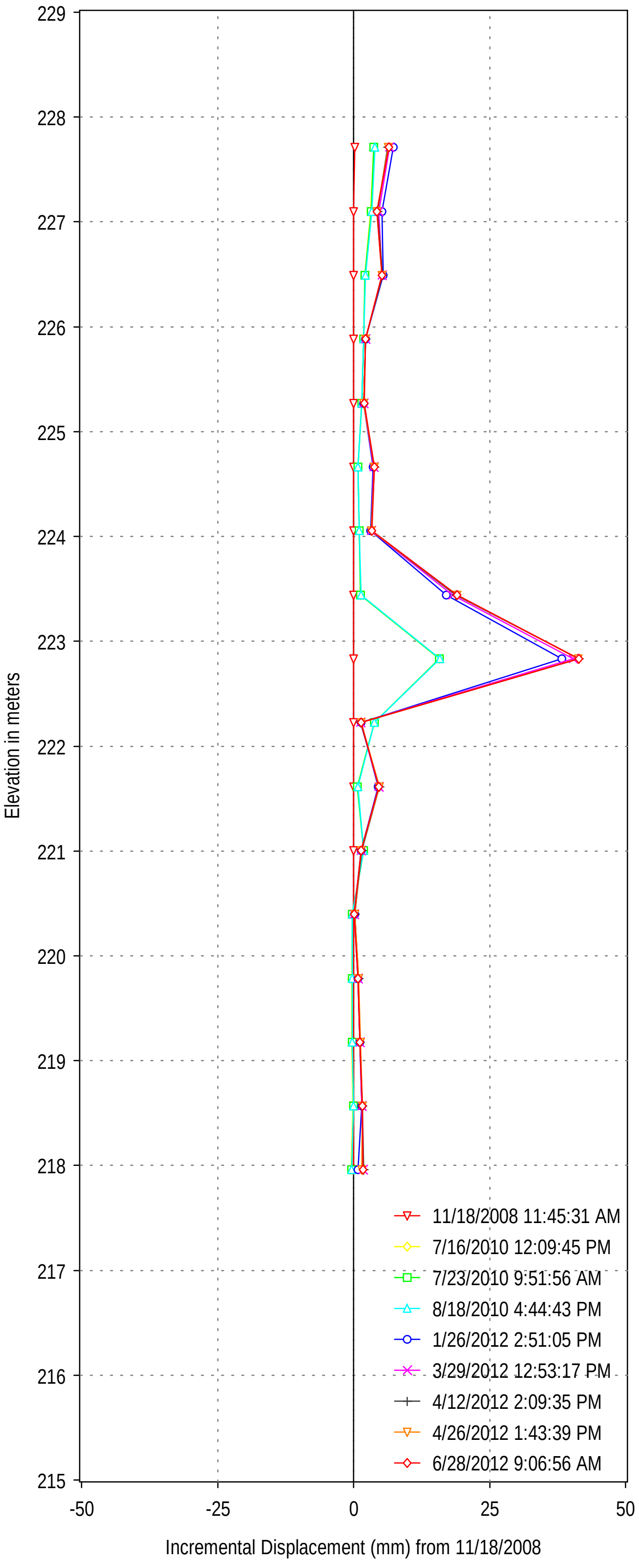
Midtown Feedermain South Bank
SI08-02
Ground Surface at Elev. 229.1 m
Time vs. Displacement



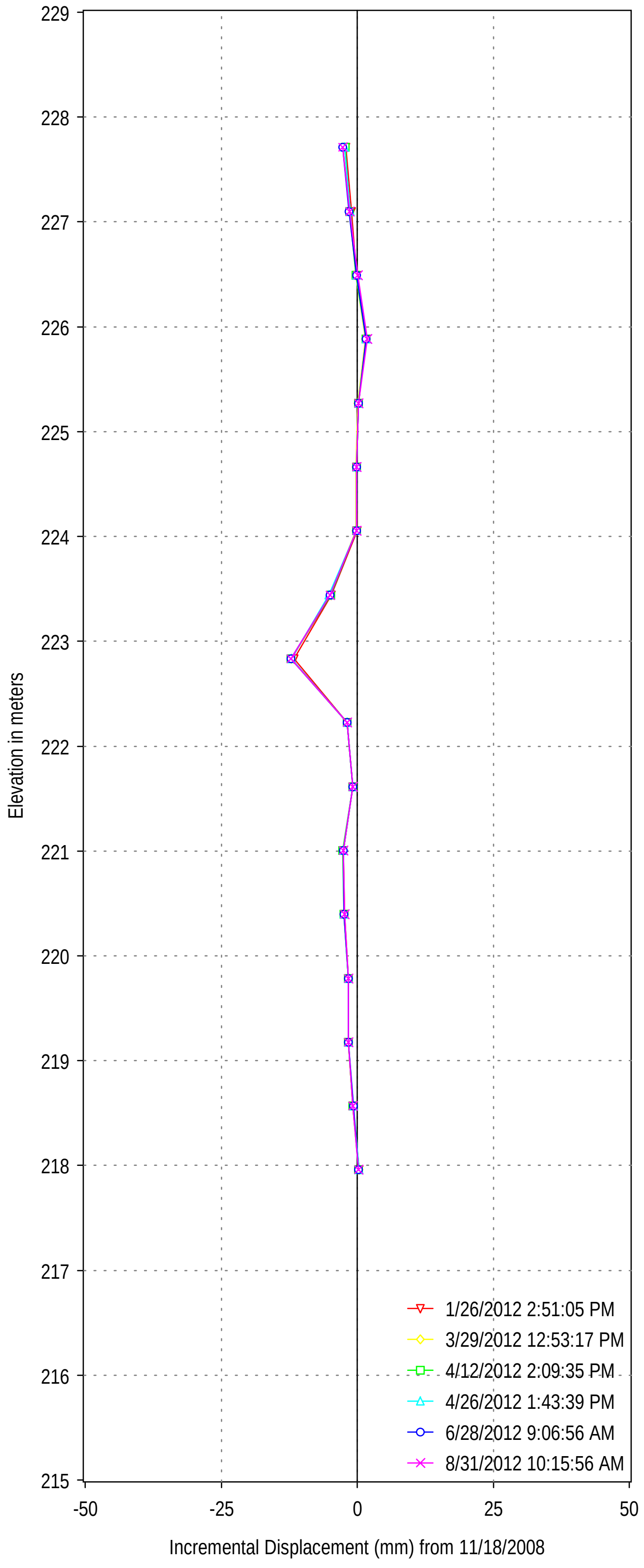


Midtown Feedermain South Bank
SI080-03
Ground Surface at Elev. 227.4 m
Cumulative Displacement

AECOM



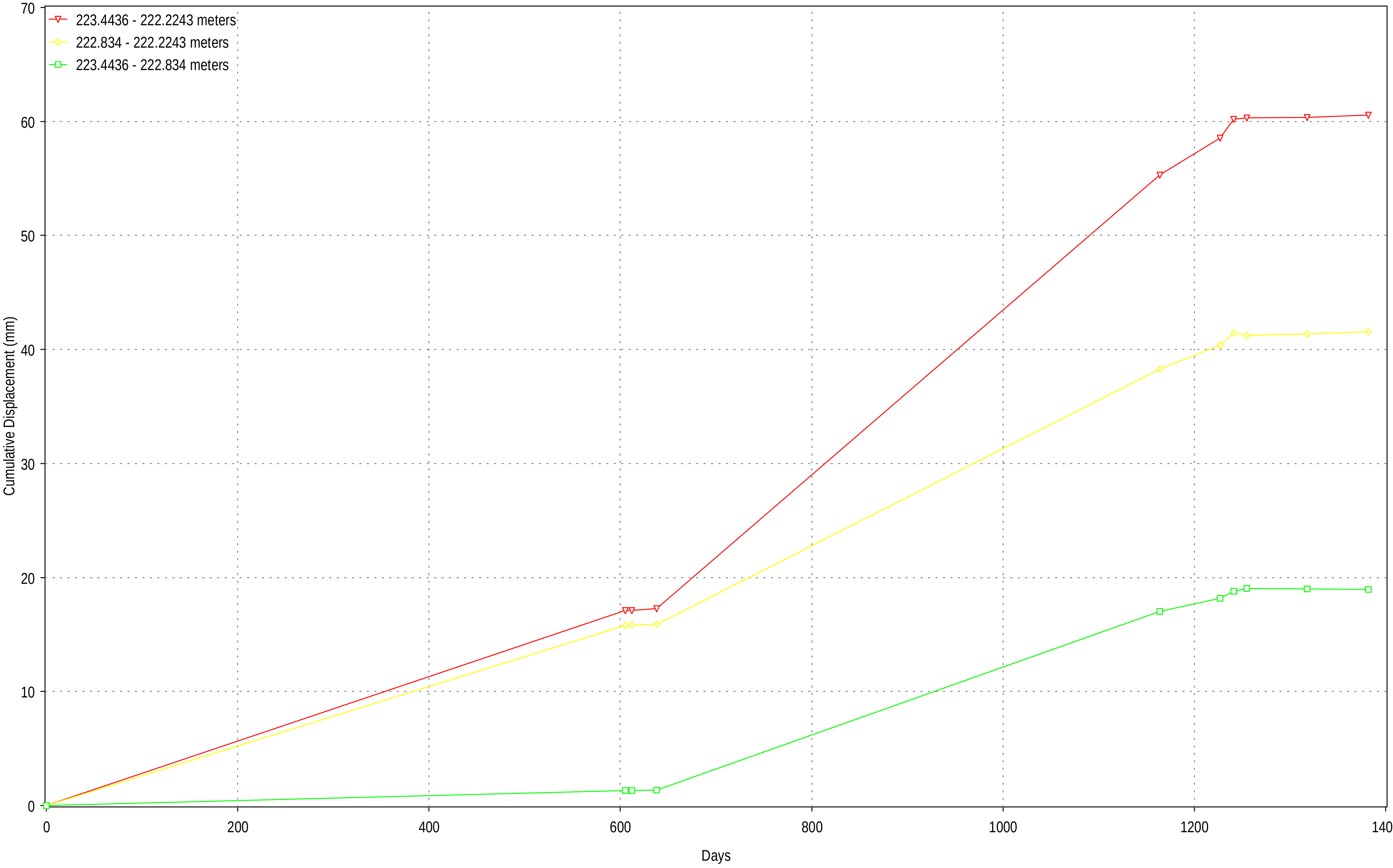
SI03, A-Axis



SI03, B-Axis

Midtown Feedermain South Bank
SI08-03
Ground Surface at Elev. 227.4 m
Incremental Displacement

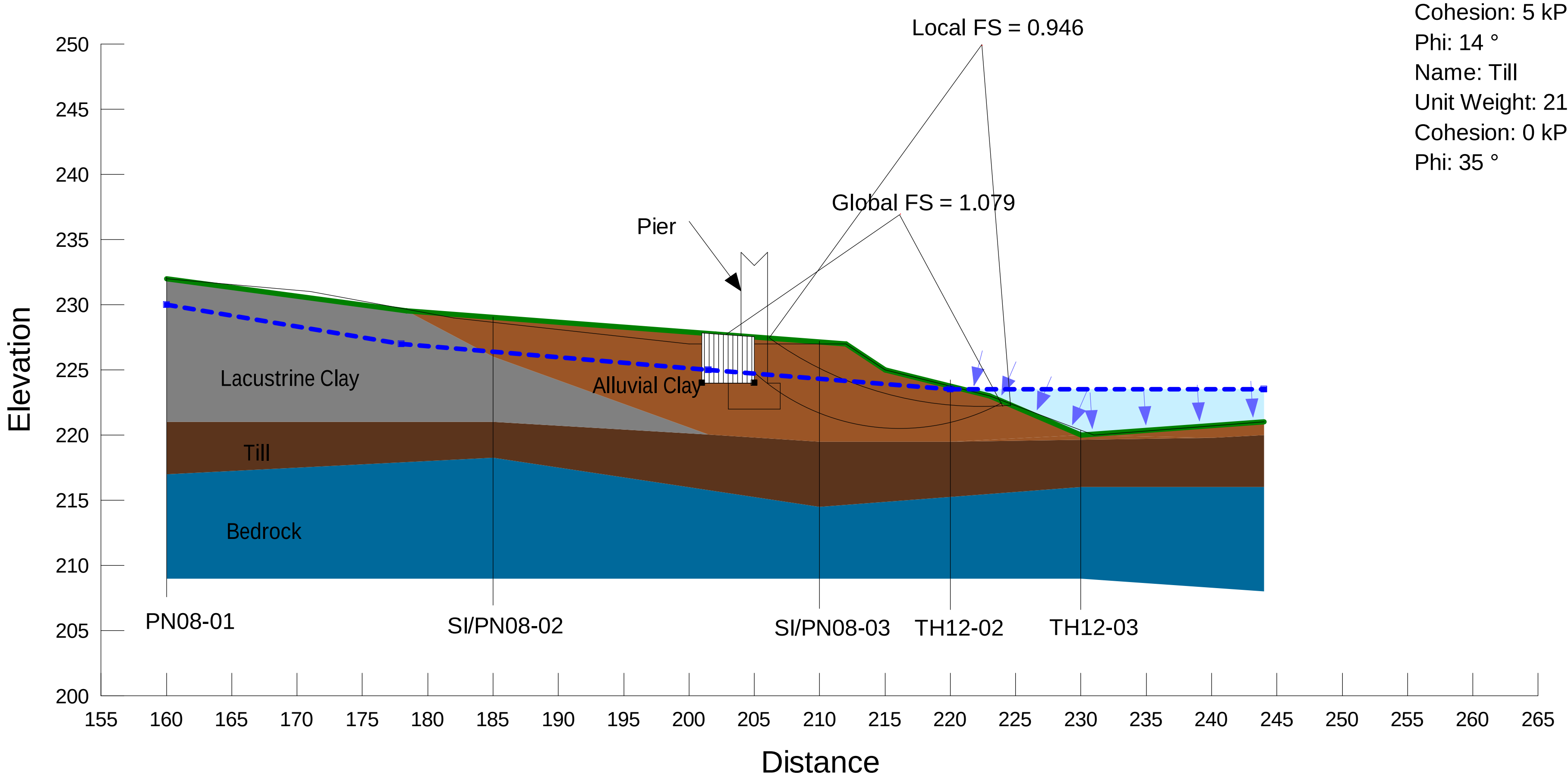
MIDTWN SI03, A-Axis



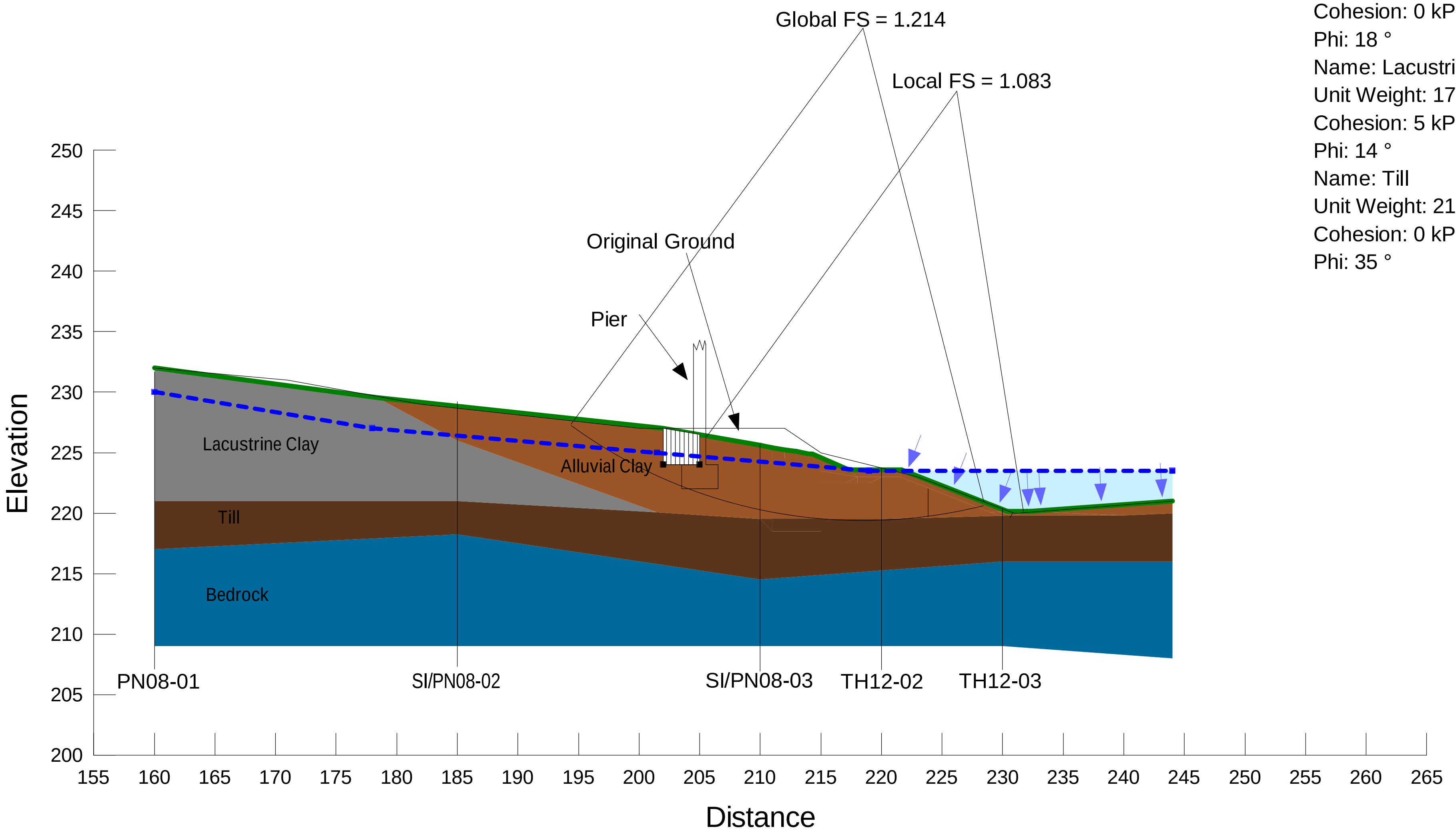
Midtown Feedermain South Bank
SI08-03
Ground Surface at Elev. 227.4 m
Time vs. Displacement

File Name: Midtown Feedermain - #2-South Bank LGW.gsz
Name: SLOPE/W Midtown Feedermain- Existing Geometry (WL = 223.5 m)
Method: Morgenstern-Price
Description: Figure 1: South Bank - Existing Geometry (WL = 223.5 m)

Name: Alluvial Clay
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Name: Lacustrine Clay
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 14 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 35 °

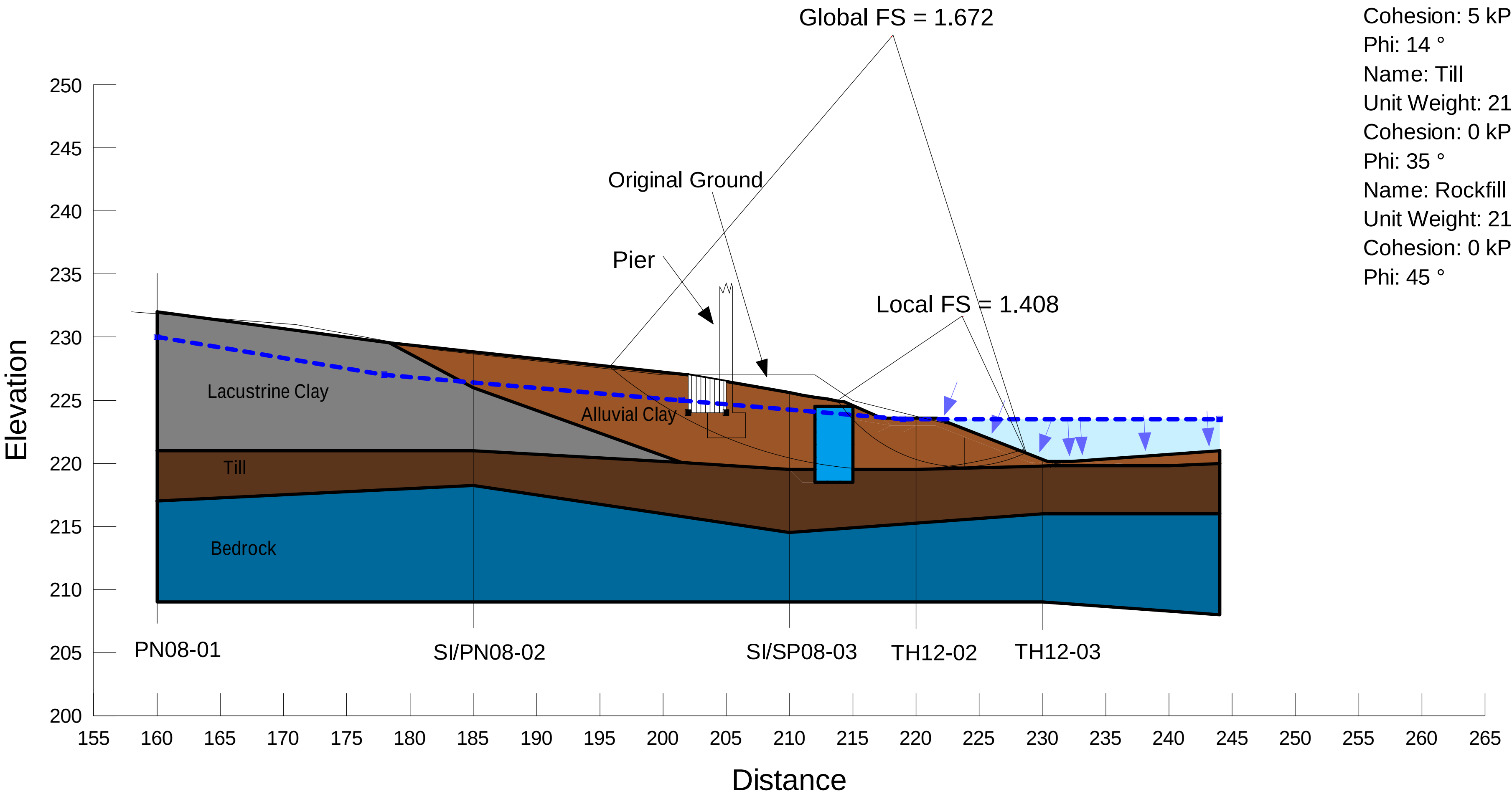


File Name: Midtown Feedermain - #21 South Bank (Regrading Only).gsz
Name: SLOPE/W Midtown FM - Water Level = 223.5 m
Method: Morgenstern-Price
Description: Figure 2: South Bank - Regrading Only



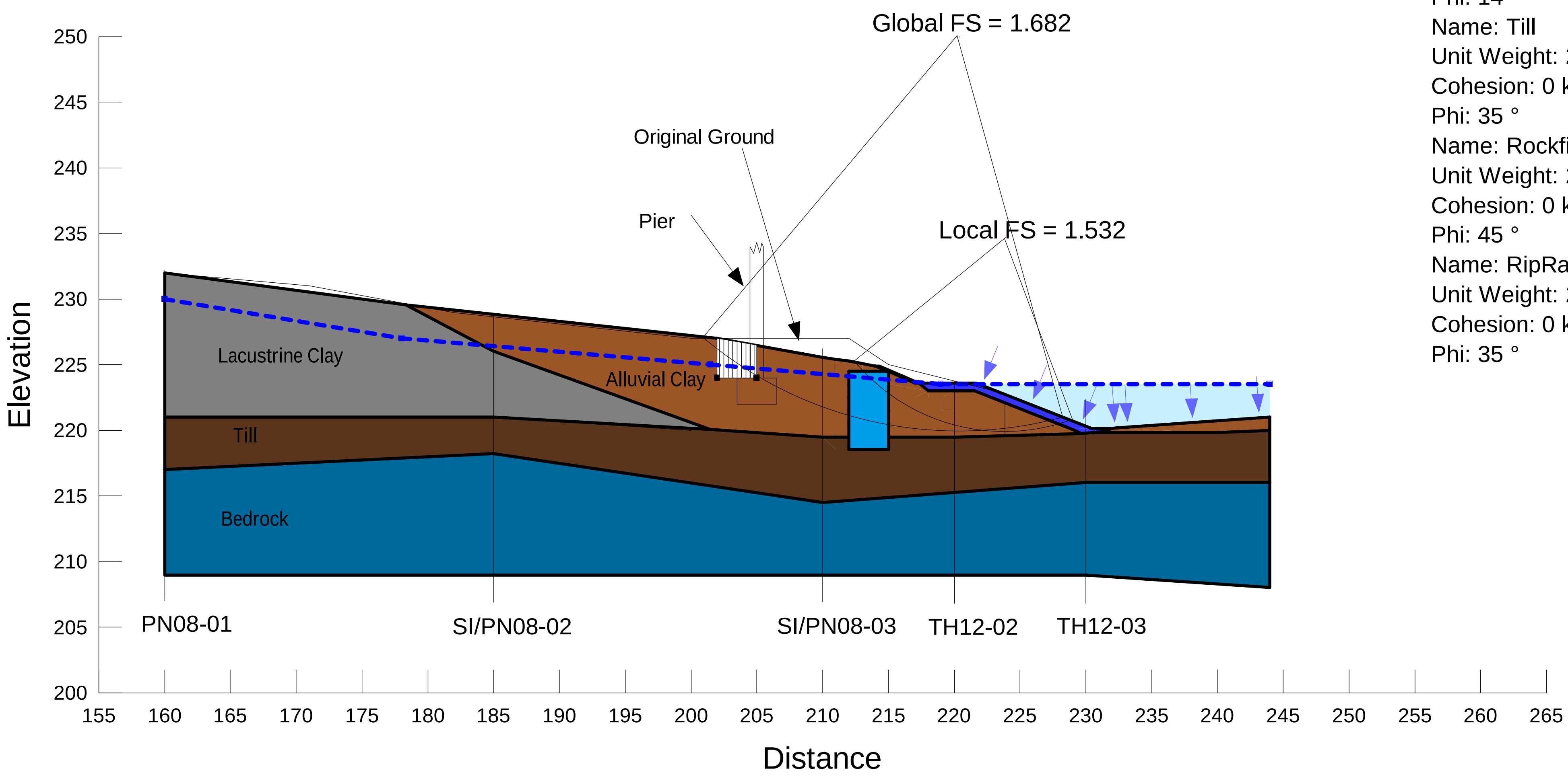
Name: Alluvial Clay
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Name: Lacustrine Clay
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 14 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 35 °

File Name: Midtown Feedermain - #22 South Bank (Regrading + Compacted 3mRC).gsz
Name: SLOPE/W Midtown FM - Water Level = 223.5 m
Method: Morgenstern-Price
Description: Figure 3: South Bank - Regrading + Shear key (3m)



Name: Alluvial Clay
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Name: Lacustrine Clay
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 14 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Name: Rockfill
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 45 °

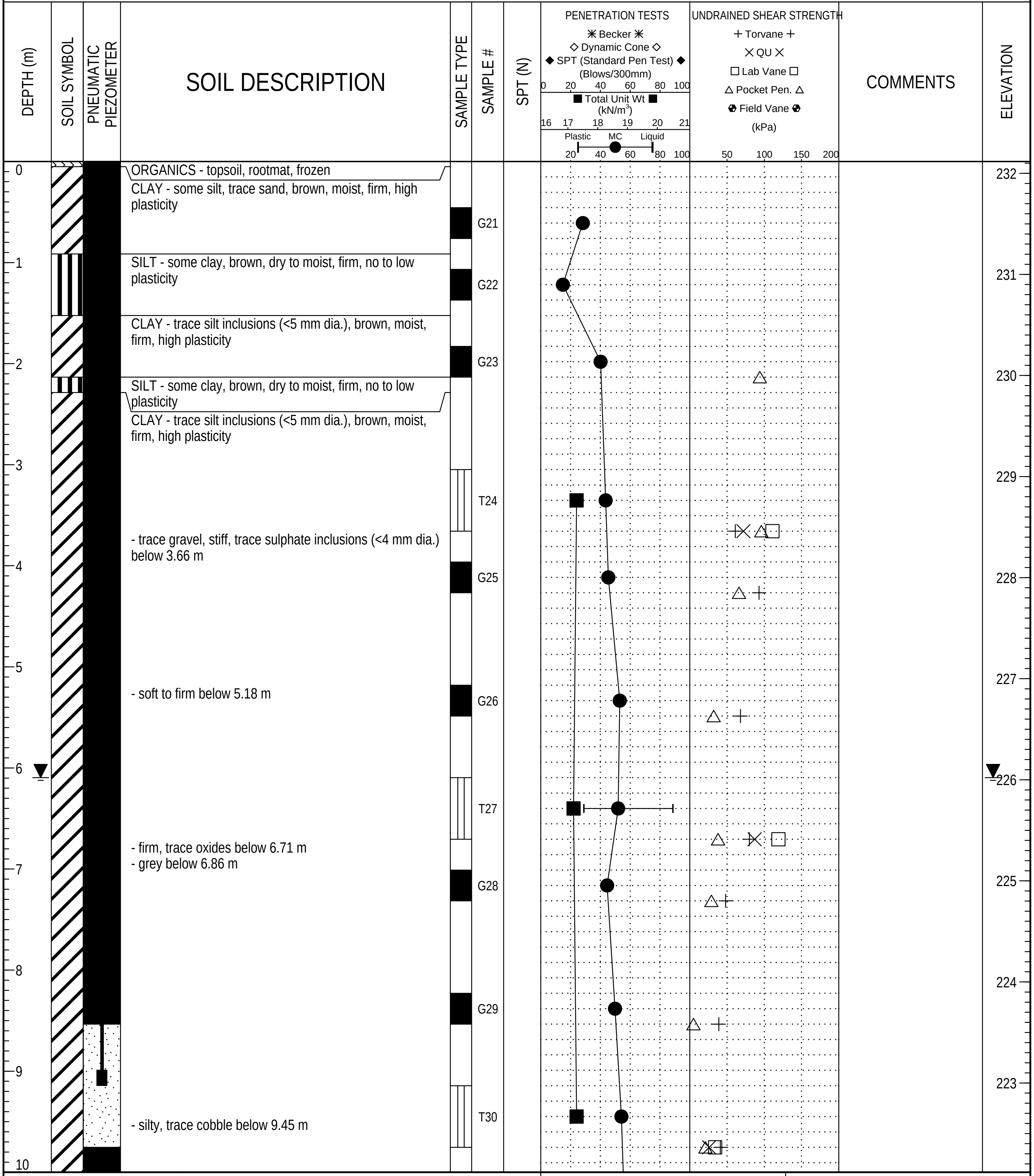
File Name: Midtown Feedermain - Final#23 South Bank (Compacted 3 m-ReG+RC+RP).gsz
Name: SLOPE/W Midtown FM - Water Level = 223.5 m
Method: Morgenstern-Price
Description: Figure 4: South Bank - Regrading + Shear Key(3m) + Rip Rap Blanket



Name: Alluvial Clay
Unit Weight: 17 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Name: Lacustrine Clay
Unit Weight: 17 kN/m³
Cohesion: 5 kPa
Phi: 14 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Name: Rockfill
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 45 °
Name: RipRap
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 35 °

PROJECT: Midtown Feedermain Geotechnical Investigation
CLIENT: City of Winnipeg
TESTHOLE NO: PN08-01
LOCATION: 631039.365 E, 5526408.918 N, top of south bank
PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.
METHOD: Acker ASS, 125 mm SSA
ELEVATION (m): 232.117

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	◪ NO RECOVERY	▮ CORE
BACKFILL TYPE	■ BENTONITE	⁚ GRAVEL	▥ SLOUGH	⁘ GROUT	◪ CUTTINGS	⁚ SAND



ORGANICS - topsoil, rootmat, frozen

CLAY - some silt, trace sand, brown, moist, firm, high plasticity

SILT - some clay, brown, dry to moist, firm, no to low plasticity

CLAY - trace silt inclusions (<5 mm dia.), brown, moist, firm, high plasticity

SILT - some clay, brown, dry to moist, firm, no to low plasticity

CLAY - trace silt inclusions (<5 mm dia.), brown, moist, firm, high plasticity

- trace gravel, stiff, trace sulphate inclusions (<4 mm dia.) below 3.66 m
- soft to firm below 5.18 m
- firm, trace oxides below 6.71 m
- grey below 6.86 m
- silty, trace cobble below 9.45 m

AECOM

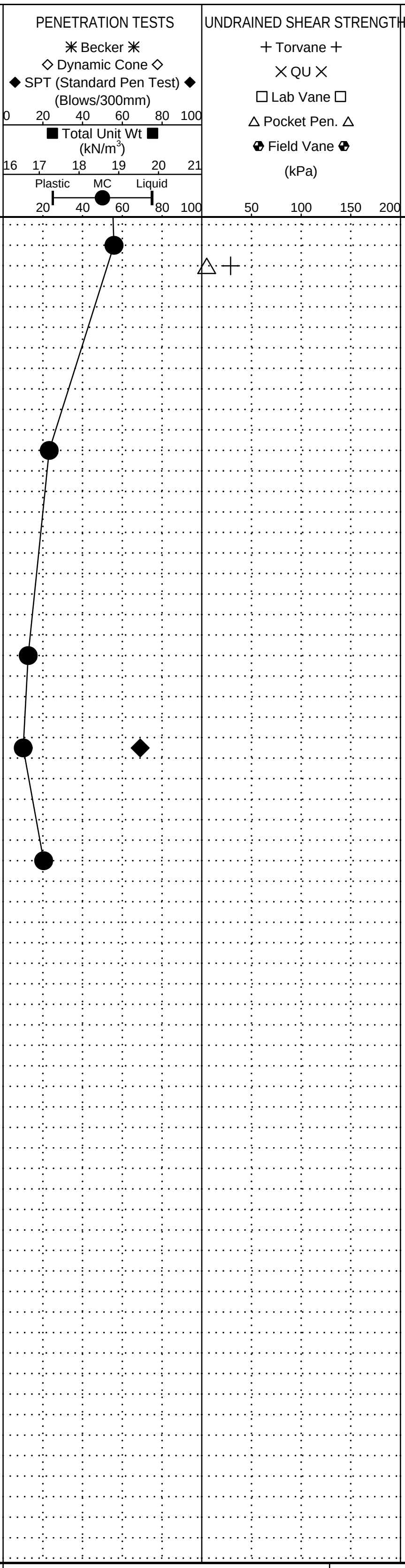
LOGGED BY: Jared Baldwin
REVIEWED BY: Jeff Tallin
PROJECT ENGINEER: Jeff Tallin
COMPLETION DEPTH: 14.94 m
COMPLETION DATE: 10/11/08

PROJECT: Midtown Feedermain Geotechnical Investigation	CLIENT: City of Winnipeg	TESTHOLE NO: PN08-01
LOCATION: 631039.365 E, 5526408.918 N, top of south bank		PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, 125 mm SSA	ELEVATION (m): 232.117

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ▨ NO RECOVERY ▌CORE

BACKFILL TYPE ■ BENTONITE ⁙ GRAVEL ▥ SLOUGH ⁙ GROUT ▨ CUTTINGS ⁙ SAND

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
10		■	G31			222
11	CLAY (Putty Till) - silty, some sand, trace gravel (<20 mm dia.), light grey, moist, soft, intermediate plasticity	■	G32			221
12						220
13	SILT (Till) - sandy, clayey, some gravel (<20 mm dia.), light grey, moist, firm, low to intermediate plasticity	■	G33			219
14	- some clay, stiff to very stiff below 14.02 m	☒	S34	69	SPT Blows: 8, 30, 39	218
		■	G35			
15	End of test hole at 14.94 m in TILL Notes: 1) Auger refusal at 14.94 m below ground suface. 2) No sloughing. 3) Seepage encountered at 11.28 m below ground surface. 4) Water level measured at 6.1 m below ground surface immediately after drilling. 5) Pnuematic piezometer (PN08-01) installed at 9.14 m below ground surface. 6) Above ground protective metal casing installed.					217
16						216
17						215
18						214
19						213
20						

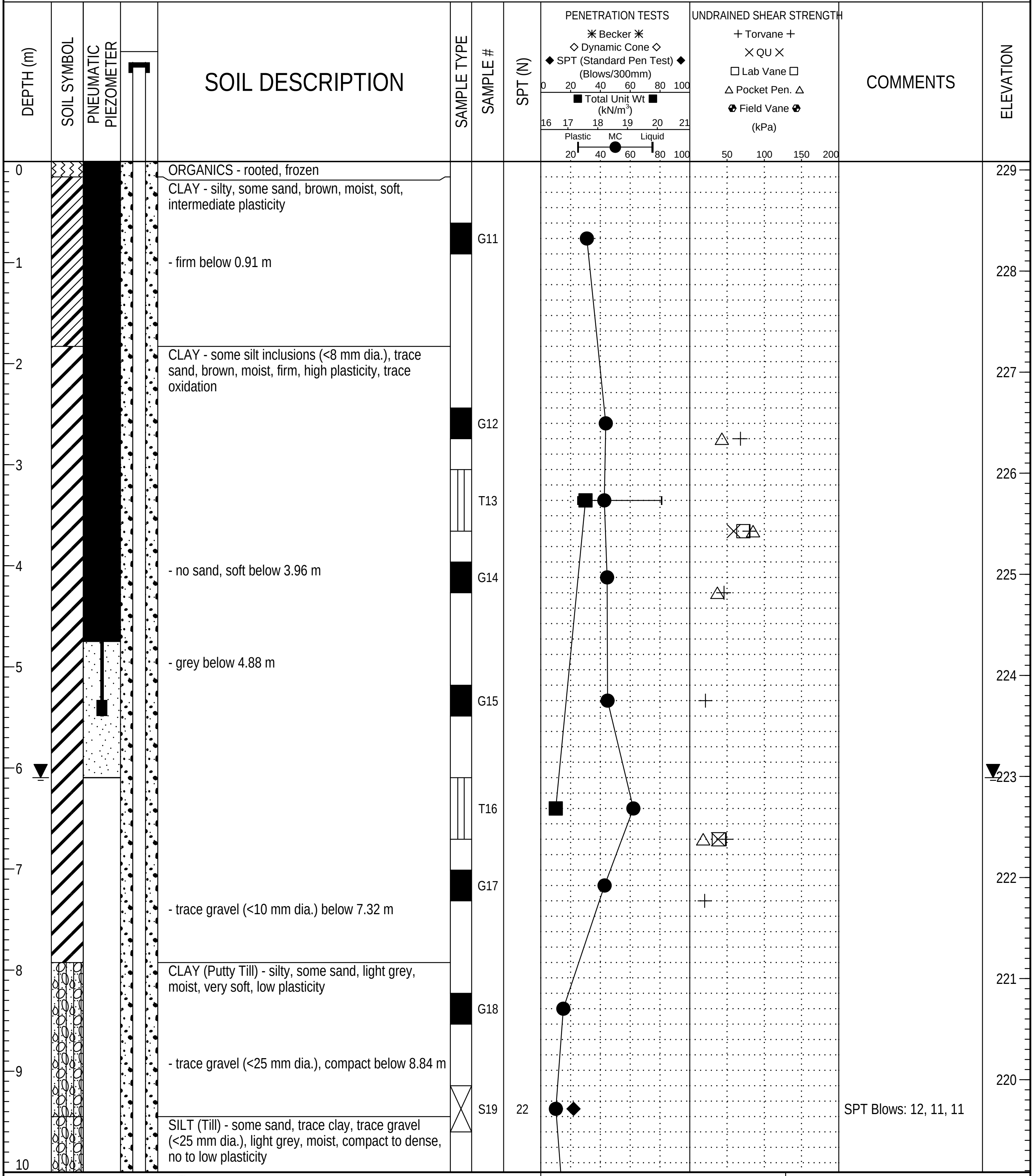


LOGGED BY: Jared Baldwin	COMPLETION DEPTH: 14.94 m
REVIEWED BY: Jeff Tallin	COMPLETION DATE: 10/11/08
PROJECT ENGINEER: Jeff Tallin	Page 2 of 2

AECOM

PROJECT: Midtown Feedermain Geotechnical Investigation	CLIENT: City of Winnipeg	TESTHOLE NO: SI/PN08-02
LOCATION: 631053.861 E, 5526428.148 N, middle of south bank		PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, 125 mm SSA	ELEVATION (m): 229.084

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	▨ NO RECOVERY	▮ CORE
BACKFILL TYPE	■ BENTONITE	⁚ GRAVEL	▥ SLOUGH	⁘ GROUT	▨ CUTTINGS	⁚ SAND



ORGANICS - rooted, frozen

CLAY - silty, some sand, brown, moist, soft, intermediate plasticity

- firm below 0.91 m

CLAY - some silt inclusions (<8 mm dia.), trace sand, brown, moist, firm, high plasticity, trace oxidation

- no sand, soft below 3.96 m

- grey below 4.88 m

- trace gravel (<10 mm dia.) below 7.32 m

CLAY (Putty Till) - silty, some sand, light grey, moist, very soft, low plasticity

- trace gravel (<25 mm dia.), compact below 8.84 m

SILT (Till) - some sand, trace clay, trace gravel (<25 mm dia.), light grey, moist, compact to dense, no to low plasticity

SPT Blows: 12, 11, 11

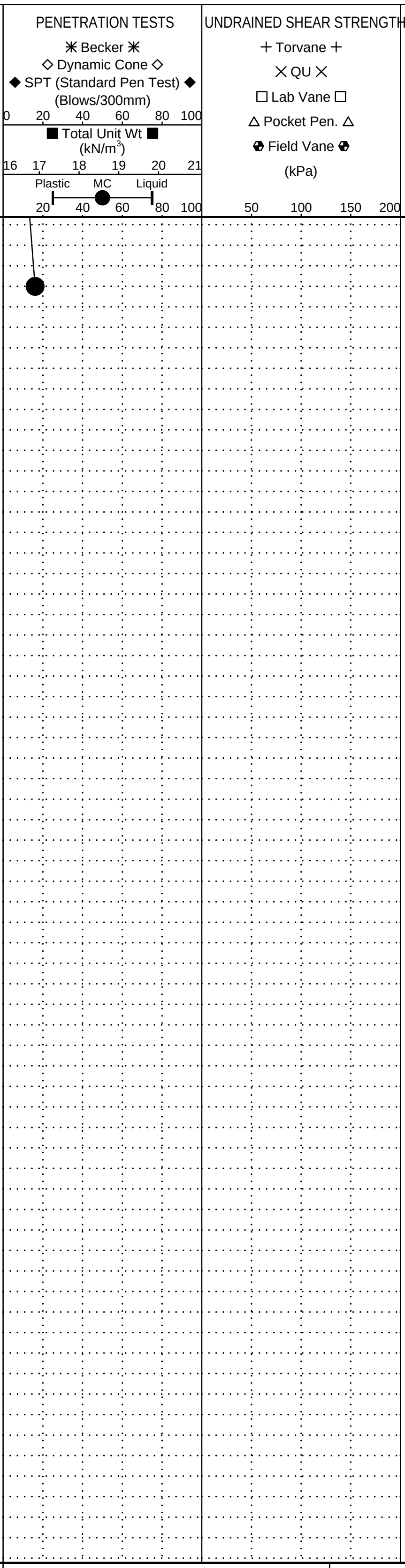
LOGGED BY: Jared Baldwin	COMPLETION DEPTH: 10.67 m
REVIEWED BY: Jeff Tallin	COMPLETION DATE: 9/11/08
PROJECT ENGINEER: Jeff Tallin	Page 1 of 2

AECOM

PROJECT: Midtown Feedermain Geotechnical Investigation	CLIENT: City of Winnipeg	TESTHOLE NO: SI/PN08-02
LOCATION: 631053.861 E, 5526428.148 N, middle of south bank		PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, 125 mm SSA	ELEVATION (m): 229.084

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	▨ NO RECOVERY	▮ CORE
BACKFILL TYPE	■ BENTONITE	⁚ GRAVEL	▥ SLOUGH	⁚ GROUT	▨ CUTTINGS	⁚ SAND

DEPTH (m)	SOIL SYMBOL	PNEUMATIC PIEZOMETER	SLOPE INCLINOMETER	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
10				- wet below 10.06 m					219
					■	G20			
11				End of test hole at 10.67 m in TILL Notes: 1) Auger refusal at 10.67 m below ground surface. 2) Sloughing below 10.62 m below ground suffface.. 3) Seepage encountered at 9.45 m below ground surface. 4) Water level measured at 6.1 m below ground surface immediately after drilling. 5) Slope inclinometer (SI08-02) installed to 10.62 m below ground surface. 6) Pneumatic piezometer (PN08-02) installed adjacent to SI08-02 at 5.49 m below ground surface. 7) Above ground protective metal casings installed.					218
12									217
13									216
14									215
15									214
16									213
17									212
18									211
19									210
20									



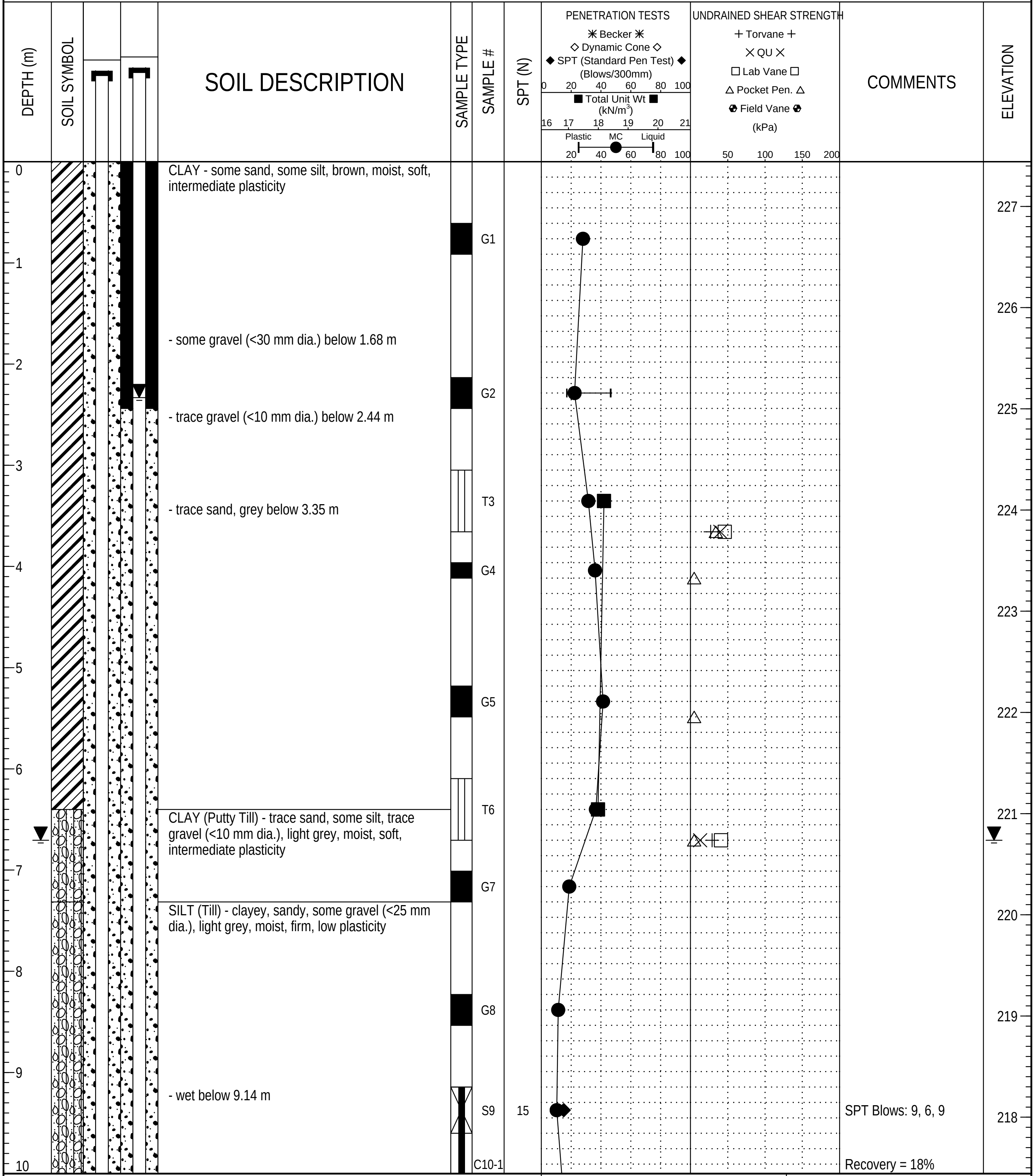
AECOM	LOGGED BY: Jared Baldwin	COMPLETION DEPTH: 10.67 m
	REVIEWED BY: Jeff Tallin	COMPLETION DATE: 9/11/08
	PROJECT ENGINEER: Jeff Tallin	Page 2 of 2

PROJECT: Midtown Feedermain Geotechnical Investigation | CLIENT: City of Winnipeg | TESTHOLE NO: SI/SP08-03

LOCATION: 631061.453 E, 5526453.423 N, toe of south bank | PROJECT NO.: D265-230-01

CONTRACTOR: Paddock Drilling Ltd. | METHOD: Acker ASS, 125 mm SSA / HQ Coring | ELEVATION (m): 227.442

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	◸ NO RECOVERY	▮ CORE
BACKFILL TYPE	■ BENTONITE	⁘ GRAVEL	▥ SLOUGH	⁘ GROUT	▨ CUTTINGS	⁘ SAND



CLAY - some sand, some silt, brown, moist, soft, intermediate plasticity

- some gravel (<30 mm dia.) below 1.68 m

- trace gravel (<10 mm dia.) below 2.44 m

- trace sand, grey below 3.35 m

CLAY (Putty Till) - trace sand, some silt, trace gravel (<10 mm dia.), light grey, moist, soft, intermediate plasticity

SILT (Till) - clayey, sandy, some gravel (<25 mm dia.), light grey, moist, firm, low plasticity

- wet below 9.14 m

SPT Blows: 9, 6, 9

Recovery = 18%

LOG OF TEST HOLE TEST HOLE LOGS - D265-230-01 - NOV 4 TO 10.GPJ UMA WINN.GDT 16/1/09

AECOM

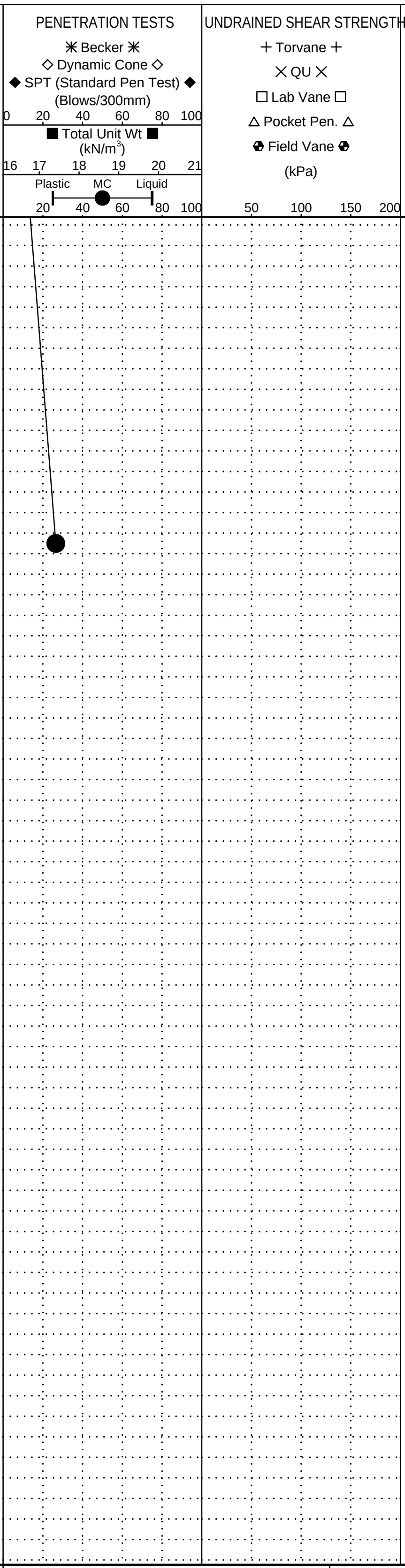
LOGGED BY: Jared Baldwin	COMPLETION DEPTH: 23.62 m
REVIEWED BY: Jeff Tallin	COMPLETION DATE: 9/11/08
PROJECT ENGINEER: Jeff Tallin	Page 1 of 3

PROJECT: Midtown Feedermain Geotechnical Investigation	CLIENT: City of Winnipeg	TESTHOLE NO: SI/SP08-03
LOCATION: 631061.453 E, 5526453.423 N, toe of south bank		PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, 125 mm SSA / HQ Coring	ELEVATION (m): 227.442

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ▨ NO RECOVERY ▌ CORE

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

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
10	COBBLE - (< 300mm dia.), gravely (subangular and angular), some granite, predominantly yellow/white limestone, some silt till					217
11		CORE	C10-2		Recovery = 63%	216
12		CORE	C10-3		Recovery = 98%	
		SPLIT SPOON	S10		SPT Blows: 50/5	215
13	BEDROCK - bedrock contact zone, limestone/dolomite, fine grained and slightly foliated, occasional rubble and clay filled seams	CORE	C10-4		RQD = 0%, Recovery = 28%	214
14		CORE	C10-5		RQD = 15%, Recovery = 55%	213
15		CORE	C10-6		RQD = 47%, Recovery = 100%	212
16	LIMESTONE - sound bedrock, white/light grey, massive, slight foliations and laminations, occasional pyrite inclusions - R4 strength, class 2 flow, moderately close discontinuity spacing					211
17		CORE	C10-7		RQD = 75%, Recovery = 72%	210
18	- rubbled zone, 1 to 5 cm pieces, some gravel and sand particles between 18.09 and 18.54 m	CORE	C10-8		RQD = 28%, Recovery = 72%	209
19						208
20		CORE	C10-9		RQD = 92%, Recovery =	



LOGGED BY: Jared Baldwin	COMPLETION DEPTH: 23.62 m
REVIEWED BY: Jeff Tallin	COMPLETION DATE: 9/11/08
PROJECT ENGINEER: Jeff Tallin	

PROJECT: Midtown Feedermain Geotechnical Investigation
CLIENT: City of Winnipeg
TESTHOLE NO: SI/SP08-03
LOCATION: 631061.453 E, 5526453.423 N, toe of south bank
PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.
METHOD: Acker ASS, 125 mm SSA / HQ Coring
ELEVATION (m): 227.442

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◿ NO RECOVERY ▮ CORE

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

PENETRATION TESTS: ✳ Becker ✳ ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100; ■ Total Unit Wt ■ (kN/m^3) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100

UNDRAINED SHEAR STRENGTH: + Torvane + × QU × ☐ Lab Vane ☐ △ Pocket Pen. △ ● Field Vane ● (kPa) 50 100 150 200

DEPTH (m)	SOIL DESCRIPTION	SAMPLE #	COMMENTS	ELEVATION
20			100%	
				207
21				
		C10-10	RQD = 93%, Recovery = 100%	206
22				
				205
		C10-11	RQD = 79%, Recovery = 100%	
23				
				204
	End of test hole at 23.62 m in LIMESTONE Notes: 1) No sloughing. 2) Solid stem auger to 9.14 m below ground surface. HQ coring to 23.62 m below ground surface. 3) Water level measured at 6.71 m below ground surface immediately after drilling. 4) Standpipe piezometer (SP08-03) with casagrande tip installed at 22.94 m below ground surface. 5) Slope inclinometer (SI08-03) installed adjacent to SP08-03 to 10.16 m below ground surface. 6) Above ground protective metal casings installed.			
24				
				203
25				
				202
26				
				201
27				
				200
28				
				199
29				
				198
30				

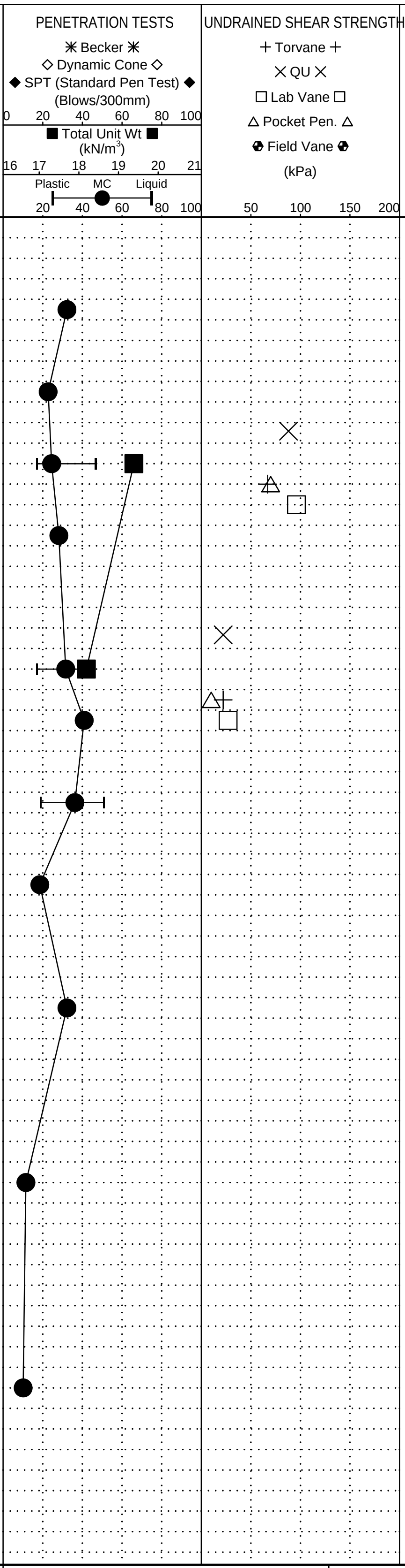
AECOM

LOGGED BY: Jared Baldwin
COMPLETION DEPTH: 23.62 m
REVIEWED BY: Jeff Tallin
COMPLETION DATE: 9/11/08
PROJECT ENGINEER: Jeff Tallin

PROJECT: Midtown Feedermain Geotechnical Investigation | CLIENT: City of Winnipeg | TESTHOLE NO: TH08-06
LOCATION: 631099.928 E, 5526535.755 N, toe of north bank | PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd. | METHOD: Acker ASS, 125 mm SSA / HQ Coring | ELEVATION (m): 227.076

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◿ NO RECOVERY ▮ CORE

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
0	▨	CLAY - silty, trace sand, trace reddish sand inclusions (<5 mm dia.), trace organics, brown, firm to stiff, moist, intermediate plasticity	■	G1			227
1		- black sandy seam, trace gravel, trace cobbles (<50 mm dia.) below 1.22 m	■ ▥	G2 T3			226
2	▥	SILT - clayey, trace to some sand, brown, soft, moist, intermediate plasticity	■	G4			225
3		- some sand to sandy below 3.05 m	▥	T5			224
4	▨	CLAY - silty, sandy, trace oxide inclusions (<5 mm dia.), brown, soft, moist to wet, high plasticity, intermittent fine sand seams (<25 mm thick) to 4.27 m - grey, some silt below 4.12 m	■ ■	G6 G7			223
▼		- some sand, some gravel (<15 mm dia.), brown, wet below 4.57 m					▼
5			■	G8			222
6		- trace sand, trace gravel below 5.79 m	■	G9			221
7		SILT (Till) - trace clay, trace sand, trace gravel, light grey, loose, moist, intermediate plasticity	■	G10			220
8		- compact below 7.62 m	■	G11			219
9		GRAVEL and COBBLE - trace boulders, large to medium limestone gravel, granite cobble					218
10							



LOGGED BY: Ryan Belbas | COMPLETION DEPTH: 25.48 m
REVIEWED BY: Jeff Tallin | COMPLETION DATE: 30/9/08
PROJECT ENGINEER: Jeff Tallin

AECOM

PROJECT: Midtown Feedermain Geotechnical Investigation | CLIENT: City of Winnipeg | TESTHOLE NO: TH08-06
LOCATION: 631099.928 E, 5526535.755 N, toe of north bank | PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd. | METHOD: Acker ASS, 125 mm SSA / HQ Coring | ELEVATION (m): 227.076
SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ◺ NO RECOVERY ▮ CORE

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS ✳ Becker ✳ ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100 ■ Total Unit Wt ■ (kN/m^3) 16 17 18 19 20 21 Plastic MC Liquid 20 40 60 80 100	UNDRAINED SHEAR STRENGTH + Torvane + × QU × □ Lab Vane □ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa) 50 100 150 200	COMMENTS	ELEVATION
10									217
		- limestone boulder (480 mm dia.) at 10.21 m							
		- granite boulder (300 mm dia.) at 10.82 m		C12				Recovery = 54%	
11									216
				C13				Recovery = 46%	
12									215
13									214
		- granite boulder (180 mm dia.) at 13.41 m - limestone boulder (300 mm dia.) at 13.56 m		C14				Recovery = 66%	
14									213
				C15				Recovery = 41%	
15									212
16									211
				C16				Recovery = 17%	
17									210
18									209
19									208
				C17				Recovery = 0%	
20									

AECOM

LOGGED BY: Ryan Belbas | COMPLETION DEPTH: 25.48 m
REVIEWED BY: Jeff Tallin | COMPLETION DATE: 30/9/08
PROJECT ENGINEER: Jeff Tallin

PROJECT: Midtown Feedermain Geotechnical Investigation	CLIENT: City of Winnipeg	TESTHOLE NO: TH08-06
LOCATION: 631099.928 E, 5526535.755 N, toe of north bank		PROJECT NO.: D265-230-01
CONTRACTOR: Paddock Drilling Ltd.	METHOD: Acker ASS, 125 mm SSA / HQ Coring	ELEVATION (m): 227.076

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ⧄ NO RECOVERY ▌ CORE

PENETRATION TESTS: ✳ Becker ✳ ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100; ■ Total Unit Wt ■ (kN/m^3) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100

UNDRAINED SHEAR STRENGTH: + Torvane + × QU × ☐ Lab Vane ☐ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa) 50 100 150 200

DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	COMMENTS	ELEVATION
20		▌				207
21	LIMESTONE - sound bedrock, white, massive, fine grained, slight foliation and bedding - R4 strength, class 3 flow, moderately close discontinuity spacing	▌	C17		RQD 88%, Recovery = 100%	206
22		▌				205
23	- limestone becoming more red with depth, bedding and foliation more pronounced below 23.72 m	▌	C18		RQD 89%, Recovery = 100%	204
24		▌				203
25		▌	C19		RQD 83%, Recovery = 100%	202
26	END OF TEST HOLE AT 25.5 m IN LIMESTONE BEDROCK Notes: 1. Seepage at 4.6 m from clay layer. 2. No sloughing observed. 3. Auger refusal at 10.1 m. Switch from SSA to HQ coring at 10.1 m. HQ coring from 10.1 to 25.5 m. 4. Test hole backfilled with bentonite chips.					201
27						200
28						199
29						198
30						

AECOM	LOGGED BY: Ryan Belbas	COMPLETION DEPTH: 25.48 m
	REVIEWED BY: Jeff Tallin	COMPLETION DATE: 30/9/08
	PROJECT ENGINEER: Jeff Tallin	Page 3 of 3