

**FOUNDATION INVESTIGATION REPORT  
PAGWACHUAN RIVER WEST CULVERT REPLACEMENT  
HIGHWAY 11  
DISTRICT OF THUNDER BAY, ONTARIO**

**G.W.P. 6134-04-00, SITE No. 48E-85/C**

**Geocres Number: 42F-29**

**Report to**

**MMM GROUP LIMITED**

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**FOUNDATION INVESTIGATION REPORT  
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**G.W.P. 6134-04-00, SITE No. 48E-85/C**

**Geocres Number: 42F-29**

**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of the replacement culvert carrying Highway 11 over Pagwachuan River West, located approximately 80 km east of Longlac, in the District of Thunder Bay, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM), under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0011.

**2 SITE DESCRIPTION**

The existing Pagwachuan River West culvert is located approximately 80 km (by highway) east of Longlac, Ontario and about 6 km west of the intersection of Highway 11 and South Pagwachuan Road. Pagwachuan River West is a tributary of the main Pagwachuan River, which runs in a meandering west to east direction, south of Highway 11. At the existing Highway 11 crossing, the tributary flows in a general northeast to southwest direction for approximately 3 km before meeting the main Pagwachuan River.

The culvert under the existing highway embankment consists of a 26 m long by 4.2 m wide, twin-cell timber culvert and the highway embankment is approximately 3 m high. Preliminary drawings provided by MMM indicate a water level of Elev. 224.3 at the outlet of the culvert in April 2011.

The surrounding lands are densely treed with grass and shrubs in close proximity to the highway. Photographs in Appendix C show the existing Pagwachuan River West culvert and the general nature of the site.

The site lies within the physiographic region known as the Quetico Subprovince of the Superior Province of the Canadian Shield. Based on Ontario Geological Survey (OGS) Map s365, titled “Algoma-Cochrane Surficial Geology”, dated 1962, the site is located in an area consisting of lacustrine deposits of varved clay and silt, fine sand, and clayey till ground moraine. The bedrock in the region is early Precambrian and based on OGS Map 2543, titled “Bedrock Geology of Ontario, East-Central Sheet”, dated 1991, the bedrock consists of metasedimentary bedrock (paragneiss and migmatites).

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project was carried out between April 8 and 28, 2014. The investigation comprised drilling and sampling four boreholes identified as Boreholes PWC-01 to PWC-04 along the proposed replacement culvert alignment. Boreholes PWC-01 and PWC-04 were drilled near the proposed inlet and outlet respectively, and Boreholes PWC-02 and PWC-03 were drilled on the east and west sides of the culvert alignment through the shoulders of the existing highway embankment.

The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix D.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Boreholes PWC-02 and PWC-03 were advanced to depths of 21.6 and 30.6 m (Elev. 205.4 and 196.4 m) respectively, with drilling carried out using a truck mounted drill rig with NW casing and wash boring techniques. Boreholes PWC-01 and PWC-04 were drilled using portable tripod equipment and wash boring to advance NW casing until encountering refusal at depths of 12.8 and 11.0 m respectively. Dynamic Cone Penetration Tests (DCPTs) were conducted from the bottom of Boreholes PWC-01 and PWC-04 to advance to total depths of 14.0 and 11.5 m respectively upon encountering DCPT refusal. Soil samples were obtained at selected intervals in the boreholes using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was conducted to further assess the undrained shear strength of the cohesive deposits.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber’s technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber’s laboratory for further examination and testing.

Groundwater conditions were observed in the open boreholes upon completion of the drilling operations. Standpipe piezometers were installed in two boreholes to measure groundwater levels.

The piezometers were subsequently decommissioned in general accordance with MOE Regulation 903 following completion of the final water level reading. The piezometer installation and borehole completion details are summarized in Table 3.1.

**Table 3.1 – Borehole Completion and Piezometer Installation Details**

<b>Borehole</b>	<b>Piezometer Tip Depth/ Elev. (m)</b>	<b>Completion and Installation Details</b>
PWC-01	12.5 / 212.5	19 mm diameter piezometer installed with filter sand from 12.5 m to 9.0 m, then bentonite holeplug to surface.
PWC-02	None installed	Backfilled with bentonite holeplug to 0.1m, then sand to surface.
PWC-03	None installed	Backfilled with bentonite holeplug to 0.1 m, then sand and gravel to surface.
PWC-04	10.8 / 214.7	19 mm diameter piezometer installed with filter sand from 10.8 m to 7.0 m, then bentonite holeplug to surface.

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and sieve) and Atterberg Limits testing, where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the “Borehole Locations and Soil Strata” drawing included in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general, the subsurface stratigraphy encountered at the culvert site consisted of existing embankment fill, overlying native deposits comprising silt, a thick deposit of silty clay, and layers of gravelly sand and sandy silt till. More detailed descriptions of the individual strata are presented below.

### **5.1 Topsoil**

A thin layer of topsoil was encountered at the ground surface in Boreholes PWC-01 and PWC-04. The topsoil layer was 100 to 125 mm thick at these locations. The thickness of the topsoil layer may vary between and beyond the borehole locations.

### **5.2 Fill**

Cohesionless embankment fill consisting of sand and gravel was encountered at the ground surface in Boreholes PWC-02 and PWC-03, which were drilled through the highway shoulders. The fill contains trace to some silt and some cobbles. The base of the fill was encountered at 3.3 to 3.4 m depth (Elev. 223.6 to 223.7 m).

SPT N-values recorded in the sand and gravel fill typically ranged from 65 blows for 0.3 m penetration to 50 blows for 0.125 m penetration, indicating a very dense condition and/or possible cobbles. An N-value of 20 blows for 0.3 m penetration (compact condition) was also recorded near the base of the fill in Borehole PWC-03. Moisture contents of the sand and gravel fill ranged from 8% to 22%.

Two samples of the sand and gravel fill were selected for laboratory grain size analysis testing. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets included in Appendix A. The grain size distribution curves for the samples are plotted on Figure B1, Appendix B.

Gravel %	49 to 51
Sand %	35 to 43
Silt and Clay %	6 to 16

Underlying the topsoil in Boreholes PWC-01 and PWC-04, a layer of fill was encountered, which ranged in composition from silty sand to clayey silt. Trace gravel and organic material was noted in the fill. The thickness of the silty sand to clayey silt fill ranged from 0.4 to 0.8 m, with the lower boundary at a depth of 0.5 to 0.9 m (Elev. 225.0 to 224.1 m).

SPT N-values recorded in the silty sand to clayey silt fill were 4 and 11 blows for 0.3 m penetration respectively, indicating that the silty sand fill is loose and the clayey silt fill is stiff. The measured moisture contents were 31% and 25% respectively.

### **5.3 Silt**

Native deposits of silt were encountered below the fill in all of the boreholes. In Borehole PWC-04, a 1.0 m thick layer of sandy silt with trace clay was encountered to a depth of 1.5 m (Elev. 224.0 m). An SPT N-value of 16 blows for 0.3 m penetration was recorded in the sandy silt, indicating that the material is compact. The moisture content of the sandy silt was measured at 20%.

Underlying the fill in Boreholes PWC-01 to PWC-03, and the sandy silt in PWC-04, a cohesive silt layer ranging from some clay to clayey was encountered. The cohesive silt layer ranged in thickness from 1.3 to 2.7 m, and the lower boundary was at depths of 3.0 to 6.1 m (Elev. 222.4 to 220.9 m).

SPT N-values recorded in the cohesive silt ranged between 5 and 16 blows for 0.3 m penetration, indicating a firm to very stiff condition. In situ shear vane tests conducted in the cohesive silt indicated undrained shear strengths of 53 to 62 kPa, indicating a stiff condition.

Moisture contents in the cohesive silt between 18% and 41% were measured.

Grain size analysis testing was undertaken on four samples of the deposit. The results are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 of Appendix B. The results are summarized below.

Gravel%	0
Sand%	0
Silt%	63 to 86
Clay%	14 to 37

#### **5.4 Silty Clay**

Native silty clay was encountered below the silt deposit in all of the boreholes. The silty clay was typically brown to grey with trace sand and trace gravel.

The silty clay layer was 4.8 to 9.2 m thick, with a lower boundary encountered at depths of 10.5 to 13.3 m (Elev. 216.1 to 212.8 m).

SPT N-values recorded in the silty clay ranged from 0 to 24 blows for 0.3 m penetration, typically less than 3. In situ shear vane testing indicated undrained shear strengths in the order of 22 to 44 kPa. Based on this data, the consistency of the silty clay is generally soft to firm.

The moisture content of the silty clay ranged from 18% to 60%, typically 20% to 40%.

The results of grain size distribution analyses conducted on samples of the silty clay are presented on the Record of Borehole sheets in Appendix A and on Figures B3 and B4 in Appendix B. The results of Atterberg Limits testing conducted on the samples are presented on the Record of Borehole sheets and plotted on Figures B7 and B8 of Appendix B. The results are summarized below.

Gravel%	0 to 2
Sand%	0 to 16
Silt%	23 to 54
Clay%	36 to 77
Liquid Limit	31 to 75
Plastic Limit	15 to 27

The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate plasticity (CI), varying from low to high plastic (CL to CH).

### 5.5 Gravelly Sand to Sand

Underlying the silty clay deposit, the boreholes encountered interbedded deposits of sand and sandy silt till.

The sand deposit was encountered in all of the boreholes and ranged in composition from gravelly sand with some silt and occasional cobbles to sand with trace silt and trace gravel. Where fully penetrated in Boreholes PWC-02 and PWC-03, an upper sand layer was encountered with a thickness of 1.8 to 2.5 m with a lower boundary of 13.4 to 15.1 m depth (Elev. 213.6 to 211.9 m). A lower sand layer was also encountered below the sandy silt till with a thickness ranging from 1.8 to 8.6 m and a lower boundary at 19.4 to 27.2 m depth (Elev. 207.6 to 199.8 m). Boreholes PWC-01 and PWC-04 were terminated within the sand deposit upon DCPT refusal at depths from 11.5 to 14.0 m (Elev. 214.0 to 211.0 m).

SPT N-values recorded within the sand deposit ranged from 22 to 61 blows for 0.3 m penetration to 100 blows for 0.025 m penetration, indicating a variable relative density of compact to very dense. Moisture contents ranged from 10% to 20%.

Three samples of the sand were selected for laboratory grain size analysis testing, the results of which are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A and grain size distribution curves on Figure B5, Appendix B.

Gravel%	2 to 33
Sand%	52 to 89
Silt & Clay%	9 to 17

### 5.6 Sandy Silt Till

Two layers of sandy silt till with some clay and trace gravel were encountered below the upper sand layer in Boreholes PWC-02 and PWC-03. The upper till layer was 3.5 to 4.2 m thick with a lower boundary of 17.6 to 18.6 m depth (Elev. 209.4 to 208.4 m). Both



boreholes were terminated in a second till layer underlying the lower sand layer. The boreholes were terminated at depths of 21.6 to 30.6 m (Elev. 205.4 to 196.4 m), indicating that the lower till layer is at least 2.2 to 3.4 m thick.

SPT N-values recorded in the till deposit were all greater than 50 blows for 0.3 m penetration (typically greater than 100 blows for 0.3 m penetration), indicating that the sandy silt till is very dense. Moisture contents from 7% to 14% were measured.

Three samples of the sandy silt till were selected for laboratory grain size analysis testing, the results of which are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A and grain size distribution curves on Figure B6, Appendix B.

Gravel%	0 to 4
Sand%	20 to 28
Silt%	55 to 65
Clay%	9 to 24

Glacial till deposits inherently contain cobbles and boulders.

## 5.7 Water Levels

Groundwater levels in the boreholes were observed during drilling and standpipe piezometers were installed in two boreholes to monitor groundwater levels after completion of drilling. A summary of the recorded groundwater levels is provided below.

**Table 5.2 - Groundwater Level Measurements**

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation	
PWC-01	April 22, 2014	-0.5*	225.5	In piezometer
	April 29, 2014	-0.5*	225.5	
PWC-04	April 22, 2014	-0.6*	226.1	In piezometer
	April 29, 2014	-0.6*	226.1	

\* indicates artesian groundwater level above the ground surface

The water levels recorded above the ground surface are indicative of artesian pressures present in the gravelly sand layer below the silty clay.

The recorded groundwater levels are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected, particularly after spring snowmelt as well as periods of prolonged and/or significant precipitation.

The groundwater level is also expected to be influenced by the water level in the Pagwachuan River West tributary, which is shown on the preliminary drawings provided by MMM to be at Elev. 224.3 at the outlet in April 2011.

## 6 MISCELLANEOUS

In general, the borehole locations were positioned in the field by Thurber staff and were established relative to site features. The co-ordinates and ground surface elevations at the boreholes were inferred from the MMM Group Limited General Arrangement drawing dated March 2014.

Eastern Ontario Diamond Drilling Limited from Hawkesbury, Ontario supplied a tri-pod and truck mounted CME 75 drill rig and conducted the drilling, sampling and in-situ testing operations.

Full time supervision of the field activities was carried out by Ms. Eckie Siu of Thurber. Overall supervision of the field program was conducted by Mr. Mark Farrant, P. Eng.

Interpretation of the data and preparation of this report were carried out by Mr. Mark Farrant, P.Eng. and Mr. Murray R. Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

### Thurber Engineering Ltd

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## **Appendix A**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level

$C_{pen}$  Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT              Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W <sub>L</sub> < 50%	ML	Inorganic silts and very fine sands, rock flour, 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. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic 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.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No PWC-01

1 OF 2

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 653.6 E 200 276.0 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Tripod/NW Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.08 - 2014.04.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE						W <sub>p</sub>	W <sub>L</sub>
225.0							20	40	60	80	100	20	40	60				
0.0																		
0.1	<b>TOPSOIL</b> , rootlets Dark Brown (100mm)		1	SS	4								○					
	Silty <b>SAND</b> , trace gravel, trace organics																	
224.1	Loose Brown Moist (FILL)		2	SS	13		224						○					
0.9	<b>SILT</b> , some clay to clayey Stiff Brown		3	SS	12		223						○			0 0 73 27		
			4	SS	8								○					
222.0							222											
3.0	Silty <b>CLAY</b> Firm Brown (Cl)		5	SS	4								○			0 0 46 54		
							221	5.0 +										
			6	SS	3		220						○					
							219	5.0 +										
	Occasional sand seams		7	SS	4		218	2.0 +										
							217						○			2 16 46 36		
	Some sand, trace gravel Occasional gravel seams		8	SS	5													
							216	3.0 +										
			9	SS	1								○					

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PWC-01

2 OF 2

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 653.6 E 200 276.0 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Tripod/NW Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.08 - 2014.04.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT		UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
								○ UNCONFINED      + FIELD VANE					
								● QUICK TRIAXIAL      × LAB VANE					
	Continued From Previous Page							20   40   60   80   100	20   40   60				
212.8													
12.2	Gravelly <b>SAND</b> , some silt Very Dense Grey Moist  DCPT started at 12.8m		11	SS	50								
211.0													
14.0	END OF BOREHOLE AT 14.0m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) Apr. 22/14    0.5*      225.5 Apr. 29/14    0.5*      225.5  * Artesian Condition (Above Ground Surface)												



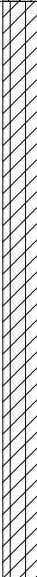
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PWC-02

1 OF 3

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 640.2 E 200 283.9 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.28 - 2014.04.28 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								20	40	60	80	100	W <sub>P</sub>	W			W <sub>L</sub>	
227.0																		
0.0	<b>SAND</b> and <b>GRAVEL</b> , trace to some silt Very Dense Brown Moist (FILL)  Occasional cobbles		1	SS	99/ 0.275													
			2	SS	65													
			3	SS	86/ 0.275													
			4	SS	50/ 0.125													
223.6			5	SS	9													
3.4	<b>SILT</b> , some clay to clayey, occasional oxide staining Firm to Stiff Brown																	
			6	SS	5													
220.9																		
6.1	Silty <b>CLAY</b> Firm Grey (Cl)		7	SS	0													
			8	SS	1													
			9	SS	0													

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No PWC-02

2 OF 3

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 640.2 E 200 283.9 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.28 - 2014.04.28 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)									
								20   40   60   80   100				w <sub>P</sub> w                      w <sub>L</sub>									
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE													
Continued From Previous Page																					
216.1								6.0 +													
10.9	Gravelly <b>SAND</b> , some silt, some cobbles Very Dense		10	SS	9		216										0	0	23	77	
							215														
			11	SS	100/ 0.025		214														
213.6																					
13.4	Sandy <b>SILT</b> , some clay, trace gravel Very Dense Grey Moist (TILL)		12	SS	50/ 0.050		213											0	28	55	17
							212														
			13	SS	50/ 0.100		211														
							210														
	Some gravel		14	SS	106/ 0.175																
209.4																					
17.6	Gravelly <b>SAND</b> , some silt, occasional cobbles Very Dense Grey Wet		15	SS	88/ 0.250		209														
							208														
207.6																					
19.4	Sandy <b>SILT</b> , some clay, trace gravel Very Dense Grey Moist																				

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PWC-02

3 OF 3

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 640.2 E 200 283.9 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.28 - 2014.04.28 CHECKED BY MEF




SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	Sandy <b>SILT</b> , some clay, trace gravel Very Dense Grey Moist (TILL)																
205.4			16	SS	105/												
21.6	END OF BOREHOLE AT 21.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN SAND TO SURFACE.				0.250												

# RECORD OF BOREHOLE No PWC-03

1 OF 4

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.27 - 2014.04.27 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>						
227.0																					
0.0	<b>SAND</b> and <b>GRAVEL</b> , trace to some silt Very Dense to Compact Brown Moist (FILL)  Occasional cobbles		1	SS	89/ 0.275								○								
			2	SS	98/ 0.250								○						49   35   16 (SI+CL)		
			3	SS	69								○								
			4	SS	20								○								
223.7																					
3.3	<b>SILT</b> , some clay to clayey, trace organics Stiff Brown		5	SS	12								○						0   0   63   37		
222.4																					
4.6	Silty <b>CLAY</b> , trace sand, trace gravel Firm Brown to Grey (CL)		6	SS	5									○							
			7	SS	1									○							
			8	SS	1									○	○				0   7   54   39		
			9	SS	0								○								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PWC-03

2 OF 4

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4 ORIGINATED BY ES  
HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2014.04.27 - 2014.04.27 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL LIMIT      MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE						
	Continued From Previous Page						20   40   60   80   100	20   40   60						
	Silty <b>CLAY</b> , trace sand, trace gravel Firm Grey (CH)		10	SS	0		4.0 +							
			11	SS	1		5.0 +							
213.7														
13.3	Gravelly <b>SAND</b> , some silt, some cobbles Compact Grey Wet		12	SS	22									
211.9														
15.1	Sandy <b>SILT</b> , trace clay, trace gravel Very Dense to Dense Grey Moist (TILL)		13	SS	100/ 0.125									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PWC-03

3 OF 4

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4 ORIGINATED BY ES  
HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2014.04.27 - 2014.04.27 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page													
	SAND, trace silt, trace gravel Dense to Very Dense Grey Wet		16	SS	34		206							
							205							
							204							
							203							
			17	SS	61		202							2 89 9 (SI+CL)
							201							
							200							
199.8							199							
27.2	Sandy SILT, some clay, trace gravel Very Dense Grey Moist (TILL)		18	SS	110/ 0.275									
							198							0 20 56 24
			19	SS	106/ 0.225									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 10 5 0  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PWC-03

4 OF 4

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.27 - 2014.04.27 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
196.4			20	SS	100/												
30.6	END OF BOREHOLE AT 30.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN SAND AND GRAVEL TO SURFACE.				0.150												

# RECORD OF BOREHOLE No PWC-04

1 OF 2

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 623.9 E 200 281.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Tripod/NW Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.08 - 2014.04.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
225.5								20	40	60	80	100		
0.0	TOPSOIL, rootlets: (125mm)													
0.1	Clayey SILT, some sand, trace gravel, trace organics		1	SS	11									
225.0	Stiff Dark Brown (FILL)													
0.5	Sandy SILT, trace clay		2	SS	16									
	Compact Brown Damp													
224.0	SILT, some clay to clayey													
1.5	Very Stiff to Firm Brown		3	SS	8									
			4	SS	16									0 0 72 28
			5	SS	6									
221.4	Silty CLAY, trace to some sand													
4.1	Soft to Firm Brown (Cl)		6	SS	0									0 0 43 57
			7	SS	0									
			8	SS	3									
			9	SS	3									0 10 38 52

Continued Next Page





+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PWC-04

2 OF 2

METRIC

WP# 6134-04-00 LOCATION Pagwachuan West Culvert N 5 515 623.9 E 200 281.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE Tripod/NW Wash Boring COMPILED BY AN  
 DATUM Geodetic DATE 2014.04.08 - 2014.04.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									WATER CONTENT (%)	
	Continued From Previous Page							20	40	60	80	100						
215.0	Silty <b>CLAY</b> Very Soft Grey						215	4.0	+									
10.5	Gravelly <b>SAND</b> , some silt Very Dense Grey Wet DCPT started at 11.0m		10	SS	50/													
214.0					0.100													
11.5	END OF BOREHOLE AT 11.5m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Apr. 22/14 0.6* 226.1 Apr. 29/14 0.6* 226.1  * Artesian Condition (Above Ground Surface)																	



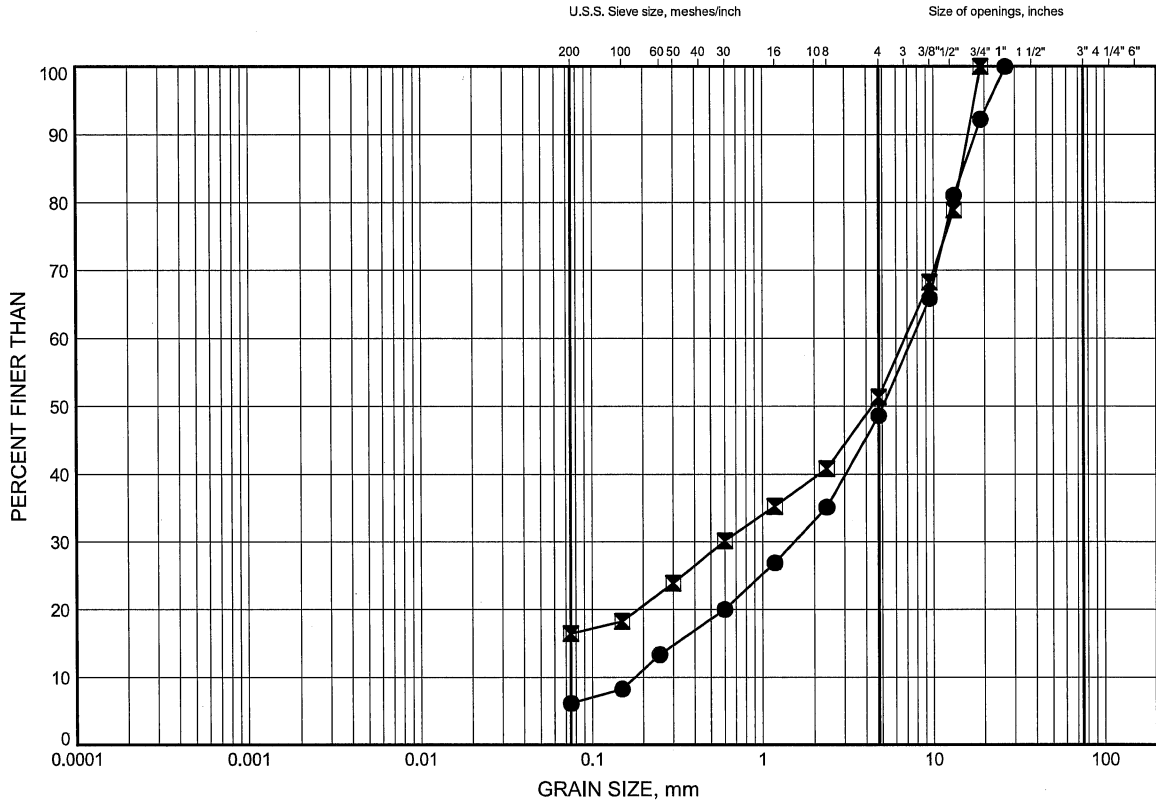
## **Appendix B**

### **Laboratory Test Results**

Pagwachau West Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL FILL



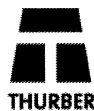
SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-02	1.07	225.93
⊠	PWC-03	0.97	226.03

GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

Date June 2014  
GWP# 6134-04-00

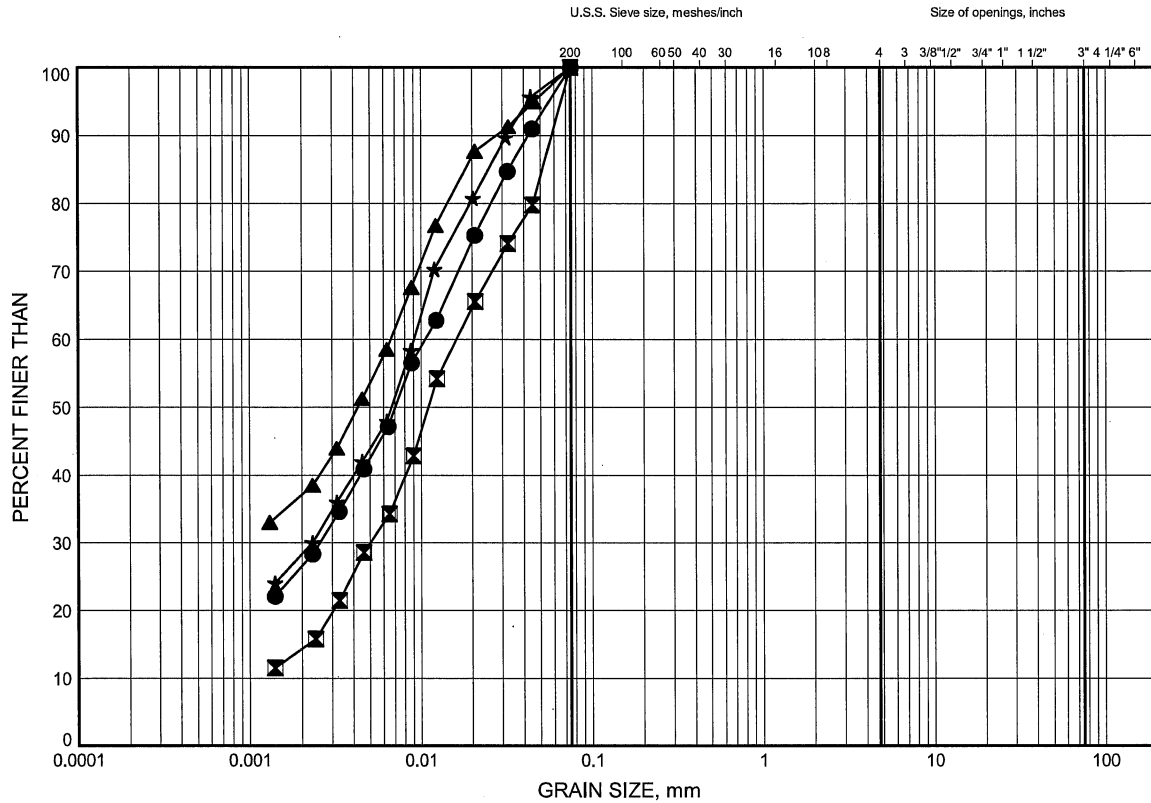


Prep'd AN  
Chkd. MEF

Pagwachau West Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE B2

SILT, Some Clay to Clayey



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	1.83	223.17
⊠	PWC-02	3.35	223.65
▲	PWC-03	3.35	223.65
★	PWC-04	2.59	222.91

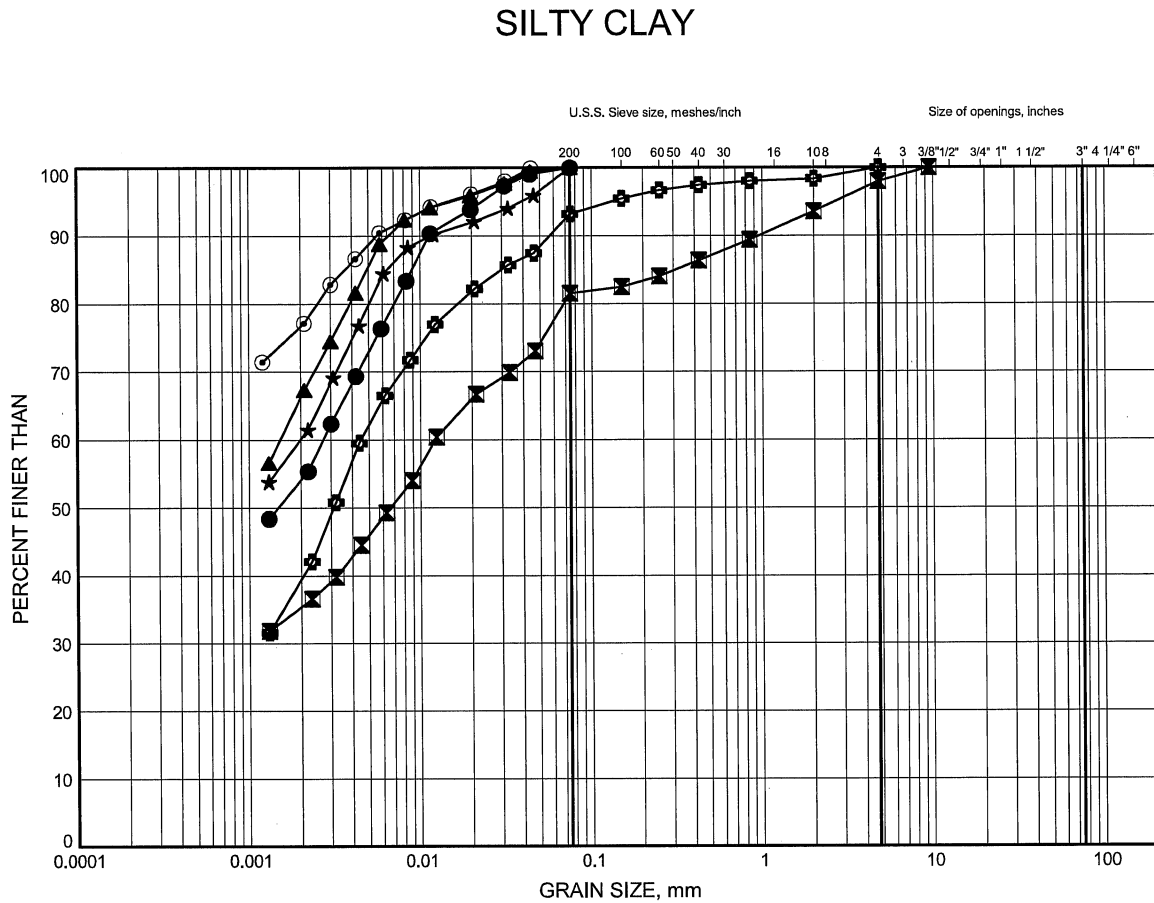
Date June 2014  
GWP# 6134-04-00



Prep'd AN  
Chkd. MEF

# Pagwachau West Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	3.35	221.65
⊠	PWC-01	7.92	217.08
▲	PWC-01	10.97	214.03
★	PWC-02	6.40	220.60
⊙	PWC-02	10.97	216.03
⊕	PWC-03	7.92	219.08

Date June 2014  
GWP# 6134-04-00

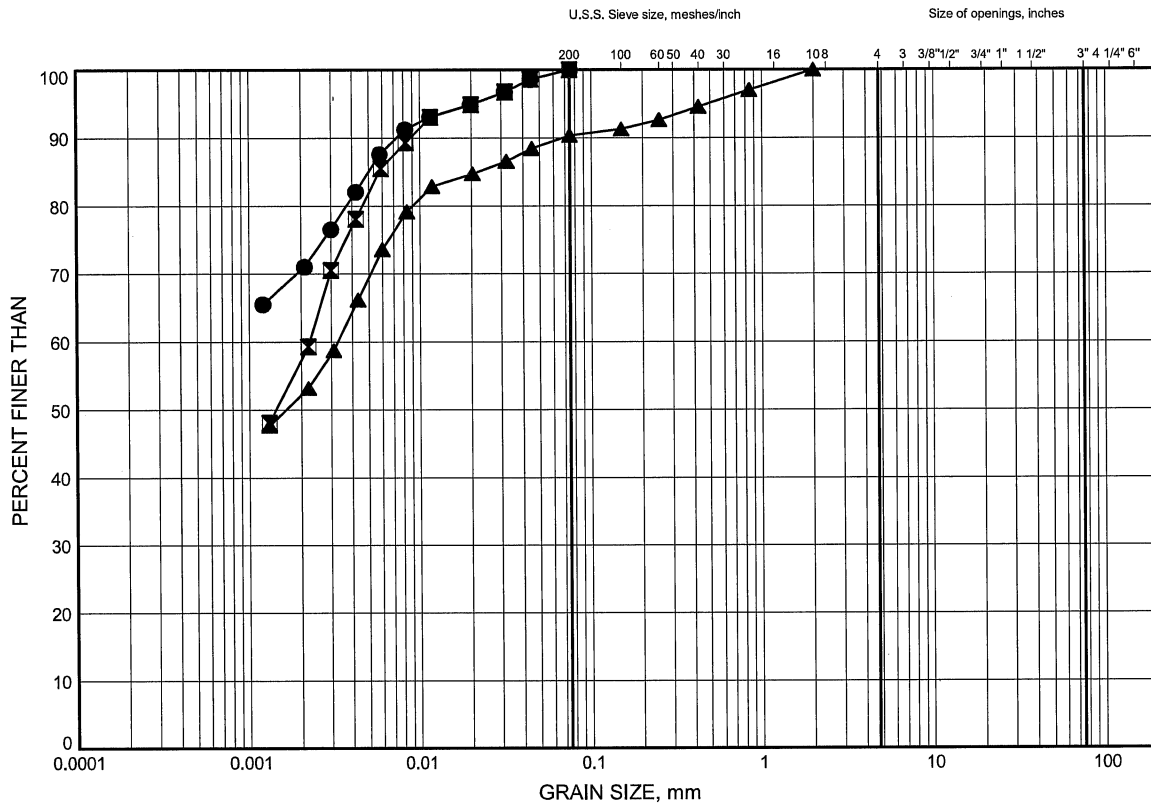


Prep'd AN  
Chkd. MEF

Pagwachau West Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-03	12.50	214.50
■	PWC-04	4.88	220.62
▲	PWC-04	9.45	216.05

Date June 2014  
GWP# 6134-04-00

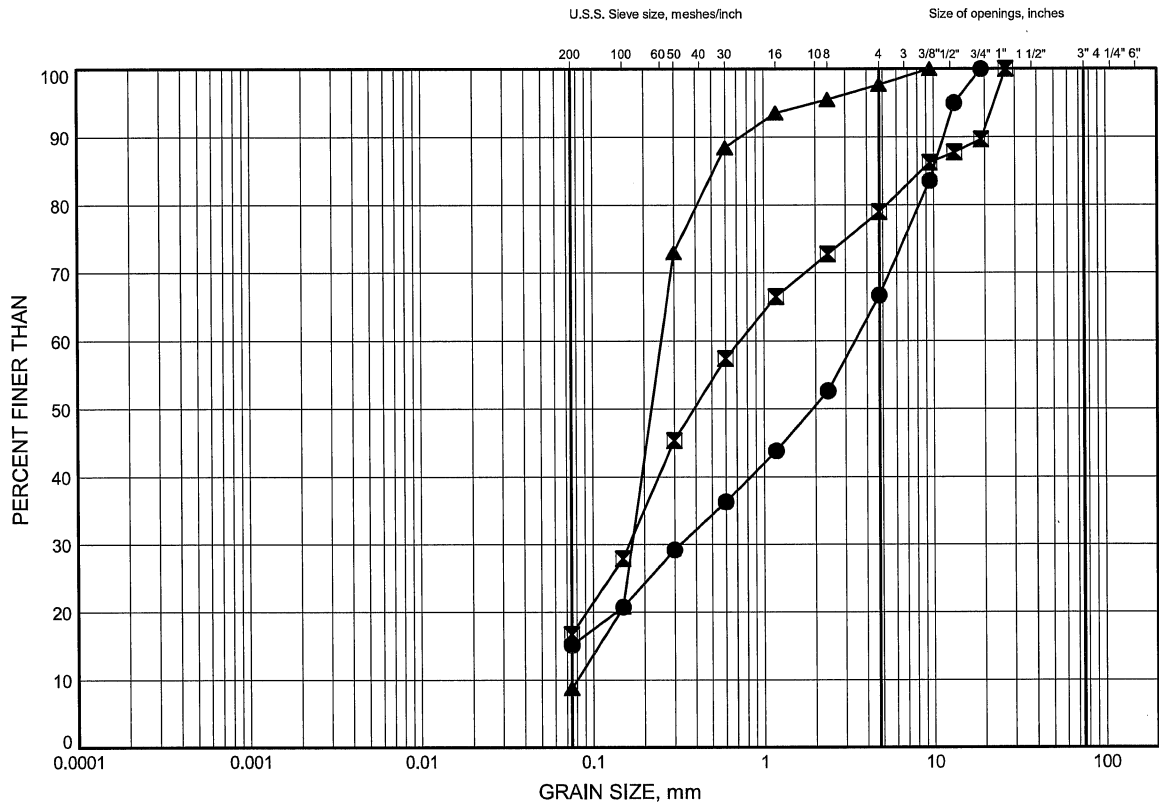


Prep'd AN  
Chkd. MEF

Pagwachaun West Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE B5

GRAVELLY SAND TO SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-02	18.49	208.51
⊠	PWC-03	14.02	212.98
▲	PWC-03	24.69	202.31

Date June 2014  
GWP# 6134-04-00

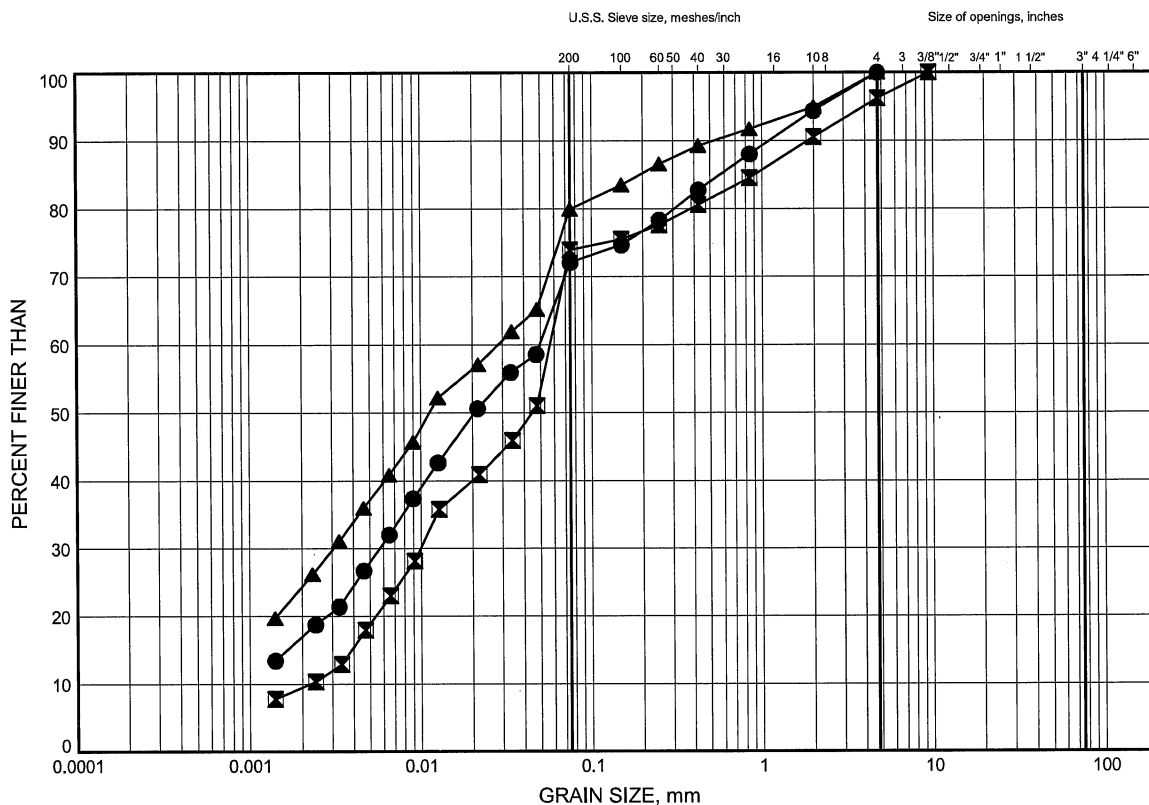


Prep'd AN  
Chkd. MEF

# Pagwachau West Culvert GRAIN SIZE DISTRIBUTION

FIGURE B6

## SANDY SILT TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-02	13.82	213.18
■	PWC-03	16.89	210.11
▲	PWC-03	29.07	197.93

Date June 2014  
GWP# 6134-04-00

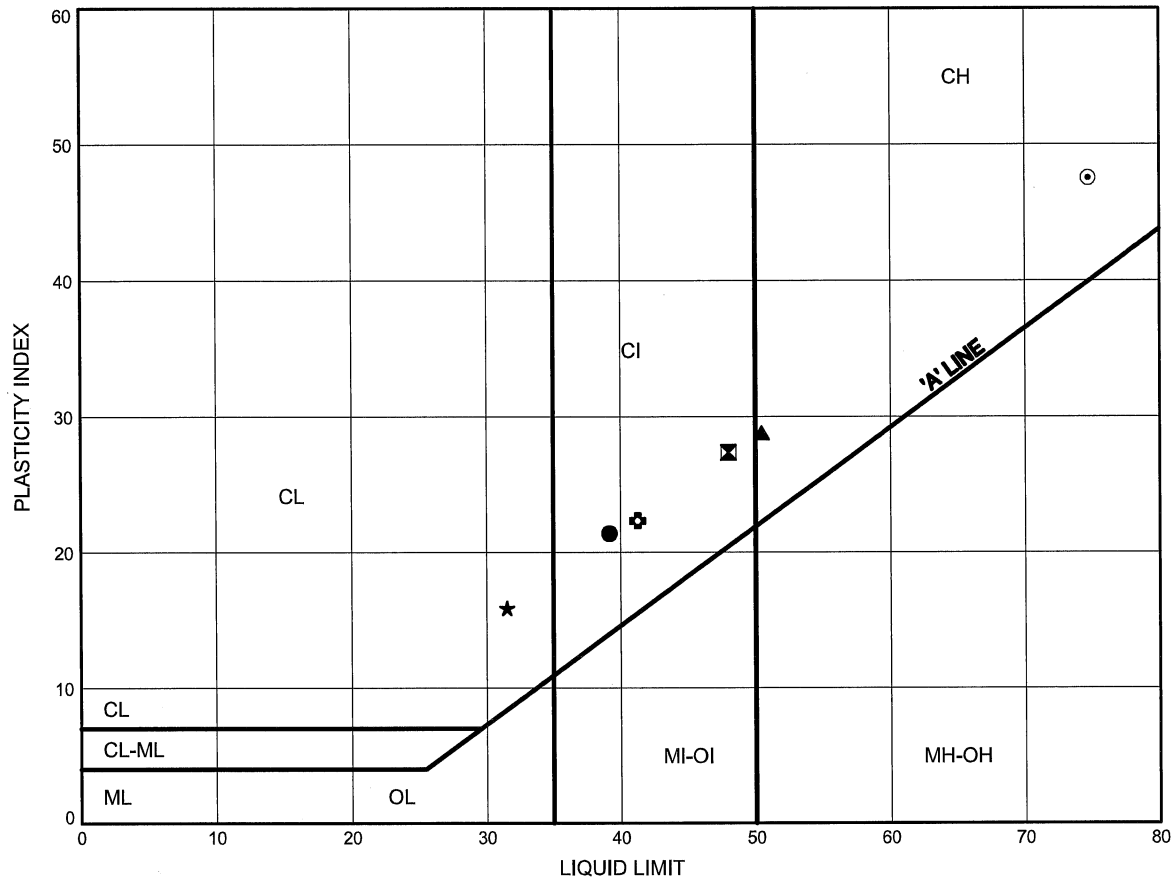


Prep'd AN  
Chkd. MEF

Pagwachaun West Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B7

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	3.35	221.65
⊠	PWC-01	10.97	214.03
▲	PWC-02	6.40	220.60
★	PWC-03	7.92	219.08
⊙	PWC-03	12.50	214.50
⊕	PWC-04	4.88	220.62

Date June 2014  
 GWP# 6134-04-00



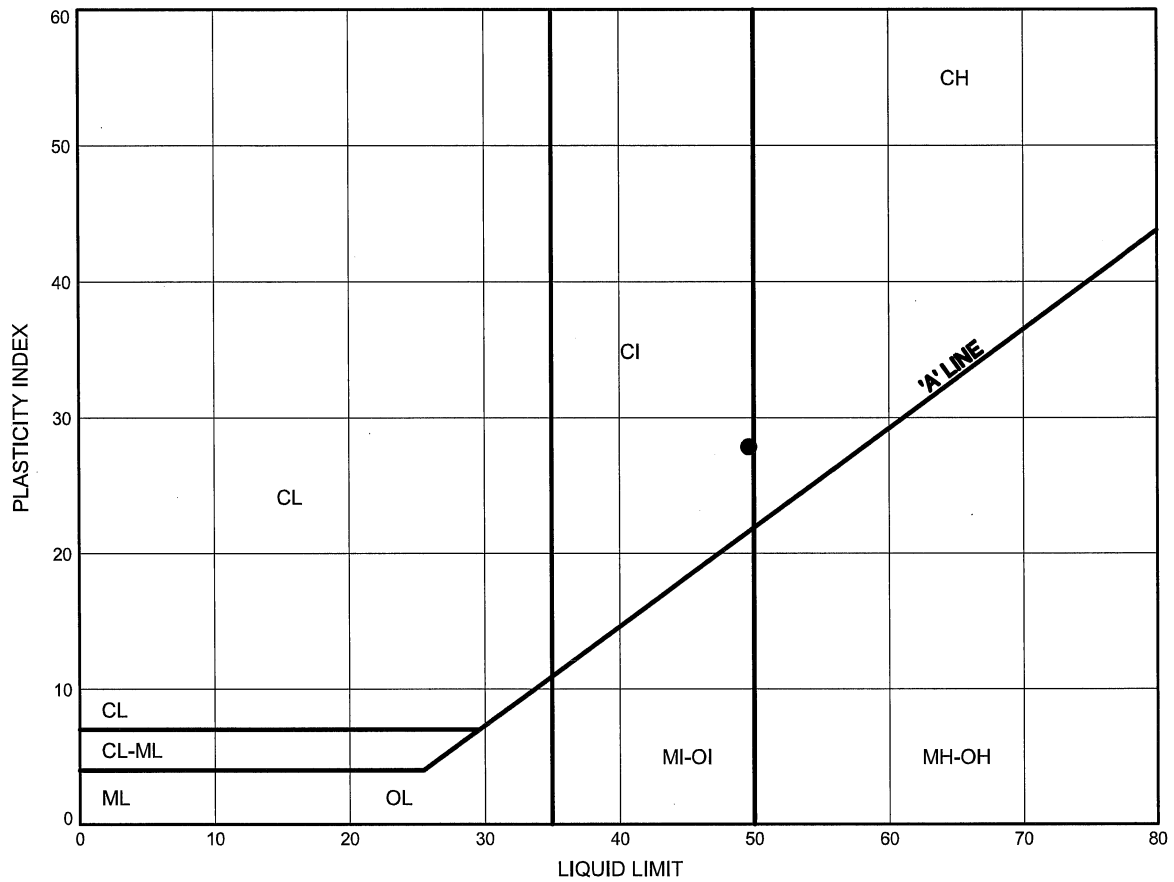
Prep'd AN  
 Chkd. MEF



Pagwachaun West Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B8

**SILTY CLAY**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-04	9.45	216.05

Date June 2014  
 GWP# 6134-04-00



Prep'd AN  
 Chkd. MEF

## **Appendix C**

### **Site Photographs**



**Photograph 1 – North end of culvert, looking east at culvert inlet and highway embankment**



**Photograph 2 – North end of culvert, looking west at culvert inlet**





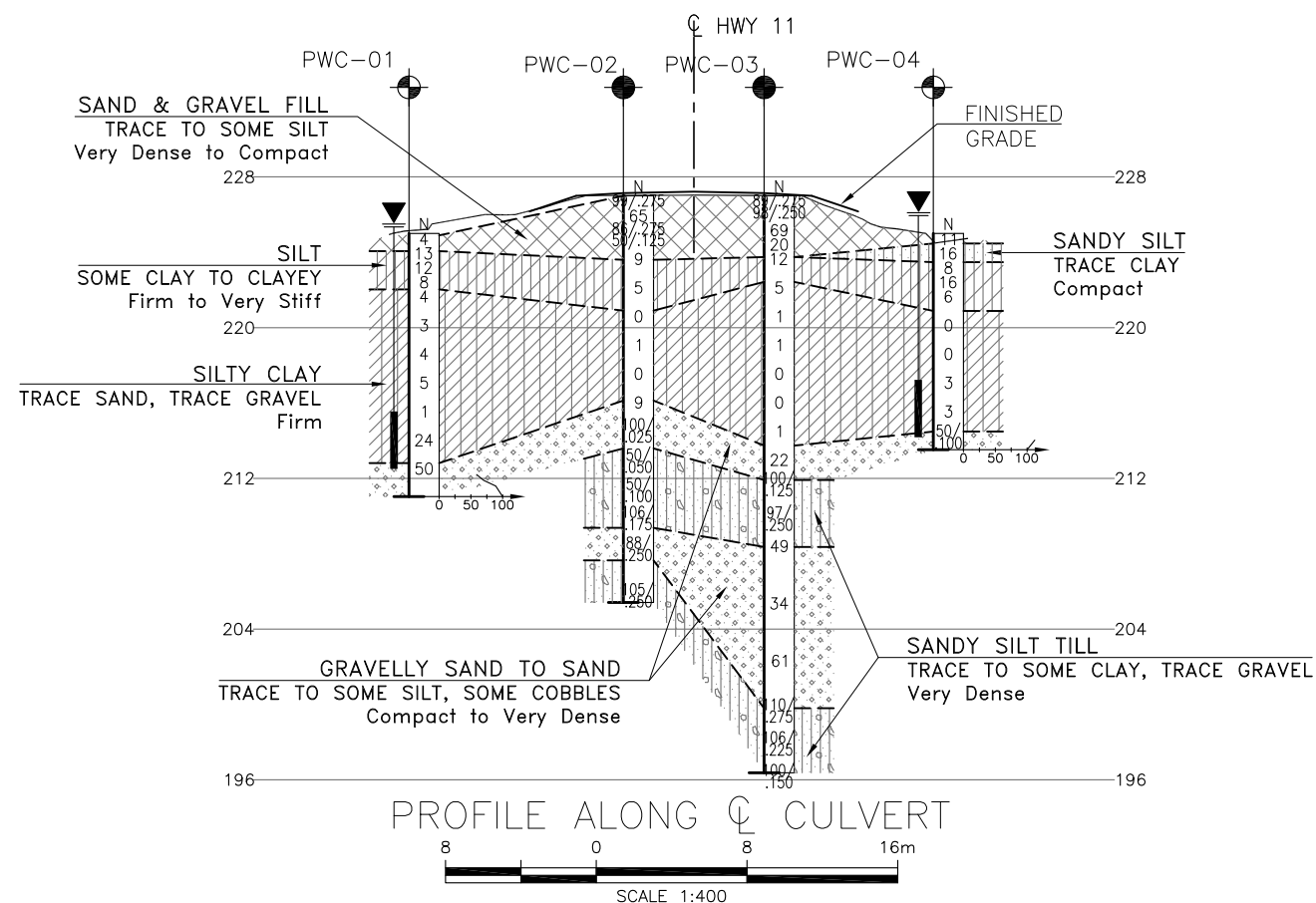
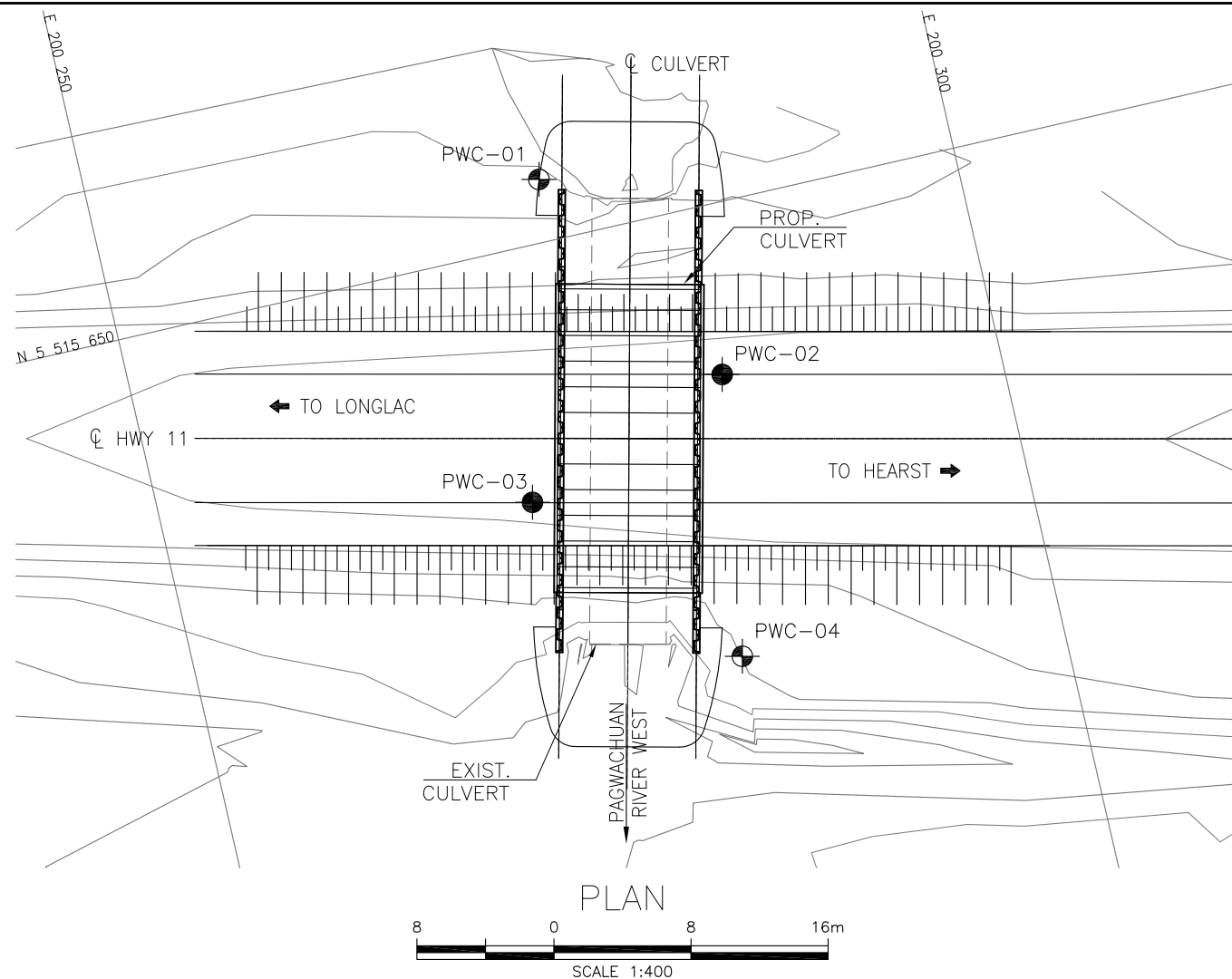
**Photograph 3 – South end of culvert, looking east at culvert outlet and highway embankment**



**Photograph 4 – South end of culvert, looking southwest at culvert outlet**

## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**

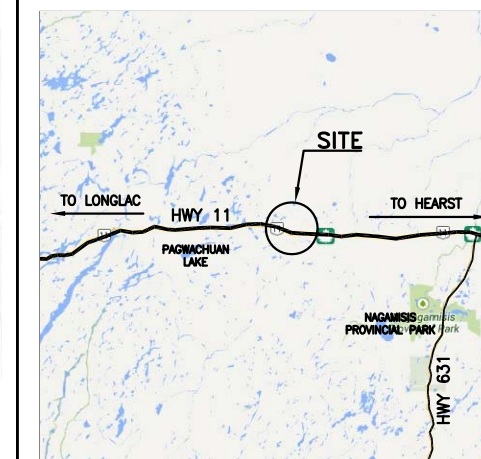


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN







CONT No  
WP No 6163-04-01

HIGHWAY 11  
PAGWACHUAN RIVER WEST  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



## KEYPLAN

## LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level During Drilling
	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

[illegible]

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

**GEOCRES No. 42F-29**

[illegible]