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FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 3 Widening
Windsor to Leamington
Victoria Avenue Overpass
GWP 317-98-00
Ministry of Transportation, Ontario - West Region

Submitted to:

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REPORT



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Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
2.1 General.....	1
2.2 Site Geology.....	1
3.0 EXPLORATION PROCEDURES	2
4.0 SUBSURFACE CONDITIONS.....	3
4.1 Site Geology	3
4.2 Site Stratigraphy	3
4.2.1 Topsoil	4
4.2.2 Fill	4
4.2.3 Silty Clay to Clayey Silt Glacial Till.....	4
4.2.4 Granular Soils	5
4.2.5 Bedrock.....	6
4.3 Groundwater Conditions	6
5.0 MISCELLANEOUS	7

PART B – FOUNDATION DESIGN REPORT

6.0 ENGINEERING RECOMMENDATIONS.....	9
6.1 General.....	9
6.2 Consequence and Site Understanding Classification	9
6.3 Bridge Foundations.....	9
6.3.1 Driven Steel H Piles	10
6.4 Liquefaction Potential and Seismic Analysis.....	12
6.4.1 Seismic Considerations.....	12
6.4.2 Seismic Hazard Assessment	12
6.5 Lateral Earth Pressures for Design.....	12
6.6 Approach Embankments	14
6.6.1 Assessment of Alternatives.....	14
6.6.2 Preferred Alternative	16



FOUNDATION INVESTIGATION AND DESIGN REPORT VICTORIA AVENUE OVERPASS - HIGHWAY 3 WIDENING

6.6.3	Additional Considerations	17
6.7	Excavations	17
6.8	Construction Considerations.....	18
6.8.1	Deep Foundations.....	18
6.8.2	CSPs for Integral Abutment	18
6.8.3	Temporary Protection Systems	18
7.0	MISCELLANEOUS	20

LIST OF ABBREVIATIONS

LIST OF SYMBOLS

RECORD OF BOREHOLE SHEETS

FIGURE 1 - Key Plan

FIGURE 2 – CPT-203 and CPT-206 Field Data

FIGURE 3 – Summary of Properties Inferred from CPTu and Laboratory Testing

DRAWING 1 - Borehole Locations & Soil Strata

APPENDICES

APPENDIX A

Laboratory Test Data

APPENDIX B

Site Photographs



PART A
FOUNDATION INVESTIGATION REPORT

**HIGHWAY 3 WIDENING
WINDSOR TO LEAMINGTON
VICTORIA AVENUE OVERPASS
GWP 317-98-00
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation explorations as part of the design work for GWP 317-98-00. This report addresses the geotechnical aspects of the proposed Victoria Avenue overpass.

The purpose of the foundation explorations are to assess the subsurface conditions at the location of the overpass structure by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Requests for Proposal and in Golder Associates' proposals 11-1132-0143-P01 dated February 27, 2012 and 11-1132-0143-1001 dated February 1, 2019. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated June 2012.

2.0 SITE DESCRIPTION

2.1 General

The location of the proposed Victoria Avenue overpass structure is shown on the Key Plan, Figure 1.

For the purposes of this report, Highway 3 and Victoria Avenue are assumed to be oriented in east-west and north-south directions, respectively. This section of Highway 3 is currently a two lane highway with left turn lanes. The area immediately surrounding the site generally consists of flat-lying agricultural lands, residential properties and municipal properties. Ground surface elevations are about 194 to 195 metres.

It is understood that this section of Highway 3 is to be realigned to accommodate the proposed pavement widening and the new overpass structure.

2.2 Site Geology

The site is situated on the Essex Clay Plain, a subregion of the physiographic region of southern Ontario known as the St. Clair Clay Plains.¹ This subregion is described as a bevelled till plain with little relief that has been locally smoothed by shallow deposits of lacustrine clay deposited in depressions in the till.

The dominant surficial soil is clayey silt till which contains features indicative of a waterlain deposit.² The underlying bedrock surface is reportedly about 33 to 37 metres below the ground surface.³ The bedrock is described as a brown cherty crinoidal limestone belonging to the Dundee Formation of the Hamilton group.⁴

¹ L.J. Chapman and D.F. Putnam, 1984. *The Physiography of Southern Ontario*. Third Edition. Ontario Geological Survey, Special Volume 2.

² Vagners, U. J., 1972. *Quaternary Geology of the Windsor-Essex Area, (Western Part) Southern Ontario*. Ontario Department of Mines and Northern Affairs, Preliminary Maps P. 749, Geological Series. Scale 1:50,000.

³ Vagners, U.J., Sado, E.V., and Yundt, S.E. 1973. *Drift Thickness of the Windsor-Essex Area (Western Part), Southern Ontario*, Ontario Division of Mines, Preliminary Maps P.814, Drift Thickness Series. Scale 1:50,000.

⁴ Sanford, B.V., 1969. *Geology, Toronto-Windsor Area, Ontario*. Map 1263A. Geological Survey of Canada. 1:250,000.



3.0 EXPLORATION PROCEDURES

The initial exploration program was carried out between February 21 and 28, 2013, during which time two boreholes, identified as BH-101 and BH-102, were drilled at the locations shown on the Borehole Location Plan, Drawing 1. Subsequently, four additional boreholes were drilled and two piezocone penetration tests (CPTu) were completed between September 5 and 17, 2019. The locations of the additional boreholes and CPTu tests are shown on the Borehole Location Plan, Drawing 1. The table below summarizes the borehole locations, ground surface elevations at the borehole locations and borehole depths.

Borehole/CPT	Location		Ground Surface Elevation (m)	Borehole/CPT Depth (m)
	Northing (m)	Easting (m)		
BH-101	4 669 710	277 047	194.65	42.8
BH-102	4 669 687	277 094	194.03	38.2
BH-201	4 669 784	276 991	193.96	20.3
BH-202	4 669 752	277 019	193.97	36.4
CPT-203	4 669 720	277 046	194.61	25.0
BH-204	4 669 615	277 141	193.94	20.3
BH-205	4 669 657	277 116	194.06	36.9
CPT-206	4 669 680	277 091	193.98	31.6

Field work was carried out using an all-terrain vehicle mounted drilling rig supplied and operated by a specialist drilling contractor. In the boreholes, samples of the overburden were obtained at generally 0.76 metre intervals of depth using 50 millimetre outside diameter split spoon sampling equipment in accordance with the standard penetration test (SPT) procedures (ASTM D1586). The recorded SPT N values are noted on the Record of Borehole sheets.

The split spoon samplers used limit the maximum particle size that can be sampled and tested to about 38 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions.

Thin-walled Shelby tube samples were obtained in the boreholes at selected depths in accordance with ASTM D1587. In addition, in-situ vane testing was carried out in accordance with ASTM D2573 to determine the undrained shear strength of softer cohesive soils encountered in the boreholes. The bedrock in BH-101 was cored using NQ-sized rock coring equipment.

The boreholes were terminated 20.3 to 42.8 metres below the existing ground surface and piezometers were installed in BH-101, BH-202 and BH-204. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

Field work was monitored on a full-time basis by experienced Golder staff members who also located the boreholes in the field, monitored the drilling, sampling and in situ testing operations, logged the boreholes and monitored to CPTu testing. The samples were identified in the field, placed in labelled containers, and transported to our Windsor and Mississauga laboratories for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations,



were carried out on selected samples. Consolidation (oedometer) testing was carried out on selected Shelby tube samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A. Additional grain size distribution analyses and Atterberg limits determinations are in progress and will be included in the finalized report. The results of the CPTu testing are provided on Figure 2 and shows the data recorded in the field including tip resistance, porewater pressure and sleeve friction resistance.

4.0 SUBSURFACE CONDITIONS

4.1 Site Geology

The project area is located in the physiographic region of Southwestern Ontario known as the St. Clair Clay Plains. Within this region, Essex County and the southwestern part of Kent County are normally discussed as a sub-region known as the Essex Clay Plain. The clay plain was deposited during the retreat of ice sheets (late Pleistocene Era) when a series of glacial lakes inundated the area. In general, the ice sheets deposited materials with a glacial-till-like gradation in the area of Windsor. Depending on the locations of the glacial ice sheets and depths of water in the ice-contact glacial lakes, the materials may have been directly deposited at the contact between the ice sheet and the bedrock or, as the lake levels rose and the ice sheets retreated and floated, the soil and rock debris within and at the base of the ice were deposited through the lake water (glaciolacustrine depositional environment). The term “glacial till”, in its common usage, often indicates a very dense or hard composition resulting from consolidation and densification under the weight of the ice sheet and the mineral soil particles typically have a distribution of grain sizes ranging from cobbles to clay. In areas of southwestern Ontario in the Windsor and Essex County region, however, the majority of the soils described as “glacial till” were deposited through water and have a soft to firm consistency below an upper “crust” that has since become stiff to hard through weathering and desiccation.

4.2 Site Stratigraphy

The detailed subsurface soil, rock and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The results of the CPTu testing are shown on Figure 2. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole and CPTu locations.

The boreholes drilled and the CPTu tests completed at the site generally encountered surficial topsoil or fill materials overlying layers of till-like silty clay. Layers of sand, silty fine sand, sandy silt and silt were encountered within the cohesive till. Beneath the till, the boreholes encountered and were terminated in limestone bedrock. It should be noted that the previous boreholes (BH-101 and BH-102) identify clayey silt till. Based on changes in soil classification convention since that work was completed, the clayey silt till in these boreholes will be referred to as silty clay till within the remainder of this report. While the naming convention has changed since the earlier work this deposit naturally varies in grain size distribution and plasticity and both naming conventions may be considered applicable to these soils for the purposes of analysis and design expectations.



FOUNDATION INVESTIGATION AND DESIGN REPORT VICTORIA AVENUE OVERPASS - HIGHWAY 3 WIDENING

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile, are shown on Drawing 1. Detailed descriptions of the subsurface conditions encountered in the boreholes and CPTu tests are provided on the Record of Borehole sheets and on Figure 2.

4.2.1 Topsoil

Approximately 200 to 380 millimetres of clayey topsoil was encountered at the ground surface at all of the borehole locations except BH-101.

Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

4.2.2 Fill

A layer of clayey silt fill about 0.8 metres thick was encountered at the ground surface in BH- 101.

4.2.3 Silty Clay to Clayey Silt Glacial Till

Fine-grained, cohesive glacial till was encountered beneath the fill in BH-101 and beneath the topsoil in the remaining boreholes 102. The silty clay to clayey silt till was encountered at about elevations 193.7 and 193.9 metres. The upper 2.8 to 3.9 metres of this deposit was weathered and brown in colour, becoming grey between about elevation 190 and 191 metres.

The N values, as determined in the standard penetration testing, generally ranged from 2 to 33 blows per 0.3 metres. The lower portion of the cohesive deposit had N values of 15 to 75 blows per 0.3 metres. The water contents of samples of the silty clay to clayey silt ranged from about 9 to 34 per cent with an average water content of about 21 per cent. The till had corresponding average plastic and liquid limits of 17 and 33 per cent, respectively, based on 31 Atterberg limits determinations, the results of which are shown on Figure A-5. Grain size distribution curves for samples of the silty clay to clayey silt glacial till are provided on Figures A-1 and A-2.

Consolidation testing was carried out on samples of the silty clay to clayey silt till and the results are provided on Figures A-6 and A-7. The consolidation testing indicated the following properties of the silty clay to clayey silt till:

Borehole	Sample	Depth (m)	Effective Overburden Pressure (kPa)	Initial Void Ratio	Recompression Index, C_R	Compression Index, C_C	Preconsolidation Pressure (kPa)
BH-101	12	12.5	163	0.49	0.023	0.203	472
BH-101	16	18.5	229	0.49	0.017	0.199	470
BH-202	9	9.5	131	0.57	0.014	0.183	270
BH-202	13	15.5	197	0.62	0.018	0.216	363
BH-202	17	21.7	264	0.58	0.021	0.190	357
BH-202	19	24.7	296	0.32	0.007	0.060	406
BH-205	7	6.4	98	0.56	0.04	0.160	510



FOUNDATION INVESTIGATION AND DESIGN REPORT VICTORIA AVENUE OVERPASS - HIGHWAY 3 WIDENING

Borehole	Sample	Depth (m)	Effective Overburden Pressure (kPa)	Initial Void Ratio	Recompression Index, C_R	Compression Index, C_c	Preconsolidation Pressure (kPa)
BH-205	11	12.5	164	0.59	0.017	0.226	438
BH-205	15	18.6	230	0.63	0.028	0.229	355

Seven CPTu dissipation tests were also completed. The coefficient of horizontal consolidation measured during the dissipation tests are summarized in the following table.

CPTu	Dissipation Test Elevation (m)	Coefficient of Consolidation, c_h (cm ² /s)
CPT-203	188.5	6×10^{-3} to 7×10^{-3}
	185.6	6×10^{-3} to 7×10^{-3}
	185.3	6×10^{-3} to 8×10^{-3}
	182.5	5×10^{-3} to 6×10^{-3}
	179.5	4×10^{-3} to 5×10^{-3}
CPT-206	172.2	6×10^{-3} to 7×10^{-3}
	168.2	7×10^{-3} to 9×10^{-3}

4.2.4 Granular Soils

Layers of fine granular soils were encountered within or beneath the cohesive glacial till. A summary of the relevant information related to these layers is provided in the following table.

Borehole	Soil Type	Elevation	N value (blows/0.3m)	Water Content (%)
BH-101	Silty fine sand	178.5 to 179.1	23	11
	Sandy silt	169.5 to 170.9	10	16
	Silt	160.2 to 161.6	>100	14
BH-102	Sand	174.7 to 175.6	28	
	Silt	161.0 to 162.3	120	15
BH-201	Sandy silt	180.8 to 181.7	15	15
BH-202	Sandy silt	162.5 to 164.0	14	15
	Silty sand	161.0 to 162.5	>100	16
	Silty sand	157.5 to 157.9	>100	9
BH-205	Silt	159.5 to 162.6	64, 92	13, 15
	Silty sand	157.2 to 158.0	>100	11

Grain size distribution curves for samples of the fine grained granular soils are provided on Figures A-3 and A-4.



4.2.5 Bedrock

Limestone bedrock of the Dundee Formation was encountered beneath the silty clay till in BH- 101 at about elevation 157.7 metres, or some 36.9 metres below the ground surface at the borehole location. The samples of rock core were described as being light brown and horizontally bedded. The upper 3.4 metres of the rock was highly weathered.

Samples of rock core were obtained from BH-101 using an NQ-size core barrel. The bedrock was explored for about 5.9 metres before terminating the borehole. The Rock Quality Designation (RQD), Total Core Recovery (TCR) and Solid Core Recovery (SCR) for the relatively intact rock are summarized in the following table.

Borehole	Elevation (m)		RQD (%)	TCR (%)	SCR (%)
	From	To			
BH-101	154.3	153.4	89	100	89
	153.4	151.9	86	100	100

The RQD values of 86 and 89 per cent indicate the bedrock has a rock quality described as good.

Bedrock was encountered beneath the clayey silt till in BH-102 at about elevation 156.5 metres or at about 37.5 metres depth. The bedrock was explored by augering for about 0.6 metres. BH-202 and BH-205 were terminated on inferred bedrock at elevation 157.6 and 157.2 metres, respectively.

4.3 Groundwater Conditions

The boreholes were advanced using mud rotary drilling techniques, thus groundwater observations during drilling were precluded. Piezometers were installed in BH-101, BH-201 and BH-202 as shown on the Record of Borehole sheets. The measured groundwater levels are summarized below:

Borehole	Ground Surface Elevation (m)	Installation	Measured Groundwater Elevation (m)	
			April 1, 2013	November 9, 2019
BH-101	194.65	Standpipe	192.4	
		Piezometer	185.9	
BH-202	193.97	Piezometer		189.1
BH-205	194.06	Piezometer		190.8

The above-noted water levels are not necessarily considered to be representative of the long-term, stabilized groundwater conditions. Based on the measured groundwater levels and the soil colour change from brown to grey, the inferred groundwater level is at elevation 191 metres. Groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

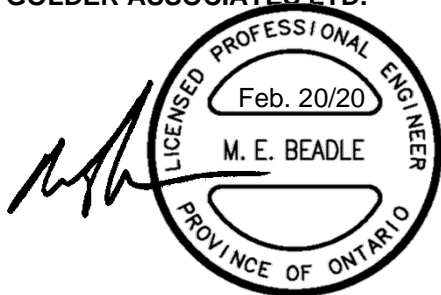


5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Aardvark Drilling Inc. and Orbit Garant Drilling Inc., Ontario Ministry of Environment licensed well contractors. The field operations were supervised by Mr. Steven Mayer and Mr. Mark Henderson under the direction of Mr. Michael E. Beadle, P. Eng.

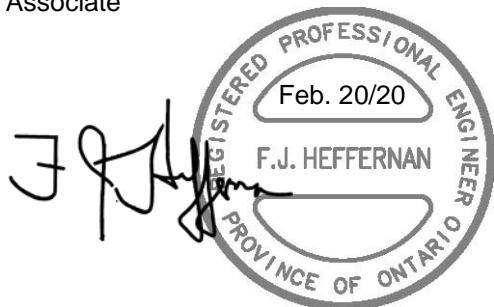
The laboratory testing was carried out at Golder Associates' Windsor and Mississauga laboratories under the direction of Mr. Chris M. Sewell, Ms. Laura Zarlenga and Dr. Paul Dittrich, P.Eng. The laboratories are accredited participants in the MTO Soil and Aggregate Proficiency Program and are certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. In addition, the Mississauga laboratory is approved for High Complexity testing for MTO Foundations Engineering projects. This report was prepared by Mr. Michael E. Beadle, P.Eng. and reviewed by Dr. Storer J. Boone, P. Eng. This report was also reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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PART B
FOUNDATION DESIGN REPORT
HIGHWAY 3 WIDENING
WINDSOR TO LEAMINGTON (PHASE 3A)
VICTORIA AVENUE OVERPASS
GWP 317-98-00
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION



6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the preliminary design of the proposed Victoria Avenue overpass to be constructed as part of the Highway 3 widening. The recommendations are based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction, they are provided only to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, and scheduling.

Based on the preliminary design information provided by Dillon, it is understood that the new structure will be a single span bridge with approximately 7 metre high abutments and the related earth fill approaches.

6.2 Consequence and Site Understanding Classification

The bridge is being designed in accordance with the current Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC 2014). In accordance with Section 6.5 of CHBDC (2014) and its Commentary, the proposed bridge and its foundation system are considered to be classified as having a "typical consequence level" associated with exceeding limits states design. The degree of understanding, based on the scope of the current foundation investigation and design, is considered 'typical' as described in Clause 6.5.3.2 of CHBDC (2014). The appropriate corresponding Ultimate Limit States (ULS) and Serviceability Limit States (SLS) consequence factors, Ψ , and geotechnical resistance factors at ULS (ϕ_{gu}) and SLS (ϕ_{gs}), respectively, from Tables 6.1 and 6.2 of the CHBDC have been used for design in this report.

6.3 Bridge Foundations

The subsurface soil and rock conditions typically consisted of relatively thin layers of topsoil or fill materials overlying an extensive stratum of silty clay till which was encountered at about elevation 194 metres. Layers of fine grained granular soils were encountered within and beneath the silty clay till. Bedrock was encountered between elevation 156.5 to 157.7 metres.

Alternatives for preliminary design of the bridge abutment foundations include shallow foundations, drilled cast-in-place concrete piles (caissons) and steel H-piles driven to bedrock.

Since new approach embankments will be constructed, settlement of the embankment fills and adjacent soils over the deep silty clay are anticipated. Abutments founded on shallow foundations or shallow caissons are vulnerable to settlement and are, therefore, not recommended. Abutment settlement(s) can be effectively mitigated by founding abutments on steel H piles driven to bedrock. Further, if the new bridge structure is designed with integral abutments, steel H piles are appropriate. Caissons to the bedrock beyond 35 metres depth are not considered to be economical at this site. Therefore, steel H piles are considered the preferred alternative, from a foundations perspective, for support of the abutments.



6.3.1 Driven Steel H Piles

Geotechnical Axial Resistance

Steel HP 310 x 110 piles driven to refusal into the weathered bedrock may be designed using a factored geotechnical resistance at Ultimate Limits States (ULS) of 1,500 kilonewtons (kN). It is anticipated that refusal will be achieved at about elevation 154 to 157 metres. Based on the existing ground surface elevation at the site and 1.2 metres cover for pile cap frost protection, it is anticipated that the cut-off elevations will be at about 197 metres; therefore pile lengths are estimated to be about 36 metres. A Serviceability Limits States (SLS) value is not provided since the bedrock is considered to be unyielding.

Piles supporting integral abutments require pre-augering and placement of a corrugated steel pipe (CSP) liner filled with loose, uniform sand around the upper 3 metres of the pile to allow some lateral movement.

Downdrag Loads (Negative Skin Friction)

The new approach embankments will induce consolidation settlement(s) of the underlying silty clay till. Consolidation settlement is time-dependent and will not completely occur during the construction period, unless the embankments are placed well in advance of bridge construction. Post-construction settlement(s) of the cohesive deposits will take place and settlement of the clayey materials relative to the piles will result in the development of negative skin friction acting on the piles. Therefore, negative skin friction, or downdrag loads, will need to be taken into account during design of the piles supporting the abutments unless some appropriate form of settlement mitigation is completed. The magnitude of the downdrag load should be determined during detailed design based on the preferred settlement mitigation alternative and consideration of construction sequencing and schedule.

Resistance to Lateral Loads

Lateral loading could be resisted fully or partially by the use of battered piles. In the case of integral abutments, the vertical piles must provide the resistance to the lateral loading.

Where ground conditions are generally competent and the lateral loads on piles are relatively small such that the maximum lateral pile deflections will be relatively small, the resistance to lateral loading in front of a single pile can be estimated using subgrade reaction theory as outlined below. However, it should be noted that the response of a pile to lateral loads is highly nonlinear and methods that assume linear behavior (such as subgrade reaction theory) are only appropriate where the maximum pile deflections are less than 1 percent of the pile diameter, where the loading is static (no cycling) and where the pile material is linear (CFEM, 2006). Where these conditions are not met, the non-linear lateral behavior of the soil should be considered by the use of P-y curves.

The factored serviceability geotechnical response of the soil in front of the piles under lateral loading at this site may be calculated using subgrade reaction theory suggested in the 2014 CHBDC Commentary (Section C6.11.2.2), where the coefficient of horizontal subgrade reaction, k_h , (kPa/m) is based on the equation given below, as described by Terzaghi (1955) and the Canadian Foundation Engineering Manual (CFEM 2006).



FOUNDATION INVESTIGATION AND DESIGN REPORT VICTORIA AVENUE OVERPASS - HIGHWAY 3 WIDENING

$$k_h = \text{coefficient of horizontal subgrade reaction (MPa/m)} = n_h (z/d) \quad \text{for cohesionless soils}$$

$$= \frac{67 S_u}{d} \quad \text{for cohesive soils}$$

d = pile width or diameter (m)

n_h = constant of horizontal subgrade reaction (MPa/m)

S_u = undrained shear strength of the soil (MPa)

z = depth below ground surface grade (m)

The range in values reflects the variability in subsurface conditions as well as the two extremes of design: the requirement for flexibility if integral abutments are selected and the requirement for lateral support in the case of conventional abutments.

Soil Type	Elevation (m)	n_h (MPa/m)	S_u (MPa)
Granular backfill in CSPs (for integral abutments)	Where applicable	2 to 8	-
Native cohesive soils	190 to 194	-	0.100 to 0.300
	180 to 190	-	0.070 to 0.125
	162 to 180	-	0.050 to 0.080
	157 to 162	-	0.200 to 0.300

Group action for lateral loading should be considered when the pile spacing in the direction of the loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R , as follows:

<i>Pile Spacing in Direction of Loading, d = Pile Diameter</i>	<i>Subgrade Reaction Reduction Factor R</i>
8d	1.00
6d	0.70
4d	0.40
3d	0.25

The lateral resistances for single HP 310 x 110 piles along both the strong and weak axes are summarized in the following table:



Pile Type	Lateral Resistance	
	Factored ULS (kN)	SLS (kN)
HP 310 x 110 (driven to refusal into bedrock)		
- Weak axis bending (Integral abutments)	165	110
- Strong axis bending (all other abutment types)	200	135

The lateral resistances were calculated using the procedures outlined by Matlock and Reese (1960)⁵. A fixed-head pile was assumed with the horizontal load applied at the ground surface. The SLS values are based on 10 millimetres of deflection at the ground surface.

6.4 Liquefaction Potential and Seismic Analysis

6.4.1 Seismic Considerations

Subsurface ground conditions for seismic site characterization were established based on the results of the borehole investigations. Based on the anticipated foundation levels, the site may be classified as Site Class D in accordance with Table 4.1 of the CHBDC (2014). This site should be considered to be located in Seismic Performance Zone 1. In accordance with Section 4.4.5.1 of the CHBDC, no seismic analysis is required for structures located in Seismic Performance Category 1 unless the bridge is considered to be a lifeline bridge, however minimum requirements specified in Clause 4.4.10.5 still apply.

6.4.2 Seismic Hazard Assessment

The liquefaction potential is considered to be low based on the soil profile type, age of the deposits, relative density and the historically low seismicity. Therefore, a detailed evaluation of the liquefaction potential of the foundation soils, impact of liquefaction on the bridge foundations, and the effect of seismic forces on embankment stability is not considered warranted unless the structure is deemed to be a lifeline bridge.

6.5 Lateral Earth Pressures for Design

The lateral pressures acting on the bridge abutments and associated wing/retaining walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the freedom of lateral movement of the structure and the drainage conditions behind the walls.

- Select, free-draining granular fill meeting the specifications of Ontario Provincial Standards Specifications (OPSS) Granular A or Granular B Type II or III should be used as backfill behind the abutments and walls. This fill should be compacted in loose lifts not greater than 200 millimetres in thickness in accordance with

⁵ Matlock, H. and Reese, L. "Generalized Solutions for Laterally Loaded Piles", Journal of Soil Mechanics and Foundation Division, ASCE, SM5, October 1960.



OPSS.PROV 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the abutment granular backfill requirements with respect to subdrains and frost taper should be in accordance with Ontario Provincial Standard Drawing (OPSD) 3101.150 and 3190.100.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with CHBDC (2014) Section 6.12.3 and Figure 6.6. Care must be taken during the compaction operation not to overstress the wall. Heavy construction equipment should be maintained at a distance of at least 1 m away from the walls while the backfill soils are being placed. Hand-operated compaction equipment should be used to compact the backfill soils immediately behind the walls as per OPSS.PROV 501. Other surcharge loadings should be accounted for in the design as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.2 m behind the back of the wall (in accordance with Figure C6.20 (a) of the Commentary to the CHBDC). For unrestrained walls, granular fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing in accordance with Figure C6.20(b) of the Commentary to the CHBDC (2014).
- For Case a, the restrained case, the pressures are based on the proposed embankment fill materials and the following parameters (unfactored) may be used assuming the use of Select Subgrade Material (SSM).

Soil unit weight: 20 kN/m³

Coefficient of lateral earth pressure:
At rest, K_0 0.50

- For Case b, the unrestrained case, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	<u>GRANULAR A</u>	<u>GRANULAR B</u> <u>Type II</u>	<u>GRANULAR B</u> <u>Type III</u>
Soil unit weight:	22 kN/m ³	21 kN/m ³	21 kN/m ³
Coefficients of lateral earth pressure:			
Active, K_a	0.27	0.27	0.31
At rest, K_p	3.7	3.7	3.3

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures may be used in the foundation design of the structure. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as:
 - Rotation of approximately 0.002 about the base of a vertical wall (where the rotation is calculated as the horizontal displacement divided by the height of the wall);
 - Horizontal translation of 0.001 times the height of the wall; and/or
 - A combination of both.



- If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.
- For integral abutments, passive earth pressures may be used in the geotechnical design of the structure. The movements required to fully mobilize passive pressure or resistance are much larger than those required to mobilize active pressure. In practice, movements may not be sufficient to mobilize the full passive resistance. A resistance factor equal to 0.5 should be applied to the calculated total passive resistance in accordance with Table 6.1 of the CHDBC.

It should be noted that the above design parameters assume level backfill and ground surface behind the wall. The lateral earth pressure coefficients should be adjusted if there is sloping ground at the back of the wall.

6.6 Approach Embankments

It is anticipated that the new embankments will be approximately 7 metres in height and the crests will be approximately 37 metres wide. Settlement analyses were carried out for the approach embankments using the results of the boreholes, CPTu tests, field and laboratory testing, including in situ vane shear strength tests and oedometer testing. A summary of the interpreted parameters used in the settlement analyses is shown on Figure 3.

For comparison of various settlement mitigation alternatives, settlements and time-rates of consolidation were calculated assuming no special ground improvement or settlement mitigation measures would be implemented to define a “base case”. Analyses of this base case indicate that settlement at the embankment crests may be about 250 millimetres. Settlement at the embankment toes is expected to be less than 60 millimetres. Ninety per cent of the long-term settlement is expected to occur about 30 years following embankment construction with 50 per cent of the settlement occurring within 6 years.

The alternatives considered to mitigate the effects of settlement on the highway and structure performance are:

1. Do nothing (Base Case);
2. Preload and surcharge;
3. Preload and surcharge in conjunction with the installation of prefabricated vertical drains;
4. Construct portions of the new embankments using lightweight fill; and
5. Ground improvement.

6.6.1 Assessment of Alternatives

Alternative 1 – “Do Nothing” – This alternative is not considered appropriate given that, as indicated above, ongoing post construction settlements of a significant magnitude are expected to occur over a span of 30 years or more. This alternative will induce downdrag loads on the pile foundations, settlement at the approaches will be problematic and settlements along the embankment will not meet the settlement criteria established by the MTO. Provided that the piles are designed to accept the downdrag loads and ongoing periodic maintenance and



pavement ponding at the approaches and abutments can be managed or accepted, this alternative would be considered the least expensive alternative.

Alternative 2 – Preload and Surcharge – This alternative is also not considered appropriate for similar reasons as Alternative 1. In cases where the subsurface conditions are sufficiently permeable, allowing excess pore pressures to dissipate in a reasonable period (on the order of a few years), preloading and surcharging about a year in advance of bridge construction has been successful. However, in this case, given the soft and cohesive nature of the silty clay till, settlements are not expected to be sufficiently complete in a reasonable period of time (i.e., less than about one year). Thus, while cost effective, this alternative is expected to result in significant schedule issues unless larger, on-going post construction settlements and maintenance requirements can be tolerated that will not necessarily meet the settlement criteria established by the MTO.

Alternative 3 – Preload and Surcharge with Wick Drains - Prefabricated vertical drains could be installed prior to construction of the embankments. Prefabricated vertical drains would typically be installed on a 1.5 metre triangular grid pattern and penetrate to the bottom of the silty clay deposit. Following construction of the embankments, a 2 metre surcharge could be placed to accelerate consolidation. It is estimated that 90 per cent of the long-term settlements would be complete in about 6 to 8 months using wick drains on an approximately 1.5 to 2 metre triangular grid. While more costly than Alternative 2, settlements are expected to be achieved provided the wick drains can be installed and the embankment constructed one season in advance of the bridge foundations and superstructure.

Alternative 4 – Construct Embankments with Lightweight Fill – Lightweight fill, consisting of expanded polystyrene (EPS), could be placed to form the approach embankments in any areas in which the embankment height will exceed about 2 metres. Following placement of the EPS, at least one metre of soil cover would be placed over the EPS to provide protection and to facilitate pavement and side slope construction. Since EPS can be considered essentially “weightless”, only nominal loads from the soil cover and pavement are transmitted to the ground addressing settlement issues. From an economic perspective, this alternative is estimated to be about ten times as costly as Alternative 3.

Alternative 5 – Ground Improvement – Although Alternative 3 is a form of ground improvement, for consideration of this particular alternative, techniques such as deep dynamic compaction, deep soil mixing, rammed aggregate piers and rigid inclusions were considered.

- **Deep Dynamic Compaction** – Given that the predominant soils at the site are cohesive and that the softer soils are generally present about 10 to 20 metres below ground surface, deep dynamic compaction is not considered appropriate at this site. Since settlement is driven by the dissipation of excess pore pressures, some nominal improvement may be realized in the upper weathered portion of the silty clay till but it is not expected to have any meaningful influence on settlement mitigation. Further, given the thickness of the silty clay till, it is not expected that surface impacts will have any influence at depth.
- **Deep Soil Mixing** – Ground improvement could be completed using deep soil mixing in which a specialized machine is used to effectively mix the existing soils with a cementing material (such as Portland cement or other specialized additive) to increase the overall strength of the ground. While deep soil mixing has been used successfully on many projects to mitigate settlements in soft ground, it is not considered to be feasible at this site. The necessary soil mixing equipment is not, to our knowledge, readily available in southern Ontario, which could result in schedule challenges. In addition, deep soil



mixing is expected to be very expensive compared to other alternatives; we understand that it can be competitive on projects in which large footprints require ground improvement, but given the relatively small surface area of the embankments being contemplated, we expect that deep soil mixing will not be an economical alternative.

- **Rammed Aggregate Piers** – Rammed aggregate piers are generally economical and used to improve subsurface conditions to accommodate higher loads. A mandrel is pushed into the ground or a hole is made by augering to the desired treatment depth. Aggregates are placed in lifts at the base of the hole and successively compacted to create “stone columns” in the ground. Rammed aggregate piers at this site may not necessarily be successful since the aggregate column must rely on the adjacent soils to provide lateral support. Particularly at depth where the “weakest” soils are present, less than ideal lateral support could permit the aggregate column to progressively “bulge” resulting in settlements at the surface.
- **Rigid Inclusions** – Rigid inclusions are similar to rammed aggregate piers in that vertical columns of strong materials are installed on a closely-spaced grid. These columns can be constructed using drilled piles, auger-cast piles or driven piles among other techniques. Typically geogrids and controlled granular fill materials are used to distribute embankment loads to the inclusions.

The various alternatives and their appropriateness for this project are summarized in the following table.

Alternative	Description	Appropriate for Project?
1	“Do Nothing”	No – technical considerations – excessive time dependent settlements
2	Preload and Surcharge	No – technical considerations – schedule and excessive time dependent settlement
3	Preload, Surcharge and Wick Drains	Yes – moderately expensive, potential schedule considerations, addresses technical issues and settlement
4	Lightweight Fill	Maybe – very expensive, limited schedule considerations, addresses technical issues and settlement
5	Ground Improvement	No – potential cost issues, effectiveness of treatment and/or excessive cost

6.6.2 Preferred Alternative

The preferred alternative would be the installation of vertical drains prior to construction of the embankments with the use of a 2 metre surcharge in order to accelerate the consolidation. It is estimated that 90 per cent of the long-term settlements would be complete in about 6 to 8 months using wick drains on an approximately 2 metre triangular grid.

Prior to installation of the wick drains, the subgrade within the embankment footprint should be sloped to the perimeter at a 2 per cent grade or greater to perimeter ditches at least 0.5 metres below subgrade level. Subsequently, a minimum 0.5 metre granular pad should be constructed embankment within the embankment footprint using free-draining Granular A or Granular B Type II. Wick drains should be installed in areas where the final embankment height (including pavement structure) is greater than 2 metres and in accordance with OPSS 220. The wick drains should extend to elevation 163 metres.



It is recommended that at least four vibrating wire piezometers (two in each approach embankment) be installed to monitor post construction pore-pressures, excess pore pressures developed during fill placement, and dissipation of pore pressures after the construction of the 2 metre surcharge. Pore pressures returning to near the pre-construction level will assist with confirming that settlements have effectively ceased.

In addition, it is also recommended that four settlement plates be installed on the subgrade immediately prior to embankment construction. These could consist of 450 by 450 millimetre steel plates 12 millimetres thick. Threaded riser rods should be welded to the plates and additional lengths of riser rod available to accommodate increasing fill height. An initial survey should be completed twice prior to construction to confirm the plate elevation. A 100 millimetre diameter threaded rigid PVC sleeve should be provided around the riser rods to prevent frictional effects.

The vibrating wire piezometers and settlement plates should be read weekly for the initial three months and then every two weeks thereafter with the results promptly provided to the Contract Administrator or Project Engineer for review.

6.6.3 Additional Considerations

A Factor of Safety against slope failure of greater than 1.4 is available for embankments no steeper than 2 vertical to 1 horizontal constructed with select subgrade material and founded on the firm to very stiff silty clay till soils at the site.

The embankment subgrade should be prepared by removing any topsoil, fill and/or organic materials from within the area of the embankment. The exposed subgrade soils should be proofrolled prior to fill placement under the direction of qualified geotechnical personnel. Any softened areas identified should be subexcavated and backfilled with an approved fill material and compacted.

Construction of the embankment above the prepared subgrade may be carried out using clean earth fill or select subgrade material depending on material availability. All embankment fill should be placed in regular lifts with loose thicknesses not exceeding 300 millimetres and uniformly compacted to 95 per cent of standard Proctor maximum dry density. The top 1 metre of the embankment fill that will form the pavement subgrade should be compacted to at least 98 per cent of standard Proctor maximum dry density.

6.7 Excavations

Excavations for the pile caps and/or abutments will penetrate the existing fill and topsoil into the silty clay till. The groundwater level is expected to be at about elevation 191 metres and will fluctuate seasonally and in response to significant precipitation events. The excavations may penetrate the groundwater level; however seepage volumes are expected to be minor and groundwater may be controlled by using properly filtered and constructed sumps in the base of the excavations. Sumps should be maintained outside of the actual pile cap and/or abutment limits. Surface water runoff should be directed away from the excavations at all times.

All excavations should be carried out in accordance with the guidelines outlined in the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The topsoil and fill materials at



this site would be classified as Type 3 soils as would any cohesionless materials below the groundwater level. The native clayey materials and properly dewatered cohesionless materials would be classified as Type 2 soils.

6.8 Construction Considerations

6.8.1 Deep Foundations

All pile installation/driving operations for the driven steel H-piles should be in accordance with OPSS.PROV 903 (Deep Foundations). The piles should be fitted with driving shoes or flange plates (reinforced tips) in accordance with OPSD 3000.100 (Steel H-Pile Driving Shoe) to minimize damage to the pile tip during driving.

6.8.2 CSPs for Integral Abutment

CSPs should be in accordance with OPSS 1801 and should be from a supplier listed under DSM#4.60.80. The CSP should be of the diameter and wall thickness specified, and should be galvanized in accordance with CSA G164-M.

The sand fill for backfilling the CSP should meet the gradation requirements:

MTO Sieve Designation		Percentage Passing by Weight
2 mm	#10	100%
600 µm	#30	80% to 100%
425 µm	#40	40% to 80%
250 µm	#60	5% to 25%
150 µm	#100	0% to 6%

The sand fill should be placed dry of optimum and free-flowing, completely filling the volume between the CSP and pile. No additional compaction effort other than the action of placing the sand itself should be applied to the sand fill.

6.8.3 Temporary Protection Systems

Temporary protection systems (if required) to allow for construction of the approach embankments and bridge should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems), provided that any existing adjacent structures or utilities can tolerate this magnitude of deformation. The lateral movement of the temporary shoring systems should meet Performance Level 2 as specified in OPSS.PROV 539.



Temporary support systems could consist of soldier piles and lagging, where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds, or driven steel sheet piling. Support to the system(s) could be in the form of struts and walers or rakers and anchors. The support system must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as address the impact(s) of sloping ground behind the system.

The selection and design of the excavations and temporary protection systems will be ultimately the responsibility of the Contractor.



7.0 MISCELLANEOUS

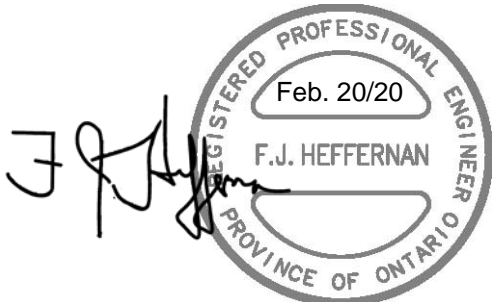
This report was prepared by Mr. Michael E. Beadle, P.Eng. and reviewed by Dr. Storer J. Boone, P. Eng. This report was also reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

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NG/MEB/SJB/FJH/cr

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ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (*q_t*), porewater pressure (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	≥ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 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	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
E	void ratio
N	porosity
S	degree of saturation

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index $= (w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)


C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

PROJECT 11-1132-0143		RECORD OF BOREHOLE No 101		1 OF 3	METRIC
W.P. 317-98-00		LOCATION N 4669710.5 , E 277046.5 (Lat 42.166428 , Long -82.835892)		ORIGINATED BY SM	
DIST _____ HWY 3		BOREHOLE TYPE BOREHOLE		COMPILED BY WDF	
DATUM GEODETIC		DATE February 21 - 26, 2013		CHECKED BY 	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)					
							20 40 60 80 100	20 40 60 80 100	10 20 30					
194.65	GROUND SURFACE													
0.00	FILL, clayey silt, some sand, trace gravel, trace topsoil Brown and grey													
193.89														
0.76	SILTY CLAY TILL, some sand, trace gravel Stiff to hard Brown becoming grey at about elev. 191.0m		1	SS	9									
			2	SS	9									
			3	SS	26									
			4	SS	33									
			5	SS	21									
			6	SS	16									
			7	SS	12									
188.75														
5.90	CLAYEY SILT TILL, some sand, trace gravel Stiff to very stiff Grey		8	TO	PH									
			9	SS	11									
			10	SS	10									
			11	SS	10									
			12	TO	PH									
			13	SS	8									

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

METRIC

PROJECT 11-1132-0143

W.P. 317-98-00

LOCATION N 4669710.5, E 277046.5 (Lat 42.166428, Long -82.835892)

ORIGINATED BY SM

DIST HWY 3

BOREHOLE TYPE BOREHOLE

COMPILED BY WDF

DATUM GEODETTIC

DATE February 21 - 26, 2013

CHECKED BY

[illegible]

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

LDN_MTO_06 1111320143-1000.GPJ LDN_MTO.GDT 06/12/19

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No 101		3 OF 3	METRIC
W.P. <u>317-98-00</u>		LOCATION <u>N 4669710.5 , E 277046.5 (Lat 42.166428 , Long -82.835892)</u>		ORIGINATED BY <u>SM</u>	
DIST <u> </u> HWY <u>3</u>		BOREHOLE TYPE <u>BOREHOLE</u>		COMPILED BY <u>WDF</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 21 - 26, 2013</u>		CHECKED BY <u>W</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT CONTENT LIMIT			UNIT WEIGHT γ kN/m³	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						
						20 40 60 80 100	20 40 60 80 100	10 20 30						
	CLAYEY SILT TILL, some sand, trace gravel Stiff to hard Grey		24	SS	7									
			25	SS	75									
161.58														
33.07	SILT, some clay, trace sand Very dense Grey		26	SS	145/ 250mm									1 4 79 16
160.21														
34.44	CLAYEY SILT TILL, some sand, some gravel Hard Grey		27	SS	51									
157.74			28	SS	175/ 200mm									
36.91	LIMESTONE, highly weathered, with clayey silt infill Light brown		29	NQ RC										
			30	NQ RC										
154.32			31	NQ RC										
40.33	LIMESTONE, lightly weathered, horizontally bedded Light brown		32	NQ RC										
151.89														
42.76	END OF BOREHOLE													
	Water level in Standpipe at elev. 192.4m on Apr. 1, 2013. Water level in Piezometer at elev. 185.9m on Apr. 1, 2013.													

LDN_MTO_06 111320143-1000.GPJ LDN_MTO.GDT 06/12/19

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No 102		1 OF 3	METRIC
W.P. <u>317-98-00</u>	LOCATION <u>N 4669686.8 , E 277093.5 (Lat 42.166216 , Long -82.835322)</u>	ORIGINATED BY <u>SM</u>			
DIST <u> </u> HWY <u>3</u>	BOREHOLE TYPE <u>BOREHOLE</u>	COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>	DATE <u>February 26 - 28, 2013</u>	CHECKED BY <u>W</u>			

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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
194.03	GROUND SURFACE						194							
0.00	TOPSOIL, clayey Black													
0.30	SILTY CLAY TILL, some sand, trace gravel Firm to very stiff Brown becoming grey at about elev. 191.0m		1	SS	7		193							
			2	SS	7		192							
			3	SS	23		191						1 15 45 39	
			4	SS	27		190							
			5	SS	13		189							
			6	SS	11		188							
188.85	CLAYEY SILT TILL, some sand, trace gravel Firm to very stiff Grey		7	SS	8		187							1 14 46 39
5.18			8	SS	7		186							
			9	TO	PH		185							
			10	SS	7		184							1 15 45 39
			11	TO	PH		183							
			12	SS	6		182							
							181							
							180							1 23 45 31

Continued Next Page

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No 102		2 OF 3	METRIC
W.P. <u>317-98-00</u>	LOCATION <u>N 4669686.8 , E 277093.5 (Lat 42.166216 , Long -82.835322)</u>	ORIGINATED BY <u>SM</u>			
DIST <u> </u> HWY <u>3</u>	BOREHOLE TYPE <u>BOREHOLE</u>	COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>	DATE <u>February 26 - 28, 2013</u>	CHECKED BY <u>LV</u>			



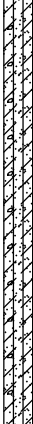


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		w _p	w	w _L			WATER CONTENT (%)
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100						GR SA SI CL	
	CLAYEY SILT TILL, some sand, trace gravel Firm to very stiff Grey		13	TO	PH										
			14	TO	PH										
175.59															
18.44	SAND, fine, some silt, trace gravel Compact Grey		15	SS	28										
174.74															
19.29	CLAYEY SILT TILL, some sand, trace gravel Stiff to very stiff Grey														
			16	SS	6										1 16 44 39
				17	TO	PH									
			18	SS	7										
			19	SS	11										
			20	SS	10										
			21	SS	7										

LDN_MTO_06 111320143-1000.GPJ LDN_MTO.GDT 06/12/19

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No 102		3 OF 3	METRIC
W.P. <u>317-98-00</u>	LOCATION <u>N 4669686.8 , E 277093.5 (Lat 42.166216 , Long -82.835322)</u>	ORIGINATED BY <u>SM</u>			
DIST <u> </u> HWY <u>3</u>	BOREHOLE TYPE <u>BOREHOLE</u>	COMPILED BY <u>WDF</u>			
DATUM <u>GEODETIC</u>	DATE <u>February 26 - 28, 2013</u>	CHECKED BY <u>W</u>			


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 ³	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 _P	W	W _L						
						○ UNCONFINED + FIELD VANE															
						● QUICK TRIAXIAL × LAB VANE															
						20 40 60 80 100					10 20 30										
30.02	CLAYEY SILT TILL, some sand, some gravel Stiff to very stiff Grey						164														
			23	SS	5		163														1 15 56 28
162.33																					
31.70	SILT, some sand, trace clay Very dense Grey		24	SS	120		162												0 13 80 7		
160.96																					
33.07	CLAYEY SILT TILL, some sand, trace gravel Very stiff to hard Grey						161														
								160													
					26		SS	45	159												
									158												
							157														
156.54	Weathered LIMESTONE						156														
37.49																					
155.84	END OF BOREHOLE		28	SS	100/ 100mm																
38.19																					

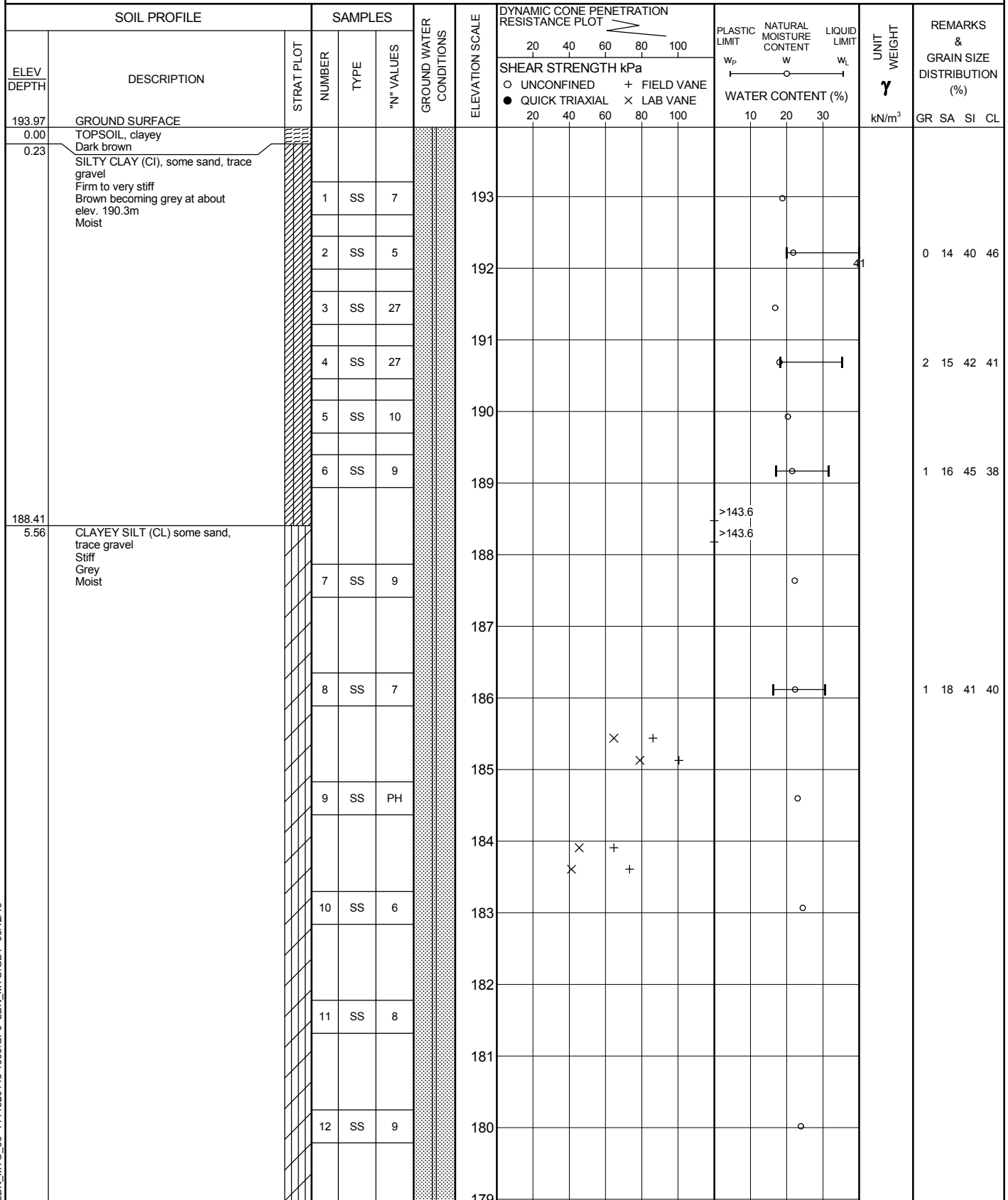
+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No BH-201		2 OF 2	METRIC
W.P. <u>317-98-00</u>		LOCATION <u>N 4669784.4 , E 276991.2 (Lat 42.167092 , Long -82.836565)</u>		ORIGINATED BY <u>MH</u>	
DIST <u> </u> HWY <u>3</u>		BOREHOLE TYPE <u>BOREHOLE</u>		COMPILED BY <u>ZJB</u>	
DATUM <u>GEODETIC</u>		DATE <u>September 16 - 17, 2019</u>		CHECKED BY <u>W</u>	

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/m³	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 _p	W	W _L						
	CLAYEY SILT (CL), some sand, trace gravel Stiff Grey Moist		13	SS	10																
					14	SS	8														
					15	SS	7														

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 11-1132-0143		RECORD OF BOREHOLE No BH-202		1 OF 3	METRIC
W.P. 317-98-00		LOCATION N 4669751.9, E 277018.7 (Lat 42.166800, Long -82.836230)		ORIGINATED BY MH	
DIST HWY 3		BOREHOLE TYPE BOREHOLE		COMPILED BY ZJB	
DATUM GEODETIC		DATE September 14 - 16, 2019		CHECKED BY 	



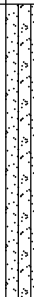
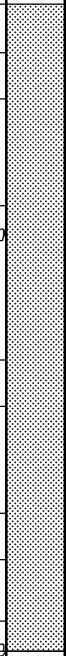

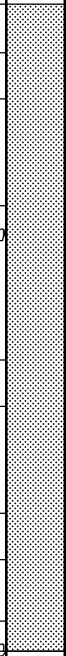

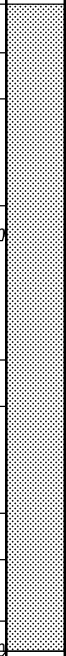
LDN_MTO_06 111320143-1000.GPJ LDN_MTO.GDT 06/12/19

Continued Next Page

 +³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE


PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No BH-202		3 OF 3	METRIC
W.P. <u>317-98-00</u>		LOCATION <u>N 4669751.9, E 277018.7 (Lat 42.166800, Long -82.836230)</u>		ORIGINATED BY <u>MH</u>	
DIST <u> </u> HWY <u>3</u>		BOREHOLE TYPE <u>BOREHOLE</u>		COMPILED BY <u>ZJB</u>	
DATUM <u>GEODETIC</u>		DATE <u>September 14 - 16, 2019</u>		CHECKED BY <u>W</u>	

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					w _p	w	w _L		GR	SA	SI	CL	
29.95	SILTY SAND (SM) TO SANDY SILT (ML) trace clay Compact to very dense Grey Moist						VWP S/N1301292	20	40	60	80	100				7	36	39	18		
			23	SS	14		163														
			24	SS	170/ 200mm		162														
160.97	CLAYEY SILT (CL), some sand, trace gravel Hard Grey Moist															2	71	21	6		
33.00			25	SS	55		161														
							160														
			26	SS	74		159														
157.85	SILTY SAND (SM), and gravel, trace fines Very dense Grey Moist END OF BOREHOLE INFERRED BEDROCK																				
36.12 157.55 36.42			27	SS	112/ 300mm		158														

PROJECT <u>11-1132-0143</u>		RECORD OF BOREHOLE No BH-204		2 OF 2	METRIC
W.P. <u>317-98-00</u>		LOCATION <u>N 4669615.0 , E 277141.2 (Lat 42.165572 , Long -82.834742)</u>		ORIGINATED BY <u>MH</u>	
DIST <u> </u> HWY <u>3</u>		BOREHOLE TYPE <u>BOREHOLE</u>		COMPILED BY <u>ZJB</u>	
DATUM <u>GEODETIC</u>		DATE <u>September 5, 2019</u>		CHECKED BY <u>W</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT			UNIT WEIGHT γ kN/m³	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 _p W W _L				
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100		10 20 30				


+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 11-1132-0143		RECORD OF BOREHOLE No BH-205		1 OF 3	METRIC
W.P. 317-98-00		LOCATION N 4669656.6 , E 277116.4 (Lat 42.165946 , Long -82.835043)		ORIGINATED BY MH	
DIST _____ HWY 3		BOREHOLE TYPE BOREHOLE		COMPILED BY ZJB	
DATUM GEODETIC		DATE September 12 - 14, 2019		CHECKED BY 	

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _P W W _L	WATER CONTENT (%)			GR	SA	SI	CL	
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
194.06	GROUND SURFACE						194											
0.00	TOPSOIL, clayey Dark brown																	
0.30	SILTY CLAY (CI), some sand, trace gravel Stiff to very stiff Brown becoming grey at about elev. 191.2m Moist		1	SS	11		193											
			2	SS	9		192									4	18 40 38	
			3	SS	26													
			4	SS	14		191											
			5	SS	11													
			6	SS	13		190									0	17 45 38	
							189											
188.50	CLAYEY SILT (CL), some sand, trace gravel, with silty sand layers Stiff Grey Moist		7	SS	PH		188											
5.56							187											
			8	SS	8		186									0	16 47 37	
							185											
			9	SS	10		184											
			10	SS	9		183											
			11	SS	PH		182											
							181											
			12	SS	8		180											

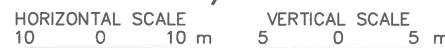
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+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

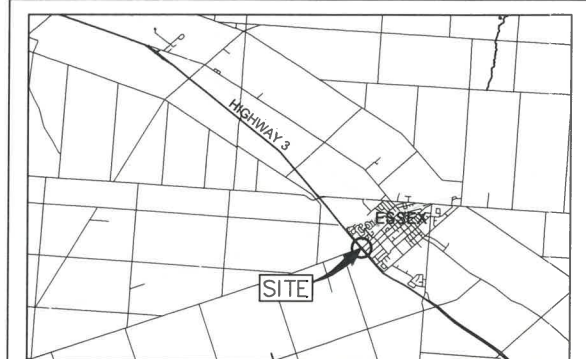
PROJECT 11-1132-0143		RECORD OF BOREHOLE No BH-205		3 OF 3	METRIC
W.P. 317-98-00		LOCATION N 4669656.6 , E 277116.4 (Lat 42.165946 , Long -82.835043)		ORIGINATED BY MH	
DIST _____ HWY 3		BOREHOLE TYPE BOREHOLE		COMPILED BY ZJB	
DATUM GEODETIC		DATE September 12 - 14, 2019		CHECKED BY 	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED	● QUICK TRIAXIAL	+	×	FIELD VANE	LAB VANE	W _P	W		W _L			

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



SHEET



SCALE IN KILOMETRES



	Borehole – Current Investigation
	Cone Penetration Test – Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
100%	Rock Quality Designation (RQD)
	Seal
	Standpipe
	Vibrating wire piezometer
	WL measured on April 1, 2013.
DRY	Water level not established

No.	ELEVATION	CO-ORDINATES (MTM ZONE 11)	
		NORTHING	EASTING
BH-101	194.65	4 669 710.4	277 046.5
BH-102	194.03	4 669 686.8	277 093.5
BH-201	193.96	4 669 784.4	276 991.2
BH-202	193.97	4 669 751.9	277 018.7
BH-204	193.94	4 669 615.0	277 141.2
BH-205	194.06	4 669 656.6	277 116.4
CPT-203	194.62	4 669 720.4	277 046.3
CPT-206	193.98	4 669 680.2	277 091.0

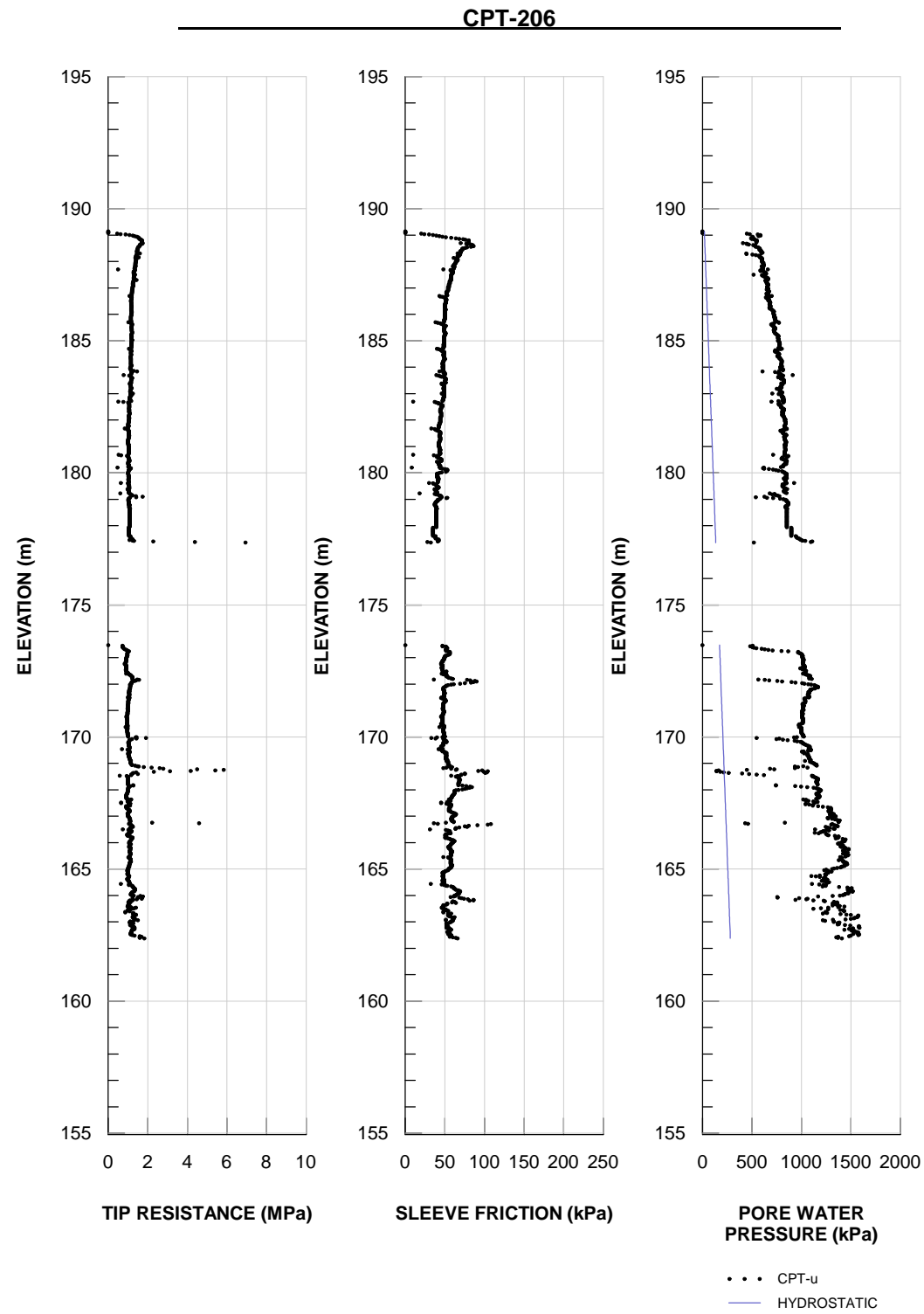
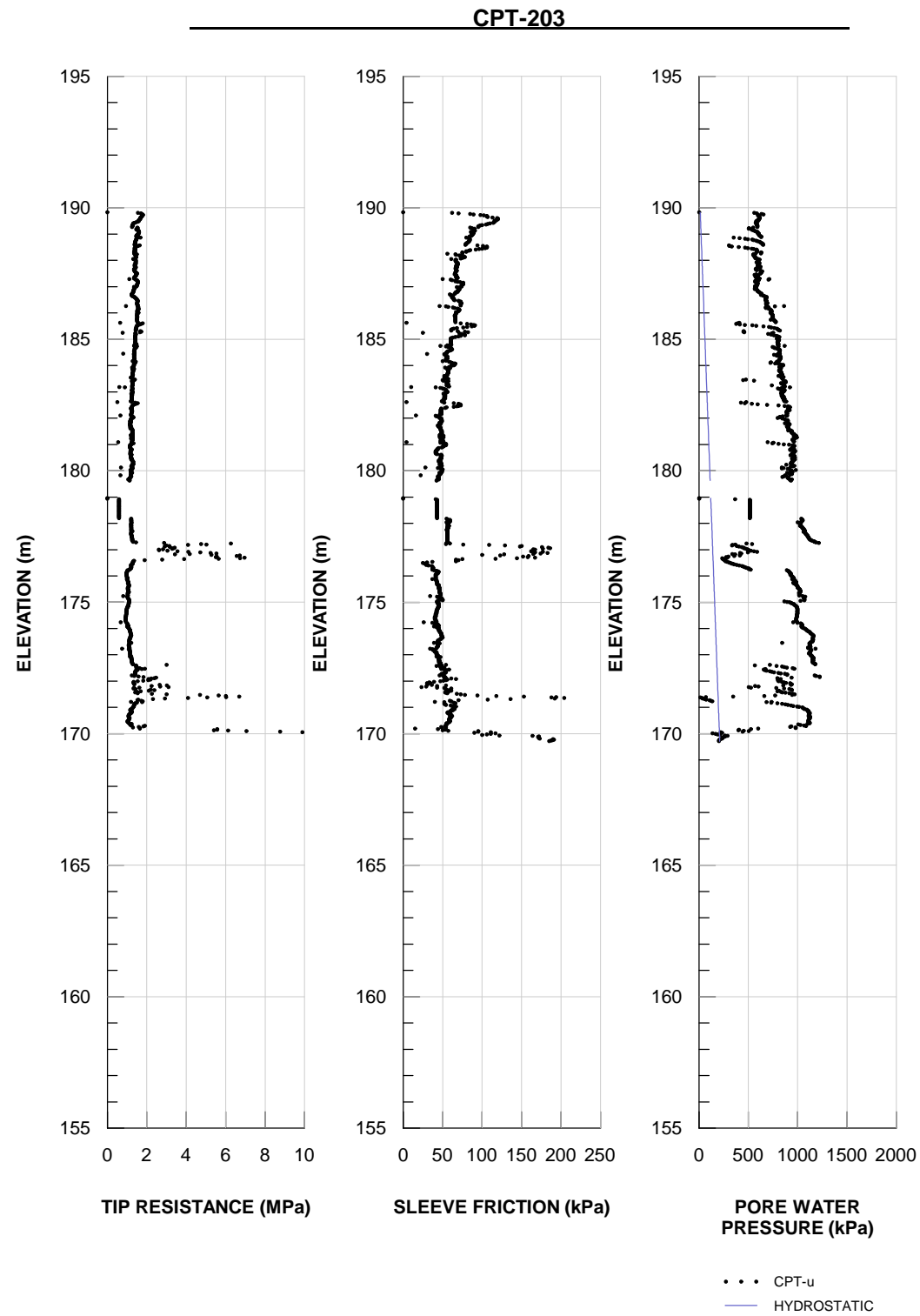
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.


The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

Base plans provided in digital format by DILLON

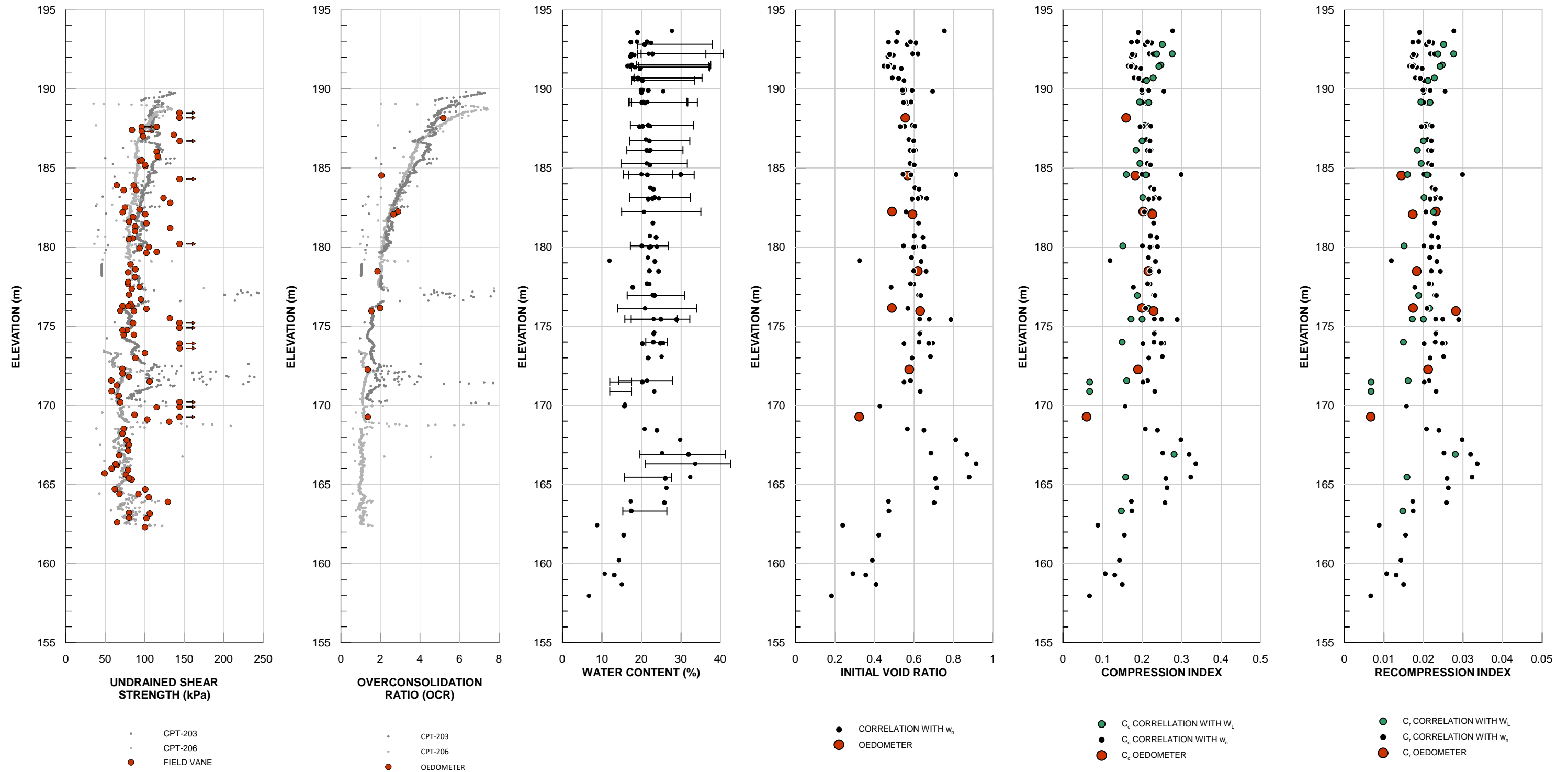
NO.		DATE		BY		REVISION	
Geocres No. 40J2-127							
HWY. 3		PROJECT NO. 11-1132-0143				DIST.	
SUBM'D. MH		CHKD. MH		DATE: Feb 13/20		SITE:	
DRAWN: ZJB		CHKD. FJH		APPD.		DWG. 1	



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PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00		
TITLE		CPT-203 AND CPT-206 FIELD DATA		
		PROJECT No.	11-1132-0143	FILE No.
		DRAWN	MEB	NOV 1-19
CHECK		[Signature]		SCALE AS SHOWN
				REV. 0
		FIGURE 2		

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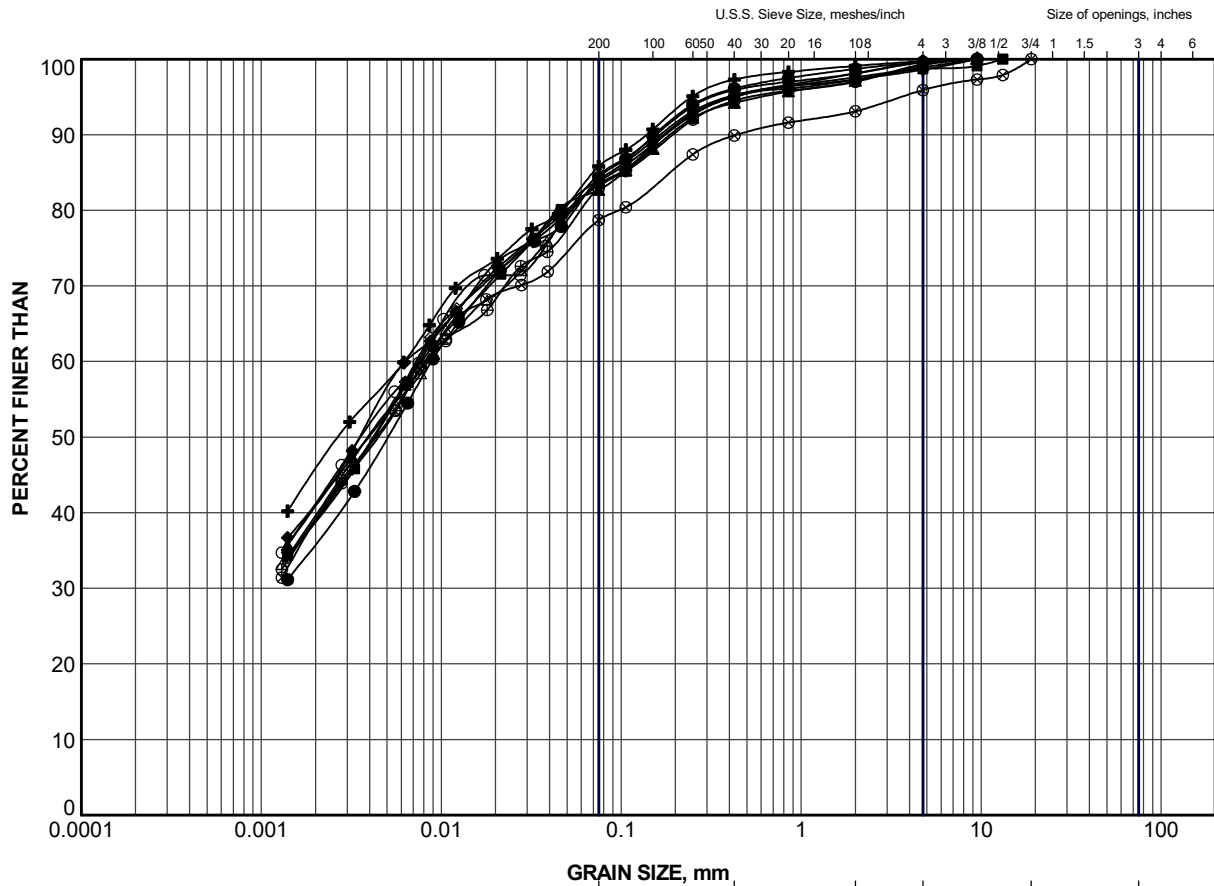


PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00				
TITLE		SUMMARY OF PROPERTIES INFERRED FROM CPT _u , FIELD AND LABORATORY TESTING				
	PROJECT No.		11-1132-0143		FILE No.	Fig 3-R
					SCALE	AS SHOWN
	DRAWN	MEB	NOV 1-19		REV.	0
	CHECK				FIGURE 3	



APPENDIX A

Laboratory Test Data

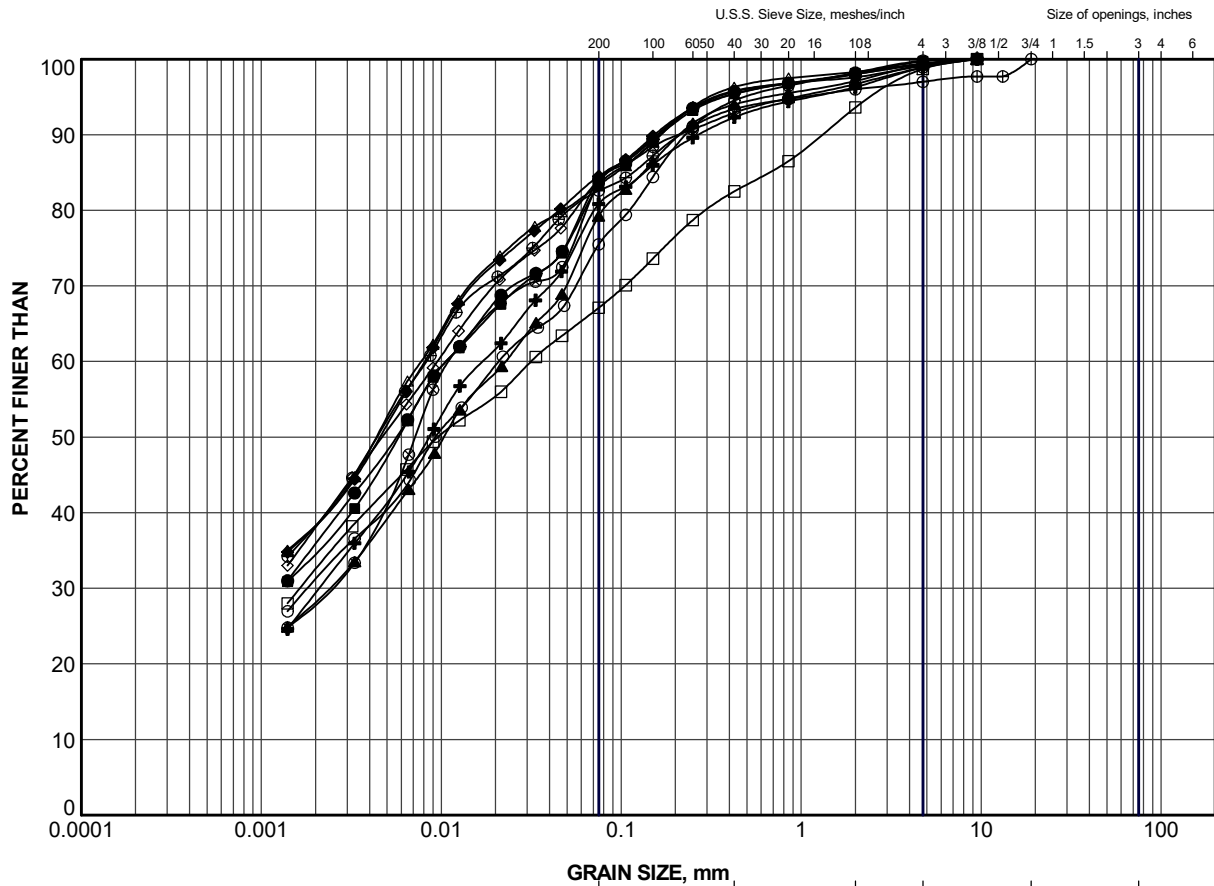


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	4	191.4
■	102	3	191.5
▲	BH-201	2	192.2
+	BH-202	2	192.2
◆	BH-202	4	190.7
◇	BH-202	6	189.2
○	BH-204	3	191.4
△	BH-204	6	189.1
⊗	BH-205	2	192.3
⊕	BH-205	5	190.0

PROJECT				FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SILTY CLAY TILL			
		PROJECT No.		11-1132-0143		FILE No. 1111320143-1001-F020A1	
		DRAWN		ZJB		Feb 13/20	
		CHECK		[Signature]			
		SCALE		N/A		REV.	
						FIGURE A-1	

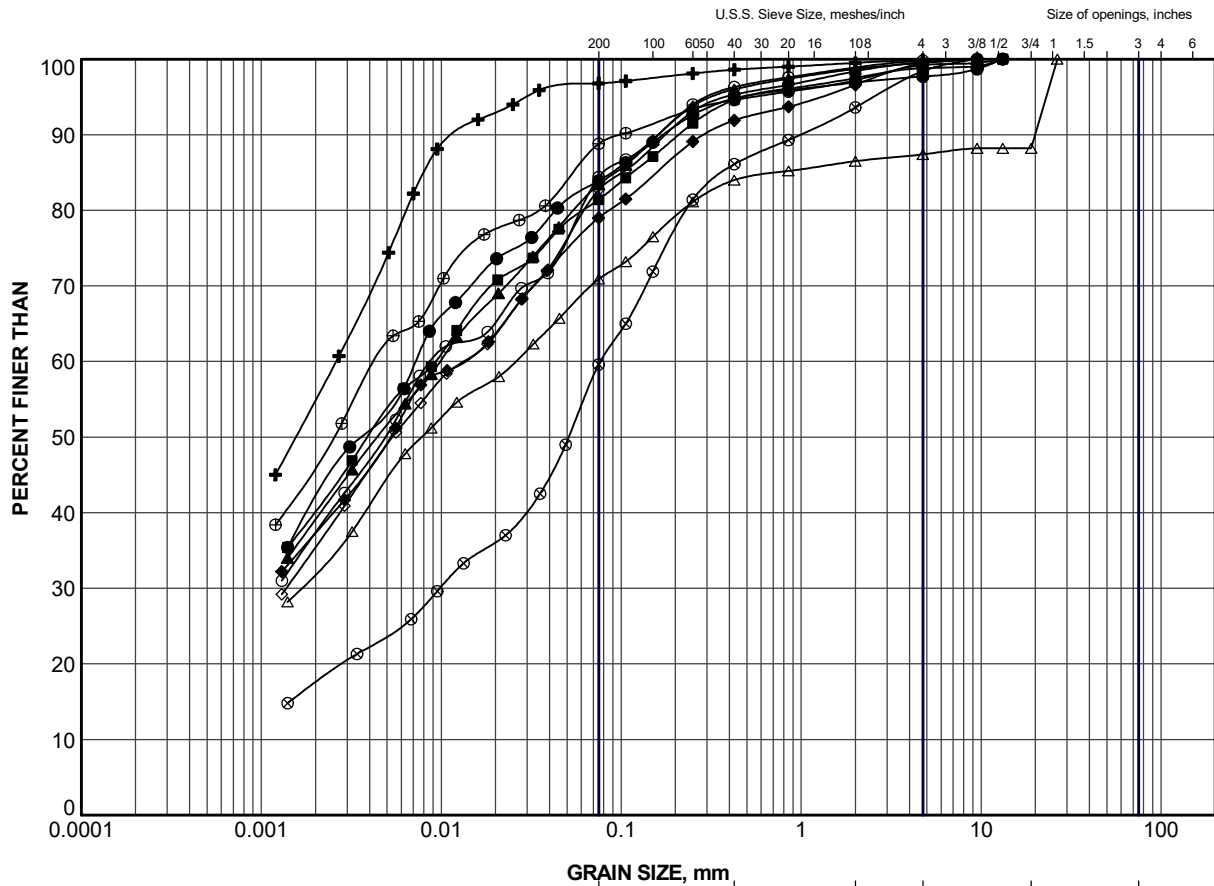


CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	10	185.3
■	101	14A	179.3
▲	101	19	171.6
+	101	23	165.4
◆	102	7	187.7
◇	102	10	183.1
○	102	12	180.1
△	102	16	174.0
⊗	102	23	163.3
⊕	BH-201	6	189.2
□	BH-201	9	184.6

PROJECT				FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00			
TITLE				GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL (1 OF 2)			
		PROJECT No.		11-1132-0143		FILE No. 1111320143-1001-F020A2-1	
		DRAWN		ZJB		Feb 13/20	
		CHECK		[Signature]			
		SCALE		N/A		REV.	
		FIGURE A-2-1					

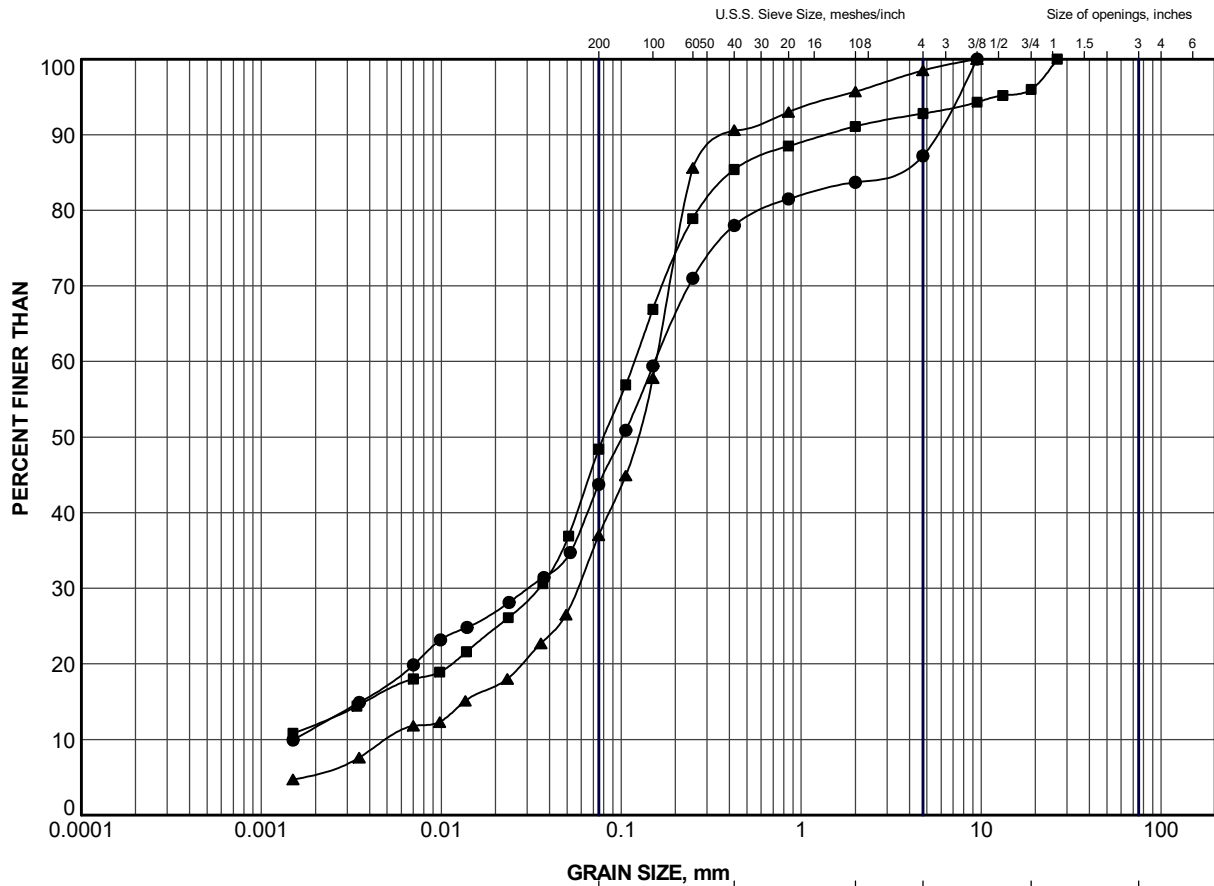


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-201	15	175.4
■	BH-202	8	186.1
▲	BH-202	15	175.4
+	BH-202	21	166.3
◆	BH-204	9	184.6
◇	BH-204	14	176.9
○	BH-205	8	186.2
△	BH-205	14B	177.0
⊗	BH-205	18	171.0
⊕	BH-205	21	166.4

PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00				
TITLE		GRAIN SIZE DISTRIBUTION CLAYEY SILT TILL (2 OF 2)				
		PROJECT No.	11-1132-0143	FILE No.	1111320143-1001-F020A2-2	
		DRAWN	ZJB	Feb 13/20	SCALE	N/A
		CHECK	W		REV.	
		FIGURE A-2-2				

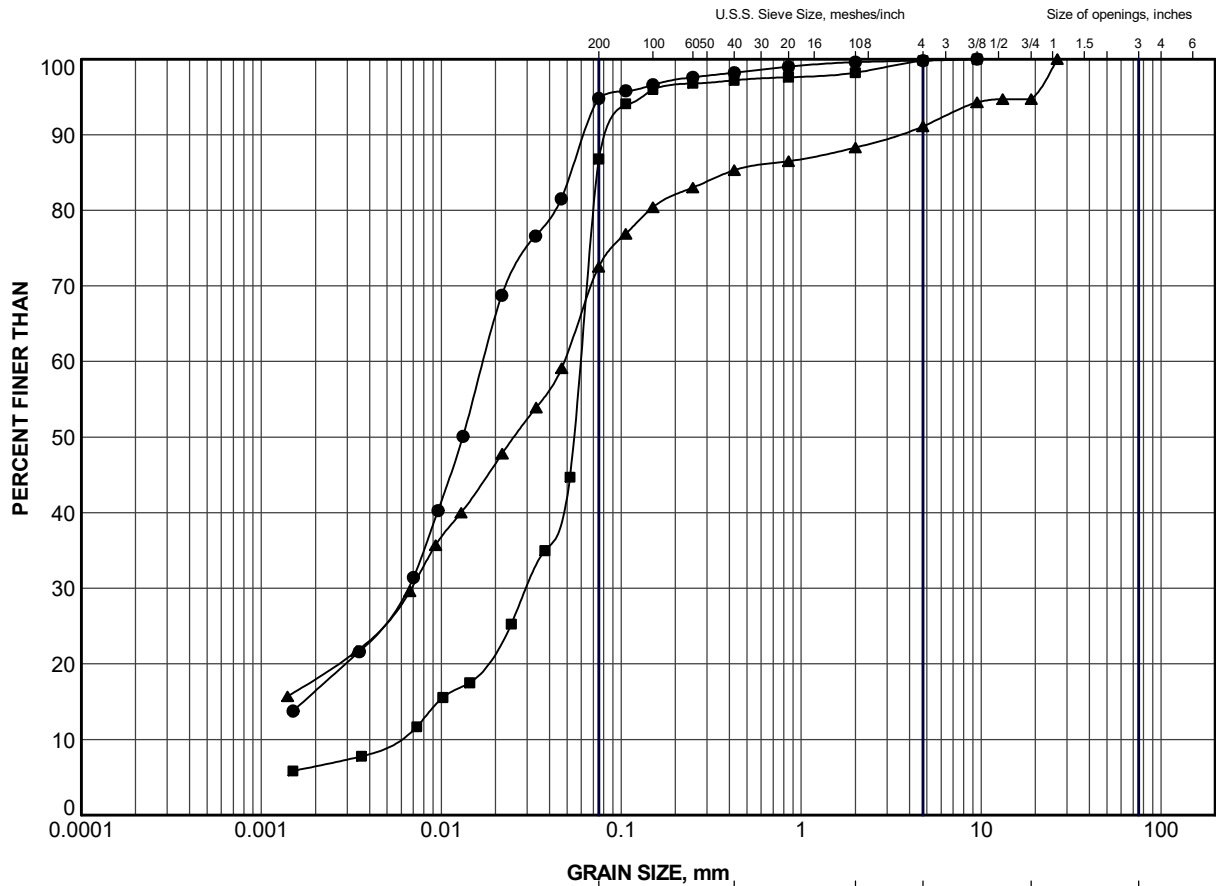


CLAY AND SILT	SAND SIZE			GRAVEL SIZE		Cobble Size
	fine	medium	coarse	fine	coarse	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	14B	179.0
■	BH-201	11	181.5
▲	BH-202	24	161.9

PROJECT					ADDITIONAL FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS GWP 317-98-00				
TITLE					GRAIN SIZE DISTRIBUTION SILTY SAND				
PROJECT No.		11-1132-0143			FILE No.		1111320143-1001-F020A3		
DRAWN		DCH		Feb 14-20		SCALE		N/A	
CHECK		[Signature]				REV.			
					FIGURE A-3				

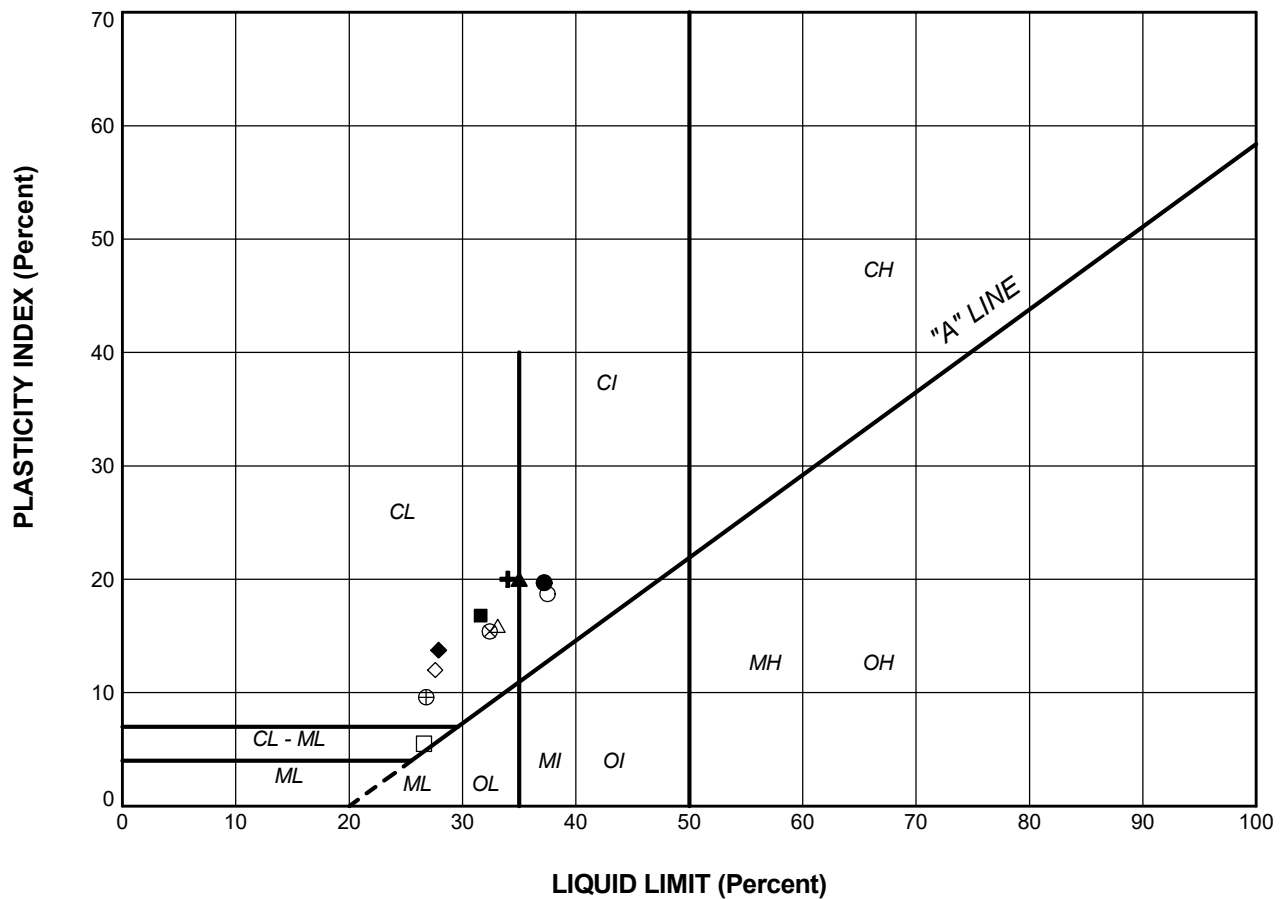


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	101	26	160.9
■	102	24	161.8
▲	BH-205	24	161.8

PROJECT				FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00			
TITLE				GRAIN SIZE DISTRIBUTION SILT			
PROJECT No.		11-1132-0143		FILE No.		1111320143-1001-F020A4	
DRAWN		ZJB		SCALE		N/A	
CHECK		Feb 13/20		REV.			
				FIGURE A-4			

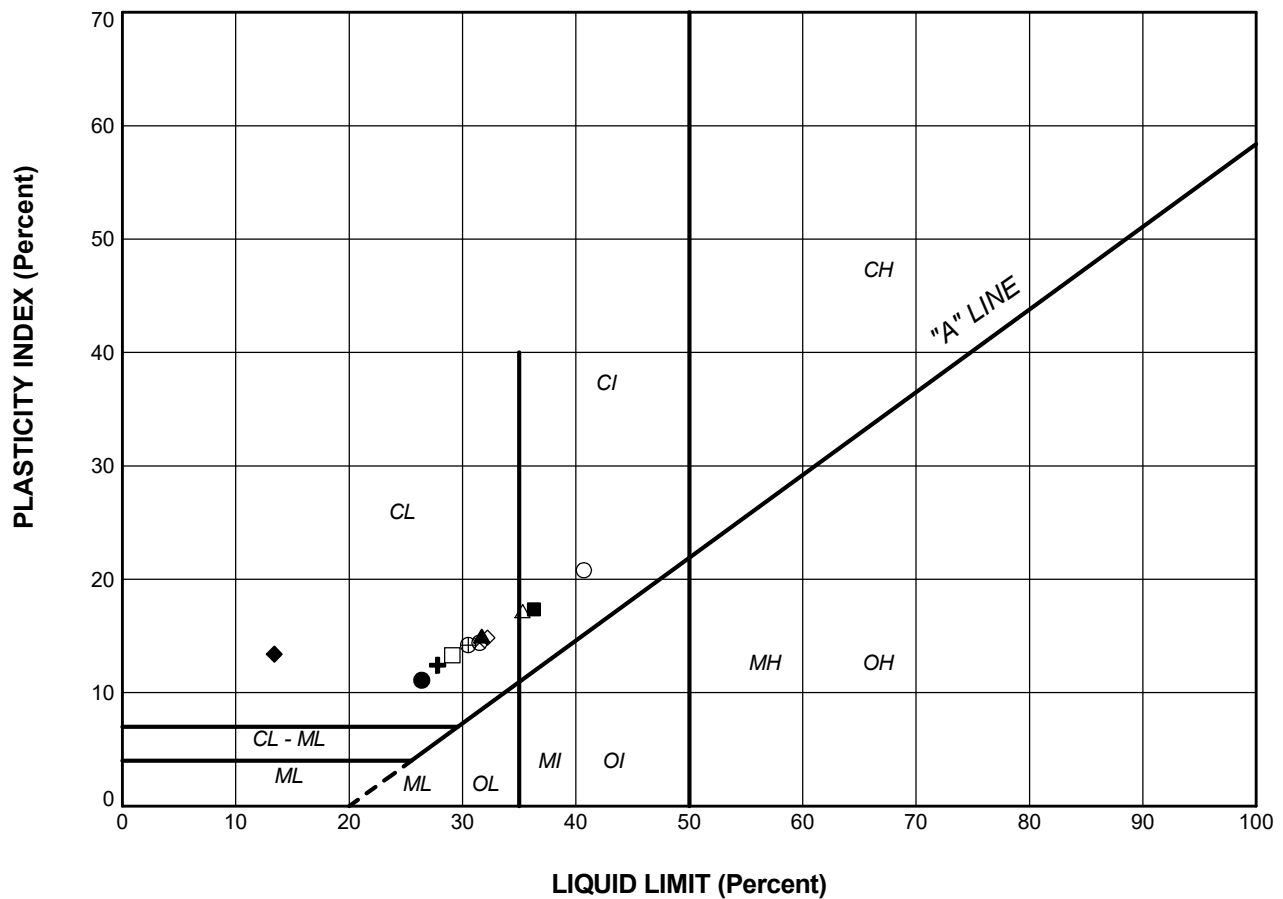
LDN_MTO_GSD_GLDR_LDN.GDT 05/12/19 16:14



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	101	4	37.2	17.5	19.7
■	101	10	31.6	14.8	16.8
▲	101	12	35.0	15.0	20.0
+	101	16	34.0	14.0	20.0
◆	101	19	27.9	14.2	13.8
◇	101	23	27.6	15.6	12.0
○	102	3	37.5	18.8	18.7
△	102	7	33.1	17.2	15.9
⊗	102	10	32.4	17.0	15.4
⊕	102	12	26.8	17.2	9.6
□	102	16	26.6	21.1	5.5

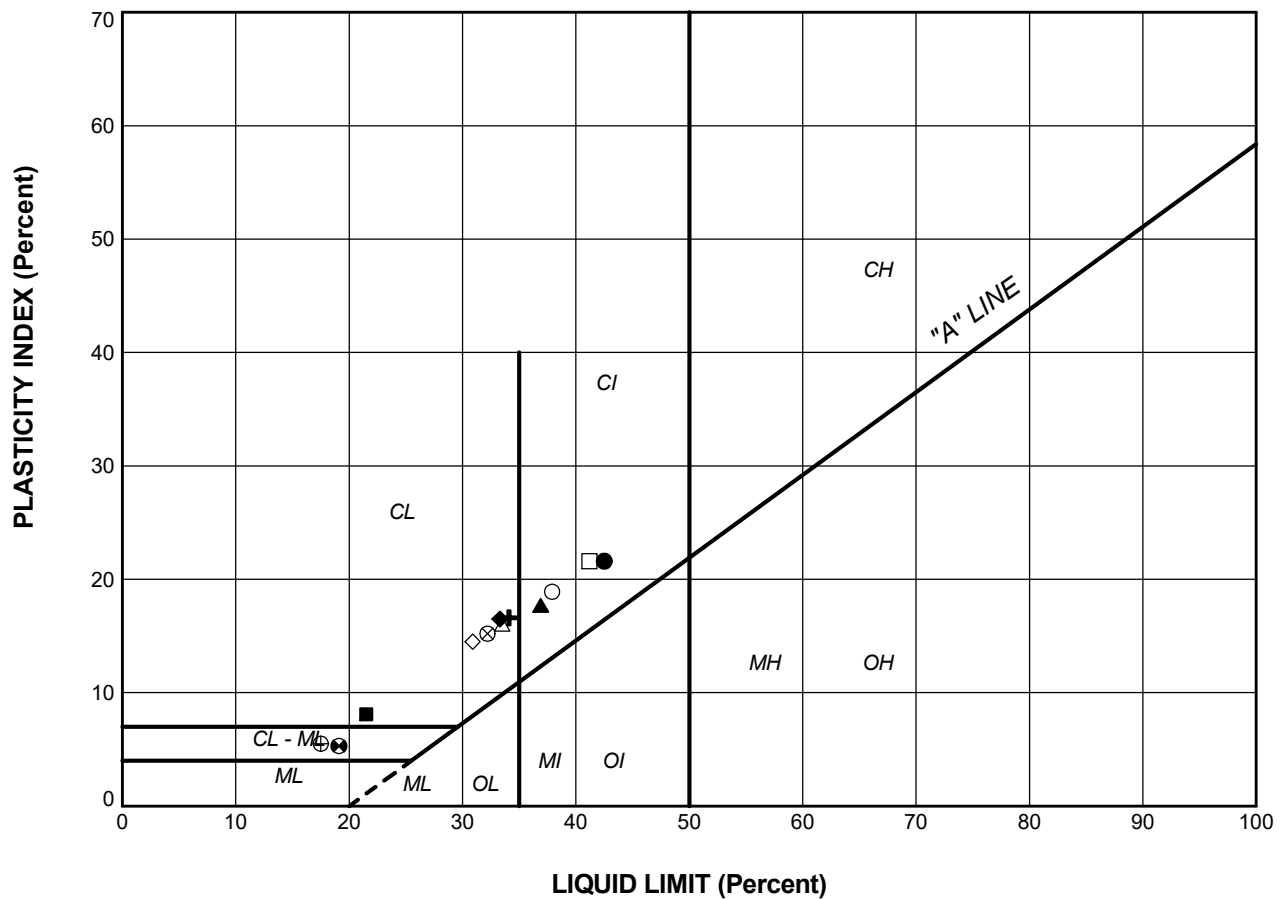
PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00	
TITLE		PLASTICITY CHART (1 OF 3)	
PROJECT No. 11-1132-0143		FILE No. 1111320143-1001-F020A5-1	
DRAWN	ZJB	Feb 13/20	SCALE N/A REV.
CHECK	<i>[Signature]</i>		FIGURE A-5-1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	102	23	26.4	15.3	11.1
■	BH-201	2	36.3	19.0	17.4
▲	BH-201	6	31.7	16.7	15.0
+	BH-201	9	27.8	15.4	12.4
◆	BH-201	11	13.4	0.0	13.4
◇	BH-201	15	32.2	17.4	14.9
○	BH-202	2	40.7	19.9	20.8
△	BH-202	4	35.3	18.1	17.2
⊗	BH-202	6	31.5	17.1	14.4
⊕	BH-202	8	30.5	16.3	14.2
□	BH-202	15	29.1	15.8	13.3

PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00	
TITLE		PLASTICITY CHART (2 OF 3)	
PROJECT No.	11-1132-0143	FILE No.	1111320143-1001-F020A5-2
DRAWN	ZJB	SCALE	N/A
CHECK	Feb 13/20	REV.	
GOLDER		FIGURE A-5-2	

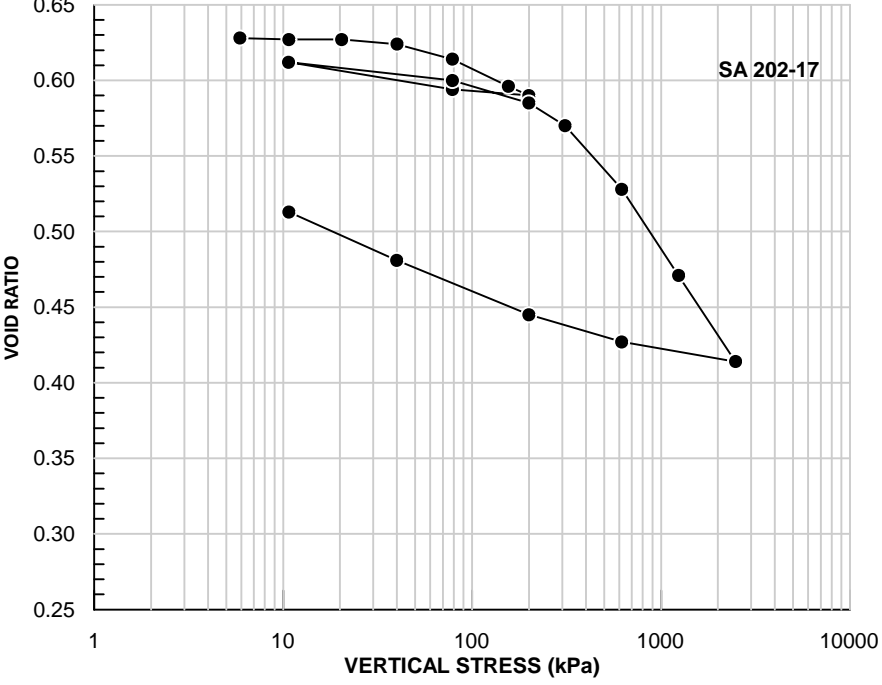
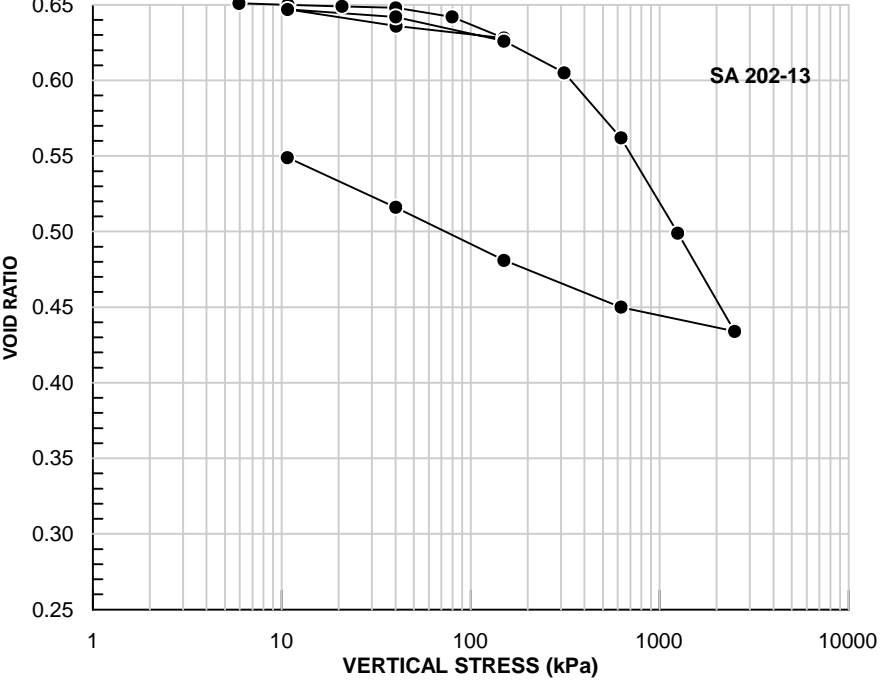
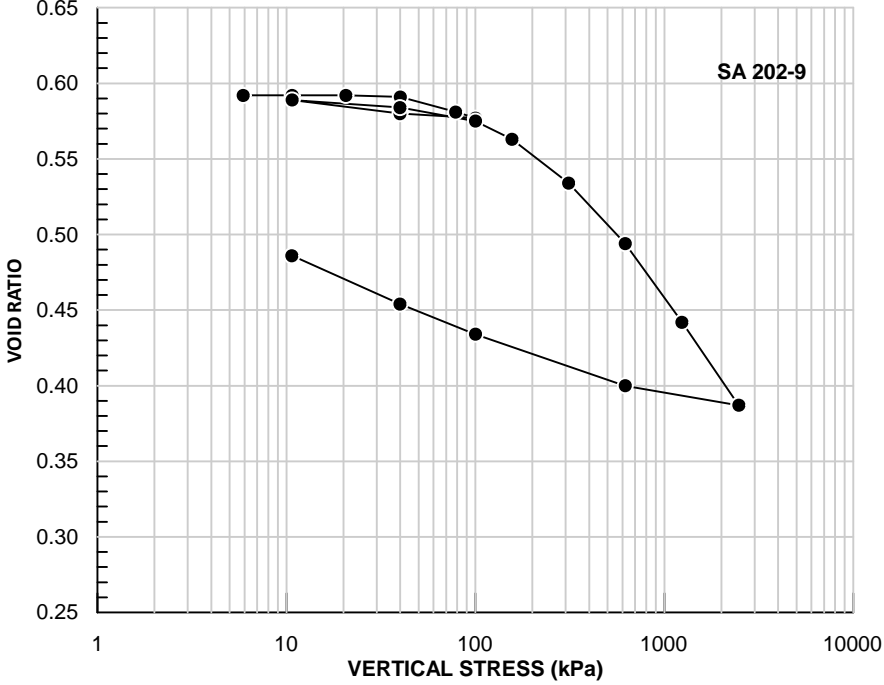
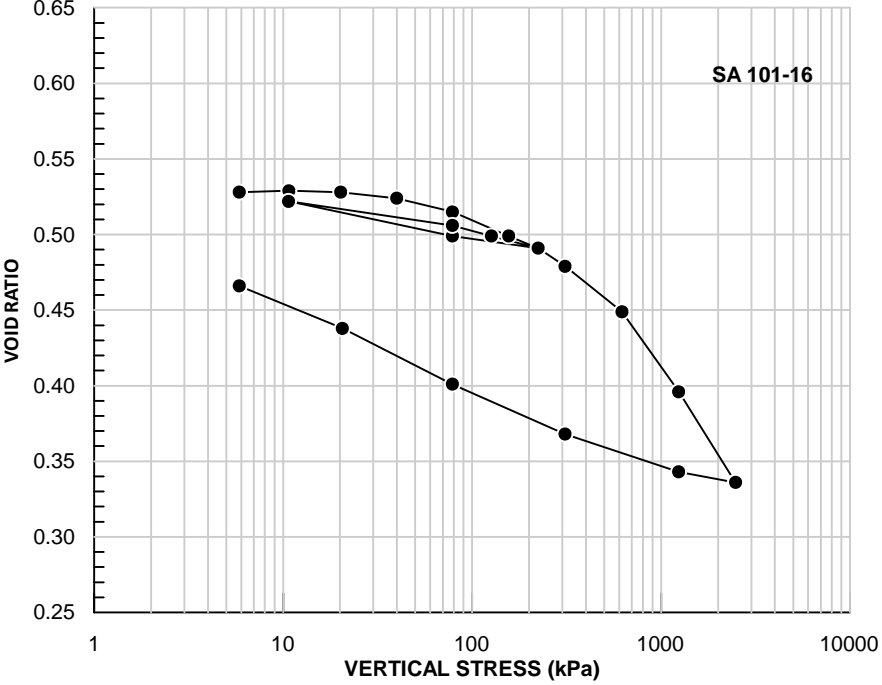
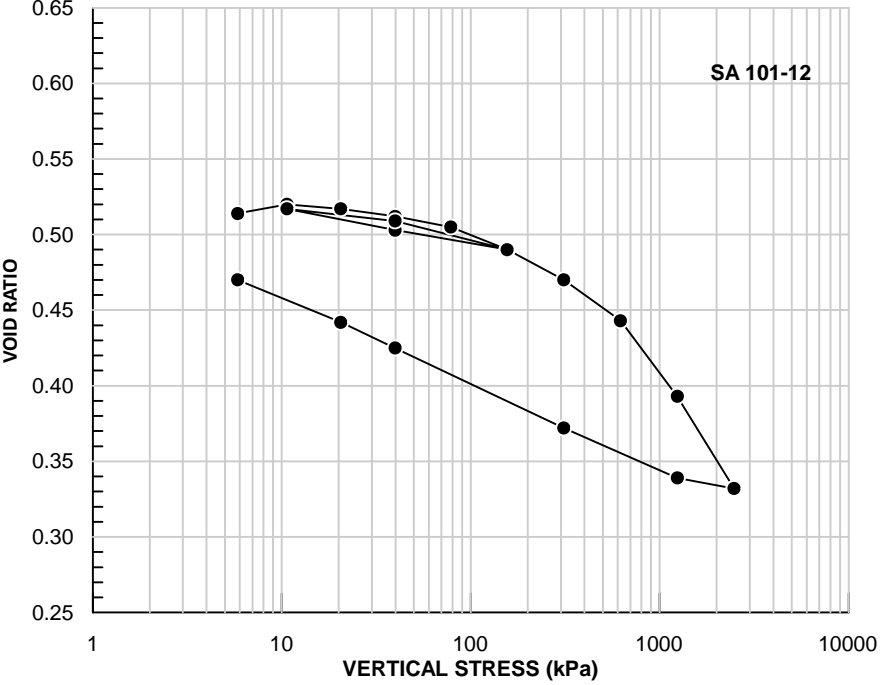




LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH-202	21	42.5	20.9	21.6
■	BH-202	23	21.5	13.4	8.1
▲	BH-204	3	36.9	19.2	17.7
+	BH-204	6	34.1	17.5	16.6
◆	BH-204	9	33.3	16.8	16.5
◇	BH-204	14	30.9	16.4	14.5
○	BH-205	2	37.9	19.0	18.9
△	BH-205	5	33.5	17.5	16.0
⊗	BH-205	8	32.2	17.0	15.2
⊕	BH-205	18	17.5	12.0	5.5
□	BH-205	21	41.2	19.6	21.6
⊙	BH-205	24	19.1	13.8	5.3

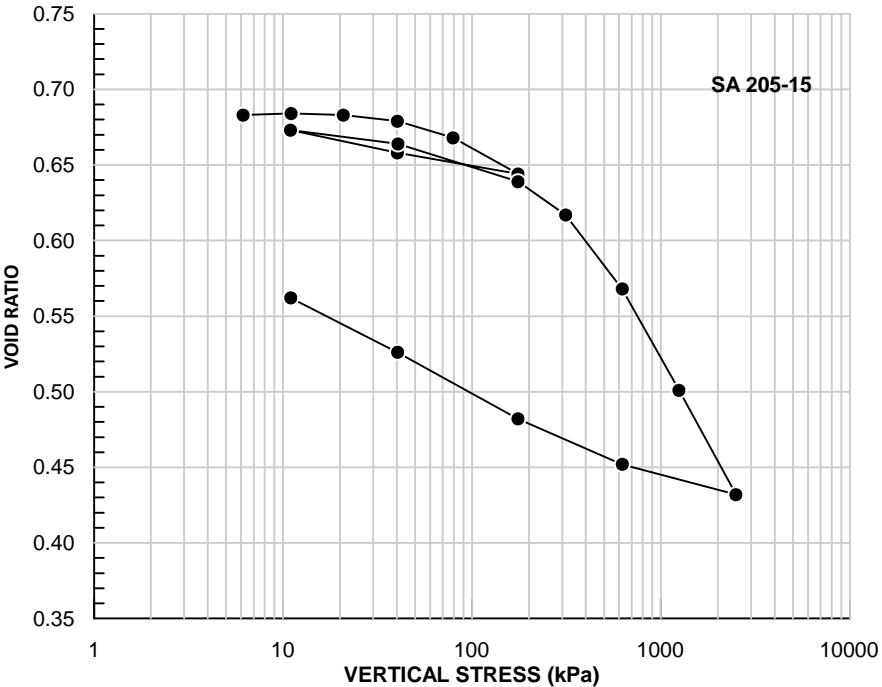
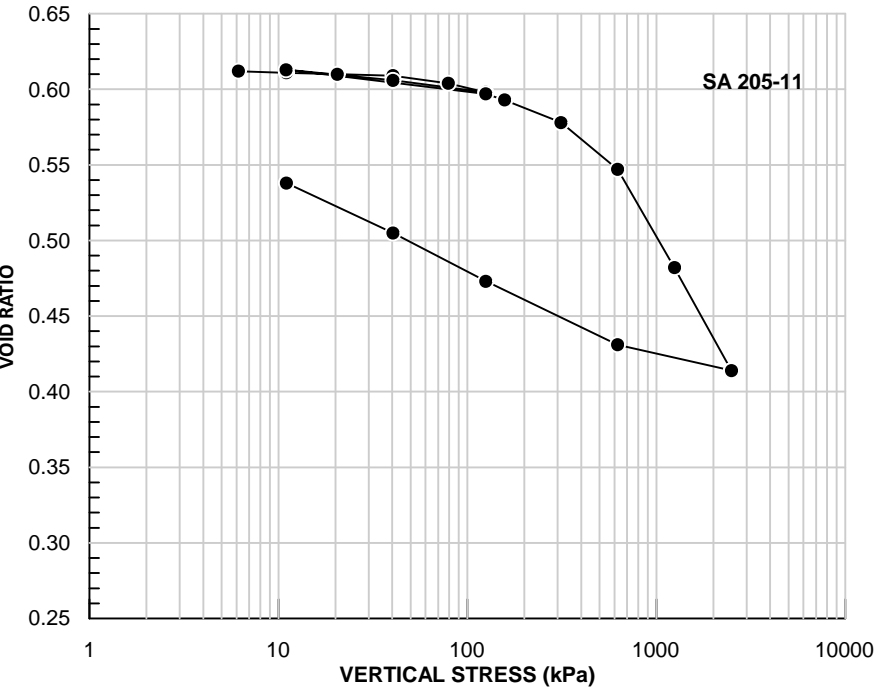
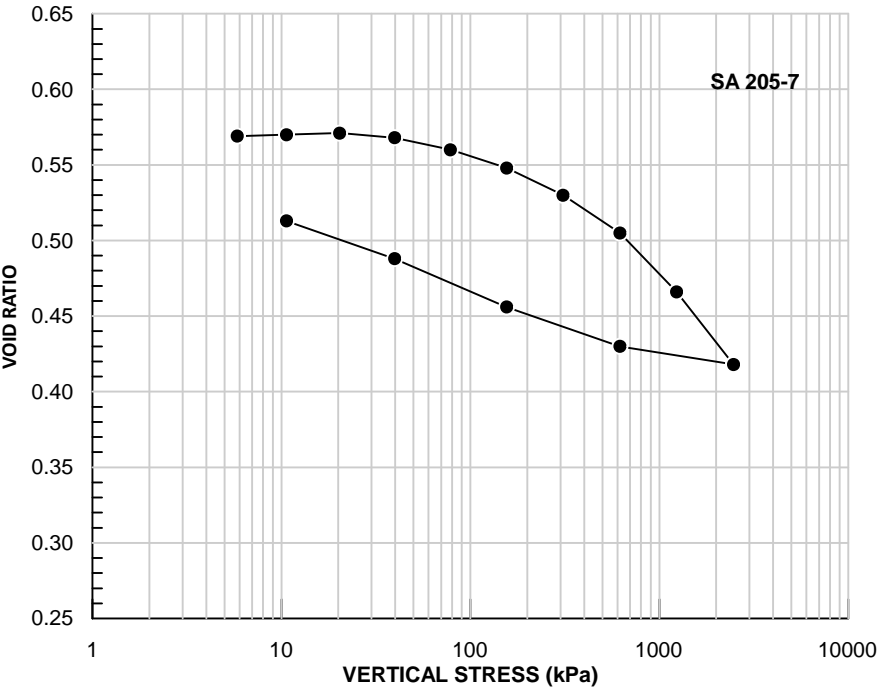
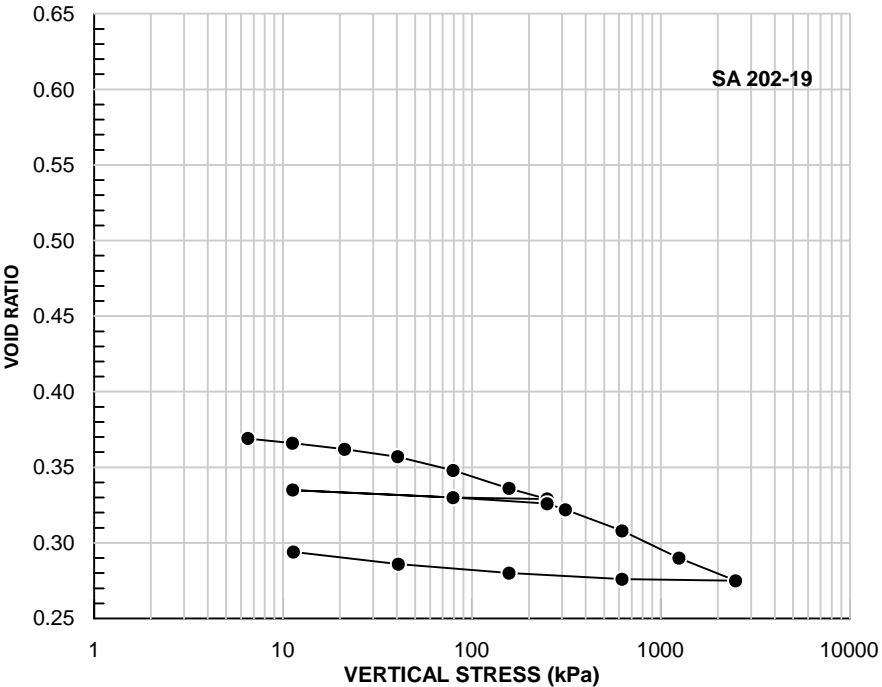
PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00	
TITLE		PLASTICITY CHART (3 OF 3)	
PROJECT No. 11-1132-0143		FILE No. 1111320143-1001-F020A5-3	
DRAWN	ZJB	Feb 13/20	SCALE N/A REV.
CHECK	<i>[Signature]</i>		FIGURE A-5-3


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PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00				
TITLE		OEDOMETER TESTING				
	PROJECT No.		11-1132-0143		FILE No.	Fig
	DRAWN		MEB	NOV 1-19	SCALE	AS SHOWN
	CHECK				REV.	0
					FIGURE A-6	

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PROJECT		FOUNDATION INVESTIGATION VICTORIA AVENUE OVERPASS HIGHWAY 3, GWP 317-98-00						
TITLE								
OEDOMETER TESTING								
		PROJECT No.		11-1132-0143	FILE No.	Fig		
					SCALE	AS SHOWN	REV.	0
		DRAWN	MEB	NOV 1-19	FIGURE A-7			
CHECK								

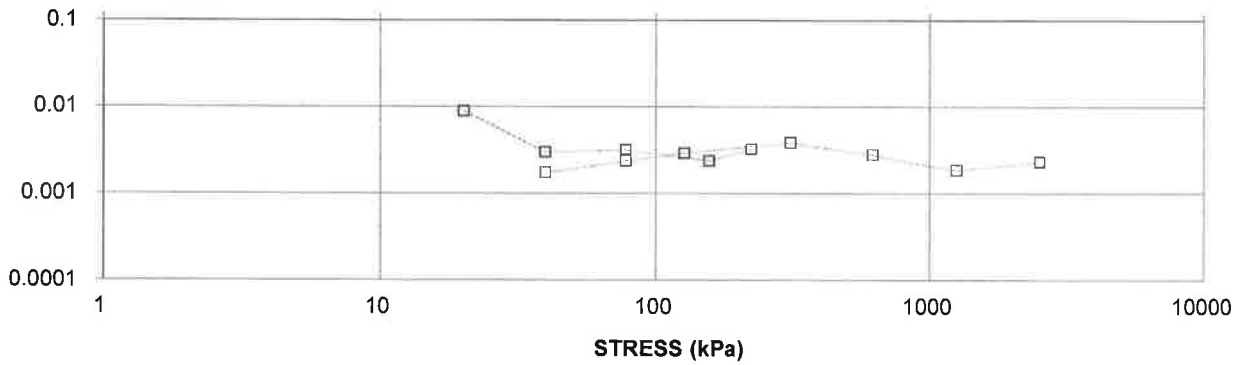
CONSOLIDATION TEST SUMMARY					FIGURE		
SAMPLE IDENTIFICATION							
Project Number	11-1132-0143	Sample Number	16				
Borehole Number	101A	Sample Depth, m	18.3-18.7				
TEST CONDITIONS							
Test Type	Standard	Load Duration, hr	24				
Oedometer Number	8						
Date Started	2/27/2013						
Date Completed	3/20/2013						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.90	Unit Weight, kN/m ³	20.82				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.22				
Area, cm ²	31.64	Specific Gravity, measured	2.68				
Volume, cm ³	60.11	Solids Height, cm	1.245				
Water Content, %	20.88	Volume of Solids, cm ³	39.40				
Wet Mass, g	127.62	Volume of Voids, cm ³	20.72				
Dry Mass, g	105.58	Degree of Saturation, %	106.4				
TEST COMPUTATIONS							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv, cm ² /s	mv m ² /kN	k cm/s
0.00	1.900	0.526	1.900				
5.86	1.903	0.528	1.902				
10.70	1.904	0.529	1.904				
20.15	1.902	0.528	1.903	86	8.93E-03	1.11E-04	9.75E-08
39.83	1.898	0.524	1.900	254	3.01E-03	1.07E-04	3.16E-08
78.65	1.887	0.515	1.892	240	3.16E-03	1.56E-04	4.83E-08
155.89	1.867	0.499	1.877	311	2.40E-03	1.34E-04	3.14E-08
223.76	1.856	0.491	1.861	228	3.22E-03	8.53E-05	2.69E-08
78.65	1.867	0.499	1.861				
39.83	1.877	0.507	1.872				
10.67	1.895	0.522	1.886				
39.88	1.885	0.514	1.890	437	1.73E-03	1.80E-04	3.06E-08
78.60	1.876	0.506	1.880	317	2.36E-03	1.29E-04	2.99E-08
126.71	1.866	0.499	1.871	252	2.94E-03	1.02E-04	2.94E-08
310.68	1.842	0.479	1.854	190	3.84E-03	6.92E-05	2.60E-08
620.00	1.804	0.449	1.823	254	2.77E-03	6.43E-05	1.75E-08
1239.14	1.738	0.396	1.771	359	1.85E-03	5.65E-05	1.03E-08
2476.96	1.663	0.336	1.701	265	2.31E-03	3.16E-05	7.17E-09
1239.14	1.672	0.343	1.668				
310.68	1.703	0.368	1.687				
78.60	1.745	0.401	1.724				
20.58	1.790	0.438	1.768				
5.86	1.826	0.466	1.808				
Note: k calculated using cv based on t ₉₀ values. Specimen swelled under 10.7kPa							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.83	Unit Weight, kN/m ³	21.48				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.92				
Area, cm ²	31.64	Specific Gravity, measured	2.68				
Volume, cm ³	57.77	Solids Height, cm	1.245				
Water Content, %	19.85	Volume of Solids, cm ³	39.40				
Wet Mass, g	126.54	Volume of Voids, cm ³	18.38				
Dry Mass, g	105.58						
<div style="display: flex; justify-content: space-between;"> Prepared By: LFG Golder Associates Checked By: </div>							

CONSOLIDATION TEST SUMMARY

FIGURE

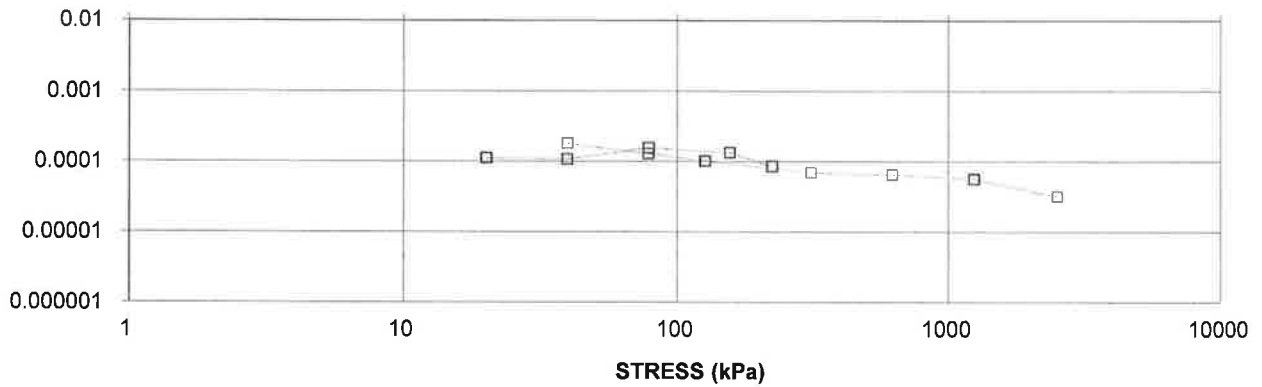
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 101A SA 16



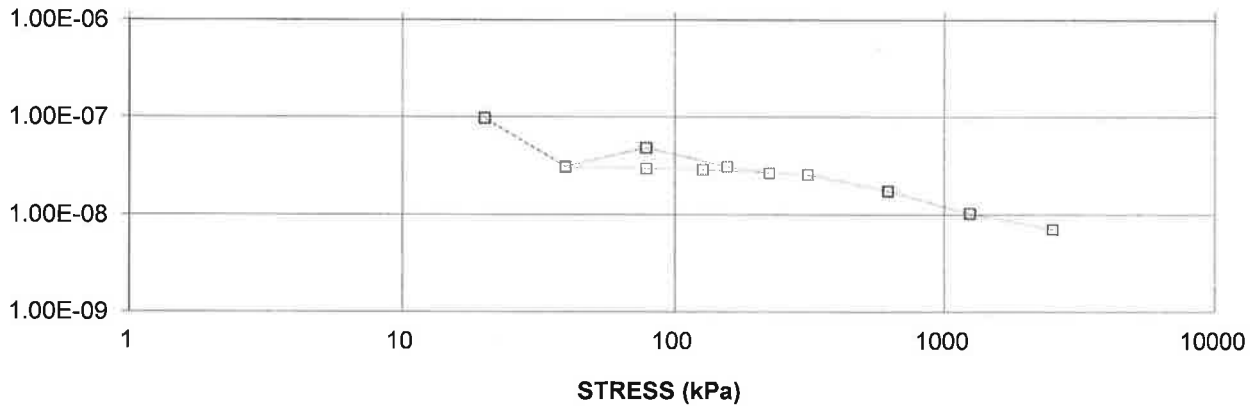
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 101A SA 16



HYDRAULIC CONDUCTIVITY, cm/s

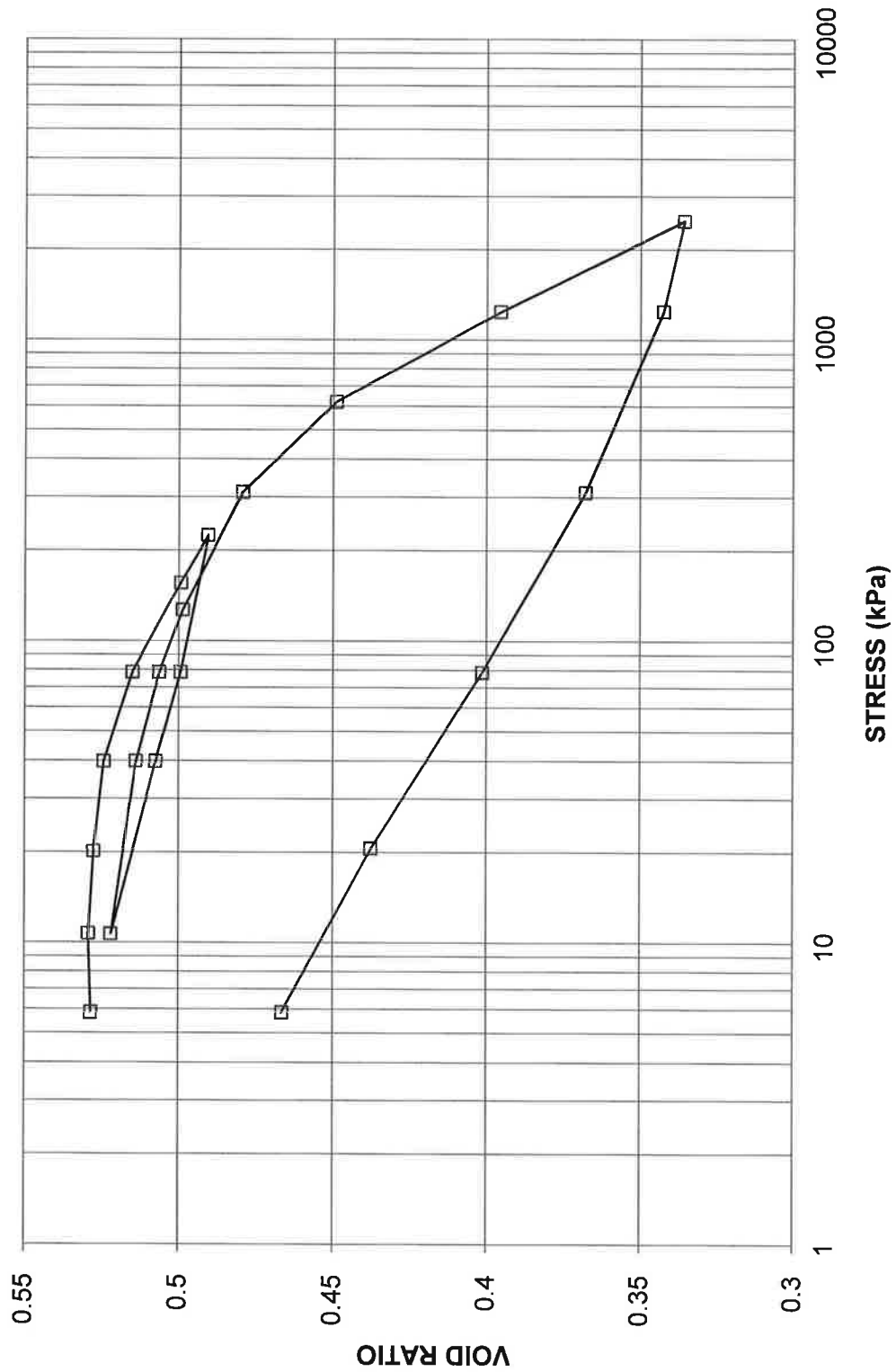
CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 101A SA 16



**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

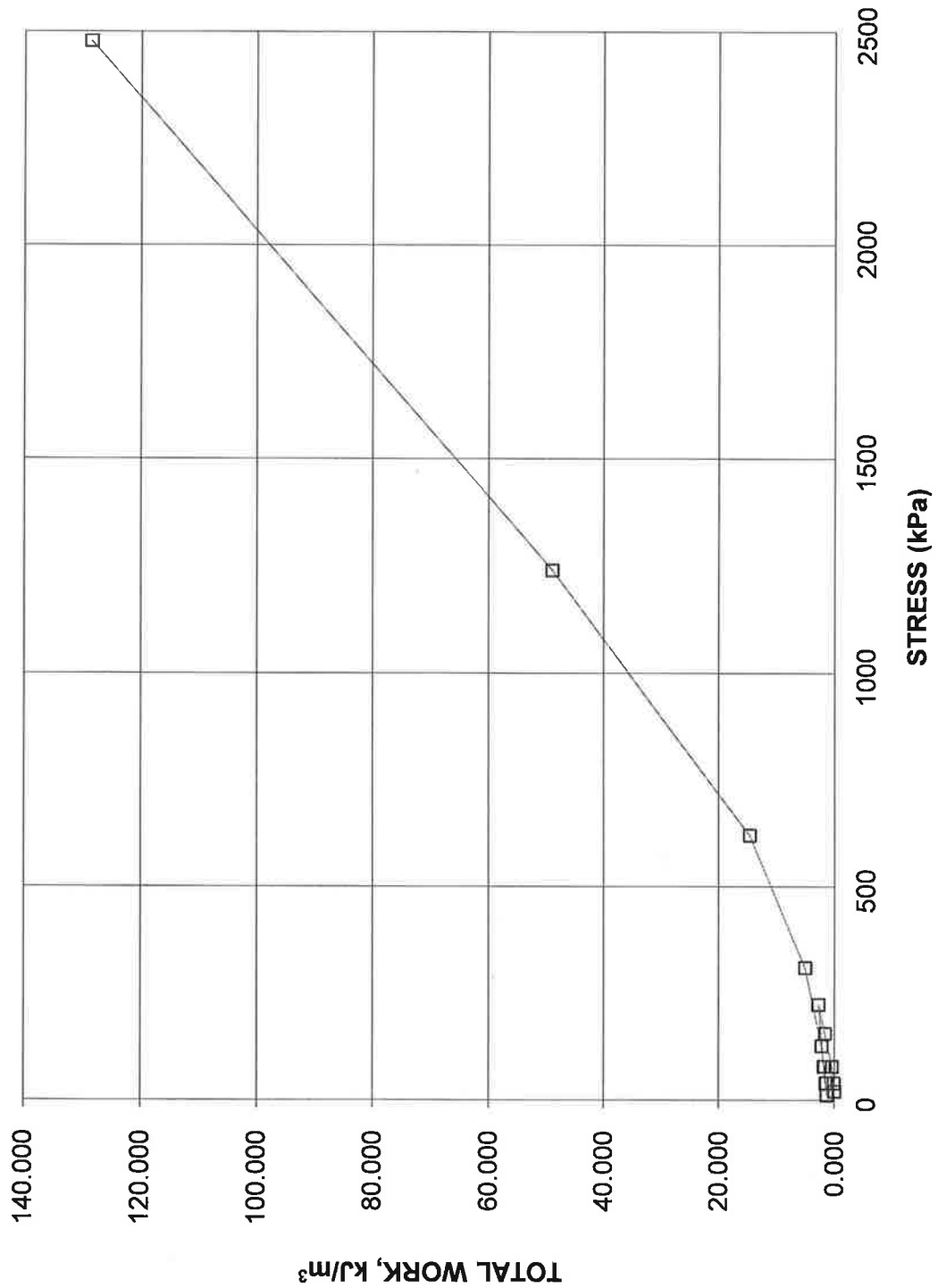
**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 101A SA 16**



CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 101A SA 16



Project No. 11-1132-0143

Prepared By: LFG

Golder Associates

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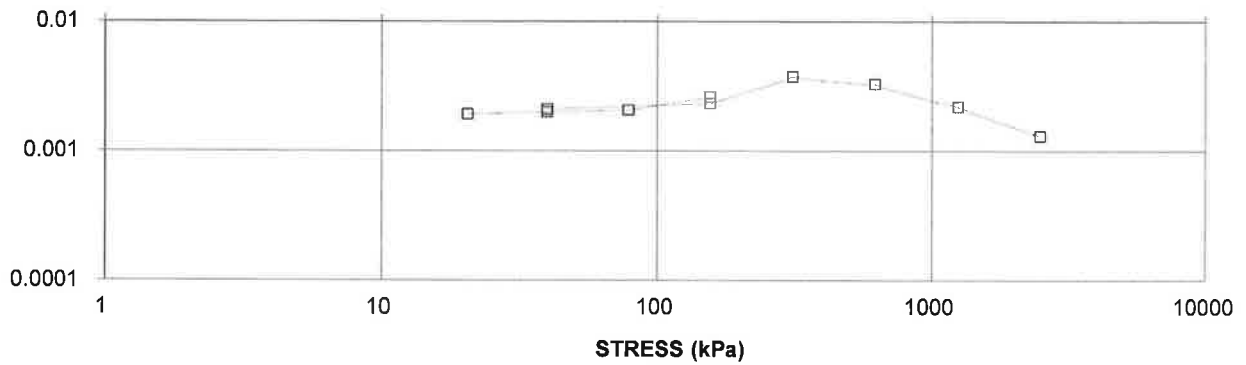
CONSOLIDATION TEST SUMMARY					FIGURE		
SAMPLE IDENTIFICATION							
Project Number	11-1132-0143	Sample Number	12				
Borehole Number	101A	Sample Depth, m	12.2-12.6				
TEST CONDITIONS							
Test Type	Standard	Load Duration, hr	24				
Oedometer Number	5						
Date Started	2/27/2013						
Date Completed	3/16/2013						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	1.89	Unit Weight, kN/m ³	20.78				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.23				
Area, cm ²	31.68	Specific Gravity, measured	2.67				
Volume, cm ³	59.84	Solids Height, cm	1.243				
Water Content, %	20.56	Volume of Solids, cm ³	39.39				
Wet Mass, g	126.78	Volume of Voids, cm ³	20.46				
Dry Mass, g	105.16	Degree of Saturation, %	105.7				
TEST COMPUTATIONS							
Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv, cm ² /s	mv m ² /kN	k cm/s
0.00	1.889	0.519	1.889				
5.84	1.883	0.514	1.886				
10.67	1.890	0.520	1.886				
20.54	1.886	0.517	1.888	392	1.93E-03	2.15E-04	4.05E-08
39.74	1.880	0.512	1.883	375	2.00E-03	1.65E-04	3.25E-08
78.50	1.871	0.505	1.876	360	2.07E-03	1.20E-04	2.44E-08
155.78	1.852	0.490	1.862	282	2.61E-03	1.32E-04	3.38E-08
39.74	1.869	0.503	1.860				
10.64	1.886	0.517	1.877				
39.82	1.877	0.509	1.881	356	2.11E-03	1.60E-04	3.30E-08
155.78	1.852	0.490	1.864	317	2.32E-03	1.13E-04	2.58E-08
310.77	1.828	0.470	1.840	194	3.70E-03	8.33E-05	3.02E-08
619.71	1.794	0.443	1.811	214	3.25E-03	5.79E-05	1.84E-08
1237.87	1.732	0.393	1.763	304	2.17E-03	5.33E-05	1.13E-08
2473.45	1.656	0.332	1.694	470	1.29E-03	3.22E-05	4.09E-09
1237.87	1.665	0.339	1.660				
310.77	1.706	0.372	1.685				
39.74	1.771	0.425	1.738				
20.54	1.793	0.442	1.782				
5.84	1.828	0.470	1.811				
Note: k calculated using cv based on t ₉₀ values. Specimen swelled at 10.67kPa.							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	1.83	Unit Weight, kN/m ³	21.43				
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.81				
Area, cm ²	31.68	Specific Gravity, measured	2.67				
Volume, cm ³	57.92	Solids Height, cm	1.243				
Water Content, %	20.37	Volume of Solids, cm ³	39.39				
Wet Mass, g	126.58	Volume of Voids, cm ³	18.53				
Dry Mass, g	105.16						
<div style="display: flex; justify-content: space-between;"> <div>Prepared By: LFG</div> <div style="text-align: center;">Golder Associates</div> <div>Checked By: </div> </div>							

CONSOLIDATION TEST SUMMARY

FIGURE

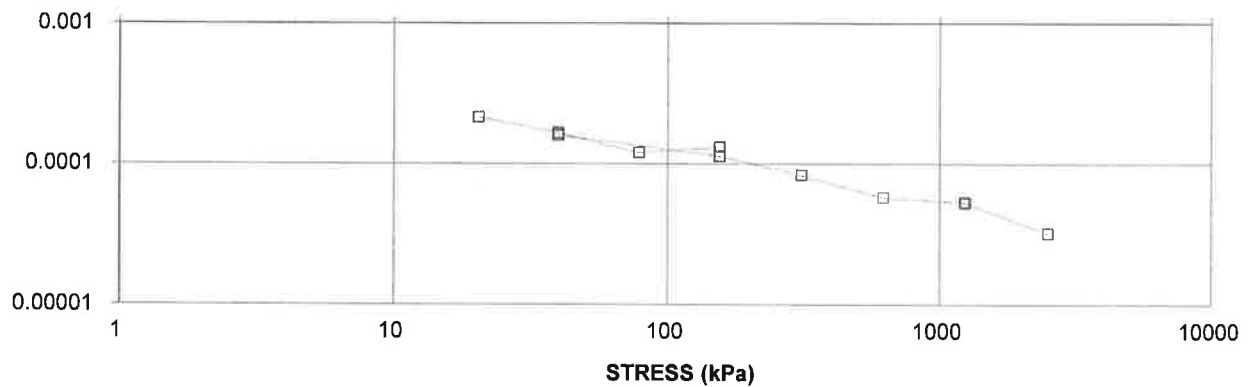
CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 101A SA 12

COEFFICIENT OF CONSOLIDATION,
cm²/s



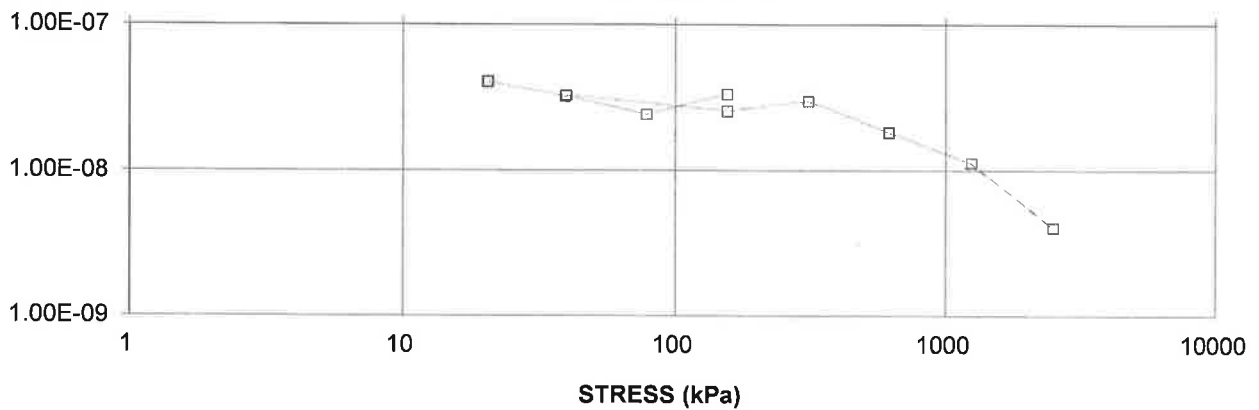
CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 101A SA 12

VOLUME COMPRESSIBILITY, m²/kN



CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 101A SA 12

HYDRAULIC CONDUCTIVITY, cm/s



Project No. 11-1132-0143

Prepared By: LFG

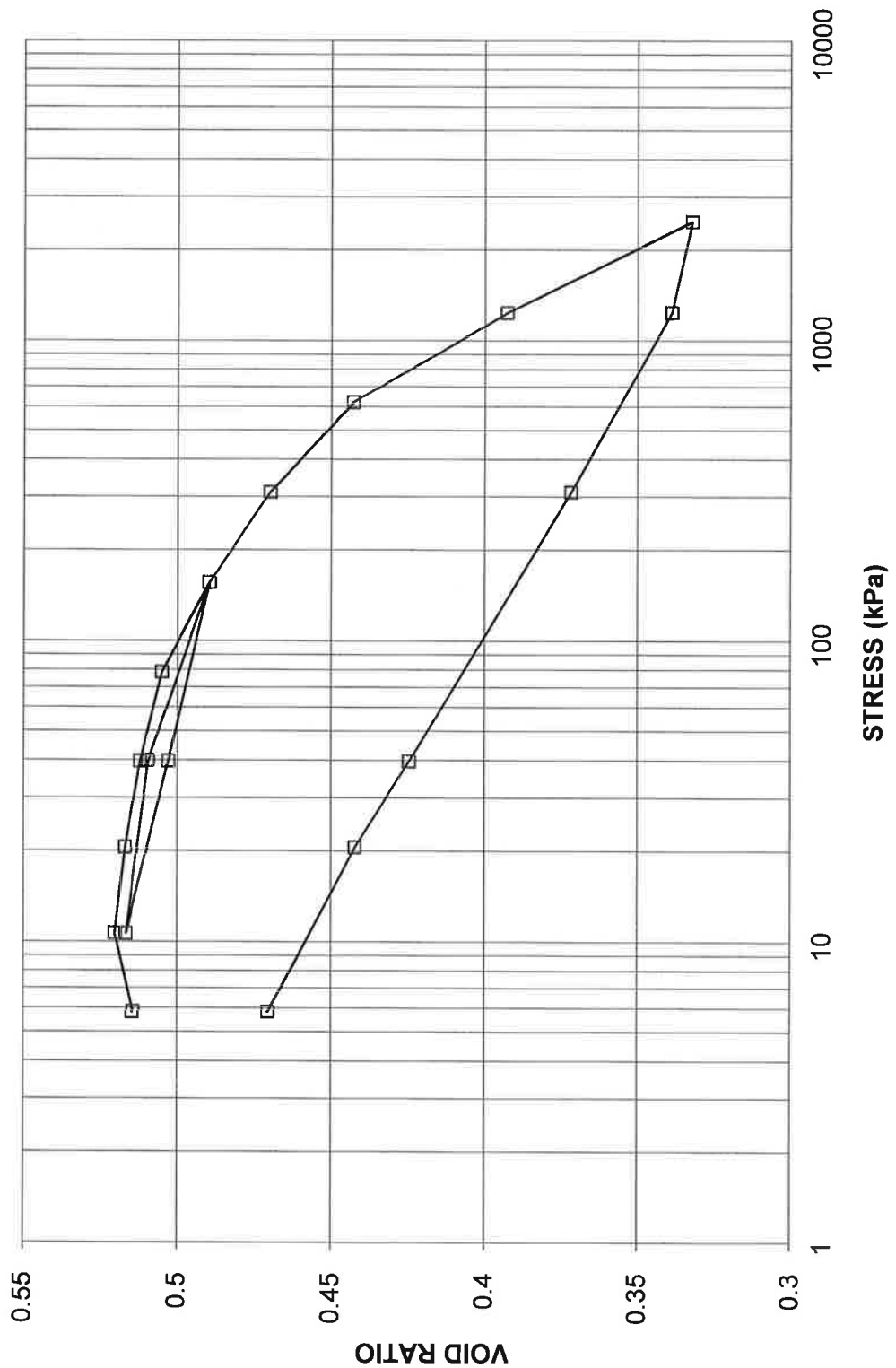
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 101A SA 12



Project No. 11-1132-0143

Prepared By: LFG

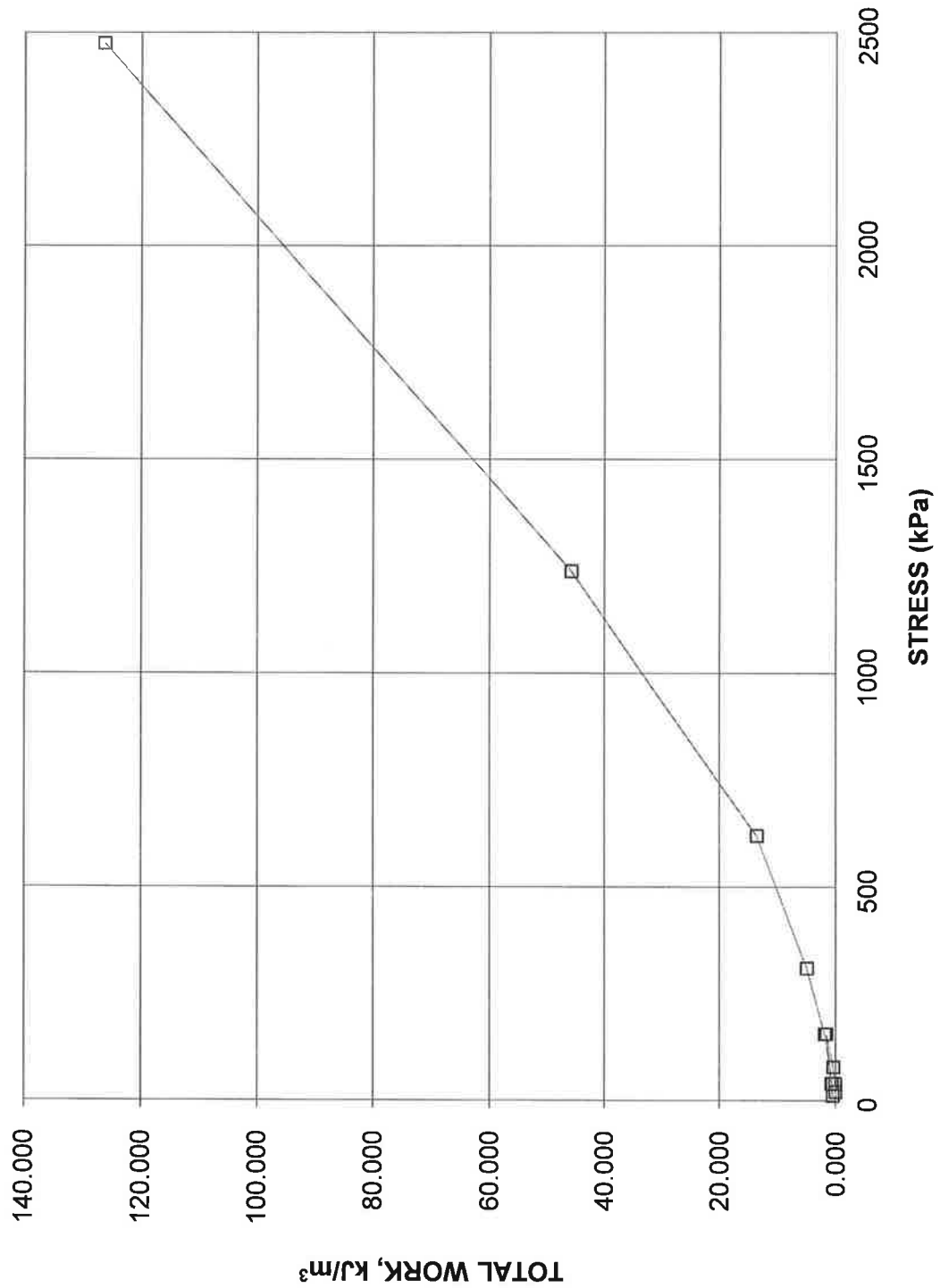
Golder Associates

Checked By: *mu*

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 101A SA 12**



Project No. 11-1132-0143

Prepared By: LFG

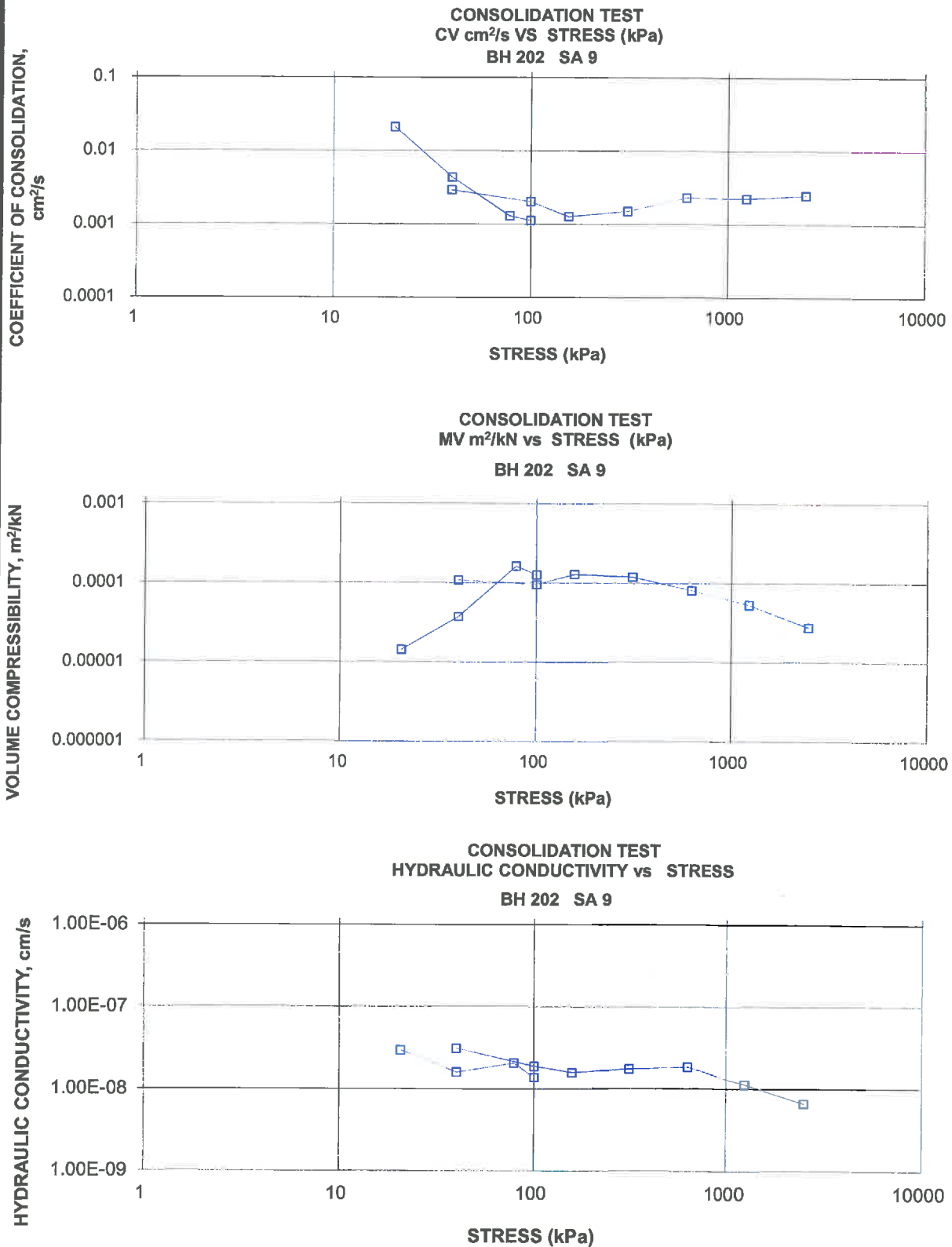
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST SUMMARY					FIGURE		
ASTM D2435/D2435M							
SAMPLE IDENTIFICATION							
Project Number	11-1132-0143(1001)			Sample Number	9		
Borehole Number	BH202			Sample Depth, m	9.15-9.76		
TEST CONDITIONS							
Test Type	Laboratory Standard			Load Duration, hr	24		
Oedometer Number	2						
Date Started	09/24/2019						
Date Completed	10/09/2019						
SAMPLE DIMENSIONS AND PROPERTIES - INITIAL							
Sample Height, cm	2.54			Unit Weight, kN/m ³	20.46		
Sample Diameter, cm	6.35			Dry Unit Weight, kN/m ³	16.81		
Area, cm ²	31.65			Specific Gravity, measured	2.73		
Volume, cm ³	80.29			Solids Height, cm	1.593		
Water Content, %	21.68			Volume of Solids, cm ³	50.42		
Wet Mass, g	167.50			Volume of Voids, cm ³	29.87		
Dry Mass, g	137.66			Degree of Saturation, %	99.9		
TEST COMPUTATIONS							
	Corr.		Average				
Stress	Height	Void	Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.537	0.592	2.537				
5.90	2.536	0.592	2.537				
10.73	2.537	0.592	2.537				
20.59	2.537	0.592	2.537	66	2.07E-02	1.44E-05	2.92E-08
39.99	2.535	0.591	2.536	317	4.30E-03	3.74E-05	1.58E-08
78.61	2.519	0.581	2.527	1058	1.28E-03	1.62E-04	2.03E-08
99.99	2.512	0.577	2.516	1215	1.10E-03	1.25E-04	1.36E-08
39.89	2.518	0.580	2.515				
10.73	2.531	0.589	2.525				
39.89	2.523	0.584	2.527	470	2.88E-03	1.08E-04	3.05E-08
100.01	2.509	0.575	2.516	673	1.99E-03	9.51E-05	1.86E-08
155.96	2.491	0.563	2.500	1058	1.25E-03	1.28E-04	1.56E-08
310.51	2.444	0.534	2.467	866	1.49E-03	1.19E-04	1.74E-08
619.72	2.380	0.494	2.412	540	2.28E-03	8.15E-05	1.82E-08
1238.42	2.298	0.442	2.339	522	2.22E-03	5.26E-05	1.14E-08
2475.77	2.209	0.387	2.254	437	2.46E-03	2.81E-05	6.78E-09
619.72	2.231	0.400	2.220				
100.00	2.285	0.434	2.258				
39.83	2.316	0.454	2.300				
10.69	2.363	0.483	2.339				
Note: Consolidation loading and unloading schedule assigned by the client. cv and k are approximate only based on t ₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M) Specimen taken 5-9cm from bottom of the tube. Specimen swelled under 10.73kPa.							
SAMPLE DIMENSIONS AND PROPERTIES - FINAL							
Sample Height, cm	2.36			Unit Weight, kN/m ³	21.39		
Sample Diameter, cm	6.35			Dry Unit Weight, kN/m ³	18.05		
Area, cm ²	31.65			Specific Gravity, measured	2.73		
Volume, cm ³	74.77			Solids Height, cm	1.593		
Water Content, %	18.48			Volume of Solids, cm ³	50.42		
Wet Mass, g	163.10			Volume of Voids, cm ³	24.35		
Dry Mass, g	137.66						
Prepared By: LH				Golder Associates		Checked By:	

CONSOLIDATION TEST SUMMARY

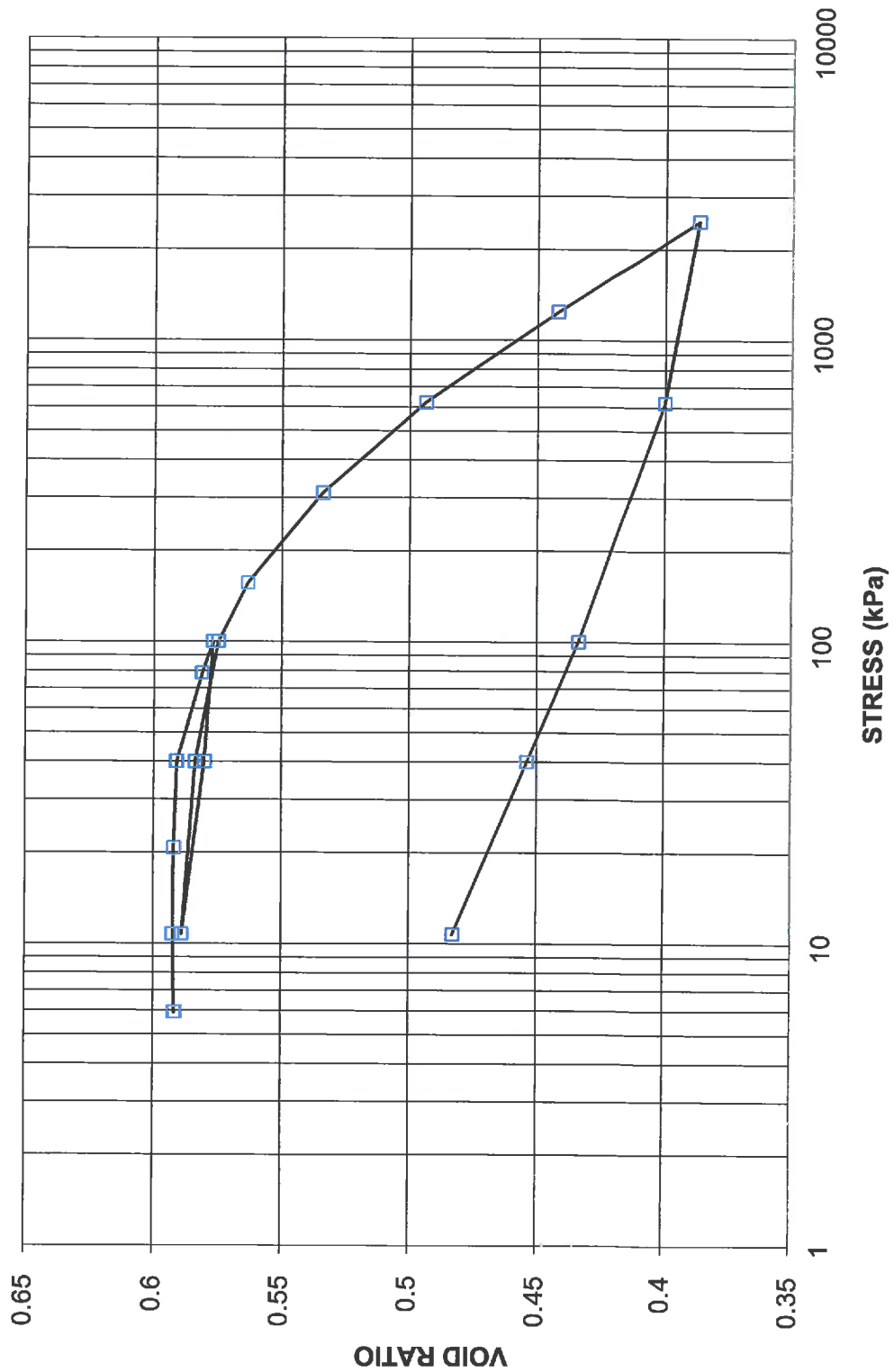
FIGURE



CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs. STRESS
BH 202 SA 9



Project No. 11-1132-0143(1001)

Prepared By: LH

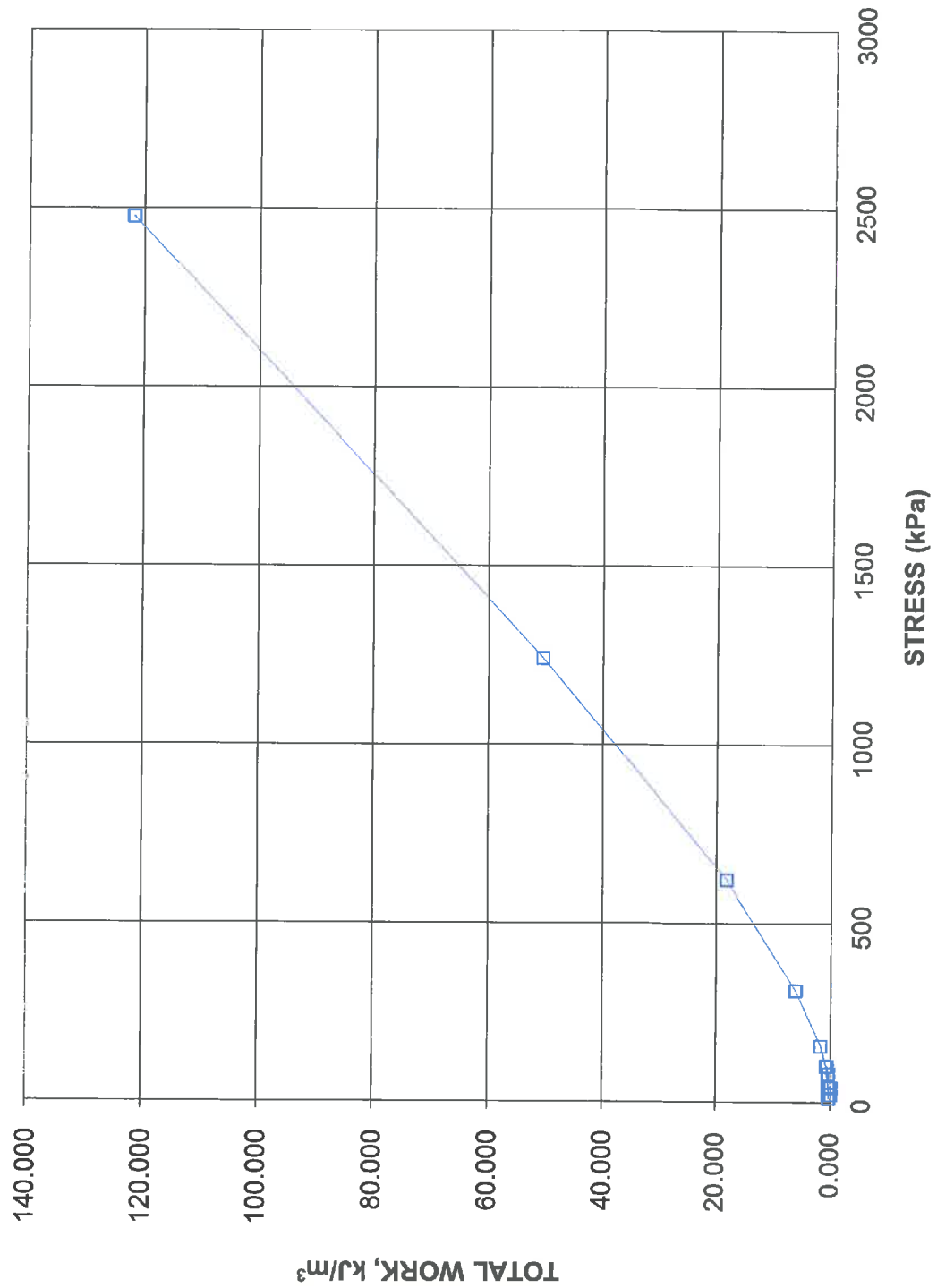
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 202 SA 9



Project No. 11-1132-0143(1001)

Prepared By: LH

Golder Associates

Checked By:

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CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	11-1132-0143(1001)	Sample Number	13
Borehole Number	BH202	Sample Depth, m	15.24-15.85

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	3		
Date Started	09/24/2019		
Date Completed	10/09/2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.53	Unit Weight, kN/m ³	20.13
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	16.27
Area, cm ²	31.48	Specific Gravity, measured	2.74
Volume, cm ³	79.74	Solids Height, cm	1.534
Water Content, %	23.76	Volume of Solids, cm ³	48.28
Wet Mass, g	163.71	Volume of Voids, cm ³	31.46
Dry Mass, g	132.28	Degree of Saturation, %	99.9

TEST COMPUTATIONS

Stress	Corr. Height	Void	Average Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.533	0.652	2.533				
5.93	2.532	0.651	2.533	8	1.70E-01	6.66E-05	1.11E-06
10.79	2.531	0.650	2.532	6	2.26E-01	8.12E-05	1.80E-06
20.79	2.529	0.649	2.530	73	1.86E-02	7.90E-05	1.44E-07
40.16	2.528	0.648	2.528	167	8.12E-03	2.38E-05	1.89E-08
79.69	2.518	0.642	2.523	406	3.32E-03	9.52E-05	3.10E-08
149.99	2.497	0.628	2.508	375	3.55E-03	1.20E-04	4.17E-08
40.29	2.509	0.636	2.503				
10.74	2.525	0.647	2.517				
40.10	2.518	0.642	2.521	437	3.08E-03	1.04E-04	3.13E-08
150.02	2.494	0.626	2.506	317	4.20E-03	8.62E-05	3.55E-08
312.26	2.461	0.605	2.477	346	3.76E-03	7.96E-05	2.93E-08
623.32	2.396	0.562	2.428	577	2.17E-03	8.29E-05	1.76E-08
1245.60	2.298	0.499	2.347	540	2.16E-03	6.17E-05	1.31E-08
2489.61	2.199	0.434	2.249	454	2.36E-03	3.16E-05	7.31E-09
623.32	2.224	0.450	2.212				
150.01	2.271	0.481	2.248				
40.10	2.325	0.516	2.298				
10.70	2.376	0.549	2.350				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 6-9.5cm from bottom of the tube.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

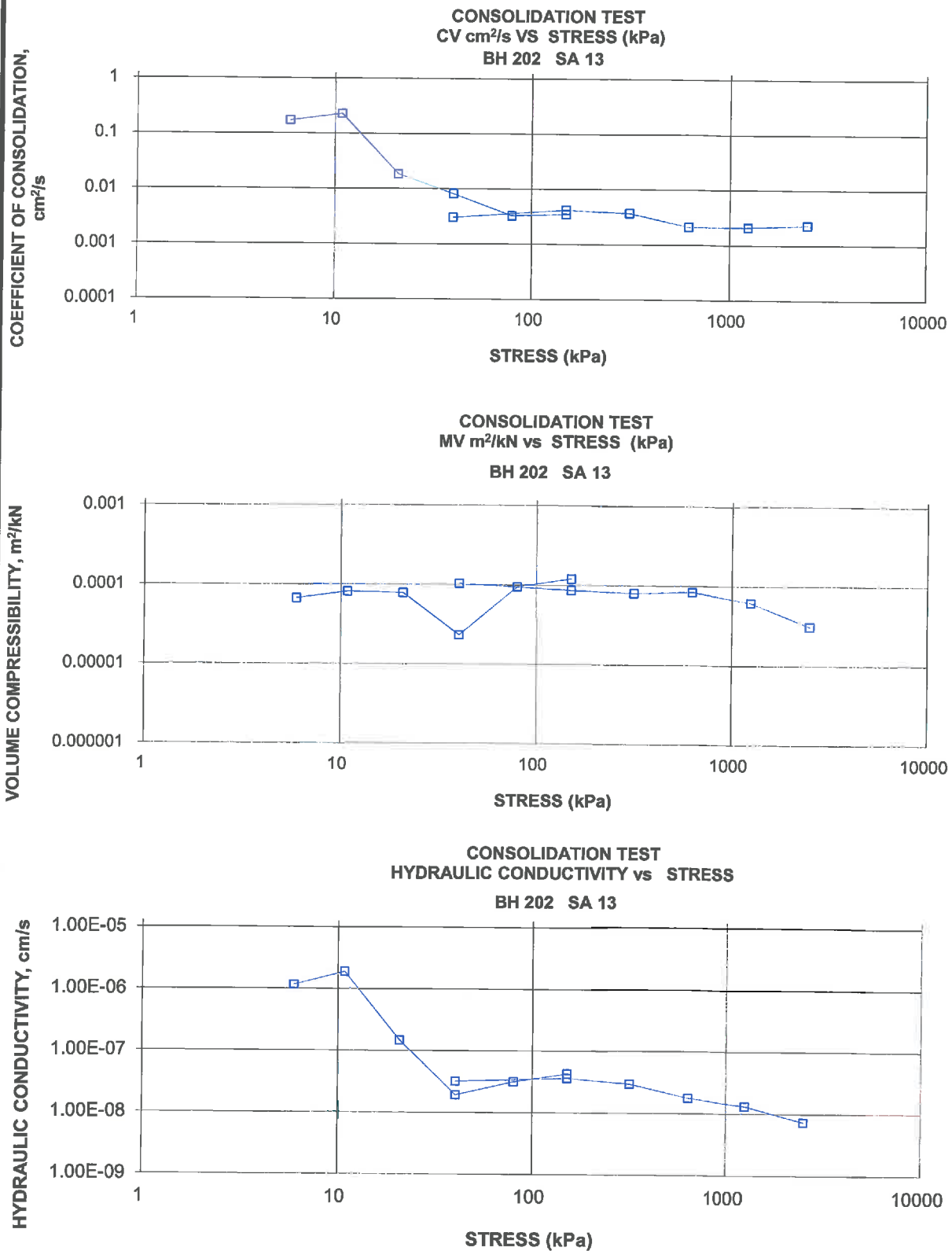
Sample Height, cm	2.38	Unit Weight, kN/m ³	21.05
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	17.34
Area, cm ²	31.48	Specific Gravity, measured	2.74
Volume, cm ³	74.79	Solids Height, cm	1.534
Water Content, %	21.35	Volume of Solids, cm ³	48.28
Wet Mass, g	160.52	Volume of Voids, cm ³	26.52
Dry Mass, g	132.28		

Prepared By: LH

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE



Project No. 11-1132-0143(1001)

Prepared By: LH

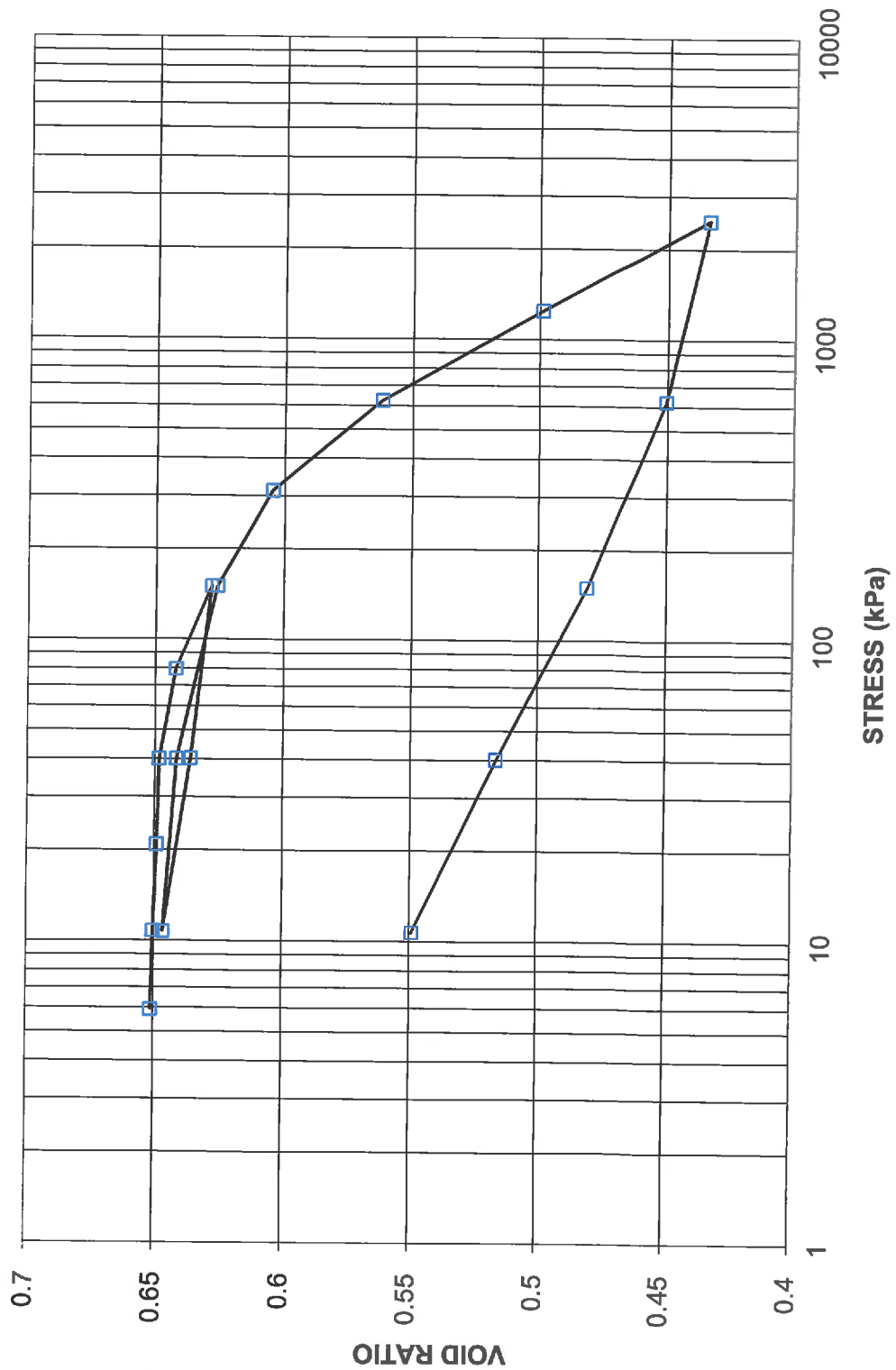
Golder Associates

Checked By: *chb*

CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 202 SA 13



Project No. 11-1132-0143(1001)

Prepared By: LH

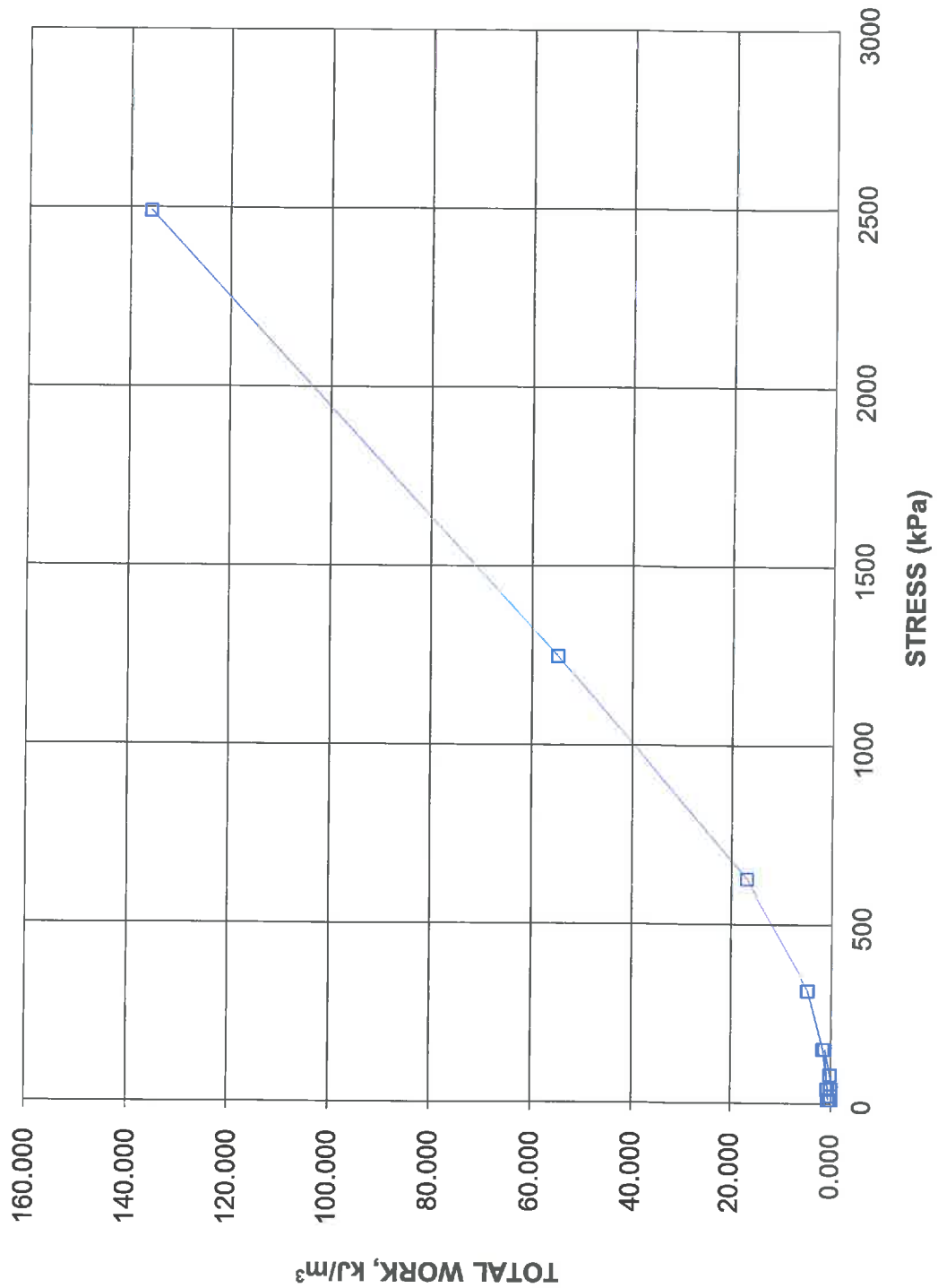
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 202 SA 13



Project No. 11-1132-0143(1001)

Prepared By: LH

Golder Associates

Checked By:

bb

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	11-1132-0143(1001)	Sample Number	17
Borehole Number	BH202	Sample Depth, m	21.34-21.95

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	09/23/2019		
Date Completed	10/08/2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.56	Unit Weight, kN/m ³	20.15
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	16.45
Area, cm ²	31.67	Specific Gravity, measured	2.73
Volume, cm ³	80.91	Solids Height, cm	1.570
Water Content, %	22.54	Volume of Solids, cm ³	49.71
Wet Mass, g	166.29	Volume of Voids, cm ³	31.21
Dry Mass, g	135.7	Degree of Saturation, %	98.0

TEST COMPUTATIONS

Stress	Corr. Height	Void	Average Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.555	0.628	2.555				
5.90	2.556	0.628	2.555				
10.72	2.554	0.627	2.555				
20.43	2.554	0.627	2.554	194	7.13E-03	8.96E-06	6.26E-09
40.05	2.550	0.624	2.552	470	2.94E-03	8.33E-05	2.40E-08
78.56	2.533	0.614	2.541	406	3.37E-03	1.71E-04	5.64E-08
155.80	2.505	0.596	2.519	505	2.66E-03	1.41E-04	3.68E-08
200.01	2.495	0.590	2.500	454	2.92E-03	8.59E-05	2.46E-08
78.56	2.503	0.594	2.499				
10.68	2.531	0.612	2.517				
78.56	2.511	0.600	2.521	406	3.32E-03	1.14E-04	3.71E-08
199.99	2.488	0.585	2.499	390	3.40E-03	7.57E-05	2.52E-08
310.35	2.464	0.570	2.476	375	3.47E-03	8.23E-05	2.79E-08
619.33	2.399	0.528	2.432	470	2.67E-03	8.28E-05	2.17E-08
1237.40	2.309	0.471	2.354	454	2.59E-03	5.71E-05	1.45E-08
2475.00	2.220	0.414	2.264	470	2.31E-03	2.82E-05	6.39E-09
619.33	2.239	0.427	2.229				
200.00	2.269	0.445	2.254				
39.86	2.324	0.481	2.297				
10.72	2.375	0.513	2.350				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 6-10cm from bottom of the tube.

Specimen swelled under 10.72kPa.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

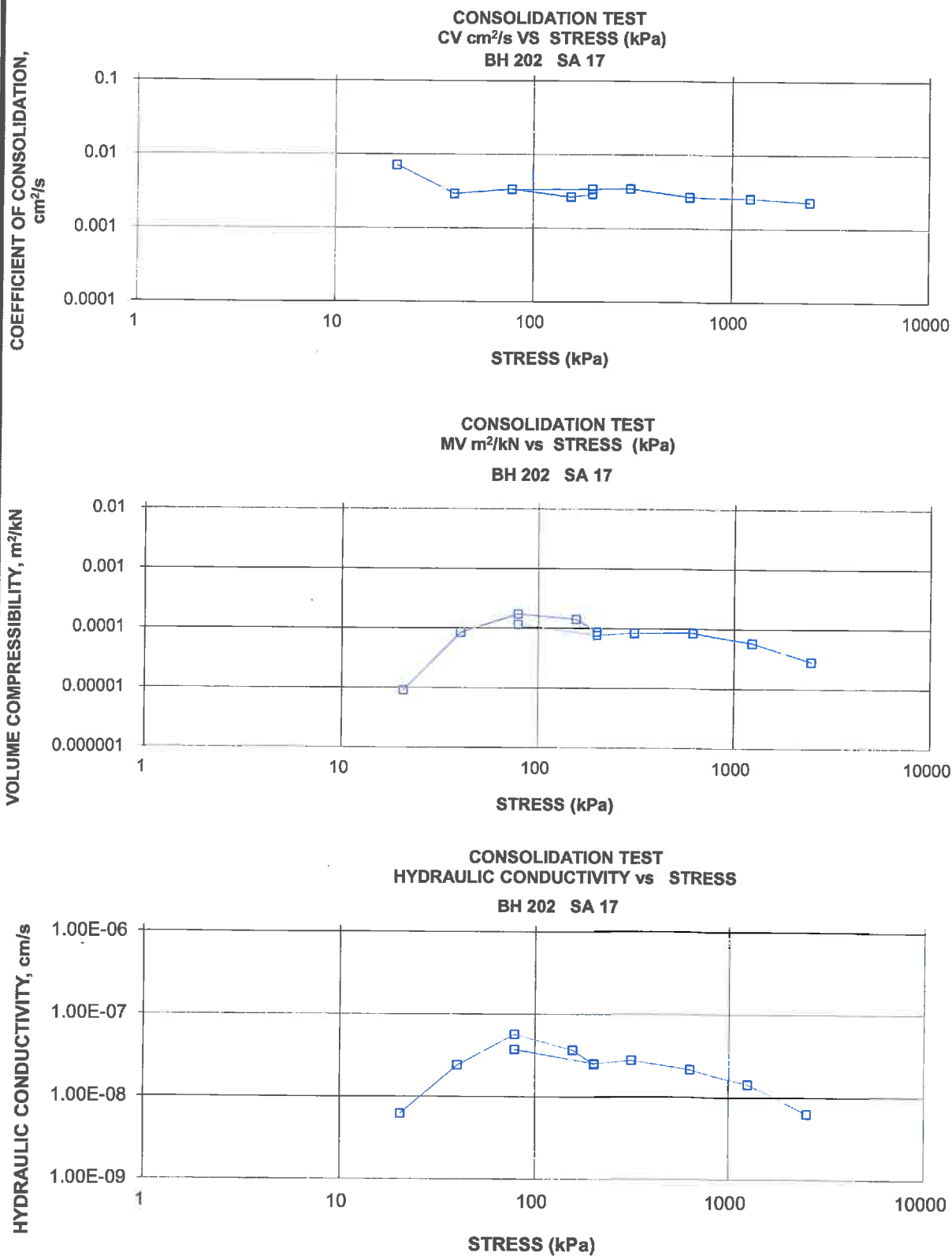
Sample Height, cm	2.37	Unit Weight, kN/m ³	21.07
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	17.69
Area, cm ²	31.67	Specific Gravity, measured	2.73
Volume, cm ³	75.21	Solids Height, cm	1.570
Water Content, %	19.07	Volume of Solids, cm ³	49.71
Wet Mass, g	161.58	Volume of Voids, cm ³	25.50
Dry Mass, g	135.7		

Prepared By: LH

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

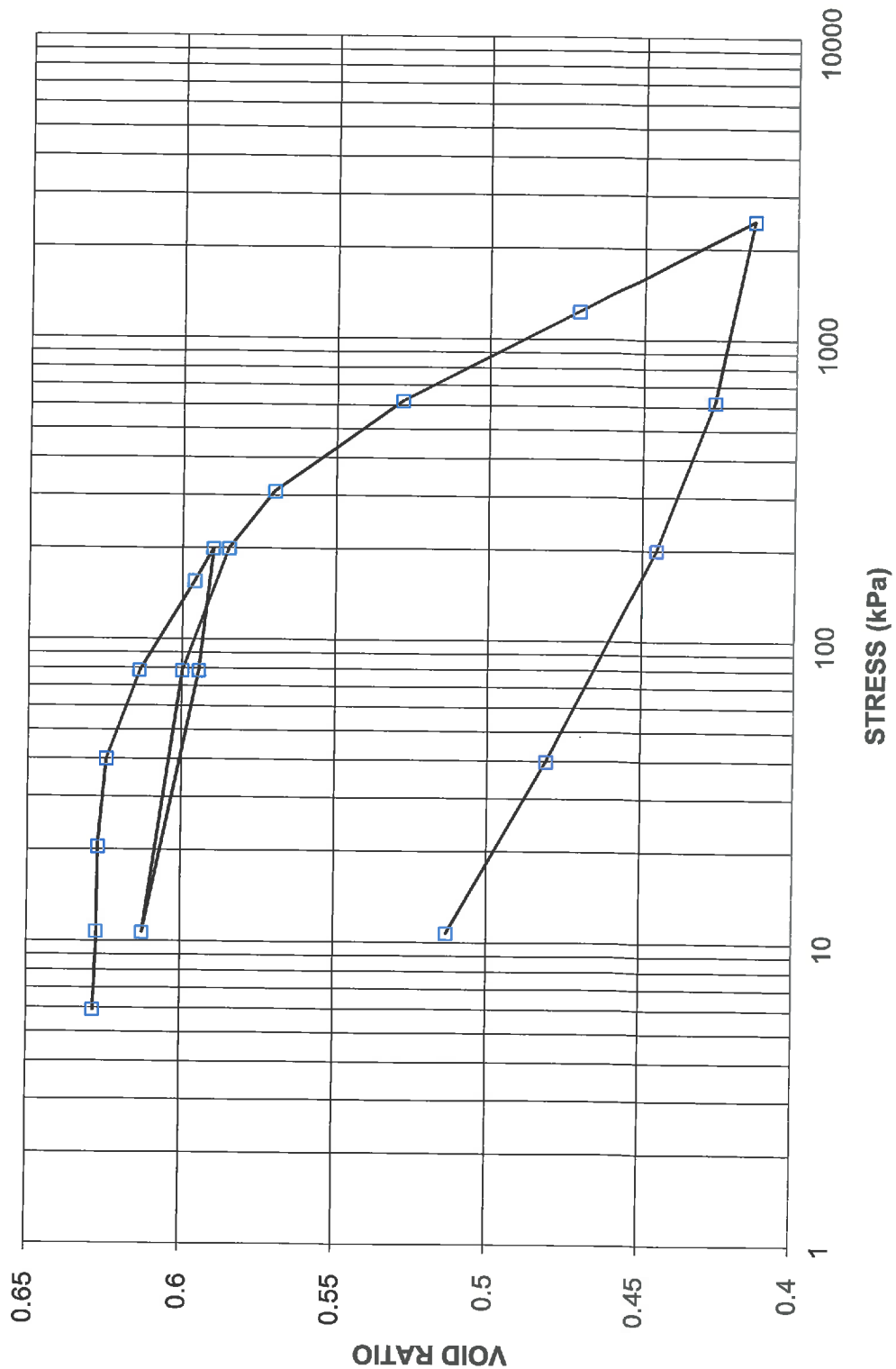
FIGURE



CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 202 SA 17



Project No. 11-1132-0143(1001)

Prepared By: LH

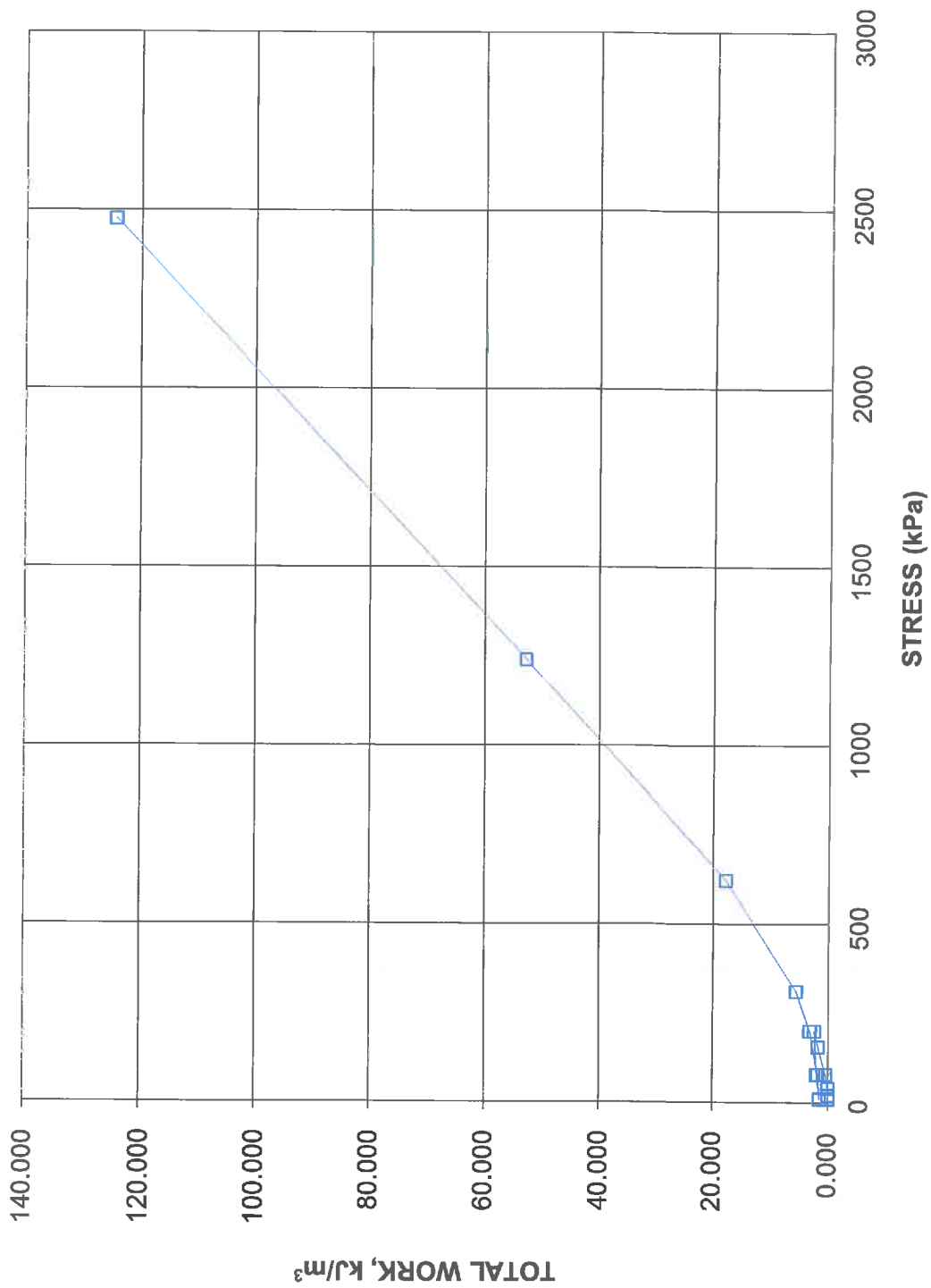
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 202 SA 17



Project No. 11-1132-0143(1001)

Prepared By: LH

Golder Associates

Checked By:

[Signature]

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	11-1132-0143-1001	Sample Number	SA19
Borehole Number	BH202	Sample Depth, m	24.38-24.99

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	9		
Date Started	09/23/2019		
Date Completed	10/09/2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m ³	22.22
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	19.55
Area, cm ²	31.52	Specific Gravity, measured	2.73
Volume, cm ³	59.92	Solids Height, cm	1.388
Water Content, %	13.67	Volume of Solids, cm ³	43.75
Wet Mass, g	135.77	Volume of Voids, cm ³	16.17
Dry Mass, g	119.44	Degree of Saturation, %	101.0

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv. cm ² /s	mv m ² /kN	k cm/s
0.00	1.901	0.370	1.901				
6.53	1.900	0.369	1.900	7	1.09E-01	1.16E-04	1.24E-06
11.20	1.896	0.366	1.898	129	5.92E-03	3.50E-04	2.03E-07
21.14	1.891	0.362	1.894	240	3.17E-03	3.05E-04	9.46E-08
40.47	1.883	0.357	1.887	305	2.48E-03	2.00E-04	4.86E-08
79.33	1.871	0.348	1.877	194	3.85E-03	1.74E-04	6.55E-08
157.14	1.855	0.336	1.863	154	4.78E-03	1.04E-04	4.88E-08
250.00	1.845	0.329	1.850	190	3.82E-03	5.59E-05	2.09E-08
79.41	1.846	0.330	1.845				
11.25	1.854	0.335	1.850				
79.52	1.847	0.330	1.850	49	1.48E-02	5.38E-05	7.81E-08
250.01	1.840	0.326	1.843	49	1.47E-02	2.01E-05	2.89E-08
312.39	1.835	0.322	1.837	294	2.43E-03	4.77E-05	1.14E-08
623.05	1.815	0.308	1.825	101	6.99E-03	3.23E-05	2.21E-08
1244.25	1.791	0.290	1.803	101	6.82E-03	2.09E-05	1.39E-08
2486.62	1.770	0.275	1.781	173	3.89E-03	8.68E-06	3.30E-09
623.05	1.771	0.276	1.771				
157.07	1.777	0.280	1.774				
40.71	1.785	0.286	1.781				
11.32	1.796	0.294	1.790				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 4cm from bottom of the tube.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

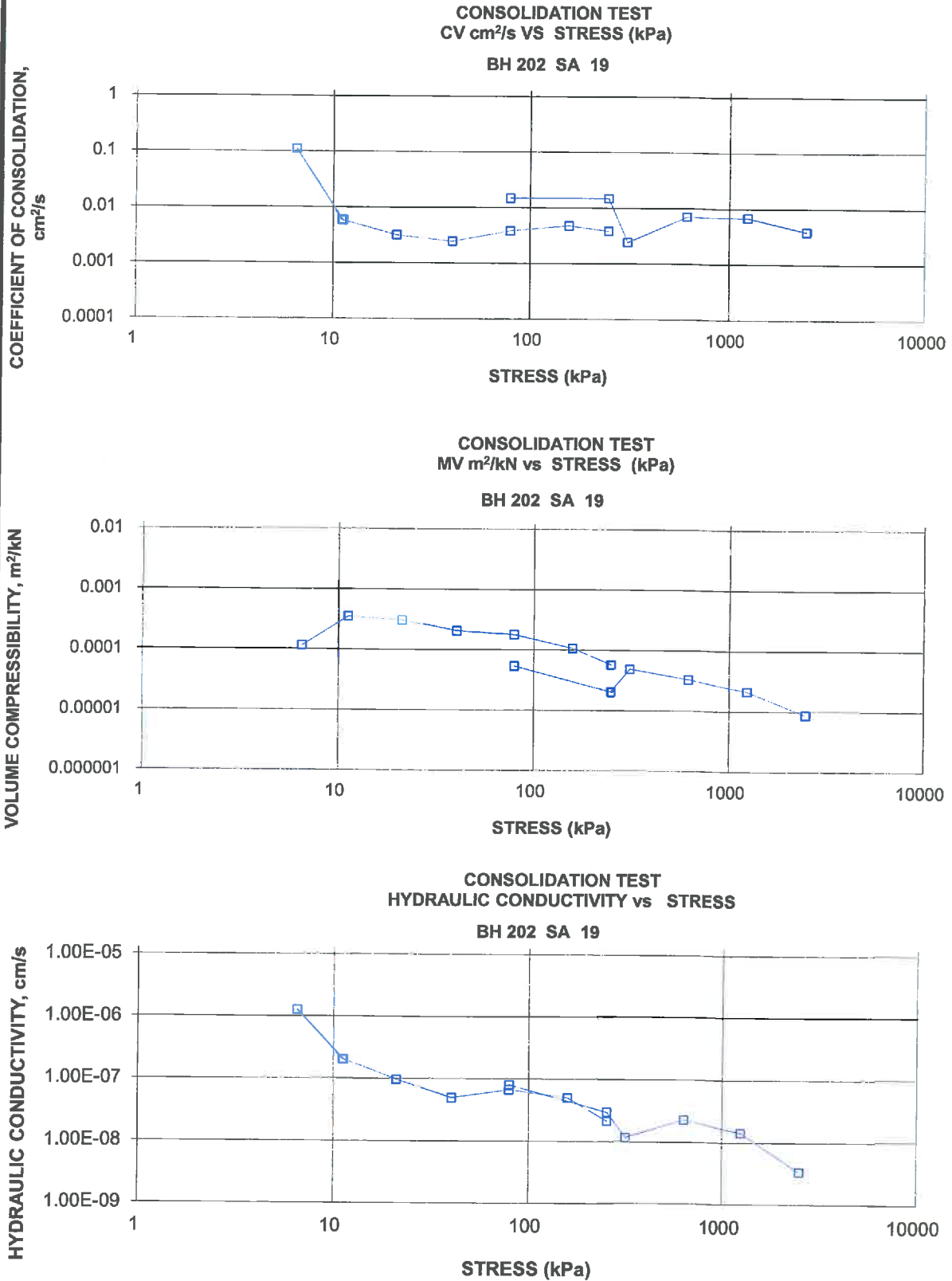
Sample Height, cm	1.80	Unit Weight, kN/m ³	23.18
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m ³	20.69
Area, cm ²	31.52	Specific Gravity, measured	2.73
Volume, cm ³	56.60	Solids Height, cm	1.388
Water Content, %	12.01	Volume of Solids, cm ³	43.75
Wet Mass, g	133.78	Volume of Voids, cm ³	12.85
Dry Mass, g	119.44		

Prepared By: SJ

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

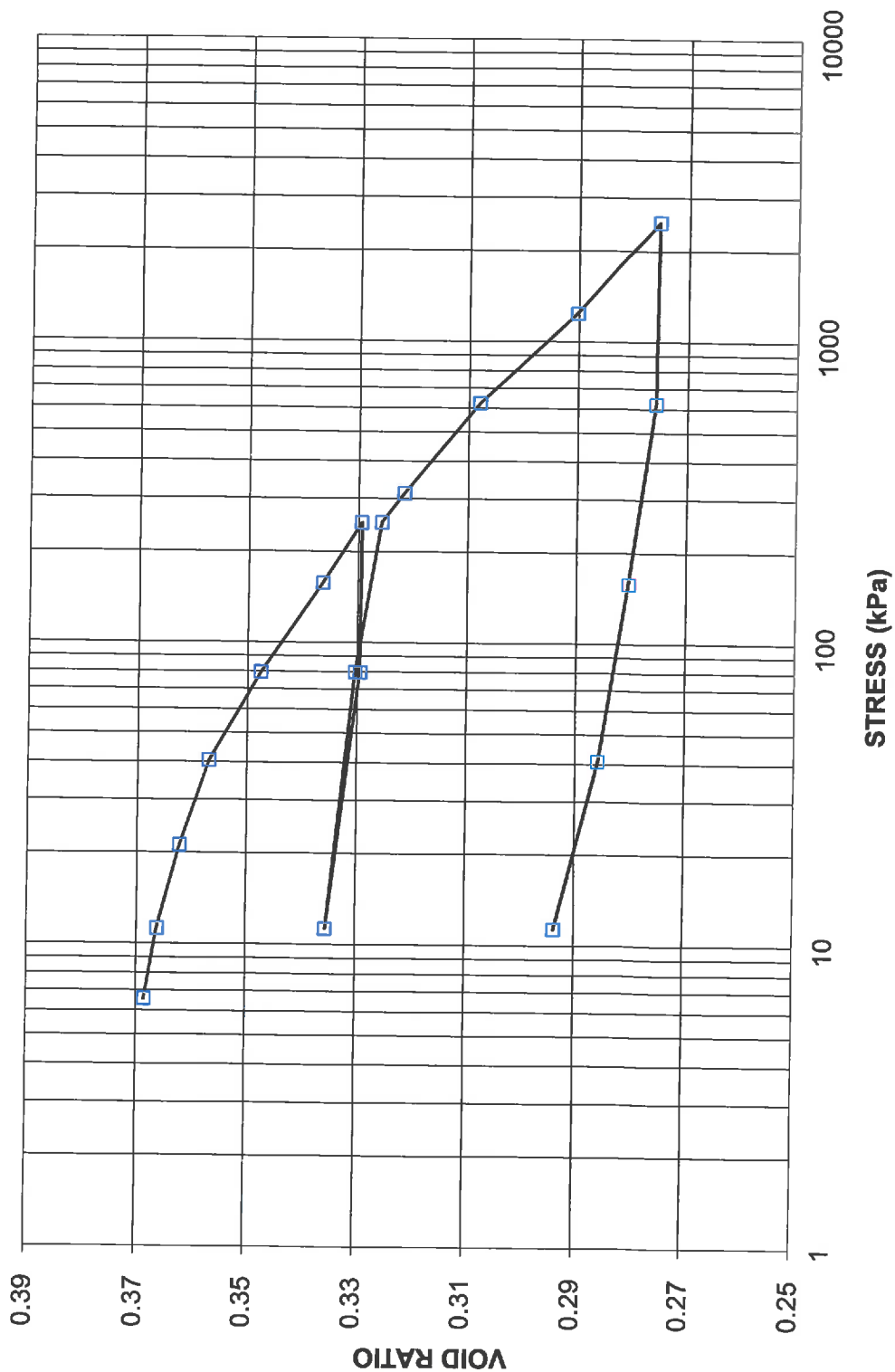
FIGURE



CONSOLIDATION TEST VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 202 SA 19



Project No. 11-1132-

Prepared By: SJ

Golder Associates

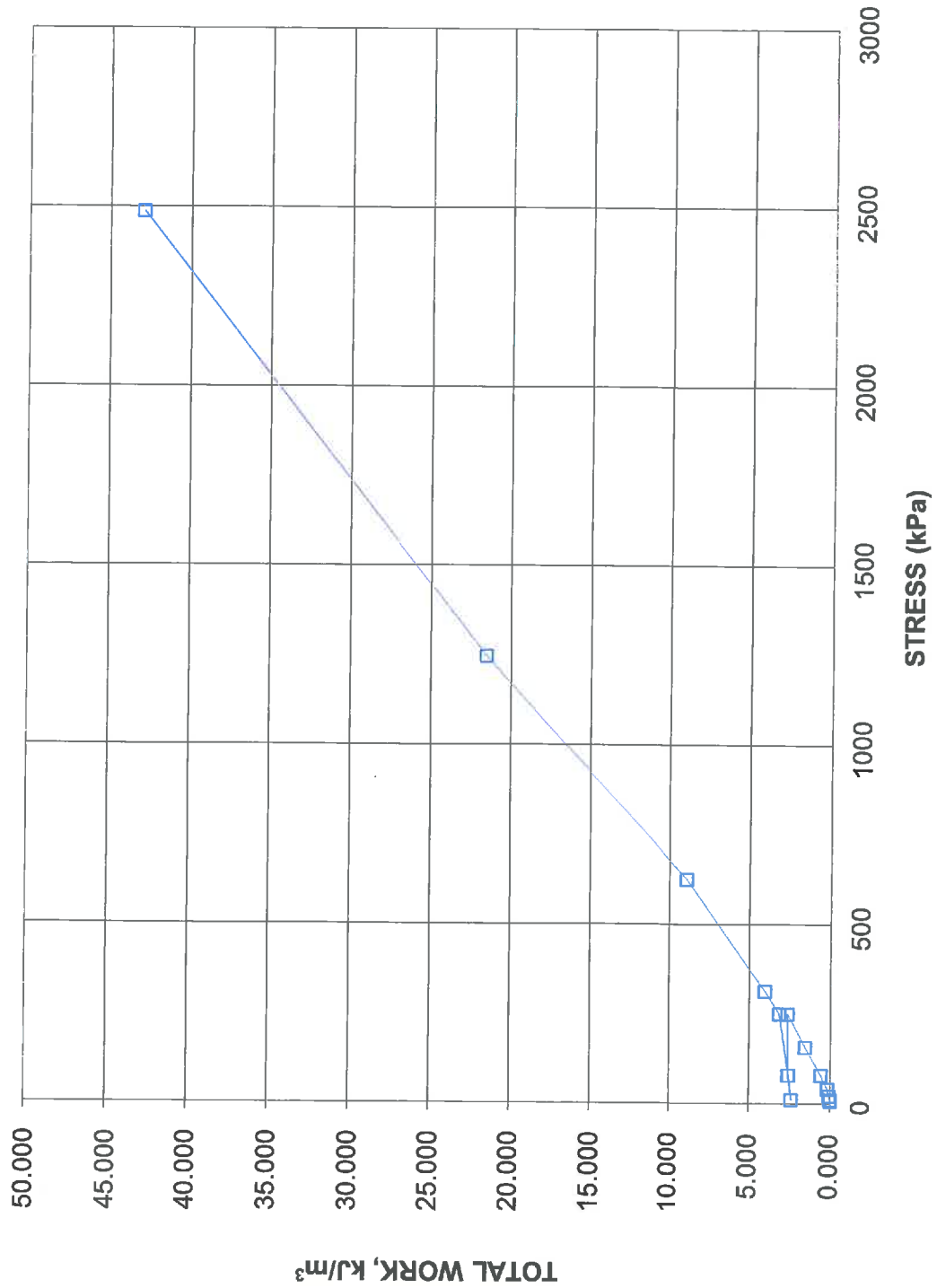
Checked By:

[Signature]

**CONSOLIDATION TEST
TOTAL WORK VS STRESS**

FIGURE

**CONSOLIDATION TEST
TOTAL WORK, kJ/m³ vs STRESS
BH 202 SA 19**



Project No. 11-1132-0143-1001

Prepared By: SJ

Golder Associates

Checked By:

[Signature]

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number 11-1132-0143 (1001)
Borehole Number BH205

Sample Number SA7
Sample Depth, m 6.10-6.71

TEST CONDITIONS

Test Type Laboratory Standard
Oedometer Number 10
Date Started 9/24/2019
Date Completed 10/04/2019

Load Duration, hr 24

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.53	Unit Weight, kN/m ³	20.64
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m ³	17.12
Area, cm ²	31.75	Specific Gravity, measured	2.74
Volume, cm ³	80.42	Solids Height, cm	1.614
Water Content, %	20.56	Volume of Solids, cm ³	51.24
Wet Mass, g	169.27	Volume of Voids, cm ³	29.18
Dry Mass, g	140.4	Degree of Saturation, %	98.9

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average		t ₉₀ sec	cv. cm ² /s	mv m ² /kN	k cm/s
	Height cm		Height cm					
0.00	2.533	0.569	2.533					
5.83	2.532	0.569	2.533					
10.64	2.534	0.570	2.533					
20.33	2.535	0.571	2.535					
39.70	2.531	0.568	2.533	154	8.83E-03	8.91E-05	7.71E-08	
78.42	2.517	0.560	2.524	540	2.50E-03	1.39E-04	3.40E-08	
155.41	2.498	0.548	2.508	577	2.31E-03	9.89E-05	2.24E-08	
309.61	2.470	0.530	2.484	577	2.27E-03	7.31E-05	1.62E-08	
618.30	2.429	0.505	2.449	437	2.91E-03	5.24E-05	1.49E-08	
1235.04	2.367	0.466	2.398	437	2.79E-03	3.97E-05	1.08E-08	
2468.48	2.289	0.418	2.328	346	3.32E-03	2.49E-05	8.11E-09	
618.30	2.308	0.430	2.298					
155.41	2.350	0.456	2.329					
39.71	2.401	0.488	2.376					
10.64	2.442	0.513	2.422					

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 8.0-11.0cm from bottom of the tube.

Specimen swelled under 20.33kPa

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	2.44	Unit Weight, kN/m ³	21.19
Sample Diameter, cm	6.36	Dry Unit Weight, kN/m ³	17.76
Area, cm ²	31.75	Specific Gravity, measured	2.74
Volume, cm ³	77.54	Solids Height, cm	1.614
Water Content, %	19.36	Volume of Solids, cm ³	51.24
Wet Mass, g	167.58	Volume of Voids, cm ³	26.30
Dry Mass, g	140.4		

Prepared By: SJ

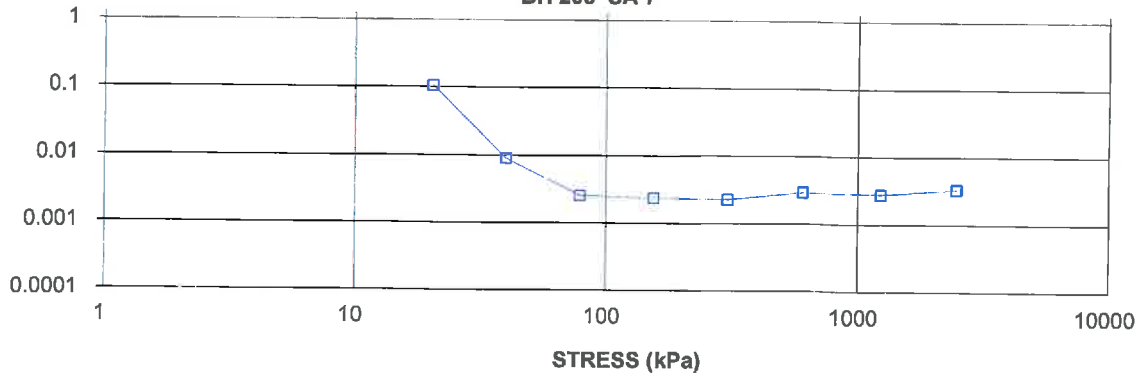
Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE

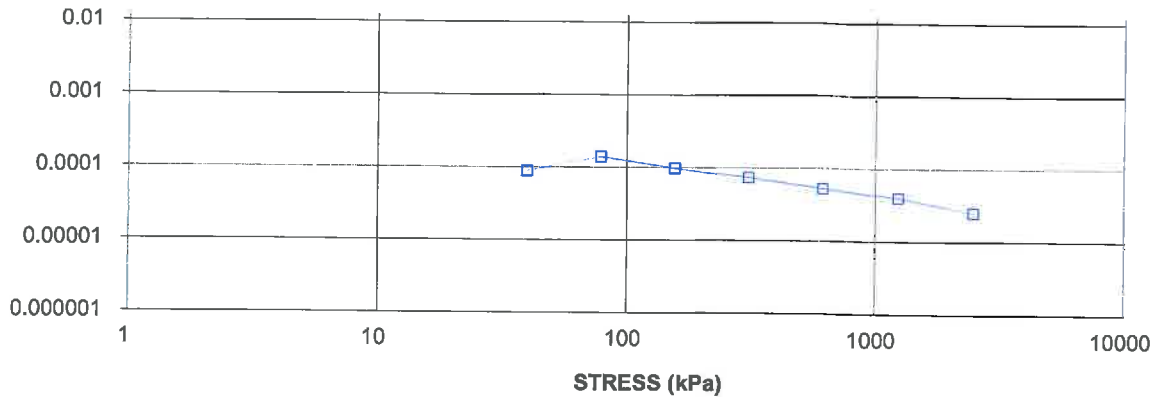
COEFFICIENT OF CONSOLIDATION,
cm²/s

CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 205 SA 7



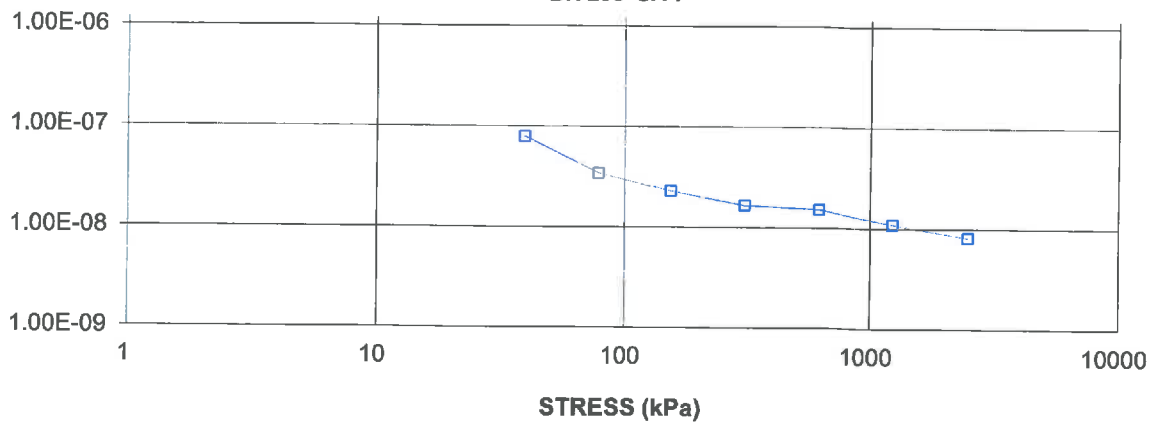
VOLUME COMPRESSIBILITY, m²/kN

CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 205 SA 7



HYDRAULIC CONDUCTIVITY, cm/s

CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 205 SA 7



Project No. 11-1132-0143 (1001)

Prepared By: SJ

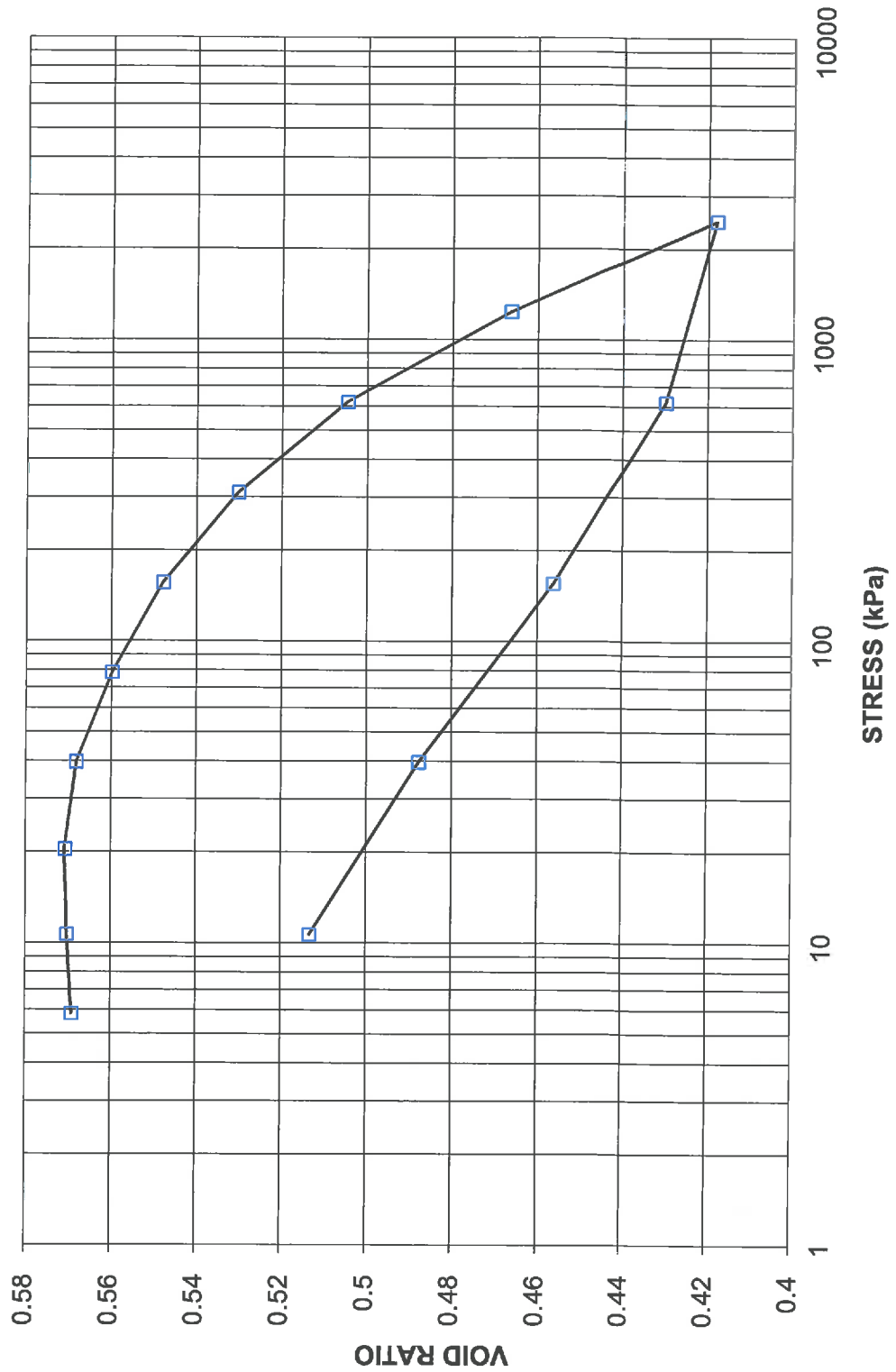
Golder Associates

Checked By: *[Signature]*

**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 205 SA 7**



Project No. 11-1132-0143

Prepared By: SJ

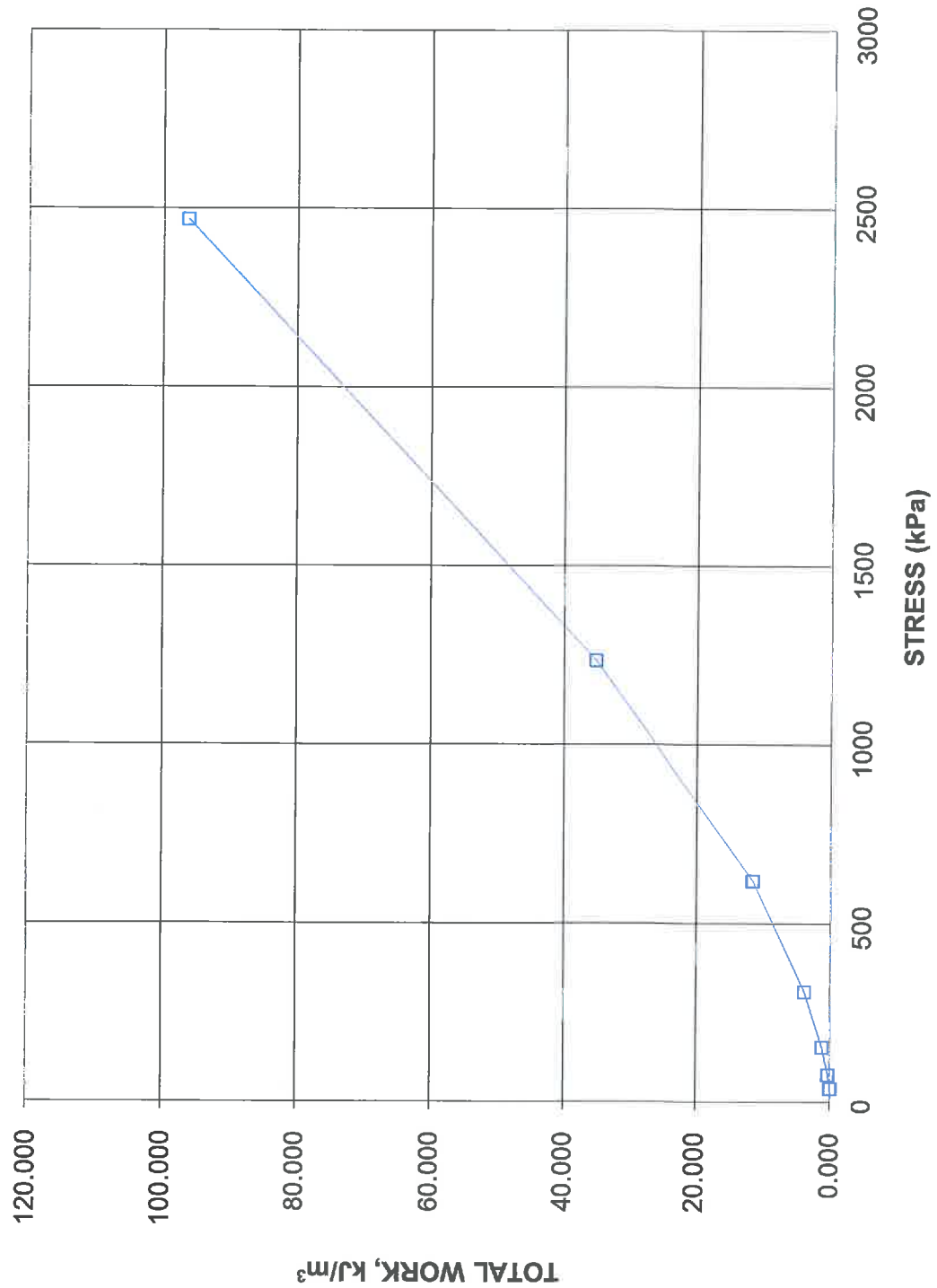
Golder Associates

lcl

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 205 SA 7



Project No. 11-1132-0143 (1001)

Prepared By: SJ

Golder Associates

[Signature]

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	11-1132-0143-1001	Sample Number	SA11
Borehole Number	BH205	Sample Depth, m	12.19-12.80

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	09/24/2019		
Date Completed	10/06/2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m ³	20.43
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	16.64
Area, cm ²	31.46	Specific Gravity, measured	2.74
Volume, cm ³	59.84	Solids Height, cm	1.178
Water Content, %	22.77	Volume of Solids, cm ³	37.06
Wet Mass, g	124.67	Volume of Voids, cm ³	22.78
Dry Mass, g	101.55	Degree of Saturation, %	101.5

TEST COMPUTATIONS

Stress	Corr. Height	Void	Average Height	t ₉₀	cv.	mv	k
kPa	cm	Ratio	cm	sec	cm ² /s	m ² /kN	cm/s
0.00	1.902	0.615	1.902				
6.13	1.900	0.612	1.901	7	1.09E-01	2.09E-04	2.24E-06
10.99	1.898	0.611	1.899	6	1.27E-01	1.93E-04	2.40E-06
20.50	1.897	0.610	1.897	73	1.05E-02	3.76E-05	3.85E-08
40.26	1.895	0.609	1.896	346	2.20E-03	4.47E-05	9.65E-09
79.31	1.890	0.604	1.893	375	2.03E-03	7.51E-05	1.49E-08
125.02	1.882	0.598	1.886	240	3.14E-03	8.58E-05	2.64E-08
40.32	1.892	0.606	1.887				
10.97	1.900	0.613	1.896				
125.12	1.882	0.597	1.891	296	2.56E-03	8.47E-05	2.13E-08
157.15	1.877	0.593	1.879	187	4.00E-03	7.86E-05	3.08E-08
312.68	1.859	0.578	1.868	187	3.95E-03	6.13E-05	2.38E-08
623.93	1.822	0.547	1.840	231	3.11E-03	6.18E-05	1.88E-08
1246.26	1.746	0.482	1.784	406	1.66E-03	6.40E-05	1.04E-08
2491.41	1.666	0.414	1.706	290	2.13E-03	3.38E-05	7.05E-09
623.93	1.686	0.431	1.676				
124.99	1.735	0.473	1.711				
40.32	1.773	0.505	1.754				
10.99	1.811	0.538	1.792				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 5-8cm from bottom of the tube.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

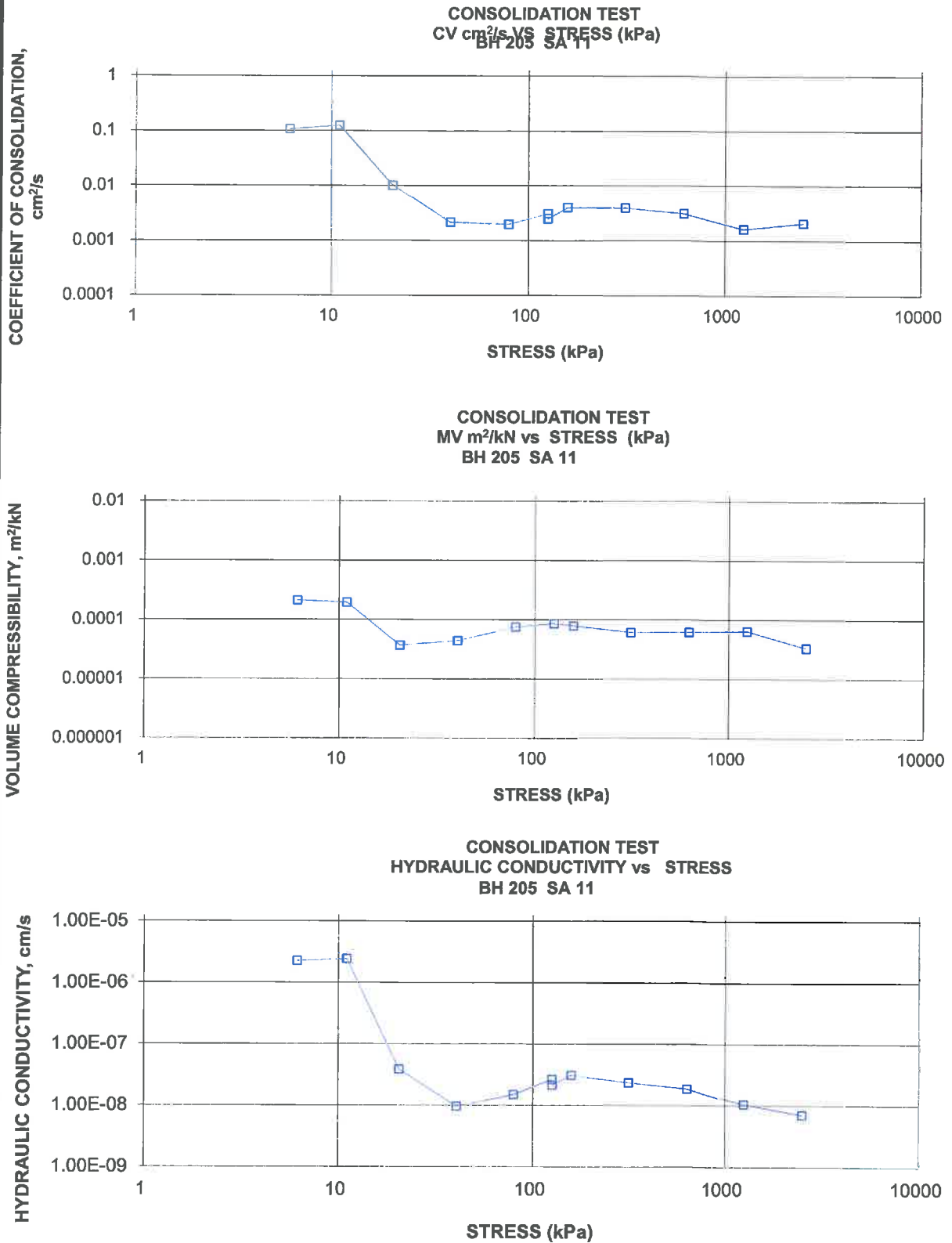
Sample Height, cm	1.81	Unit Weight, kN/m ³	21.11
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	17.48
Area, cm ²	31.46	Specific Gravity, measured	2.74
Volume, cm ³	56.99	Solids Height, cm	1.178
Water Content, %	20.77	Volume of Solids, cm ³	37.06
Wet Mass, g	122.64	Volume of Voids, cm ³	19.92
Dry Mass, g	101.55		

Prepared By: SJ

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE



Project No. 11-1132-0143-1001

Prepared By: SJ

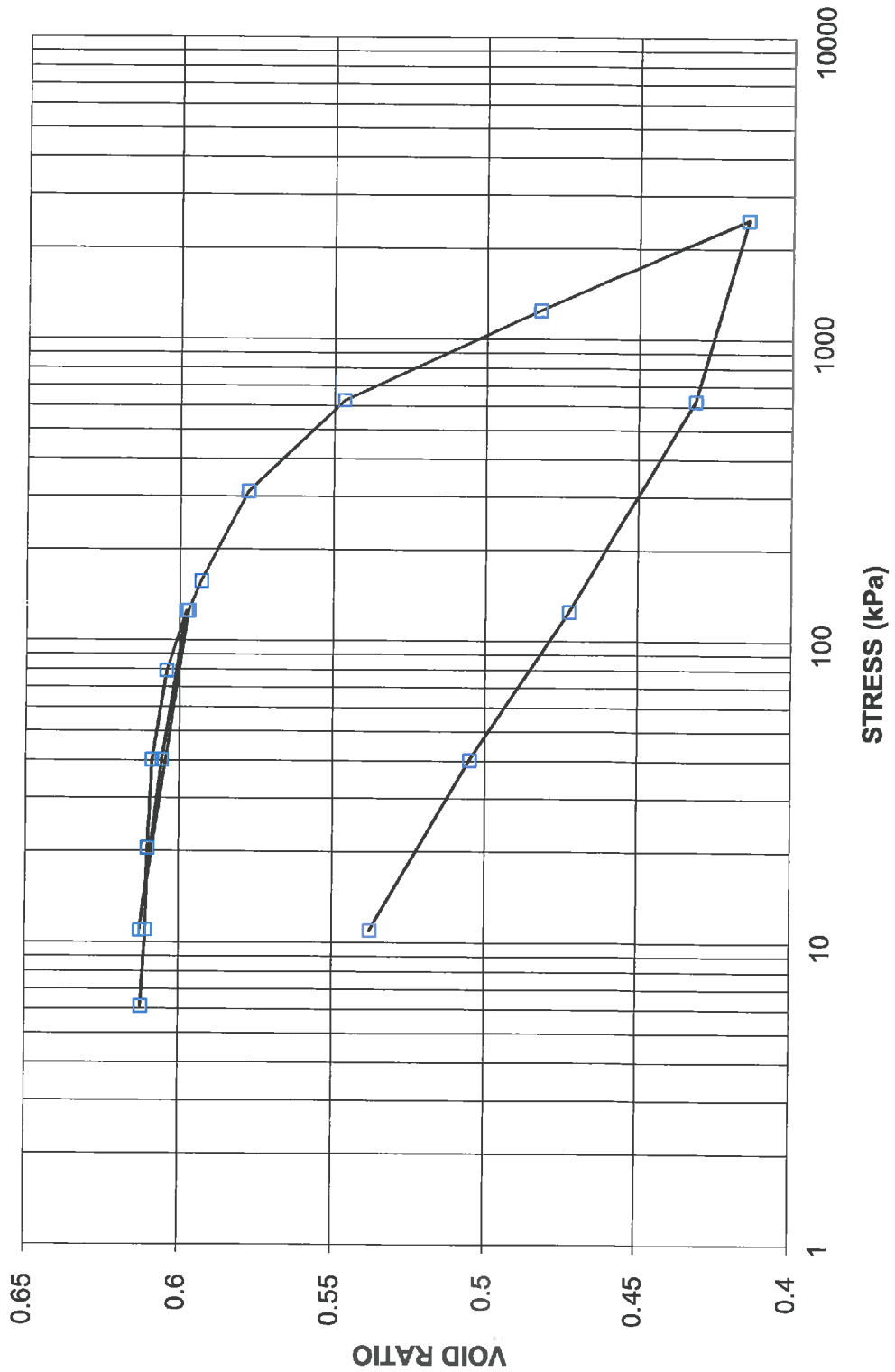
Golder Associates

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CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE

CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 205 SA 11



Project No. 11-1132-0143-1001

Prepared By: SJ

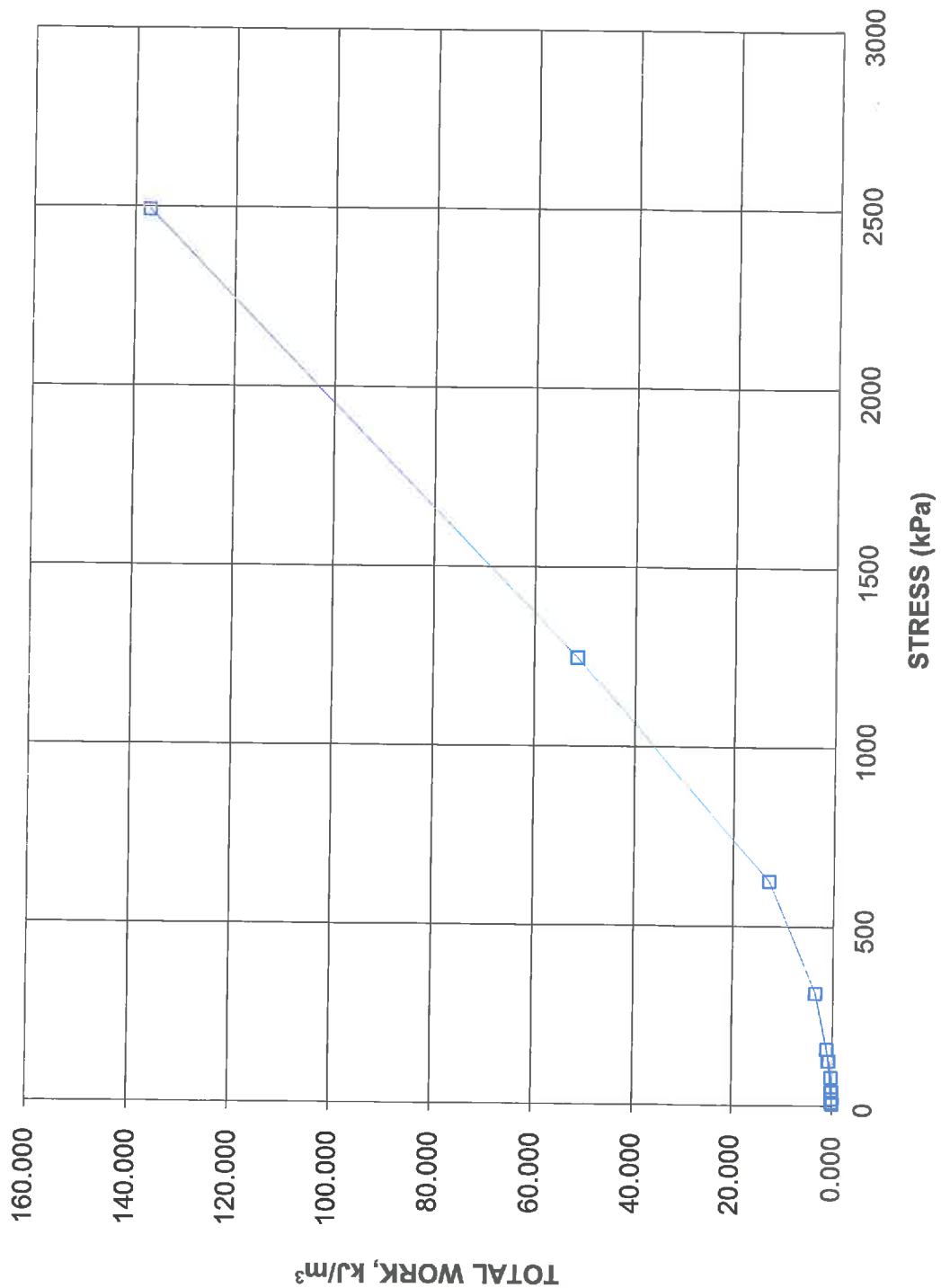
Golder Associates

Checked By: *lab*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 205 SA 11



Project No. 11-1132-0143-1001

Prepared By: SJ

Golder Associates

Checked By:

[Signature]

CONSOLIDATION TEST SUMMARY**FIGURE****ASTM D2435/D2435M****SAMPLE IDENTIFICATION**

Project Number	11-1132-0143 (1001)	Sample Number	SA15
Borehole Number	BH205	Sample Depth, m	18.29-18.90

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	4		
Date Started	09/24/2019		
Date Completed	10/09/2019		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.54	Unit Weight, kN/m ³	20.06
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	16.04
Area, cm ²	31.45	Specific Gravity, measured	2.75
Volume, cm ³	79.88	Solids Height, cm	1.511
Water Content, %	25.04	Volume of Solids, cm ³	47.51
Wet Mass, g	163.37	Volume of Voids, cm ³	32.37
Dry Mass, g	130.65	Degree of Saturation, %	101.1

TEST COMPUTATIONS

Stress	Corr. Height	Void Ratio	Average Height	t ₉₀	cv.	mv	k
kPa	cm		cm	sec	cm ² /s	m ² /kN	cm/s
0.00	2.540	0.681	2.540				
6.16	2.542	0.683	2.541				
11.02	2.544	0.684	2.543				
20.82	2.543	0.683	2.543	86	1.59E-02	4.82E-05	7.53E-08
40.28	2.536	0.679	2.539	265	5.16E-03	1.36E-04	6.85E-08
79.50	2.519	0.668	2.528	735	1.84E-03	1.69E-04	3.05E-08
175.22	2.483	0.644	2.501	540	2.46E-03	1.48E-04	3.56E-08
40.30	2.504	0.658	2.494				
10.92	2.528	0.673	2.516				
40.55	2.513	0.664	2.520	653	2.06E-03	1.93E-04	3.89E-08
175.23	2.477	0.639	2.495	452	2.92E-03	1.07E-04	3.05E-08
313.12	2.443	0.617	2.460	614	2.09E-03	9.51E-05	1.95E-08
624.27	2.369	0.568	2.406	694	1.77E-03	9.44E-05	1.64E-08
1246.98	2.267	0.501	2.318	653	1.74E-03	6.41E-05	1.10E-08
2493.20	2.164	0.432	2.215	346	3.01E-03	3.27E-05	9.64E-09
624.27	2.193	0.452	2.178				
175.19	2.239	0.482	2.216				
40.35	2.305	0.526	2.272				
11.00	2.360	0.562	2.332				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t₉₀ estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen taken 5-8cm from bottom of the tube.

Specimen swelled under 11.02 kPa

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

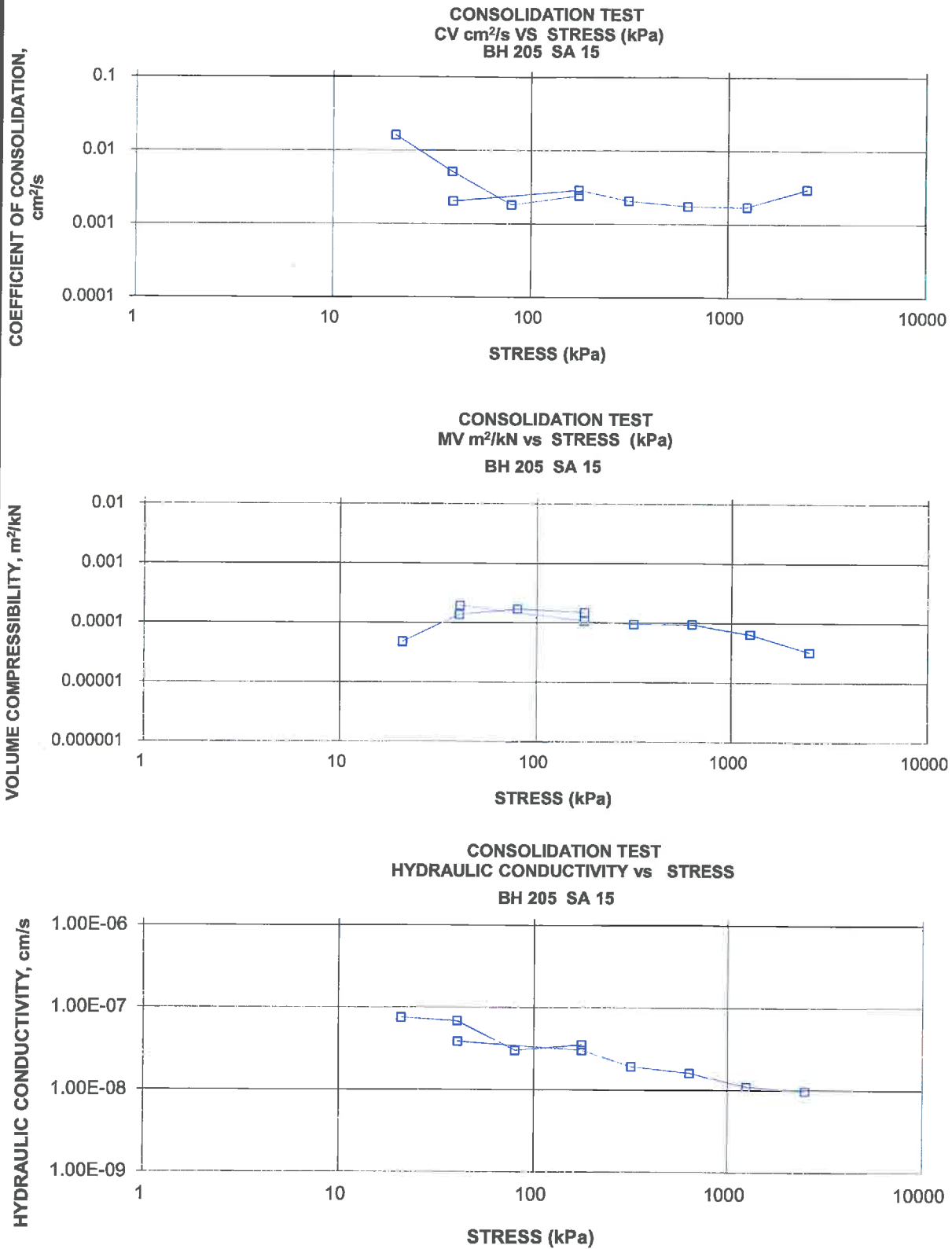
Sample Height, cm	2.36	Unit Weight, kN/m ³	21.01
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m ³	17.26
Area, cm ²	31.45	Specific Gravity, measured	2.75
Volume, cm ³	74.23	Solids Height, cm	1.511
Water Content, %	21.73	Volume of Solids, cm ³	47.51
Wet Mass, g	159.04	Volume of Voids, cm ³	26.72
Dry Mass, g	130.65		

Prepared By: SJ

Golder AssociatesChecked By: 

CONSOLIDATION TEST SUMMARY

FIGURE



Project No. 11-1132-0143 (1001)

Prepared By: SJ

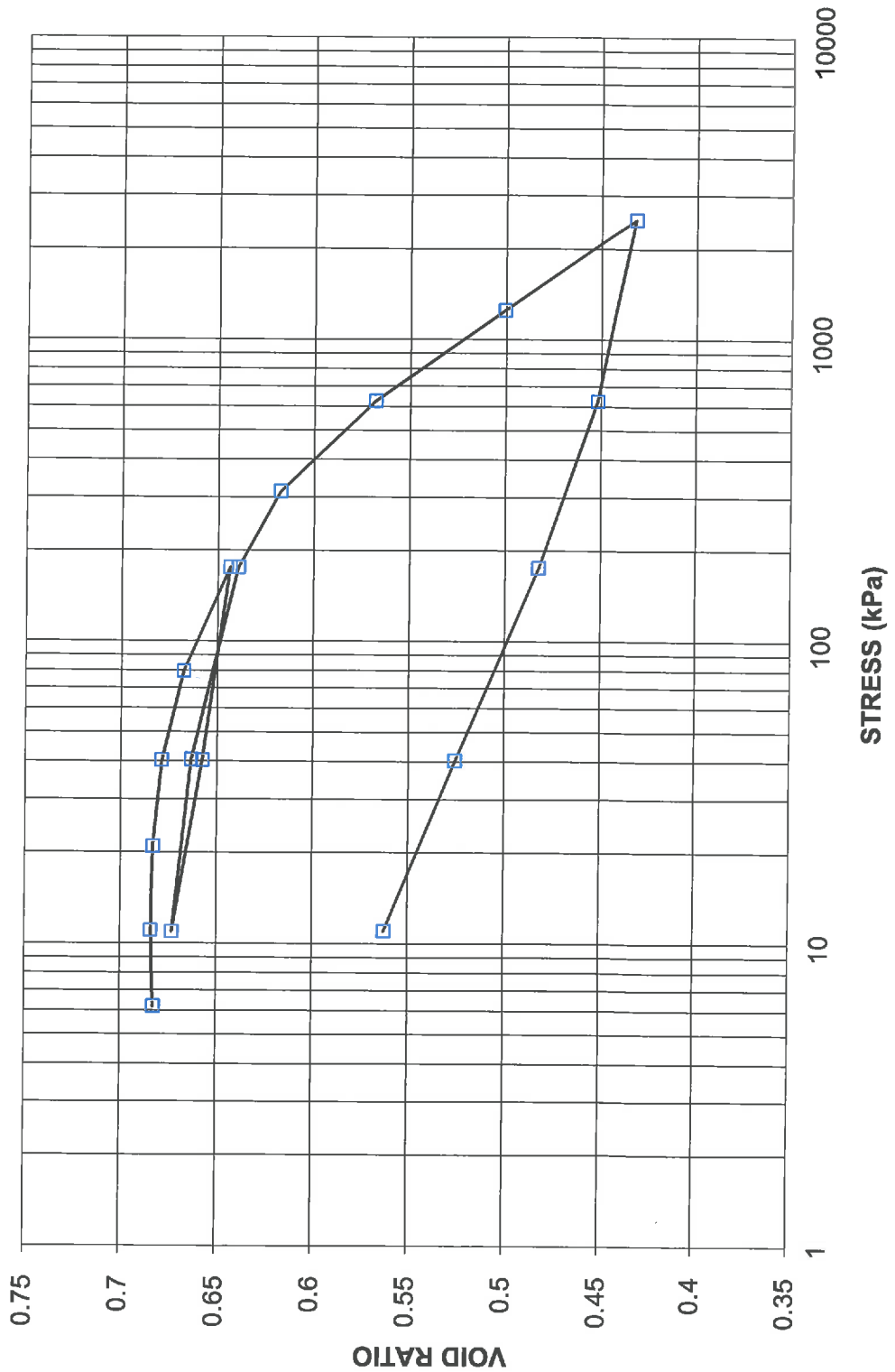
Golder Associates

Checked By: *[Signature]*

**CONSOLIDATION TEST
VOID RATIO VS LOG STRESS**

FIGURE

**CONSOLIDATION TEST
VOID RATIO vs STRESS
BH 205 SA 15**



Project No. 11-1132-0143 (1001)

Prepared By: SJ

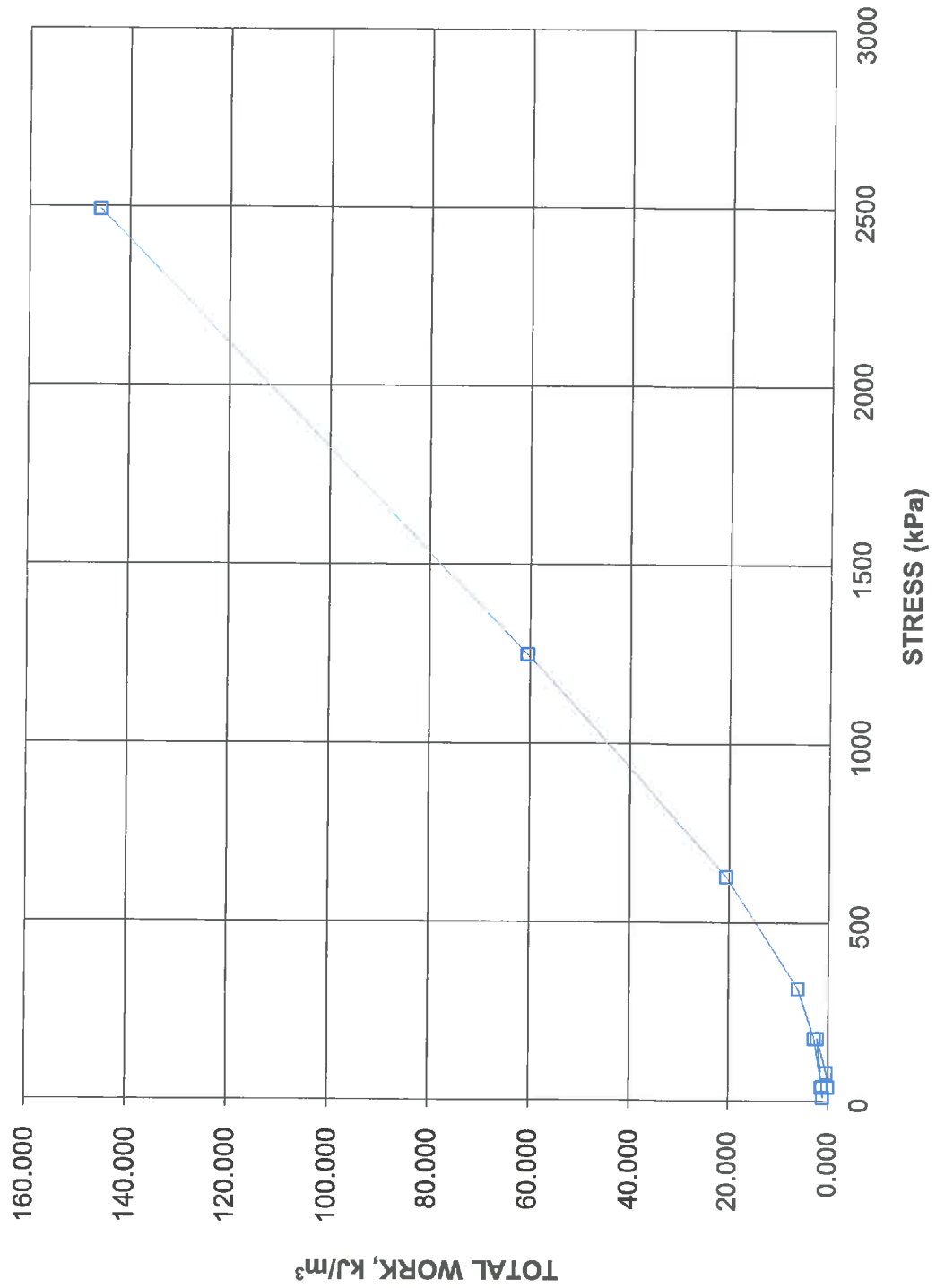
Golder Associates

Checked By: *[Signature]*

CONSOLIDATION TEST TOTAL WORK VS STRESS

FIGURE

CONSOLIDATION TEST
TOTAL WORK, kJ/m^3 vs STRESS
BH 205 SA 15



Project No. 11-1132-0143 (1001)

Prepared By: SJ

Golder Associates

Checked By:

Handwritten signature



APPENDIX B

Site Photographs



APPENDIX B SITE PHOTOGRAPHS



Photograph 1: Borehole 101, proposed location of west abutment.



Photograph 2: Borehole 102, proposed location of east abutment.

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At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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