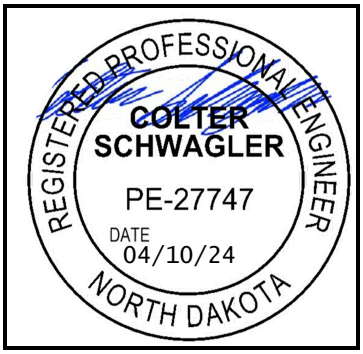
SLOPE STABILITY ANALYSIS

TO:	**File**
FROM:	**Geotechnical Section**
DATE:	**04/10/2024**
HIGHWAY:	**HWY 16**
PROJECT NUMBER:	**SS-5-016(031)111**
PCN:	**23485**
LOCATION:	**3 MI N TROTTERS N TO 8 MI N TROTTERS**
SUBJECT:	**Slope Stability Analysis**



Project Information

The geotechnical section was notified of a proposed steep slope on the left and right side of the roadway on ND 16 at approximately RP 116.055. Based on historical imagery, this area has also been experiencing erosion/slope instability since at least 2012. Below is the figure showing the location of the boring that was completed in the vicinity of the area.

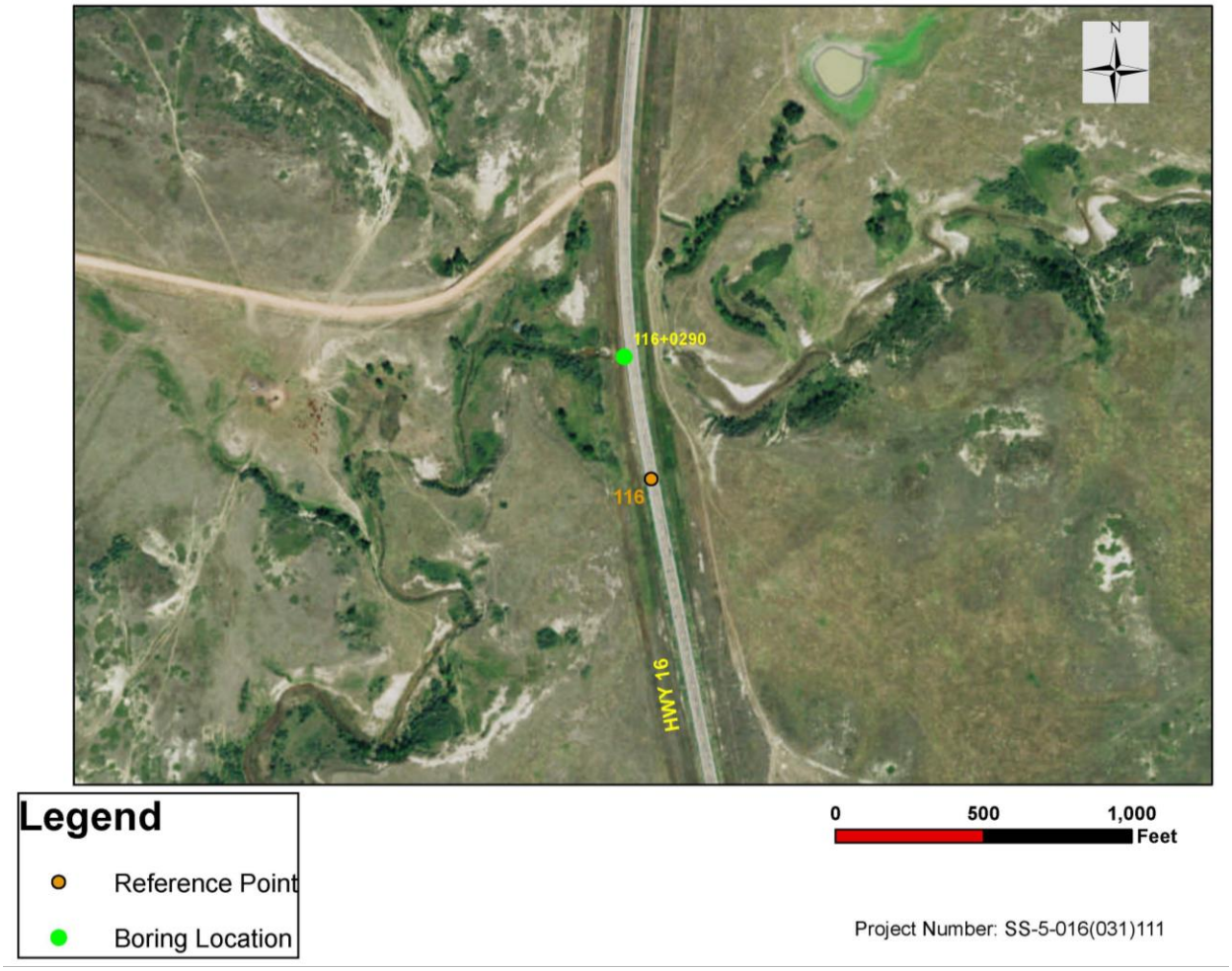


Figure 1 - Project Location

A soil boring was completed at this location to identify the stratigraphy of the site and the engineering parameters of the different soil layers.

See Appendix B for the soil boring log and Appendix C for the lab summary.

Slope Stability Analysis and Recommendations

NDDOT Design Division developed cross sections showing the existing and proposed roadway design and these cross sections were imported into Slope/W software to analyze the factor of safety of the proposed slope. See below for the proposed cross-section.

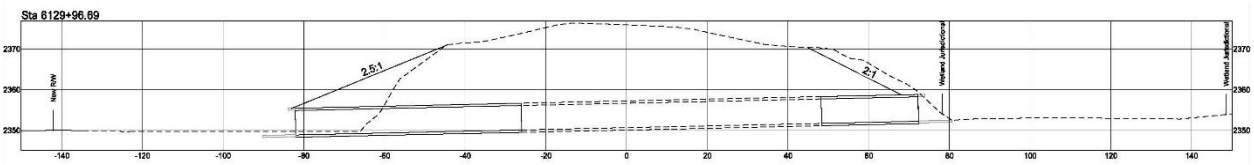


Figure 2 – Cross-section Drawing

The cross section depicting the slope in the steepest direction was analyzed. After analysis, it was found that a proposed 2.5:1 on the left side and 2:1 on the right side met an acceptable factor of safety.

See Appendix A for the slope stability printouts at this location.

Temporary Shoring

It is our understanding that temporary shoring will be required for this project. See Appendix B and C for soil information for shoring design.

Limitations

This report should be made available to prospective designers and contractors for information on factual data only and not as a warranty of subsurface conditions. This report should not be used without approval if any of the following occurs:

- Conditions change due to natural forces or human activity under, at, or adjacent to the site.
- Assumptions stated in this report have changed.
- Project details change or new information becomes available such that our analyses, conclusions, and recommendations may be affected.
- The site ownership or land use has changed.
- More than 5 years has passed since the date of this report.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by a limited boring and testing program.

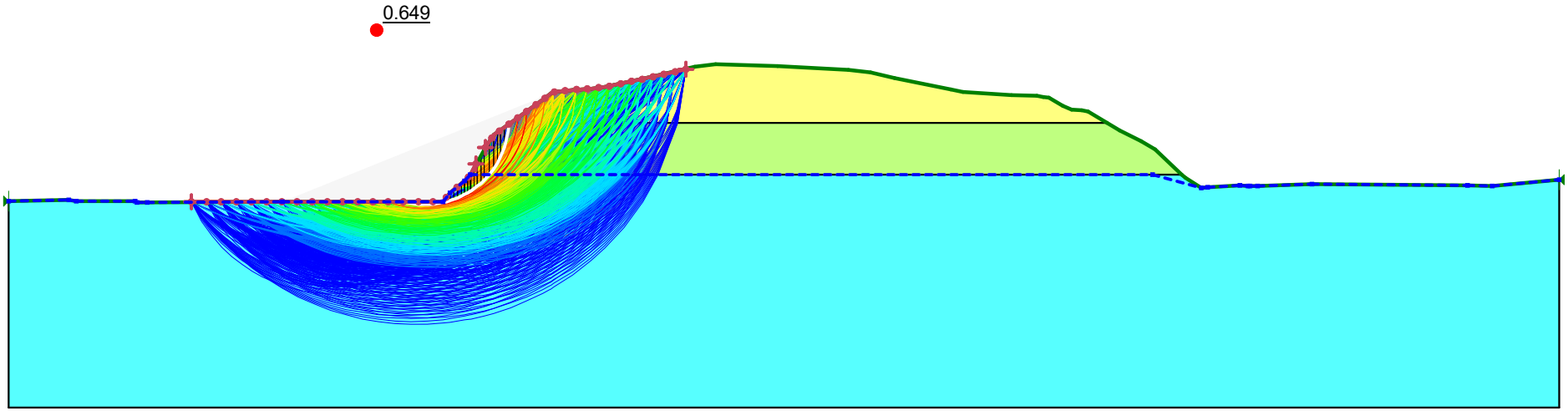
Within the limitations of scope, schedule and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geotechnical and geological principles and practice in this area at the time this report was prepared. We make no other warranty, either express or implied.

If there are any questions or concerns, please contact Habtamu Yeshaw hyeshaw@nd.gov or Colter Schwagler cschwagler@nd.gov of the NDDOT Geotechnical Section.

Appendix A
Slope Stability Outputs

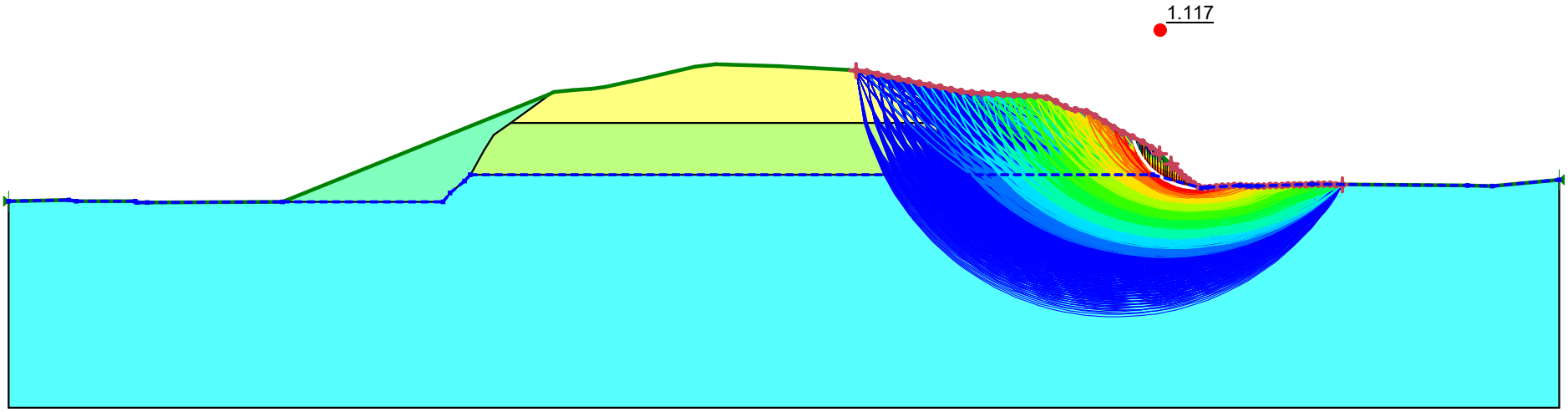
Effective Stress Analysis
Project Number: SS-5-016(031)111
ND HWY 16 RP 116
Existing Ground, Left Side

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Strength Function	Phi-B (°)	Piezometric Surface
	Layer 1 - Meium Stiff Clay	Shear/Normal Fn.	120	Layer 1 CU-26-22 & CU-27-22	0	1
	Layer 2 - Stiff Clay	Shear/Normal Fn.	131.7	Layer 2 CU-28-22, CU-29-22 & CU-30-22	0	1
	Layer 3 - Soft to Medium Stiff Clay	Shear/Normal Fn.	120	Layer 3 CF=40 & LL=30	0	1



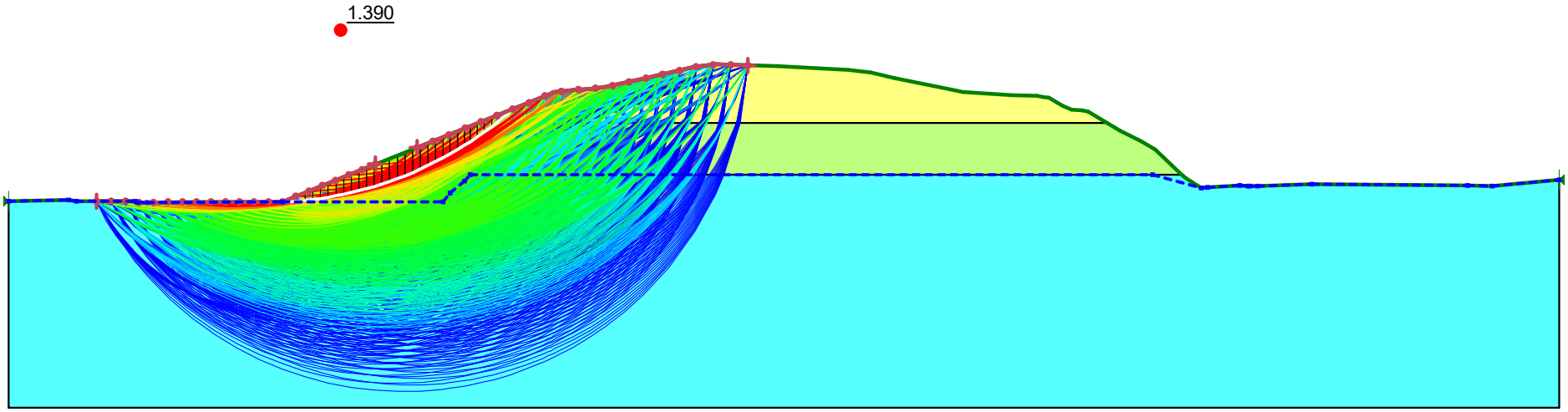
Effective Stress Analysis
Project Number: SS-5-016(031)111
ND HWY 16 RP 116
Existing Ground, Right Side

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Strength Function	Phi-B (°)	Piezometric Surface
	Layer 1 - Meium Stiff Clay	Shear/Normal Fn.	120			Layer 1 CU-26-22 & CU-27-22	0	1
	Layer 2 - Stiff Clay	Shear/Normal Fn.	131.7			Layer 2 CU-28-22, CU-29-22 & CU-30-22	0	1
	Layer 3 - Soft to Medium Stiff Clay	Shear/Normal Fn.	120			Layer 3 CF=40 & LL=30	0	1
	New Embankment	Mohr-Coulomb	120	0	28		0	1



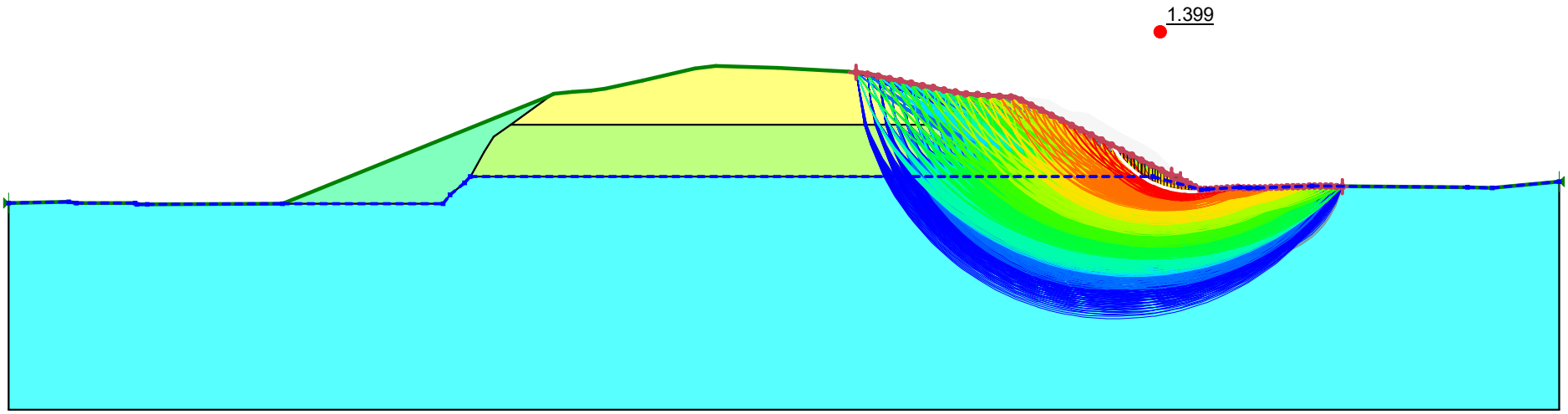
Effective Stress Analysis
Project Number: SS-5-016(031)111
ND HWY 16 RP 116
Proposed Ground - New Embankment
Material, Left Side

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Strength Function	Phi-B (°)	Piezometric Surface
	Layer 1 - Meium Stiff Clay	Shear/Normal Fn.	120			Layer 1 CU-26-22 & CU-27-22	0	1
	Layer 2 - Stiff Clay	Shear/Normal Fn.	131.7			Layer 2 CU-28-22, CU-29-22 & CU-30-22	0	1
	Layer 3 - Soft to Medium Stiff Clay	Shear/Normal Fn.	120			Layer 3 CF=40 & LL=30	0	1
	New Embankment	Mohr-Coulomb	120	0	28		0	1



Effective Stress Analysis
Project Number: SS-5-016(031)111
ND HWY 16 RP 116
Proposed Ground - 2:1, Right Side

Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Strength Function	Phi-B (°)	Piezometric Surface
	Layer 1 - Meium Stiff Clay	Shear/Normal Fn.	120			Layer 1 CU-26-22 & CU-27-22	0	1
	Layer 2 - Stiff Clay	Shear/Normal Fn.	131.7			Layer 2 CU-28-22, CU-29-22 & CU-30-22	0	1
	Layer 3 - Soft to Medium Stiff Clay	Shear/Normal Fn.	120			Layer 3 CF=40 & LL=30	0	1
	New Embankment	Mohr-Coulomb	120	0	28		0	1



Appendix B
Soil Boring Log

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

LOG OF BORING SB - 1

PROJECT NUMBER SS-5-016(031)111 **DATE STARTED** 8/4/22 **COMPLETED** 8/4/22

PCN 23485 **ELEVATION** 2376 ft

LOCATION Mckenzie County **Northing** 5264312.82 ft **Easting** 125173.68 ft

DRILLED BY Dallan **LOGGED BY** Jamie **DRILLING METHOD**

ENGINEER

NOTES Coordinate System: NAD_1983_UTM_Zone_14N

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	GRAPHIC LOG	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE (20 40 60 80)	MC / PL LL (20 40 60 80) / CLAY FRACTION (%) (20 40 60 80)	TESTS & REMARKS
2375	0	Stiff Moist Brn Lean Clay w/Sand		A-7-6	CL	SS 406	25	12	19 42	
				A-7-6	CL	SS 407	25	7	17 47	
	5			A-6	CL	3TW 408	75		18 33	
2370		2370.0 ft 6.0 ft								
		Medium Stiff Moist Brn Lean Clay w/Sand		A-6	CL	SS 409	80	5	17 33	
	10			A-7-6	ML	3TW 410	75		28 43	γ_d = 100.0 pcf γ = 120.1 pcf CU=24.5°, c'=474psf
2365		2365.0 ft 11.0 ft								
		Stiff Moist Brn Lean Clay		A-4	CL	SS 411	90	14	1927	
	15			A-6	CL	3TW 412	80		18 35	
2360				A-6	CL	SS 413	80	14	15 35	
	20	2355.0 ft 21.0 ft		A-6	CL	3TW 414	90		1729	γ_d = 109.7 pcf γ = 131.7 pcf CU=32.6°, c'=205psf
2355		Soft to Medium Stiff Wet Brn Lean Clay w/Sand. Water bearing starting at 21`		A-4	CL	SS 415	85	5	1727	
	25			A-6	CL	3TW 416	75		18 34	
2350				A-4	CL	SS 417	90	7	1929	
	30			A-2-4	SM	3TW 418	100		24	
2345				A-6	CL	SS 419	100	3	1730	
	35			A-4	CL-ML	3TW 420	100		25	
2340				A-4	CL-ML	SS 421	100	3	26	
						3TW 422	100			
	40			A-6	CL	SS 423	100	4	16 38	
2335		2334.0 ft 42.0 ft								

Bottom of borehole at 42.0 ft

NDDOT LOG LAT/LONG - 20171219.GDT - 3/28/24 08:54 - F:\LAB\PROJECTS\GINT\5-016(031)111.GPJ

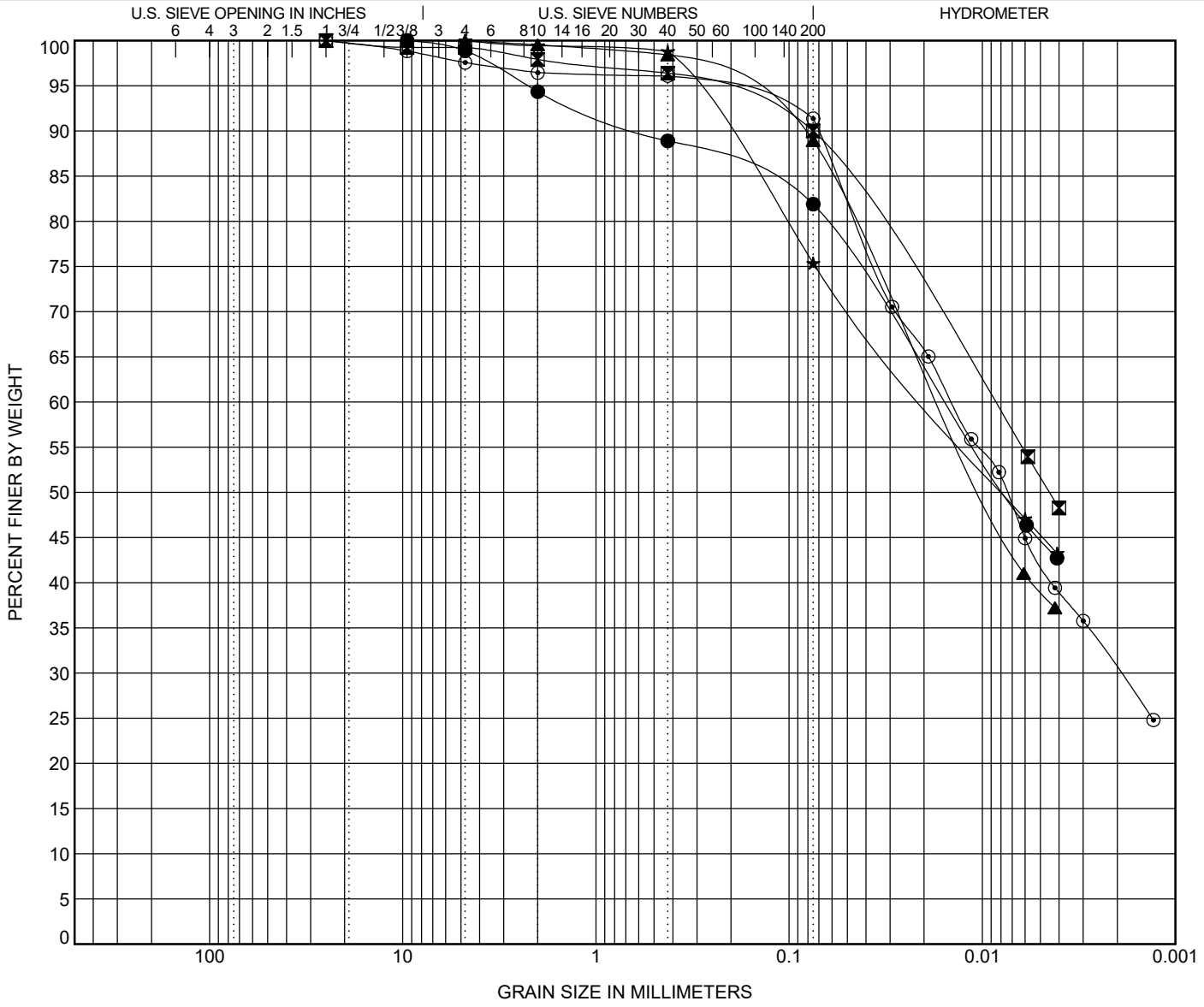
Appendix C
Lab Analysis

GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER SS-5-016(031)111 **LOCATION** Mckenzie County

PCN 23485



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	0.0	A-7-6 (19)	CL	42	19	23		
⊠	SB - 1	2.0	A-7-6 (28)	CL	47	17	30		
▲	SB - 1	4.0	A-6 (13)	CL	33	18	15		
★	SB - 1	6.0	A-6 (10)	CL	33	17	16		
⊙	SB - 1	9.0	A-7-6 (16)	ML	43	28	15		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	0.0	9.5	0.016			1.1	17.0	81.9	
⊠	SB - 1	2.0	25	0.009			0.7	9.3	90.0	
▲	SB - 1	4.0	9.5	0.016			0.1	11.0	88.9	
★	SB - 1	6.0	4.75	0.019			0.0	24.6	75.4	
⊙	SB - 1	9.0	25	0.014	0.002		2.4	6.2	60.9	30.5

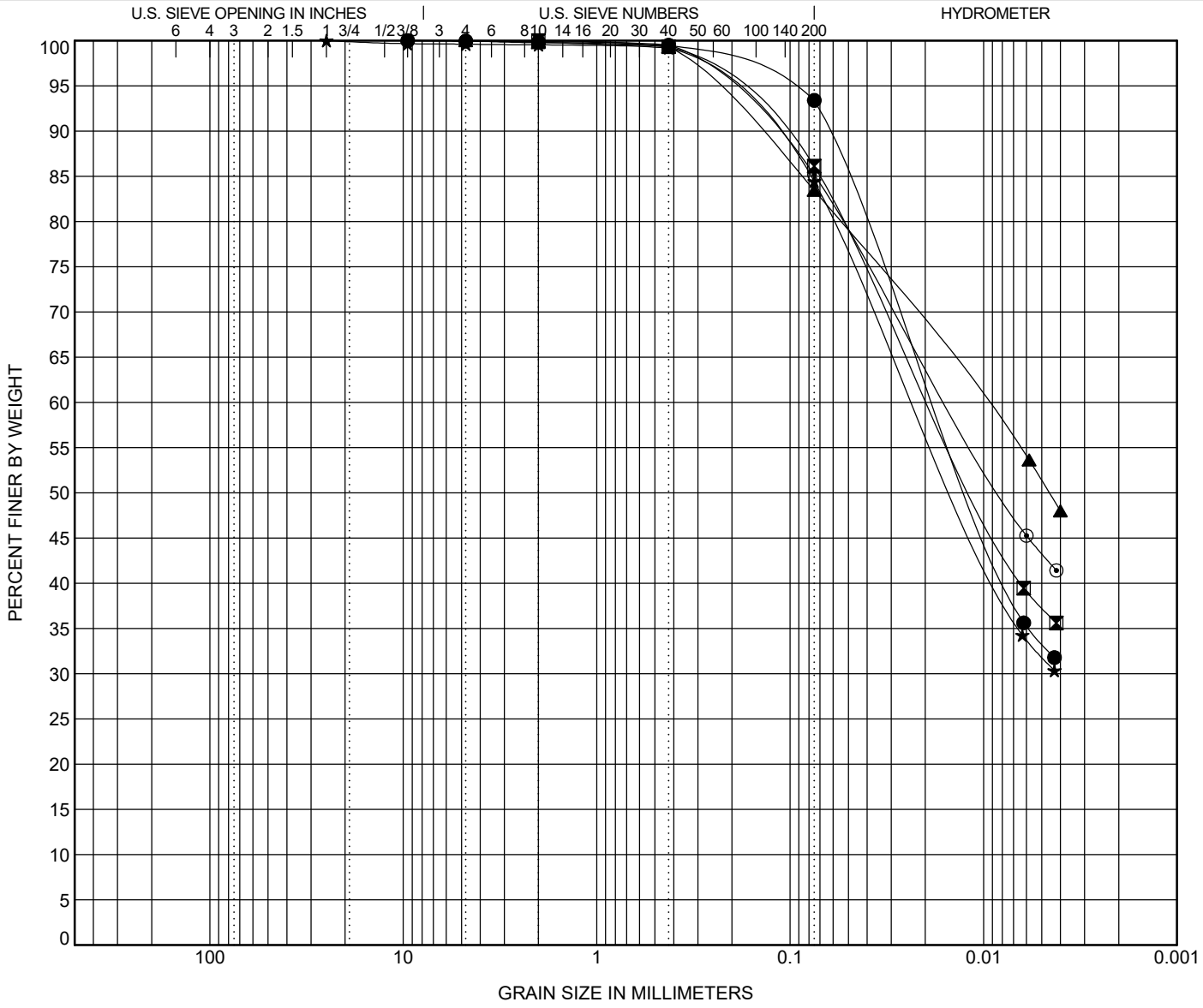
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GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER SS-5-016(031)111 **LOCATION** Mckenzie County

PCN 23485



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	11.0	A-4 (6)	CL	27	19	8		
⊠	SB - 1	14.0	A-6 (14)	CL	35	18	17		
▲	SB - 1	16.0	A-6 (15)	CL	35	15	20		
★	SB - 1	19.0	A-6 (8)	CL	29	17	12		
⊙	SB - 1	21.0	A-4 (7)	CL	27	17	10		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	11.0	9.5	0.018			0.1	6.6	93.4	
⊠	SB - 1	14.0	2	0.019			0.0	13.9	86.1	
▲	SB - 1	16.0	4.75	0.01			0.0	16.5	83.5	
★	SB - 1	19.0	25	0.022			0.4	15.2	84.4	
⊙	SB - 1	21.0	9.5	0.015			0.0	14.8	85.2	

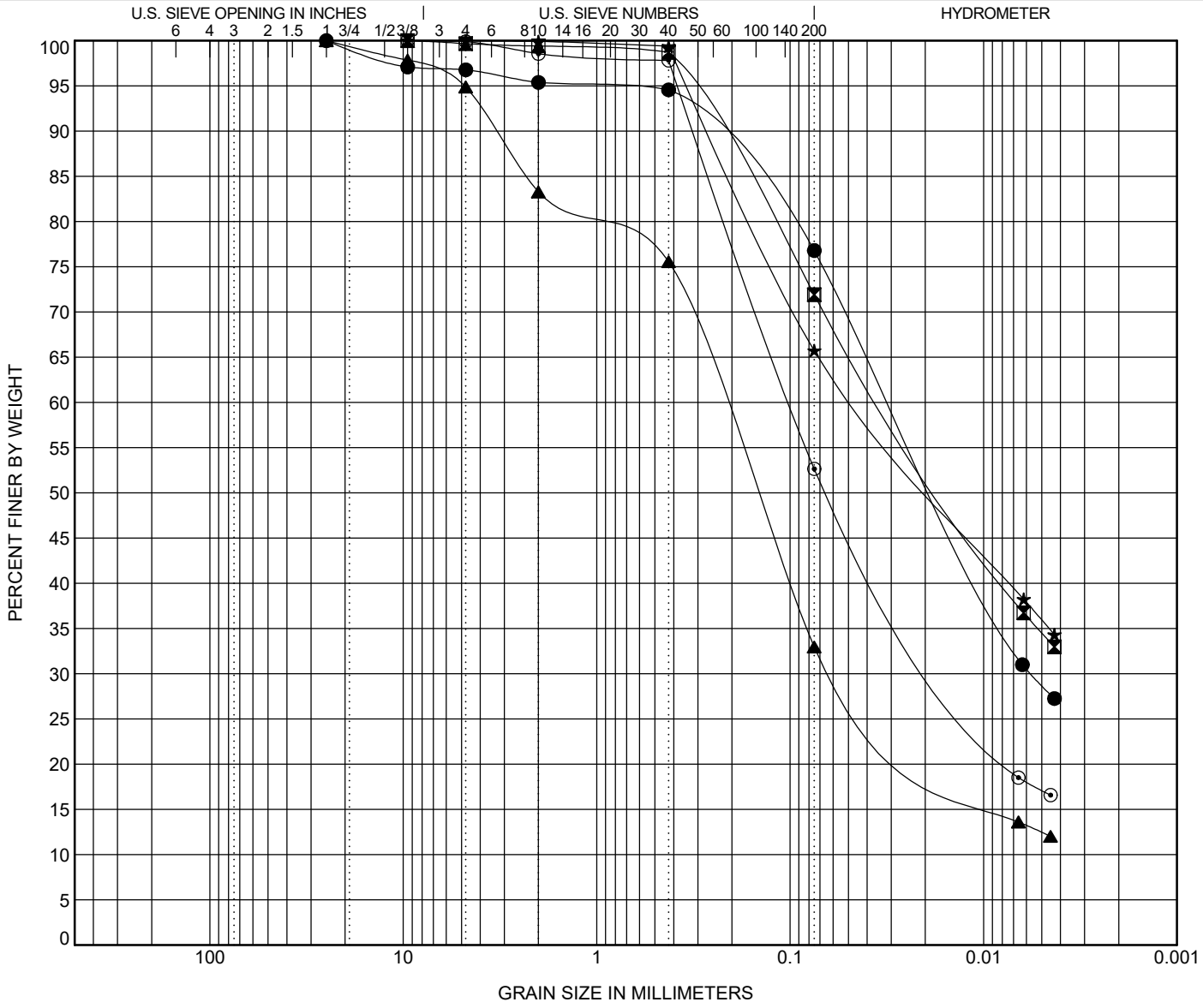
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GRAIN SIZE DISTRIBUTION

NDDOT North Dakota Department of Transportation
NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER SS-5-016(031)111 **LOCATION** Mckenzie County

PCN 23485



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	24.0	A-6 (11)	CL	34	18	16		
⊠	SB - 1	26.0	A-4 (5)	CL	29	19	10		
▲	SB - 1	29.0	A-2-4 (0)	SM	24	22	2		
★	SB - 1	31.0	A-6 (6)	CL	30	17	13		
⊙	SB - 1	34.0	A-4 (0)	CL-ML	25	21	4		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	24.0	25	0.03	0.006		3.2	20.0	76.8	
⊠	SB - 1	26.0	9.5	0.032			0.3	27.8	71.9	
▲	SB - 1	29.0	25	0.226	0.052		5.1	61.9	33.0	
★	SB - 1	31.0	9.5	0.045			0.0	34.3	65.7	
⊙	SB - 1	34.0	9.5	0.099	0.015		0.1	47.3	52.6	

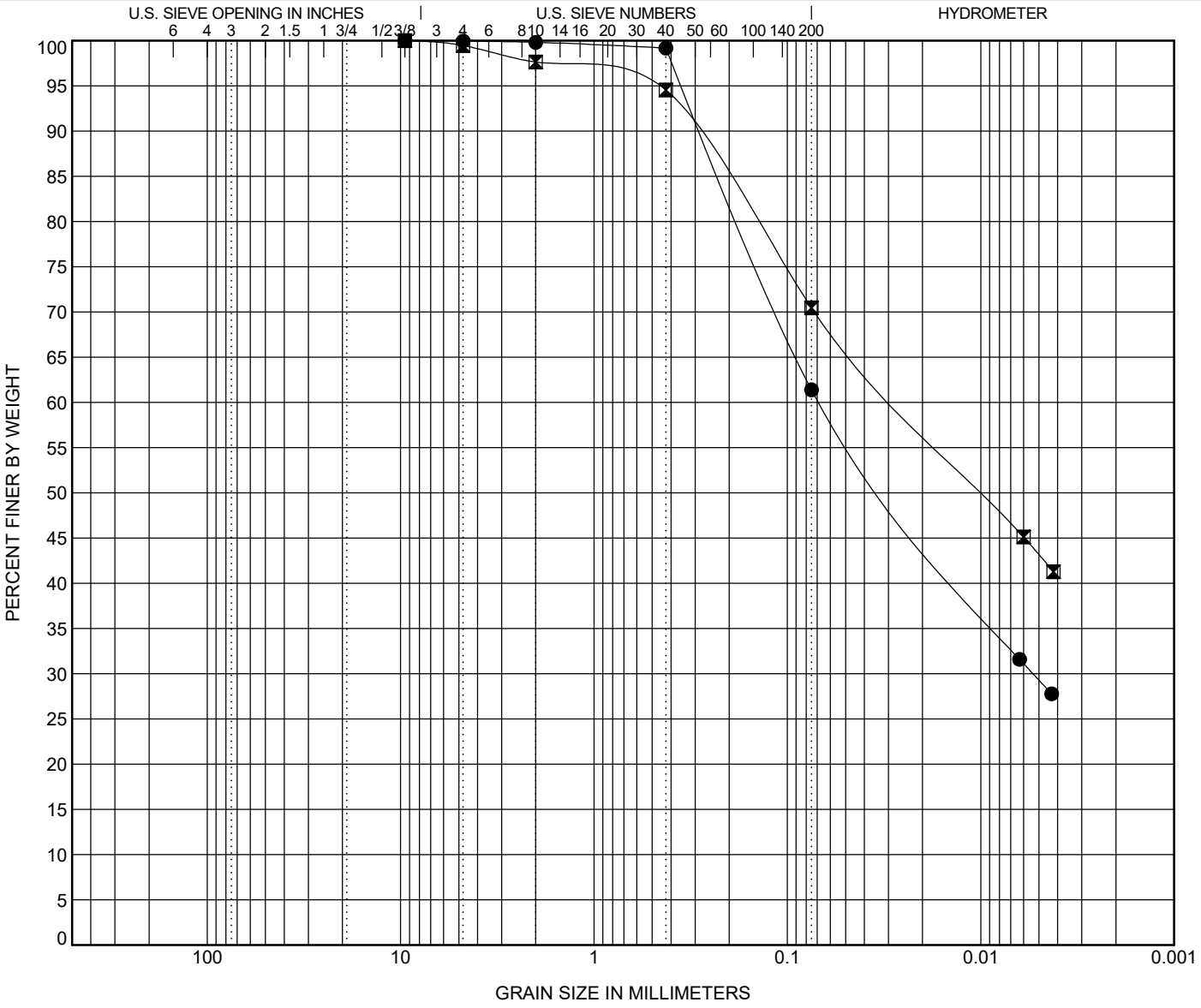
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GRAIN SIZE DISTRIBUTION

NORTH DAKOTA DEPARTMENT OF TRANSPORATION
300 AIRPORT ROAD
BISMARCK, ND 58504

PROJECT NUMBER SS-5-016(031)111 **LOCATION** Mckenzie County

PCN 23485



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	36.0	A-4 (2)	CL-ML	26	20	6		
⊠	SB - 1	40.0	A-6 (13)	CL	38	16	22		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	36.0	9.5	0.067	0.005		0.0	38.6	61.4	
⊠	SB - 1	40.0	9.5	0.026			0.5	29.0	70.5	

GRAIN SIZE - 20171219.GDT - 4/4/24 09:33 - F:\LAB\PROJECTS\GINT\5-016(031)111.GPJ

SUMMARY OF LABORATORY RESULTS

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
300 AIRPORT ROAD
BISMARCK, ND 58504

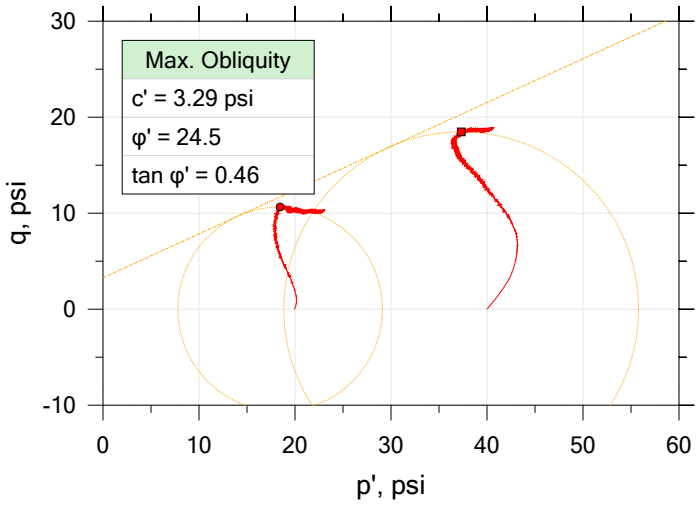
PROJECT NUMBER SS-5-016(031)111 **LOCATION** Mckenzie County

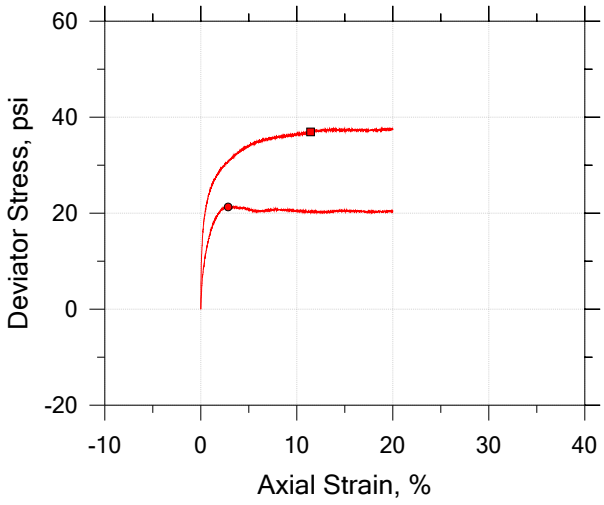
PCN 23485

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	AASHTO Classification	USCS Class-ification	Water Content (%)	Avg. Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
SB - 1	0.0	42	19	23	9.5	82	A-7-6 (19)	CL	10.9	10.9			
SB - 1	2.0	47	17	30	25	90	A-7-6 (28)	CL	24.3	24.3			
SB - 1	4.0	33	18	15	9.5	89	A-6 (13)	CL	22.8	22.8			
SB - 1	6.0	33	17	16	4.75	75	A-6 (10)	CL	25.3	25.3			
SB - 1	9.0	43	28	15	25	91	A-7-6 (16)	ML	20.1	20.1	100.0		
SB - 1	11.0	27	19	8	9.5	93	A-4 (6)	CL	14.6	14.6			
SB - 1	14.0	35	18	17	2	86	A-6 (14)	CL	16.2	16.2			
SB - 1	16.0	35	15	20	4.75	83	A-6 (15)	CL	18.8	18.8			
SB - 1	19.0	29	17	12	25	84	A-6 (8)	CL	20.1	20.1	109.7		
SB - 1	21.0	27	17	10	9.5	85	A-4 (7)	CL	22.4	22.4			
SB - 1	24.0	34	18	16	25	77	A-6 (11)	CL	26.4	26.4			
SB - 1	26.0	29	19	10	9.5	72	A-4 (5)	CL	21.3	21.3			
SB - 1	29.0	24	22	2	25	33	A-2-4 (0)	SM	31.1	31.1			
SB - 1	31.0	30	17	13	9.5	66	A-6 (6)	CL	27.1	27.1			
SB - 1	34.0	25	21	4	9.5	53	A-4 (0)	CL-ML	27.4	27.4			
SB - 1	36.0	26	20	6	9.5	61	A-4 (2)	CL-ML	25.2	25.2			
SB - 1	40.0	38	16	22	9.5	70	A-6 (13)	CL	28.6	28.6			

LAB SUMMARY - 20171219.GDT - 4/4/24 09:38 - F:\LAB\PROJECTS\GINT\5-016(031)111.GPJ

Consolidated Undrained by ASTM D4767



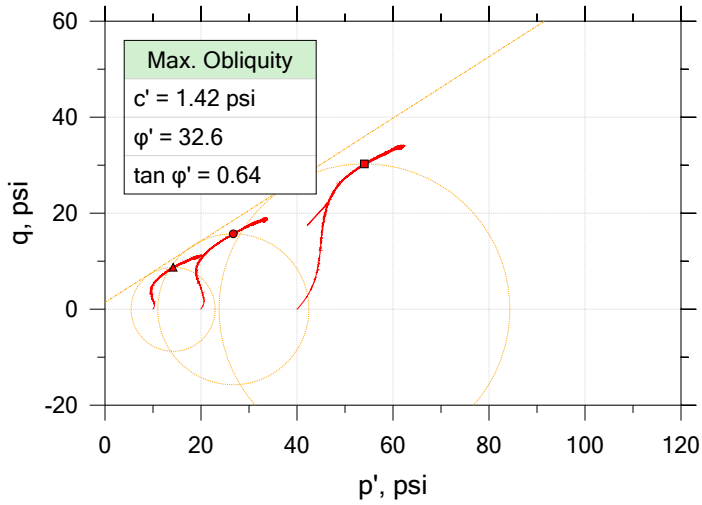


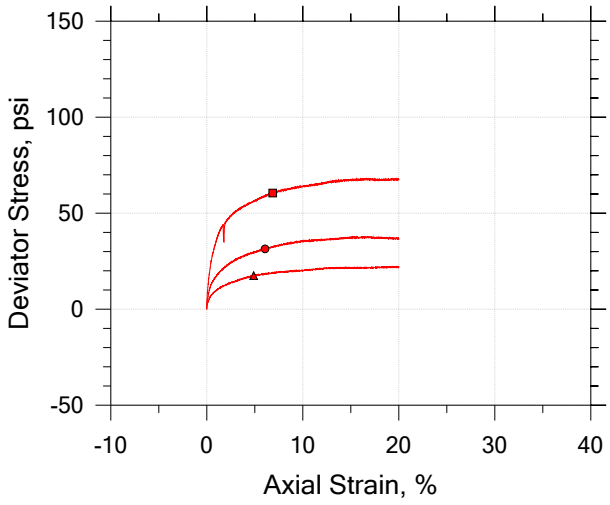
Symbol		■	●		
Sample ID		SS -410- 22	SS -410- 22		
Depth		9.0 - 11.0	9.0 - 11.0		
Test Number		CU -26- 22	CU -27- 22		
Initial	Height, in	2.799	2.800		
	Diameter, in	1.416	1.419		
	Moisture Content (from Cuttings), %	23.3	24.2		
	Dry Density, pcf	99.9	100.		
	Saturation (Wet Method), %	92.7	97.2		
	Void Ratio	0.674	0.668		
Final	Moisture Content, %	19.9	24.5		
	Dry Density, pcf	109.	101.		
	Cross-Sectional Area (Method A), in²	1.474	1.577		
	Saturation, %	100.0	100.0		
	Void Ratio	0.532	0.657		
	Back Pressure, psi	75.99	90.07		
Vertical Effective Consolidation Stress, psi		39.71	19.77		
Horizontal Effective Consolidation Stress, psi		40.01	19.94		
Vertical Strain after Consolidation, %		2.480	1.069		
Volumetric Strain after Consolidation, %		9.273	2.686		
Time to 50% Consolidation, min		0.0000	0.0000		
Shear Strength, psi		18.47	10.65		
Strain at Failure, %		11.4	2.85		
Strain Rate, %/min		0.0003000	0.0003000		
Deviator Stress at Failure, psi		36.95	21.30		
Effective Minor Principal Stress at Failure, psi		18.84	7.795		
Effective Major Principal Stress at Failure, psi		55.78	29.09		
B-Value		0.95	0.97		

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project Name: SS-5-016(031)116	Location:	Project Number:
	Boring Number: 1	Tester: MD	Checker: JL
	Sample Number: SS -410- 22	Test Date: 12/8/22	Depth: 9.0 - 11.0
	Test Number: CU -26- 22	Preparation:	Elevation:
	Description: 22" Brn Cly with silt Deposits, Scoria Rock up to 1/2", Organics		
	Remarks: Sample Test Depth 9.7-10.1		

Consolidated Undrained by ASTM D4767





Symbol		■	●	▲	
Sample ID		SS -414- 22	SS -414- 22	SS -414- 22	
Depth		19.0 - 21.0	19.0 - 21.0	19.0 - 21.0	
Test Number		CU -28- 22	CU -29- 22	CU -30- 22	
Initial	Height, in	2.797	2.802	2.771	
	Diameter, in	1.383	1.396	1.407	
	Moisture Content (from Cuttings), %	20.1	19.4	18.8	
	Dry Density, pcf	109.	109.	111.	
	Saturation (Wet Method), %	101.2	96.2	98.6	
	Void Ratio	0.533	0.541	0.511	
Final	Moisture Content, %	16.6	17.0	17.1	
	Dry Density, pcf	116.	115.	115.	
	Cross-Sectional Area (Method A), in²	1.434	1.458	1.506	
	Saturation, %	100.0	100.0	100.0	
	Void Ratio	0.444	0.456	0.458	
	Back Pressure, psi	44.00	87.97	96.00	
Vertical Effective Consolidation Stress, psi		39.79	19.90	9.920	
Horizontal Effective Consolidation Stress, psi		39.99	20.02	9.988	
Vertical Strain after Consolidation, %		1.382	0.7168	0.3340	
Volumetric Strain after Consolidation, %		5.965	5.333	3.479	
Time to 50% Consolidation, min		0.0000	0.0000	0.0000	
Shear Strength, psi		30.28	15.72	8.749	
Strain at Failure, %		6.87	6.08	4.89	
Strain Rate, %/min		0.0004000	0.0004000	0.0004000	
Deviator Stress at Failure, psi		60.56	31.45	17.50	
Effective Minor Principal Stress at Failure, psi		23.76	11.00	5.433	
Effective Major Principal Stress at Failure, psi		84.32	42.45	22.93	
B-Value		0.96	0.97	0.95	

Notes:
- Before Shear Saturation set to 100% for phase calculation.
- Moisture Content determined by ASTM D2216.
- Deviator Stress includes membrane correction.
- Values for c and φ determined from best-fit straight line for the specific test conditions. Actual strength parameters may vary and should be determined by an engineer for site conditions.

	Project Name: SS-5-016(031)116	Location:	Project Number:
	Boring Number: 1	Tester: MD	Checker: JL
	Sample Number: SS -414- 22	Test Date: 12/21/22	Depth: 19.0 - 21.0
	Test Number: CU -28- 22	Preparation:	Elevation:
	Description: 23" Brn Silty Cly with I.O. Deposits,(Very Silty)		
	Remarks: Sample Test Depth 19.5 - 19.8		