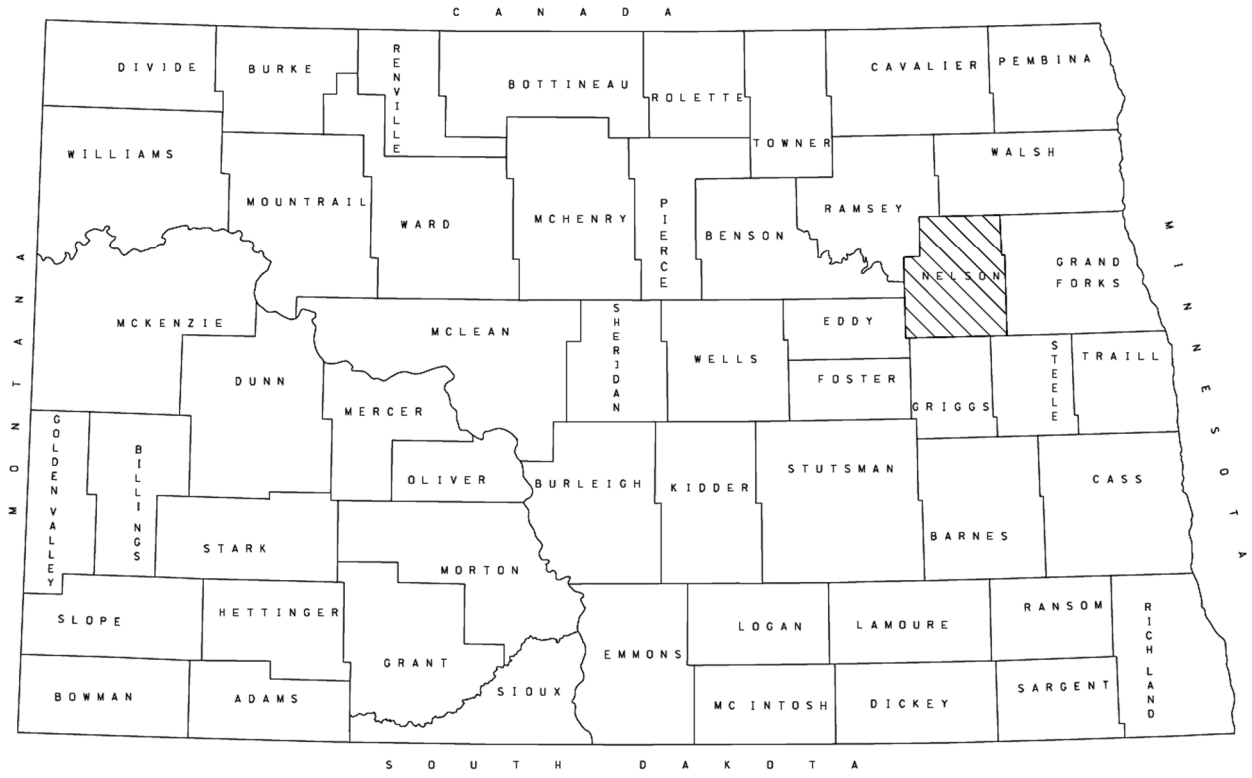
Deep Foundation Report and Analysis

PROJECT NO. BND-NH-6-002(134)313

PCN 22278

COUNTY Nelson

Bridge #: 0002-313.399L WB



PREPARED BY: Jared Loegering, PE

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION

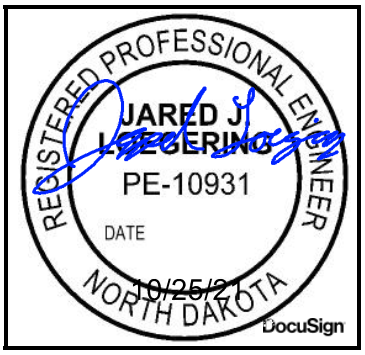
October 2021

BND-NH-6-002(134)313

1 Mile East of ND 32 South
Bridge #0002-313.399L Westbound

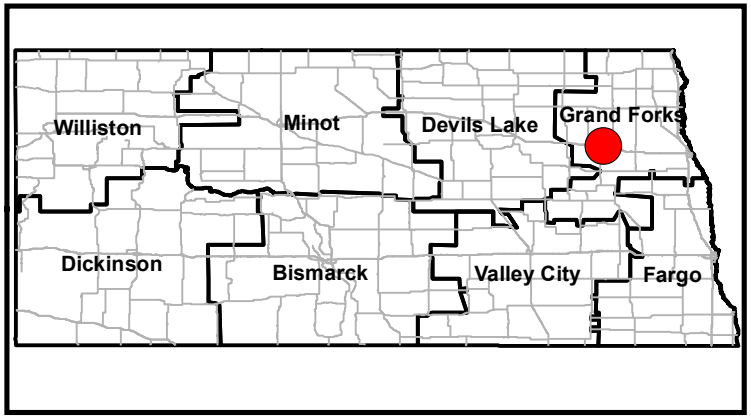
CERTIFICATION

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly registered professional engineer under the laws of the State of North Dakota. This document was originally issued and sealed by Jared J. Loegering, Registration number PE-10931 on 10/25/2021 and the original document is stored at the North Dakota Department of Transportation.



Petersburg Bridge
Deep Foundation Borings

Project: BND-NH-6-002(134)313
PCN: 22278
Bridge: 0002-313.399L WB
Scope: New Structure
Location: 1 East of ND 32 South



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Introduction

The purpose of the project is to address the existing deficiencies of the current structure by removing and replacing the bridge on a new alignment adjacent to the eastbound US 2 roadway.

This report will provide foundation, settlement and bridge end slope recommendations for the construction of the new structure.

Existing Structure Information

There is an existing bridge on US 2 that will be removed as part of the project. The information for this structure is below.

Bridge #0002-313.200 L
Main Structure Type: Steel Stringer
Length: 427'
Foundation Types: Abutments – Treated Timber Pile
Piers – Treated Timber Pile
Year Constructed: 1936

Soil Borings

A total of 2 borings were completed near the proposed structure. See the project location map for the boring locations.

Boring #1

Boring #1 has an elevation of approximately 1524 feet at the top of boring and is located near the proposed east abutment. This boring extends to a depth of 65 feet.

Boring #2

Boring #2 has an elevation of approximately 1519 feet at the top of boring and is located near the proposed west abutment. This boring extends to a depth of 62 feet.

Sampling and Testing Procedures:

Shelby tube sampling and split spoon sampling were used to extract the samples from a hollow stem auger.

Shelby tube sampling provides an "undisturbed" sample of fine-grained soils for laboratory testing via a thin wall tube that is slowly pushed into the soils to be sampled. Densities were calculated according to AASHTO test method T-296.

Split spoon samplers are utilized during advancement of the boring to perform the Standard Penetration Test (SPT). The samples are considered "disturbed", due to the

driving nature in which they are obtained. The SPT results in an N-value, or number of blows required to drive the split spoon sampler 1 foot. This N-value is used to estimate the friction angle of non-cohesive soils and define the consistency of cohesive soils.

For cohesive soils, the shear strength values were determined from the Unconsolidated Undrained and Consolidated Undrained tests utilizing Shelby tubes samples.

The samples from the split spoon and Shelby tubes are submitted to the laboratory for determination of AASHTO classification, moisture content, dry density, sieve analysis, and Atterberg limits.

Test Results

A summary of the lab analysis has been included in the Appendix B.

Proposed Structure

Main Structure Type: 3 Span
Foundation Type: Steel H-Piles

Foundation Recommendation

Steel Piling

Pile recommendations are given as termination elevations. The pile sizes that have been analyzed are HP10x42, HP12x53 and HP14x102. See table 3 below for the recommended termination elevations.

The software “APile” was used in conjunction with engineering judgment and past experience in pile driving in these types of soils to estimate the pile lengths. The output from this analysis is available upon request from the NDDOT Geotechnical Section.

Below are simplified soil profiles for each boring that was used to predict the unfactored nominal geotechnical resistance in APile. A graphical representation of the unfactored nominal geotechnical resistance is also shown below in figures 1-2. The nominal geotechnical resistance is used to help predict the pile termination elevations which can be found in table 3 below.

Table 1 - Boring #1 Simplified Soil Profile-East Approach Slab, Abutment & Pier

Layer	Depth (feet)	Elevation (feet)	Cohesion (lb/ft^2)	Friction Angle	Effective Unit Weight (lb/ft^3)
Stiff Brown/Gray Clay	0.0-24.00	1524.0-1500.0	c'=141 psf c=3136 psf	ϕ=31.3°	61.7
Loose Sand	24.0-34.0	1500.0-1490.0	-	ϕ=28°	67.6
Hard Gray Clay	34.0-39.0	1490.0-1485.0	c=3887 psf	-	62.6
Hard Gray Silty Sand	39.0-44.0	1485.0-1480.0	-	ϕ=45°	67.6
Hard Gray Silty Clay	44.0-65.0	1480.0-1459.0	c=4000 psf	-	62.6

Table 2 - Boring #2 Simplified Soil Profile-West Approach Slab, Abutment & Pier

Layer	Depth (feet)	Elevation (feet)	Cohesion (lb/ft^2)	Friction Angle	Effective Unit Weight (lb/ft^3)
Medium Stiff Brown/Gray Clay	0.0-26.0	1519.0-1493.0	c'=166 psf c=1575 psf	ϕ=29.5°	61.7
Loose Silty Sand	26.0-30.0	1493.0-1489.0	-	ϕ=28°	67.6
Hard Gray Silty Clay	30.0-39.0	1489.0-1480.0	c=3887 psf	-	62.6
Hard Gray Silty Sand	39.0-41.0	1480.0-1478.0	-	ϕ=45.0°	67.6
Hard Gray Clay	41.0-62.0	1478.0-1457.0	c=4000 psf	-	62.6

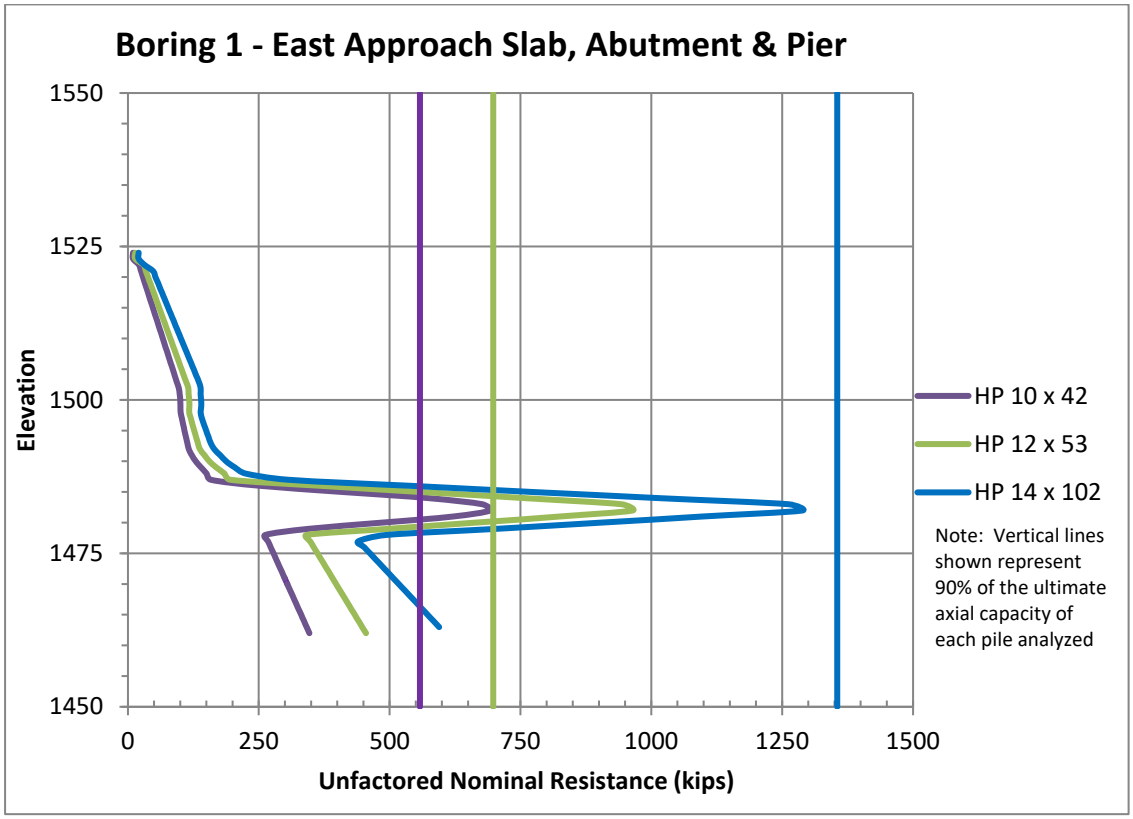


Figure 1: Nominal Resistance for Pile at East Approach Slab, Abutment & Pier

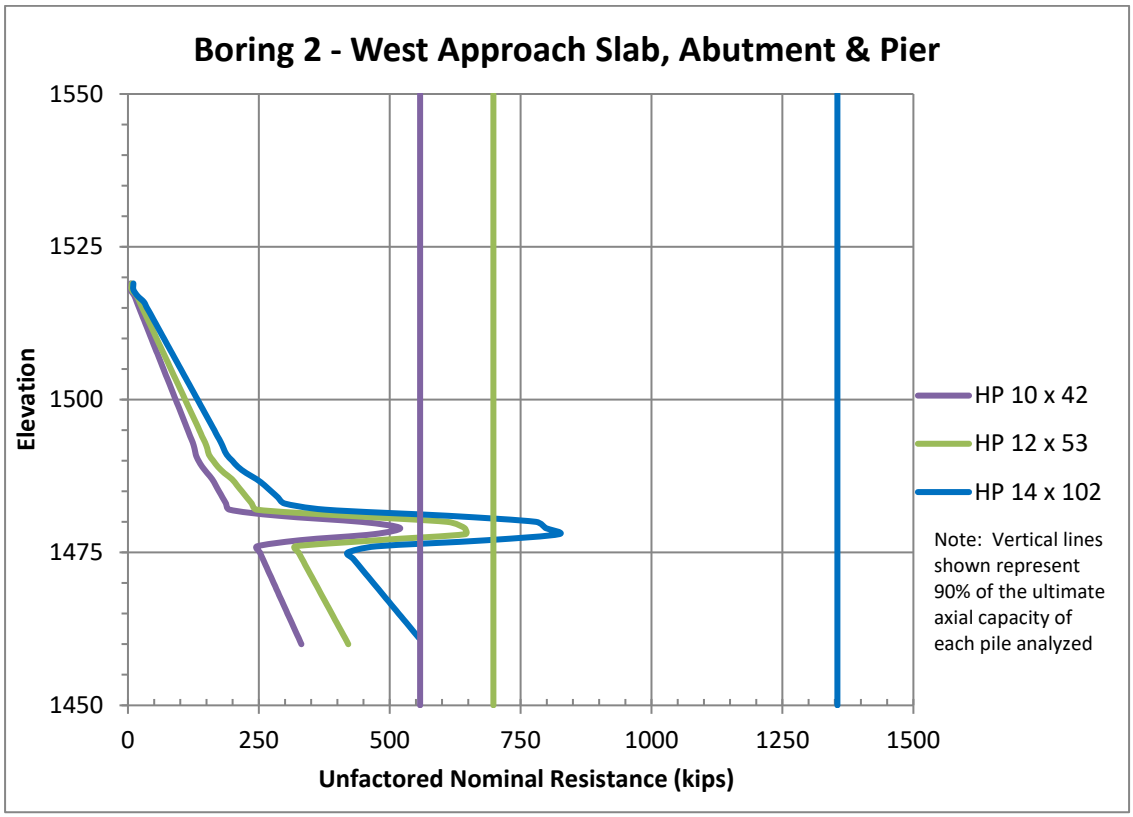


Figure 2: Nominal Resistance for Pile at West Approach Slab, Abutment & Pier

Based on the Apile information, past experience and engineering judgement the pile termination elevations were selected as shown in the table below.

Table 3 - Pile Length Information

Pile Type	90% Ultimate Axial Capacity	East Abutment/ Approach Slab	East Pier	West Pier	West Abutment/ Approach Slab
	kips	Termination Elevation	Termination Elevation	Termination Elevation	Termination Elevation
HP10x42	558	1463*	1463*	1463*	1463*
HP12x53	698	1463*	1463*	1463*	1463*
HP14x102	1355	1463*	1463*	1463*	1463*

*Based on engineering judgement/past experience

Pile Tips

It is not anticipated that pile tips will be required for this bridge.

Downdrag

The structure requires approximately 33’ of fill on the west and east abutments. Due to the proposed fill, a downdrag analysis was completed for the west and east abutment & approach slab piling. The unfactored down drag loads are shown in the table below.

Table 4 - Downdrag Loads

Location	Pile Size	Unfactored Downdrag Load (kips)
West Approach Slab Piling	HP10x42	160.5
West Abutment Piling	HP12x53	198.8
East Abutment Piling	HP12x53	178.8
East Approach Slab Piling	HP10x42	145.8

Scour

This is not a water crossing so scour is not applicable at this structure.

Compaction Recommendation

Compact roadway embankment material to at least 90 percent of the maximum dry density with moisture content no less than the optimum moisture and no more than 5.0 percentage points above the optimum moisture. The Engineer will determine the maximum dry density and optimum moisture content as specified in ND T 180.

Compact the aggregate transitions at the bridge ends according to section 714.04 A.7.

Slope Recommendation

A slope stability analysis was conducted with Slope/W developed by Geo-Slope International. The analysis was a two-dimensional limit equilibrium method. For the bridge end slopes the steepest slopes proposed were 2.5:1. The proposed slopes were analyzed, and an acceptable factor of safety was obtained. The stability analysis outputs can be found in Appendix C.

Drainage Recommendation

The drainage off the bridge should be controlled so that water does not drain directly off the bridge ends and cause erosion around the wing-wall. A combination of inlets, downdrains, and/or deckdrains should be used to control water runoff. Water should not be allowed to drain off the bridge as to allow the in slopes and end slopes to become saturated, which is a common cause of slope failure.

Settlement Analysis/Recommendation

Based on proposed cross section and profiles provided by the Design Division, the construction of the new bridge will require fills up to approximately 33 feet. Those locations are summarized in the table below:

Table 5 - Fill Locations

Location	Critical Station	Total Fill (feet)
West Abutment	457+01	33.0
East Abutment	460+21	32.0

A settlement analysis was completed based on one-dimensional consolidation tests performed on soil samples that were collected from the soil borings. Settlement calculations were completed using Settle 3D software. The table below shows the expected amount of settlement at the centerline of the roadway at each abutment:

Table 6 - Settlement Amounts

Location	Critical Station	Consolidation Settlement (in)
West Abutment	457+01	4.6
East Abutment	460+21	4.4

In order to remediate the expected settlement, it is recommended to place a 15’ surcharge on the roadway on both the west and east side of the roadway, starting at the abutments and extending approximately 1000’ on both the east and west side of the structure. It is expected that the surcharge will need to be in place for 9 months. The surcharge cannot be removed until directed by the NDDOT geotechnical section.

In order to ensure the stability of the embankment and existing ground during construction, the embankment needs to be built to the final roadway elevation and then left in place for a minimum of three weeks. This wait time will enable the increase of pore water pressures in the existing ground to dissipate. The proposed surcharge cannot be added to the embankment until directed by the NDDOT geotechnical section.

In order to monitor the amount of settlement, it is also recommended that settlement plates be placed at the locations shown in the table below:

Table 7 - Settlement Plate Locations

Station	Offset (feet)
456+00	22’ Lt
456+75	6’ Lt
456+75	22’ Lt
460+50	6’ Lt
460+50	22’ Lt
462+00	22’ Lt

Pre-Boring

Pre-Boring will be necessary for the piling at the east and west abutments and approach slabs. It is recommended to pre-bore through the proposed embankment and through the existing ground to the elevations shown in the table below:

Table 8 – Pre-boring Elevations

Location	Prebore Elevation
West Abutment/Approach Slab	1518
East Abutment/Approach Slab	1522

APPENDIX A

Boring Logs

LOG OF BORING SB - 1

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

PROJECT NUMBER BND-NH-6-002(134)313 **DATE STARTED** 9/3/19 **COMPLETED** 9/3/19

PCN 22278 **ELEVATION** 1524 ft

LOCATION Nelson County **RP+Feet** ft **Offset** 0

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

ENGINEER

NOTES East Side

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
	0	Topsoil 0.7 ft	A-7-6	CL	755	50	14	21 42	
		1523.3 ft	A-7-6	CL	756	65	15	20 44	
1520		Moist Stiff Brn/Tan Lean Cly	A-7-6	CL	757	65		19 42	γ_d = 101.0 pcf γ = 120.5 pcf CU=31.3°, c'=141 psf
			A-6	CL	758	85	14	18 38	
	10		A-6	CL	759	75		20 40	
			A-6	CL	760	90	13	17 38	
1510		1508.0 ft 16.0 ft	A-7-6	CL	761	90		20 42	γ_d = 105.0 pcf γ = 127.7 pcf UU=3136 psf
		Moist Stiff Gry Lean Cly	A-6	CL	762	90	16	17 39	
	20		A-6	CL	763	90		19 39	
			A-6	CL	764	70	10	19 34	
1500		1500.0 ft 24.0 ft							
		Water bearing Loose Gry Slty Snd	A-4	ML	765	75		0	
			A-2-4	SM	766	90	4	0	
	30	Possible rock, too hard to push, no sample.							
1490		1490.0 ft 34.0 ft							
		Moist Hard Gry Clayey Snd	A-6	SC	767	55	63	21 37	
			A-6	CL	768	50	59	21 32	
		1485.0 ft 39.0 ft							
	40	Moist Dense Gry Slty Snd	A-4	SM	769	85	47	0	
			A-2-4	SM	770	75	47	0	
1480		1480.0 ft 44.0 ft							
		Moist Hard Gry Slty Cly	A-7-5	MH	771	65	40	31 58	
			A-7-5	SM	772	25	42	30 53	
	50		A-7-5	SM	773	100	35	32 58	
			A-7-5	MH	774	70	41	31 57	
1470		1470.0 ft 54.0 ft							
		Moist Hard Gry Cly	A-6	CL	775	75	28	19 30	
			A-6	CL	776	90	42	20 36	
	60	1463.0 ft 61.0 ft	A-6	SC	777	100	34	19 34	
		Moist Hard Elastic Silt	A-7-5	MH	778	100		100 40 65	
1460		1459.0 ft 65.0 ft	A-7-5	MH	779	100		100 39 66	

Bottom of borehole at 65.0 ft

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

LOG OF BORING SB - 2

PROJECT NUMBER BND-NH-6-002(134)313 **DATE STARTED** 10/30/19 **COMPLETED** 10/30/19

PCN 22278 **ELEVATION** 1519 ft

LOCATION Nelson County **RP+Feet** ft **Offset** 0

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

ENGINEER

NOTES West Side

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	AASHTO	USCS	SAMPLE TYPE & NUMBER	RECOVERY (%)	SPT N VALUE	MC / PL / LL / CLAY FRACTION (%)	TESTS & REMARKS
	0	Topsoil 0.5 ft							
1518.5		1518.5 ft							
		Moist Medium Stiff Brn Lean Cly	A-6	CL	1079	75		18 37	
			A-6	CL	1080	50	4	19 38	
1510	10		A-7-6	CL	1081	75		20 43	Con-33-19
			A-7-6	CL	1082	85	15	20 42	
		1506.0 ft 13.0 ft							
		Moist Medium Stiff Gry Lean Cly	A-6	CL	1083	85		19 38	Con-34-19 UU=1369 psf
			A-6	CL	1084	100	8	17 37	
1500	20		A-6	CL	1085	85		18 37	CU=29.5°, c'=166 psf
			A-6	CL	1086	75	8	18 36	
		1493.0 ft 26.0 ft	A-6	CL	1087	100		21 35	Con-35-19 UU=1781 psf
		Water Bearing Loose Slty Snd	A-4	SM	1088	75	6	0	
1490		1489.0 ft 30.0 ft	A-4	SM	1089	100		0	
	30	Moist Hard Gry Slty Cly	A-7-5	ML	1090	75	28	32 45	UU=3887 psf
			A-6	CL	1091	75	39	20 40	
			A-7-5	MH	1092	70	33	32 56	
1480		1480.0 ft 39.0 ft							
	40	Water Bearing Hard Gry Slty Snd 41.0 ft	A-4	ML	1093	75	56	0	
		1478.0 ft							
		Moist Very Stiff to Hard Gry Silty Cly	A-6	CL	1094	90	16	20 40	
			A-7-6	CH	1095	75	25	28 51	
			A-7-5	MH	1096	90	30	42 64	
1470	50		A-7-5	MH	1097	85	68	40 67	
			A-7-5	SM	1098	75	45	35 62	
		1463.0 ft 56.0 ft	A-7-6	CH	1099	85	49	29 55	
		Moist Hard Gry Elastic Silt	A-7-5	MH	1100	100		100 39 64	
1460	60		A-7-5	MH	1101	100		100 42 66	
		1457.0 ft 62.0 ft	A-7-5	MH	1102	100		100 40 62	

Bottom of borehole at 62.0 ft

APPENDIX B

Lab Results

SUMMARY OF LABORATORY RESULTS

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

PROJECT NUMBER BND-NH-6-002(134)313 **LOCATION** Nelson County

PCN 22278

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	21	21	9.5	58	A-7-6 (10)	CL	12.7	12.7			
SB - 1	2.0	44	20	24	25	66	A-7-6 (14)	CL	22.7	22.7			
SB - 1	4.0	42	19	23	25	56	A-7-6 (10)	CL	19.4	19.4	101.0		
SB - 1	6.0	38	18	20	9.5	59	A-6 (9)	CL	22.0	22.0			
SB - 1	9.0	40	20	20	25	60	A-6 (10)	CL	21.9	21.9			
SB - 1	11.0	38	17	21	9.5	58	A-6 (9)	CL	18.5	18.5			
SB - 1	14.0	42	20	22	25	56	A-7-6 (9)	CL	21.6	21.6	105.0		
SB - 1	16.0	39	17	22	9.5	59	A-6 (10)	CL	20.6	20.6			
SB - 1	19.0	39	19	20	25	60	A-6 (9)	CL	21.4	21.4			
SB - 1	21.0	34	19	15	9.5	56	A-6 (6)	CL	19.4	19.4			
SB - 1	24.0	NP	NP	NP	25	52	A-4 (0)	ML	25.3	25.3			
SB - 1	26.0	NP	NP	NP	25	13	A-2-4 (0)	SM	27.8	27.8			
SB - 1	34.0	37	21	16	9.5	45	A-6 (4)	SC	13.2	13.2			
SB - 1	36.0	32	21	11	25	51	A-6 (3)	CL	19.9	19.9			
SB - 1	39.0	NP	NP	NP	9.5	37	A-4 (0)	SM	23.2	23.2			
SB - 1	41.0	NP	NP	NP	9.5	26	A-2-4 (0)	SM	24.9	24.9			
SB - 1	44.0	58	31	27	9.5	50	A-7-5 (10)	MH	25.7	25.7			
SB - 1	46.0	53	30	23	9.5	47	A-7-5 (7)	SM	30.6	30.6			
SB - 1	49.0	58	32	26	9.5	50	A-7-5 (10)	SM	28.8	28.8			
SB - 1	51.0	57	31	26	9.5	55	A-7-5 (12)	MH	34.8	34.8			
SB - 1	54.0	30	19	11	9.5	50	A-6 (3)	CL	19.2	19.2			
SB - 1	56.0	36	20	16	9.5	54	A-6 (6)	CL	22.3	22.3			
SB - 1	59.0	34	19	15	9.5	44	A-6 (3)	SC	24.4	24.4			
SB - 1	61.0	65	40	25	4.75	63	A-7-5 (16)	MH	27.3	27.3			
SB - 1	64.0	66	39	27	9.5	56	A-7-5 (14)	MH	36.9	36.9			
SB - 2	4.0	37	18	19	9.5	64	A-6 (10)	CL	25.7	25.7			
SB - 2	6.0	38	19	19	9.5	56	A-6 (8)	CL	24.7	24.7			
SB - 2	9.0	43	20	23	9.5	60	A-7-6 (11)	CL	20.2	20.2			
SB - 2	11.0	42	20	22	9.5	58	A-7-6 (10)	CL	22.5	22.5			
SB - 2	14.0	38	19	19	25	57	A-6 (8)	CL	20.3	20.3			
SB - 2	16.0	37	17	20	9.5	59	A-6 (9)	CL	21.9	21.9			
SB - 2	19.0	37	18	19	25	57	A-6 (8)	CL	21.0	21.0			
SB - 2	21.0	36	18	18	9.5	58	A-6 (8)	CL	23.1	23.1			
SB - 2	24.0	35	21	14	25	54	A-6 (5)	CL	19.5	19.5			
SB - 2	26.0	NP	NP	NP	25	37	A-4 (0)	SM	30.1	30.1			
SB - 2	29.0	NP	NP	NP	25	41	A-4 (0)	SM	26.2	26.2			
SB - 2	30.0	45	32	13	9.5	51	A-7-5 (5)	ML	29.7	29.7			
SB - 2	34.0	40	20	20	25	51	A-6 (7)	CL	18.0	18.0			
SB - 2	36.0	56	32	24	9.5	55	A-7-5 (11)	MH	35.0	35.0			
SB - 2	39.0	NP	NP	NP	9.5	61	A-4 (0)	ML	26.7	26.7			
SB - 2	41.0	40	20	20	9.5	66	A-6 (11)	CL	23.0	23.0			
SB - 2	44.0	51	28	23	50	53	A-7-6 (10)	CH	36.2	36.2			
SB - 2	46.0	64	42	22	9.5	50	A-7-5 (9)	MH	37.2	37.2			

SUMMARY OF LABORATORY RESULTS

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

PROJECT NUMBER BND-NH-6-002(134)313 **LOCATION** Nelson County

PCN 22278

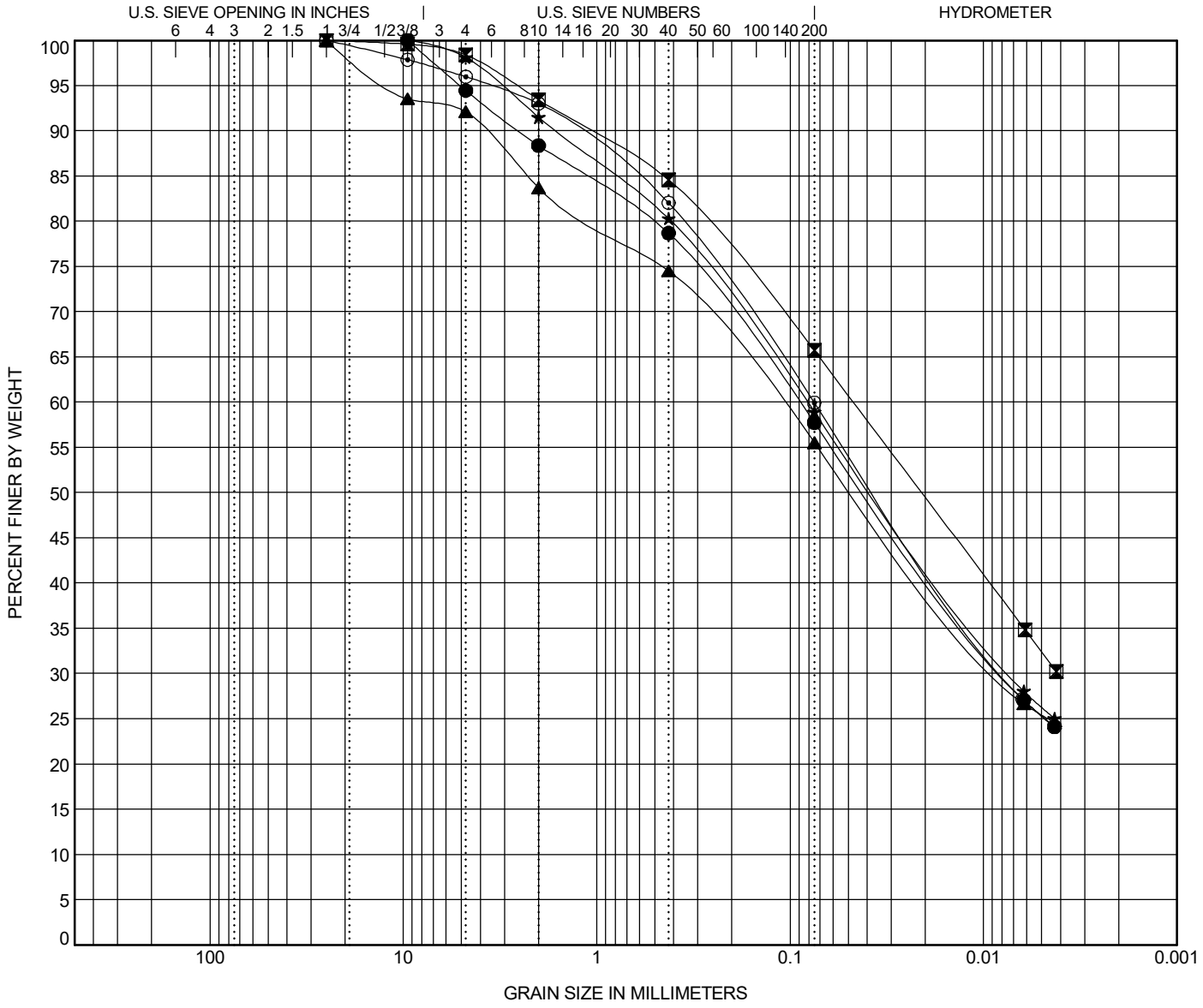
Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	AASHTO Classification	USCS Class-ification	Water Content (%)	Avg. Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
SB - 2	49.0	67	40	27	9.5	55	A-7-5 (14)	MH	35.1	35.1			
SB - 2	51.0	62	35	27	9.5	48	A-7-5 (10)	SM	33.0	33.0			
SB - 2	54.0	55	29	26	25	51	A-7-6 (10)	CH	22.4	22.4			
SB - 2	56.0	64	39	25	4.75	58	A-7-5 (14)	MH	30.7	30.7			
SB - 2	59.0	66	42	24	9.5	53	A-7-5 (11)	MH	32.5	32.5			
SB - 2	61.0	62	40	22	9.5	52	A-7-5 (10)	MH	30.6	30.6			

GRAIN SIZE DISTRIBUTION

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

PROJECT NUMBER BND-NH-6-002(134)313 **LOCATION** Nelson County

PCN 22278



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 (10)	CL	42	21	21		
⊠	SB - 1	2.0	A-7-6 (14)	CL	44	20	24		
▲	SB - 1	4.0	A-7-6 (10)	CL	42	19	23		
★	SB - 1	6.0	A-6 (9)	CL	38	18	20		
⊙	SB - 1	9.0	A-6 (10)	CL	40	20	20		

BOREHOLE		DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	0.0	9.5	0.091	0.008		5.5	36.7	57.7	
⊠	SB - 1	2.0	25	0.047			1.6	32.7	65.7	
▲	SB - 1	4.0	25	0.113	0.008		7.9	36.6	55.5	
★	SB - 1	6.0	9.5	0.082	0.007		1.9	39.2	58.9	
⊙	SB - 1	9.0	25	0.075	0.008		4.0	36.0	59.9	

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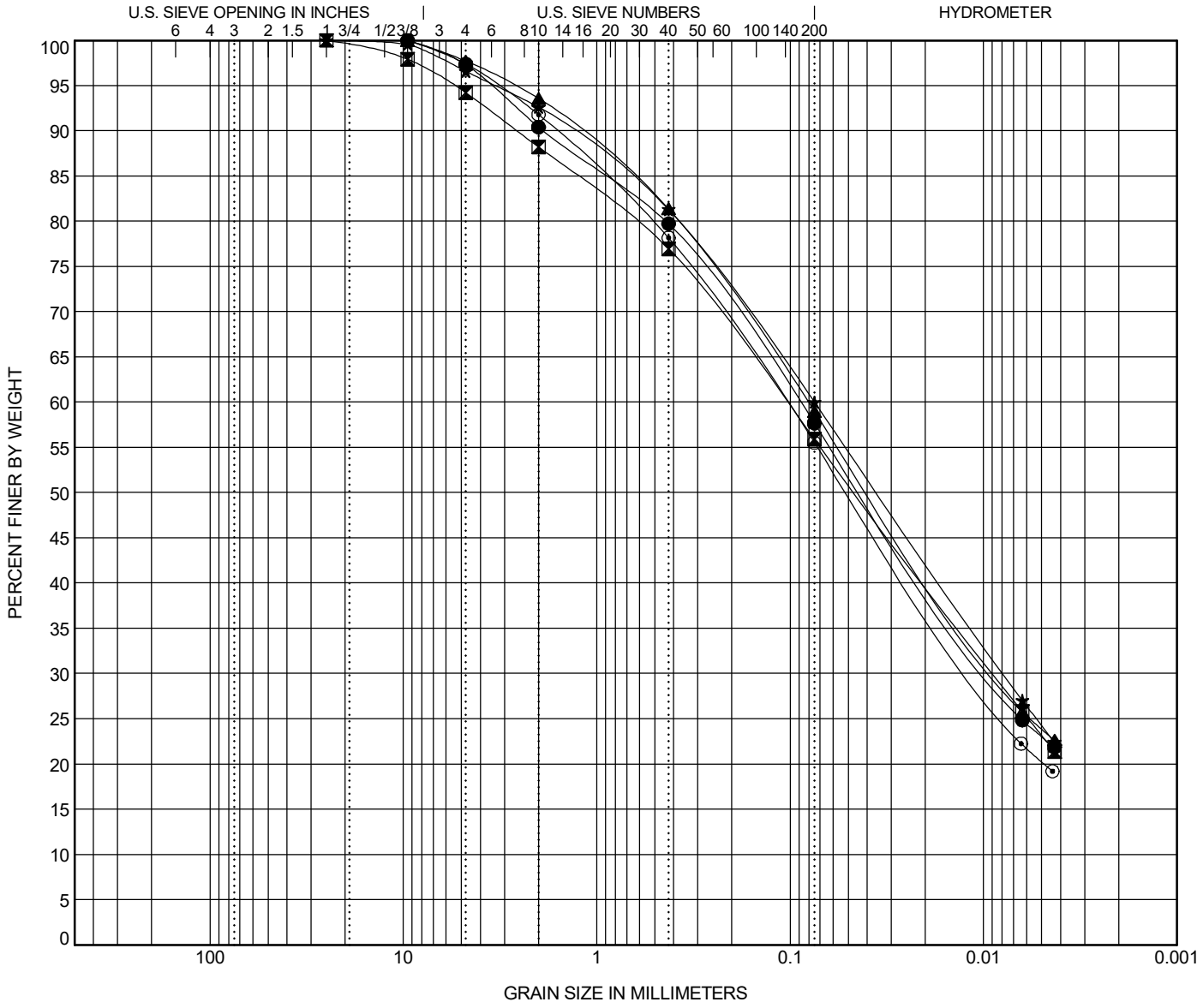

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	11.0	A-6 (9)	CL	38	17	21		
⊠	SB - 1	14.0	A-7-6 (9)	CL	42	20	22		
▲	SB - 1	16.0	A-6 (10)	CL	39	17	22		
★	SB - 1	19.0	A-6 (9)	CL	39	19	20		
⊙	SB - 1	21.0	A-6 (6)	CL	34	19	15		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	11.0	9.5	0.09	0.009		2.7	39.7	57.7	
⊠	SB - 1	14.0	25	0.105	0.009		5.8	38.3	55.9	
▲	SB - 1	16.0	9.5	0.081	0.009		2.3	38.8	59.0	
★	SB - 1	19.0	25	0.075	0.008		3.4	36.6	60.0	
⊙	SB - 1	21.0	9.5	0.106	0.011		2.6	41.9	55.5	

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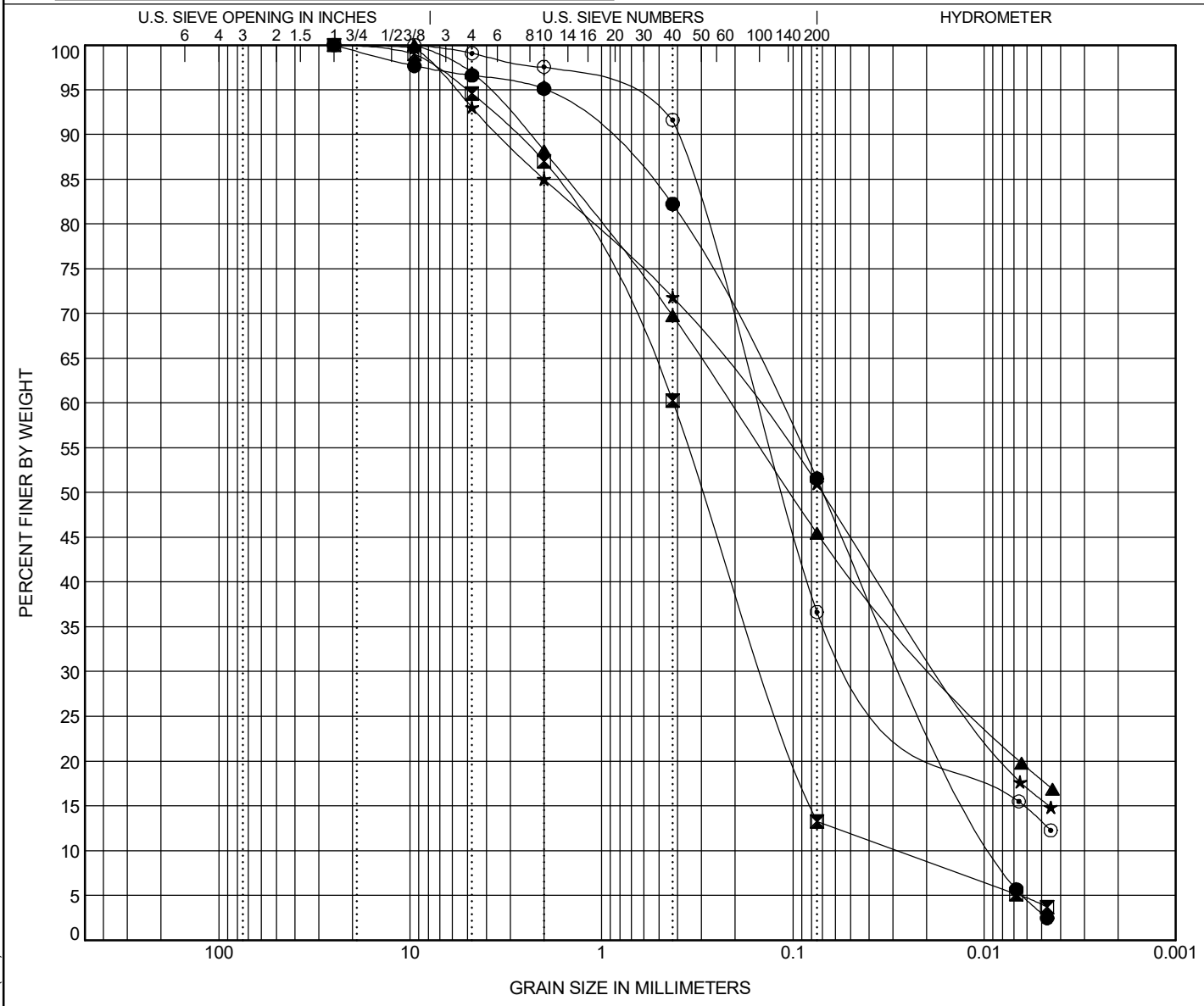

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
● SB - 1	24.0	A-4 (0)	ML	NP	NP	NP	0.57	14.16
⊠ SB - 1	26.0	A-2-4 (0)	SM	NP	NP	NP	1.61	14.71
▲ SB - 1	34.0	A-6 (4)	SC	37	21	16		
★ SB - 1	36.0	A-6 (3)	CL	32	21	11		
⊙ SB - 1	39.0	A-4 (0)	SM	NP	NP	NP		

BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB - 1	24.0	25	0.121	0.024	0.009	3.4	45.1	51.5	
⊠ SB - 1	26.0	25	0.421	0.139	0.029	5.4	81.3	13.3	
▲ SB - 1	34.0	9.5	0.212	0.017		3.1	51.5	45.5	
★ SB - 1	36.0	25	0.159	0.016		7.0	42.0	51.0	
⊙ SB - 1	39.0	9.5	0.157	0.035		0.9	62.4	36.7	

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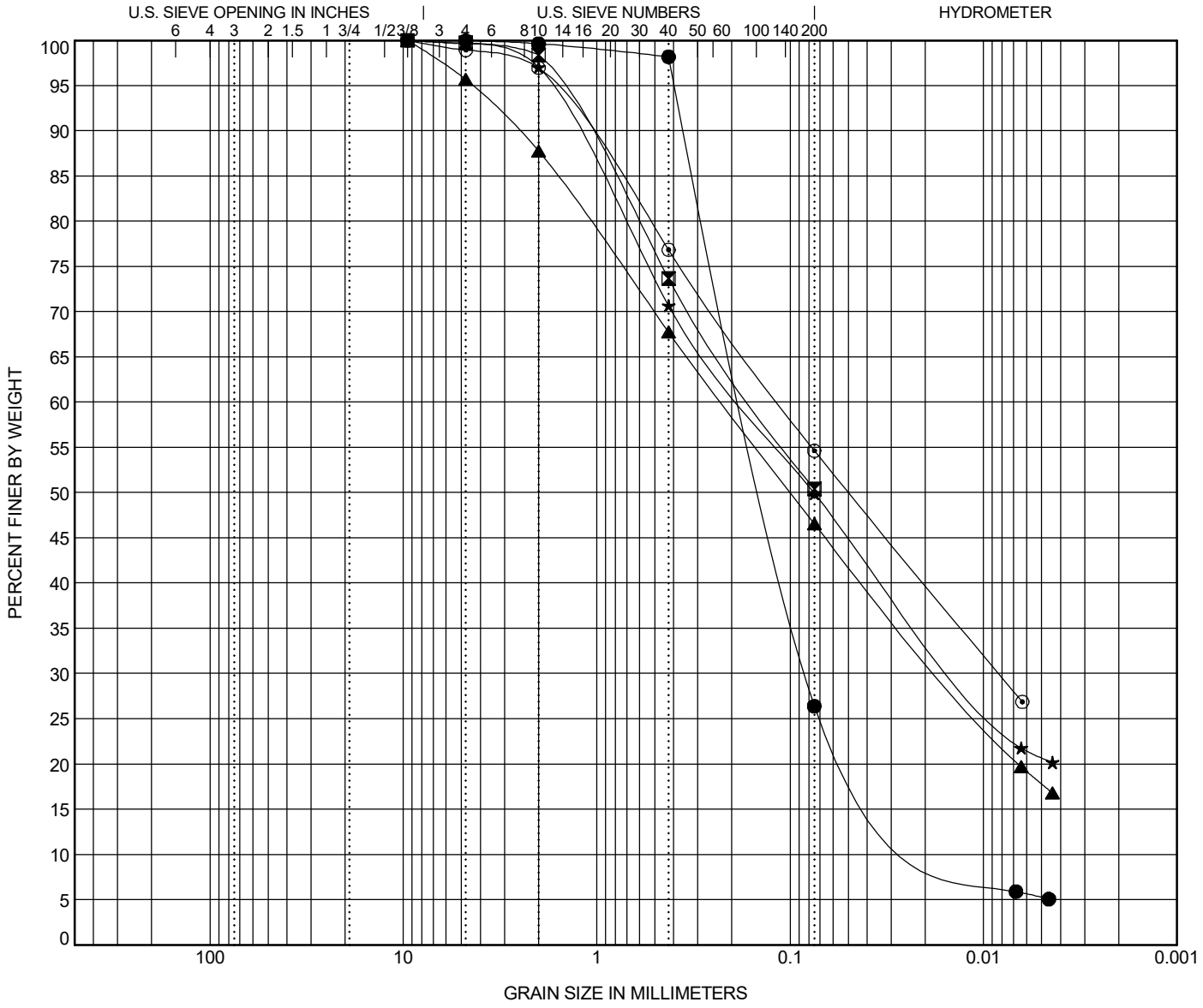

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	41.0	A-2-4 (0)	SM	NP	NP	NP	3.60	15.32
⊠	SB - 1	44.0	A-7-5 (10)	MH	58	31	27		
▲	SB - 1	46.0	A-7-5 (7)	SM	53	30	23		
★	SB - 1	49.0	A-7-5 (10)	SM	58	32	26		
⊙	SB - 1	51.0	A-7-5 (12)	MH	57	31	26		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	41.0	9.5	0.169	0.082	0.011	0.0	73.6	26.4	
⊠	SB - 1	44.0	9.5	0.154			0.3	49.3	50.4	
▲	SB - 1	46.0	9.5	0.226	0.016		4.3	49.1	46.5	
★	SB - 1	49.0	9.5	0.174	0.013		0.4	49.7	49.9	
⊙	SB - 1	51.0	9.5	0.114	0.008		1.1	44.3	54.6	

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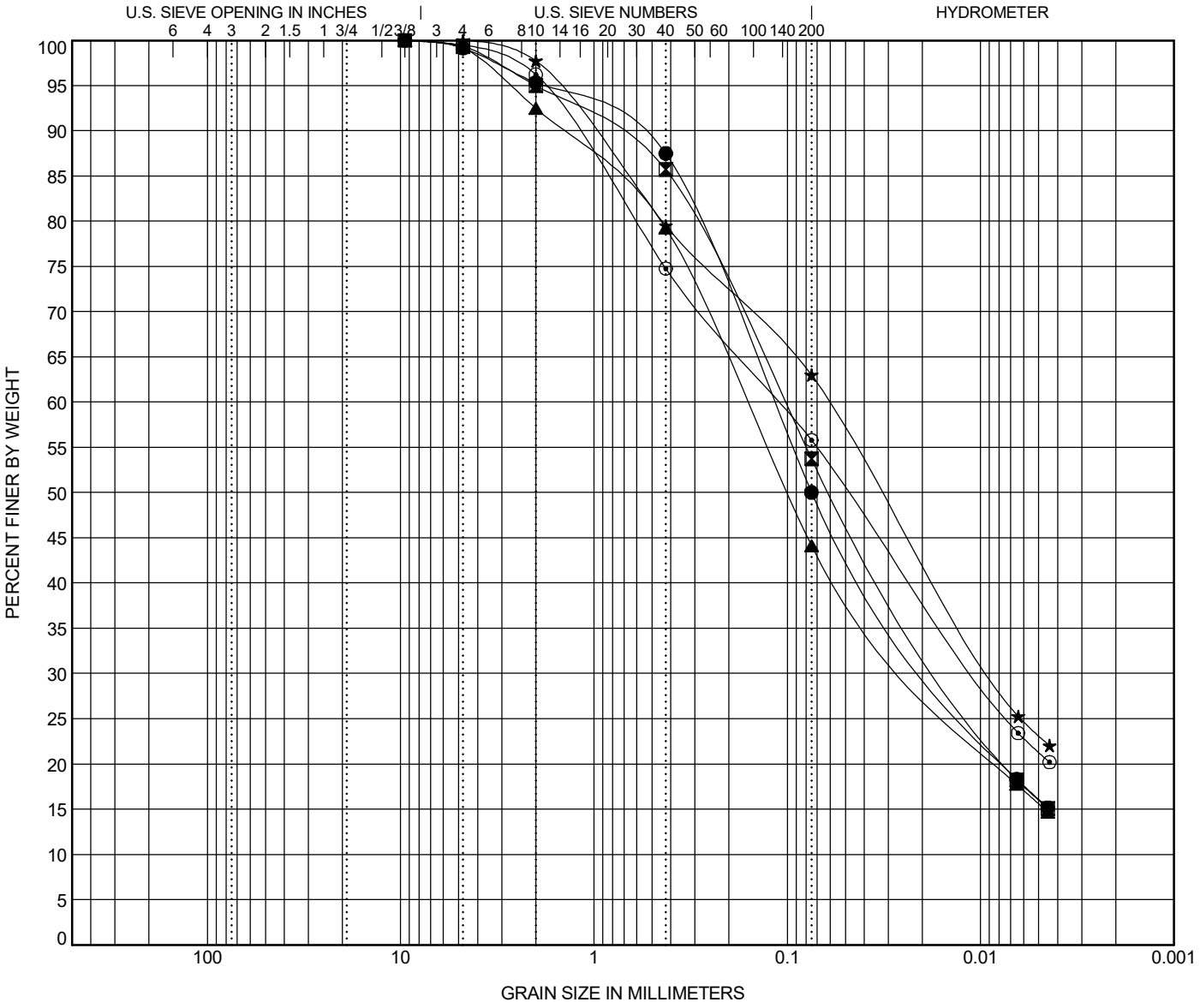

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 1	54.0	A-6 (3)	CL	30	19	11		
⊠	SB - 1	56.0	A-6 (6)	CL	36	20	16		
▲	SB - 1	59.0	A-6 (3)	SC	34	19	15		
★	SB - 1	61.0	A-7-5 (16)	MH	65	40	25		
⊙	SB - 1	64.0	A-7-5 (14)	MH	66	39	27		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 1	54.0	9.5	0.119	0.016		0.9	49.1	50.0	
⊠	SB - 1	56.0	9.5	0.105	0.015		0.6	45.6	53.7	
▲	SB - 1	59.0	9.5	0.164	0.02		0.8	55.1	44.1	
★	SB - 1	61.0	4.75	0.062	0.009		0.0	37.0	63.0	
⊙	SB - 1	64.0	9.5	0.11	0.011		0.5	43.7	55.8	

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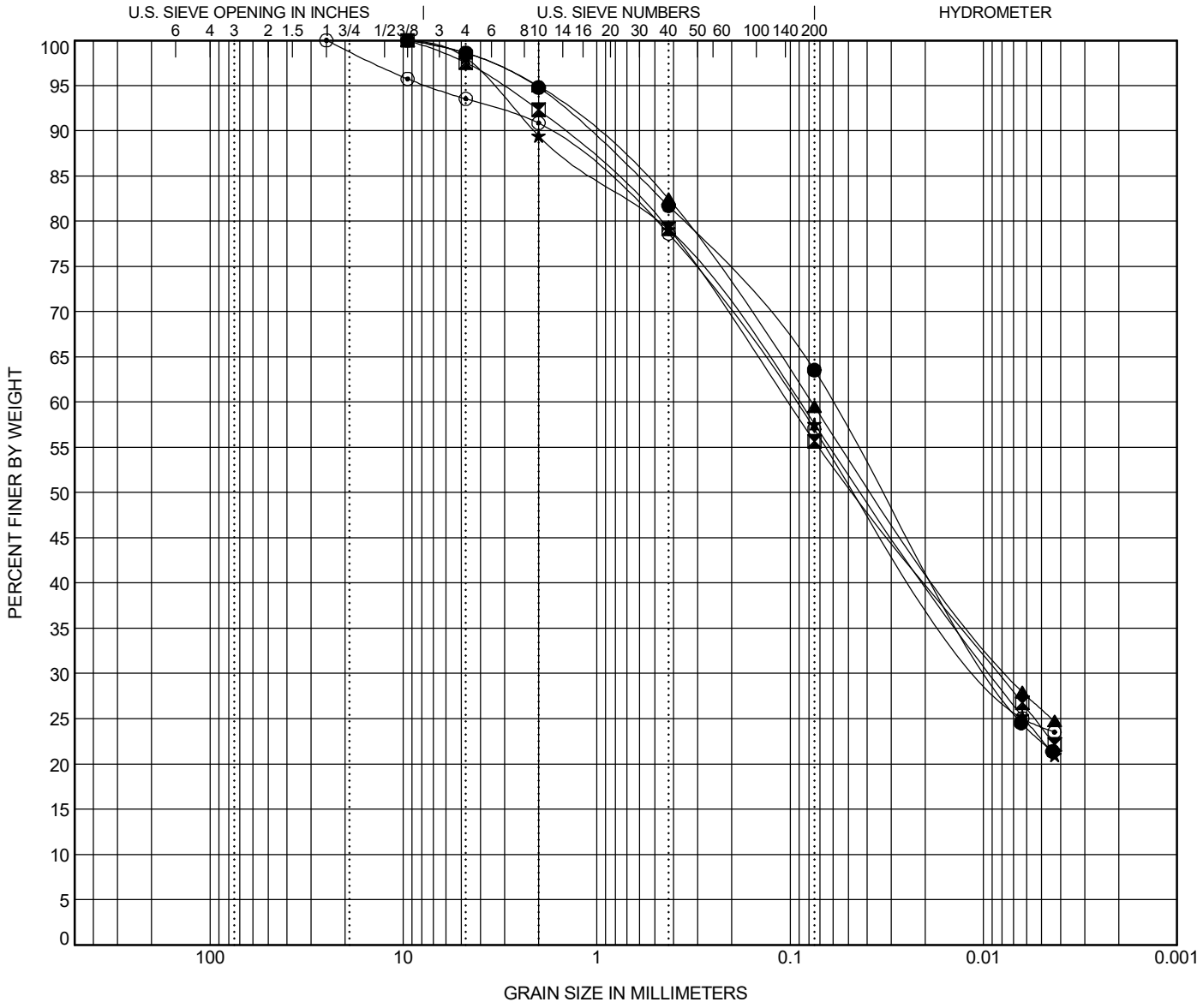

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 2	4.0	A-6 (10)	CL	37	18	19		
⊠	SB - 2	6.0	A-6 (8)	CL	38	19	19		
▲	SB - 2	9.0	A-7-6 (11)	CL	43	20	23		
★	SB - 2	11.0	A-7-6 (10)	CL	42	20	22		
⊙	SB - 2	14.0	A-6 (8)	CL	38	19	19		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 2	4.0	9.5	0.06	0.009		1.4	35.1	63.5	
⊠	SB - 2	6.0	9.5	0.103	0.008		2.5	41.9	55.7	
▲	SB - 2	9.0	9.5	0.078	0.007		1.4	39.1	59.5	
★	SB - 2	11.0	9.5	0.091	0.009		1.9	40.5	57.6	
⊙	SB - 2	14.0	25	0.095	0.009		6.5	36.5	57.0	

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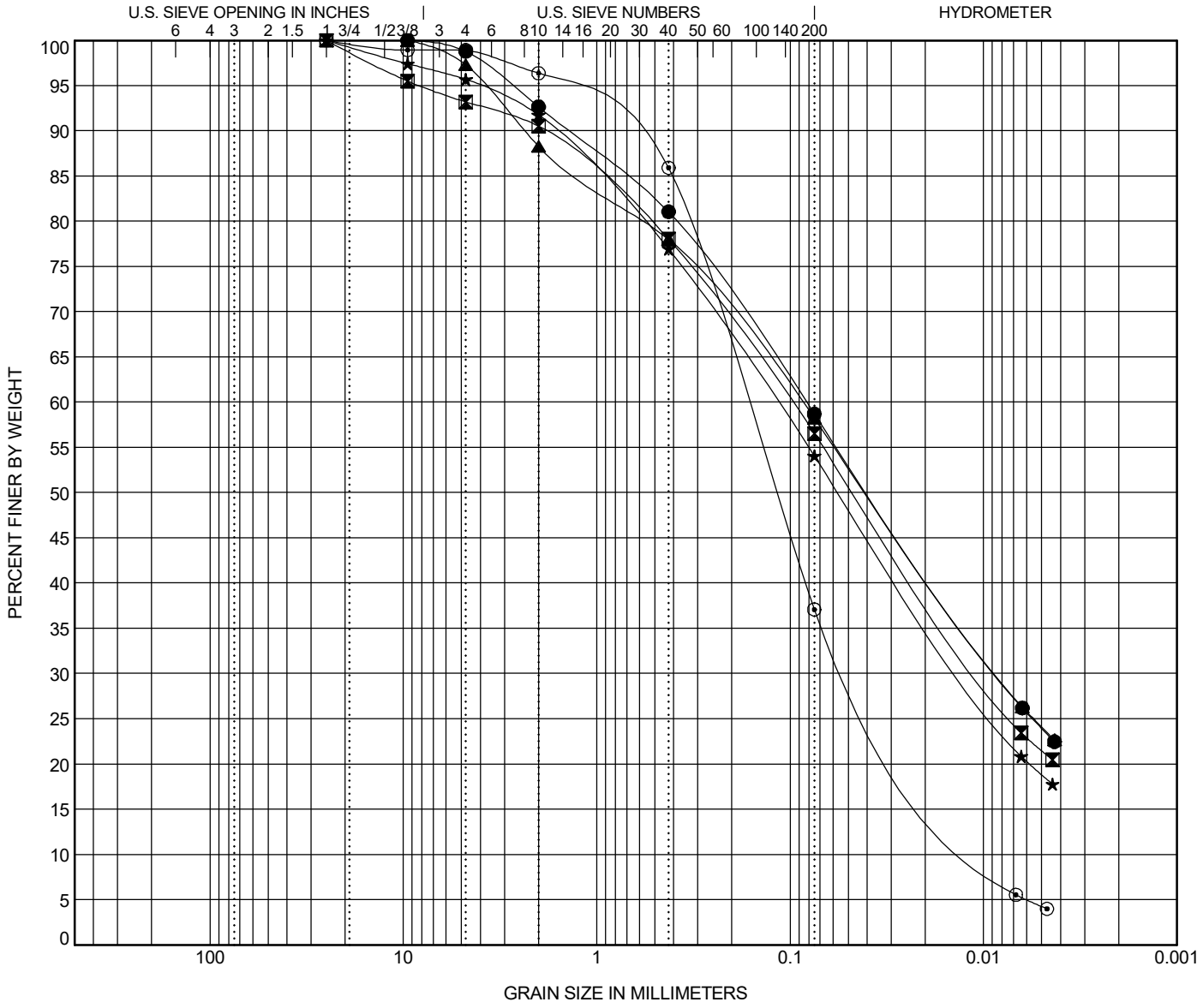

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
● SB - 2	16.0	A-6 (9)	CL	37	17	20		
⊠ SB - 2	19.0	A-6 (8)	CL	37	18	19		
▲ SB - 2	21.0	A-6 (8)	CL	36	18	18		
★ SB - 2	24.0	A-6 (5)	CL	35	21	14		
⊙ SB - 2	26.0	A-4 (0)	SM	NP	NP	NP	1.18	17.71

BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB - 2	16.0	9.5	0.083	0.008		1.2	40.1	58.7	
⊠ SB - 2	19.0	25	0.099	0.01		6.8	36.7	56.5	
▲ SB - 2	21.0	9.5	0.088	0.008		2.7	39.1	58.2	
★ SB - 2	24.0	25	0.118	0.013		4.3	41.6	54.1	
⊙ SB - 2	26.0	25	0.169	0.044	0.01	1.1	61.9	37.1	

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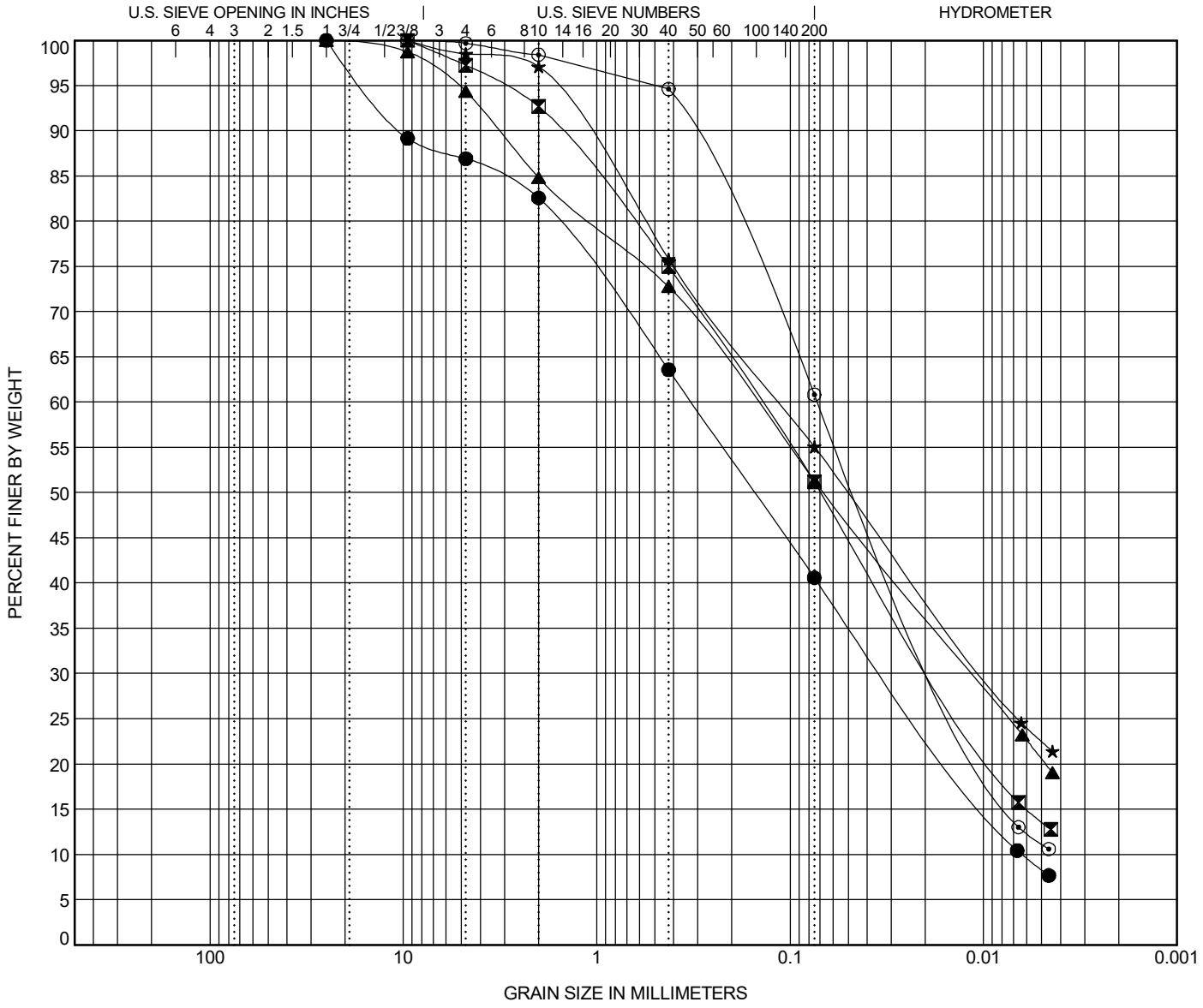

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
● SB - 2	29.0	A-4 (0)	SM	NP	NP	NP	0.50	51.23
⊠ SB - 2	30.0	A-7-5 (5)	ML	45	32	13		
▲ SB - 2	34.0	A-6 (7)	CL	40	20	20		
★ SB - 2	36.0	A-7-5 (11)	MH	56	32	24		
⊙ SB - 2	39.0	A-4 (0)	ML	NP	NP	NP		

BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB - 2	29.0	25	0.324	0.032	0.006	13.1	46.3	40.6	
⊠ SB - 2	30.0	9.5	0.143	0.018		2.7	46.1	51.2	
▲ SB - 2	34.0	25	0.152	0.011		5.6	43.1	51.3	
★ SB - 2	36.0	9.5	0.113	0.01		1.5	43.4	55.1	
⊙ SB - 2	39.0	9.5	0.072	0.016		0.3	38.8	60.8	

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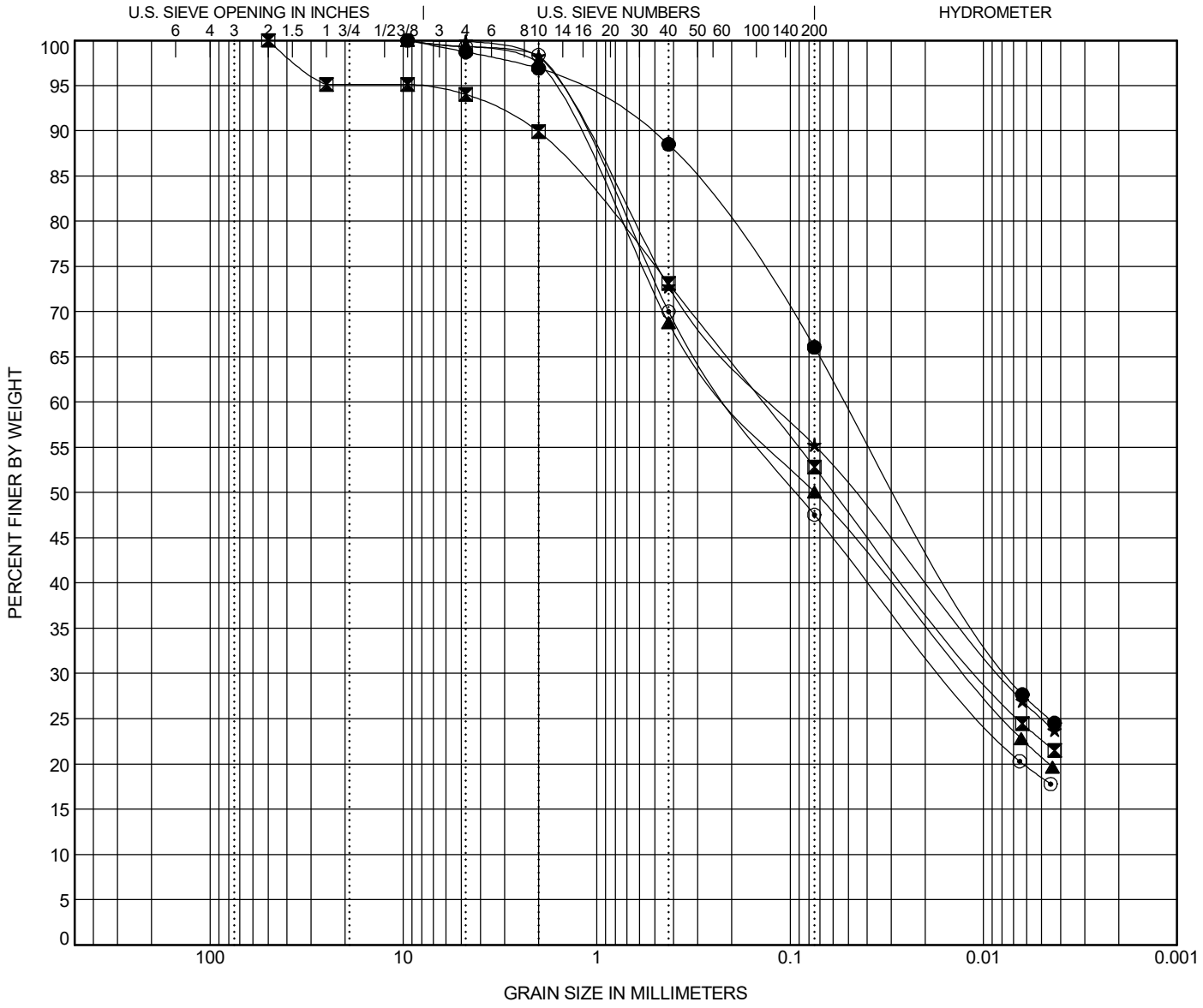

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 2	41.0	A-6 (11)	CL	40	20	20		
⊠	SB - 2	44.0	A-7-6 (10)	CH	51	28	23		
▲	SB - 2	46.0	A-7-5 (9)	MH	64	42	22		
★	SB - 2	49.0	A-7-5 (14)	MH	67	40	27		
⊙	SB - 2	51.0	A-7-5 (10)	SM	62	35	27		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 2	41.0	9.5	0.051	0.007		1.3	32.7	66.1	
⊠	SB - 2	44.0	50	0.139	0.01		6.0	41.2	52.8	
▲	SB - 2	46.0	9.5	0.189	0.012		0.6	49.3	50.1	
★	SB - 2	49.0	9.5	0.12	0.008		0.1	44.6	55.3	
⊙	SB - 2	51.0	9.5	0.196	0.016		0.7	51.8	47.6	

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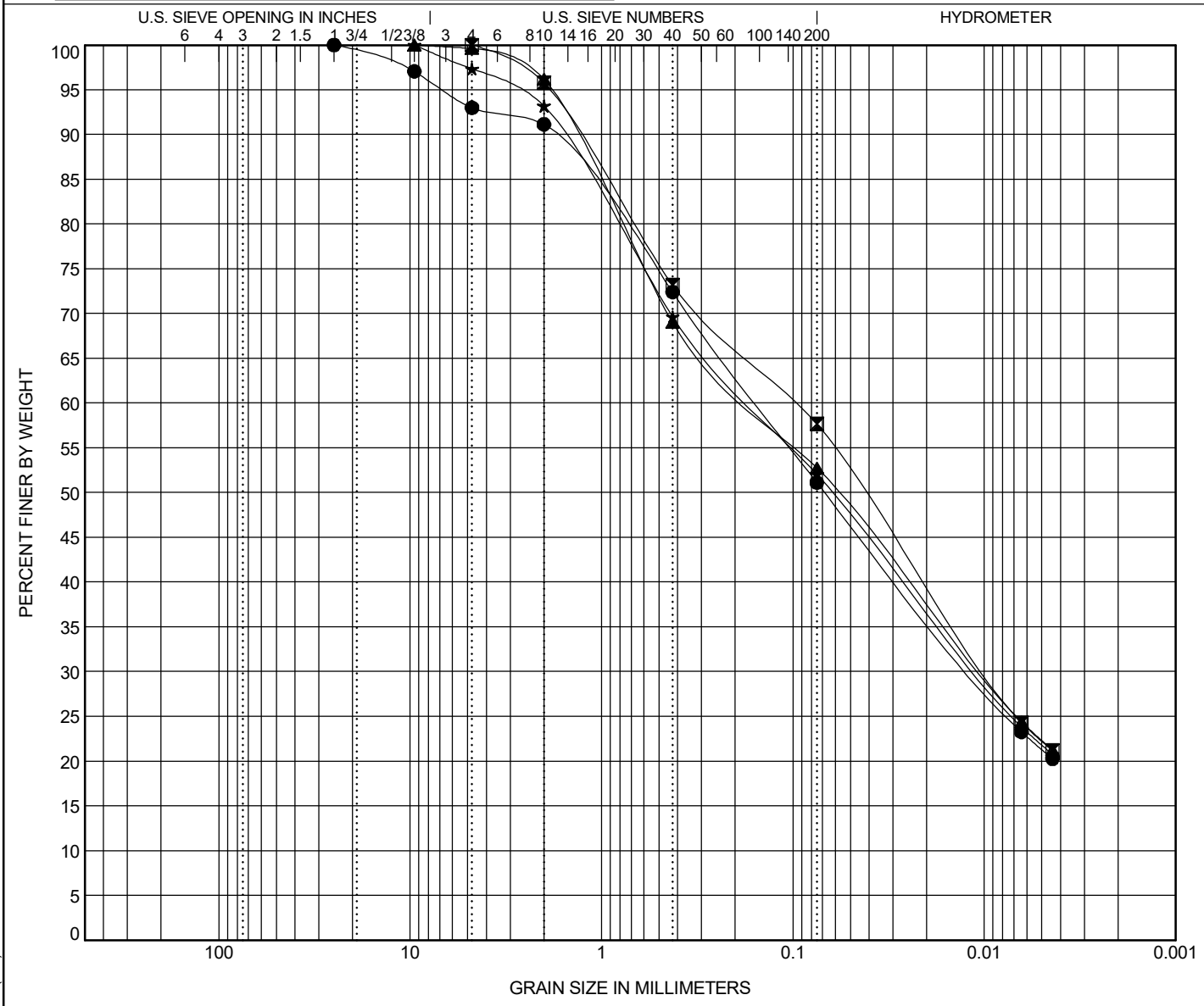

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	AASHTO Classification	USCS Classification	LL	PL	PI	Cc	Cu
●	SB - 2	54.0	A-7-6 (10)	CH	55	29	26		
⊠	SB - 2	56.0	A-7-5 (14)	MH	64	39	25		
▲	SB - 2	59.0	A-7-5 (11)	MH	66	42	24		
★	SB - 2	61.0	A-7-5 (10)	MH	62	40	22		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB - 2	54.0	25	0.155	0.012		7.0	41.9	51.1	
⊠	SB - 2	56.0	4.75	0.097	0.01		0.0	42.3	57.7	
▲	SB - 2	59.0	9.5	0.163	0.01		0.4	46.9	52.7	
★	SB - 2	61.0	9.5	0.164	0.011		2.7	45.3	52.0	

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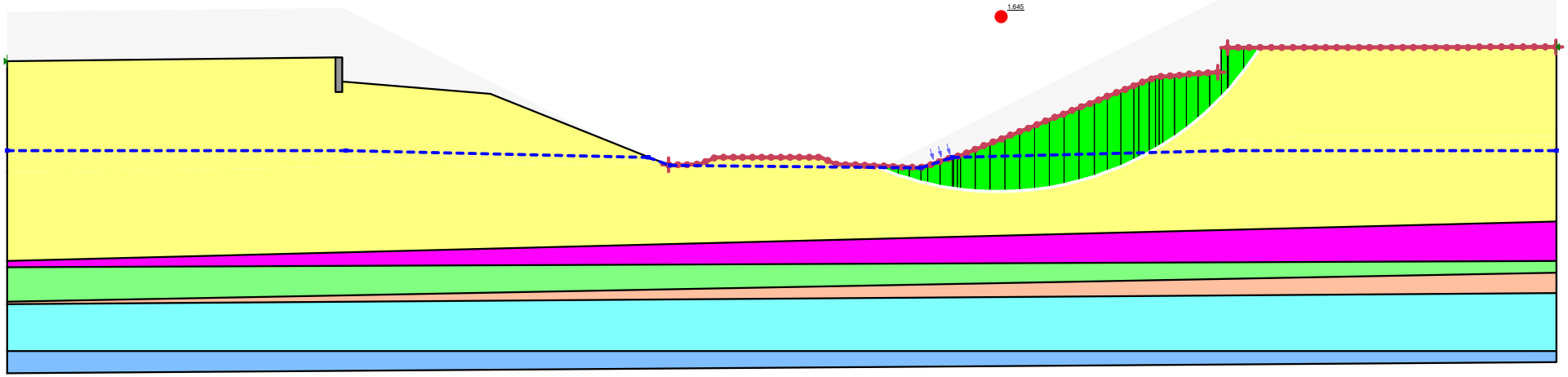
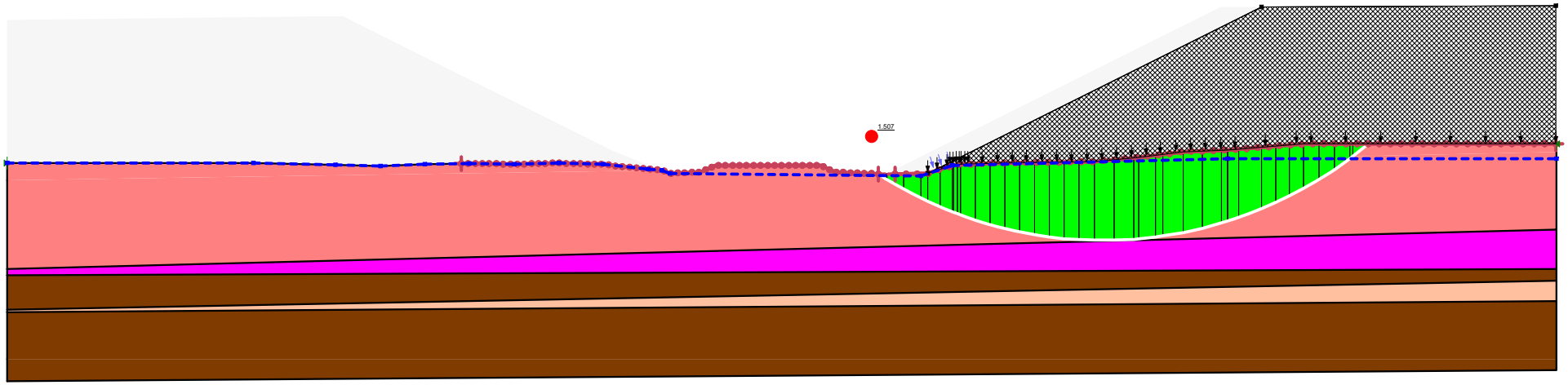
APPENDIX C

Stability Analysis Outputs

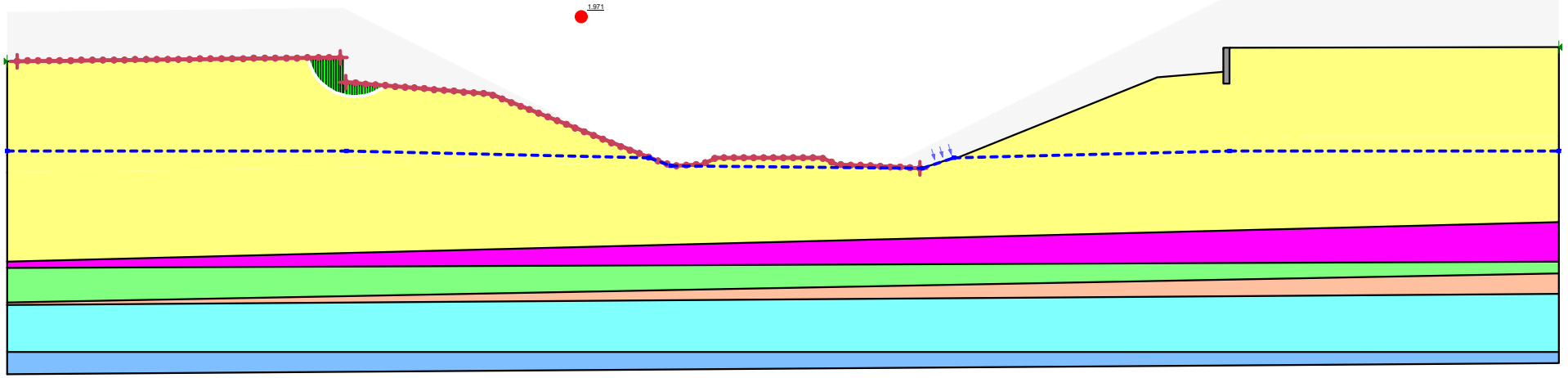
Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Concrete (Abutment)	Mohr-Coulomb	145		10,000	0	0	1
	Layer 1, Brn/Gry Cly	Mohr-Coulomb	120		35	29.5	0	1
	Layer 2, Loose Slty Sand	Mohr-Coulomb	120		0	28	0	1
	Layer 3, Gry Slty Clay, LL=47, CF=50	Shear/Normal Fn.	120	Layer 3, LL=47, CF=50			0	1
	Layer4, Hard Slty Sand	Mohr-Coulomb	120		0	45	0	1
	Layer5, Gry Clay, LL=57, CF=50	Shear/Normal Fn.	120	Layer 5, LL=57, CF=50			0	1
	Layer6, Elastic Silt, LL=66, CF=50	Shear/Normal Fn.	120	Layer 6, LL=66, CF=50			0	1



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Layer 2, Loose Slty Sand	Mohr-Coulomb	120	0	28	0	1
	Layer4, Hard Slty Sand	Mohr-Coulomb	120	0	45	0	1
	TSA Check, Layer 1	Mohr-Coulomb	120	1,300	0	0	1
	TSA Check, Layer 2	Mohr-Coulomb	120	3,100	0	0	1



Color	Name	Model	Unit Weight (pcf)	Strength Function	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Concrete (Abutment)	Mohr-Coulomb	145		10,000	0	0	1
	Layer 1, Brn/Gry Cly	Mohr-Coulomb	120		35	29.5	0	1
	Layer 2, Loose Slty Sand	Mohr-Coulomb	120		0	28	0	1
	Layer 3, Gry Slty Clay, LL=47, CF=50	Shear/Normal Fn.	120	Layer 3, LL=47, CF=50			0	1
	Layer4, Hard Slty Sand	Mohr-Coulomb	120		0	45	0	1
	Layer5, Gry Clay, LL=57, CF=50	Shear/Normal Fn.	120	Layer 5, LL=57, CF=50			0	1
	Layer6, Elastic Silt, LL=66, CF=50	Shear/Normal Fn.	120	Layer 6, LL=66, CF=50			0	1



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Layer 2, Loose Slty Sand	Mohr-Coulomb	120	0	28	0	1
	Layer4, Hard Slty Sand	Mohr-Coulomb	120	0	45	0	1
	TSA Check, Layer 1	Mohr-Coulomb	120	1,300	0	0	1
	TSA Check, Layer 2	Mohr-Coulomb	120	3,100	0	0	1