Structural
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PAVEMENT DESIGN REPORT

Copper Chase at Sterling Ranch, Filing No. 1
Phase 2
El Paso County, Colorado

PREPARED FOR:

Challenger Communities
8605 Explorer Drive, Suite 250
Colorado Springs, CO 80920

JOB NO. 193596-2

June 4, 2024

Respectfully Submitted,

RMG – Rocky Mountain Group

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PCD File No. SF Number 2316 and PCD File No. PAV242

TABLE OF CONTENTS

GENERAL SITE AND PROJECT DESCRIPTION..... 3
Project Description.....3
Existing Site Conditions..... 3
FIELD INVESTIGATION AND LABORATORY TESTING.....3
Drilling.....3
Subsurface Materials.....4
Groundwater..... 4
Laboratory Testing..... 4
CONCLUSIONS AND RECOMMENDATIONS.....5
Overexcavation and Replacement.....6
Foundation Recommendations.....6
Open Excavation Observations.....6
Subgrade Preparation..... 6
Structural Floor Systems.....7
Interior Partitions..... 7
CLOSING..... 7

FIGURES
Site Vicinity Map..... 1
Test Boring Location Plan 2
Explanation of Test Boring Logs..... 3
Test Boring Logs.....4-6
Summary of Laboratory Test Results.....7
Soil Classification Data..... 8-9
Swell/Consolidation Test Results..... 10-11
Moisture-Density Relationship Curve..... 12
California Bearing Ratio Test Results..... 13-14

APPENDIX A
1993 AASHTO Empirical Equation for Flexible Pavements

GENERAL SITE AND PROJECT DESCRIPTION

Location

Copper Chase at Sterling Ranch, Filing No. 1 is generally located south of the intersection of Vollmer Road and Alzada Drive in the northeastern portion of El Paso County, Colorado. The location of the site is shown on the Site Vicinity Map, Figure 1.

Existing Conditions

At the time of our investigation the project site was overlot graded, the roadways were rough graded and utilities had been installed. Curb and gutter had not been installed.

Project Description

This Pavement Design Report was performed to determine the subsurface conditions present along the roadway alignments within the proposed Phase II of the development, and to develop recommendations for the design and construction of the proposed flexible pavements.

The proposed streets included in this investigation are shown on Figure 2.1 and 2.2. The streets considered herein are classified as Urban Local.

FIELD INVESTIGATION AND SUBSURFACE CONDITIONS

Drilling

The subsurface conditions on the site were investigated by drilling five exploratory test borings. The approximate locations of the test borings are presented in the Test Boring Location Plan, Figure 2.1.

The test borings were advanced with a power-driven, continuous-flight auger drill rig to depths of about 5 to 10 feet below the existing ground surface. Samples were obtained in general accordance with ASTM D-3550 utilizing a 2½-inch OD modified California sampler. Representative bulk samples of subsurface materials were obtained from each boring at a depth of approximately 0 to 2 feet below the existing ground surface. An Explanation of Test Boring Logs is presented in Figure 3. The Test Boring Logs are presented in Figures 4 through 6.

Subsurface Materials

The soil encountered in all the borings, TB-5 through TB-9, consisted of silty to clayey sand fill, sandy clay, clayey sand, sandstone, and claystone. These soils classify as clayey sand (SC) in accordance with the Unified Soil Classification System. For pavement design purposes, the soil classifies as A-2-6 with group indexes ranging from 0 to 2, A-6 with a group index of 9, and A-7-6 with group indexes ranging from 4 to 8 in accordance with the American Association of State Highway and Transportation Officials (AASHTO) classification system.

A composite bulk sample from the TB-6 and TB-8 Test Borings, a composite A-7-6 soil, was tested to determine its moisture-density relationship curve in accordance with ASTM D1557 (Modified Proctor compaction test). The results are presented below:

Composite Sample Derived From	Composite Sample Classification	% Passing #200 Sieve	LL	PI	Maximum Dry Density (pcf)	Optimum Moisture (%)	Resulting CBR
TB-6 and TB-8	A-7-6	44.5	42	27	126.6	8.5	11.1

Groundwater

Groundwater was encountered in one of the test borings, TB-6 at a depth of 8 feet, during field exploration. While groundwater is not expected to be a factor in pavement construction on this site, fluctuations in groundwater and subsurface moisture conditions may occur due to variations in rainfall and other factors not readily apparent at this time. Development of the property and adjacent properties may also affect groundwater levels.

LABORATORY TESTING

Laboratory Testing

The moisture content for the recovered samples was obtained in the laboratory. Grain-size analysis and Atterberg Limits tests were performed on selected samples for purposes of classification and to develop pertinent engineering properties. A Summary of Laboratory Test Results is presented in Figure 7. Soil Classification Data are presented in Figures 8 and 9. Swell/Consolidation test results are presented in Figures 10 and 11.

A combined bulk sample of A-6 soil was tested to determine the optimum moisture-density relationship in accordance with ASTM D-698 (Standard Proctor compaction test). California Bearing Ratio, CBR tests were performed at varying densities with moisture content near optimum. At 95% of the maximum Standard Proctor density, the CBR of the bulk sample was 1.24. The Moisture-Density Relation Curve is presented in Figure 12. The CBR Test Results are presented in Figures 13 and 14.

Figure 13 & 14 refer to the bulk sample A-7-6 soil from TB-6 and TB-8. Provide the test results for the bulk A-6 soil sample and include explanation for its inclusion in this report. The pavement was not designed based on the resulting CBR value here. A more robust section would be required for the CBR of 1.24.

The developer intends to install a composite roadway section consisting of Hot Mix Asphalt over Aggregate Base Course (ABC).

PAVEMENT DESIGN

The discussion presented below is based on the subsurface conditions encountered in the test borings, laboratory test results and the project characteristics previously described. If the subsurface conditions are different from those described in this report or the project characteristics change, RMG should be retained to review our recommendations and modify them, if necessary. The conclusions and recommendations presented in this report should be verified by RMG during construction.

The pavement design was performed using the El Paso County Engineering Criteria Manual, Appendix D. The pavement design parameters and design calculations are presented below.

Street Classification – Urban Local

1) Lost Trail Drive and Blue Feather Loop
   ESAL = 292,000 (Table D-2)
   Serviceability Index = 2.0 (Table D-1)

2) Strength coefficients (Table D-3)

Material	Strength Coefficients
Asphalt (HMA): a_1 =	0.44
Cement Stabilized Subgrade: a_2 =	0.11

3) Subgrade
   M_r = CBR x 1500 = 11.1 x 1500 = 16,650 psi

4) Structural number (SN) = 1.89 (per 1993 AASHTO Empirical Equation for Flexible Pavements, presented in Appendix A)

5) Composite asphalt/base course section
   Minimum HMA thickness = D_1 = 3.5 inches (Table D-2)
   ABC thickness = D_2 = {SN – (D_1 x a_1)} / a_2 = {1.89 – (3.5 x 0.44)} / 0.11 = 3.2 inches
   Minimum ABC thickness = 8 inches (Table D-2)
   SN = (4.0 x 0.44) + (8 x 0.11) = 2.64 > 1.89 (Min. SN required)
   Use minimum HMA thickness = 4.0 inches over ABC thickness = 8.0 inches (Paragraph D.4.1-F: base course thickness cannot exceed 2.5 times the HMA thickness)

Pavement Thickness

Based on the design calculations, the recommended pavement sections are presented below and on Figure 2.2.

Street	Sample	Required SN	HMA (in.)	ABC (in.)	CTS (in.)	Calculated SN	OK
Lost Trail Drive and Blue Feather Loop	CBR-Proctor	1.89	4	8	0	2.64	Y

Pavement Materials

Pavement materials should be selected, prepared, and placed in accordance with El Paso County specifications and the *Pikes Peak Region Asphalt Paving Specifications*. Tests should be performed in accordance with the applicable procedures presented in the specifications.

Soil Mitigation

The PDCM notes that mitigation measures may be required for expansive soils, shallow ground water, subgrade instability, etc. Based on the AASHTO classification for the soils in this subdivision, the claystone subgrade soils evaluated for this pavement design can be expected to be expansive and need to be removed and replaced. Groundwater or wet and unstable soils were not encountered in the borings. Therefore, special mitigation will be necessary for selected portion of roadway, consisting of the removal and replacement of claystone bedrock within 24 inches of structural fill as indicated below and on Figure 2.1.

Subgrade Preparation

Claystone with swell potential above 2.0 percent are prone to heaving upon wetting. We recommend that claystone within pavement boundaries in the vicinity of TB-8 (as shown on Figure 2.1) be removed to a depth of at least 24 inches below the bottom of the ABC layer and disposed of. The exposed soil should be proofrolled with a heavy pneumatic-tired vehicle to a firm and unyielding condition. After proofrolling, backfill with 24-inches of granular on-site soil installed in 8-inch loose lifts and compacted to 95 percent of the Standard Proctor value as determined by ASTM D-1557.

All subgrade fill material placed below pavements should be moisture-conditioned and compacted in accordance with the ***Structural Fill – General*** section of this report. Prior to placement of the pavement section, the final subgrade in areas not overexcavated as indicated above should be scarified to a depth of 12 inches, adjusted to within 2 percent of the optimum moisture content and recompacted. The subgrade should then be proof-rolled with a heavy, pneumatic tired vehicle. Areas which deform under wheel loads should be removed and replaced.

Base course should be compacted to at least 95 percent of the maximum Modified Proctor density (ASTM D-1557).

Surface Drainage

Surface drainage is important for the satisfactory performance of pavement. Wetting of the subgrade soils or base course will cause a loss of strength which can result in pavement distress. Surface drainage should provide for efficient removal of storm-water runoff. Water should not be allowed to pond on the pavement or at the edges of the pavement.

Subgrade Observations and Testing

The pavement thicknesses presented above assume pavement construction is completed in accordance with El Paso County specifications and the *Pikes Peak Region Asphalt Paving Specifications*. RMG should be present at the site during subgrade preparation, placement of fill, and construction of pavements to perform site observations and testing.

CLOSING

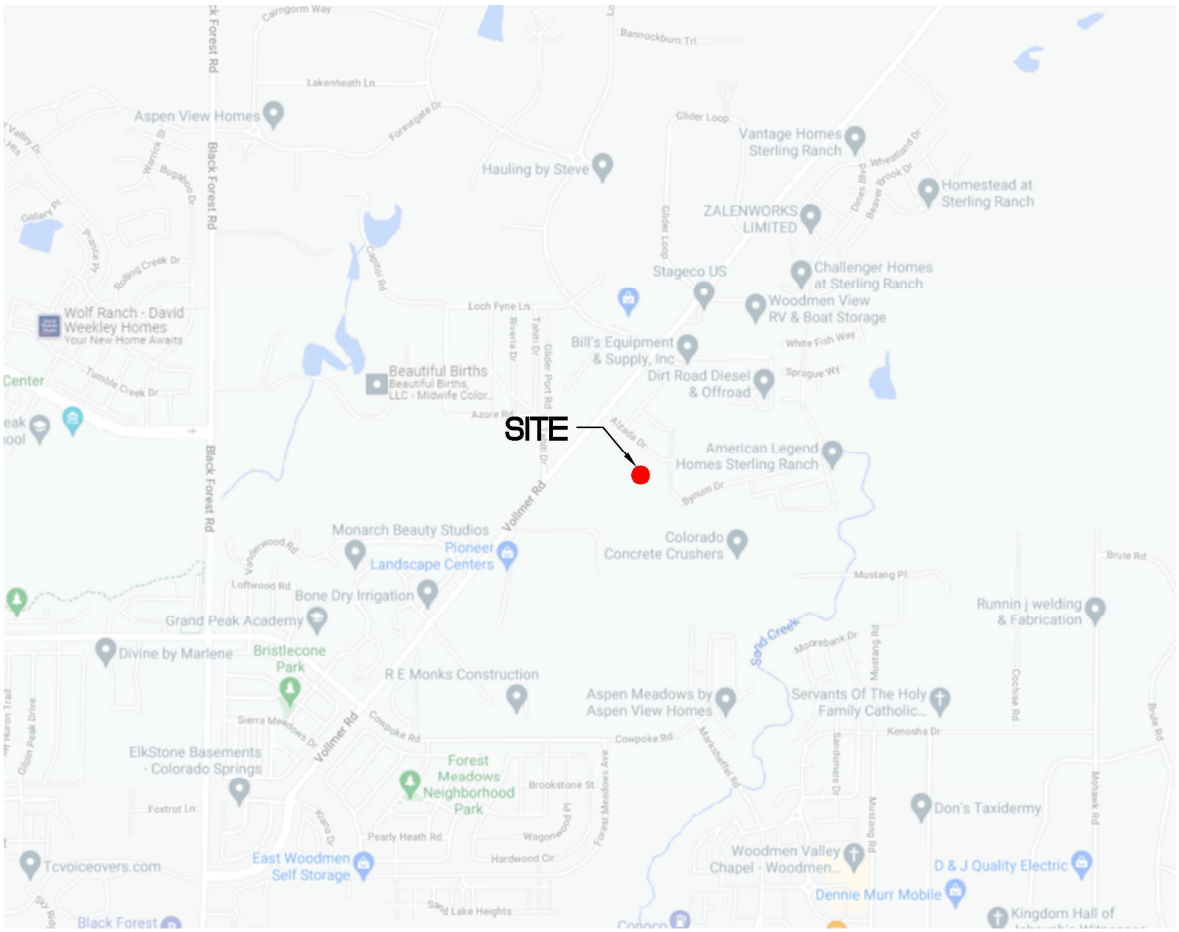
Our field exploration was conducted to provide geotechnical information for pavement thickness design. Variations in subsurface conditions not indicated by the borings may be encountered. This report has been prepared for **Challenger Communities** for application as an aid in the design of the proposed development in accordance with generally accepted geotechnical engineering practices. The analyses and recommendations in this report are based in part upon data obtained from exploratory borings and test pits, site observations and the information presented in referenced reports. The nature and extent of variations may not become evident until construction. If variations then become evident, RMG should be retained to re-evaluate the recommendations of this report, if necessary.

Our professional services were performed using that degree of care and skill ordinarily exercised, under similar circumstances, by geotechnical engineers practicing in this or similar localities. RMG Engineers does not warrant the work of regulatory agencies or other third parties supplying information which may have been used during the preparation of this report. No warranty, express or implied is made. Any contractor reviewing this report for bidding purposes must draw his own conclusions regarding site conditions and specific construction techniques to be used on this project.

This report is for the exclusive purpose of providing geotechnical information and pavement thickness design recommendations. The scope of services for this project does not include, either specifically or by implication, environmental assessment of the site or identification of contaminated or hazardous materials or conditions. Development of recommendations for the mitigation of environmentally related conditions, including but not limited to biological or toxicological issues, are beyond the scope of this report. If the Client desires investigation into the potential for such contamination or conditions, other studies should be undertaken.

If we can be of further assistance in discussing the contents of this report or analysis of the proposed development, from a geotechnical engineering point-of-view, please feel free to contact us.

FIGURES



NOT TO SCALE

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SITE VICINITY MAP

COPPER CHASE AT STERLING RANCH
FILING NO. 1
EL PASO COUNTY, COLORADO
CHALLENGER COMMUNITIES

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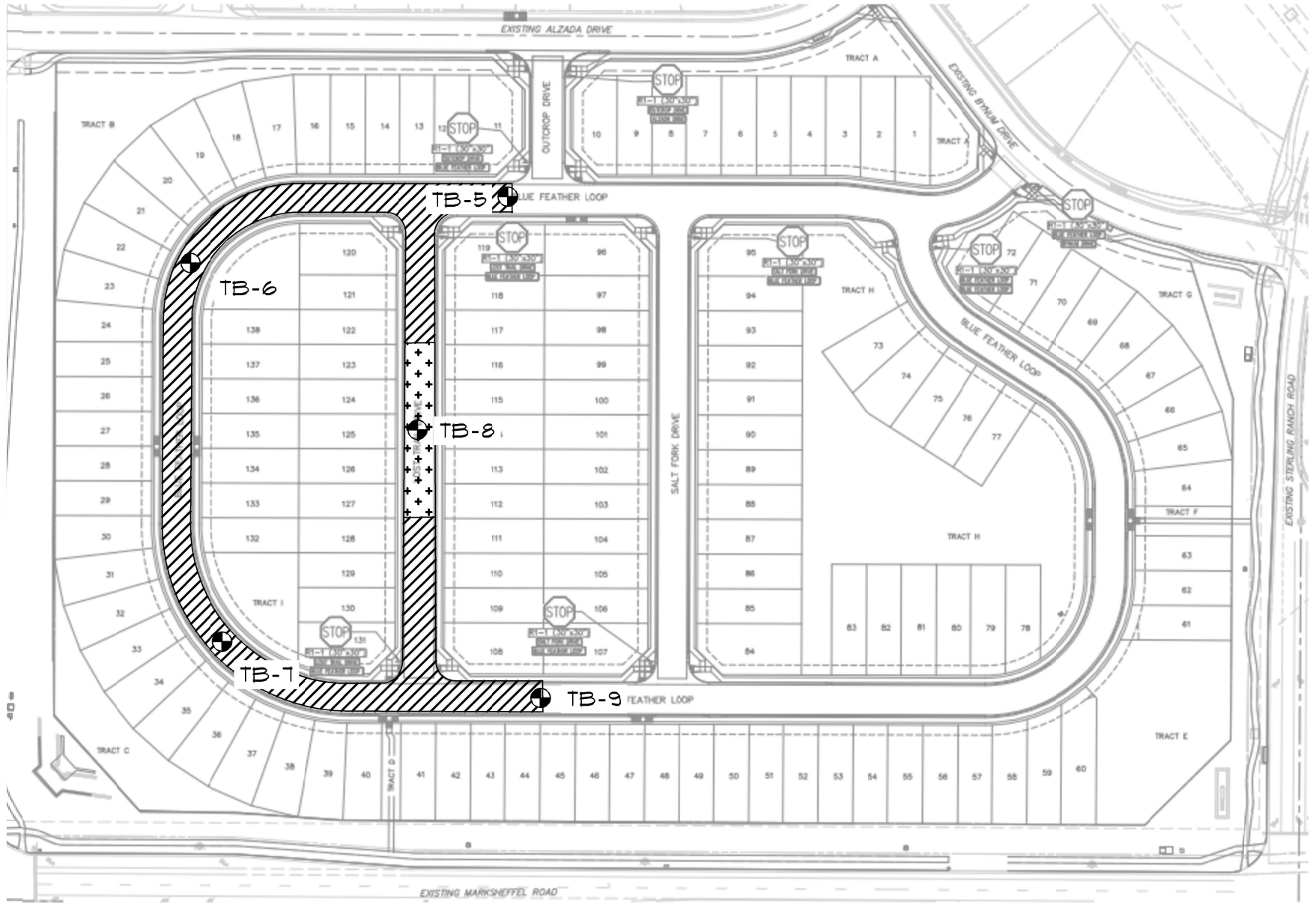
FIG No. 1

DATE 5-6-2024



INDICATES AREAS INCLUDED IN THIS REPORT WHERE SOIL MITIGATIONS ARE NOT ANTICIPATED.

INDICATES AREAS INCLUDED IN THIS REPORT WHERE OVEREXCAVATION AND REPLACEMENT OF CLAYSTONE IS ANTICIPATED.

0 25 50 100
SCALE IN FEET

NOT TO SCALE

DENOTES LOTS WHERE TEST BORINGS WERE PERFORMED

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FILING NO. 1, PHASE 2
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ENGINEER:	TM
DRAWN BY:	JM
CHECKED BY:	TM
ISSUED:	6-4-2024

TEST BORING LAYOUT PLAN

SHEET No.
FIG-2.1

Urban Local: Lost Trail Drive
and Blue Feather Loop
ESAL - 292,000

4.0" HMA
OVER
18.0" ABC

0 25 50 100
SCALE IN FEET

NOT TO SCALE

DENOTES LOTS WHERE TEST BORINGS WERE PERFORMED

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PAVEMENT RECOMMENDATIONS

SHEET No.
FIG-2.2

SOILS DESCRIPTION


CLAYEY SAND


CLAYSTONE


FILL: SAND, SILTY TO CLAYEY


SANDSTONE


SANDY CLAY

UNLESS NOTED OTHERWISE, ALL LABORATORY
TESTS PRESENTED HEREIN WERE PERFORMED BY:
RMG - ROCKY MOUNTAIN GROUP
2910 AUSTIN BLUFFS PARKWAY
COLORADO SPRINGS, COLORADO

SYMBOLS AND NOTES


XX — STANDARD PENETRATION TEST - MADE BY DRIVING A SPLIT-BARREL SAMPLER INTO THE SOIL BY DROPPING A 140 LB. HAMMER 30", IN GENERAL ACCORDANCE WITH ASTM D-1586. NUMBER INDICATES NUMBER OF HAMMER BLOWS PER FOOT (UNLESS OTHERWISE INDICATED).


XX — UNDISTURBED CALIFORNIA SAMPLE - MADE BY DRIVING A RING-LINED SAMPLER INTO THE SOIL BY DROPPING A 140 LB. HAMMER 30", IN GENERAL ACCORDANCE WITH ASTM D-3550. NUMBER INDICATES NUMBER OF HAMMER BLOWS PER FOOT (UNLESS OTHERWISE INDICATED).


FREE WATER TABLE


DEPTH AT WHICH BORING CAVED


BULK — DISTURBED BULK SAMPLE


AUG — AUGER "CUTTINGS"

4.5 — WATER CONTENT (%)

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EXPLANATION OF TEST BORING LOGS

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FIGURE No. 3

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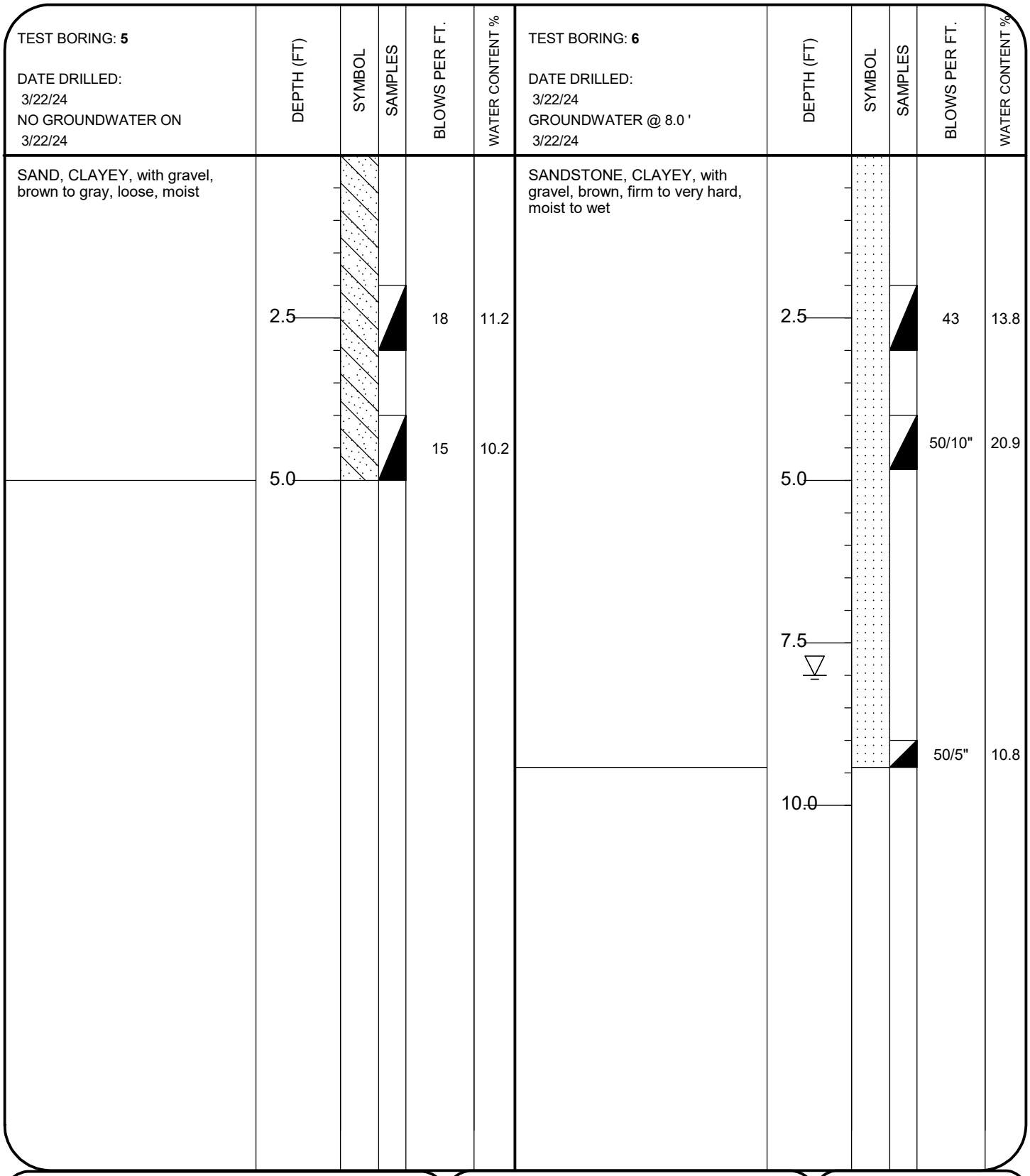

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TEST BORING LOG

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FIGURE No. 4

DATE June/04/2024

TEST BORING: **7** DATE DRILLED: 3/22/24 NO GROUNDWATER ON 3/22/24	DEPTH (FT)	SYMBOL	SAMPLES	BLOWS PER FT.	WATER CONTENT %
SAND, CLAYEY, with gravel, dark brown, loose, moist	2.5			15	8.6
CLAY, SANDY, dark brown, very stiff, moist	5.0			40	13.1

TEST BORING: **8** DATE DRILLED: 3/22/24 NO GROUNDWATER ON 3/22/24	DEPTH (FT)	SYMBOL	SAMPLES	BLOWS PER FT.	WATER CONTENT %
SANDSTONE, CLAYEY, brown, medium hard, moist					
CLAYSTONE, SANDY, dark gray, medium hard, moist	2.5			50	14.1
	5.0			50/10"	12.8

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TEST BORING LOG

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FIGURE No. 5

DATE June/04/2024

TEST BORING: **9**

DATE DRILLED:
3/22/24
NO GROUNDWATER ON
3/22/24

DEPTH (FT)	SYMBOL	SAMPLES	BLOWS PER FT.	WATER CONTENT %
FILL: SAND, CLAYEY, brown to gray, loose, moist				
2.5			13	10.5
			11	13.1
5.0				

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TEST BORING LOG

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FIGURE No. 6

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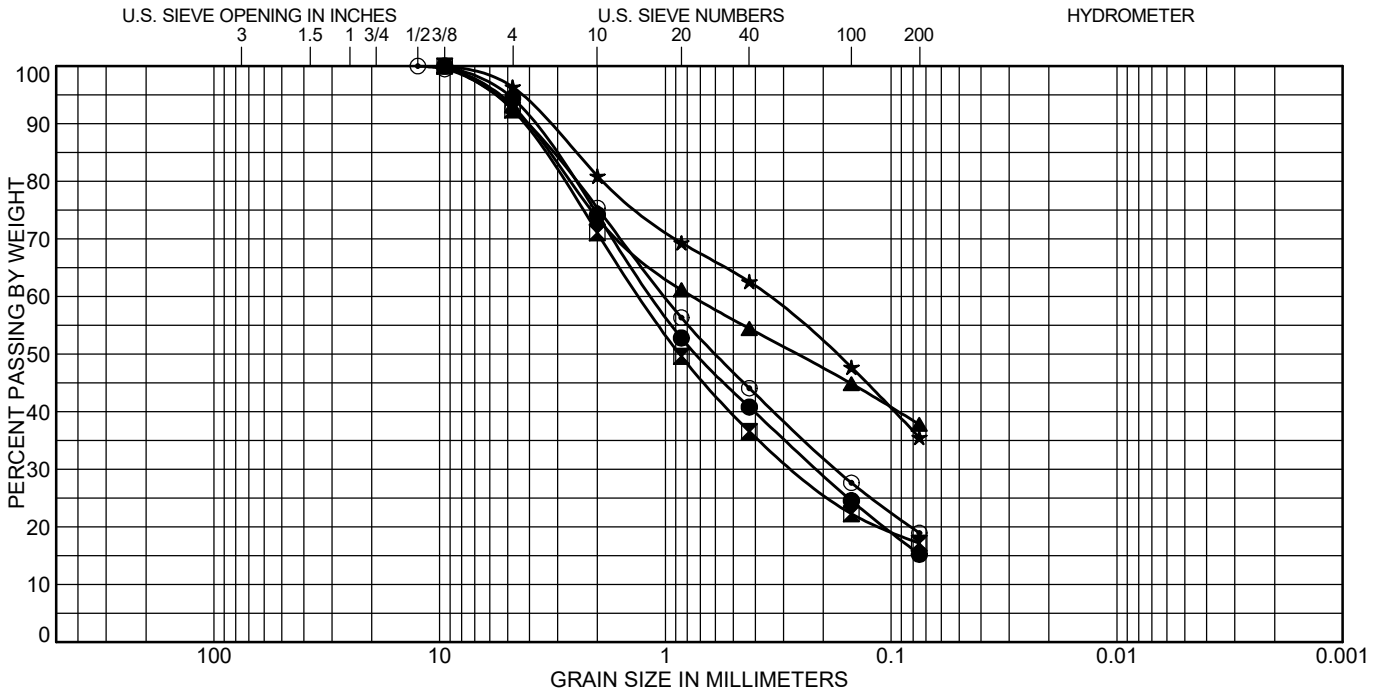
Test Boring No.	Depth	Water Content (%)	Dry Density (pcf)	Liquid Limit	Plasticity Index	% Retained No.10 Sieve	% Retained No.40 Sieve	% Passing No. 200 Sieve	% Swell @ 100 psf	AASHTO Classification
5	0.0			33	18	25.8	59.4	15.2		A-2-6 (0)
5	2.0	11.2		35	17	29.0	63.6	17.2		A-2-6 (0)
5	4.0	10.2								
6	0.0			41	25	26.4	45.7	37.8		A-7-6 (4)
6	2.0	13.8	106.8			19.1	37.6	35.5	0.8	
6	4.0	20.9	100.6						0.4	
6	9.0	10.8								
7	0.0			31	14	24.6	56.1	18.9		A-2-6 (0)
7	2.0	8.6		31	15	18.2	50.1	25.0		A-2-6 (1)
7	4.0	13.1								
8	0.0			42	27	7.3	23.1	46.7		A-7-6 (8)
8	2.0	14.1	113.6	37	23	3.8	15.8	53.6	3.8	A-6 (9)
8	4.0	12.8								
9	0.0			34	20	13.7	41.4	31.2		A-2-6 (2)
9	2.0	10.5		34	18	19.7	53.3	27.3		A-2-6 (1)
9	4.0	13.1								

SUMMARY OF LABORATORY TEST RESULTS

JOB No. 193596
FIGURE No. 7
PAGE 1 OF 1
DATE June/04/2024



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Test Boring	Depth (ft)	Classification	LL	PL	PI
●	5	0.0	**CLAYEY SAND(SC)**	33	15	18
⧓	5	2.0	**CLAYEY SAND(SC)**	35	18	17
▲	6	0.0	**CLAYEY SAND(SC)**	41	16	25
★	6	2.0				
⊙	7	0.0	**CLAYEY SAND(SC)**	31	17	14

	Test Boring	Depth (ft)	%Gravel	%Sand	%Silt	%Clay
●	5	0.0	5.6	79.2	15.2	
⧓	5	2.0	7.6	75.2	17.2	
▲	6	0.0	6.9	55.3	37.8	
★	6	2.0	3.6	60.8	35.5	
⊙	7	0.0	7.4	73.7	18.9	

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SOIL CLASSIFICATION DATA

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FIGURE No. 8

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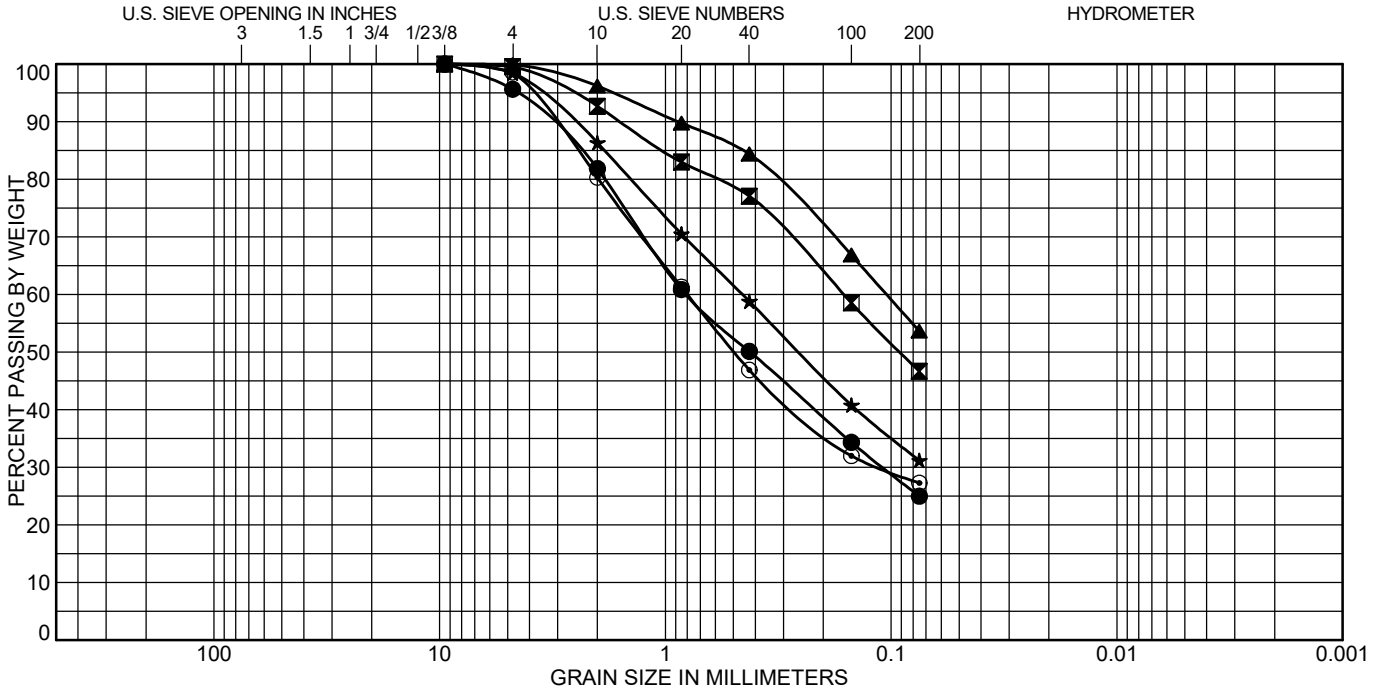

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Test Boring	Depth (ft)	Classification	LL	PL	PI
●	7	2.0	CLAYEY SAND(SC)	31	16	15
⊠	8	0.0	CLAYEY SAND(SC)	42	15	27
▲	8	2.0	SANDY LEAN CLAY(CL)	37	14	23
★	9	0.0	CLAYEY SAND(SC)	34	14	20
⊙	9	2.0	CLAYEY SAND(SC)	34	16	18

	Test Boring	Depth (ft)	%Gravel	%Sand	%Silt	%Clay
●	7	2.0	4.4	70.7	25.0	
⊠	8	0.0	0.5	52.9	46.7	
▲	8	2.0	0.1	46.3	53.6	
★	9	0.0	1.6	67.3	31.2	
⊙	9	2.0	1.4	71.3	27.3	

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SOIL CLASSIFICATION DATA

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FIGURE No. 9

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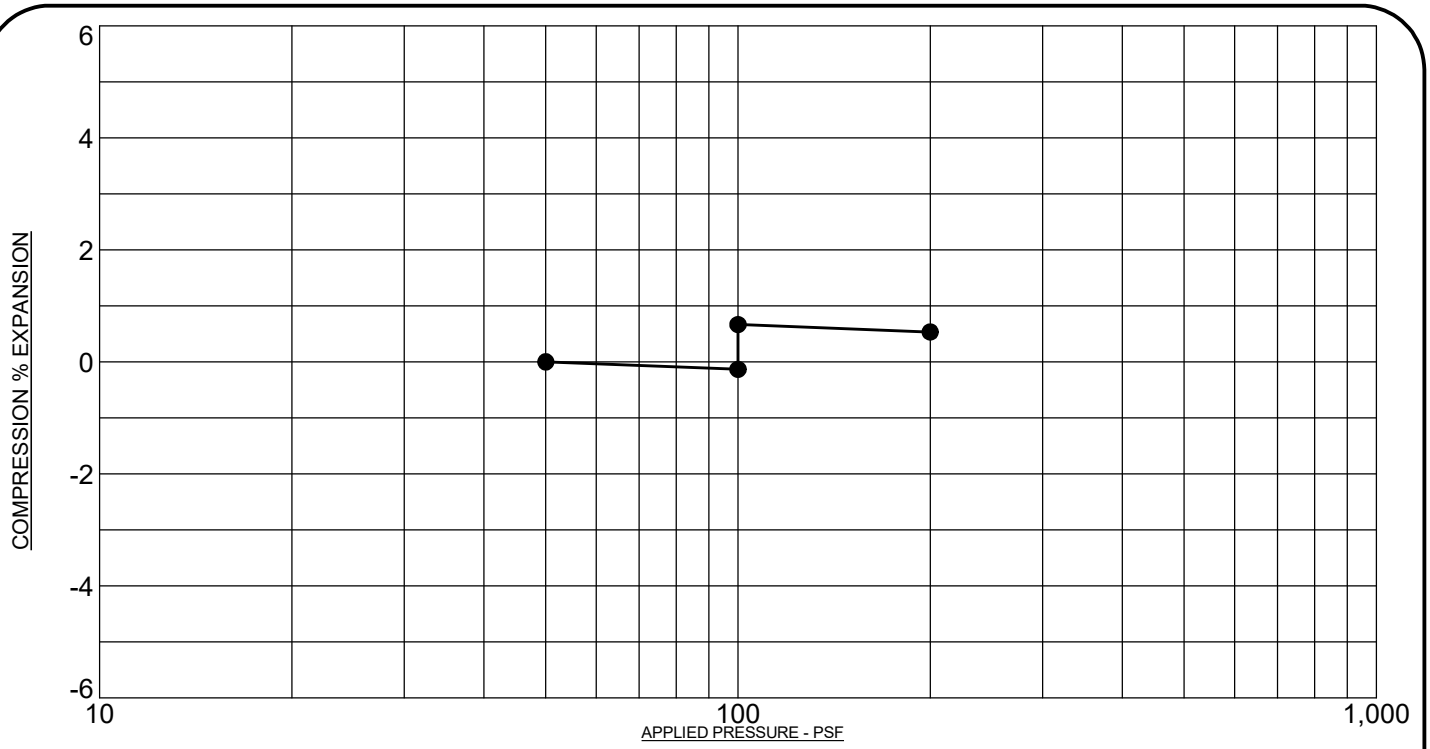
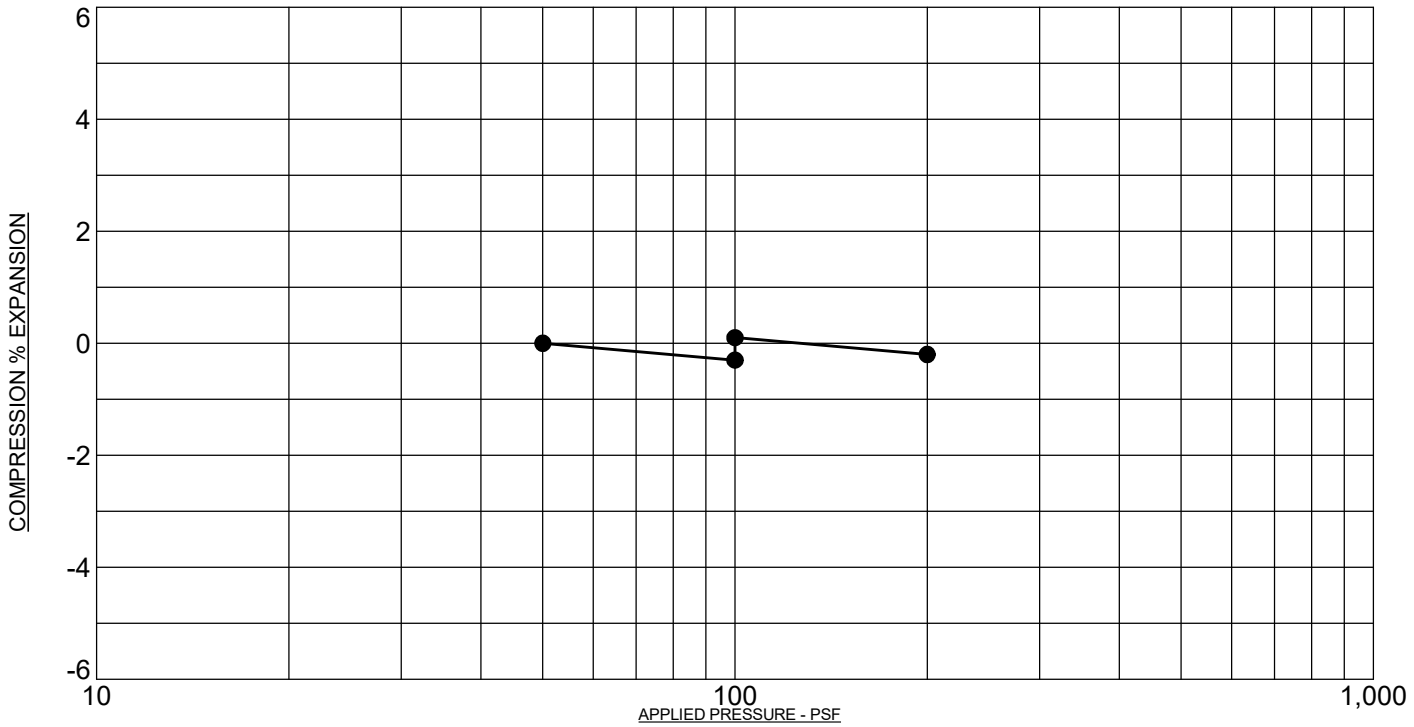


PROJECT: **Copper Chase at Sterling Ranch, Filing No. 1, El Paso County, Colorado**
SAMPLE DESCRIPTION: **SANDSTONE, CLAYEY**
NOTE: SAMPLE WAS INUNDATED WITH WATER AT 100 PSF

SAMPLE LOCATION: **6 @ 2 FT**
NATURAL DRY UNIT WEIGHT: **106.8 PCF**
NATURAL MOISTURE CONTENT: **13.8%**
PERCENT SWELL/COMPRESSION: **0.8**



PROJECT: **Copper Chase at Sterling Ranch, Filing No. 1, El Paso County, Colorado**
SAMPLE DESCRIPTION: **SANDSTONE, CLAYEY**
NOTE: SAMPLE WAS INUNDATED WITH WATER AT 100 PSF

SAMPLE LOCATION: **6 @ 4 FT**
NATURAL DRY UNIT WEIGHT: **100.6 PCF**
NATURAL MOISTURE CONTENT: **20.9%**
PERCENT SWELL/COMPRESSION: **0.4**

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SWELL/CONSOLIDATION TEST RESULTS

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FIGURE No. 10

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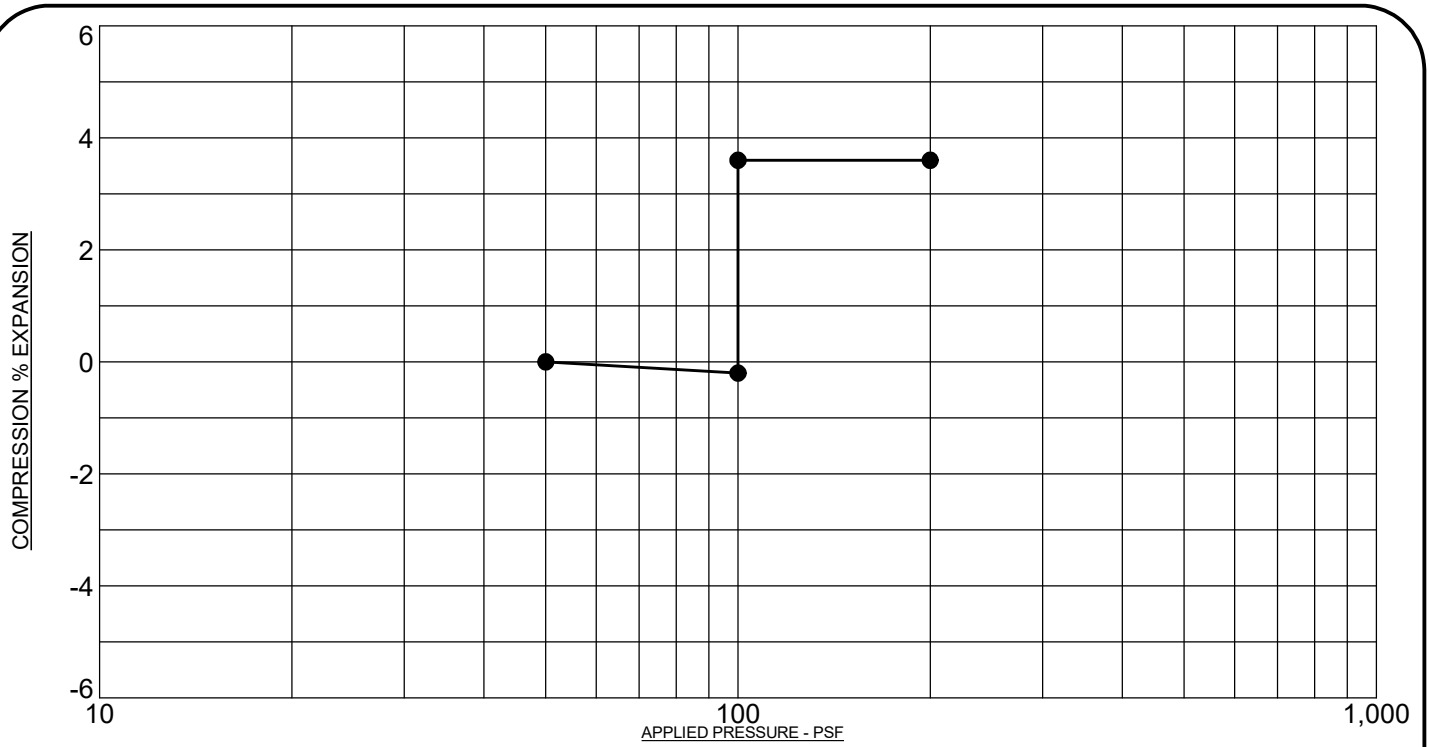

PROJECT: **Copper Chase at Sterling Ranch, Filing No. 1, El Paso County, Colorado**
SAMPLE DESCRIPTION: **CLAYSTONE, SANDY,**
NOTE: SAMPLE WAS INUNDATED WITH WATER AT 100 PSF

SAMPLE LOCATION: **8 @ 2 FT**
NATURAL DRY UNIT WEIGHT: **113.6 PCF**
NATURAL MOISTURE CONTENT: **14.1%**
PERCENT SWELL/COMPRESSION: **3.8**

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SWELL/CONSOLIDATION TEST RESULTS

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FIGURE No. 11

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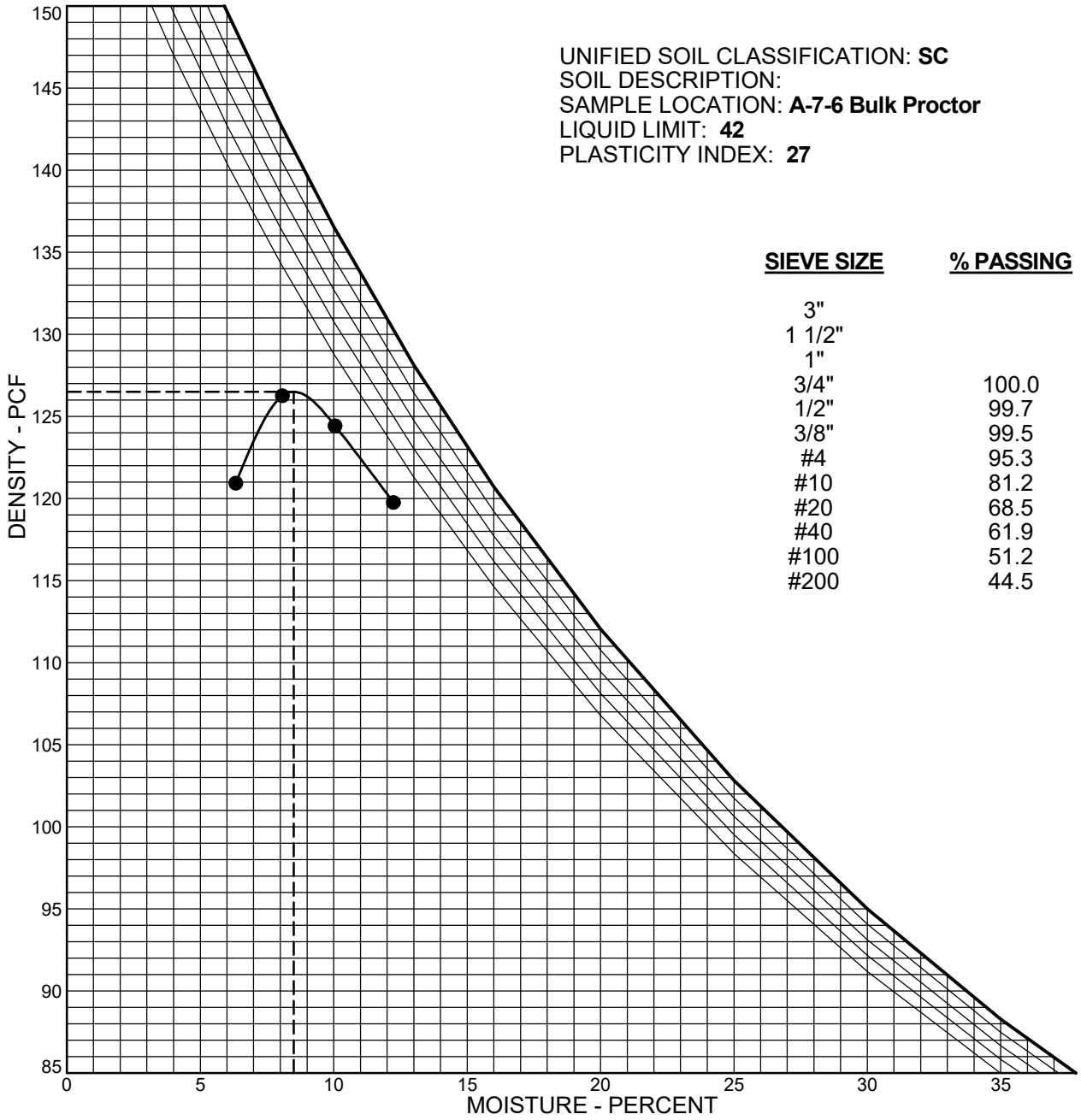
CLIENT: Challenger Colorado, LLC **SAMPLE NUMBER:** A-7-6 Proctor

PROJECT: **Copper Chase at Sterling Ranch, Filing No. 1, Phase II, El Paso County, Colorado**



UNIFIED SOIL CLASSIFICATION: **SC**
SOIL DESCRIPTION:
SAMPLE LOCATION: **A-7-6 Bulk Proctor**
LIQUID LIMIT: **42**
PLASTICITY INDEX: **27**

SIEVE SIZE	% PASSING
3"	
1 1/2"	
1"	
3/4"	100.0
1/2"	99.7
3/8"	99.5
#4	95.3
#10	81.2
#20	68.5
#40	61.9
#100	51.2
#200	44.5

DESIGNATION **ASTM D-1557A**
MAX. DRY DENSITY **126.6 pcf**
OPTIMUM MOISTURE **8.5 %**
FRACTION USED **#4**
MOLD VOLUME **0.0333 cu.ft.**

NOTE: ZERO AIR VOIDS CURVES PLOTTED FOR:
Gs = 2.60
Gs = 2.65
Gs = 2.70
Gs = 2.75
Gs = 2.80

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SOUTHERN COLORADO, DENVER METRO, NORTHERN COLORADO

MOISTURE-DENSITY RELATION CURVE

JOB No. 193596

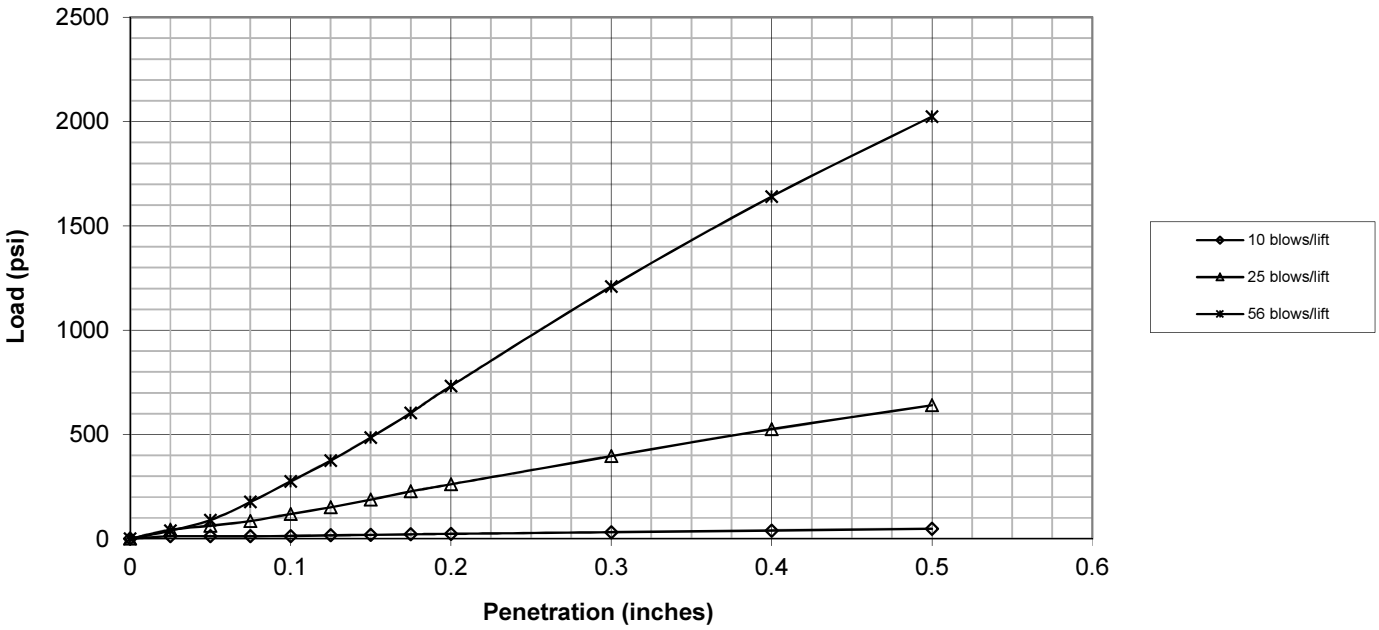
FIGURE No. 12

DATE June/04/2024

CALIFORNIA BEARING RATIO TEST RESULTS

Project: Copper Chase at Sterling Ranch, Filing No. 1, Phase II
Job No.: 193596
AASHTO Classification" A-7-6
Sample Number: CBR
Sample Location: Combined Bulk Sample
Soil Description: Clayey Sand

Penetration (in)	10 blows/lift Load (psi)	25 blows/lift Load (psi)	56 blows/lift Load (psi)
0.000	0.0	0.0	0.0
0.025	11.8	42.3	38.3
0.050	11.8	62.1	89.7
0.075	11.8	85.0	176.0
0.100	13.1	118.6	275.1
0.125	16.5	150.8	374.2
0.150	18.5	187.5	485.4
0.175	21.2	227.1	603.3
0.200	23.5	261.0	732.0
0.300	31.2	395.7	1209.4
0.400	39.0	525.4	1641.0
0.500	47.4	640.0	2024.7



	Corrected Penetration (in)	Corrected Load (psi)
10 blows/lift	0.100	1.3
25 blows/lift	0.100	11.9
56 blows/lift	0.100	27.5

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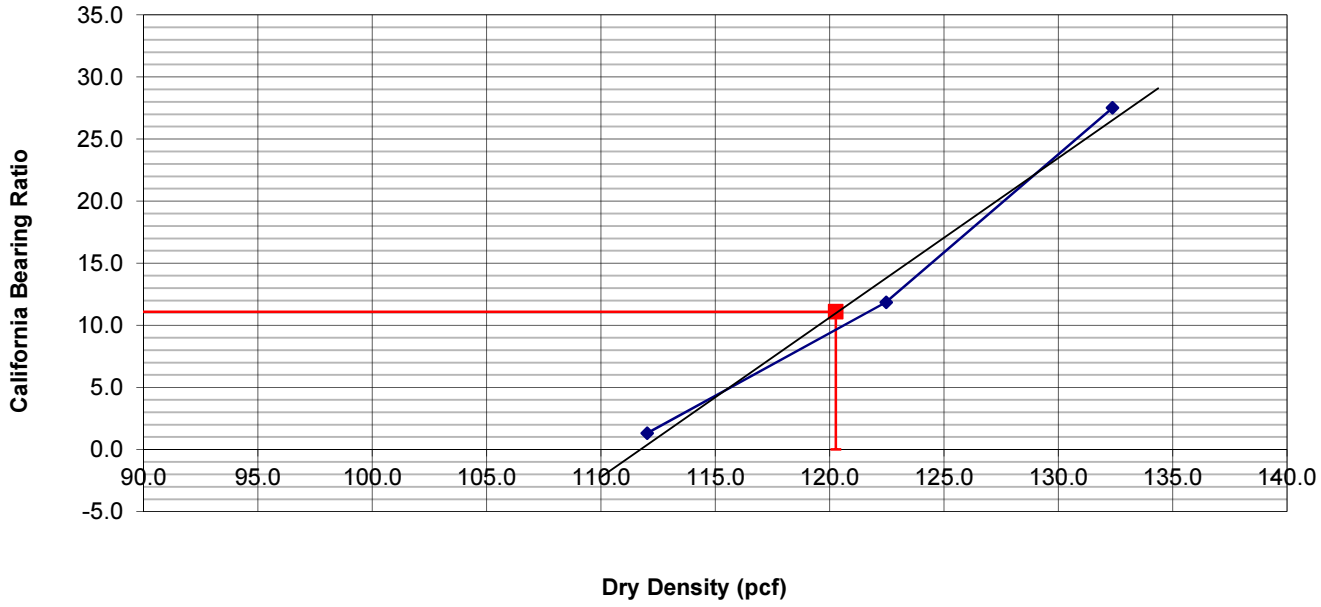
Figure No. 13

CALIFORNIA BEARING RATIO TEST RESULTS

Project: Copper Chase at Sterling Ranch, Filing No. 1, Phase II
Job No.: 193596
AASHTO Classification" A-7-6
Sample Number: CBR
Sample Location: Combined Bulk Sample
Soil Description: Clayey Sand

	10 blows/lift	25 blows/lift	56 blows/lift
Corrected California Bearing Ratio	1.3	11.9	27.5
Dry Density (pcf)	112.0	122.5	132.4
Percent Compaction	88	97	105
Percent Moisture After Soaking	13.0	10.7	10.4
Percent Expansion (+) / Compression (-)	0.0%	0.1%	0.2%
Surcharge Weight (lbs)	12.60	12.60	12.60



California Bearing Ratio	11.1
Dry Density (pcf)	126.6
Percent Compaction	95%
Target Dry Density	120.3
Compaction Test Method	ASTM D-1557
Condition of sample	Soaked

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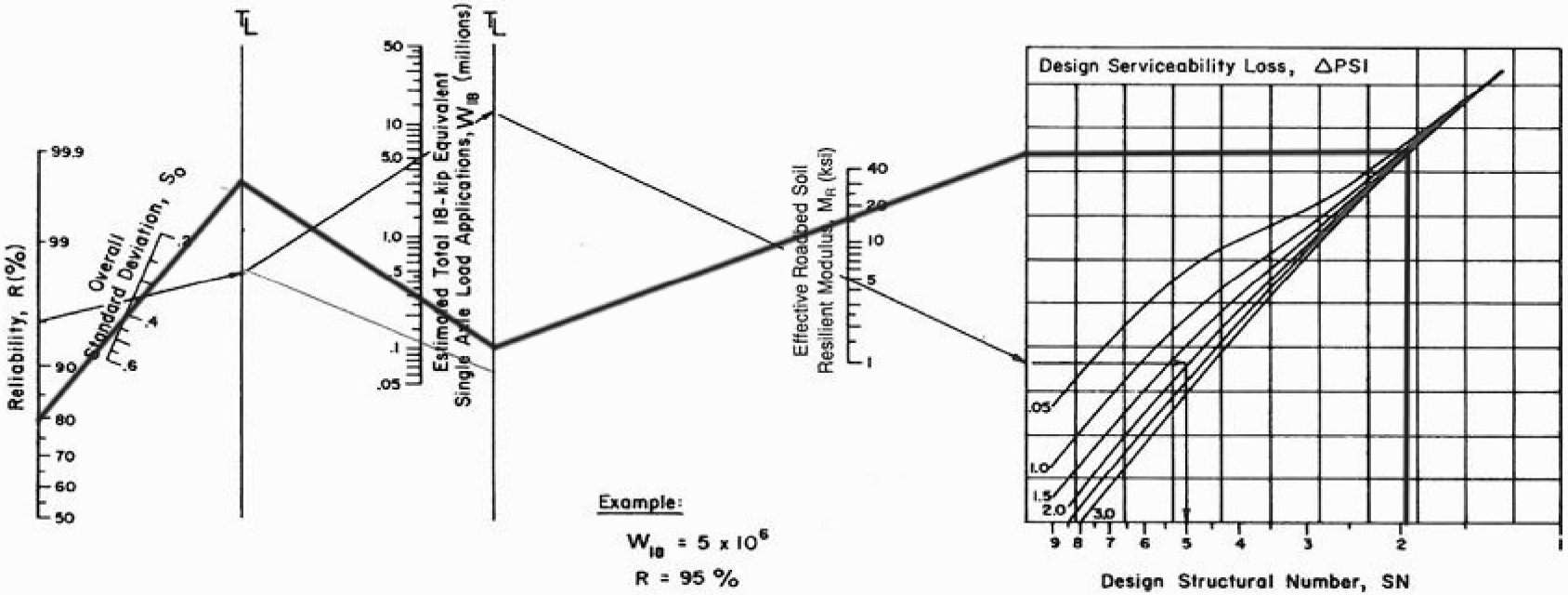
Figure No. 14

APPENDIX A

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R * S_o + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$



Example:

$W_{18} = 5 \times 10^6$

R = 95 %

$S_o = 0.35$

$M_R = 5000$ psi

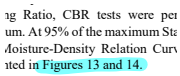
ΔPSI = 1.9

Solution: SN = 5.0

NOTE: FROM ASSHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES (1993)

Pavement Report - Copper Chase at Sterling Ranch Fil 1, Phase 2.pdf Markup Summary

Engineer (2)



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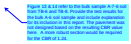

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Figure 13 & 14 refer to the bulk sample A-7-6 soil from TB-6 and TB-8. Provide the test results for the bulk A-6 soil sample and include explanation for its inclusion in this report. The pavement was not designed based on the resulting CBR value here. A more robust section would be required for the CBR of 1.24.