Geotechnical Engineering Report

Pedological and Geological Survey
I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma
Job Piece No. 29843(04)
Engineering Contract No. EC-1500N

December 21, 2018
Terracon Project No. 03165261

Prepared for:
Garver, LLC.
Tulsa, Oklahoma

Prepared by:
Terracon Consultants, Inc.
Oklahoma City, Oklahoma

December 21, 2018

Terracon

Garver, LLC
6450 South Lewis, Suite 300
Tulsa, Oklahoma 74136

Attn: Ms. Jenny Sallee
P: [918] 858 4166
E: jesallee@garverusa.com

Re: Geotechnical Engineering Report
Pedological and Geological Survey
Interstate 35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma
Job Piece No. 29843(04)
Engineering Contract No. EC-1500N
Terracon Project No. 03165261

Dear Ms. Sallee:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. The scope of our services was outlined in the Geotechnical Scope of Work Revision 2 (Terracon Proposal No. P03165261) dated August 16, 2016.

We appreciate the opportunity to work with you on this project. If you have any questions regarding this report, or if we may be of further service in other ways, please let us know.

Sincerely,
Terracon Consultants, Inc.
Cert. Of Auth. #CA-4531 exp. 6/30/19

Kristi Daisen

for: Diana Vargas-Suaza, E.I.
Senior Staff Engineer

Norman Tan, P.E.
Oklahoma No. 23083

LICENSED PROFESSIONAL ENGINEER
NORMAN TAN
12/21/18
23083
OKLAHOMA

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Copies to: Addressee (1 via email)

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INTERSTATE 35 OVER WATERLOO ROAD INTERCHANGE
OKLAHOMA AND LOGAN COUNTIES, OKLAHOMA
JOB PIECE NO. 29843(04)
ENGINEERING CONTRACT NO. EC-1500N

Terracon Project No. 03165261

December 21, 2018

1.0 INTRODUCTION

The proposed project is located at the Interstate 35 and Waterloo Road interchange in Oklahoma and Logan Counties, Oklahoma. We understand the project includes the realignment of Sooner Road, Industrial Boulevard and Boucher Drive. We also understand the project will include widening of Waterloo Road between Sooner Road and Air Depot Boulevard to accommodate a three-to-five lane roadways.

The landscape consists of very gently sloping to moderately steep side slopes of hills in the North Cross Timbers, slopes ranging from 1 to 25 percent, as well as backslopes and foot slopes of low hills in the northern cross timbers with slopes ranging from 3 to 45 percent and urban land.

Soils in the area consists of moderately deep, well drained, soils formed in material weathered from sandstone of Permian age as well as soils that are very deep to sandstone, well drained soils that have also formed from sandy and loamy colluvium weathered from sandstone of Permian age. Additionally, the soils can be moderately well drained, very slowly permeable soils that formed in material weathered from sandstone or shale of Permian age. These soils are mainly used for rangeland with some areas used for cropland such as: wheat, grain sorghum, small grains and peanuts. It is also used for tame pasture as well as improved pasture. Native vegetation is mainly post oak, blackjack oak, hickory, and eastern red cedar with an understory of tall to mid grasses as well as big bluestem and little bluestem. A topographic map of the area is shown in Exhibit A-1.

2.0 TEST HOLES

The test holes were manually advanced with a bucket hand auger. Representative samples of each subhorizon and the bulk composite samples of each required horizon were obtained from the bucket auger cuttings. The samples were tagged for identification and returned to the laboratory for further examination, testing, and classification. The borings are shown in Exhibit A-2.

3.0 LABORATORY TESTING FOR PEDOLOGICAL SURVEY

The samples obtained from each horizon and subhorizon were tested for their Atterberg limits and percentage passing the No. 4, No. 10, No. 40 and No. 200 U.S. Standard sieves. These results were used to determine the Oklahoma Subgrade Index (OSI), American Association of State Highway Transportation Officials (AASHTO) Soils Group and Group Index, and the soil classification per the Unified Soil Classification System (USCS). Soil pH, electrical resistivity and sulfate tests were also determined for each subhorizon.

Moisture-density relationship and resilient modulus tests were performed on bulk composite samples from the Harrah and Stephenville Series of the soils tested. Two soil samples from the Urban Land fill materials were also tested for moisture-density relationship and resilient modulus. The moisture-density and resilient modulus tests were performed in accordance with AASHTO-T-99 and AASHTO-T-307, respectively. The results of these tests are presented in Appendix B of this report.

4.0 PEDOLOGICAL SOIL AND GEOLOGICAL SURVEY

The proposed project was transposed onto the digital soil survey map of Logan and Oklahoma Counties[1]. The Soil Survey of Logan and Oklahoma Counties[2] identified ten mapping units within and adjacent to the specified new alignment and widening, as illustrated in the soil map in Exhibit A-2 of Appendix A and detailed below:

Map Unit	Soil Series
HarC	Harrah fine sandy loam, 3 to 5 percent slopes
HarC2	Harrah fine sandy loam, 3 to 5 percent slopes, eroded
PukA	Pulaski fine sandy loam, 0 to 1 percent slopes, frequently flooded
SNDN	Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes
SDND2	Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes, eroded
StDC	Stephenville-Darsil complex, 1 to 5 percent slopes
StDC2	Stephenville-Darsil complex, 1 to 5 percent slopes, eroded
SUND	Stephenville-Urban Land-Newalla complex, 1 to 8 percent slopes

[1] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for [Logan and Oklahoma Counties, Oklahoma]. Available online at http://soildatamart.nrcs.usda.gov. Accessed [October, 2018]

[2] Natural Resources Conservation Service, Soil survey of Logan and Oklahoma Counties, Oklahoma. United States. Soil Conservation Service, Dept. of Agriculture. Available online at http://websoilsurvey.nrcs.usda.gov .

Map Unit	Soil Series
TriA	Tribbey fine sandy loam, 0 to 1 percent slopes, frequently flooded
URB	Urban land

The soils in the new alignment and widening areas were also formed of urban land fill materials which may contain non-native fill materials.

Sampling and analysis for this survey included the Harrah, Stephenville Series and two Urban Land soil types. Soils adjacent and near the alignment were sampled and evaluated to classify the soils and identify the appropriate series. These soils are detailed in the "Typical Characteristics of Soil Series" table attached to this report. Sampling locations are illustrated in Exhibit A-2. Detailed field descriptions are included in the attached "Pedological Soil Survey" table in Appendix A.

Official soil series descriptions were obtained from the Natural Resource Conservation Service for soils that occur at the site[3]. The Official Series Descriptions of the soils that were sampled are included in Appendix C. The taxonomic classifications for the significant soils that occur in the alignment are listed below:

Series Name	Classification
Darsil	Thermic, shallow, coated Ustic Quartzipsamments
Harrah	Fine-loamy, siliceous, active, thermic Ultic Paleustalfs
Newalla	Fine-Loamy over clayey, siliceous, superactive, thermic Udic Haplustalfs
Stephenville	Fine-loamy, siliceous, active, thermic, Ultic Haplustalfs

Field characterization of soil types included initial identification of the map unit adjacent to the alignment. Once the map unit was identified, characterized, and geographically verified, samples were collected from the appropriate depths using a closed bucket hand auger. All samples were collected from public right-of-way in areas relatively near the project alignment.

The soils within the Darsil and Newalla map unit delineation appear to deviate from the typical known characteristics of the soil series. When comparing aerial imagery and topographic maps, it's evident the landscape has been modified due to the urban development. The original landscape has been modified to accommodate the new highway and roads and other local urban development. As a result, soils within this map unit delineation are inconsistent and may contain non-native fill material in some areas. Soils with Darsil and Newalla characteristics in the native state were not readily located within the alignment; additionally, verification borings for the Harrah and Stephenville series did not match the known and expected characteristics of the soil series.

[3] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available online at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx Accessed [October, 2018]

Therefore, the soil samples collected for laboratory analysis consisted mainly of native (Harrah and Stephenville Soil Series) and non-native materials classified as Urban Land soils. Darsil and Newalla soil series were not found in the alignment.

The following recommendations are based on laboratory results from the borings collected at the specific locations that may have been modified from their native state. These results may or may not be reproducible at other locations with the map unit delineation within the alignment. We also provide recommendations based on the published official soil series descriptions obtained from the Natural Resource Conservation Service for the Darsil and Newalla soils.

4.1 Soil Series Taxonomy[4]

4.1.1 Darsil Series

The Darsil Series consists shallow, excessively drained, soils that formed in materials weathered from weakly sandstone of Permian age. These soils occur on convex ridge crests of low hills in the North Cross Timbers. Slopes range from 1 to 8 percent in the alignment. Darsil soils are part of the Stephenville-Darsil-Newalla Complex or Stephenville-Darsil Complex which represent approximately 41% of the soils along the alignment.

The Darsil soil series was not readily located within the alignment or project area and therefore the samples were not collected for this study.

Recommendations: Based on taxonomic classification, NRCS - Official Series Description, and basic soil behavior concepts, the following recommendations are for the Darsil Series as they apply to roadway design:

- Based on NRCS - Official Series Description, an undercut of approximately 13 inches minimum will be required throughout the Darsil Series.
- Darsil soils do not possess an argillic horizon of accumulated clay. Cement kiln dust may be helpful to provide adequate subgrade strength.
- NRCS rates these soils as “poor” for potential use as a source of roadfill material due to depth to rock.

4.1.2 Harrah Series

The Harrah Series consist of soils that are very deep to sandstone, well drained soils. They formed from sandy and loamy colluvium weathered from sandstone of the Permian age. These soils are

[4] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Agriculture Handbook, Number 436. 1999. *Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys*. Second Edition. Washington, DC: U.S. Government Printing Office.

on backslopes and foot slopes of low hills in the Northern Cross Timber. Slopes range from 3 to 5 percent along the alignment. Harrah soils represent approximately 11% of the soils along the alignment.

The Harrah soils series was collected from public right-of-way on I-35, approximately 0.5 miles north of Waterloo Road.

Recommendations: Based on taxonomic classification, NRCS - Official Series Description, and basic soil behavior concepts, the following recommendations are for the Harrah Series as they apply to roadway design:

- Based on the results of our boring, an undercut of approximately 30 inches minimum will be required throughout the Harrah Series.
- Harrah soils possess an argillic horizon of accumulated clay. Our laboratory results indicate the soils exhibit moderate to high shrink-swell potential. Cement kiln dust, fly ash, or lime treatment may be helpful to stabilize the activity of the clays and provide adequate subgrade strength.
- Based on the laboratory test results these soils are rated “poor” for potential use as a source of roadfill material per AASHTO. NRCS rates these soils as “good” for potential use as a source of roadfill material.

4.1.3 Newalla Series

The Newalla Series consists of deep, moderately well drained, very slow permeable soils. The upper part formed in material weathered from sandstone and the lower part formed in material weathered from shale of Permian age. These soils are on very gently sloping to steep summits and back slopes of uplands in the northern Cross Timbers. Slopes range from 3 to 8% for the map units in the alignment. Newalla soils are part of the Stephenville-Urban Land-Newalla Complex or Stephenville-Darsil-Newalla Complex which represent approximately 35% of the soils along the alignment.

The Newalla soil series was not readily located within the alignment or project area and therefore the samples were not collected for this study.

Recommendations: Based on taxonomic classification, NRCS - Official Series Description, and basic soil behavior concepts, the following recommendations are for the Newalla Series as they apply to roadway design:

- Based on NRCS - Official Series Description, an undercut of approximately 6 inches minimum will be required throughout the Newalla Series.
- Newalla soils possess an argillic horizon of accumulated clay. NRCS - Official Series

Description indicate the soil complex exhibit low to high shrink-swell potential. Cement kiln dust, fly ash or lime may be helpful to stabilize the activity of the clays and provide adequate subgrade strength.

- NRCS rates these soils as "poor" for potential use as a source of roadfill material due to low strength, shrink-swell, depth to rock and dust.

4.1.4 Stephenville Series

The Stephenville Series consists of moderately deep, well drained, soils formed in material weathered from sandstone of Permian age. These soils are on very gently sloping to moderately steep side slopes of hills in the North Cross Timbers. Slopes range from 1 to 8% for the map units in the alignment. Stephenville soils are found in the Stephenville-Urban land-Newalla complex, Stephenville-Darsil-Newalla complex and Stephenville-Darsil complex which represent approximately 47% of the soils along the alignment.

The Stephenville Series was collected from public right-of-way, approximately 0.7 miles south of Waterloo Road.

Recommendations: Based on taxonomic classification, NRCS - Official Series Description, and basic soil behavior concepts, the following recommendations are for the Stephenville Series as they apply to roadway design:

- Based on the results of our boring, an undercut of approximately 17 inches minimum will be required throughout the Stephenville Series.

- Stephenville soils possess an argillic horizon of accumulated clay. Depending on clay content, these soils could exhibit low to moderate shrink swell behavior. Our laboratory results indicate the soils exhibit low to moderate shrink-swell potential. Cement kiln dust, fly ash, or lime treatment may be helpful to stabilize the activity of the clays and provide adequate subgrade strength.

- Based on the laboratory test results, these soils are rated "fair" and "poor" for potential use as a source of roadfill material per AASHTO. NRCS rates these soils as "poor" for potential use as a source of roadfill material due to depth to bedrock.

4.2 Analysis and Discussion

The main landforms that occur near the project are convex hillslopes, backslopes, footslopes and hills. Urban soils are also exhibited near the project.

Soil taxonomy and field descriptions reveal that the dominant soils in the proposed interchange are moderately well to well drained. Taxonomy indicates that these soils are Alfisols that may

exhibit shrink swell features. Based on AASHTO information, the Harrah and Stephenville soils and the Urban Land soils studied for this survey are rated “poor” for use as potential source of roadfill material. NRCS rates Harrah soils studied for this survey as “good” and Darsil, Newalla and Stephenville, soils studied for this survey as “poor” for potential use as a source of roadfill material.

Soils in the alignment will require removal of topsoil and A horizons to depths approximately 6 to 30 inches during construction.

The soil series along the alignment do not appear to satisfy ODOT’s Section 705, Select Borrow requirements of A-1, A-2-4 or A-3 soils.

5.0 GENERAL COMMENTS

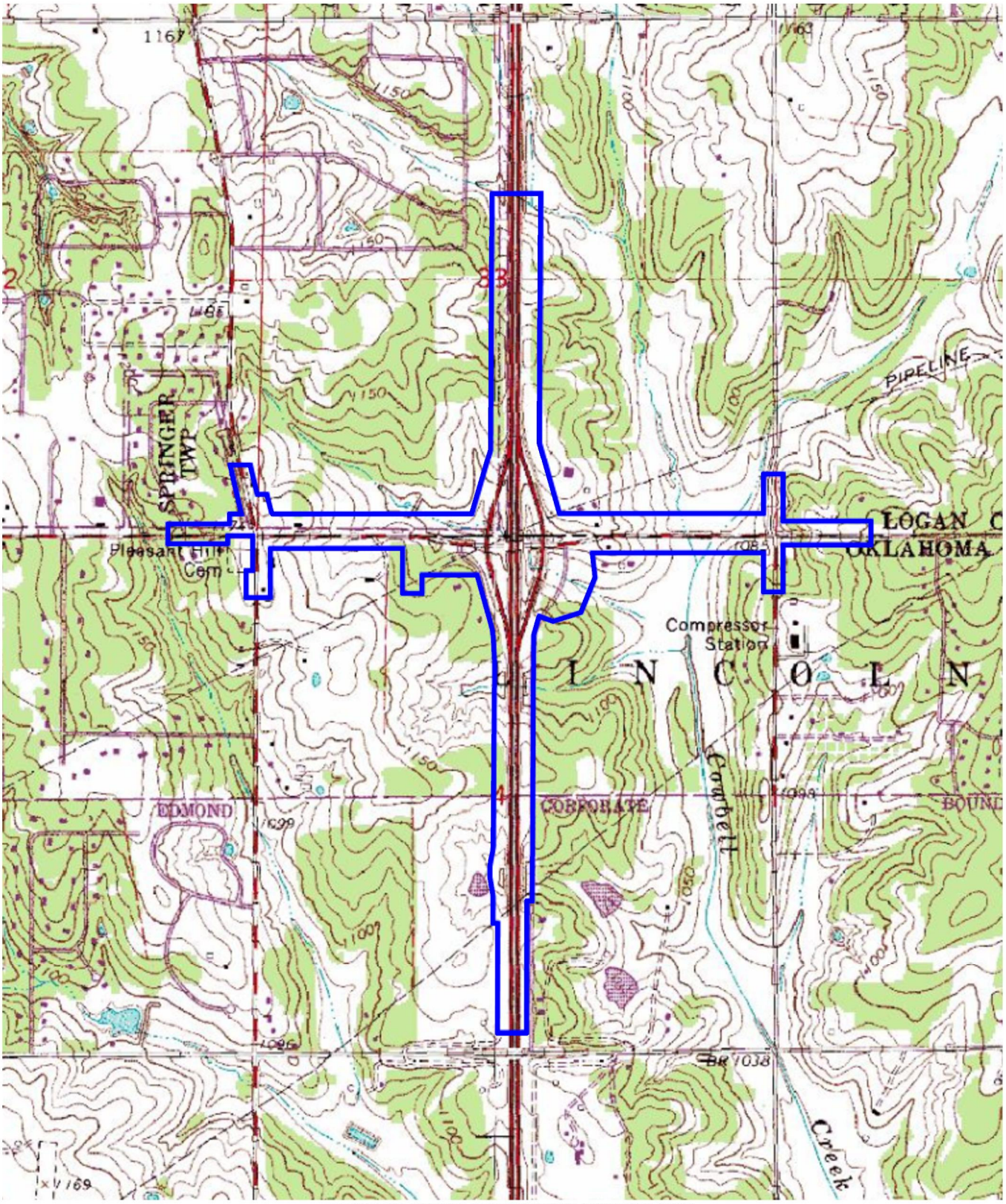
Terracon Consultants, Inc. should be retained to provide testing and observation during excavation, grading, and construction phases of the project.

The results presented in this report are based upon the data obtained from the borings performed at the indicated locations and from any other information discussed in this report. This report does not reflect any variations which may occur between borings or across the site. The nature and extent of such variations may not become evident until construction. If variations appear, it will be necessary to re-evaluate the recommendations of this report.

The scope of services for this project does not include either specifically or by implication any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed, and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, neither expressed nor implied are intended or made. In the event that any changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon Consultants, Inc. reviews the changes, and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION



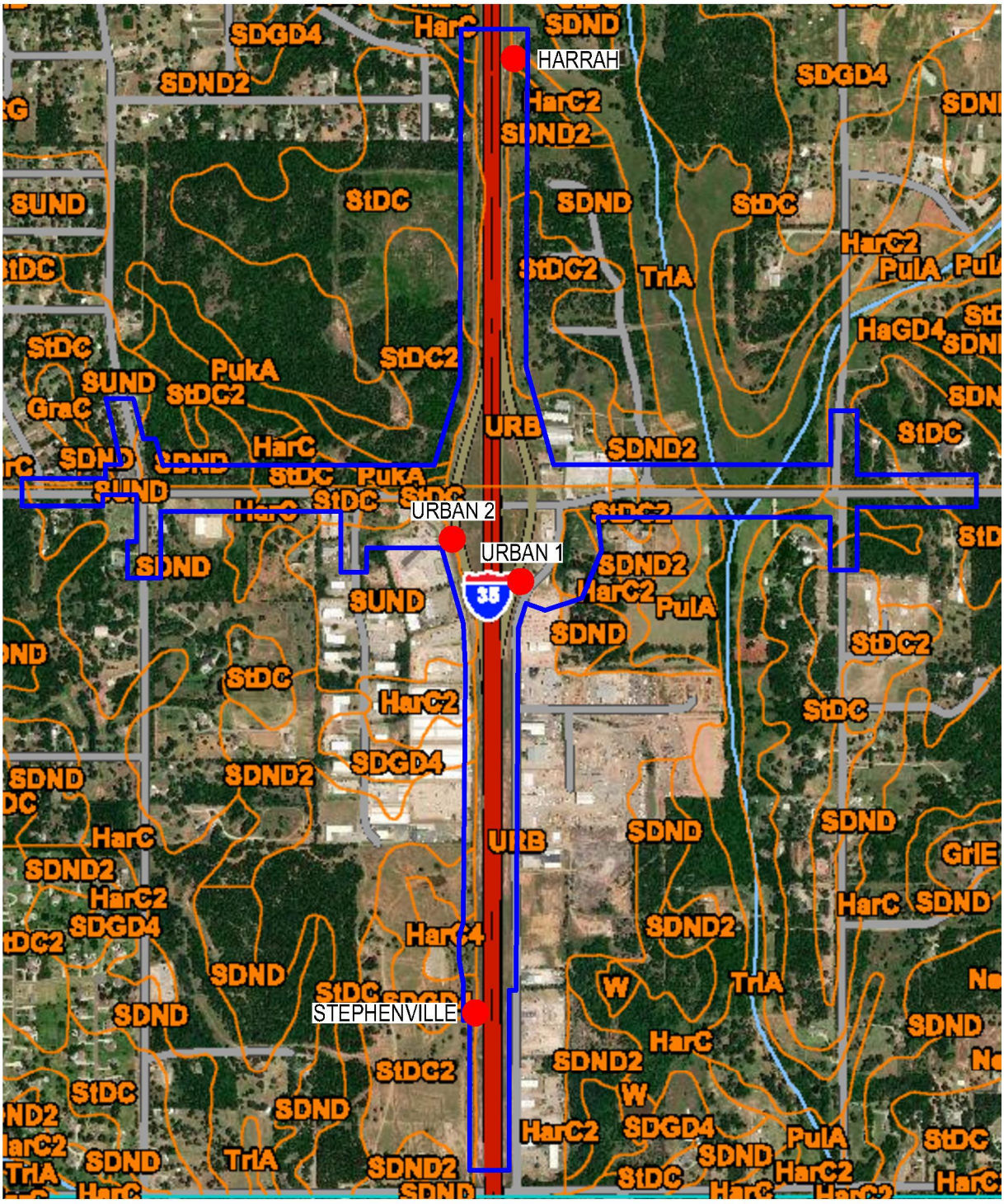
TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY
QUADRANGLES INCLUDE: EDMOND, OK (1/1/1983).

LEGEND

PROJECT BOUNDARY

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Mngr: DCVS	Project No. 03165261	Terracon Consulting Engineers and Scientists	SITE LOCATION PLAN
Drawn By: CAN	Scale: NTS	4701 N STILES AVE OKLAHOMA CITY, OKLAHOMA 73105	PEDOLOGICAL AND GEOLOGICAL SURVEY INTERSTATE 35 AND WATERLOO ROAD INTERCHANGE LOGAN AND OKLAHOMA COUNTIES, OKLAHOMA
Checked By: DCVS	File No. 03165261 (A1-A2)	PH. (405) 525-0453 FAX. (405) 557-0549	EXHIBIT A1
Approved By: NKT	Date: DEC 2018		



LEGEND

- SAMPLE HOLE LOCATION
- PROJECT BOUNDARY
- SUND STEPHENVILLE-URBAN LAND-NEWALLA COMPLEX, 1 TO 8 PERCENT SLOPES
- SDND STEPHENVILLE-DARSIL-NEWALLA COMPLEX, 3 TO 8 PERCENT SLOPES
- SDND2 STEPHENVILLE-DARSIL-NEWALLA COMPLEX, 3 TO 8 PERCENT SLOPES, ERODED
- StDC STEPHENVILLE-DARSIL COMPLEX, 1 TO 5 PERCENT SLOPES
- StDC2 STEPHENVILLE-DARSIL COMPLEX, 1 TO 5 PERCENT SLOPES, ERODED
- HarC HARRAH FINE SANDY LOAM, 3 TO 5 PERCENT SLOPES
- HarC2 HARRAH FINE SANDY LOAM, 3 TO 5 PERCENT SLOPES, ERODED
- URB HEIDEN CLAY, 1 TO 3 PERCENT SLOPES

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Mngr: DCVS	Project No. 03165261	Terracon Consulting Engineers and Scientists	PUBLISHED SOIL SURVEY AND SAMPLE LOCATIONS
Drawn By: CAN	Scale: NTS	4701 N STILES AVE OKLAHOMA CITY, OKLAHOMA 73105	PEDOLOGICAL AND GEOLOGICAL SURVEY
Checked By: DCVS	File No. 03165261 (A1-A2)	PH. (405) 525-0453 FAX. (405) 557-0549	INTERSTATE 35 AND WATERLOO ROAD INTERCHANGE
Approved By: NKT	Date: DEC 2018		LOGAN AND OKLAHOMA COUNTIES, OKLAHOMA

EXHIBIT A2

TYPICAL CHARACTERISTICS OF SOIL SERIES

PEDOLOGICAL AND GEOLOGICAL SURVEY
INTERSTATE 35 OVER WATERLOO ROAD INTERCHANGE
OKLAHOMA AND LOGAN COUNTIES
ENGINEERING CONTRACT NO. EC-1500N
JOB PIECE NO. 29843(04)

TERRACON PROJECT NO. 03165261

Soil Series (Map Symbol)	Est. Area Extent (%)	Slope Variability of Map Units (%)	Parent Material	Depth to Bedrock (in.)	Drainage	Permeability	Shrink-Swell Potential	Shrinkage / Swell Factor	Comments
Harrah (HarC, HarC2)	11%	3 - 5%	Residual	102	Well Drained	Moderately High	Moderate to High	B Horizon Shrinkage: 3.7%	-AASHTO rates these soils as "poor" for potential source of roadfill -Undercut depth: 30"
Stephenville (SDND, SDND2, StDC, StDC2, SUND)[1, 2]	47%	1 - 8%	Residual	50	Well Drained	Moderately High	Low to Moderate	B Horizon Shrinkage: 8.4% C Horizon Shrinkage 12%	-AASHTO rates these soils as "fair" to "poor" for potential source of roadfill -Undercut depth: 17"
Urban Land 1 (URB)[3]	26%	---	---	37	---	---	Moderate	Shrinkage: 7.4%[4]	-AASHTO does not provide a rating for these soils -Undercut depth: 24"
Urban Land 2 (URB)[3]	26%	---	---	46	---	---	Moderate	Shrinkage: 3.7%[4]	-AASHTO does not provide a rating for these soils -Undercut depth: 24"

1. This soil series is composed of the following complexes: Stephenville-Darsil-Newalla, Stephenville-Darsil and Stephenville-Darsil -Urban Land-Newalla Complex
2. Darsill and Newalla soil series were not readily located within the alignment or project area and therefore the samples were not collected for this study
3. Urban Land soils were tested due to their predominant area in the project alignment and because the native soils in the areas where they were anticipated to be found were not encountered during our field exploration.
4. Assuming the soils are residual

Terracon

PEDOLOGICAL SOIL SURVEY

Surveyed By: Terracon Consultants, Inc.	**03165261**
Client: Garver, LLC	**Project: Pedological Soil Survey**
Date Surveyed: October 12, 23 and November 7, 2018	**Location: Interstate 35 over Waterloo Road Interchange**
Date Reported: December 21, 2018	**County: Logan and Oklahoma State: Oklahoma**

Identifications		Subgrade Survey				Physical and Mechanical Analysis									
Material No.	AASHTO Class.	Location	Description of Sample	Depth (inches)	Horizon	LL	PI	Percent Passing #4	#10	#40	#200	OSI No.	pH	Sufate (mg/kg)	Resist. (ohm-cm)
HARRAH SERIES															
	A-2-4 (0)	GPS: 35°43'55.66"N, 97°24'57.13"W	Dark brown (7.5YR 3/3), silty sand (SM), granular/blocky structure, not friable.	0 - 14	A	NP	NP	100	100	99	29.0	0	6.88	<200	7,140
	A-2-4 (0)	Elevation: 1130 ft	Dark Brown (7.5YR 7/4), brown (7.5YR 4/2), silty sand (SM), granular structure, not friable.	14 30	E	NP	NP	100	100	100	24.7	0	7.15	<200	6,730
	A-6 (11)		Red (2.5 YR 4/6), sandy lean clay (CL), blocky structure, not friable.	30 38	Bt1	35	20	100	99	98	67.7	14	7.62	<200	2,270
	A-7-6 (31)		Red (2.5 YR 4/6), fat clay with sand (CH), blocky structure, not friable, some black concretions present.	38 55	Bt2	57	39	95	95	93	77.7	27	7.96	<200	1,691
	A-7-6 (31)		Dark Red (2.5 YR 3/6), fat clay with sand (CH), blocky structure, not friable, some light redoxomorphic features.	55 67	Bt3b	53	37	100	99	97	81.8	25	8.51	<200	1,829
	A-7-6 (29)		Red (2.5 YR 4/8), lean clay (CL), Massive structure, not friable, black concretions present.	67 102	Bt4b	47	32	99	98	96	88.4	22	9.09	<200	1,584
	A-7-6 (24)		**"B" Composite** - Red (2.5YR 4/6 &4/8) and dark red (2.5YR 3/6), lean clay with sand (CL)	30 - 102	---	47	31	100	99	97	79.0	22	---	<200	---

Exhibit A-4

Terracon

PEDOLOGICAL SOIL SURVEY

Surveyed By: Terracon Consultants, Inc.	**03165261**
Client: Garver, LLC	**Project: Pedological Soil Survey**
Date Surveyed: October 12, 23 and November 7, 2018	**Location: Interstate 35 over Waterloo Road Interchange**
Date Reported: December 21, 2018	**County: Logan and Oklahoma State: Oklahoma**

Identifications		**Subgrade Survey**				**Physical and Mechanical Analysis**									
Material No.	**AASHTO Class.**	**Location**	**Description of Sample**	**Depth (inches)**	**Horizon**	**LL**	**PI**	**Percent Passing #4**	**#10**	**#40**	**#200**	**OSI No.**	**pH**	**Sufate (mg/kg)**	**Resist. (ohm-cm)**
STEPHENVILLE SERIES															
	A-2-4 (0)	GPS: 35°42'52.45" N, 97°24'59.98"W	Reddish brown (2.5 YR 4/3), clayey sand (SC), Granular structure, single grained, not friable, many fine roots.	0 - 6	A	24	9	100	97	94	26.7	1	8.19	<200	3,490
	A-2-4 (0)	Elevation: 1125 ft	Yellowish red (5 YR 5/6), silty sand (SM), Granular to somewhat blocky structure, not friable.	6 - 17	E	NP	NP	100	99	98	17.8	0	8.45	<200	5,400
	A-6 (15)		Reddish brown (2.5 YR 4/4) matrix with white (2.5 Y 8/1) as a second predominant color, lean clay with sand (CL), subangular blocky structure, friable somewhat sticky.	17 - 24	Bt1	35	22	100	100	100	76.5	16	8.26	<200	2,900
	A-6 (21)		Red (10R 5/6), lean clay (CL), blocky to subangular blocky structure, friable somewhat sticky with some black redoxomorphic features.	24 - 36	Bt2	37	22	100	100	100	94.9	16	7.68	<200	2,500
	A-6 (10)		Very pale brown (10YR 8/2), dark reddish brown (2.5YR 3/4), and some fine yellow (10YR 7/8), lean clay with sand (CL), blocky to granular structure, not friable loose. Significant color variations.	36 - 40	Cr1	29	16	100	100	99	79.2	12	7.62	<200	3,180
	A-6 (2)		Reddish brown (2.5 YR 5/4), clayey sand (SC), granular to blocky structure, not friable, not significant color variations.	40 - 50	Cr2	23	11	100	100	96	46.6	6	7.91	<200	6,220
	A-6 (15)		**"B" Composite** - Reddish brown (2.5 YR 4/4), red (10R 5/6) and white (2.5Y 8/1), lean clay with sand (CL)	17 - 36	---	34	20	100	100	98	81.4	15	---	<200	---
	A-4 (2)		**"C" Composite** - very pale brown (10YR 8/2), dark reddish brown (2.5YR 3/4) and reddish brown (2.5 YR 5/4), sandy lean clay (CL)	36 - 50	---	23	8	100	100	99	54.0	5	---	<200	---

Exhibit A-4

Terracon

PEDOLOGICAL SOIL SURVEY

Surveyed By: Terracon Consultants, Inc.	**03165261**
Client: Garver, LLC	**Project: Pedological Soil Survey**
Date Surveyed: October 12, 23 and November 7, 2018	**Location: Interstate 35 over Waterloo Road Interchange**
Date Reported: December 21, 2018	**County: Logan and Oklahoma State: Oklahoma**

Identifications		Subgrade Survey				Physical and Mechanical Analysis									
Material No.	AASHTO Class.	Location	Description of Sample	Depth (inches)	Horizon	LL	PI	Percent Passing #4	#10	#40	#200	OSI No.	pH	Sufate (mg/kg)	Resist. (ohm-cm)
Urban Land 1															
	---	GPS: 35°43'24.38"N, 97°24'55.96"W Elevation: 1102 ft	Reddish-brown (2.5YR 4/3) granular structure, somewhat friable.	0 - 24	A	---	---	---	---	---	---	---	---	---	---
	A-6 (2)		Red (2.5YR 4/6) clayey sand (SC), somewhat blocky structure, sticky, not friable.	24 - 37	B	32	16	100	100	99	38.0	6	---	<200	---
	A-6 (2)		**Bulk Urban Land 1** - Red (2.5YR 4/6) clayey sand (SC)	24 - 37	---	32	16	100	100	99	38.0	6	---	<200	---

Exhibit A-4

Terracon

PEDOLOGICAL SOIL SURVEY

Surveyed By: Terracon Consultants, Inc.	**03165261**
Client: Garver, LLC	**Project: Pedological Soil Survey**
Date Surveyed: October 12, 23 and November 7, 2018	**Location: Interstate 35 over Waterloo Road Interchange**
Date Reported: December 21, 2018	**County: Logan and Oklahoma State: Oklahoma**

Identifications		Subgrade Survey				Physical and Mechanical Analysis									
Material No.	AASHTO Class.	Location	Description of Sample	Depth (inches)	Horizon	LL	PI	Percent Passing #4	#10	#40	#200	OSI No.	pH	Sufate (mg/kg)	Resist. (ohm-cm)
Urban Land 2															
	---	GPS: 35°43'27.55"N, 97°25'2.63"W	Dark reddish-brown (5YR 3/3), granular structure, somewhat friable.	0 - 24	A	---	---	---	---	---	---	---	---	---	---
	A-6 (6)	Elevation: 1114 Ft	Dark red (2.5YR 3/6), sandy lean clay (CL),somewhat blocky structure, not friable.	24 - 46	B	33	18	100	99	97	54.1	10	---	<200	---
	A-6 (6)		**Bulk Urban Land 2** - Dark red (2.5YR 3/6), sandy lean clay (CL)	24 - 46	---	33	18	100	99	97	54.1	10	---	<200	---

Exhibit A-4

SOIL MAP UNIT EXTENTS

PEDOLOGICAL AND GEOLOGICAL SURVEY
INTERSTATE 35 OVER WATERLOO ROAD INTERCHANGE
OKLAHOMA AND LOGAN COUNTIES
ENGINEERING CONTRACT NO. EC-1500N
JOB PIECE NO. 29843(04)

TERRACON PROJECT NO. 03165261

Lateral Extent			Soil Unit Name
Starting from West End of Project			
10+00	to	14+50 (Sooner Rd)	Stephenville-Urban land Newalla complex
14+50	to	21+00 (Sooner Rd)	Stephenville-Darsil-Newalla complex
40+02	to	48+09 (Waterloo Rd)	Stephenville-Darsil-Newalla complex
48+09	to	52+69 (Waterloo Rd)	Harrah fine sandy loam
52+92	to	57+92 (Waterloo Rd)	Stephenville-Darsil
57+92	to	62+87 (Waterloo Rd)	Pulaski fine sandy loam
62+87	to	75+62 (Waterloo Rd)	Urban land
75+62	to	77+72 (Waterloo Rd)	Stephenville-Darsil, eroded
77+72	to	82+40 (Waterloo Rd)	Stephenville-Darsil-Newalla complex, eroded
82+40	to	91+12 (Waterloo Rd)	Tribbey fine sandy loam
91+12	to	92+69 (Waterloo Rd)	Stephenville-Darsil-Newalla complex
10+28	to	16+45 (Boucher Frontage Rd)	Urban land
10+00	to	11+94 (Industrial Blvd)	Urban land
11+94	to	15+50 (Industrial Blvd)	Harrah fine sandy loam, eroded
15+50	to	18+02 (Industrial Blvd)	Stephenville-Darsil-Newalla complex, eroded
18+02	to	20+17 (Industrial Blvd)	Stephenville-Darsil, eroded

APPENDIX B

LABORATORY TESTING

Laboratory Compaction Characteristics of Soil

Terracon
4701 North Stiles Ave.
Oklahoma City, OK 73105
(405) 525 0453

Client Name: Garver, LLC
Project Name: Pedological and Geological Soil Survey
Location: I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma

Source Material: Harrah Bulk B (30-102")
Sample Description: Lean Clay With Sand, Red (2.5YR 4/6 & 4/8)
and dark red (2.5YR 3/6)
Material Designation: Lab 696 Sample date: 10/23/18
Test Method: Method A
Test Procedure: AASHTO T-99
Sample Preparation: Dry
Rammer: X Mechanical ___ Manual

Project No.: 03165261 Date: 11/14/18

TEST RESULTS
Maximum Dry Unit Wt.: 110.6 pcf
Optimum Water Content: 16.3 %

Liquid Limit: 47 Plastic Limit: 16
Plasticity Index: 31
% passing # 200 sieve: 79
AASHTO Class. A-7-6(24) USCS: CL
Reviewed by: DCVS

Zero air voids for specific gravity of 2.70

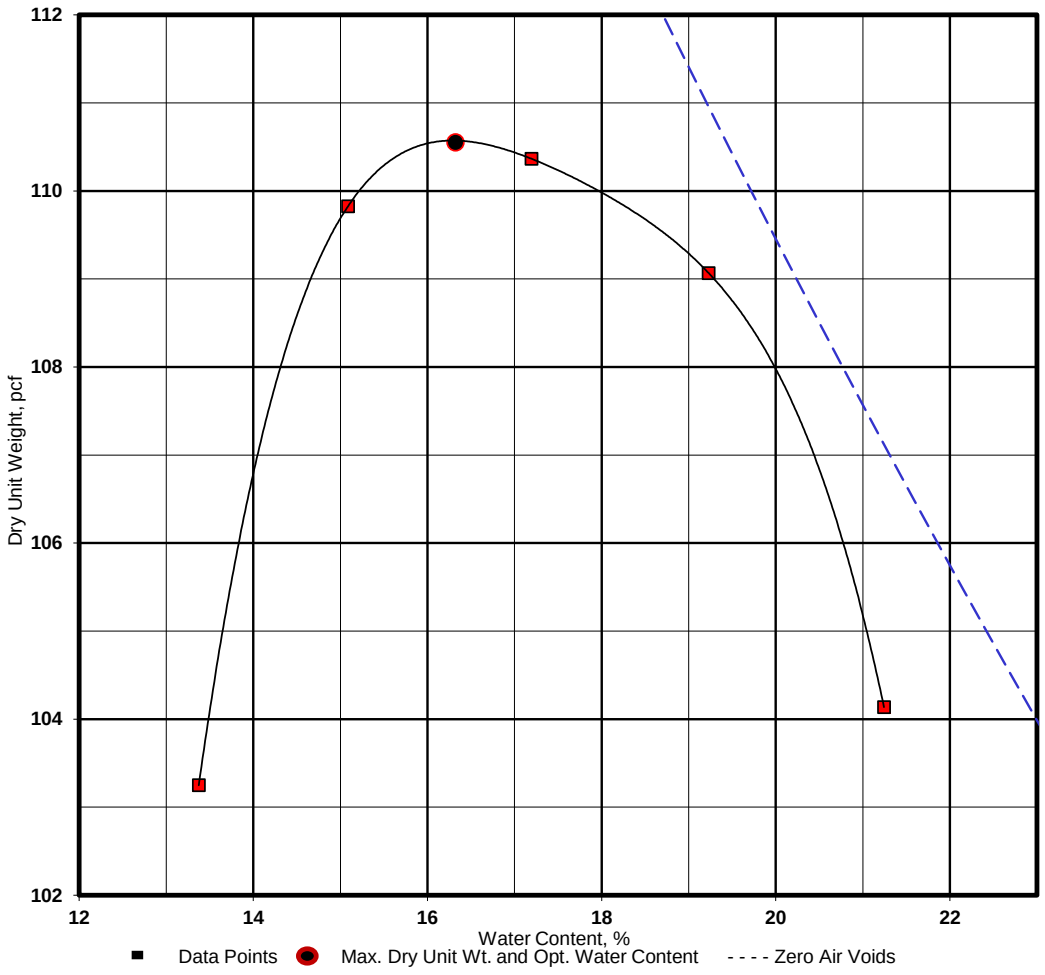


Exhibit B-1

Laboratory Compaction Characteristics of Soil

Terracon
4701 North Stiles Ave.
Oklahoma City, OK 73105
(405) 525 0453

Client Name: Garver, LLC
Project Name: Pedological and Geological Soil Survey
Location: I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma

Project No.: 3165261 Date: 11/14/18

Source Material: Stephenville Bulk B (17 - 36")
Sample Description: Lean Clay with Sand, reddish-brown
(2.5YR 4/4), red (10R 5/6) & white (2.5Y 8/1)
Material Designation: lab 697 Sample date: 10/12/18
Test Method: Method A
Test Procedure: AASHTO T-99
Sample Preparation: Dry
Rammer: X Mechanical ___ Manual

TEST RESULTS
Maximum Dry Unit Wt.: 118.9 pcf
Optimum Water Content: 13.0 %

Liquid Limit: 34 Plastic Limit: 14
Plasticity Index: 20
% passing # 200 sieve: 81.4
AASHTO Class. A-6(15) USCS: CL
Reviewed by: DCVS

Zero air voids for specific gravity of 2.70

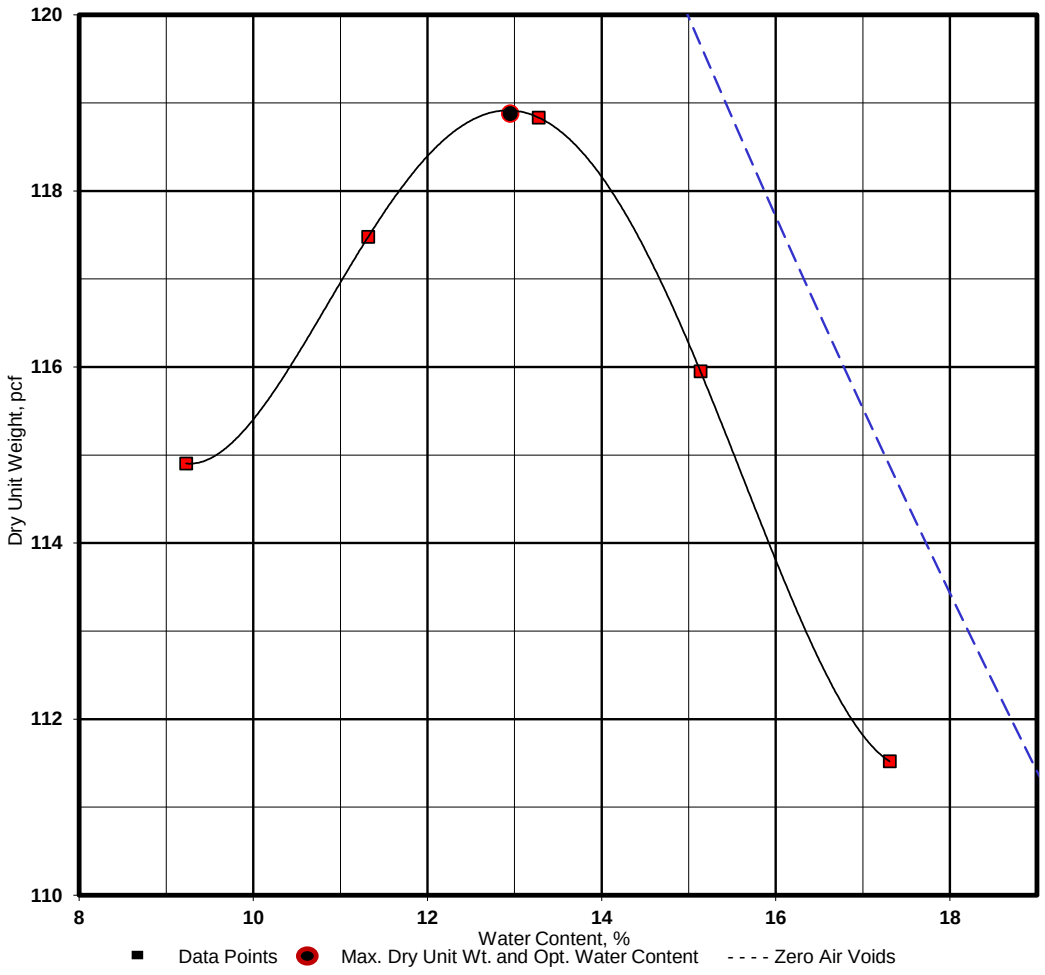


Exhibit B-2

Laboratory Compaction Characteristics of Soil

Terracon
4701 North Stiles Ave.
Oklahoma City, OK 73105
(405) 525 0453

Client Name: Garver, LLC
Project Name: Pedological and Geological Soil Survey
Location: I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma

Source Material: Stephenville Bulk C (36"-50")
Sample Description: Sandy lean clay, very pale brown (10YR 8/2), dark reddish brown (2.5YR 3/4) and reddish brown (2.5YR 5/4)

Material Designation: lab 698 Sample date: 10/12/18
Test Method: Method A
Test Procedure: AASHTO T-99
Sample Preparation: Dry
Rammer: X Mechanical ___ Manual

Project No.: 03165261 Date: 11/14/18

TEST RESULTS
Maximum Dry Unit Wt.: 118.9 pcf
Optimum Water Content: 13.0 %

Liquid Limit: 23 Plastic Limit: 15
Plasticity Index: 8
% passing # 200 sieve: 54
AASHTO Class. A-4 (2) USCS: CL
Reviewed by: DCVS

Zero air voids for specific gravity of 2.70

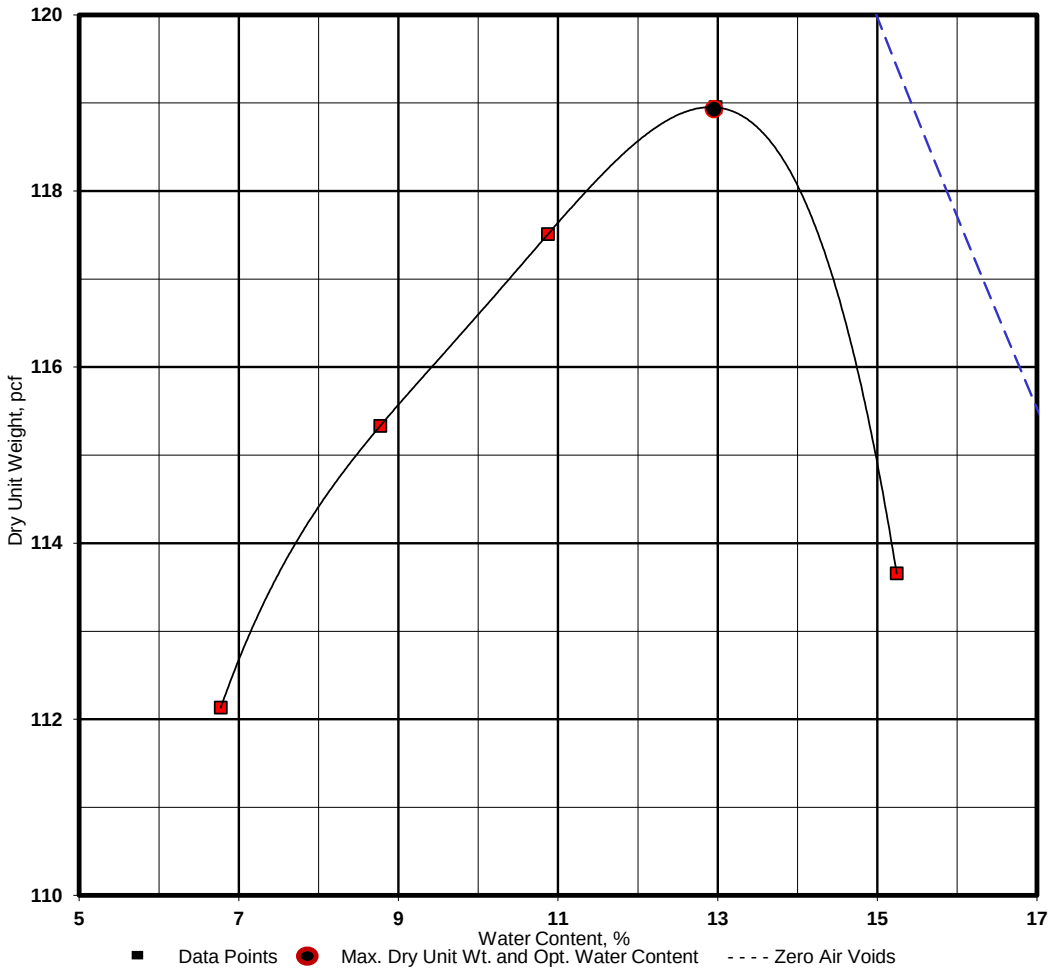


Exhibit B-3

Laboratory Compaction Characteristics of Soil

Terracon
4701 North Stiles Ave.
Oklahoma City, OK 73105
(405) 525 0453

Client Name: Garver, LLC
Project Name: Pedological and Geological Soil Survey
Location: I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma

Source Material: Urban Land 1 (Bulk)
Sample Description: Clayey Sand, Red (2.5YR 4/6)

Material Designation: lab 702 Sample date: 11/07/18
Test Method: Method A
Test Procedure: AASHTO T-99
Sample Preparation: Dry
Rammer: X Mechanical ___ Manual

Project No.: 03165261 Date: 11/15/18

TEST RESULTS
Maximum Dry Unit Wt.: 112.9 pcf
Optimum Water Content: 14.1 %

Liquid Limit: 32 Plastic Limit: 16
Plasticity Index: 16
% passing # 200 sieve: 38
AASHTO Class. A-6(2) USCS: SC
Reviewed by: DCVS

Zero air voids for specific gravity of 2.70

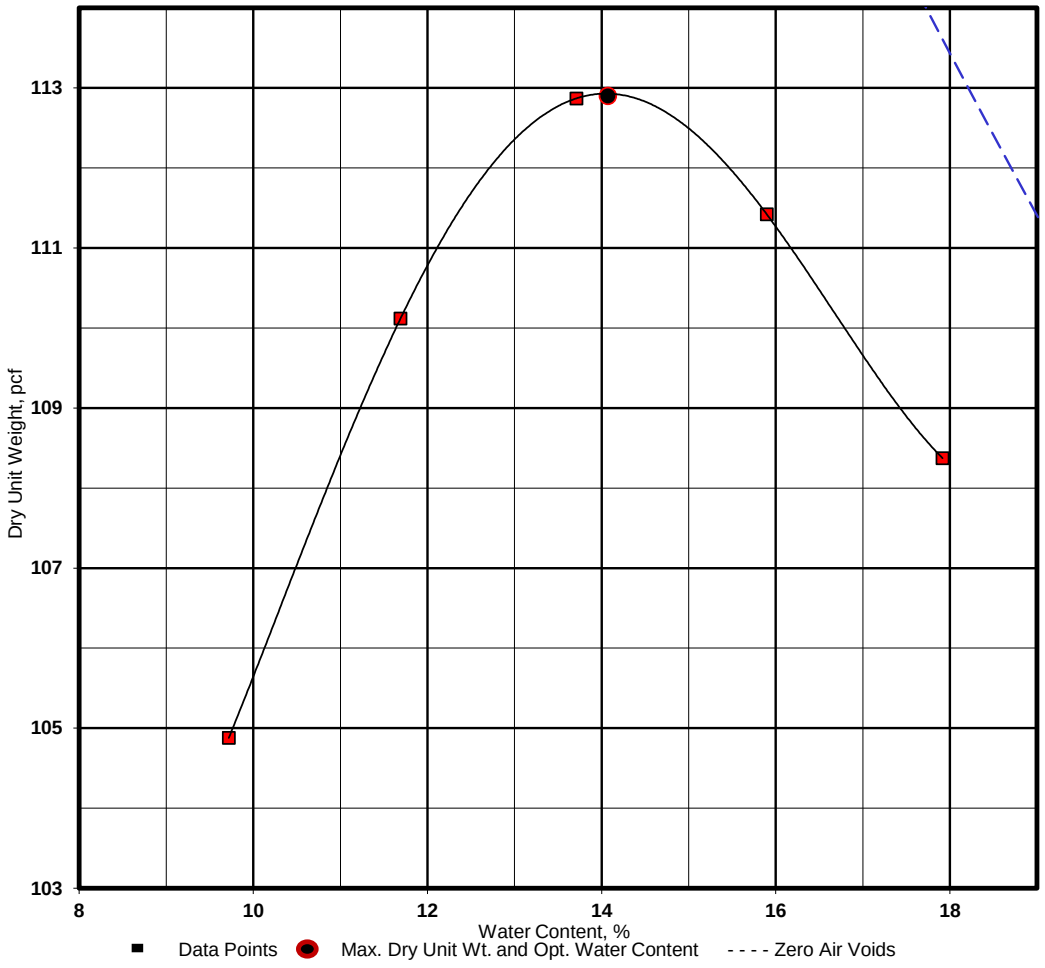


Exhibit B-4

Laboratory Compaction Characteristics of Soil

Terracon
4701 North Stiles Ave.
Oklahoma City, OK 73105
(405) 525 0453

Client Name: Garver, LLC
Project Name: Pedological and Geological Soil Survey
Location: I-35 over Waterloo Road Interchange
Oklahoma and Logan Counties, Oklahoma

Project No.: 03165261 Date: 11/15/18

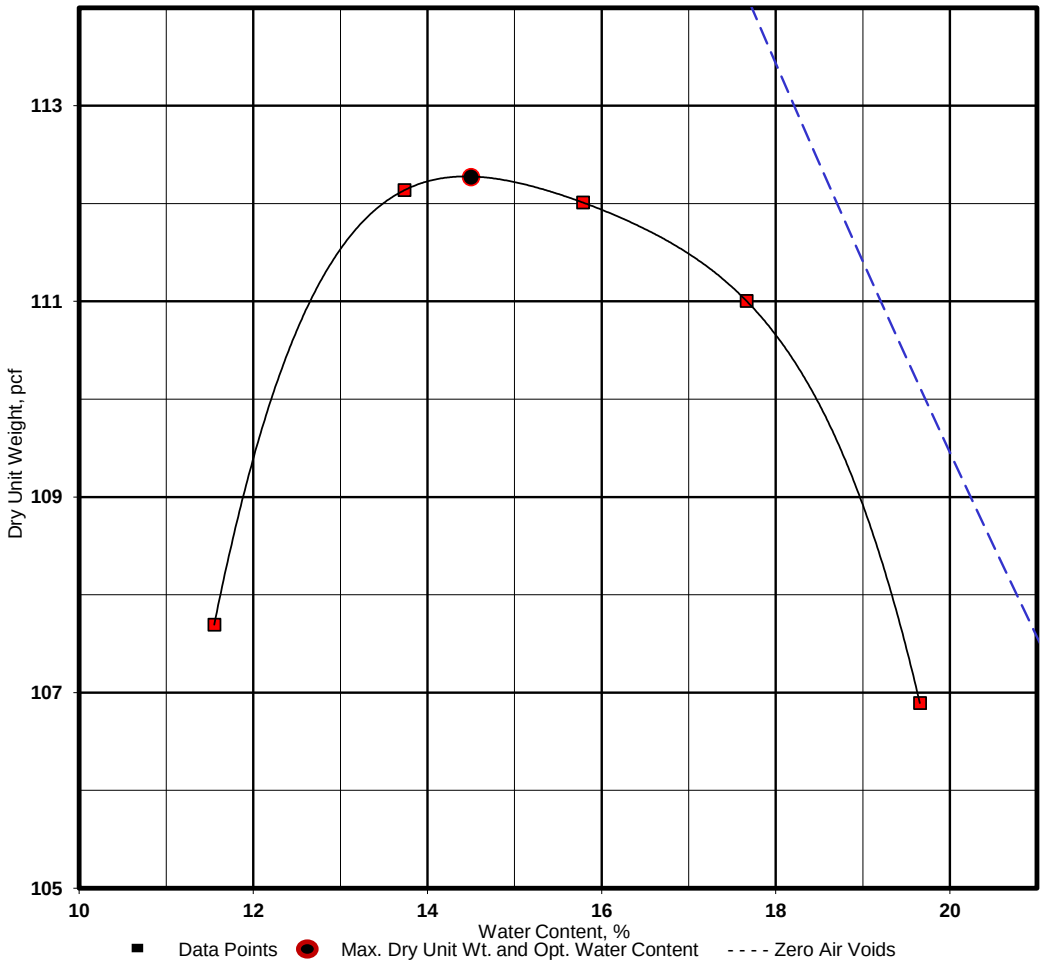
Source Material: Urban Land 2 Bulk (24" - 46")
Sample Description: Sandy Lean Clay, dark red (2.5YR 3/6)

TEST RESULTS
Maximum Dry Unit Wt.: 112.3 pcf
Optimum Water Content: 14.5 %

Material Designation: lab 703 Sample date: 11/07/18
Test Method: Method A
Test Procedure: ASTM D-698
Sample Preparation: Dry
Rammer: X Mechanical ___ Manual

Liquid Limit: 33 Plastic Limit: 15
Plasticity Index: 18
% passing # 200 sieve: 54
AASHTO Class. A-6(6) USCS: CL
Reviewed by: DCVS

Zero air voids for specific gravity of 2.70



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 696 RM 49 omc
Project No.: 03165261

Soil Map Unit:	Harrah Bulk B OMC
Soil Symbol:	A-7-6(24) / CL
Depth (in.)	30 - 102
Compaction Method	Static
Max. Dry Density (pcf)	110.6
Opt. Moisture Content (%)	16.3
Inside Mold Diameter (in)	3.94

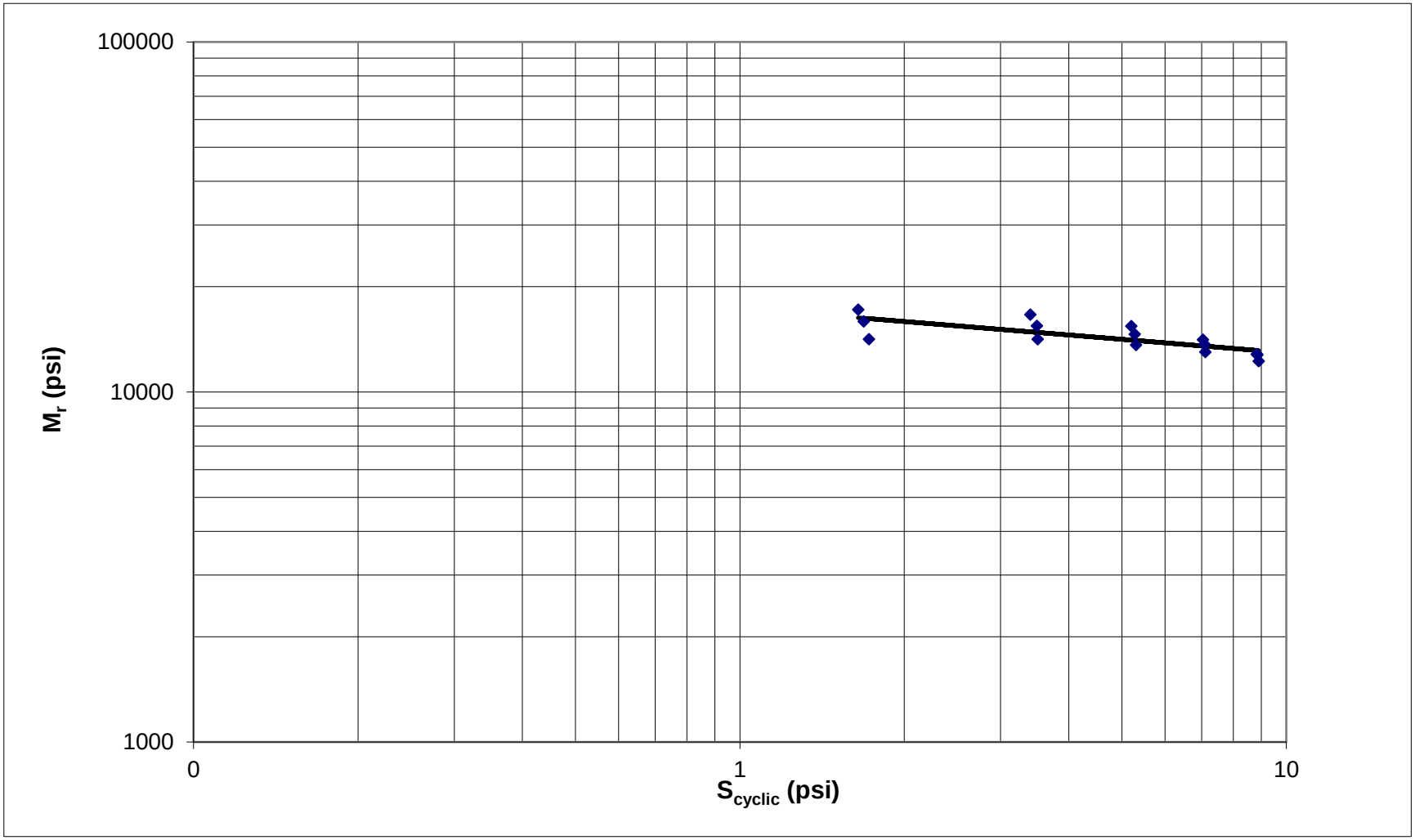
Weight of Wet Soil (lb)	6.78
Initial Sample Diameter (in)	3.94
Initial Sample Height (in)	7.87
Initial Sample Area (in^2)	12.17
Sample Volume (in^3)	95.86
Compacted Moisture Content(%)	16.6
Wet Density (pcf)	122.1
Dry Density (pcf)	104.7

Test Date: November 30, 2018

Final Sample Height (in)	7.9
Final Sample Wet Weight (lb)	6.77
Final Moisture Content (%)	16.6
Accumulated Strain (%)	0.04
Percent Passing No. 10	99
Percent Passing No. 200	79.0
Liquid Limit	47
Plasticity Index	31

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.4	20.0	3.4	1.92	1.65	0.275	0.0007	0.0008	0.0008	0.000096	17,198
6.00	4.00	47.0	41.4	5.6	3.86	3.40	0.456	0.0015	0.0018	0.0016	0.000204	16,635
6.00	6.00	71.7	63.4	8.3	5.89	5.21	0.683	0.0024	0.0029	0.0027	0.000337	15,428
6.00	8.00	96.4	85.7	10.7	7.92	7.04	0.881	0.0036	0.0043	0.0039	0.000499	14,098
6.00	10.00	121.1	107.6	13.4	9.94	8.84	1.104	0.0050	0.0058	0.0054	0.000689	12,833
4.01	2.00	24.2	20.5	3.7	1.99	1.69	0.303	0.0007	0.0009	0.0008	0.000106	15,913
4.01	4.00	48.5	42.6	6.0	3.98	3.49	0.489	0.0016	0.0020	0.0018	0.000226	15,459
4.01	6.00	72.8	64.3	8.5	5.98	5.28	0.701	0.0025	0.0032	0.0028	0.000361	14,622
4.01	8.00	97.2	86.3	10.9	7.98	7.08	0.896	0.0037	0.0045	0.0041	0.000518	13,687
4.01	10.00	121.2	107.8	13.4	9.96	8.85	1.103	0.0050	0.0059	0.0055	0.000694	12,762
2.00	2.00	23.9	21.0	2.9	1.96	1.72	0.241	0.0008	0.0011	0.0010	0.000122	14,153
2.00	4.00	48.3	42.7	5.6	3.97	3.51	0.459	0.0017	0.0022	0.0020	0.000248	14,146
2.00	6.00	72.5	64.7	7.9	5.96	5.31	0.648	0.0027	0.0034	0.0031	0.000390	13,633
2.00	8.00	96.9	86.6	10.4	7.96	7.11	0.851	0.0039	0.0047	0.0043	0.000547	13,002
2.00	10.00	121.2	108.4	12.7	9.95	8.90	1.045	0.0053	0.0062	0.0057	0.000727	12,249

Date Reported: 12/21/2018 Harrah Bulk B OMC
Terracon Lab No. 03165261 Lab 696 RM 49 omc
Project No. 03165261

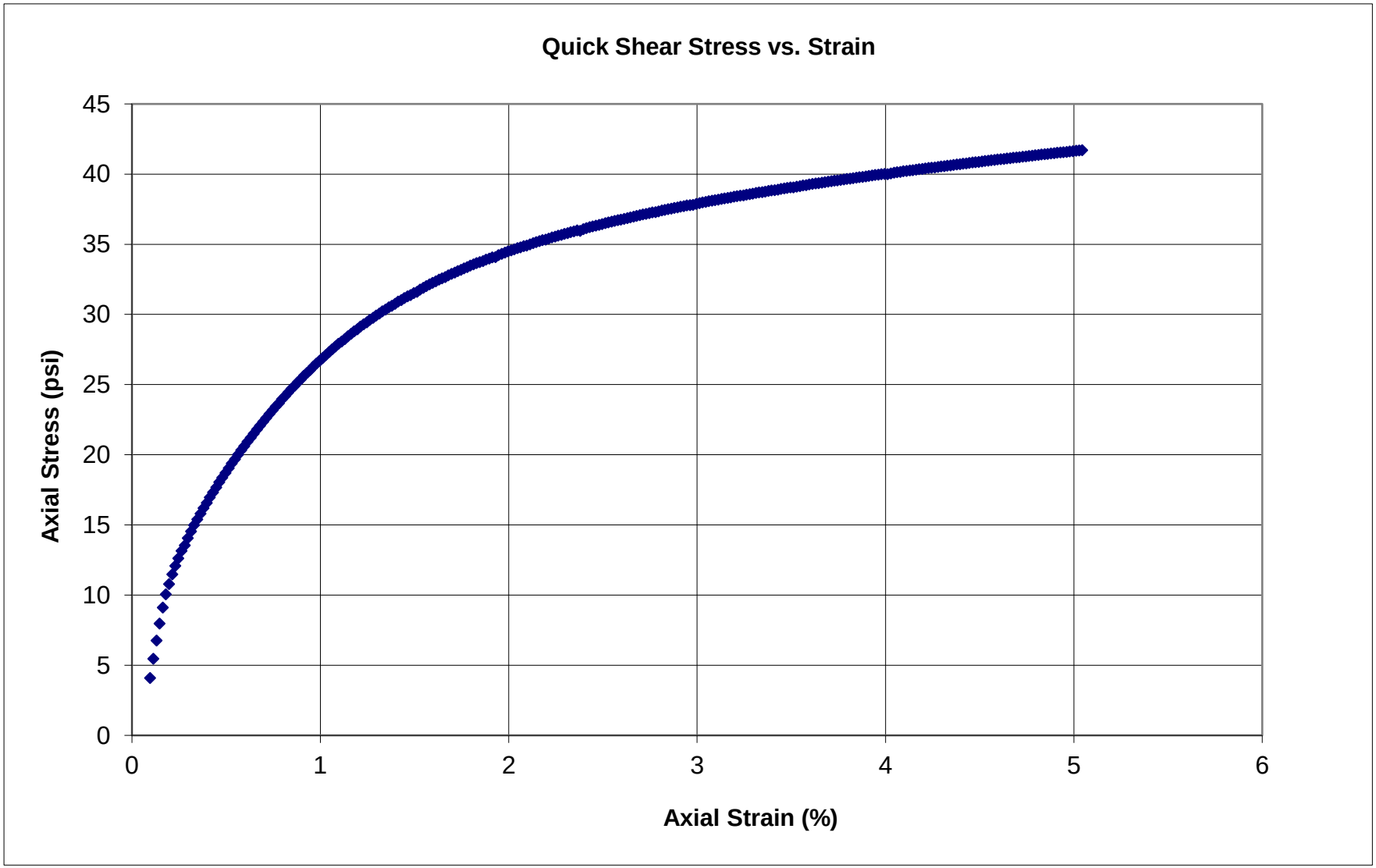


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	19471.6	-0.167	0.85
4	17513.7	-0.127	0.86
2	15204.4	-0.082	0.75
All	17364.9	-0.127	0.59

Terracon

Date Reported: 12/21/2018 Harrah Bulk B OMC
Terracon Lab No. 03165261 Lab 696 RM 49 omc
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 696 RM 49 omc+3.5
Project No.: 03165261

Soil Map Unit: Harrah Bulk B OMC+3.5
Soil Symbol: A-7-6(24) / CL
Depth (in.) 30 - 102
Compaction Method Static
Max. Dry Density (pcf) 110.6
Opt. Moisture Content (%) 16.3
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 6.97
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 20.1
Wet Density (pcf) 125.6
Dry Density (pcf) 104.6

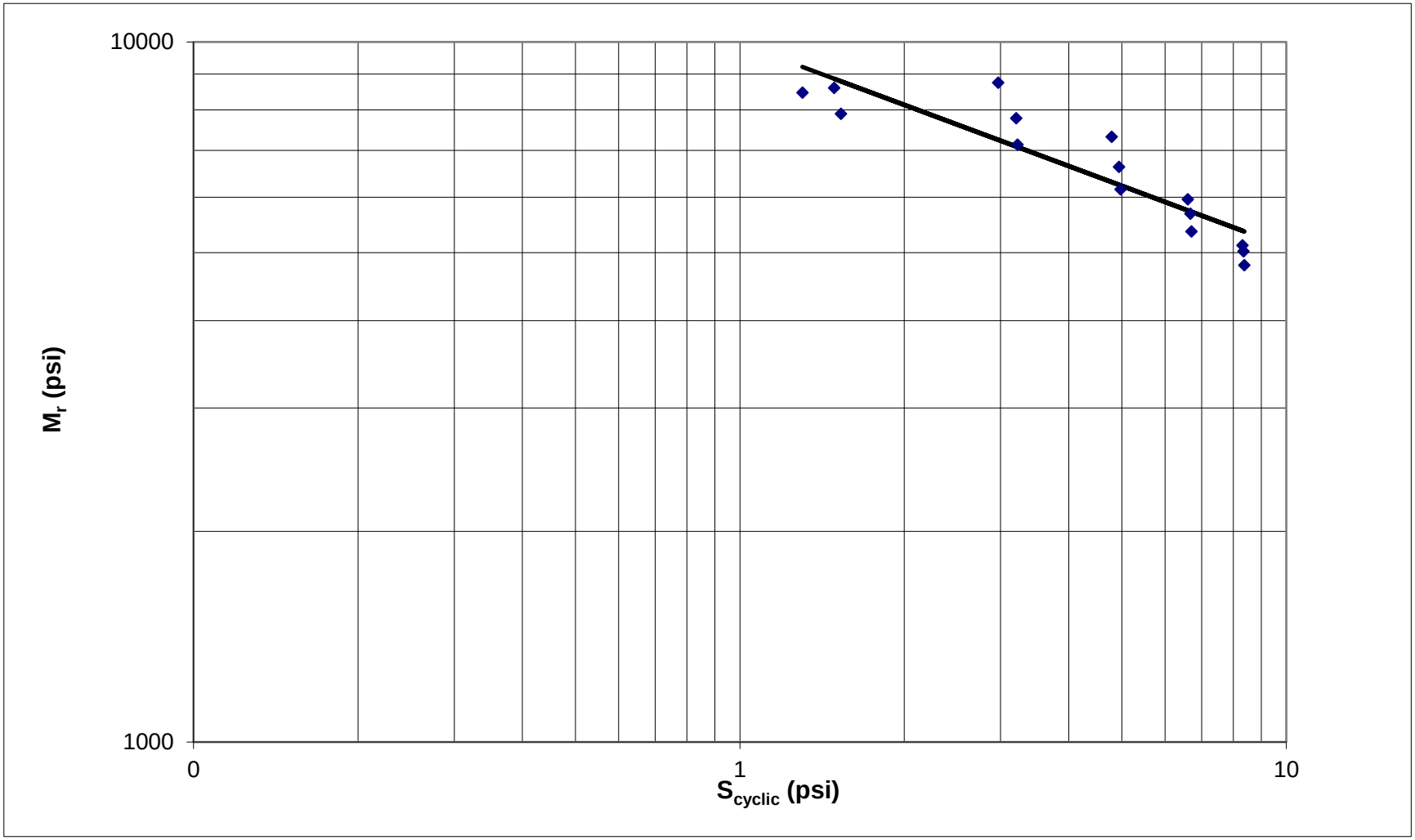
Test Date: November 30, 2018

Final Sample Height (in) 7.8
Final Sample Wet Weight (lb) 6.97
Final Moisture Content (%) 20.1
Accumulated Strain (%) 0.31

Percent Passing No. 10 99
Percent Passing No. 200 79.0
Liquid Limit 47
Plasticity Index 31

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	20.9	15.8	5.0	1.71	1.30	0.412	0.0012	0.0013	0.0012	0.000154	8,466
6.00	4.00	43.3	36.1	7.2	3.56	2.97	0.589	0.0026	0.0028	0.0027	0.000339	8,747
6.00	6.00	67.3	58.3	9.0	5.53	4.79	0.739	0.0050	0.0053	0.0052	0.000655	7,319
6.00	8.00	91.9	80.4	11.5	7.55	6.61	0.943	0.0086	0.0089	0.0087	0.001109	5,958
6.00	10.00	115.3	101.2	14.1	9.47	8.31	1.158	0.0127	0.0129	0.0128	0.001622	5,125
4.01	2.00	22.4	18.1	4.3	1.84	1.49	0.355	0.0013	0.0015	0.0014	0.000173	8,599
4.01	4.00	45.8	39.0	6.7	3.76	3.21	0.552	0.0030	0.0035	0.0032	0.000412	7,783
4.01	6.00	69.0	60.1	8.8	5.66	4.94	0.725	0.0055	0.0062	0.0059	0.000745	6,629
4.01	8.00	92.5	81.3	11.2	7.59	6.68	0.917	0.0089	0.0096	0.0092	0.001175	5,683
4.01	10.00	115.6	101.7	13.9	9.50	8.35	1.143	0.0129	0.0133	0.0131	0.001663	5,023
2.00	2.00	22.4	18.7	3.7	1.84	1.53	0.305	0.0014	0.0016	0.0015	0.000194	7,895
2.00	4.00	45.4	39.2	6.2	3.73	3.22	0.507	0.0033	0.0038	0.0036	0.000452	7,135
2.00	6.00	68.8	60.5	8.3	5.65	4.97	0.680	0.0060	0.0067	0.0064	0.000807	6,159
2.00	8.00	92.4	81.6	10.8	7.59	6.70	0.887	0.0095	0.0102	0.0098	0.001250	5,361
2.00	10.00	115.7	102.1	13.6	9.50	8.38	1.120	0.0134	0.0141	0.0138	0.001747	4,798

Date Reported: 12/21/2018 Harrah Bulk B OMC+3.5
Terracon Lab No. 03165261 Lab 696 RM 49 omc+3.5
Project No. 03165261

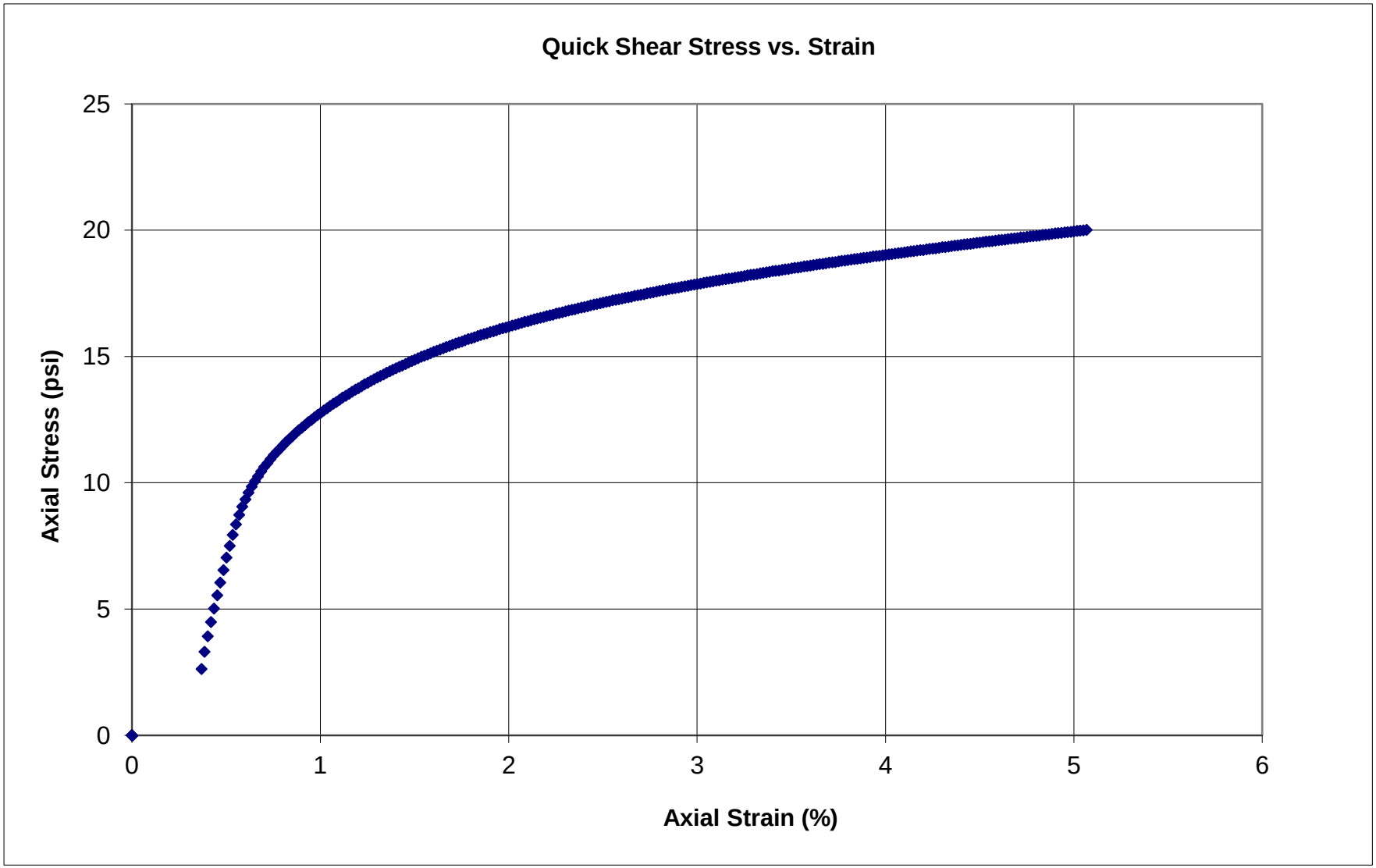


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	10111.7	-0.268	0.74
4	10307.1	-0.309	0.92
2	9391.4	-0.291	0.93
All	9945.8	-0.291	0.81

Terracon

Date Reported: 12/21/2018 Harrah Bulk B OMC+3.5
Terracon Lab No. 03165261 Lab 696 RM 49 omc+3.5
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 697 RM47 omc
Project No.: 03165261

Soil Map Unit: Stephenville Bulk B OMC
Soil Symbol: A-6(15) / CL
Depth (in.) 17 - 36
Compaction Method Static
Max. Dry Density (pcf) 118.9
Opt. Moisture Content (%) 13.0
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 7.08
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 12.7
Wet Density (pcf) 127.5
Dry Density (pcf) 113.2

Test Date: November 17, 2018

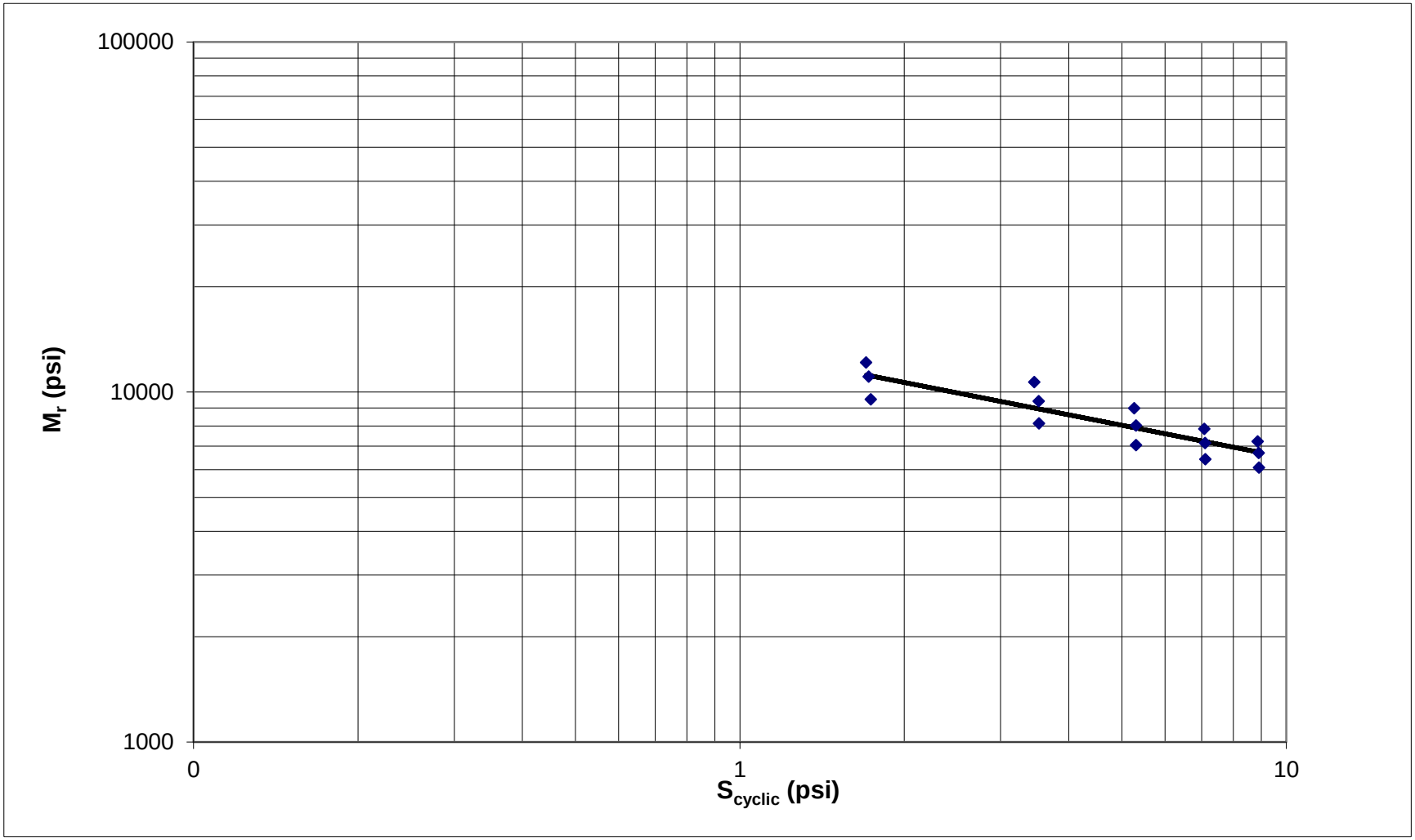
Final Sample Height (in) 7.9
Final Sample Wet Weight (lb) 7.07
Final Moisture Content (%) 13.3
Accumulated Strain (%) 0.17

Percent Passing No. 10 100
Percent Passing No. 200 81.4
Liquid Limit 34
Plasticity Index 20

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.5	20.7	2.8	1.93	1.70	0.230	0.0011	0.0011	0.0011	0.000140	12,154
6.00	4.00	47.3	42.1	5.2	3.88	3.46	0.427	0.0025	0.0026	0.0025	0.000324	10,673
6.00	6.00	72.0	64.2	7.8	5.91	5.27	0.643	0.0046	0.0047	0.0046	0.000586	8,991
6.00	8.00	96.6	86.2	10.4	7.94	7.08	0.856	0.0071	0.0071	0.0071	0.000902	7,849
6.00	10.00	120.9	108.0	13.0	9.93	8.87	1.067	0.0096	0.0097	0.0097	0.001227	7,227
4.01	2.00	24.2	21.0	3.3	1.99	1.72	0.269	0.0012	0.0012	0.0012	0.000156	11,060
4.01	4.00	48.5	42.9	5.6	3.99	3.52	0.463	0.0028	0.0031	0.0029	0.000374	9,422
4.01	6.00	72.8	64.6	8.2	5.98	5.31	0.672	0.0051	0.0053	0.0052	0.000661	8,023
4.01	8.00	97.1	86.4	10.7	7.98	7.10	0.877	0.0078	0.0078	0.0078	0.000993	7,150
4.01	10.00	121.4	108.4	13.0	9.97	8.91	1.068	0.0104	0.0105	0.0105	0.001330	6,696
2.00	2.00	24.1	21.1	3.0	1.98	1.74	0.245	0.0014	0.0015	0.0014	0.000182	9,529
2.00	4.00	48.3	42.9	5.4	3.97	3.53	0.444	0.0033	0.0035	0.0034	0.000434	8,128
2.00	6.00	72.5	64.7	7.8	5.95	5.31	0.641	0.0058	0.0060	0.0059	0.000753	7,053
2.00	8.00	97.0	86.6	10.4	7.97	7.11	0.858	0.0087	0.0088	0.0087	0.001107	6,423
2.00	10.00	121.3	108.5	12.8	9.96	8.91	1.051	0.0114	0.0116	0.0115	0.001466	6,079

Terracon

Date Reported: 12/21/2018 Stephenville Bulk B OMC
Terracon Lab No. 03165261 Lab 697 RM47 omc
Project No. 03165261

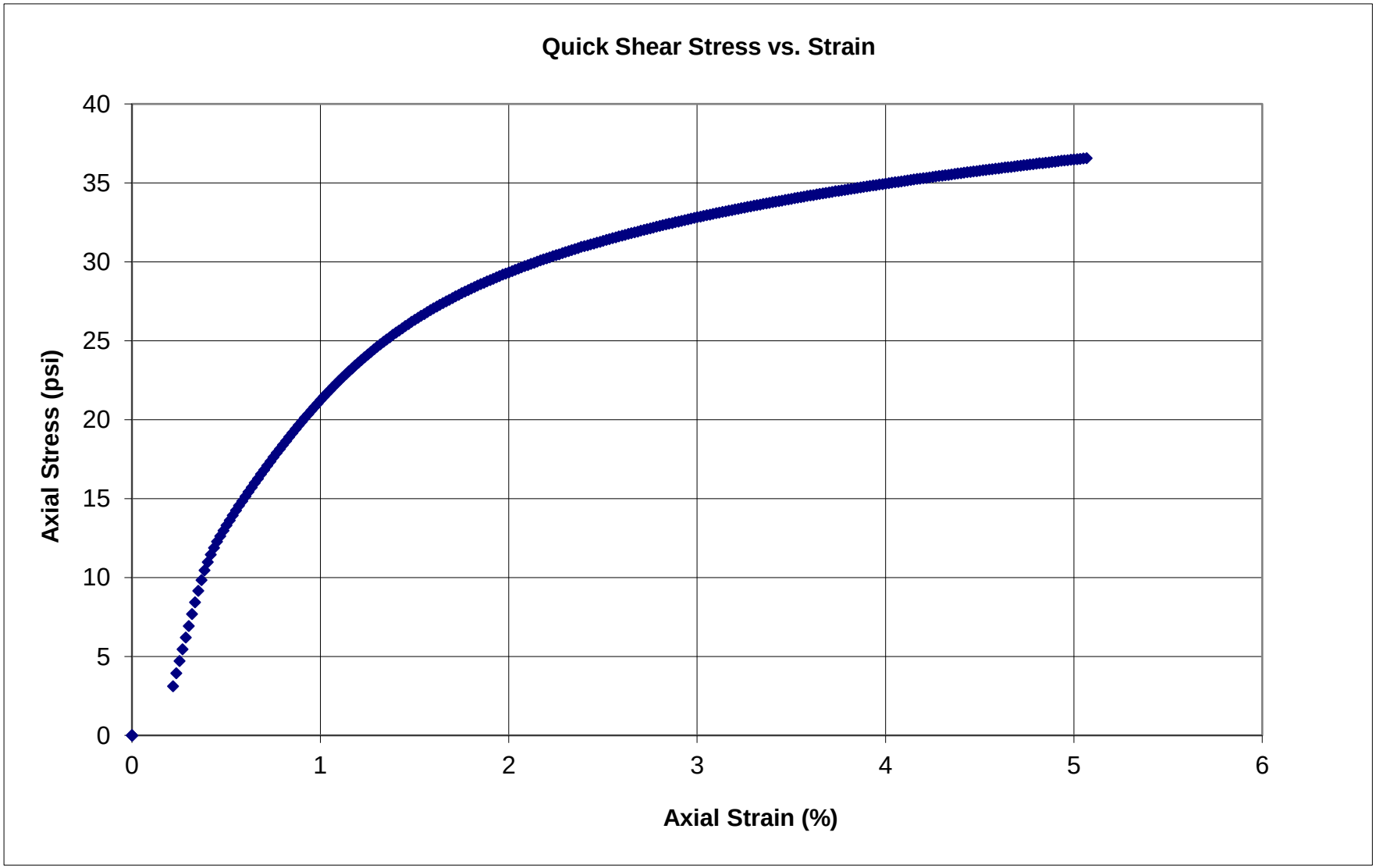


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	15001.9	-0.322	0.96
4	13422.1	-0.313	0.98
2	11285.1	-0.282	0.99
All	13174.9	-0.307	0.78

Terracon

Date Reported: 12/21/2018 Stephenville Bulk B OMC
Terracon Lab No. 03165261 Lab 697 RM47 omc
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 697 RM47 omc+3.3
Project No.: 03165261

Soil Map Unit:	Stephenville Bulk B OMC+
Soil Symbol:	A-6(15) / CL
Depth (in.)	17 - 36
Compaction Method	Static
Max. Dry Density (pcf)	118.9
Opt. Moisture Content (%)	13.0
Inside Mold Diameter (in)	3.94

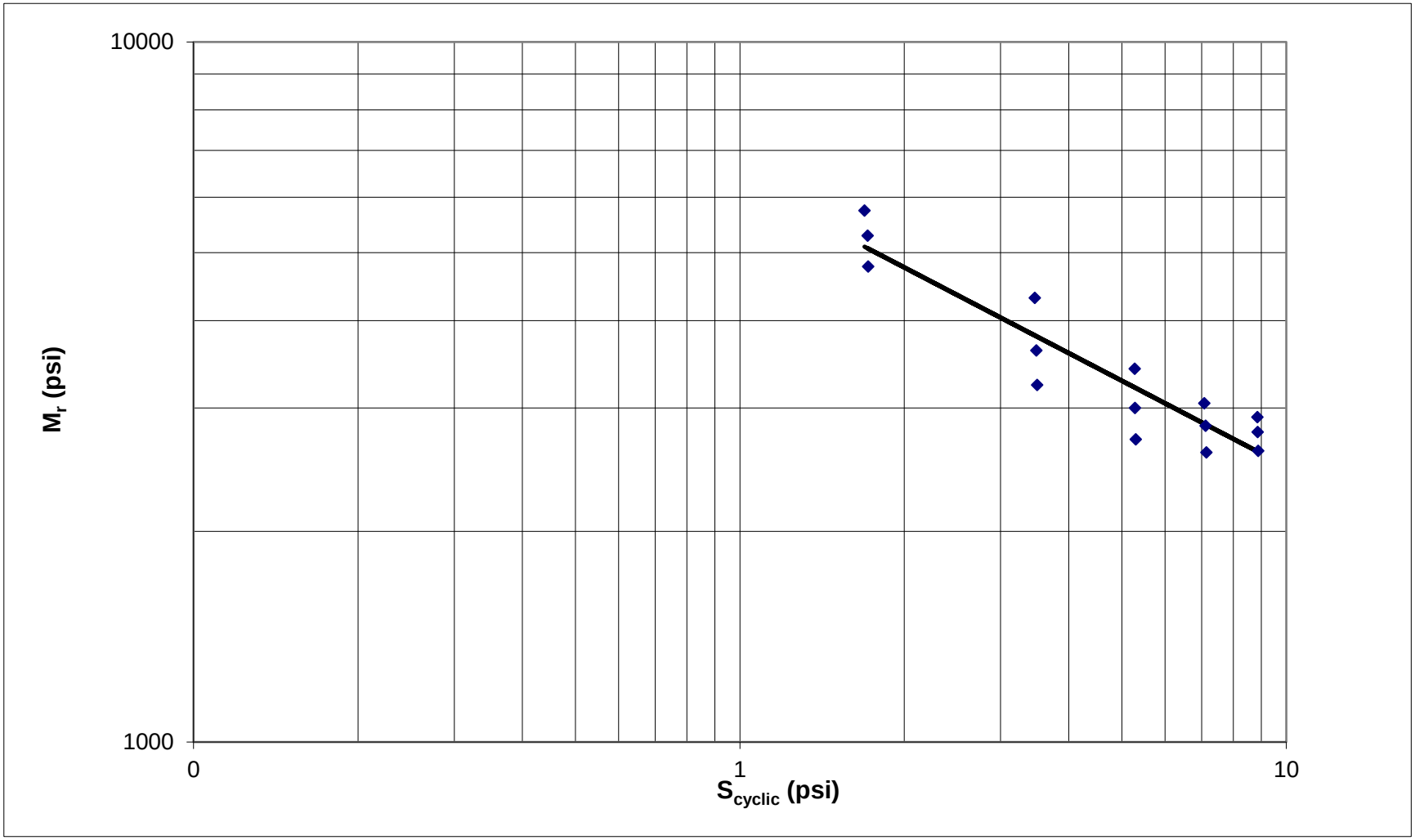
Weight of Wet Soil (lb)	7.28
Initial Sample Diameter (in)	3.94
Initial Sample Height (in)	7.87
Initial Sample Area (in^2)	12.17
Sample Volume (in^3)	95.86
Compacted Moisture Content(%)	16.6
Wet Density (pcf)	131.3
Dry Density (pcf)	112.6

Test Date: November 17, 2018

Final Sample Height (in)	7.8
Final Sample Wet Weight (lb)	7.28
Final Moisture Content (%)	16.6
Accumulated Strain (%)	1.21
Percent Passing No. 10	100
Percent Passing No. 200	81.4
Liquid Limit	34
Plasticity Index	20

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	24.2	20.6	3.6	1.98	1.69	0.294	0.0024	0.0023	0.0023	0.000294	5,746
6.00	4.00	48.3	42.2	6.1	3.97	3.47	0.499	0.0062	0.0064	0.0063	0.000804	4,310
6.00	6.00	72.7	64.3	8.4	5.97	5.28	0.690	0.0118	0.0125	0.0122	0.001546	3,413
6.00	8.00	97.1	86.2	10.9	7.98	7.08	0.899	0.0177	0.0189	0.0183	0.002322	3,048
6.00	10.00	121.3	107.8	13.5	9.96	8.85	1.111	0.0233	0.0245	0.0239	0.003041	2,912
4.00	2.00	24.4	20.9	3.6	2.00	1.71	0.292	0.0025	0.0026	0.0025	0.000324	5,290
4.01	4.00	48.5	42.5	6.0	3.98	3.49	0.491	0.0076	0.0076	0.0076	0.000962	3,625
4.01	6.00	73.1	64.4	8.7	6.00	5.28	0.716	0.0134	0.0144	0.0139	0.001762	3,000
4.01	8.00	97.8	86.7	11.0	8.03	7.12	0.907	0.0194	0.0202	0.0198	0.002516	2,831
4.01	10.00	121.4	107.9	13.5	9.97	8.86	1.107	0.0247	0.0256	0.0252	0.003198	2,772
2.00	2.00	24.0	20.9	3.1	1.97	1.72	0.256	0.0028	0.0029	0.0028	0.000359	4,778
2.00	4.00	48.2	42.6	5.6	3.96	3.50	0.456	0.0083	0.0087	0.0085	0.001081	3,237
2.00	6.00	72.6	64.6	8.0	5.96	5.31	0.655	0.0150	0.0159	0.0154	0.001960	2,707
2.00	8.00	97.3	87.0	10.3	7.99	7.14	0.847	0.0214	0.0220	0.0217	0.002755	2,593
2.00	10.00	121.1	108.2	12.9	9.95	8.89	1.059	0.0264	0.0273	0.0268	0.003409	2,607

Date Reported: 12/21/2018 Stephenville Bulk B OMC+
Terracon Lab No. 03165261 Lab 697 RM47 omc+3.3
Project No. 03165261

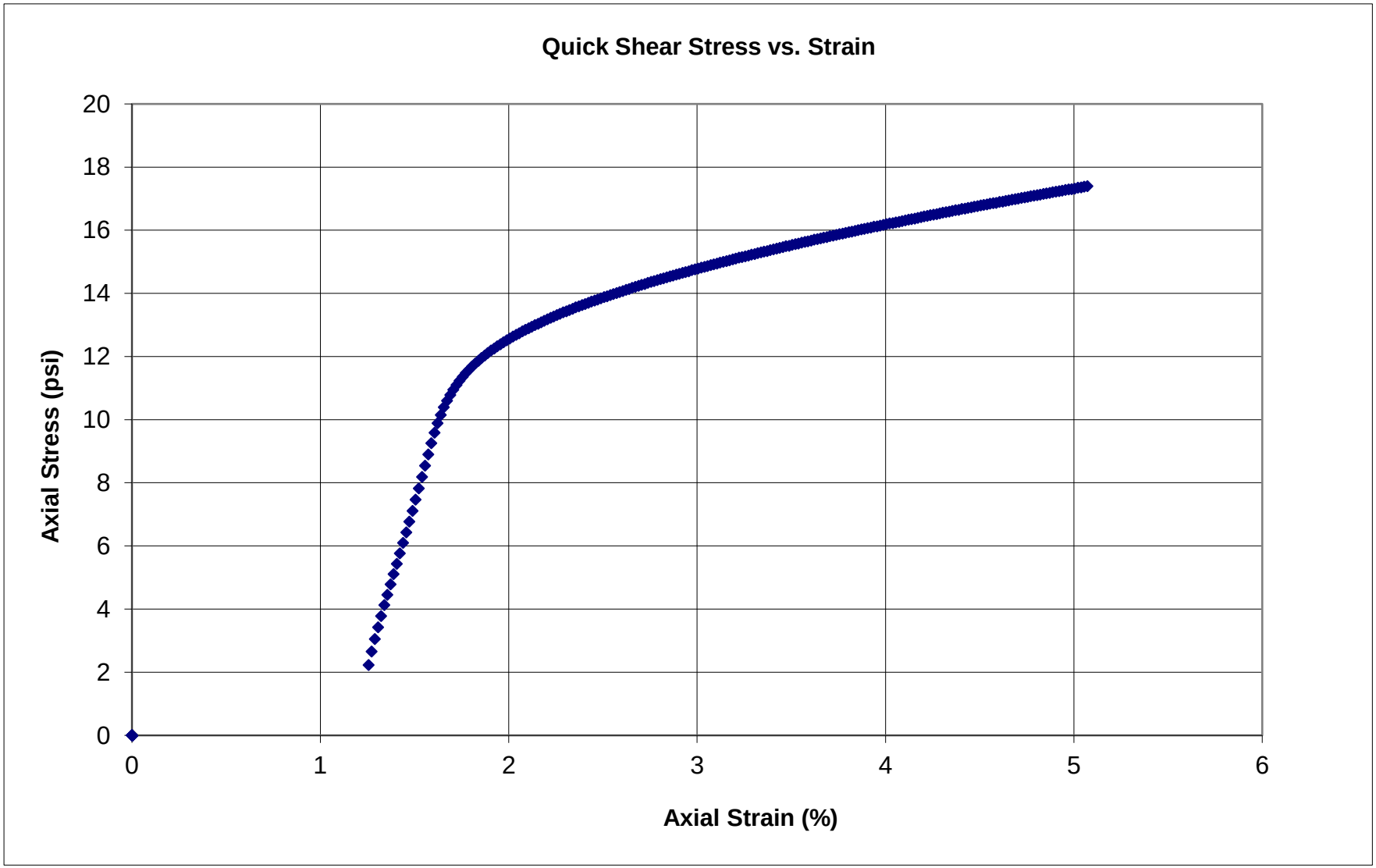


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	7188.5	-0.428	0.99
4	6283.8	-0.405	0.96
2	5549.2	-0.384	0.93
All	6314.3	-0.407	0.87

Terracon

Date Reported: 12/21/2018 Stephenville Bulk B OMC+
Terracon Lab No. 03165261 Lab 697 RM47 omc+3.3
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 698 omc rerun
Project No.: 03165261

Soil Map Unit: Stephenville Bulk C OMC
Soil Symbol: A-4(2) / CL
Depth (in.) 36 - 50
Compaction Method Static
Max. Dry Density (pcf) 118.9
Opt. Moisture Content (%) 13.0
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 7.07
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 13.4
Wet Density (pcf) 127.5
Dry Density (pcf) 112.4

Test Date: November 30, 2018

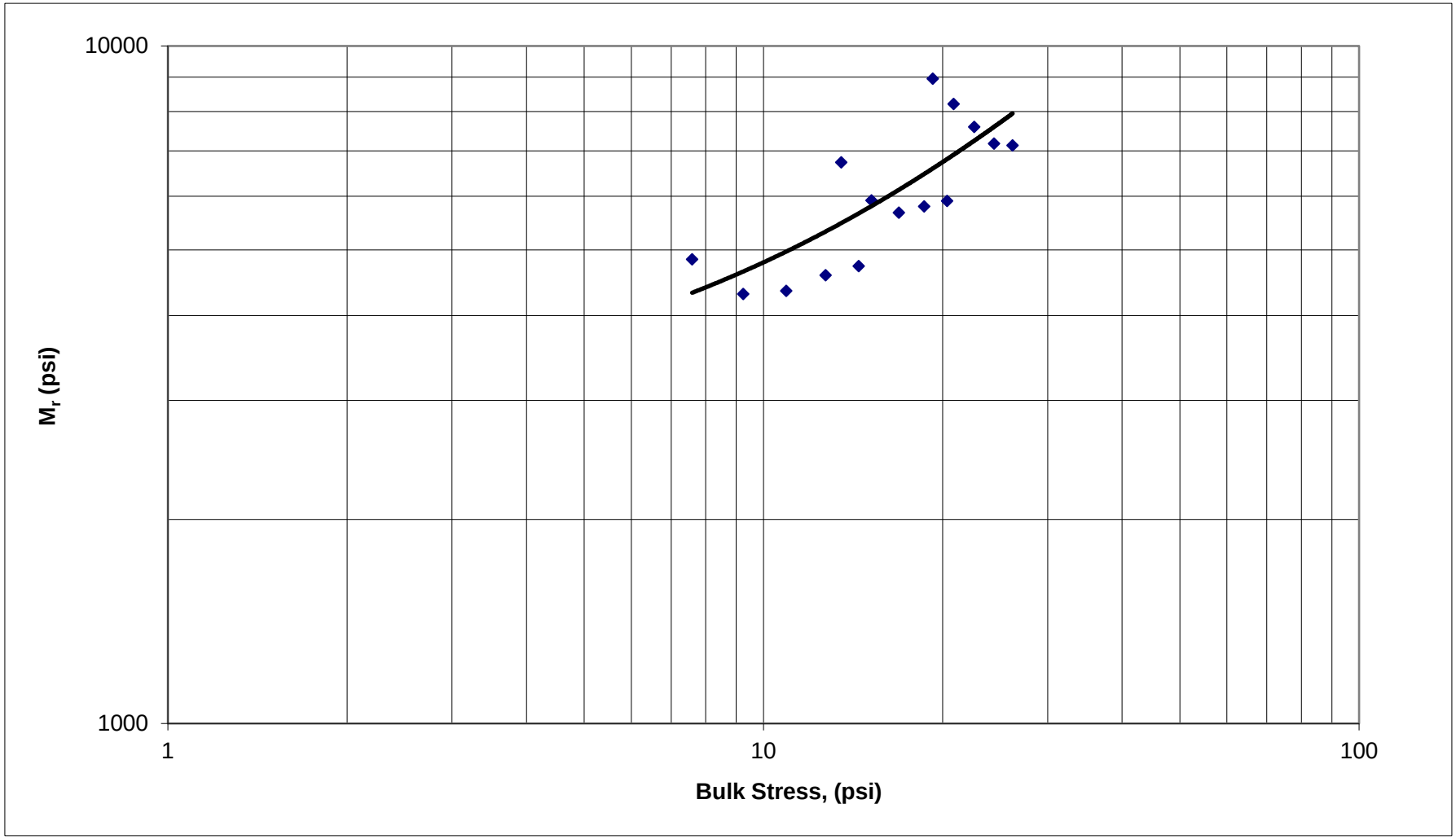
Final Sample Height (in) 7.8
Final Sample Wet Weight (lb) 7.07
Final Moisture Content (%) 13.4
Accumulated Strain (%) 0.56

Percent Passing No. 10 100
Percent Passing No. 200 54.0
Liquid Limit 23
Plasticity Index 8

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	20.2	14.9	5.3	1.66	1.22	0.432	0.0013	0.0009	0.0011	0.000137	8,946
6.00	4.00	41.9	34.7	7.3	3.44	2.85	0.598	0.0031	0.0023	0.0027	0.000347	8,208
6.00	6.00	65.6	55.7	9.8	5.39	4.58	0.808	0.0054	0.0041	0.0047	0.000603	7,593
6.00	8.00	89.9	77.7	12.2	7.39	6.38	1.005	0.0077	0.0063	0.0070	0.000889	7,180
6.00	10.00	114.1	99.7	14.4	9.37	8.19	1.183	0.0099	0.0082	0.0090	0.001147	7,135
4.01	2.00	22.2	18.1	4.1	1.82	1.49	0.337	0.0020	0.0014	0.0017	0.000221	6,736
4.01	4.00	44.8	38.5	6.2	3.68	3.16	0.513	0.0047	0.0037	0.0042	0.000535	5,919
4.00	6.00	68.3	59.3	8.9	5.61	4.87	0.734	0.0075	0.0060	0.0068	0.000858	5,677
4.01	8.00	91.7	80.2	11.5	7.53	6.58	0.946	0.0097	0.0081	0.0089	0.001136	5,799
4.01	10.00	115.0	101.1	13.9	9.44	8.30	1.141	0.0119	0.0102	0.0111	0.001406	5,905
2.00	2.00	22.5	19.3	3.2	1.85	1.59	0.263	0.0029	0.0023	0.0026	0.000328	4,843
2.00	4.00	45.0	39.5	5.5	3.69	3.24	0.451	0.0065	0.0054	0.0059	0.000753	4,306
2.00	6.00	68.0	59.7	8.3	5.59	4.91	0.680	0.0095	0.0082	0.0089	0.001128	4,351
2.00	8.00	92.4	81.7	10.7	7.58	6.71	0.875	0.0123	0.0107	0.0115	0.001463	4,587
2.00	10.00	116.4	102.7	13.6	9.56	8.44	1.120	0.0148	0.0133	0.0140	0.001782	4,733

Terracon

Date Reported: 12/21/2018 Stephenville Bulk C OMC
Terracon Lab No. 03165261 Lab 698 omc rerun
Project No. 03165261



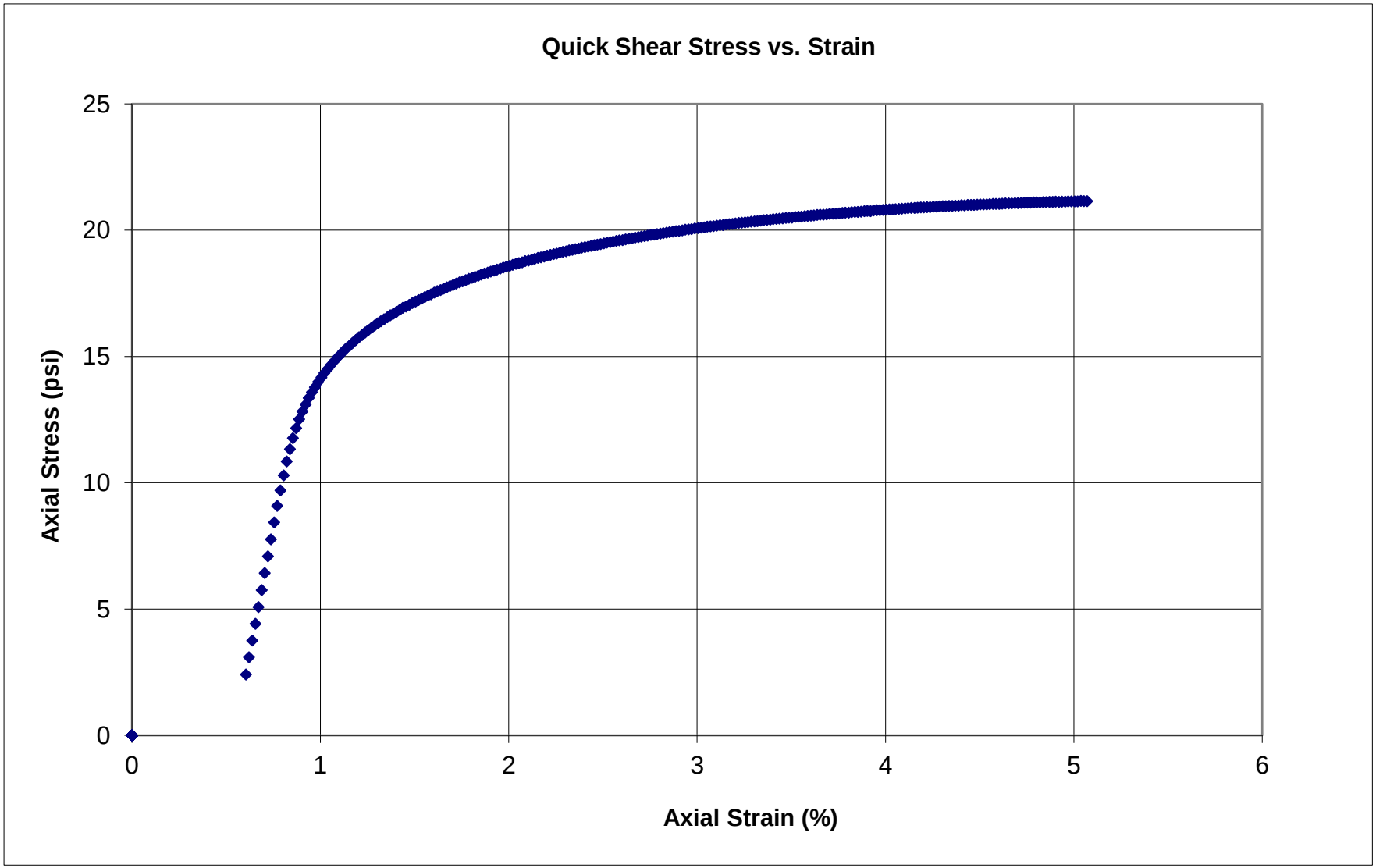
$Mr = K1 \times \Theta^{k2}$

$[\Theta = S_{cyclic} + 3\ (S3)]$

S3 (psi)	K1	K2	R^2
6	83525.6	-0.762	0.94
4	13709.4	-0.294	0.50
2	4604.2	-0.004	0.00
All	1482.6	0.503	0.59

Terracon

Date Reported: 12/21/2018 Stephenville Bulk C OMC
Terracon Lab No. 03165261 Lab 698 omc rerun
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 698 RM 48 omc+2
Project No.: 03165261

Soil Map Unit: Stephenville Bulk C OMC+2%
Soil Symbol: A-4(2) / CL
Depth (in.) 36 - 50
Compaction Method Static
Max. Dry Density (pcf) 118.9
Opt. Moisture Content (%) 13.0
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 7.20
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 15.4
Wet Density (pcf) 129.8
Dry Density (pcf) 112.5

Test Date: November 17, 2018

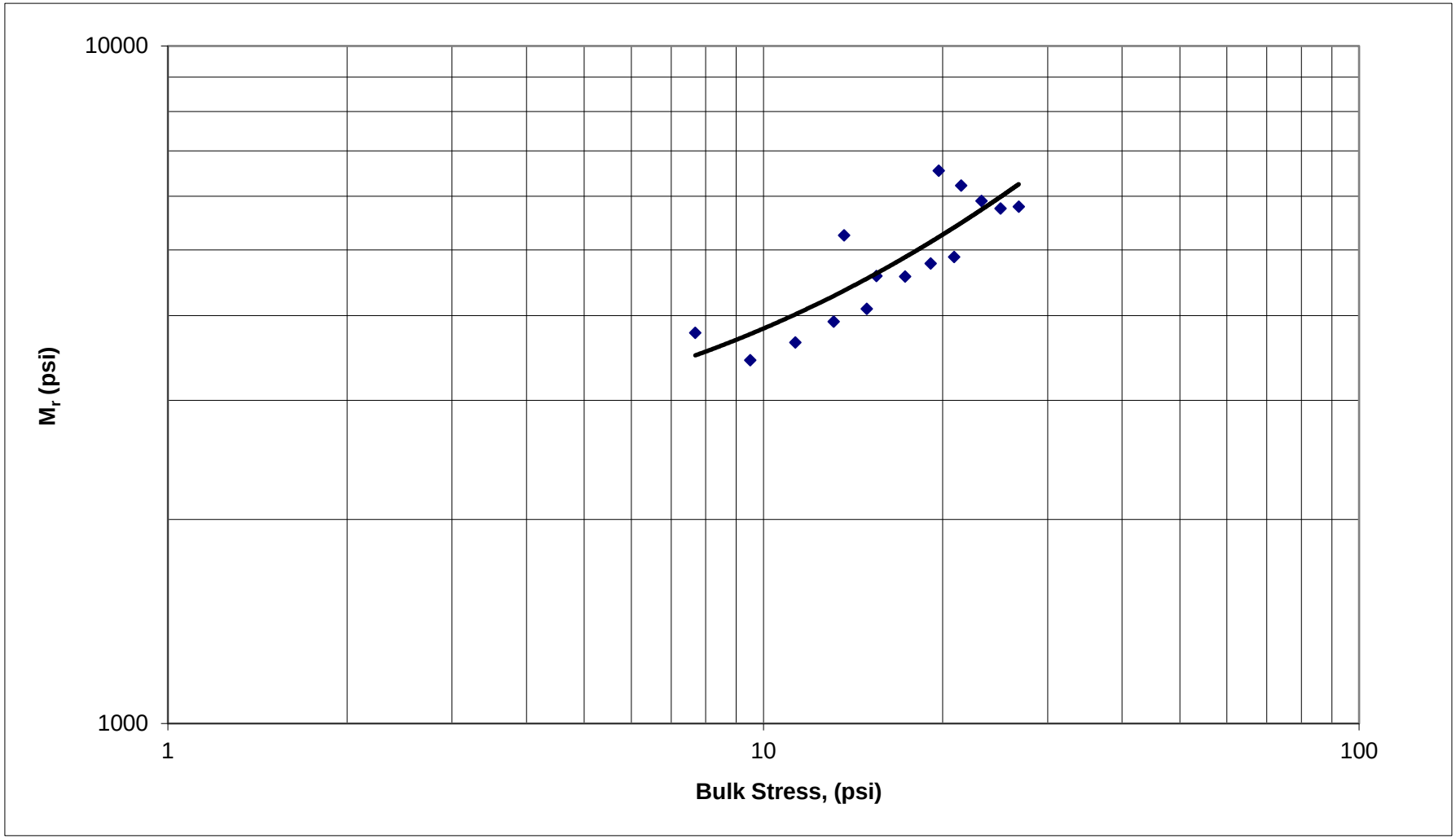
Final Sample Height (in) 7.8
Final Sample Wet Weight (lb) 7.20
Final Moisture Content (%) 15.4
Accumulated Strain (%) 1.49

Percent Passing No. 10 100
Percent Passing No. 200 54.0
Liquid Limit 23
Plasticity Index 8

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.6	20.6	3.0	1.94	1.69	0.250	0.0019	0.0022	0.0020	0.000258	6,548
6.00	4.00	47.5	42.1	5.4	3.90	3.46	0.444	0.0042	0.0046	0.0044	0.000556	6,221
6.00	6.00	71.6	63.6	8.0	5.88	5.22	0.657	0.0068	0.0071	0.0070	0.000885	5,904
6.00	8.00	95.9	85.2	10.7	7.88	7.00	0.880	0.0091	0.0100	0.0096	0.001216	5,755
6.00	10.00	121.0	107.3	13.7	9.94	8.81	1.125	0.0115	0.0124	0.0120	0.001521	5,793
4.01	2.00	23.8	19.9	3.9	1.95	1.64	0.319	0.0023	0.0026	0.0025	0.000311	5,252
4.01	4.00	48.3	42.2	6.2	3.97	3.46	0.507	0.0056	0.0063	0.0060	0.000757	4,576
4.01	6.00	72.8	64.0	8.8	5.98	5.26	0.721	0.0087	0.0094	0.0091	0.001151	4,566
4.01	8.00	97.1	86.0	11.1	7.97	7.06	0.914	0.0112	0.0120	0.0116	0.001478	4,777
4.01	10.00	121.5	108.0	13.5	9.98	8.87	1.106	0.0138	0.0148	0.0143	0.001818	4,881
2.00	2.00	23.8	20.4	3.4	1.95	1.67	0.278	0.0033	0.0037	0.0035	0.000444	3,771
2.00	4.00	48.1	42.5	5.6	3.95	3.49	0.458	0.0078	0.0082	0.0080	0.001017	3,437
2.00	6.00	72.5	64.5	8.0	5.95	5.29	0.660	0.0111	0.0117	0.0114	0.001450	3,651
2.00	8.00	97.0	86.6	10.4	7.97	7.11	0.858	0.0138	0.0148	0.0143	0.001814	3,918
2.00	10.00	121.4	108.5	12.9	9.97	8.91	1.063	0.0167	0.0176	0.0171	0.002177	4,091

Terracon

Date Reported: 12/21/2018 Stephenville Bulk C OMC+2%
Terracon Lab No. 03165261 Lab 698 RM 48 omc+2
Project No. 03165261



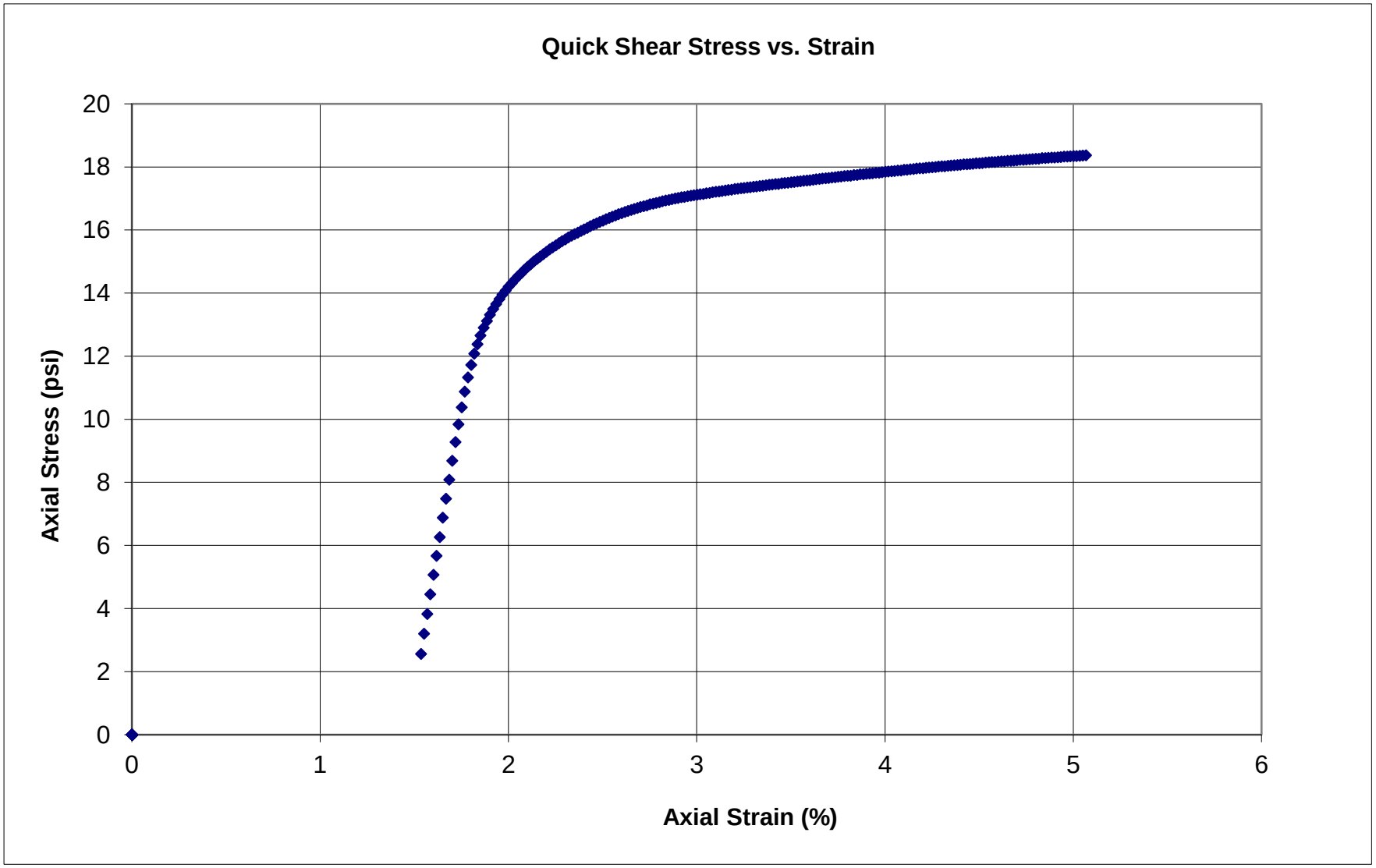
Mr = K1 x Θ^{k2}

[$\Theta = S_{cyclic} + 3\ (S3)$]

S3 (psi)	K1	K2	R^2
6	22885.0	-0.424	0.89
4	6694.1	-0.117	0.12
2	2559.5	0.161	0.40
All	1251.7	0.480	0.71

Terracon

Date Reported: 12/21/2018 Stephenville Bulk C OMC+2%
Terracon Lab No. 03165261 Lab 698 RM 48 omc+2
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 702 RM 50 omc
Project No.: 03165261

Soil Map Unit: Urban Land 1 (Bulk) OMC
Soil Symbol: A-6(2) / SC
Depth (in.) 24 - 37
Compaction Method Static
Max. Dry Density (pcf) 112.9
Opt. Moisture Content (%) 14.1
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 6.78
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 14.5
Wet Density (pcf) 122.2
Dry Density (pcf) 106.7

Test Date: November 30, 2018

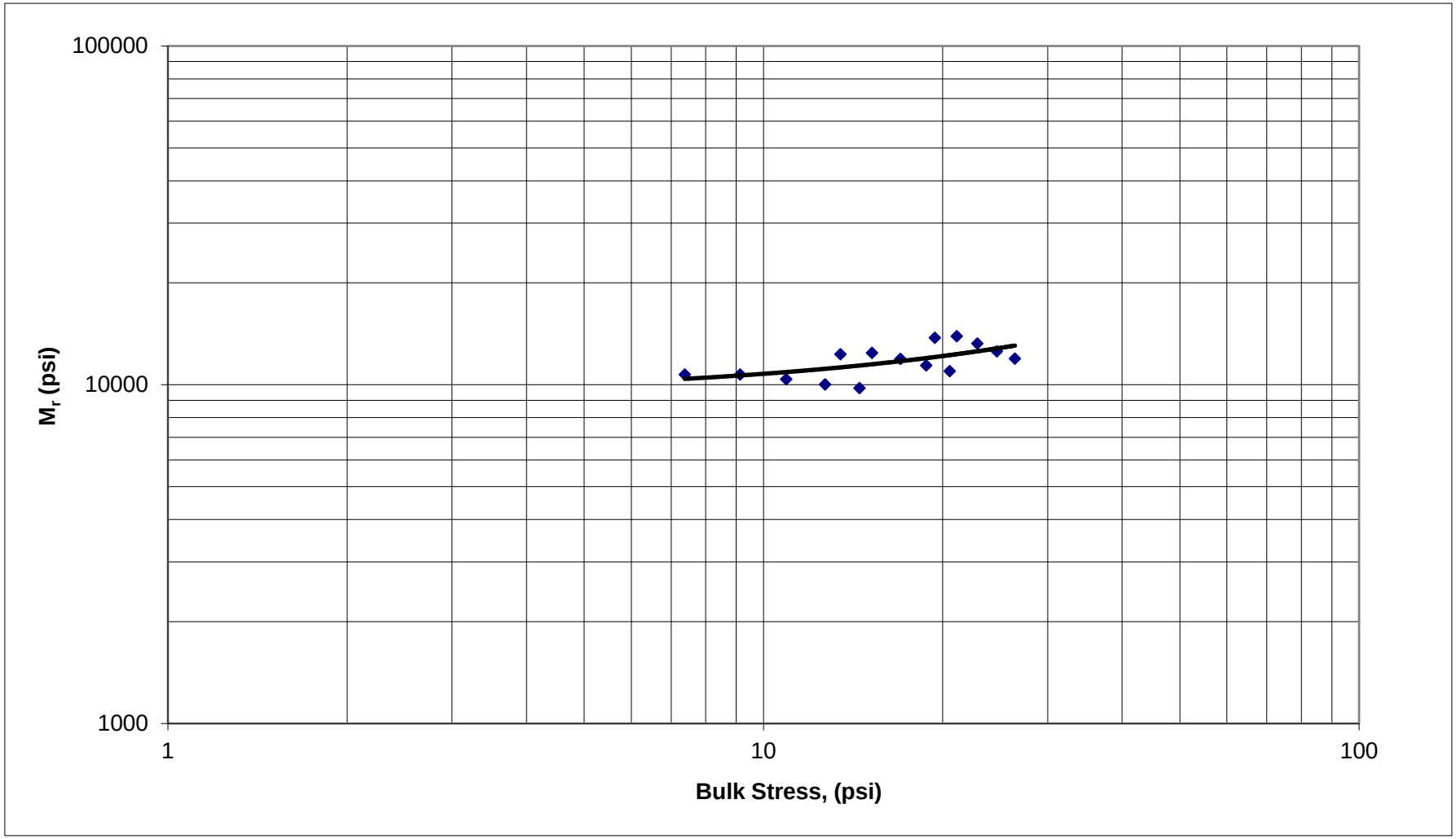
Final Sample Height (in) 7.9
Final Sample Wet Weight (lb) 6.78
Final Moisture Content (%) 14.4
Accumulated Strain (%) 0.04

Percent Passing No. 10 100
Percent Passing No. 200 38.0
Liquid Limit 32
Plasticity Index 16

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	21.3	16.9	4.5	1.75	1.39	0.367	0.0009	0.0007	0.0008	0.000101	13,753
6.00	4.00	44.8	37.9	6.9	3.68	3.11	0.567	0.0019	0.0017	0.0018	0.000224	13,912
6.00	6.00	68.9	59.2	9.6	5.66	4.86	0.792	0.0031	0.0027	0.0029	0.000368	13,230
6.00	8.00	93.2	81.0	12.2	7.65	6.65	1.000	0.0043	0.0040	0.0042	0.000530	12,550
6.00	10.00	117.5	102.6	14.8	9.65	8.43	1.216	0.0058	0.0054	0.0056	0.000706	11,942
4.01	2.00	21.8	17.7	4.2	1.79	1.45	0.343	0.0010	0.0009	0.0009	0.000118	12,304
4.01	4.00	45.7	38.9	6.8	3.75	3.19	0.559	0.0022	0.0019	0.0020	0.000257	12,407
4.01	6.00	69.7	60.3	9.4	5.73	4.95	0.773	0.0034	0.0031	0.0033	0.000416	11,917
4.01	8.00	94.0	82.1	11.8	7.72	6.75	0.971	0.0048	0.0045	0.0047	0.000592	11,401
4.01	10.00	117.9	103.7	14.2	9.68	8.52	1.164	0.0063	0.0059	0.0061	0.000776	10,977
2.00	2.00	21.2	16.7	4.5	1.74	1.37	0.371	0.0011	0.0009	0.0010	0.000128	10,715
2.00	4.00	44.9	38.0	6.8	3.68	3.12	0.560	0.0024	0.0022	0.0023	0.000292	10,712
2.00	6.00	68.9	59.8	9.1	5.66	4.91	0.746	0.0039	0.0036	0.0037	0.000473	10,377
2.00	8.00	93.0	81.3	11.7	7.64	6.68	0.962	0.0054	0.0051	0.0052	0.000666	10,028
2.00	10.00	117.2	103.4	13.8	9.63	8.49	1.135	0.0071	0.0066	0.0068	0.000869	9,775

Terracon

Date Reported: 12/21/2018 Urban Land 1 (Bulk)_OMC
Terracon Lab No. 03165261 Lab 702 RM 50 omc
Project No. 03165261



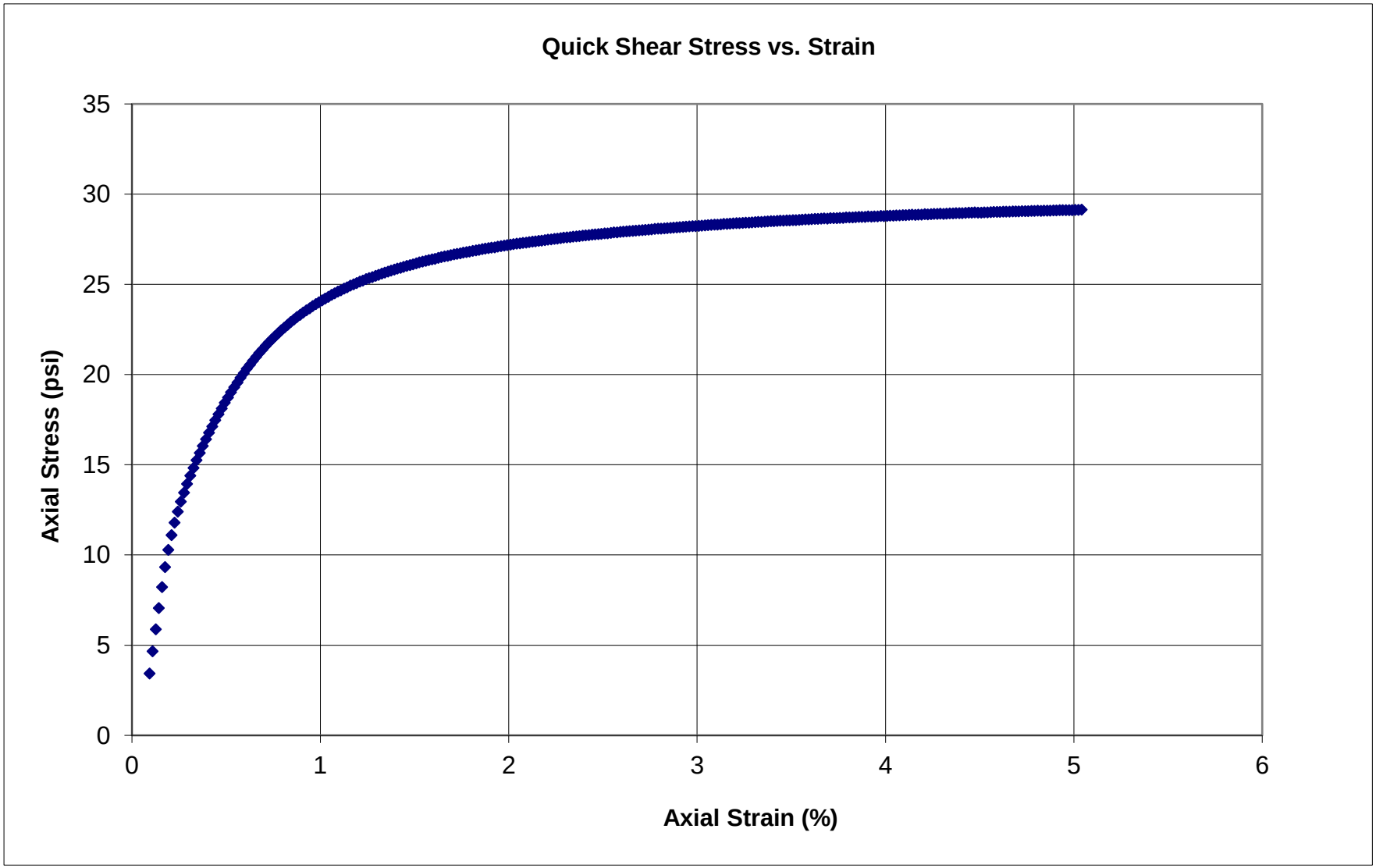
$Mr = K1 \times \Theta^{k2}$

$[\Theta = S_{cyclic} + 3\ (S3)]$

S3 (psi)	K1	K2	R^2
6	60734.3	-0.492	0.88
4	26820.6	-0.291	0.88
2	14513.6	-0.145	0.90
All	7056.3	0.181	0.37

Terracon

Date Reported: 12211/2018 Urban Land 1 (Bulk)_OMC
Terracon Lab No. 03165261 Lab 702 RM 50 omc
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 702 RM 50 omc+2
Project No.: 03165261

Soil Map Unit: Urban Land 1 (Bulk) OMC+2%
Soil Symbol: A-6(2) / SC
Depth (in.) 24 - 37
Compaction Method Static
Max. Dry Density (pcf) 112.9
Opt. Moisture Content (%) 14.1
Inside Mold Diameter (in) 3.94

Weight of Wet Soil (lb) 6.91
Initial Sample Diameter (in) 3.94
Initial Sample Height (in) 7.87
Initial Sample Area (in^2) 12.17
Sample Volume (in^3) 95.86
Compacted Moisture Content(%) 16.5
Wet Density (pcf) 124.5
Dry Density (pcf) 106.9

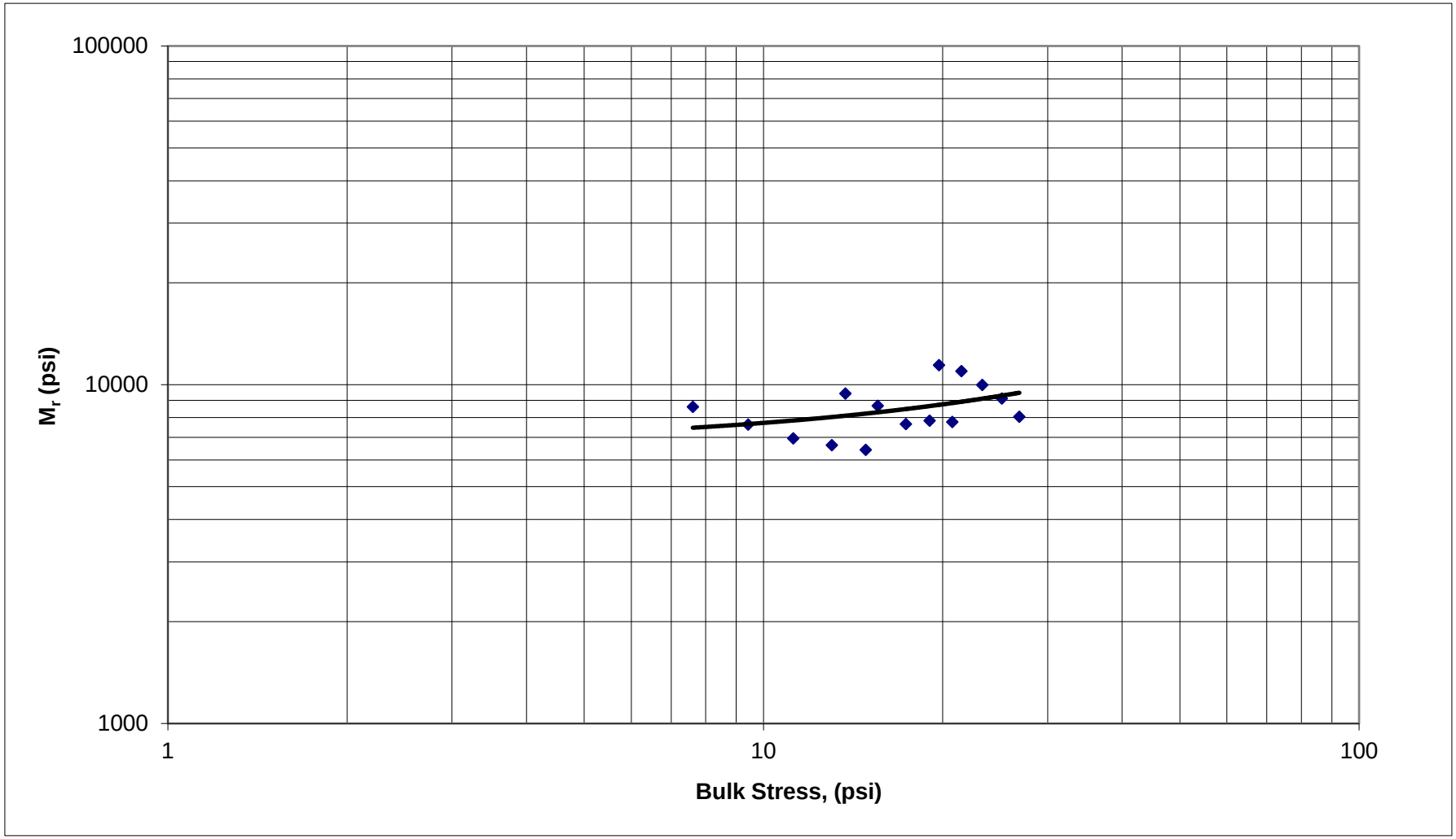
Test Date: November 30, 2018

Final Sample Height (in) 7.9
Final Sample Wet Weight (lb) 6.91
Final Moisture Content (%) 16.6
Accumulated Strain (%) 0.28

Percent Passing No. 10 100
Percent Passing No. 200 38.0
Liquid Limit 32
Plasticity Index 16

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.8	20.7	3.1	1.95	1.70	0.255	0.0012	0.0012	0.0012	0.000149	11,415
6.00	4.00	47.9	42.4	5.5	3.93	3.48	0.448	0.0025	0.0025	0.0025	0.000318	10,966
6.00	6.00	72.3	64.5	7.8	5.94	5.30	0.640	0.0041	0.0043	0.0042	0.000531	9,977
6.00	8.00	97.0	86.6	10.3	7.97	7.12	0.850	0.0059	0.0064	0.0062	0.000782	9,105
6.00	10.00	121.6	108.2	13.5	9.99	8.88	1.105	0.0066	0.0107	0.0087	0.001104	8,045
4.01	2.00	24.6	20.8	3.8	2.02	1.71	0.312	0.0014	0.0014	0.0014	0.000181	9,412
4.01	4.00	48.8	42.9	5.9	4.01	3.53	0.484	0.0026	0.0038	0.0032	0.000407	8,668
4.00	6.00	73.2	64.8	8.4	6.01	5.32	0.690	0.0034	0.0075	0.0055	0.000695	7,650
4.01	8.00	96.0	85.1	10.9	7.88	6.99	0.896	0.0056	0.0085	0.0070	0.000892	7,835
4.01	10.00	120.2	106.4	13.7	9.87	8.74	1.129	0.0087	0.0090	0.0089	0.001126	7,762
2.00	2.00	23.6	19.5	4.1	1.94	1.60	0.333	0.0014	0.0015	0.0015	0.000186	8,600
2.00	4.00	47.8	41.6	6.1	3.92	3.42	0.505	0.0033	0.0038	0.0035	0.000449	7,624
2.00	6.00	72.1	63.6	8.5	5.92	5.22	0.699	0.0057	0.0062	0.0059	0.000752	6,940
2.00	8.00	96.5	85.5	11.0	7.92	7.02	0.904	0.0081	0.0085	0.0083	0.001058	6,632
2.00	10.00	120.9	107.7	13.3	9.93	8.84	1.089	0.0106	0.0111	0.0108	0.001377	6,422

Date Reported: 12/21/2018 Urban Land 1 (Bulk) OMC+2%
Terracon Lab No. 03165261 Lab 702 RM 50 omc+2
Project No. 03165261



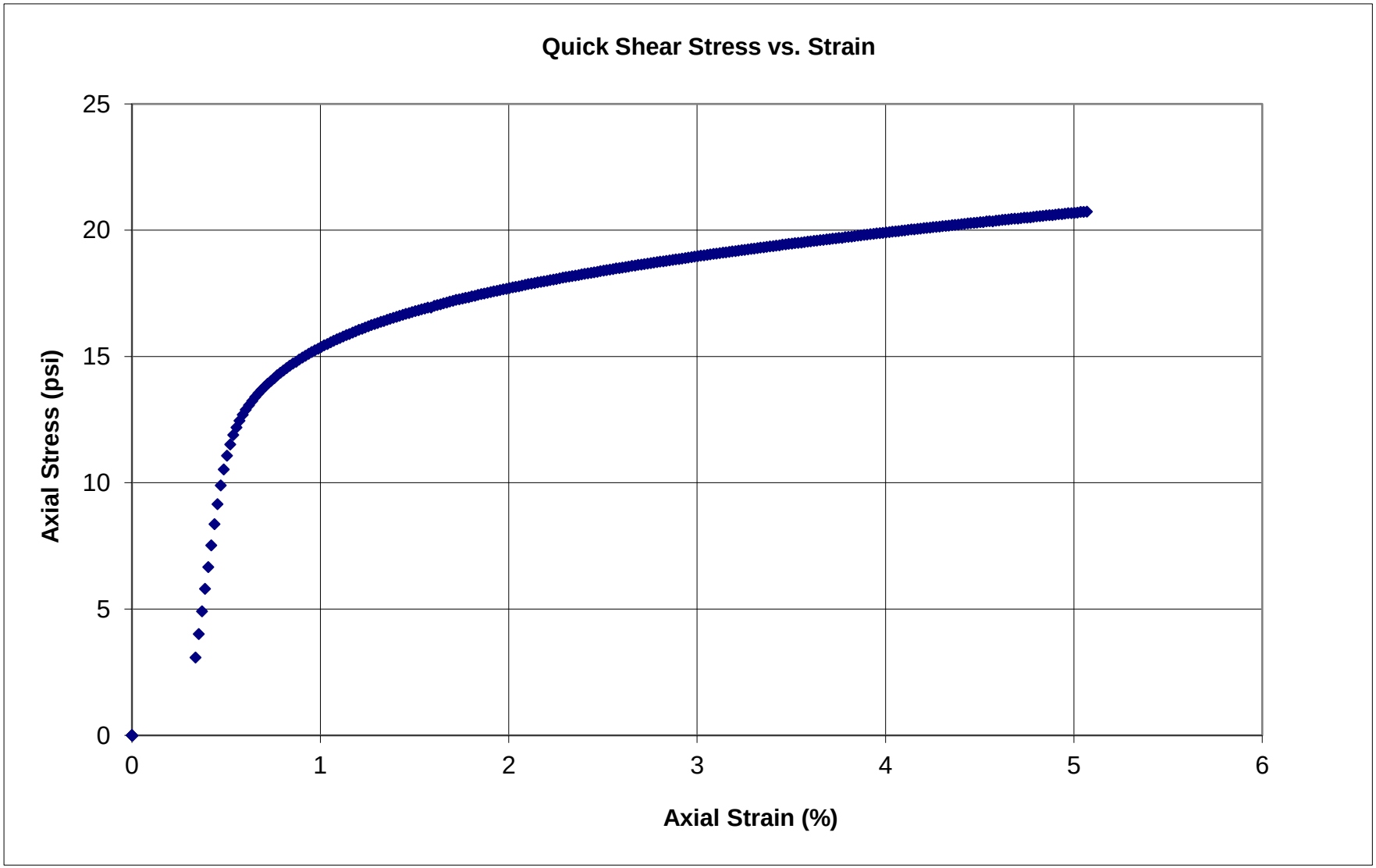
Mr = K1 x Θ^{k2}

[$\Theta = S_{cyclic} + 3\ (S3)$]

S3 (psi)	K1	K2	R^2
6	339424.1	-1.127	0.96
4	33002.8	-0.489	0.80
2	20759.3	-0.443	0.97
All	5076.0	0.178	0.15

Terracon

Date Reported: 12/21/2018 Urban Land 1 (Bulk) OMC+2%
Terracon Lab No. 03165261 Lab 702 RM 50 omc+2
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 703 RM 51 omc
Project No.: 03165261

Soil Map Unit: Urban Land 2 (Bulk) OMC
Soil Symbol: A-6(6) / CL
Depth (in.) 24 - 46
Compaction Method Static
Max. Dry Density (pcf) 112.3
Opt. Moisture Content (%) 14.5
Inside Mold Diameter (in) 3.94

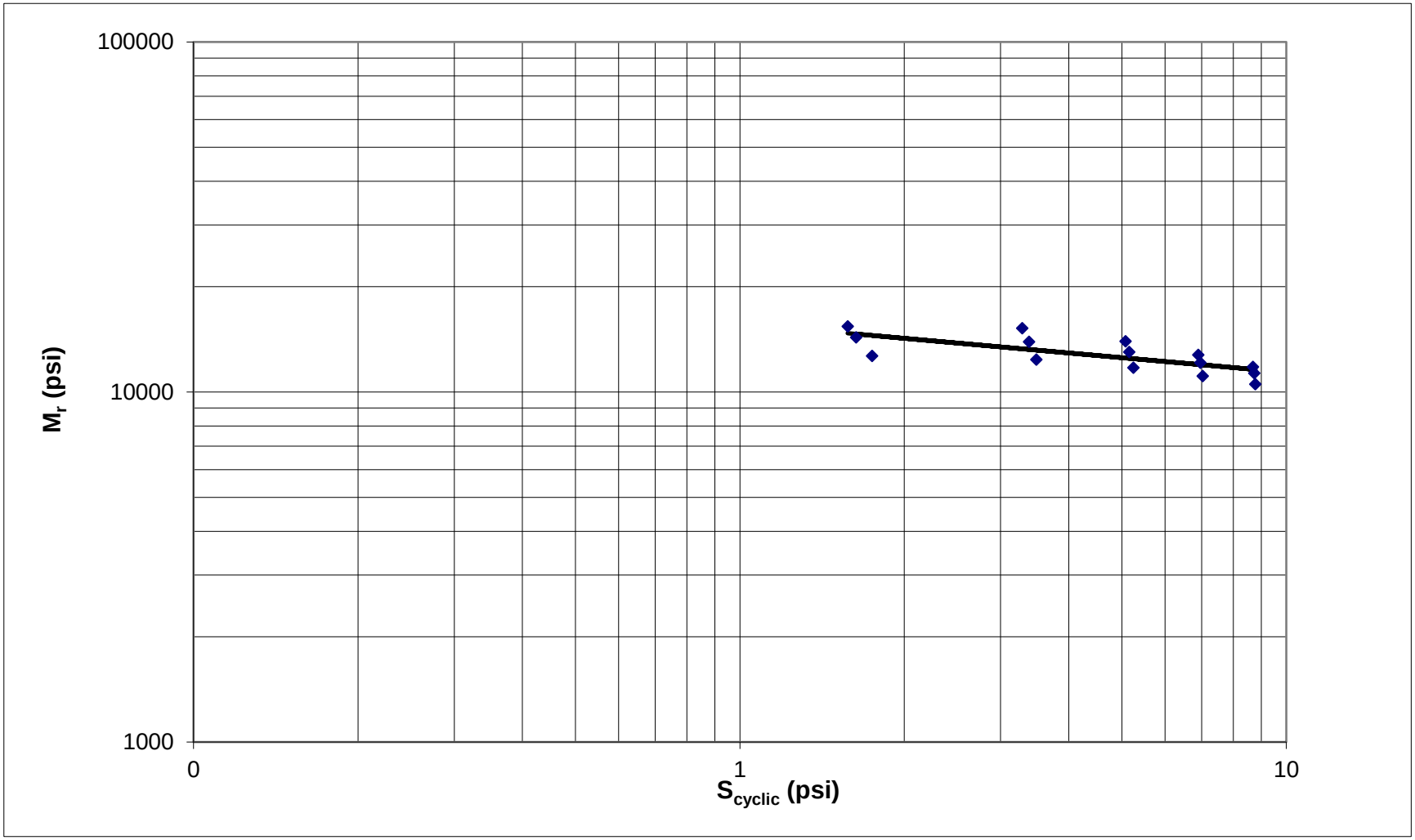
Weight of Wet Soil (lb)	6.77
Initial Sample Diameter (in)	3.94
Initial Sample Height (in)	7.87
Initial Sample Area (in^2)	12.17
Sample Volume (in^3)	95.86
Compacted Moisture Content(%)	15.1
Wet Density (pcf)	122.1
Dry Density (pcf)	106.1

Test Date: November 30, 2018

Final Sample Height (in)	7.9
Final Sample Wet Weight (lb)	6.77
Final Moisture Content (%)	15.0
Accumulated Strain (%)	0.07
Percent Passing No. 10	99
Percent Passing No. 200	54.1
Liquid Limit	33
Plasticity Index	18

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.0	19.2	3.8	1.89	1.58	0.313	0.0008	0.0009	0.0008	0.000102	15,403
6.00	4.00	46.1	40.0	6.1	3.78	3.29	0.497	0.0016	0.0018	0.0017	0.000216	15,216
6.00	6.00	70.5	61.8	8.7	5.79	5.08	0.714	0.0027	0.0030	0.0029	0.000364	13,951
6.00	8.00	95.1	84.0	11.1	7.81	6.90	0.911	0.0041	0.0044	0.0043	0.000541	12,763
6.00	10.00	119.6	105.8	13.8	9.82	8.69	1.132	0.0056	0.0060	0.0058	0.000737	11,787
4.01	2.00	23.5	19.9	3.7	1.93	1.63	0.302	0.0008	0.0010	0.0009	0.000114	14,320
4.01	4.00	47.3	41.2	6.1	3.88	3.38	0.500	0.0018	0.0020	0.0019	0.000243	13,910
4.01	6.00	71.4	62.8	8.6	5.86	5.16	0.709	0.0030	0.0033	0.0031	0.000396	13,007
4.01	8.00	95.7	84.7	11.0	7.86	6.96	0.903	0.0044	0.0047	0.0045	0.000574	12,124
4.01	10.00	119.8	106.3	13.5	9.84	8.73	1.107	0.0059	0.0063	0.0061	0.000772	11,312
2.00	2.00	24.2	21.3	2.9	1.99	1.75	0.241	0.0010	0.0011	0.0011	0.000138	12,688
2.00	4.00	48.1	42.5	5.6	3.95	3.49	0.459	0.0021	0.0023	0.0022	0.000282	12,383
2.00	6.00	72.0	64.0	8.0	5.91	5.25	0.656	0.0034	0.0037	0.0035	0.000448	11,736
2.00	8.00	96.1	85.6	10.5	7.89	7.03	0.863	0.0048	0.0052	0.0050	0.000633	11,113
2.00	10.00	119.8	106.9	12.9	9.84	8.78	1.061	0.0063	0.0068	0.0066	0.000834	10,534

Date Reported: 12/21/2018 Urban Land 2 (Bulk)_OMC
Terracon Lab No. 03165261 Lab 703 RM 51 omc
Project No. 03165261

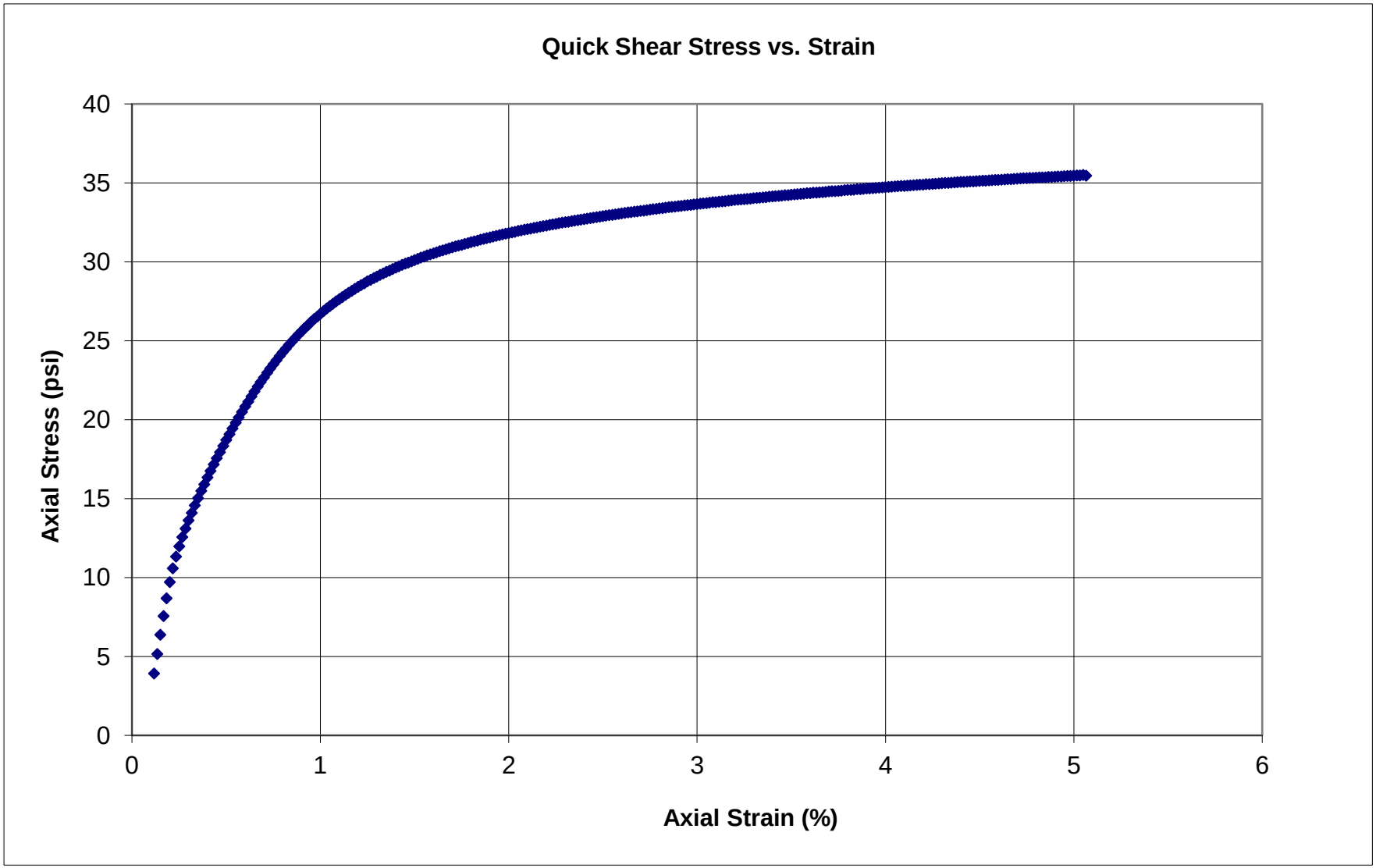


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	17270.1	-0.155	0.83
4	15804.1	-0.137	0.87
2	13838.7	-0.113	0.88
All	15678.1	-0.139	0.55

Terracon

Date Reported: 12/21/2018 Urban Land 2 (Bulk)_OMC
Terracon Lab No. 03165261 Lab 703 RM 51 omc
Project No. 03165261



Terracon

Resilient Modulus Testing - AASHTO T 307-99 English Units

Report Date: 21-Dec-18
Lab No.: 03165261 Lab 703 RM 51 omc+3
Project No.: 03165261

Soil Map Unit: Urban Land 2 (Bulk) OMC+
Soil Symbol: A-6(6) / CL
Depth (in.) 24 - 46
Compaction Method Static
Max. Dry Density (pcf) 112.3
Opt. Moisture Content (%) 14.5
Inside Mold Diameter (in) 3.94

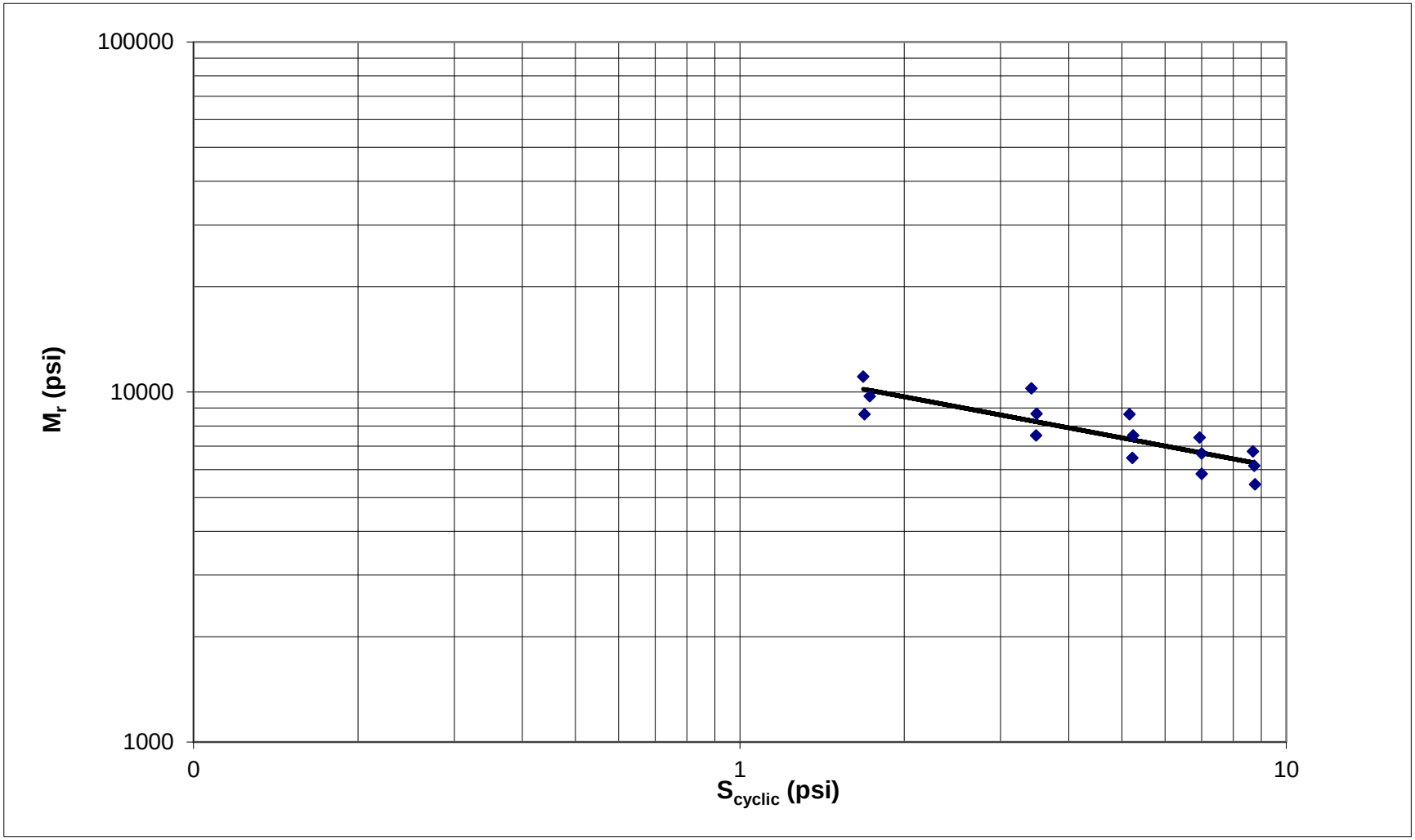
Weight of Wet Soil (lb)	6.95
Initial Sample Diameter (in)	3.94
Initial Sample Height (in)	7.87
Initial Sample Area (in^2)	12.17
Sample Volume (in^3)	95.86
Compacted Moisture Content(%)	17.8
Wet Density (pcf)	125.3
Dry Density (pcf)	106.4

Test Date: November 30, 2018

Final Sample Height (in)	7.9
Final Sample Wet Weight (lb)	6.95
Final Moisture Content (%)	17.8
Accumulated Strain (%)	0.28
Percent Passing No. 10	99
Percent Passing No. 200	54.1
Liquid Limit	33
Plasticity Index	18

Chamber Confining Pressure (S_3) psi	Nominal Maximum Axial Stress (S_{cyclic}) psi	Actual Applied Max. Axial Load (P_{max}) lb	Actual Applied Cyclic Load (P_{cyclic}) lb	Actual Applied Contact Load ($P_{contact}$) lb	Actual Applied Max. Axial Stress (S_{max}) psi	Actual Applied Cyclic Stress (S_{cyclic}) psi	Actual Applied Contact Stress ($S_{contact}$) psi	Recov. Def. LVDT #1 Reading (H_1) in	Recov. Def. LVDT #2 Reading (H_2) in	Average Recov. Def. LVDT 1 and 2 (H_{avg}) in	Resilient Strain (ϵ_r) in/in	Resilient Modulus (M_r) psi
6.00	2.00	23.5	20.5	3.1	1.93	1.68	0.251	0.0010	0.0013	0.0012	0.000152	11,070
6.00	4.00	47.0	41.6	5.4	3.86	3.42	0.447	0.0024	0.0029	0.0026	0.000334	10,242
6.00	6.00	70.9	62.8	8.0	5.82	5.16	0.659	0.0044	0.0050	0.0047	0.000597	8,646
6.00	8.00	95.1	84.5	10.5	7.81	6.94	0.865	0.0072	0.0076	0.0074	0.000936	7,420
6.00	10.00	119.0	105.8	13.2	9.77	8.69	1.084	0.0100	0.0103	0.0101	0.001284	6,762
4.01	2.00	24.0	21.0	2.9	1.97	1.73	0.242	0.0014	0.0014	0.0014	0.000178	9,726
4.01	4.00	48.0	42.5	5.4	3.94	3.49	0.446	0.0032	0.0031	0.0032	0.000403	8,663
4.01	6.00	71.7	63.9	7.8	5.89	5.24	0.644	0.0055	0.0055	0.0055	0.000697	7,521
4.01	8.00	95.5	85.2	10.3	7.85	7.00	0.847	0.0083	0.0082	0.0083	0.001048	6,680
4.01	10.00	119.2	106.4	12.8	9.79	8.74	1.053	0.0112	0.0112	0.0112	0.001419	6,160
2.00	2.00	23.6	20.6	3.0	1.94	1.69	0.249	0.0016	0.0015	0.0015	0.000196	8,636
2.00	4.00	47.7	42.4	5.3	3.92	3.48	0.437	0.0038	0.0035	0.0037	0.000464	7,510
2.00	6.00	71.4	63.7	7.8	5.87	5.23	0.637	0.0065	0.0062	0.0064	0.000807	6,478
2.00	8.00	95.4	85.2	10.2	7.84	7.00	0.838	0.0096	0.0093	0.0094	0.001199	5,840
2.00	10.00	119.3	106.7	12.6	9.80	8.76	1.037	0.0128	0.0125	0.0127	0.001609	5,447

Date Reported: 12/21/2018 Urban Land 2 (Bulk) OMC+
Terracon Lab No. 03165261 Lab 703 RM 51 omc+3
Project No. 03165261

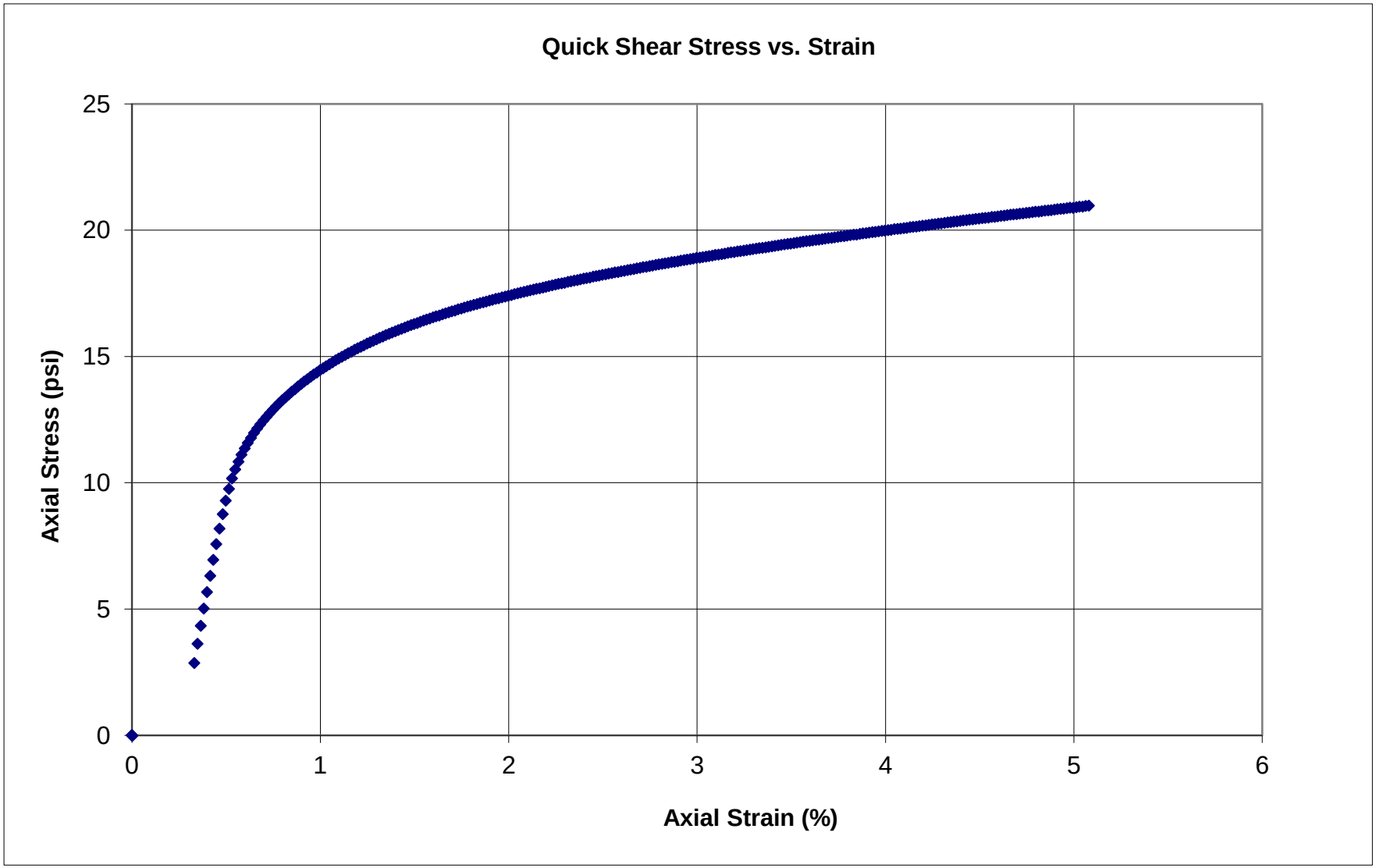


$Mr = K1 \times S_{cylic}^{k2}$

S3 (psi)	K1	K2	R^2
6	13751.9	-0.307	0.92
4	11770.6	-0.285	0.96
2	10286.6	-0.286	0.98
All	11878.5	-0.294	0.70

Terracon

Date Reported: 12/21/2018 Urban Land 2 (Bulk) OMC+
Terracon Lab No. 03165261 Lab 703 RM 51 omc+3
Project No. 03165261



APPENDIX C

MISCELLANEOUS

LOCATION DARSIL OK

Established Series
Rev. JFH:CRC:WTS
03/2014

DARSIL SERIES

The Darsil series consist of shallow, excessively drained, soils that formed in material weathered from weakly cemented sandstone of Permian age. These soils occur on convex ridge crests of low hills in the North Cross Timbers (MLRA84A). Slopes range from 1 to 45 percent. Mean annual precipitation is 864 mm (34 in). Mean air annual temperature is 15.5 degrees C (60 degrees F).

TAXONOMIC CLASS: Thermic, shallow, coated Ustic Quartzipsamments

TYPICAL PEDON: Darsil loamy fine sand, on 4 percent convex west facing slope, in a post oak-blackjack forest with an understory of native grasses. When described, the soil was moist throughout. (Colors are for dry soil unless otherwise stated.)

A--0 to 13 cm (0 to 5 in); brown (7.5YR 5/2) loamy fine sand, dark brown (7.5YR 3/2) moist; weak fine granular structure; soft, very friable; slightly acid; clear smooth boundary. (13 to 23 cm [3 to 9 in] thick)

EC--13 to 43 cm (5 to 17 in); pink (7.5YR 7/4) fine sand, brown (7.5YR 5/4) moist; weak fine granular structure; soft, very friable; 2 percent by volume of coarse fragments from 2 mm to 76 mm in diameter; neutral; clear wavy boundary. (15 to 38 cm [6 to 15 in] thick)

Cr--43 to 58 cm (17 to 23 in); red (2.5YR 5/8) weakly cemented fine grained sandstone, red (2.5YR 4/8) moist; moderately acid.

TYPE LOCATION: Cleveland County, Oklahoma, about 6 miles east of U.S. Highway 77 and Alemeda Street intersection in Norman; 700 feet east and 50 feet south of the northwest corner sec. 32, T. 9 N., R. 1 W.
USGS Topographic Quadrangle: Denver,OK
Latitude: 35.2180 decimal degrees N.
Longitude: 97.3332 decimal degrees W.,
Datum: NAD 83

RANGE IN CHARACTERISTICS:
Depth to bedrock: 25 to 51 cm (10 to 20 in)

A horizon:
Hue: 5YR to 10YR
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 2 to 6 dry or moist

Texture: loamy fine sand or fine sand
Reaction: strongly acid to slightly alkaline

EC horizon:
Hue: 2.5YR to 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma of 2 to 6 dry or moist
Texture: loamy fine sand or fine sand
Coarse fragments: 0 to 20 percent by volume of sandstone fragments from 2 mm to 76 mm diameter.
Reaction: strongly acid to slightly alkaline

Cr horizon:
Hue of 2.5YR or 5YR
Value: 4 to 6 dry, of 3 to 5 moist
Chroma of 4 to 8
Paralithic contact: weakly cemented fine grained sandstone. Root restrictive. High or very high excavation difficulty. Fractures greater than 10 cm apart. Slakes in water within 15 hours.

COMPETING SERIES: These are no other series in this family. Similar series in MLRA 84 are the Darnell (OK) series that have a cambic horizon.

GEOGRAPHIC SETTING:
Parent material: material weathered from sandstone of Permian age
Landscape: low hills
Landform: convex ridge crests and side slopes of hills
Slopes: 1 to 45 percent
Mean Annual Precipitation: 762 to 1015 mm (30 to 40 in)
Mean Annual Temperature: 14 to 17 degrees C (58 to 62 degrees F
Elevation: 229 to 396 m (750 to 1300 ft)
Frost-free period: 200 to 230 days
Thornthwaite Annual P-E indices: 48 to 64

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Darnell (OK), Harrah (OK), Littleaxe (OK), Newalla (OK), and Stephenville (OK) series.
Darnell soils: occur on similar landform positions.
Harrah, Littleaxe, and Stephenville soils: more than 50 cm (20 in) to bedrock and are on lower landform positions.

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY:
Drainage: excessively drained
Hydraulic conductivity: rapid
Runoff: medium on 1 to 5 percent slopes, high on 5 to 20 percent slopes, and very high on >20 percent slopes

USE AND VEGETATION: Rangeland. The native vegetation is post oak and blackjack oak with an understory of mid and tall grasses.

DISTRIBUTION AND EXTENT: Central Oklahoma; LRR J; North Cross Timbers (MLRA 84A).

The series is of moderate extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Cleveland County, Oklahoma; 1983.

REMARKS: OSD updated extensively for the SDJR Initiative by WTS 08/2013

Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - the zone from the soil surface to a depth of 43 cm (17 in). (A and EC horizons)

Paralithic contact - sandstone bedrock encountered at 43 cm (17 inches). (Cr horizon)

ADDITIONAL DATA: Laboratory data is available from Oklahoma State University, Stillwater, Oklahoma. Sample No. 76-OK-14-23.

Taxonomic Version: Keys to Soil Taxonomy, Eleventh Edition, 2010

National Cooperative Soil Survey
U.S.A.

LOCATION HARRAH OK

Established Series
Rev. CRC:CEW:AMS
04/2018

HARRAH SERIES

The Harrah series consists of spoils that are very deep to sandstone, well drained soils. They formed from sandy and loamy colluvium weathered from sandstone of Permian age. These soils are on backslopes and foot slopes of low hills in the Northern Cross Timbers (MLRA 84A). Slope ranges from 3 to 45 percent. Mean annual air temperature is 15 degrees C (59 degrees F), and mean annual precipitation is 860 mm (34 in).

TAXONOMIC CLASS: Fine-loamy, siliceous, active, thermic Ultic Paleustalfs

TYPICAL PEDON: Harrah fine sandy loam, on a 6 percent convex east facing slope, in a severely eroded field reseeded to native grasses, at an elevation of 344 m (1130 ft). (Colors are for dry soil unless otherwise stated.)

Ap--0 to 23 cm (0 to 9 in); brown (7.5YR 5/2) fine sandy loam, brown (7.5YR 4/2) moist; weak fine granular structure; soft, very friable; neutral; clear smooth boundary. (Thickness of the A horizon is 5 to 25 cm [2 to 10 in])

E--23 to 48 cm (9 to 19 in); light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 5/4) moist; weak fine granular structure; soft, very friable; neutral; clear smooth boundary. (Thickness of the E horizon is 0 to 51 cm [0 to 20 in])

Bt1--48 to 86 cm (19 to 34 in); red (2.5YR 5/6) sandy clay loam, red (2.5YR 4/6) moist; weak fine blocky structure; hard, firm; common faint clay films on faces of peds; slightly acid; gradual wavy boundary. (25 to 64 cm [10 to 25 in] thick)

Bt2--86 to 132 cm (34 to 52 in); red (2.5YR 5/8) sandy clay loam, red (2.5YR 4/8) moist; moderate medium prismatic structure parting to moderate medium blocky; hard, firm; common distinct clay films on faces of peds; about 5 percent by volume uncoated sand grains on vertical faces of peds and in pores; moderately acid; gradual wavy boundary. (30 to 114 cm [12 to 45 in] thick)

Bt3b--132 to 193 cm (52 to 76 in); red (2.5YR 4/6) sandy clay loam, dark red (2.5YR 3/6) moist; moderate medium prismatic structure parting to moderate medium blocky; hard, firm; common distinct clay films on faces of peds; about 20 percent by volume of uncoated sand grains on vertical faces of peds and in pores; moderately acid; gradual wavy boundary. (0 to 71 cm [0 to 28 in] thick)

Bt4b--193 to 218 cm (76 to 86 in); red (2.5YR 4/6) sandy clay loam, dark red (2.5YR 3/6) moist; moderate medium blocky structure; hard, firm; common faint clay films on faces of peds; few fine dark concretions; about 10 percent by volume of uncoated sand grains on vertical faces of peds and in

pores; slightly acid.

TYPE LOCATION: Cleveland County, Oklahoma; about 10 miles east and 2.6 miles north of U.S. Highway 77 and Robinson Street intersection in Norman; about 2,350 feet south and 900 feet east of the northwest corner of sec. 12, T. 9 N., R. 1 W.

USGS Topographic Quadrangle: Franklin, OK
Latitude: 35 degrees, 16 minutes, 11 seconds N
Longitude: 97 degrees, 15 minutes, 41 seconds W

Decimal Degrees:
Latitude: 35.26972222 degrees
Longitude: -97.261388889 degrees
Datum: NAD 83

UTM Easting: 658136.9 m
UTM Northing: 3904340.6 m
UTM Zone: 14N

RANGE IN CHARACTERISTICS:
Depth of soil: more than 152 cm (60 in)
Base saturation: sum of cations, 50 to 70 percent in the Bt horizons
Depth to a buried horizon: 76 cm to more than 203 cm (30 to more than 80 in) and averages 142 cm (56 in), but may be absent or below 203 cm (80 in) in some pedons

Ap or A horizon:
Hue: 5YR or 10YR
Value: 4 to 6 dry, moist
Chroma: 2 to 4 dry, moist
Texture: loamy fine sand or fine sandy loam
Other features: where the texture is loamy fine sand, the combined thickness of the A and E horizons is less than 51 cm (20 in)
Reaction: very strongly acid to neutral

E horizon:
Hue: 2.5YR to 7.5YR
Value: 5 to 7 dry, moist
Chroma: 4 to 6 dry, moist
Texture: loamy fine sand or fine sandy loam
Reaction: very strongly acid to neutral

Bt horizon:
Hue: 10R to 5YR
Value: 4 to 6 dry, moist
Chroma: 4 to 8 dry, moist
Texture: fine sandy loam or sandy clay loam
Clay content: 18 to 35 percent
Skeletans: amount-0 to 20 percent by volume; kind-uncoated sand grains; location-mainly on vertical faces of peds or in old root channels

Redox concentrations: amount-0 to 2 percent by volume; size-2 to 76 mm (0.75 to 3 in); kind-iron-manganese concretions; color-shades of brown; boundary-sharp
Reaction: very strongly acid to neutral

Bt3 and Bt4 horizons (where the Btb horizon is not within a depth of 203 cm [80 in]):
Hue: 10R to 5YR
Value: 4 to 6 dry, moist
Chroma: 4 to 8 dry, moist
Texture: fine sandy loam or sandy clay loam
Clay content: 18 to 35 percent
Skeletans: amount-0 to 20 percent by volume; kind-uncoated sand grains; location-mainly on vertical faces of peds or in old root channels
Redox concentrations: amount-0 to 2 percent by volume; size-2 to 76 mm (0.75 to 3 in); kind-iron-manganese concretions; color-shades of brown; boundary-sharp
Reaction: very strongly acid to neutral

Btb horizon:
Hue: 10R or 2.5YR
Value: 4 to 6 dry, moist
Chroma: 4 to 8 dry, moist
Texture: fine sandy loam or sandy clay loam
Clay content: 18 to 35 percent
Skeletans: amount-0 to 40 percent by volume; kind-uncoated sand grains; location-mainly on vertical faces of peds or in old root channels
Redox concentrations: amount-0 to 2 percent by volume; size-2 to 76 mm (0.75 to 3 in); kind-iron-manganese concretions; color-shades of brown; boundary-sharp
Rock fragments: amount-0 to 5 percent by volume; size-2 mm to 76 mm (0.75 to 3 in); kind-barite rosettes, sandstone, or quartzite
Reaction: very strongly acid to neutral

BC horizon (where present, when the Btb horizon is not present above 203 cm [80 in]):
Hue: 2.5YR
Value: 5 dry, moist
Chroma: 6 or 8 dry, moist
Texture: fine sandy loam and less often sandy clay loam
Skeletans: amount-0 to 5 percent by volume; kind-uncoated sand grains; location-mainly on vertical faces of peds or old root channels
Reaction: slightly acid or neutral

COMPETING SERIES: This is the Konsil (MLRA 78C) series in the same family. Soils in similar families in MLRA 84A are the Galey, Gasil, Konawa, Littleaxe, Stephenville, and Weatherford series.
Galey and Gasil soils: have an argillic horizon with hue of 7.5YR or yellower
Konsil soils: have a longer growing season and are warm for longer periods of time
Konawa soils: have an argillic horizon that decreases in clay content from the maximum by 20 percent or more within a depth of 152 cm (60 in), and have mixed mineralogy
Littleaxe, Stephenville and Weatherford soils: have sola less than 150 cm (60 in) to sandstone

GEOGRAPHIC SETTING:
Parent material: formed in sandy and loamy colluvium weathered from sandstone of Permian age

Landscape: low hills
Landform: convex hillslopes, backslopes and foot slopes
Slope: 3 to 45 percent
Mean annual temperature: 14 to 18 degrees C (58 to 62 degrees F)
Thornthwaite Annual P-E indices: 48 to 64
Mean annual precipitation: 760 to 970 mm (30 to 38 in)
Frost-free period: 190 to 220 days
Elevation: 305 to 396 m (1,000 to 1,300 ft)

GEOGRAPHICALLY ASSOCIATED SOILS: These are the similar Littleaxe and Stephenville series and Darnell, Darsil, Newalla, Pulaski, and Tribbey series.
Darnell and Darsil soils: are mainly on shoulders of hillslopes, do not have an argillic horizon and are less than 51 cm (20 in) thick over sandstone
Littleaxe and Stephenville soils: are on higher positions
Newalla soils: occur on similar positions, have an abrupt texture change between the A and Bt horizons, and have a fine control section
Pulaski and Tribbey soils: are on flood plains and have a coarse-loamy control sections

DRAINAGE AND PERMEABILITY:
Drainage: well
Saturated hydraulic conductivity: moderately high
Runoff: low on 3 to 5 percent slopes, medium on 5 to 20 percent slopes and high on slopes greater than 20 percent

USE AND VEGETATION: Used mainly as rangeland or improved pasture. Some areas are cultivated, wheat and grain sorghum are the main crops. The native vegetation is Savannah consisting of post oak, blackjack oak, eastern red cedar, oak, and hickory with an understory of mid and tall grasses, primarily big bluestem and little bluestem.

DISTRIBUTION AND EXTENT:
General area: central Oklahoma
Land Resource Region J-Southwestern Prairies Cotton and Forage Region
MLRA 84A-Northern Cross Timbers
Extent: moderate

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Payne County, Oklahoma; 1983 by J.E. Henley. This series was named after a town in eastern Oklahoma County.

REMARKS:
These soils were formerly included in the Dougherty, Konawa, and Stephenville series in earlier surveys.

Diagnostic horizons and features recognized in this pedon are:
Ochric epipedon: 0 to 23 cm (0 to 9 in) (A horizon)
Argillic horizon: 48 to 218 cm (19 to 86 in) (Bt horizons)

Minor revisions and formatting done by JLD, 05/2007.

Edited 03/2018 (JAD-AMS) Changed to tabular format. Updated pedon description, range in characteristics, and other sections.

ADDITIONAL DATA: Kellogg Soil Survey Lab. Lab No. 88OK03701 and 88OK03702. Laboratory data is available from Oklahoma State University, Stillwater, Oklahoma. Sample No. 78-OK-14-31 (1-8).

TAXONOMIC VERSION: Keys to Soil Taxonomy, Twelfth Edition, 2014

National Cooperative Soil Survey
U.S.A.

LOCATION NEWALLA OK

Established Series
Rev. CEW:CS:CRC:WJG
11/2005

NEWALLA SERIES

The Newalla series consists of deep, moderately well drained, very slowly permeable soils. The upper part formed in material weathered from sandstone and the lower part formed in material weathered from shale of Permian age. These soils are on very gently sloping to steep summits and back slopes of uplands in the Northern Cross Timbers (MLRA 84A). Slopes range from 1 to 25 percent. Mean annual precipitation is 33 inches. Mean annual temperature is 62 degrees F.

TAXONOMIC CLASS: Fine-loamy over clayey, siliceous, superactive, thermic Udic Haplustalfs

TYPICAL PEDON: Newalla fine sandy loam--on a 7 percent slightly convex southeast facing upland side slope-under post oak and blackjack oak savannah. (Colors are for dry soil unless otherwise stated.)

A--0 to 3 inches; brown (7.5YR 4/2) fine sandy loam, dark brown (7.5YR 3/2) moist; moderate fine granular structure; slightly hard, very friable; many very fine, fine, and common medium roots; strongly acid; clear smooth boundary. (2 to 9 inches thick)

E--3 to 6 inches; light brown (7.5YR 6/4) fine sandy loam, brown (7.5YR 5/4) moist; weak medium granular structure; slightly hard, very friable; many very fine, fine, and common medium roots; very strongly acid; abrupt wavy boundary. (0 to 7 inches thick)

Bt1--6 to 10 inches; red (2.5YR 5/6) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; hard, firm; common very fine, fine, medium, and few coarse roots; discontinuous clay films on faces of peds; many faces of peds coated with light brown (7.5YR 6/4) fine sandy loam; very strongly acid; clear wavy boundary. (3 to 15 inches thick)

2Bt2--10 to 16 inches; red (2.5YR 4/6) clay, dark red (2.5YR 3/6) moist; moderate fine and medium blocky structure; very hard, very firm; common very fine and fine roots and a few medium and coarse roots; continuous clay films on faces of peds; very strongly acid; gradual wavy boundary. (4 to 23 inches thick)

2Btss--16 to 30 inches; red (2.5YR 4/6) clay, dark red (2.5YR 3/6) moist; weak medium subangular blocky structure; extremely hard, extremely firm; common very fine and fine roots and a few medium and coarse roots; few slickensides; continuous clay films on faces of peds; few fine dark concretions; moderately acid; gradual wavy boundary. (0 to 26 inches thick)

2Btkss--30 to 42 inches; red (2.5YR 4/6) clay, dark red (2.5YR 3/6) moist; weak medium subangular blocky and blocky structure; extremely hard, extremely firm; few very fine, fine, medium and coarse roots; few slickensides; continuous clay films on faces of peds; few fine dark concretions; common fine and medium soft masses of calcium carbonate; slight effervescence; slightly alkaline; gradual wavy boundary. (0 to 28 inches thick)

2B'tss--42 to 51 inches; red (2.5YR 4/6) clay, dark red (2.5YR 3/6) moist; weak medium and coarse blocky structure; extremely hard, extremely firm; few very fine and fine roots; common slickensides; continuous clay films on faces of peds; few fine dark concretions; slight effervescence; moderately alkaline; gradual wavy boundary. (0 to 9 inches thick)

2BC--51 to 58 inches; red (2.5YR 4/6) gravelly silty clay, dark red (2.5YR 3/6) moist; common fine distinct yellowish red (5YR 4/6) redox accumulations; weak medium subangular blocky structure; very hard, very firm; few very fine roots; discontinuous clay films on faces of peds; 25 percent by volume of shale fragments from 2 mm to 76 mm in diameter; slight effervescence; slightly alkaline; clear wavy boundary. (0 to 18 inches thick)

2Cr--58 to 80 inches; red (2.5YR 4/6) weakly laminated, soft shale; slightly alkaline.

TYPE LOCATION: Cleveland County, Oklahoma; about 1 mile south and 7.4 miles east of Slaughterville; 1,900 feet east and 150 feet south from the northwest corner of sec. 21, T. 7 N., R. 1 E.

RANGE IN CHARACTERISTICS: Solum thickness and depth to bedrock ranges from 40 to 60 inches.

The A or Ap horizon has hue of 5YR to 10YR, value of 4 to 6, and chroma of 2 to 6. Texture is fine sandy loam, loam or sandy clay loam. Base saturation (by sum of cations) ranges from 35 to 50 percent. Reaction ranges from very strongly acid to neutral.

The E horizon has hue of 5YR to 10YR, value of 4 to 7, and chroma of 3 to 6. In some pedons, the E horizon is mixed with the Ap horizon in cultivation. Texture is fine sandy loam. Base saturation (by sum of cations) ranges from 25 to 35 percent. Reaction ranges from very strongly acid to neutral.

The Bt1 horizon has hue of 2.5YR to 7.5YR, value of 5 or 6, and chroma of 3 to 8. Texture is sandy clay loam or clay loam. Clay content ranges from about 20 to 35 percent. In some eroded pedons, the Bt1 horizon is mixed with the Ap horizon. Base saturation (by sum of cations) ranges from 25 to 50 percent. The boundary between the Bt1 and 2Bt is clear or abrupt. Reaction ranges from very strongly acid to neutral.

The 2Bt and 2Btss horizons have hue of 10R to 5YR, value of 4 to 6, and chroma of 4 to 8. Texture is silty clay or clay and the clay content ranges from 40 to 60 percent. Exchangeable sodium percentage ranges from 0 to 2. Base saturation (by sum of cations) ranges from 35 to 85 percent. Reaction ranges from very strongly acid to moderately alkaline. Redoximorphic concentrations in shades of red, yellow, or brown may be present below 30 inches.

The 2Btkss and 2Btksshorizons have hue of 10R to 5YR, value of 4 to 6, and chroma of 4 to 8. Texture is clay or silty clay and the clay content ranges from 40 to 60 percent. Base saturation (by sum of cations) ranges from 55 to 98 percent. Exchangeable sodium percentage ranges from 3 to 7. Soft masses of calcium carbonate range from 0 to 10 percent by volume. Reaction ranges from neutral to moderately alkaline. Redoximorphic concentrations in shades of red, yellow, or brown may be present.

The 2BC or 2BCk horizon has hue of 10R to 5YR, value of 4 to 6, and chroma of 4 to 8. Most pedons have redox concentrations in shades of red, yellow, or brown. Texture is sandy clay, silty clay, gravelly silty clay, or very gravelly silty clay and the clay content ranges from 40 to 60 percent. Shale fragments from 2 mm to 76 mm in diameter range from 0 to 50 percent by volume. Base saturation

(by sum of cations) ranges from 75 to 79 percent. Exchangeable sodium percentage ranges from 5 to 10. Reaction is slightly or moderately alkaline.

The 2Cr horizon has hue of 10R to 5YR, value of 4 to 6, and chroma of 2 to 6. Some pedons are streaked in shades of brown, yellow, or gray. In some pedons the 2Cr horizon is interbedded with thin beds of sandstone. In some pedons the 2Cr horizon has slight or very slight effervescent. Exchangeable sodium percentage ranges from 5 to 12. Reaction is slightly or moderately alkaline. This material is non paralithic and excavation difficulty is low or moderate. Fractures are greater than 10 cm apart. This material is dense enough to be root restrictive. Most of this material slakes in water within 15 hours.

COMPETING SERIES: There are no other series in the same family.

GEOGRAPHIC SETTING: Newalla soils are on very gently sloping to steep summits and back slopes of uplands in the Cross Timbers. Slopes range from 1 to 25 percent. The upper part formed in material weathered from sandstone and the lower part formed in material weathered from shale of Permian age. Mean Annual Precipitation: 30 to 40 inches. Mean Annual Temperature: 58 to 62 degrees F. Thornthwaite Annual P-E indices: 44 to 64. Frost free days: 200 to 230. Elevation: 800 to 1200 feet.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Grainola Darnell, Darsil, Harrah, Littleaxe, Renfrow, and Stephenville series. Darnell and Darsil soils lack an argillic horizon and are less than 20 inches thick over sandstone. Darnell and Darsil soils are mainly on the ridge crests. Grainola soils are on side slopes of prairie uplands. Harrah, Littleaxe, and Stephenville soils have a fine-loamy control section. In addition, Harrah soils have a solum more than 72 inches thick and Stephenville soils have a solum from 20 to 40 inches thick over sandstone. Harrah soils are on lower foot slopes and side slopes. Littleaxe soils are on ridge crests and Stephenville soils are on landscapes similar to Newalla soils. Renfrow soils have a solum more than 60 inches thick and are on higher prairie uplands.

DRAINAGE AND PERMEABILITY: Newalla soils are moderately well drained. Runoff is very high and permeability is very slow.

USE AND VEGETATION: Used mainly for range or tame pasture. The native vegetation is post oak, blackjack oak, and hickory with an understory of mid and tall grasses.

DISTRIBUTION AND EXTENT: Northern Cross Timbers (MLRA 84A) of central Oklahoma. The series is of moderate extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Temple, Texas

SERIES ESTABLISHED: Garvin County, Oklahoma; 1982.

REMARKS: Series Interpretation Record No. OK0295

These soils were formerly included with the Windthorst series in earlier surveys.

Diagnostic horizons and features recognized in the pedon are:

Ochric epipedon - the zone from the surface of the soil to a depth of 3 inches (A horizon).

Albic horizon - the zone from 3 inches to 6 inches (E horizon).

Argillic horizon - the zone from 6 inches to a depth of 51 inches (Bt horizons). Lithologic discontinuity - the contrasting material encountered at a depth of 10 inches. Accumulation of secondary calcium carbonate - the zone from 30 inches to a depth of 51 inches (2Btk horizons)
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Cr horizon - non paralithic rock like material encountered at a depth of 58 inches

ADDITIONAL DATA: Laboratory data is available from Oklahoma State University, Stillwater, Oklahoma. Sample number 80-OK-14-37 and 80-OK-14-36.

National Cooperative Soil Survey
U.S.A.

LOCATION STEPHENVILLE OK KS TX

Established Series
Rev. CRC:CS:CEW:WJG
02/2014

STEPHENVILLE SERIES

The Stephenville series consists of moderately deep, well drained, soils formed in material weathered from sandstone of Permian age. These soils are on very gently sloping to moderately steep side slopes of hills in the North Cross Timbers (MLRA 84A). Slopes range from 1 to 25 percent. Mean annual precipitation is about 810 mm (32 inches). Mean annual air temperature is about 16 degrees C (61 degrees F).

TAXONOMIC CLASS: Fine-loamy, siliceous, active, thermic Ultic Haplustalfs

TYPICAL PEDON: Stephenville loamy fine sand, on a east-facing, convex, 5 percent slope in bermuda grass pasture, at an elevation of 375 m (1,230 feet). (Colors are for dry soil unless otherwise stated.)

A--0 to 13 cm (0 to 5 inches); grayish brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak very fine granular structure; soft, very friable; many very fine and fine and few medium and coarse roots; moderately acid; clear smooth boundary. (8 to 20 cm [3 to 8 inches] thick)

E--13 to 38 cm (5 to 15 inches); light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 5/4) moist; weak fine granular structure; soft, very friable; common very fine and fine and few medium roots; strongly acid; abrupt wavy boundary. (0 to 33 cm [0 to 13 inches] thick)

Bt1--38 to 64 cm (15 to 25 inches); red (2.5YR 5/6) sandy clay loam, red (2.5YR 4/6) moist; moderate medium subangular blocky structure; very hard, firm; common very fine and fine and few medium roots; common distinct continuous clay films on faces of peds; clean sand grains along root channels; strongly acid; gradual wavy boundary.

Bt2--64 to 84 cm (25 to 33 inches); light red (2.5YR 6/6) sandy clay loam, red (2.5YR 5/6) moist; weak coarse subangular blocky structure; hard, firm; few very fine and medium, common fine and very few coarse roots; common distinct patchy clay films on faces of peds; clean sand grains along root channels; strongly acid; clear wavy boundary. (Combined thickness of Bt horizon is 33 to 76 cm [13 to 30 inches])

Cr1--84 to 102 cm (33 to 40 inches); red (2.5YR 5/6) weakly cemented fine-grained sandstone, red (2.5YR 4/6) moist; common fine and few medium roots in fractures; strongly acid; clear wavy boundary.

Cr2--102 to 130 cm (40 to 51 inches); light red (2.5YR 6/8) weakly cemented fine-grained sandstone,

red (2.5YR 5/8) moist; common fine and few medium roots in fractures; strongly acid.

TYPE LOCATION: Oklahoma County, Oklahoma; about 2.5 miles east and 1 mile north of Spencer, Oklahoma; located about 750 feet south and 450 feet east of the northwest corner of sec. 8, T. 12 N., R. 1 W. Spencer, OK USGS Topographic Quadrangle; Latitude 35 degrees, 32 minutes, 6 seconds N; Longitude 97 degrees, 20 minutes, 2.4 sec. W. NAD 83.

RANGE IN CHARACTERISTICS:
Depth to paralithic contact: 51 to 102 cm (20 to 40 inches)

A horizon
Hue: 5YR to 10YR
Value: 3 to 5 moist, 5 to 7 dry
Chroma: 2 to 6 moist or dry
Texture: loamy fine sand or fine sandy loam
Reaction: strongly acid to slightly acid (upper part of the A horizon of some pedons are neutral due to liming)

E horizon
Hue: 5YR to 10YR
Value: 4 to 6 moist, 5 to 7 dry
Chroma: 2 to 6 moist or dry
Texture: loamy fine sand or fine sandy loam
Reaction: strongly acid to slightly acid

Bt horizon
Hue: 2.5YR or 5YR
Value: 4 to 6 moist, 5 to 7 dry
Chroma: 3 to 8 moist or dry
Texture: fine sandy loam or sandy clay loam
Reaction: very strongly acid to slightly acid

BC horizon (where present)
Hue of 2.5YR or 5YR
Value: 4 or 5 moist, 5 or 6 dry
Chroma: 4 to 8 moist or dry
Texture: fine sandy loam or sandy clay loam
Coarse fragments: sandstone, less than 76 mm (3 inches) in diameter.
0 to 35 percent by volume
Reaction: very strongly acid to slightly acid

Cr horizon
Hue: 2.5YR or 5YR
Value: 4 or 6 moist, 5 to 7 dry
Chroma: 4 to 8 moist or dry
Paralithic contact: Weakly cemented sandstone. Root restrictive with fractures greater than 10 cm (4 inches) apart.

COMPETING SERIES: These are the, Littleaxe and Weatherford series in the same family. These

soils are greater than 102 cm (40 inches) to paralithic contact.

GEOGRAPHIC SETTING:
Parent material: Materials weathered from sandstone of Permian age.
Landscape: Uplands
Landform: Hills
Geomorphic Component: Side slopes
Hillslope Position: Backslopes
Slopes: 1 to 25 percent
Mean annual precipitation: 760 to 1015 mm (30 to 40 inches)
Mean annual air temperature: 13 to 17 degrees C (56 to 63 degrees F)
Frost-free period: 200 to 250 days
Elevation: 229 to 395 meters (750 to 1295 feet)
Thornthwaite annual P-E indices: 48 to 64

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Darnell, Darsil, Harrah, Konawa, and the competing Littleaxe soils.
Darnell and Darsil soils: Less than 50 cm (20 inches) to paralithic contact and occur on crests.
Harrah soils: Greater than 150 cm (60 inches) to paralithic contact and occur on base slopes.
Konawa soils: Greater than 150 cm (60 inches) to paralithic contact and occur on stream terraces.
Littleaxe soils: Occur on similar landform positions.

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY: Well drained. Runoff is low on 1 to 5 percent slopes, medium on 5 to 20 percent slopes and high on slopes greater than 20 percent. Saturated hydraulic conductivity is moderately high in the most restrictive layer above paralithic contact.

USE AND VEGETATION: Used for rangeland. Some areas used for cropland and tame pasture. Native vegetation is mainly post oak, blackjack oak, hickory, and eastern red cedar with an understory of tall and mid grasses. Cultivated crops include grain sorghums, small grains, and peanuts.

DISTRIBUTION AND EXTENT: Central Oklahoma. Land Resource Region H. MLRA 84A (Northern Cross Timbers). The series is extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Temple, Texas.

SERIES ESTABLISHED: Eastland County, Texas; 1916.

REMARKS: Major changes in the OSD were made by Walt Schaefer, as a result of the Soil Data Join Re-correlation Initiative (SDJR) in 06/2013.

Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - 13 cm (5 inches) (A horizon).

Albic materials (less than 85 percent by volume) - 13 to 38 cm (5 to 15 inches). (E horizon)

Argillic horizon - 38 to 84 cm (15 to 33 inches). (Bt horizons)

Paralithic contact - Sandstone bedrock at a depth of 84 cm (33 inches). (Cr horizon)

ADDITIONAL DATA: Soil Survey Investigation Report No. 11, May 1967, National Soil Survey Lab. Lab No. 17174-17179, 17180-17185, S89OK-083-003, and S91OK-109-002; Oklahoma State University Lab No. 70-OK-55-1.

Taxonomic Version: USDA-NRCS, Keys to Soil Taxonomy, Eleventh Edition, 2010.

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