RED ROCK
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PEDOLOGICAL & GEOLOGICAL SOIL SURVEY

SH 29 - WEST
STEPHENS COUNTY, OKLAHOMA

29657(04)

Prepared For:

SRB
100 Northeast 5th Street
Oklahoma City, Oklahoma 73104
Attention: Mr. Gregory D. Allen, PE

Prepared By:

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August 3, 2018
Project No. 18028

RED ROCK
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SRB
100 Northeast 5th Street
Oklahoma City, Oklahoma 73104

Attention: Mr. Gregory D. Allen, PE

Re: Pedological & Geological Soil Survey
SH 29 - West
Stephens County, Oklahoma
29657(04)
RRC Project No. 18028

Dear Mr. Allen,

We are pleased to submit herewith this report entitled "Pedological & Geological Soil Survey, SH 29 -West, Stephens County, Oklahoma, 29657(04)".

In an effort to provide a more environmentally friendly service, this report has been provided electronically.

If you have any questions regarding the contents of this report, please contact Red Rock Consulting. It has been our pleasure to assist you with this project.

Yours very truly,
RED ROCK CONSULTING, LLC
CA No. 5707 Exp. 06/30/19

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PEDOLOGICAL & GEOLOGICAL SOIL SURVEY

SH 29 - WEST
STEPHENS COUNTY, OKLAHOMA
29657(04)

PROJECT NO. 18028

TABLES

APPENDICES

PEDOLOGICAL & GEOLOGICAL SOIL SURVEY

SH 29 - WEST
STEPHENS COUNTY, OKLAHOMA
29657(04)

PROJECT NO. 18028

1.0 INTRODUCTION

1.1 Project Authorization

Daniel M. Bolin, EI, Project Specialist for Red Rock Consulting, LLC, assigned this project to James B. Nevels, Jr, PhD, PE, on March 19, 2018. The work was authorized by Greg Allen, PE, Director of Transportation Engineering for SRB Engineering, Surveying, Planning. The scope of work for the pedological and geological soil survey includes all resilient modulus and supporting data, soil taxonomy and soil descriptions, geologic statement, problem soils, analysis and recommendations.

The purpose of this study was to explore the subsurface conditions at the site with regards to project earthwork and pavement subgrade construction. The scope did not include any environmental assessment for the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater or air on or below or around the site.

1.2 Qualifications

Mr. James B. Nevels', Jr, PhD, PE, responsibility was limited to selecting the representative soil series sampling locations, sampling and logging the soil series descriptions, reviewing the Red Rock Consulting, LLC test data, and preparing the pedological and geological soil survey report. The laboratory processing and testing of the pedological soil samples was conducted by Red Rock Consulting, LLC and the resilient modulus tests were performed by Naji Khoury at EINCK, Corp. for Red Rock Consulting, LLC. The field sampling and laboratory testing were performed in general accordance with the current Oklahoma Department of Transportation (ODOT) Roadway Design geotechnical specification (June 29, 2011) – Pedological and Geological Soil Survey, Option A.

1.3 Proposed Construction

The project consists of a new grade and drain improvement offset approximately 59–feet north of the existing SH 29 alignment. The project also includes a new bridge over Black Bear Creek (Bridge A) and two box structures (Bridges B and C) in Stephens County. There are two transition detours sections (A and B). The proposed typical pavement section for the SH 29 consists of an 8.5–inch asphalt pavement over an 8–inch aggregate base underlain 8–inch stabilized subgrade and separator fabric that consists of widening pavement sections with a thin overlay. The typical section and other details are presented in plans provided by the client. The plans provided by the client do not include cross–sections because of sheet quantity; however, a hard copy of the cross–sections was available for review.

Based on the plans provided by the client, the proposed beginning of project (BOP) is at station 585+50, and the end of project (EOP) is station 889+00. The project roadway length of the project is 29680.33.16 feet (5.621 miles), and the total bridge length is 669.67 feet (0.127 miles). The preliminary design plans were prepared by SRB Engineering, Surveying, Planning at 100 NE 5th Street, Oklahoma City Oklahoma, 73104.

2.0 SITE CONDITIONS

2.1 Site Description

The project is located along the present SH 29 with the BOP station at approximately 1934 feet west of the center line intersection of SH 29 and NS 294 County Road (Rd) and extending east. The general location of the project location is shown in Figure 1. The existing SH 29 alignment is a 24–wide asphalt pavement with grass shoulders.

There are several utility companies along this alignment extent and utilities that will impact the construction grading. They are identified in the plans provided by the client. Additional utilities should be anticipated along the CRL of SH 29. The surrounding land use along the existing alignment of SH 29 is predominately pasture and unused land; see Figures 2, 3, and 4.

2.2 Soil Series Station Extents

An estimate of the soil series station extents along the SH 29 CRL were based on using the Web Soil Survey 3.3 soil maps on pages 2, 3, and 4 in Appendix B. These soil maps were converted to a 1:20,000 map scale. The distances were then scaled in feet and referenced along the above listed CRL and center line of survey. The reference point for stationing was the SH 29 center line intersection with NS294 Rd, NS295 Rd, NS297 Rd, and NS299 Rd. The soil series station extents are presented in Table 1.

2.3 Subsurface Conditions

The subsurface conditions throughout this project extent consist of soils developed from the following:

- Material weathered from sandstone
- Material weathered from weakly cemented sandstone
- Material weathered from sandstone underlain by material weathered from shale
- Residuum from interbedded from shale and sandstone
- Material formed in calcareous loamy alluvium
- Material formed in loamy alluvial sediments

The specifics and details of the origin of the soil series, underlying geology, geological age, and landform associated with these soil series within the project extent are presented in Table 2. The project location is in the Central Red–Bed Plains geomorphic province which consists Permian geologically aged red shales and sandstones that form gently rolling hills and broad, flat plains.

2.4 Field Investigation

Mr. James B. Nevels, Jr, PhD, PE, performed the field operations and soil sampling on May 07-08, 2018. The USDA Natural Resources Conservation Service (NRCS) Web Soil Survey 3.3 indicates that there are nine soil series (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell – in taxonomic order) that cross the CRL of SH 29 project extent. The (Zaneis, Newalla, Stephenville, and Port) soil series are found singularly in soil map units within the project extent. Predominantly the soil series found within the project extent are mapped in soil series complex map units. The mapped soil series complex units along the CRL of the SH 29 alignment in the order of occurrence beginning from the BOP are presented as follows:

- Chickasha–Huska complex, 1 to 3 percent slopes, (Ck)
- Chickasha–Zaneis soils, 1 to 8 percent slopes, severely eroded, (Et)
- Stephenville–Littleaxe, 3 to 5 percent slopes, (SbC)
- Stephenville–Littleaxe, 1 to 3 percent slopes, (SbB)
- Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes, (Rs)
- Stephenville–Newalla, 1 to 8 percent slopes, severely eroded, (Sw3)
- Stephenville–Darnell complex, 5 to 12 percent slopes, (SdE)

A soil series complex means that two or more dissimilar soil series occur in a regular repeating pattern but that these soil series cannot be mapped separately on the soil map on page 1 of the Web Soil Survey 3.3. The results of this Web Soil Survey 3.3 reported in Appendix B include the following:

- Soil survey map
- Local roads and streets and shallow excavation extended soil data

In Figures 2, 3, and 4 from the Web Soil Survey 3.3 reported in Appendix B the following information is presented:

- Project BOP and EOP locations
- Approximate (Stephenville, Littleaxe, and Pulaski) soil series sampling locations with respect to the project extent
- Area of interest (AOI)
- Soil series mapped units

The scope of work outlined in the March 19, 2018 e–mail request by, Red Rock Consulting called for sampling the (Stephenville, Littleaxe, and Pulaski) soil series. The NRCS Field Book for Describing and Sampling Soils, Version 3.0 and the NRCS OSD were used to model the (Stephenville, Littleaxe, and Pulaski) soil series profile depths and descriptions in the sampling process. The Stephenville and Littleaxe soil series were sampled from a near vertical back slope exposure, and the Pulaski was sampled with a 4⅞–inch mud hand auger. The sampling locations were within the SH 29 right of way. Sampling locations are shown in the Red Rock Consulting formatted pedological logs in Appendix F and in Figures 2, 3, and 4.

The areal mapped extents and symbols along this project extent reported in the Soil Survey of Stephens County (November 1964) are somewhat similar to those listed in the current Web Soil Survey 3.3. The soil series have been predominantly re–correlated. The (Chickasha, Port, and Stephenville) soil series are described in the Soil Survey of Stephens County (November 1964).

2.5 Soil Series Profiles

The NRCS has coupled the Soil Survey Geographic Database (SSURGO) with the Web Soil Survey 3.3 within the Google Earth program. The SSURGO database contains information about a soil series as collected by the National Cooperative Soil Survey over the course of time and is not included within the Web Soil Survey 3.3. Google Earth NRCS SSURGO allows for the presentation of block diagrams listing all of the soil series that have been historically found in a Web Soil Survey 3.3 soil map, see Appendix B. The soil maps in Google Earth NRCS SSURGO are the same as in the Web Soil Survey 3.3 soil map on page 1 in Appendix B.

The block diagrams from the NRCS SSURGO in Google Earth are inclusive and show the latest updated NRCS OSD soil profile data and percentage of each soil series within a map unit. The block diagrams for the soil series in the order of occurrence from the BOP are shown in Appendix C. As can be seen from these block diagrams, there are soil series inclusions according to the Google Earth NRCS SSURGO soil map than what is listed in the Web Soil Survey 3.3:

1. Chickasha–Huska complex, 1 to 3 percent slopes, (Ck)
2. Chickasha–Zaneis complex 1 to 8 percent slopes, severely eroded, (Et)
3. Zaneis loam, 3 to 5 percent slopes, eroded, (ZaC2)
4. Stephenville and Littleaxe soils, 3 to 5 percent slopes, (SbC)
5. Stephenville and Littleaxe soils, 1 to 3 percent slopes, occasionally flooded, (SbB)
6. Stephenville–Pulaski, frequently flooded, complex, 0 to 20 percent slopes (Rs)
7. Stephenville and Littleaxe soils, 1 to 5 percent slopes, (SbC2)
8. Newalla fine sandy loam, 3 to 20 percent slopes, (WdB)
9. Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded, (Sw3)
10. Stephenville fine sandy loam, 5 to 8 percent slopes, (SbD)
11. Stephenville–Darnell complex, 5 to 12 percent slopes, (SdE)
12. Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded, (Pf)
13. Port loam, 0 to 1 percent slopes, occasionally flooded, (Pr)

Based on the above mapped soil series within the project extent, there is the potential for the inclusion of one additional soil series according to the Google Earth NRCS SSURGO soil map. The only soil series inclusion is the Lucien soil series, see Appendix C. The percentage of occurrence of this soil series inclusion is low at 5 percent. The Lucien is a competing soil series with the Darnell soil series which means that the Lucien and Darnell soil series are in the same morphological family.

2.6 Soil Taxonomy

The soil taxonomic class for the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series recorded along the proposed SH 29 CRL are presented in Table 3, and a further taxonomic description is given in Table 4. The order of occurrence of these soil series along the project extent and their diagnostic horizons and features are presented in Table 1 and in the Soil Description in Appendix D. A Soil Taxonomy statement for the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series is presented in Appendix E.

The key features for the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series based the Taxonomic Class in Table 3, the NRCS OSD in Appendix B, Soil Description in Appendix D, and the Soil Taxonomy in Appendix E are as follows:

- The (Huska, Zaneis, Chickasha, and Port) soil series have a mollic epipedon
- The (Newalla, Zaneis, and Port) soil series have low strength
- The Newalla soil series has potential for shrink–swell
- The Huska soil series has a natric sub–horizons
- The (Newalla, Zaneis, Chickasha, and Darnell) soil series have an udic soil moisture regime (SMR)
- The Pulaski soil series has an udic–ustic soil moisture regime (SMR)
- The (Stephenville, Littleaxe, Huska, Zaneis, and Darnell) soil series have a paralithic contact
- The Port and Pulaski soil series is subject to frequent to occasional flooding

2.7 Geologic Statement

The Soil Survey of Stephens County (November 1964) does have a generalized geologic map (Figure 15) and geologic description for Stephens County, but the source of these is unspecified. The underlying geologic parent material according are the Chickasha Formation and Duncan Formation. The Chickasha Formation consists of purple–maroon, lenticular mudstone and conglomeratic sandstone and clay shale. The Formation is approximately 400–feet thick and is upper the member of the El Reno Group. Underlying the Chickasha Formation is the Duncan Formation which is the lower member of the El Reno Group. This Formation is less than 200–feet thick and consists of sandstone and clay shale. The color of the Duncan Formation is normally maroon but in spots the color is gray due to iron–reducing effects of water.

According to the Oklahoma Department of Transportation (ODOT) Engineering Classification of Geologic Materials Division Seven, 1969 (Red Book), the underlying geology for this project station extent is the El Reno Unit (Per). The El reno Unit consists of heterogenous mixture of sandstone, shale, siltstone, and siltstone conglomerate. Within the project extent the upper portion of the El reno Unit is known as the "Purple Series". Here there is 80–feet of soft purple sandstone, 50–foot of pink sandstone, and 50–foot of moderately soft purple mudstone conglomerate that is present in descending order. The total thickness of the El Reno Unit is about 420 feet in northern Stephens County.

According to the Oklahoma Geological Survey Hydrological Atlas 3, by Donald L. Hart, Jr. of the U.S. Geological Survey, 1994 Third Edition; the underlying geology for this project station extent is the Duncan Sandstone (Pd). The Duncan Sandstone generally consists of sandstone that is white to buff colored, fine– to coarse–grained, moderately indurated, interbedded with mudstone conglomerates and siltstones from 100 to 200 feet decreasing to the southeast.

The Oklahoma Geological Survey does not have a definitive current publication for this portion of Stephens County. There is some discrepancy amongst the geologic descriptions between the above listed three sources. The Division Seven, 1969 (Red Book) is considered the appropriate reference since it was taken from the 1954 Miser State Geologic Map, and the El Reno Unit is considered collectively the appropriate geology underlying the project location.

3.0 LABORATORY TESTING and TEST DATA RESULTS

3.1 Laboratory Test Procedures and Test Results

The (Stephenville, Littleaxe, and Pulaski) soil series samples obtained during the field exploration were transferred to Red Rock Consulting, LLC for laboratory processing and testing. The laboratory tests performed on the soil series samples were in agreement and applicable to AASHTO and ASTM test procedures. The laboratory testing schedule completed by the Red Rock Consulting, LLC. included the following tests: a.) determination of the natural moisture content (AASHTO T 265), b.) Atterburg limits (AASHTO T 89 and T 90), c.) grain size distribution (AASHTO T 88), d.) pH (AASHTO T 200), e.) soluble sulfate content of soils (OHDL49), f.) resistivity (ASTM G57), g.) laboratory moisture-density relations of soils (AASHTO T 99), and h.) the resilient modulus (M_R) (AASHTO T 307). The test results for the (Stephenville, Littleaxe, and Pulaski) soil series are presented in the Red Rock Consulting, Inc. formatted pedological logs and accompanying test data sheets, see Appendix F.

4.0 SHRINKAGE and SWELL FACTORS

4.1 Estimation of Shrinkage and Swell Factors

Shrinkage and swell factors for earthwork excavation are estimated from the laboratory Moisture–Density Relations of Soils, Method A (AASHTO T–99) test results for the following:

- Composite B horizon samples for the Stephenville and Littleaxe soil series
- Composite C horizon sample for the Pulaski soil series

The method used for estimating the shrinkage and swell factors for earthwork excavation is based on an ODOT in–place density chart dated January 14, 1999, see Table 5.

5.0 CONSTRUCTION CONSIDERATIONS

5.1 Soil Parameter Considerations and Compacted Fill Requirements

The soil parameters for the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series that affect compacted fill construction and the long–term performance in a compacted fill are discussed below. The NRCS drainage and permeability classes are listed in Table 6, and they are based on the frequency and duration of wet periods under conditions similar those in which the soil developed (in situ condition). The drainage class refers to the natural prevailing wetness conditions of the soil series. The drainage and permeability characteristics of these soil series when placed in a compacted fill are anticipated to have approximately the same properties as in the in–situ condition. The characteristics and ratings are taken from the following: NRCS OSD**,** Soil Taxonomy**,** and Web Soil Survey 3.3 Local Roads and Streets extended soil data, see Appendix B and E; and from the Soil Survey of Stephens County (November 1964). The Soil Survey of Stephens County (November 1964) may be found from the Web Soil Survey 3.3 homepage under Soil Surveys by State. A summary of these characteristics and ratings is presented in Table 6, and they are discussed in the following Section 5.2 Grading Assessment.

5.2 Grading Assessment

5.2 a. Site and Terrain Analysis

Regarding the suitability of the (Stephenville, Littleaxe, and Pulaski) soil series for roadway fill material; the plasticity and textural classifications for the Composite B and C horizon samples as tested at Red Rock Consulting (see, formatted pedological logs in Appendix F) were used and reported as follows:

- The Stephenville soil series Composite B sample are Sandy Lean Clay (CL)
- The Littleaxe soil series Composite B sample are Silty Sand (SM)
- The Pulaski soil series Composite C sample is a Silty Clayey Sand (SC–SM)

The plasticity and textural classifications for the Composite horizon samples for the (Newalla, Huska, Zaneis, Chickasha, Port, and Darnell) soil series as reported in the OSD and supplemented with the Soil Survey of Stephens County (November 1964) Table 17 data are interpreted as follows:

- Newalla soil series Composite B – ranges from Clayey Silt (ML) to Lean Clay (CL)
- Huska soil series Composite B – Lean Clay (CL)
- Zaneis soil series Composite B – Lean Clay (CL) to Fat Clay (CH)
- Chickasha soil series Composite B – Silty Clay (CL) to Lean Clay (CH)
- Port soil series Composite B – Silty Clay (CL)
- Darnell soil series Composite B – Sandy Clay (CL)

From a terrain analysis standpoint, the origin of the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series are respectively from the following geologic class of development: residual and alluvial; reference further detail in Table 2. The topography on site as read by eye is a 3 to 15 percent ground slope within the project extent, refer to the Slope in Table 2.

The (Stephenville, Littleaxe, and Pulaski) soil series profiles as sampled reasonably matched the NRCS OSD soil series profile depths and descriptions. The typical soil series profile and horizon depths for the (Newalla, Huska, Zaneis, Chickasha, Port, and Darnell) soil series that was not sampled are found in the NRCS OSD, in Appendix B.

Grading problems are not anticipated in the excavation, handling, and compaction of these unconsolidated residual and alluvial soil materials from the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series within the project construction extent. The construction grading will encounter the heterogenous mixture of sandstone, shale, siltstone, and siltstone conglomerate beds of the El Reno Unit based on a review of the cross–sections. Within the project extent, the cross–sections indicate that construction grading will be mixture of embankment fill, cut grading and grass–root grading. The embankment fill grading is variable with the maximum embankment fill height of approximately 35–feet.

Regarding the block diagrams in Appendix C, there is only one potential further soil series inclusion (Lucien soil series) indicated, and these are the complete soil series that are expected to be encountered within the project extent.

5.2 b. Potential Grading Issues

The potential issues for the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series in the construction grading for their performance as compacted fill performance are presented in the following discussion and summarized in Table 6 along with listed pertinent notes and definitions related to the ratings.

Soil Survey of Stephens County (November 1964)

The ratings with regard to the suitability of the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series for roadway fill presented in the Soil Survey of Stephens County (November 1964) are not listed in Table 6. The (Stephenville, Zaneis, and Chickasha) have only a subjective Good rating. The Port and Darnell soil series have a Fair to Good and a Fair to Poor subjective rating respectively. The ratings do not address any key issues and are therefore not included in Table 6.

NRCS OSD and Soil Taxonomy

From the NRCS OSD and Soil Taxonomy, the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series have the following diagnostic horizons and features that may influence construction grading are presented in Section 2.6:

- The (Huska, Zaneis, Chickasha, and Port) soil series have a mollic epipedon
- The (Newalla, Zaneis, and Port) soil series have low strength
- The Newalla soil series has potential for shrink–swell
- The Huska soil series has natric horizons
- The (Newalla, Zaneis, Chickasha, and Darnell) soil series have an udic soil moisture regime (SMR)
- The Pulaski soil series has a udic–ustic soil moisture regime (SMR)
- The (Stephenville, Littleaxe, Huska, Zaneis, and Darnell) soil series have a paralithic contact

The Port and Pulaski soil series is subject to frequent to occasional flooding from Table 6, the drainage characteristics and the permeability/saturated hydraulic conductivity rates show variations; however, all soil series when placed in a well compacted fill–section condition are anticipated to be relatively impervious. The drainage characteristics and the permeability rates for compacted fill soil materials are anticipated and expected to be comparable to the in-situ soil series characteristics and ratings presented in Table 6.

Web Soil Survey 3.3

From the Web Soil Survey 3.3 Local Roads and Streets extended soil data, the (Stephenville, Littleaxe, Huska, Chickasha, and Darnell) soil series have a not limited rating; and the (Newalla, Zaneis, Port, and Pulaski) soil series address the following key issues:

- Shrink–swell
- Low strength
- Flooding

Ratings less than (0.10) in the Web Soil Survey 3.3 Shallow Excavations extended soil data are not included in the report, being considered negligible. Specific notes regarding the rating terminology and definitions are listed for the above soil series in Table 6.

5.2 c. Assessment Summary

In summary, there appears to be no significant geo–hazards regarding the grading and use of the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series soil materials in compacted fill construction or in the long–term performance of compacted fill embankment sections constructed from borrow sources in these soil series that cannot be addressed.

The (Zaneis, Newalla, Stephenville, and Port) soil series are found in singularly mapped soil units and in soil series complexes within the project extent. The soil series complexes within the project extent are presented in Table 1 and are listed as follows:

- Chickasha–Huska complex, 1 to 3 percent slopes, (Ck)
- Chickasha–Zaneis soils, 1 to 8 percent slopes, severely eroded, (Et)
- Stephenville–Littleaxe, 3 to 5 percent slopes, (SbC)
- Stephenville–Littleaxe, 1 to 3 percent slopes, (SbB)
- Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes, (Rs)
- Stephenville–Newalla, 1 to 8 percent slopes, severely eroded, (Sw3)
- Stephenville–Darnell complex, 5 to 12 percent slopes, (SdE)

The problem with the ratings in soil series complexes is that a soil series component within the complex that has a restriction compels the rating to be applied to all remaining soil series components within the complex because there is not practical to separating the soil series in the field.

Based on a summary of the all diagnostic horizons and features in the Soil Description in Appendix D, Soil Taxonomy in Appendix E, and the ratings listed in Table 6; the following characteristics of the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series that should be considered in the construction grading are as follows:

1. The (Newalla, Huska, Zaneis, Chickasha, and Port) soil series have a potential of low strength due to the mollic epipedon depths in the surface horizons, see Table 4. The low strength can be addressed by the following:
    a) Undercutting these horizon depths at a borrow source in these soil series station extents and reserving these soil materials for use as topsoil, see Tables 1 and 4.

   b) Undercutting these horizon depths at station extents of the (Newalla, Huska, Zaneis, Chickasha, and Port) soil series that are left in–place prior to fill material placement.
   c) Avoid placement of the above listed soil horizon depths within the top two feet of the finished subgrade elevation.
2. The Newalla soil series has a severe shrink–swell potential due to the range in soil texture and plasticity. A shrink–swell potential is a grading consideration that requires the moisture control for soil material from these soil series in compacted fill placement to be placed at moisture contents wet of optimum moisture.
3. The Huska soil series has natric horizons. A natric horizon is conducive to soil dispersion and long–term erosion.
4. The (Newalla, Zaneis, Chickasha, and Darnell) soil series have a udic SMR. A udic SMR indicates a potential for wetness and/or a perched water table for a short time periods (but up to as long as 90 cumulative days) in normal years that could impact construction grading.
5. The Pulaski soil series has an udic–ustic SMR. An udic–ustic SMR has both a short–term transient and a long–term potential wetness and/or a perched water table for long time periods that could impact construction grading.
6. The Port and Pulaski subject to frequent to occasional flooding that could impact construction.

5.3 Other Factors

The (Stephenville, Littleaxe, Newalla, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series identified along this alignment are not known to have soil dispersive characteristics. The Huska soil series is a well–known dispersive soil being very susceptible to rainfall piping. Measures are necessary to protect exposed constructed earth slopes and surfaces from natural and accelerated erosion during and following construction.

All soil series are located in Area I of the Oklahoma Corrosion Stress Map indicating little or no stress with regard for potential steel pipe corrosion, see Appendix G. The resistivity values reported in the Red Rock Consulting pedological logs and accompanying test data sheets in Appendix F for the (Stephenville, Littleaxe, and Pulaski) soil series shows a range from 2020 to 5120 Ω–cm. The resistivity values indicate the following ratings with regard metal drainage pipe corrosion from Appendix G are as follows:

- Stephenville soil series – moderate corrosion potential
- Littleaxe soil series – slight to moderate corrosion potential
- Pulaski soil series – moderate corrosion potential

The soluble sulfate for the (Stephenville, Littleaxe, and Pulaski) soil series is reported to be predominately less than 200 ppm, with the maximum value of 276 ppm. Considering the relatively low soluble sulfate content values, soil stabilization and/or modification of the (Stephenville, Littleaxe, and Pulaski) soil series is not anticipated to be a significant issue with the use of calcium based chemical soil stabilizers, see Pedological Soil Logs and Test Data in Appendix F and the station extent in Table 1.

It would appear based on a review of the cross–sections from the Plans provided by the client along with the site inspection, that only a limited amount of borrow will need to be identified from an imported borrow source for the embankment fill material. It is assumed further that all incidental cut grading of the existing grade will be processed and reused on site.

5.4 Cut Section Considerations

Based on a review of the Plan Set cross–sections, there appears to be a significant amount cut section grading for SH 29 CRL project extent. The cut grading is variable ranging from side–hill cut to cut grading through the full width of the grading section. The maximum depth of cut grading is approximately 35–feet.

From the Web Soil Survey 3.3 Shallow Excavation extended soil data in Appendix B, the (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series address the following key issues:

- Dense layer
- Depth to soft bedrock
- Slope
- Too clayey
- Unstable excavation walls
- Dusty
- Flooding

Specific notes regarding the rating terminology and definitions are listed for the above soil series in Table 6. Ratings less than (0.10) in the Web Soil Survey 3.3 Shallow Excavations extended soil data are not included in the report, being considered negligible.

The (Stephenville, Littleaxe, Newalla, Huska, Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series are judged to be readily rippable. The construction grading will encounter the heterogenous mixture of sandstone, shale, siltstone, and siltstone conglomerate beds of the El Reno Unit based on a review of the cross–sections.

5.5 Groundwater Observations

During the field investigation of the (Stephenville, Littleaxe, and Pulaski) soil series, no ground water was observed at the end of sampling. The Drainage Description in the OSD in Appendix B does not report perched water tables for the (Zaneis, Chickasha, Port, Pulaski, and Darnell) soil series.

With regard to soil moisture regimes (SMR), the soil series are aligned with the following two SMR classes:

- The (Newalla, Zaneis, Chickasha, and Darnell) soil series have a udic soil moisture regime (SMR)
- The Pulaski soil series have a udic–ustic SMR

For the above listed soil series in these two SMR, there is significant likelihood of having wetness, transient perched water table, and/or long–term perched water table in one or more sub–horizons for some extensive time periods (as long as 90 cumulative days) in normal years.

A normal year is defined as a year in which the mean annual precipitation is within plus or minus one standard deviation of the long–term (30 or more years) mean annual precipitation, and monthly precipitation is within plus or minus one standard deviation of the mean monthly precipitation for 8 or more months during the year.

6.0 RECOMMENDATIONS

The recommendations for Project No. J2 – 96571(04), State Job No. 29657 (04) (West) are collective, based on the findings of the field and laboratory investigation and study at this site. The following are recommended:

1. For the (Stephenville, Littleaxe, and Pulaski) soil series, the following surface horizons of these soil series are recommended to be reserved for use as topsoil on embankment slopes and exposed soil surfaces:

    a) Stephenville series A and E horizons from the ground surface to approximate depth of 8 inches
    b) Littleaxe series A and E horizons from the ground surface to approximate depth of 16 inches
    c) Pulaski series Ap and A horizons from the ground surface to approximate depth of 19 inches

For the remaining soil series in the project extent, see the recommended topsoil depths in Table 4 and in the Soil Description in Appendix D.

2. The recommended resilient modulus (M_R) is based on a deviator stress of 6 psi for the following:
    a) Composite B horizon samples for the Stephenville and Littleaxe soil series
    b) Composite C horizon sample for the Pulaski soil series

The recommended resilient modulus at optimum and wet of optimum moisture condition for pavement design is presented in Table 7.

3. Based on the resistivity values recorded in the test data sheet for the (Stephenville, Littleaxe, and Pulaski) soil series, metal drainage pipe are not recommended due to the potential for moderate corrosion in the soil series horizons, see resistivity values reported in Appendix F. Find enclosed in Appendix G the appropriate abrasion and corrosion rating table and data.

4. The recommended minimum embankment−section slope design is a 3:1 slope ratio.

5. All grading is recommended to be compacted at a compaction moisture content between optimum moisture content and two percent wet of optimum moisture content by plan note.

6. Regarding the soil stabilization of the finished grade excavated from soil material from the (Stephenville, Littleaxe, and Pulaski) soil series station extents in Table 1 Class C Fly Ash chemical soil stabilizer is recommended.

Since a significant amount of material from an imported borrow source is most likely to be used in the construction grading, a complete soil stabilization mix design should be performed during construction of the finished subgrade in accordance with ODOT OHD L–50, Soil Stabilization Mix Design Procedure to determine the appropriate type and the optimum percentage of chemical soil stabilizer to be used.

7. Apply the appropriate mulches and native Bermuda grass to further control all erosion of the grading according subsections 230, 231, 232, 233, and 234 in the 2009 ODOT Standard Specifications for Highway Construction.

8. Since there is a potential for soil dispersion erosion from the Huska soil series from the BOP and station 592+75, a minimum of 12 inches of topsoil is recommended to cover all exposed embankment slopes, cut slopes, and exposed ground, see Table 1.

7.0 GENERAL COMMENTS

The exploration and analysis of the subsurface conditions reported herein are considered to be in sufficient detail and scope to form reasonable basis for the preliminary design of the pavement and grading sections. The recommendations submitted are based on the available soil information, laboratory testing results, local experience with soils and their taxonomy. If deviations from the noted subsurface conditions are encountered during construction, they should be brought to the attention of, Kristi Bumpas, PE, LEED AP, President of Red Rock Consulting, and I cannot be held responsible for the interpretation or implementation of this report by others. Red Rock Consulting should be retained to perform services sufficient to determine compliance with its recommendations. If Red Rock Consulting is not retained in this capacity, it will not accept any responsibility. The geotechnical engineer warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with the professional engineering practice of geotechnical engineering. No other warranties are implied or expressed. After the design plans and specifications are complete, it is recommended that the geotechnical engineer be provided the opportunity to review the final design plans and specifications so that the report recommendations have been properly interpreted and implemented. This report has been prepared for the exclusive use of SRB Engineering, Surveying, Planning for the specific application to the proposed roadway improvements project along the SH 29 in Stephens County.

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TABLES

Table 1 - Soil Series Station Extents[1]

Soil series	Symbol	Station	Station
Chickasha–Huska complex, 1 to 3 percent slopes	Ck	585+50 (BOP)	587+73
Chickasha–Zaneis soils, 1 to 8 percent slopes, severely eroded	Et	587+73	590+52
Chickasha–Huska complex, 1 to 3 percent slopes	Ck	590+52	592+75
Zaneis loam, 3 to 5 percent slopes, eroded	ZaC2	592+75	599+79
Stephenville and Littleaxe soils, 3 to 5 percent slopes	sbC	599+79	602+58
Stephenville and Littleaxe soils, 1 to 3 percent slopes	sbB	602+58	607+44
Stephenville and Littleaxe soils, 3 to 5 percent slopes	sbC	607+44	615+88
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	615+88	618+11
Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	SbC2	618+11	627+66
Newalla fine sandy loam, 1 to 5 percent slopes	WdB	627+66	633+86
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	633+86	639+17
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	639+17	644+37
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	644+37	647+11
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	647+11	648+51
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	648+51	656+83
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	656+83	662+70
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	662+70	665+16
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	665+16	673+71
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	673+71	682+03
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	682+03	683+76
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	683+76	692+14
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	692+14	697+67
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Sw3	697+67	699+85
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	699+85	715+16
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	715+16	729+41
Stephenville–Darnell complex, 5 to 12 percent slopes	SdE	729+41	740+19
Port loam, 0 to 1 percent slopes, occasionally flooded	Pf	740+19	746+95
Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Pf	746+95	758+01

Table 1 - Soil Series Station Extents[1] (Continued)

Soil series	Symbol	Station	Station
Stephenville–Darnell complex, 5 to 12 percent slopes	SdE	758+01	779+46
Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Pf	779+46	786+22
Stephenville and Littleaxe soils, 3 to 5 percent slopes	SbC	786+22	787+62
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	787+62	789+30
Stephenville–Darnell complex, 5 to 12 percent slopes	SdE	789+30	800+47
Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	SbC2	800+47	809+19
Stephenville and Littleaxe soils, 3 to 5 percent slopes	SbC	809+19	814+11
Stephenville–Pulaski, frequently flooded complex, 0 to 20 percent slopes	Rs	814+11	817+46
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	817+46	824+44
Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	SbC2	824+44	834+94
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	834+94	837+79
Stephenville–Darnell complex, 5 to 12 percent slopes	SdE	837+79	865+16
Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Pf	865+16	872+20
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	872+20	880+13
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	880+13	882+36
Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Pf	882+36	226+38
Stephenville fine sandy loam, 5 to 8 percent slopes	SbD	886+38	888+89
Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Sw3	888+89	889+00(EOP)

1. The reference for the soil series station extents is the center line of SH 29

Table 2 - General Comments on the Soil Series Investigated[1]

Soil Series	Symbol	Geology	Slope, Percent[2]
Stephenville	SbB, SbC,SbD, SdE, SbC2. Sw3, Rs	Soils formed in material weathered from sandstone of Permian geologic age. Landform is on very gently sloping to moderately steep side slopes of hills in the North Cross Timbers (MLRA 84A)[3]. The Stephenville soil series based on origin of development is a residual soil.	1 to 25
Littleaxe	SbB, SbC, SbC2	Soils formed in material weathered from weakly cemented sandstone interbedded with shale of Permian geologic age. Landform is on very sloping or gently sloping ridge crests of hills in the North Cross Timbers (MLRA 84A). The Littleaxe soil series based on origin of development is a residual soil.	1 to 5
Newalla	WdB, Sw3	Soils in the upper part formed in material weathered from sandstone and soils in the lower part have formed in material weathered from shale with both parts of Permian geologic age. The landform is on very gently sloping to steep summits and back slopes of uplands in the North Cross Timbers (MLRA 84A). The Newalla soil series based on origin of development is a residual soil.	1 to 25
Huska	Ck	Soils formed in residuum from interbedded shale and sandstone of the Permian geologic age. The landform is on crests and upper sides of low hills in the Northern Cross Timbers (MRLA 84A). The Huska soil series based on origin of development is either a residual soil.	1 to 5

Table 2 - General Comments on the Soil Series Investigated[1]

Soil Series	Symbol	Geology	Slope, Percent[2]
Zaneis	Et, ZaC2	Soils formed in material weathered from interbedded shale and sandstone of Permian geologic age. Landform is on crests and side slopes of low hills in the Northern Cross Timbers (MRLA 84A). The Yahola soil series based on origin of development is a residual soil.	0 to 8
Chickasha	Ck, Et	Soils formed in material weathered from sandstone of Permian geologic age. Landform is on nearly level to sloping broad ridgetops and side slopes of convex hills in the North Cross Timbers (MLRA 84A). The Chickasha soil series based on origin of development is a residual soil	0 to 8
Port	Pr, Pf	Soils formed in calcareous loamy alluvium of Recent geologic age. Landform is on flood plains in the North Cross Timbers (MLRA 84A). The Port soil series based on origin of development is an alluvial soil.	0 to 3
Pulaski	Rs	Soils formed in loamy alluvial sediments of Holocene geologic age. Landform is on nearly level to very gently sloping flood plains of small tributaries in the North Cross Timbers (MLRA 84A). The Pulaski soil series based on origin of development is an alluvial soil.	0 to 3
Darnell	SdE	Soils formed in material weathered from sandstone of Permian geologic age. Landform is on summits and shoulders of low hills in the North Cross Timbers (MLRA 84A). The Darnell soil series based on origin of development is a residual soil.	5 to 12

Notes:

1. General reference: USDA Soil Survey Manual, United States Department of Agriculture Handbook No 18, Issued March 2017
2. Slopes as recorded from the OSD data
3. MLRA – Major land resource area

Table 3 - Soil Series Taxonomic Class and Comments

Soil Series	Symbol	Taxonomic Class
Stephenville	SbB, SbC, SbD, SdE, SbC2, Sw3, Rs	Fine–loamy, siliceous, active[1], thermic Udic Haplustalfs
Littleaxe	SbB,SbC, SbC2	Fine–loamy, siliceous, active, thermic Ultic Haplustalfs
Newalla	WdB, Sw3	Fine–loamy over clayey, siliceous, superactive[2], thermic Udic Haplustalfs
Huska	Ck	Fine, mixed, superactive, thermic Mollic Natrustalfs
Zaneis	Et, ZaC2	Fine–loamy, siliceous, active, thermic Udic Argiustolls
Chickasha	Ck, Et	Fine–loamy, mixed, active, thermic Udic Argiustolls
Port	Pr, Pf	Fine–silty, mixed, superactive, thermic Cumulic Haplustolls
Pulaski	Rs	Coarse–loamy, mixed, superactive, nonacid[3], thermic Udic Ustifluventic
Darnell	SdE	Loamy, siliceous, active, thermic, shallow Udic Haplustepts

1. Active refers to a cation exchange activity class of the < 2mm fraction material in the control section equal to the range of 0.40 to 0.60
.
2. Superactive refers to a cation exchange activity class of the < 2mm fraction material in the control section equal to 0.60 or more
3. Nonacid refers to a reaction class where the pH is less than 5.0

Table 4 - Soil Taxonomy[1]

Soil Series	Symbol	Order	Suborder	Great Group	Subgroup Modifier	Particle Size	Mineralogy	Soil Temperature	Horizon / Mollic Epipedon Depth, inches
Stephenville	SbB, SBC, SbD, SdE, SbC2, Sw3, Rs	Alfisols	Ustalfs	Haplustalfs	Ultic	Fine–loamy	Siliceous	Thermic	A and E Horizons – 8
Littleaxe	SbB, SbC, SbC2	"	"	"	"	"	"	"	A and E Horizon – 15
Newalla	WdB, Sw3	"	"	"	Udic	Fine–loamy over Clayey	"	"	A and E Horizon – 6
Huska	Ck	"	"	Natrustalfs	Mollic	Fine	Mixed	"	A Horizon – 9
Zaneis	Et, ZaC2	Mollisols	Ustolls	Argiustolls	Udic	Fine–loamy	Siliceous	Thermic	Ap and A Horizon – 12
Chickasha	Ck, Et	"	"	"	"	"	Mixed		A Horizon – 12
Port	Pr, Pf	"	"	"	Cumulic	Fine–silty	"	"	Ap and A Horizon – 27

Table 4 - Soil Taxonomy[1]

Soil Series	Symbol	Order	Suborder	Great Group	Subgroup Modifier	Particle Size	Mineralogy	Soil Temperature	Horizon / Mollic Epipedon Depth, inches
Puaski	Rs	Entisols	Fluvents	Ustifluvents	Udic	Coarse–loamy	“	“	Ap and A Horizon – 19
Darnell	SdE	Inceptisols	Ustepts	Haplustepts	“	Loamy	Siliceous	“	A Horizon – 5

1. Reference is the Keys to Soil Taxonomy, 12th Edition, 2014

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Table 5 - Shrinkage/Swell Factors for Earthwork Excavation

Soil Series	Horizon	Depth (in)	Soil Classification (USCS)[4]	Compacted Density (Pcf) (δ_d)	OMC[5] (%)	ODOT In–Place Chart Density (Pcf) (δ_w)	Shrinkage/ Swell Factor[1]	% Shrinkage/ Swell[2,3]
Stephenville	Composite B	8–24	CL	115.8	12.4	124	0.9972	0.28 (Swell)
Littleaxe	Composite B	16–67	SM	108.3	12.8	122	0.9513	4.87 (Swell)
Pulaski	Composite C	19–65	SC-SM	119.9	11.8	119	1.0701	7.01 (Shrinkage)

1. Shrinkage/Swell Factor = 0.95 δ_d (1 + OMC) / δ_w
2. Shrinkage/Swell Factor: Swell < 1.0, Shrinkage > 1.0
3. % Shrinkage / Swell = [1.0000 +/- Factor] 100
4. For a dual soil classification, use average value of each soil classification
5. OMC – optimum moisture content in percent

Table 6 - Characteristics and Ratings Regarding the Suitability for Roadway Fill

Soil Series	Symbol	OSD		Web Soil Survey 3.3 Local Roads and Streets / Shallow Excavations
		Drainage	Permeability/ (Saturated hydraulic conductivity), in/hr	
Stephenville	SbB, SbC, SbD, SdE, SbC2, Sw3, Rs	Well drained[1]	Moderately high –0.1417 to less than 1.417	Not limited[4] / Somewhat limited – Dense layer[5] (0.50), Depth to soft bedrock[6] (0.29), Slope[7] (0.16)
Littleaxe	SbB, SbC,SbC2	Well drained	Moderate – 0.6 to less than 2.0	Not limited / Somewhat limited – Dense layer (0.50)
Newalla	WdB, Sw3	Moderately well drained[2]	Very slow –0.0015 to less than 0.06	Very limited – Shrink–swell[8] (1.00), Low strength[9] (1.00) / Somewhat limited – Too clayey[10] (0.97), Unstable excavation walls[11] (0.78), Dusty[12] (0.10)
Huska	Ck	Moderately well drained	Slow – 0.06 to less than 0.2	Not limited / Somewhat limited – Dense layer (0.50), Dusty (0.20)

Table 6 - Characteristics and Ratings Regarding the Suitability for Roadway Fill

Soil Series	Symbol	OSD		Web Soil Survey 3.3 Local Roads and Streets / Shallow Excavations
		Drainage	Permeability/ (Saturated hydraulic conductivity), in/hr	
Zaneis	Et, ZaC2	Well drained	Moderate – 0.6 to less than 2.0	Very limited – Low strength / Somewhat limited – Dense layer (0.50), Dusty (0.20)
Chickasha	Ck, Et	Well drained	Moderate – 0.6 to less than 2.0	Not limited / Somewhat limited – Unstable excavation walls (0.51), Dense layer (0.50), Too clayey (0.28), Dusty (0.28)
Port	Pr, Pf	Well drained	Moderate – 0.6 to less than 2.0	Very limited – Flooding[13] (1.00), low strength (1.00) / Somewhat limited – Flooding (0.60), Dusty (0.23)
Pulaski	Rs	Well drained	Moderately rapid – 2.0 to less than 6.0	Somewhat limited – Slope (0.16) / Somewhat limited – Flooding
Darnell	SdE	Well drained or Somewhat Excessively drained[3]	Medium to rapid – 0.6 to less than 20	Not limited / Not Rated

Notes:

1. Well drained means water is removed from the soil readily but not rapidly
2. Moderately well drained means water is removed from the soil somewhat slowly during some periods of the year
3. Somewhat excessively drained means water is removed from the soil rapidly
4. Not limited means that there are no grading restrictions indicated in the diagnostic horizons and features
5. Dense layer refers to a very firm, massive layer that has a bulk density of more than 112.3 psf
6. Depth to soft bedrock means that the bedrock is shallow in close proximity to the ground surface, the unconsolidated soil materials are limited quantity for intended use, and soft bedrock is not difficult to excavate
7. Slope refers potential erosion problems and/or shallow slope stability in earth slopes
8. Shrink–swell potential refers to the shrinking of the soil when dry due to drought or localized drying; and the swelling when becoming wet due to accumulated moisture intake over time or from extreme continued rainfall periods
9. Low strength implies subgrade instability when exposed to moisture during construction or subgrade instability due to increase in moisture with time below the paved surface
10. Too clayey refers to high plasticity soils
11. Unstable excavation walls indicate potential instability and slope wall stability in cut section extents
12. Dusty is a general term in soil interpretation to describe a soil particle–size group of soil materials which readily become airborne. In most cases it is fine silts and clays that become airborne
13. Flooding is recorded in the OSD respectively as: a.) Port soil series: occasional or frequent for brief periods during March to October; b.) Pulaski soil series occasional to frequent for brief periods during March to October

Table 7 - Recommended M_R for Pavement Design[1]

Soil Series	Horizon	Model Equation	M_R at 6 psi
Stephenville	Composite B – OMC	$M_r = 10457\ S_d^{-0.09}$	8,900
Stephenville	Composite B– OMC +2%	$M_r = 4856\ S_d^{-0.04}$	4,520
Littleaxe	Composite B – OMC	$M_r = 10156\ S_d^{-0.06}$	9,121
Littleaxe	Composite B– OMC +2%	$M_r = 4933\ S_d^{0.11}$	6,008
Pulaski	Composite C – OMC	$M_r = 11761\ S_d^{-0.06}$	10,562
Pulaski	Composite C– OMC +2%	$M_r = 8569\ S_d^{-0.17}$	6,319

1. $M_R = K1\ (Sd)^{K2}$ model used; where `S_d = 6 psi was used in the model equations

APPENDIX A

General Site Maps

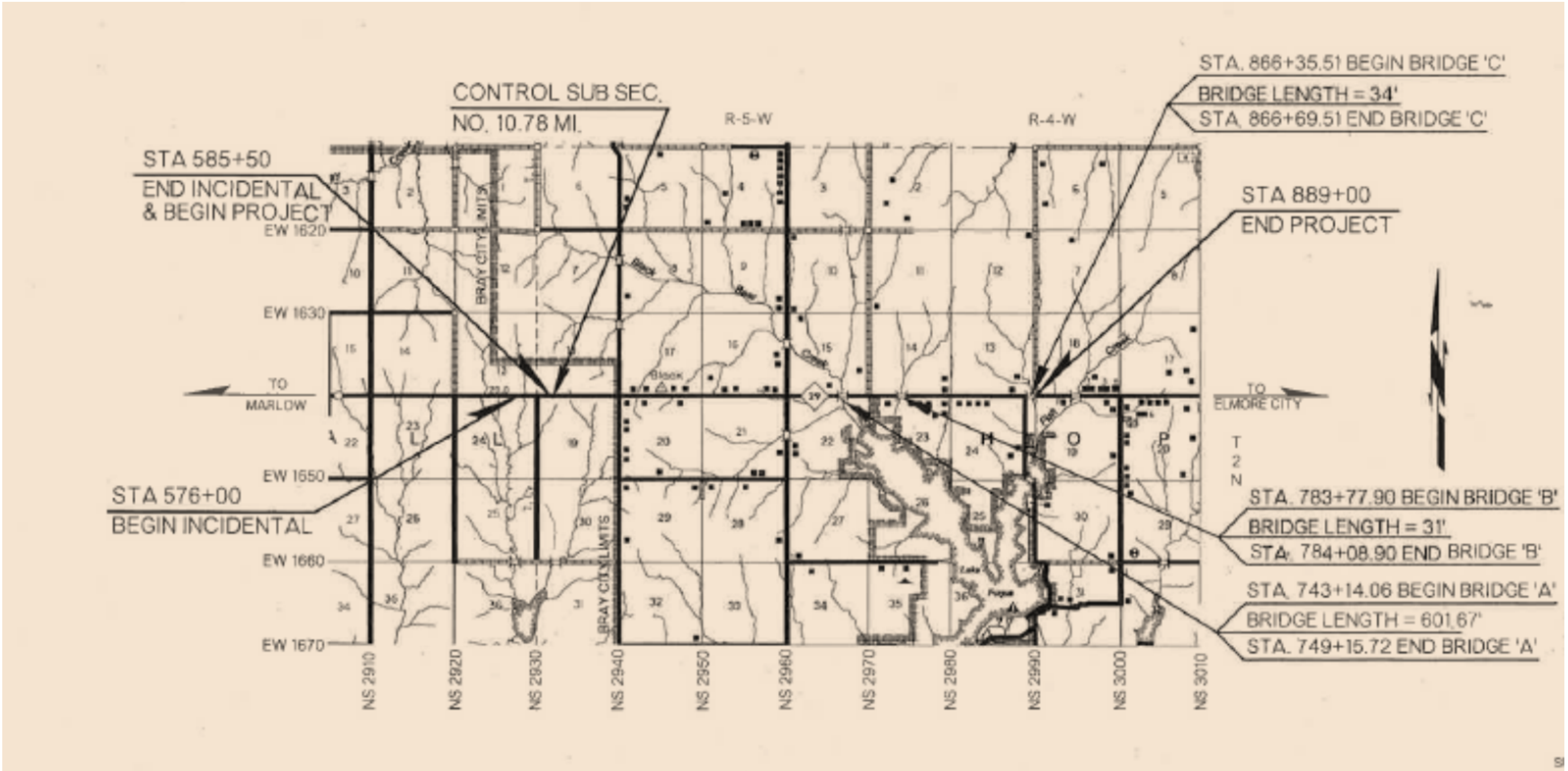


Figure 1. General location of Project J2– 96571(04), State Job No. 29657(04) in Stephens County

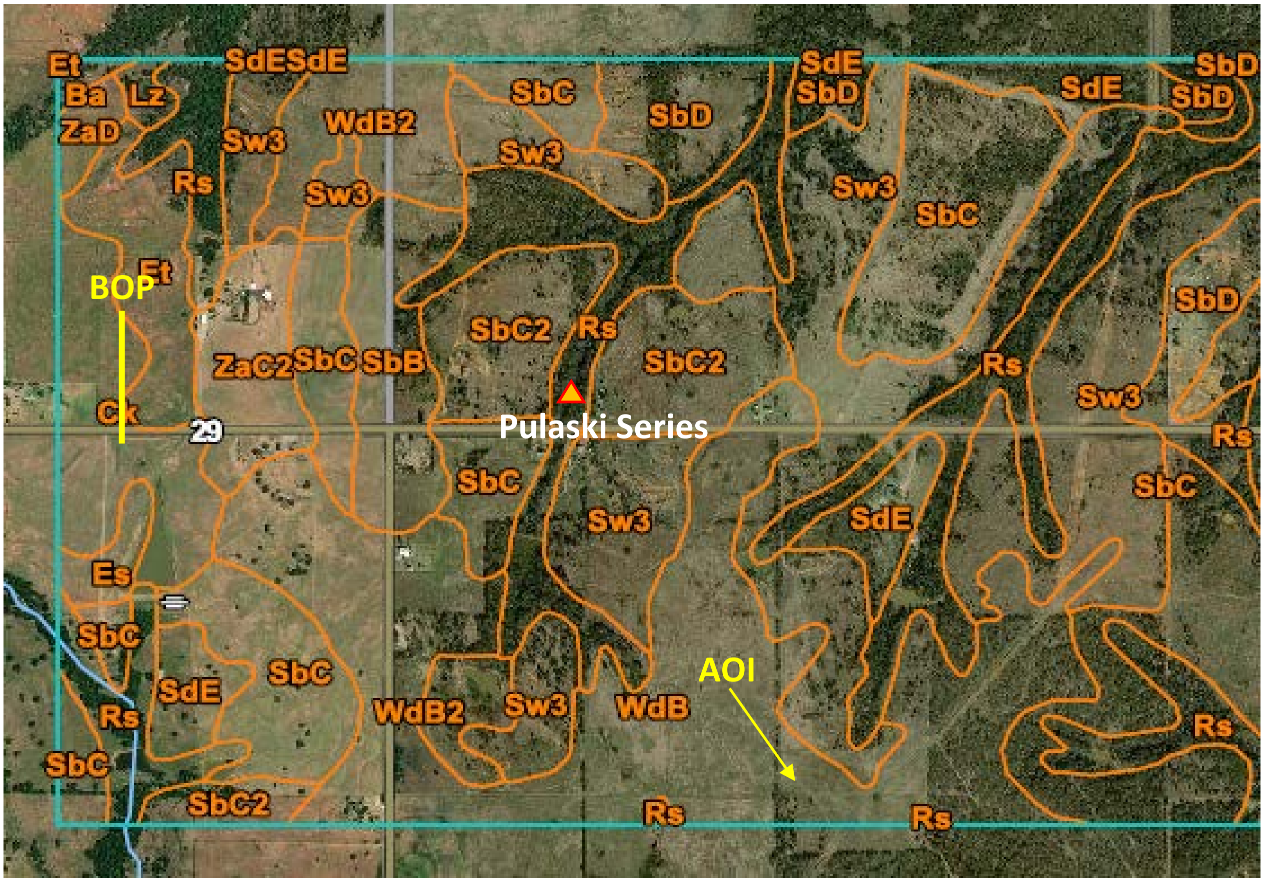


Figure 2. Enlarged soil map indicating the SH 29 BOP, soil map units, Pulaski soil series sampling location, Area of Interest (AOI) on the soil map on page 2 in Appendix B

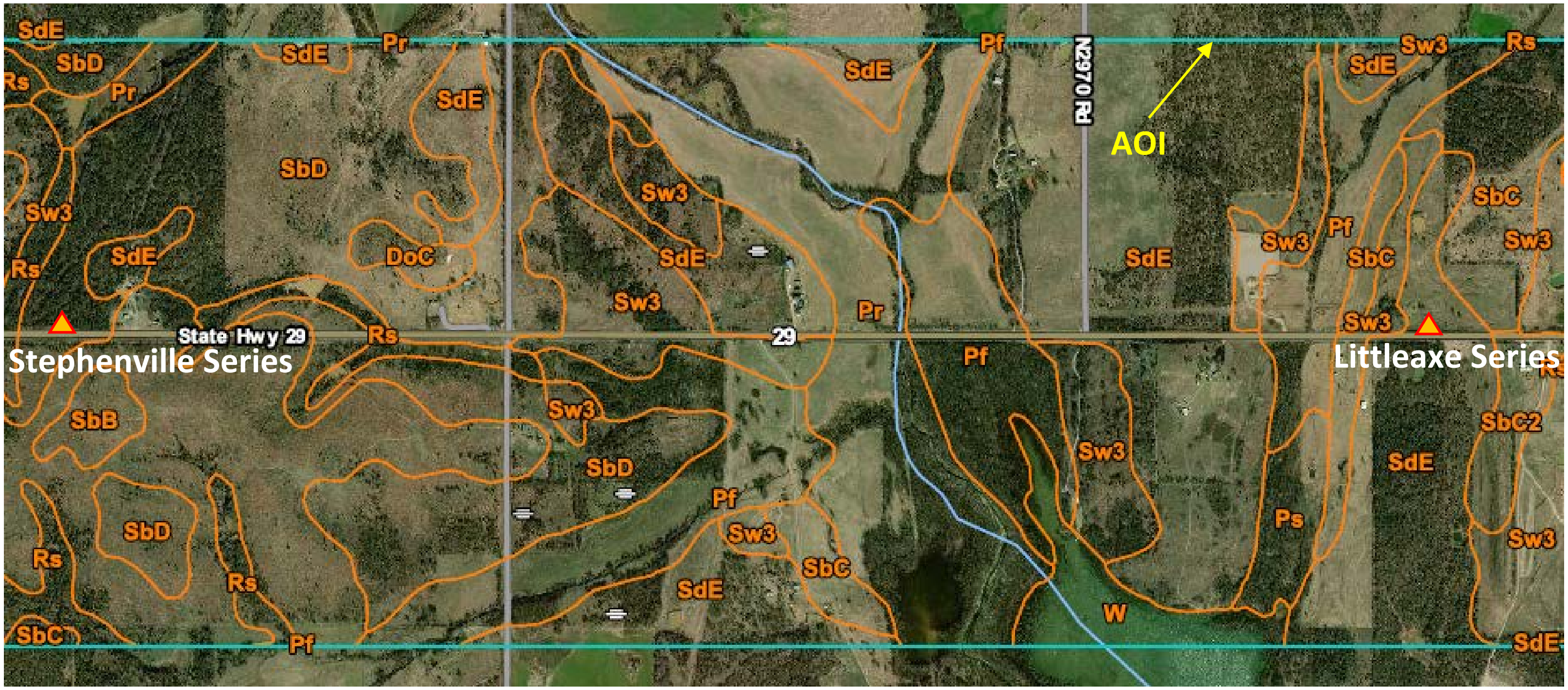


Figure 3. Enlarged soil map indicating the SH 29 soil map units, Stephenville and Littleaxe soil series sampling locations, Area of Interest (AOI) on the soil map on page 3 in Appendix B

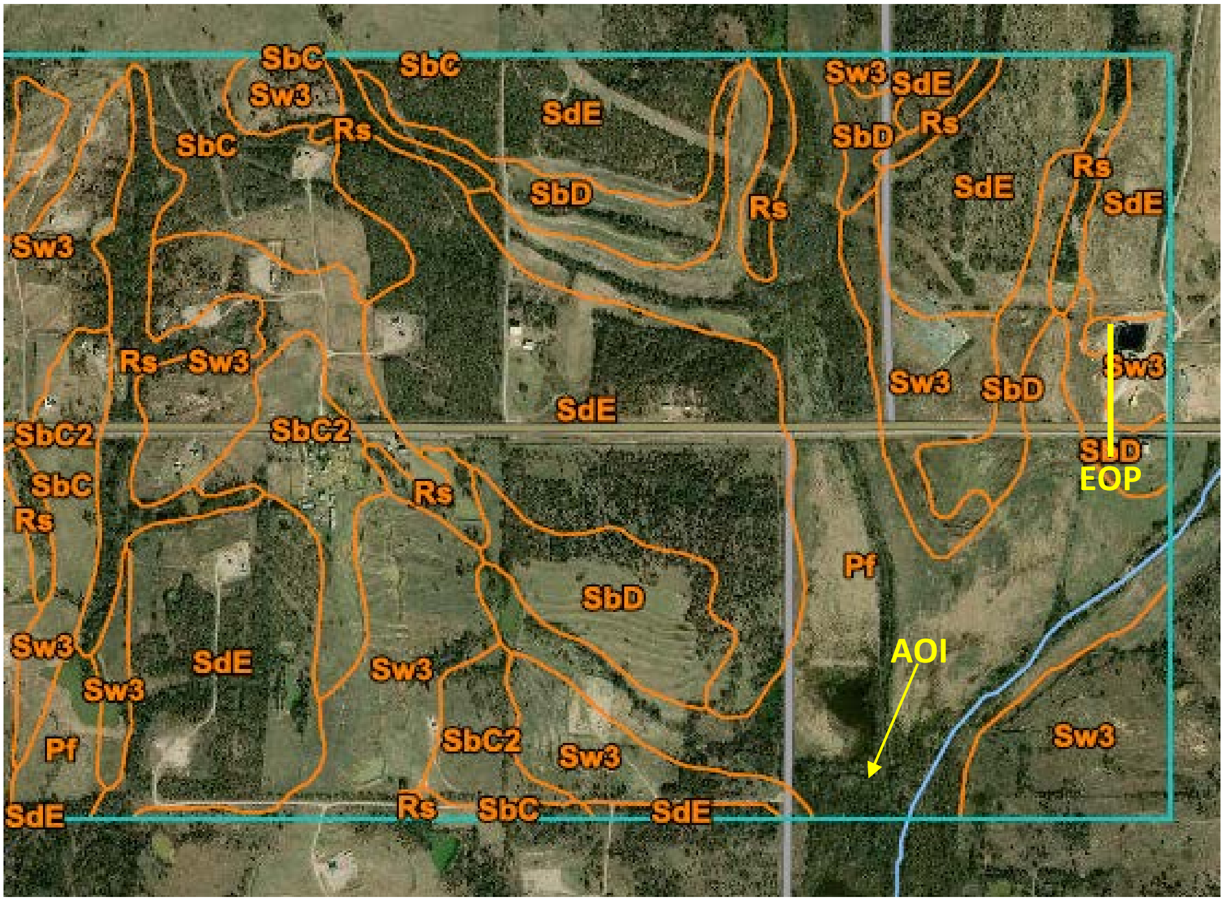
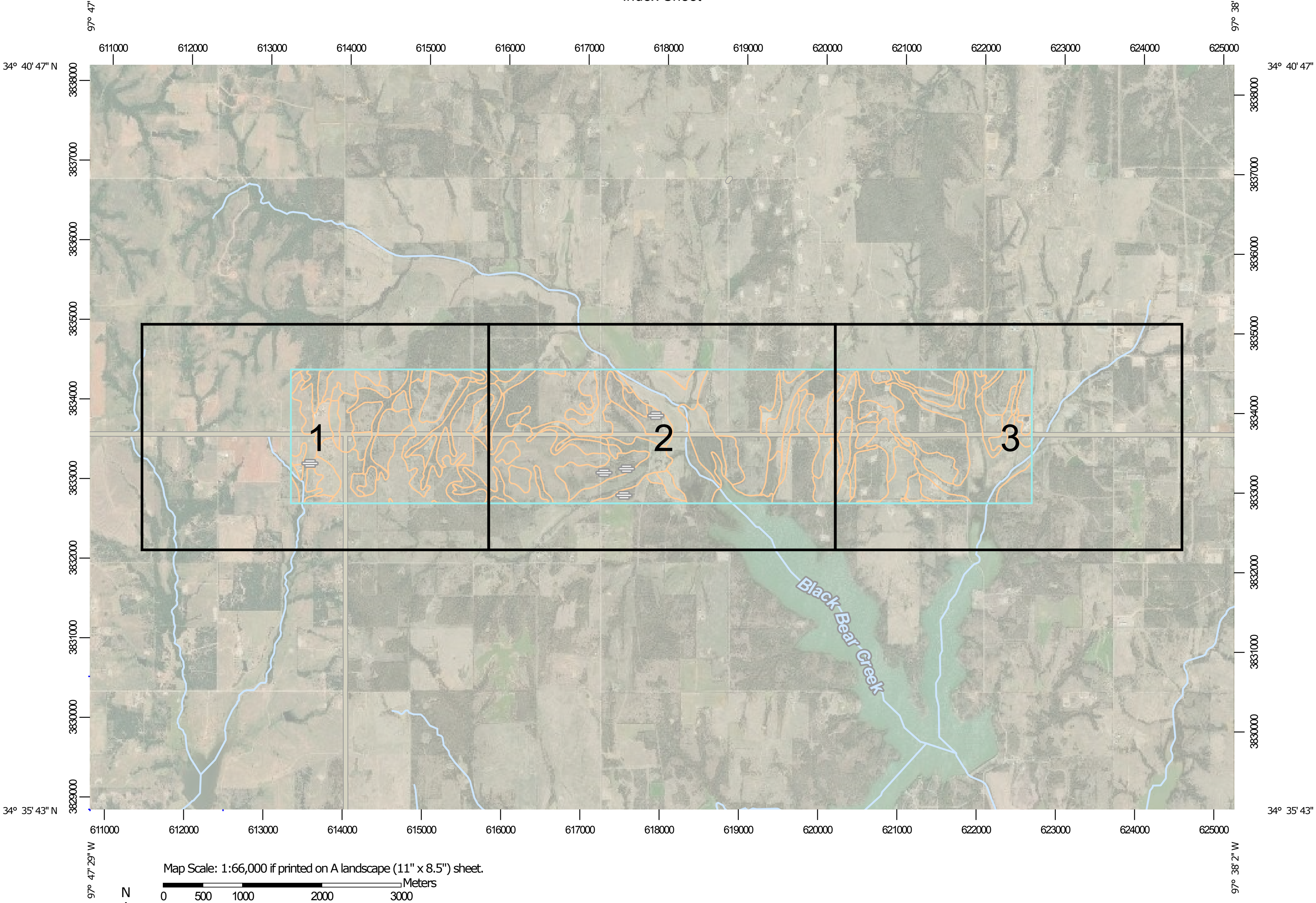


Figure 4. Enlarged soil map indicating the SH 29 soil map units, Area of Interest (AOI), and EOP on the soil map on page 4 in Appendix B

APPENDIX B

Web Soil Survey 3.3



Map Scale: 1:66,000 if printed on A landscape (11" x 8.5") sheet.

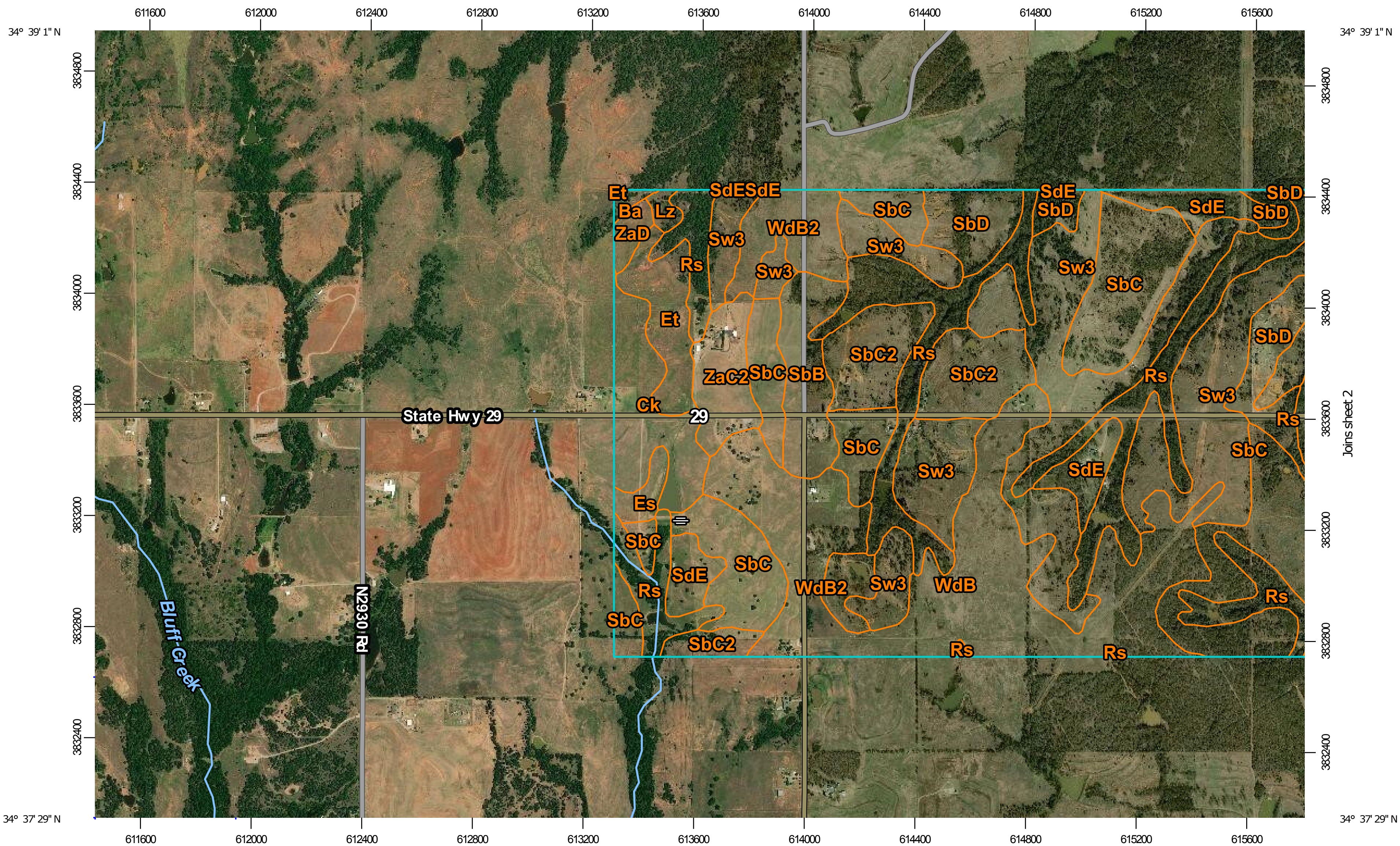
N

Meters: 0 500 1000 2000 3000

Feet: 0 3000 6000 12000 18000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

Soil Map—Stephens County, Oklahoma
Map sheet 1 of 3



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 250, 500, 1000, 1500

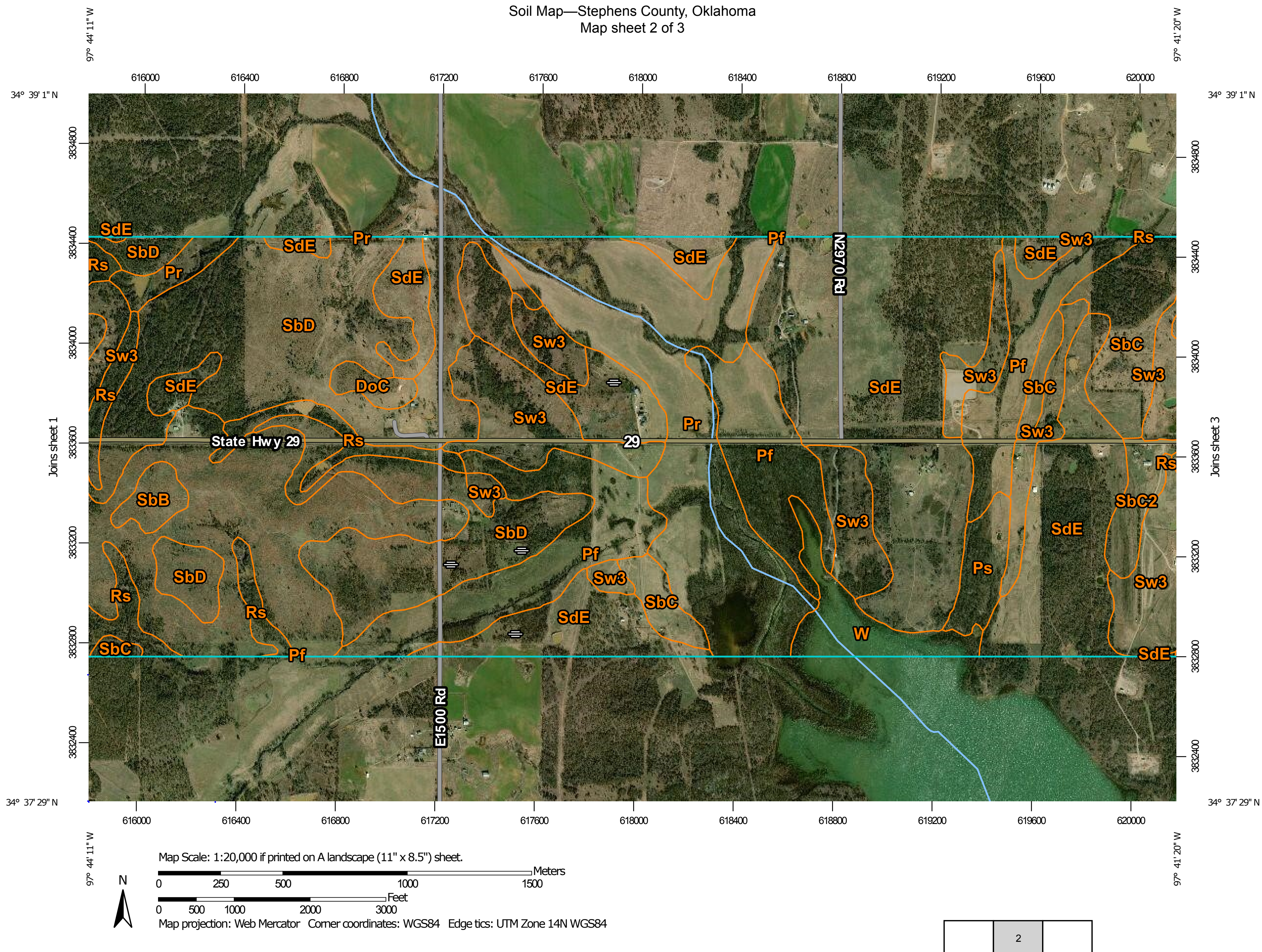
Feet: 0, 500, 1000, 2000, 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

1

Map Sheet Location

Soil Map—Stephens County, Oklahoma
Map sheet 2 of 3



Soil Map—Stephens County, Oklahoma
Map sheet 3 of 3

97° 41' 20" W

97° 38' 28" W

34° 39' 1" N

620300 620700 621100 621500 621900 622300 622700 623100 623500 623900 624300

3834700 3834300 3833900 3833500 3833100 3832700 3832300

3835100 3834700 3834300 3833900 3833500 3833100 3832700 3832300

Joins sheet 2

34° 37' 29" N

620300 620700 621100 621500 621900 622300 622700 623100 623500 623900 624300

97° 41' 20" W

97° 38' 28" W

Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 250 500 1000 1500

Feet: 0 500 1000 2000 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

		3

Map Sheet Location

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Stephens County, Oklahoma
Survey Area Data: Version 12, Sep 21, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

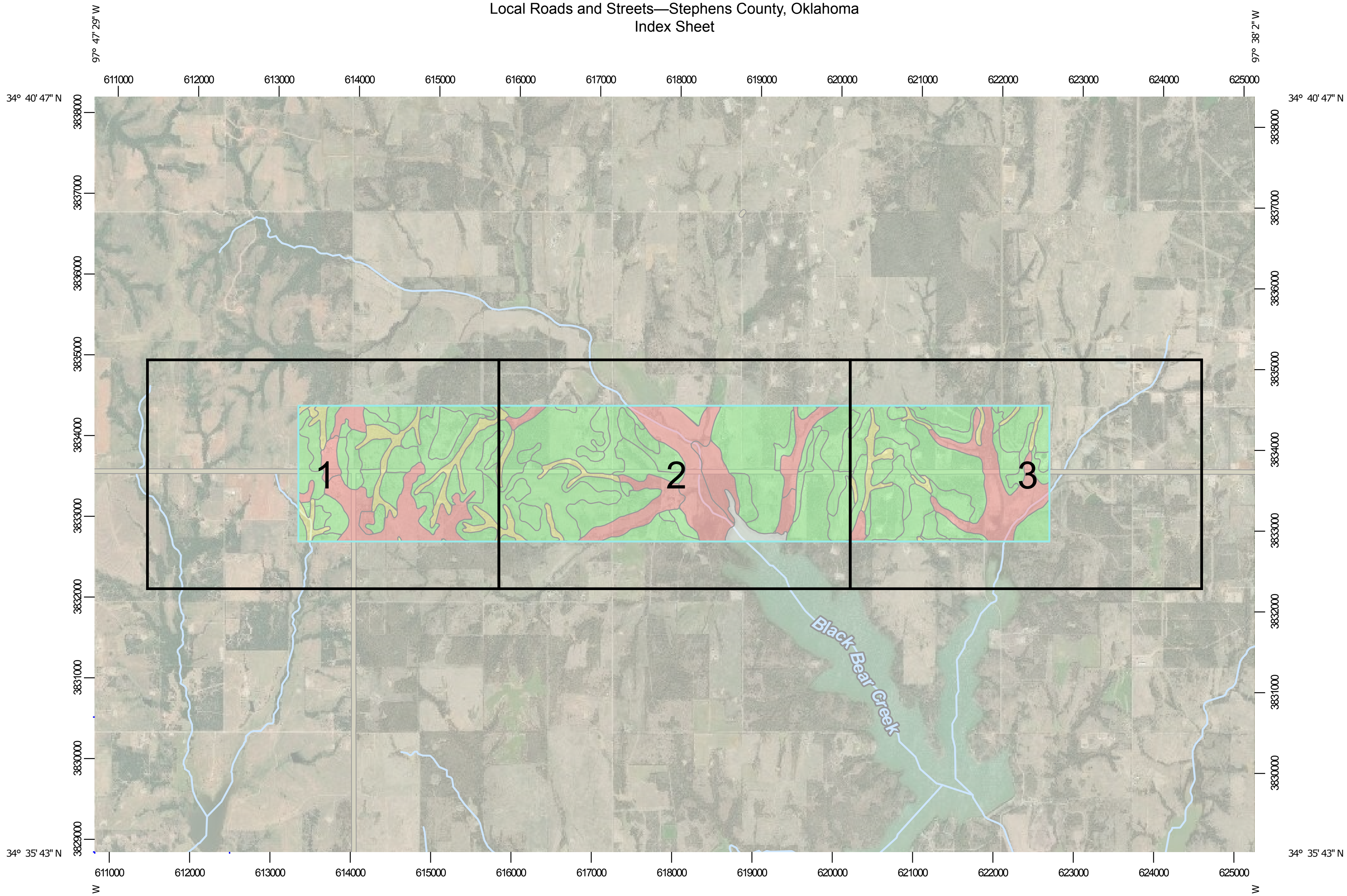
Date(s) aerial images were photographed: Dec 13, 2015—Mar 6, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

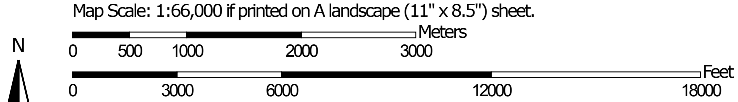
Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ba	Zaneis-Ashport frequently flooded complex, 0 to 12 percent slopes	2.0	0.1%
Ck	Chickasha-Huska complex, 1 to 3 percent slopes	37.8	1.0%
DoC	Dougherty and Konawa soils, 3 to 8 percent slopes	9.6	0.2%
Es	Renfrow and Pawhuska soils, 1 to 5 percent slopes, severely eroded	6.8	0.2%
Et	Chickasha and Zaneis soils, 1 to 8 percent slopes, severely eroded	25.3	0.6%
Lz	Zaneis-Grainola-Lucien complex, 5 to 12 percent slopes	3.2	0.1%
Pf	Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	412.5	10.6%
Pr	Port loam, 0 to 1 percent slopes, occasionally flooded	209.7	5.4%
Ps	Port-Oscar complex, 0 to 1 percent slopes, occasionally flooded	21.4	0.5%
Rs	Stephenville-Pulaski, frequently flooded, complex, 0 to 20 percent slopes	266.2	6.8%
SbB	Stephenville and Littleaxe soils, 1 to 3 percent slopes	43.8	1.1%
SbC	Stephenville and Littleaxe soils, 3 to 5 percent slopes	490.9	12.6%
SbC2	Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	125.0	3.2%
SbD	Stephenville fine sandy loam, 5 to 8 percent slopes	476.2	12.2%
SdE	Stephenville-Darnell complex, 5 to 12 percent slopes	833.7	21.4%
Sw3	Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	657.3	16.9%
W	Water	35.1	0.9%
WdB	Newalla fine sandy loam, 1 to 5 percent slopes	176.5	4.5%
WdB2	Newalla fine sandy loam, 1 to 5 percent slopes, eroded	36.2	0.9%

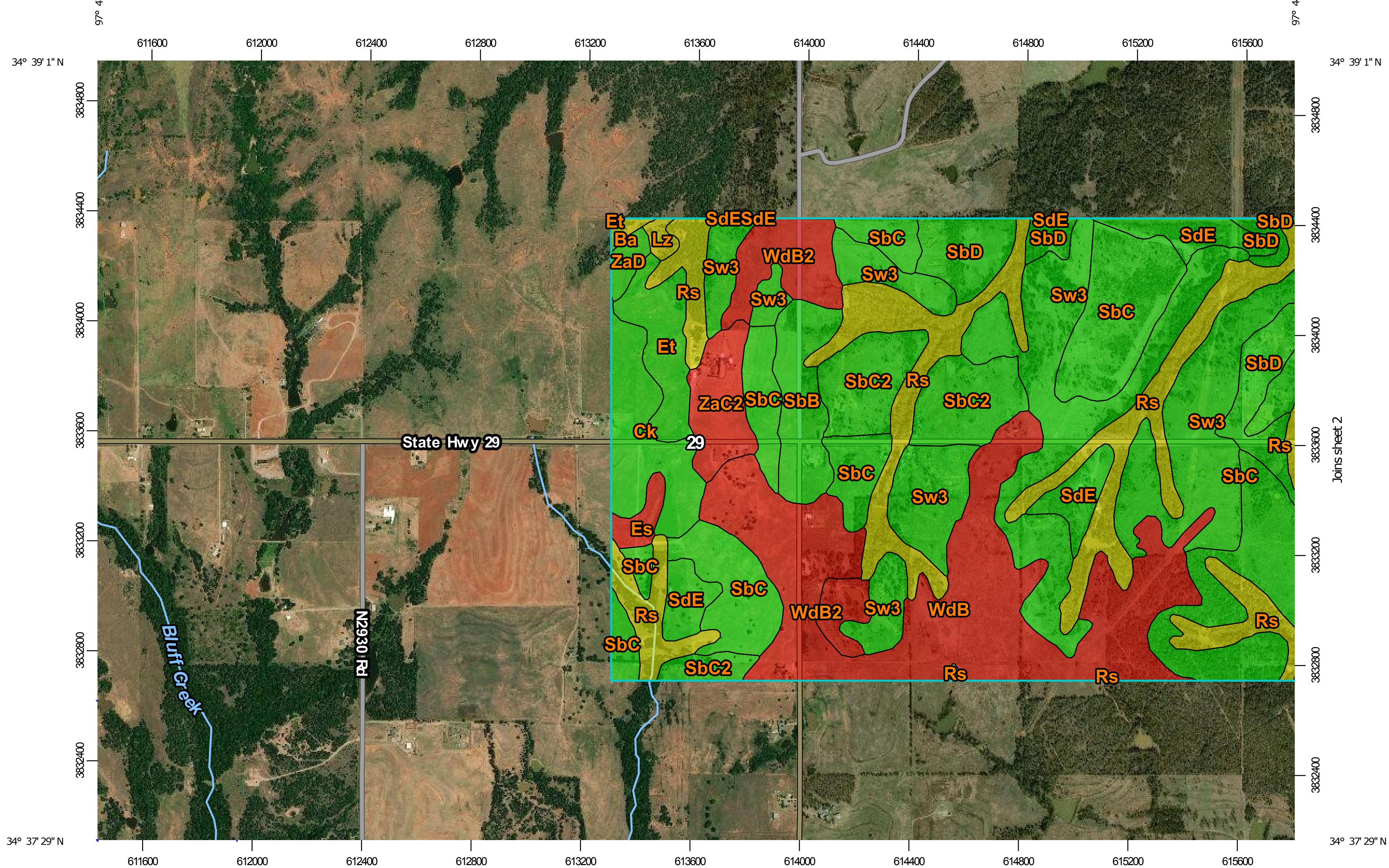
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
ZaC2	Zaneis loam, 3 to 5 percent slopes, eroded	23.9	0.6%
ZaD	Zaneis loam, 5 to 8 percent slopes	5.5	0.1%
Totals for Area of Interest		**3,898.4**	**100.0%**



Map Scale: 1:66,000 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

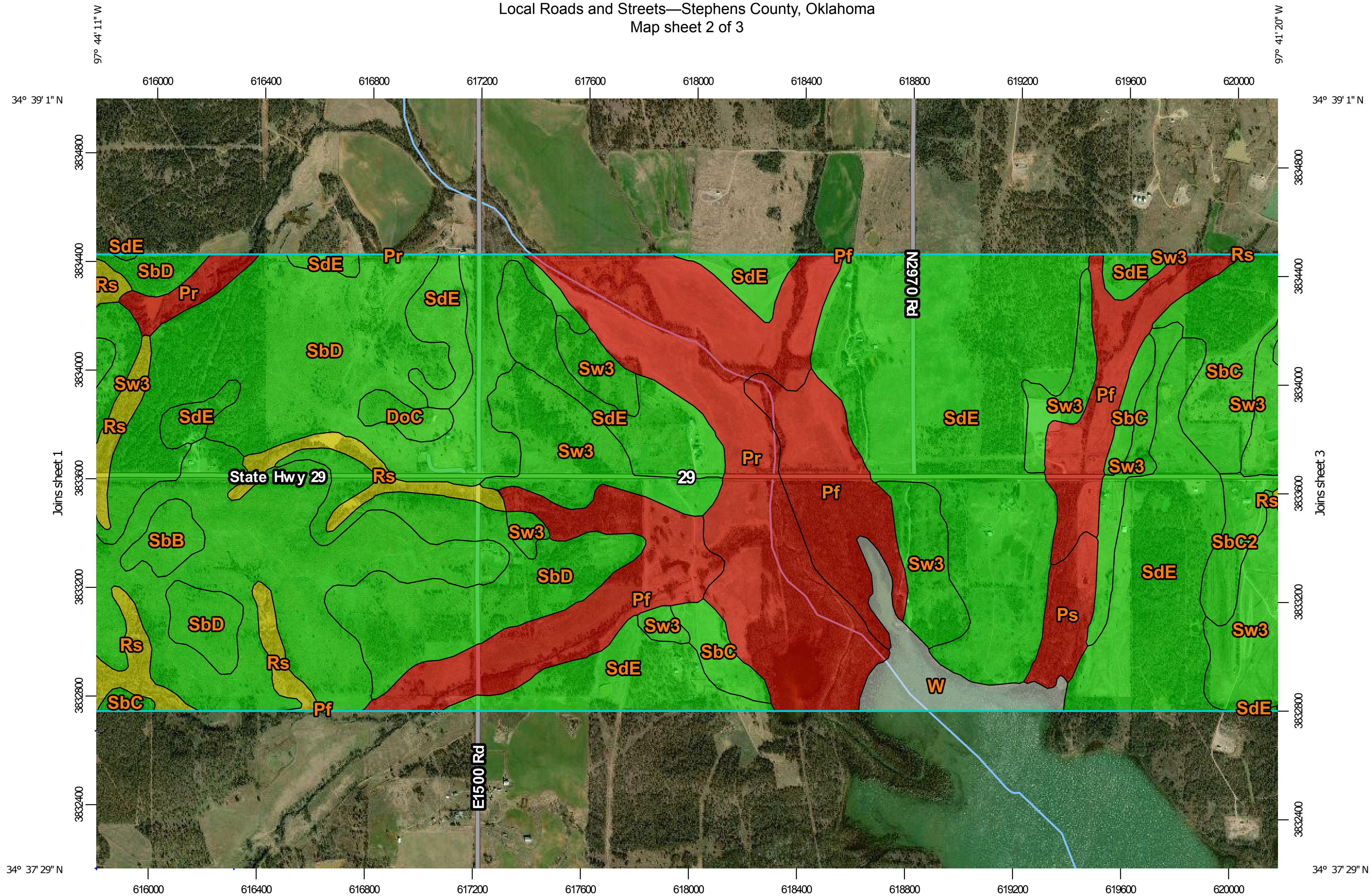
N

Meters: 0, 250, 500, 1000, 1500

Feet: 0, 500, 1000, 2000, 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

Map Sheet Location: 1



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 250, 500, 1000, 1500

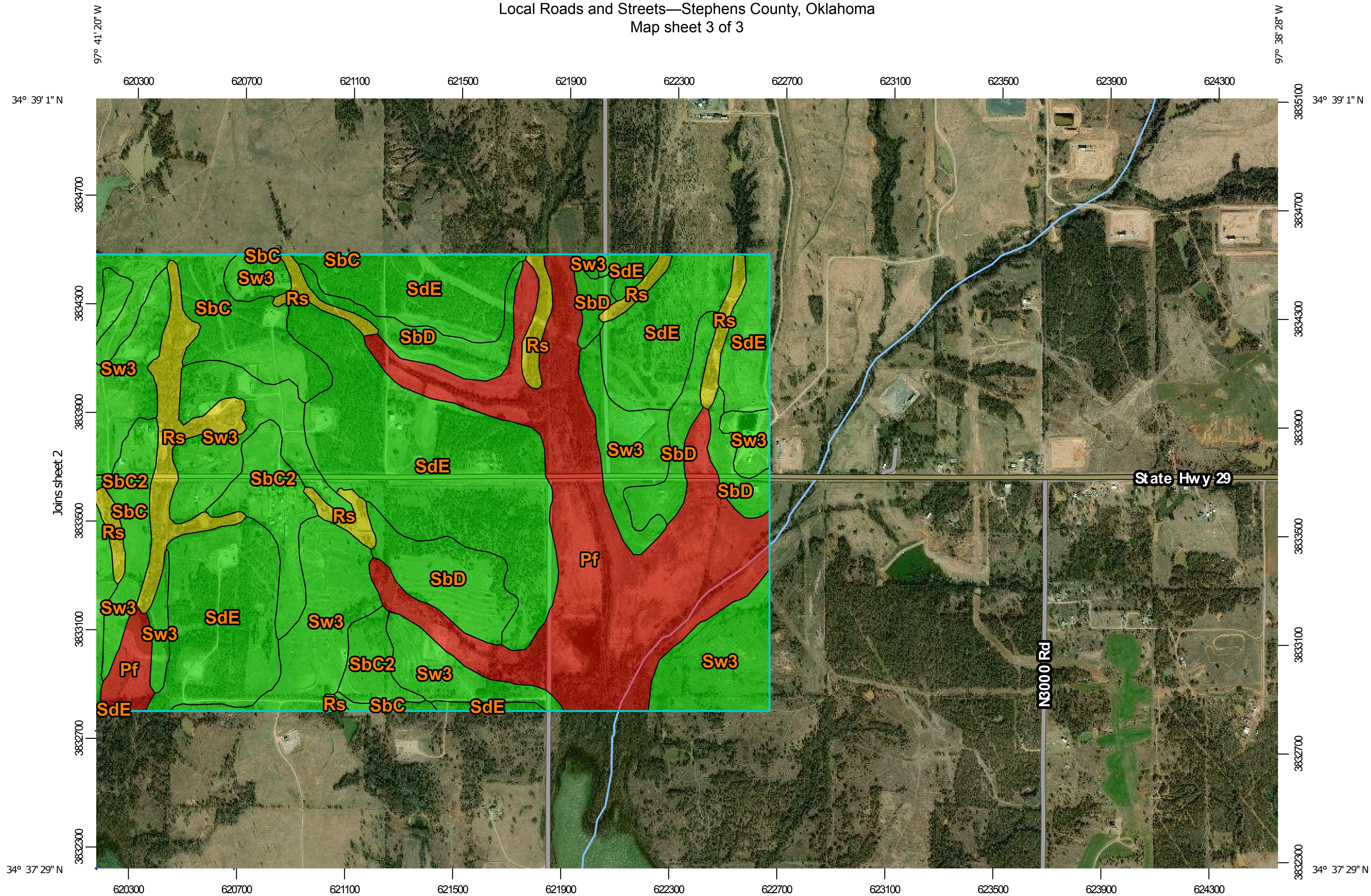
Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

Map Sheet Location: 2

Local Roads and Streets—Stephens County, Oklahoma
Map sheet 3 of 3



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0 250 500 1000 1500

Feet: 0 500 1000 2000 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

Map Sheet Location: 3

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Lines

Very limited

Somewhat limited

Not limited

Not rated or not available

Soil Rating Points

Very limited

Somewhat limited

Not limited

Not rated or not available

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Stephens County, Oklahoma
Survey Area Data: Version 12, Sep 21, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 13, 2015—Mar 6, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Local Roads and Streets

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Ba	Zaneis-Ashport frequently flooded complex, 0 to 12 percent slopes	Somewhat limited	Zaneis (80%)	Slope (0.04)	2.0	0.1%
				Shrink-swell (0.04)		
Ck	Chickasha-Huska complex, 1 to 3 percent slopes	Not limited	Chickasha (60%)		37.8	1.0%
DoC	Dougherty and Konawa soils, 3 to 8 percent slopes	Not limited	Dougherty (50%)		9.6	0.2%
			Konawa (35%)			
			Derby (5%)			
			Eufaula (5%)			
Es	Renfrow and Pawhuska soils, 1 to 5 percent slopes, severely eroded	Very limited	Renfrow, severely eroded (65%)	Shrink-swell (1.00)	6.8	0.2%
				Low strength (1.00)		
			Pawhuska, severely eroded (30%)	Shrink-swell (1.00)		
				Low strength (1.00)		
Et	Chickasha and Zaneis soils, 1 to 8 percent slopes, severely eroded	Not limited	Chickasha, severely eroded (55%)		25.3	0.6%
Lz	Zaneis-Grainola-Lucien complex, 5 to 12 percent slopes	Somewhat limited	Zaneis (60%)	Shrink-swell (0.04)	3.2	0.1%
			Lucien (20%)	Depth to soft bedrock (1.00)		
				Slope (0.16)		
Pf	Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Very limited	Port, occasionally flooded (93%)	Flooding (1.00)	412.5	10.6%
				Low strength (1.00)		
Pr	Port loam, 0 to 1 percent slopes, occasionally flooded	Very limited	Port, occasionally flooded (95%)	Flooding (1.00)	209.7	5.4%
				Low strength (1.00)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Ps	Port-Oscar complex, 0 to 1 percent slopes, occasionally flooded	Very limited	Port, occasionally flooded (68%)	Flooding (1.00)	21.4	0.5%
				Low strength (1.00)		
				Shrink-swell (0.53)		
			Oscar, occasionally flooded (25%)	Flooding (1.00)		
				Low strength (1.00)		
				Shrink-swell (0.19)		
Rs	Stephenville-Pulaski, frequently flooded, complex, 0 to 20 percent slopes	Somewhat limited	Stephenville (70%)	Slope (0.16)	266.2	6.8%
SbB	Stephenville and Littleaxe soils, 1 to 3 percent slopes	Not limited	Stephenville (45%)		43.8	1.1%
			Littleaxe (40%)			
SbC	Stephenville and Littleaxe soils, 3 to 5 percent slopes	Not limited	Stephenville (55%)		490.9	12.6%
			Littleaxe (40%)			
SbC2	Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	Not limited	Stephenville, eroded (55%)		125.0	3.2%
			Littleaxe, eroded (45%)			
SbD	Stephenville fine sandy loam, 5 to 8 percent slopes	Not limited	Stephenville (90%)		476.2	12.2%
SdE	Stephenville-Darnell complex, 5 to 12 percent slopes	Not limited	Stephenville (60%)		833.7	21.4%
Sw3	Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Not limited	Stephenville, severely eroded (55%)		657.3	16.9%
W	Water	Not rated	Water (100%)		35.1	0.9%
WdB	Newalla fine sandy loam, 1 to 5 percent slopes	Very limited	Newalla (90%)	Shrink-swell (1.00)	176.5	4.5%
				Low strength (1.00)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
WdB2	Newalla fine sandy loam, 1 to 5 percent slopes, eroded	Very limited	Newalla, eroded (95%)	Shrink-swell (1.00)	36.2	0.9%
				Low strength (1.00)		
ZaC2	Zaneis loam, 3 to 5 percent slopes, eroded	Very limited	Zaneis, eroded (85%)	Low strength (1.00)	23.9	0.6%
				Shrink-swell (0.01)		
ZaD	Zaneis loam, 5 to 8 percent slopes	Not limited	Zaneis (90%)		5.5	0.1%
Totals for Area of Interest					**3,898.4**	**100.0%**

Rating	Acres in AOI	Percent of AOI
Not limited	2,705.0	69.4%
Very limited	886.9	22.8%
Somewhat limited	271.4	7.0%
Null or Not Rated	35.1	0.9%
Totals for Area of Interest	**3,898.4**	**100.0%**

Description

Local roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a subgrade of cut or fill soil material; a base of gravel, crushed rock, or soil material stabilized by lime or cement; and a surface of flexible material (asphalt), rigid material (concrete), or gravel with a binder. The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. The properties that affect the ease of excavation and grading are depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, depth to a water table, ponding, flooding, the amount of large stones, and slope. The properties that affect the traffic-supporting capacity are soil strength (as inferred from the AASHTO group index number), subsidence, linear extensibility (shrink-swell potential), the potential for frost action, depth to a water table, and ponding.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

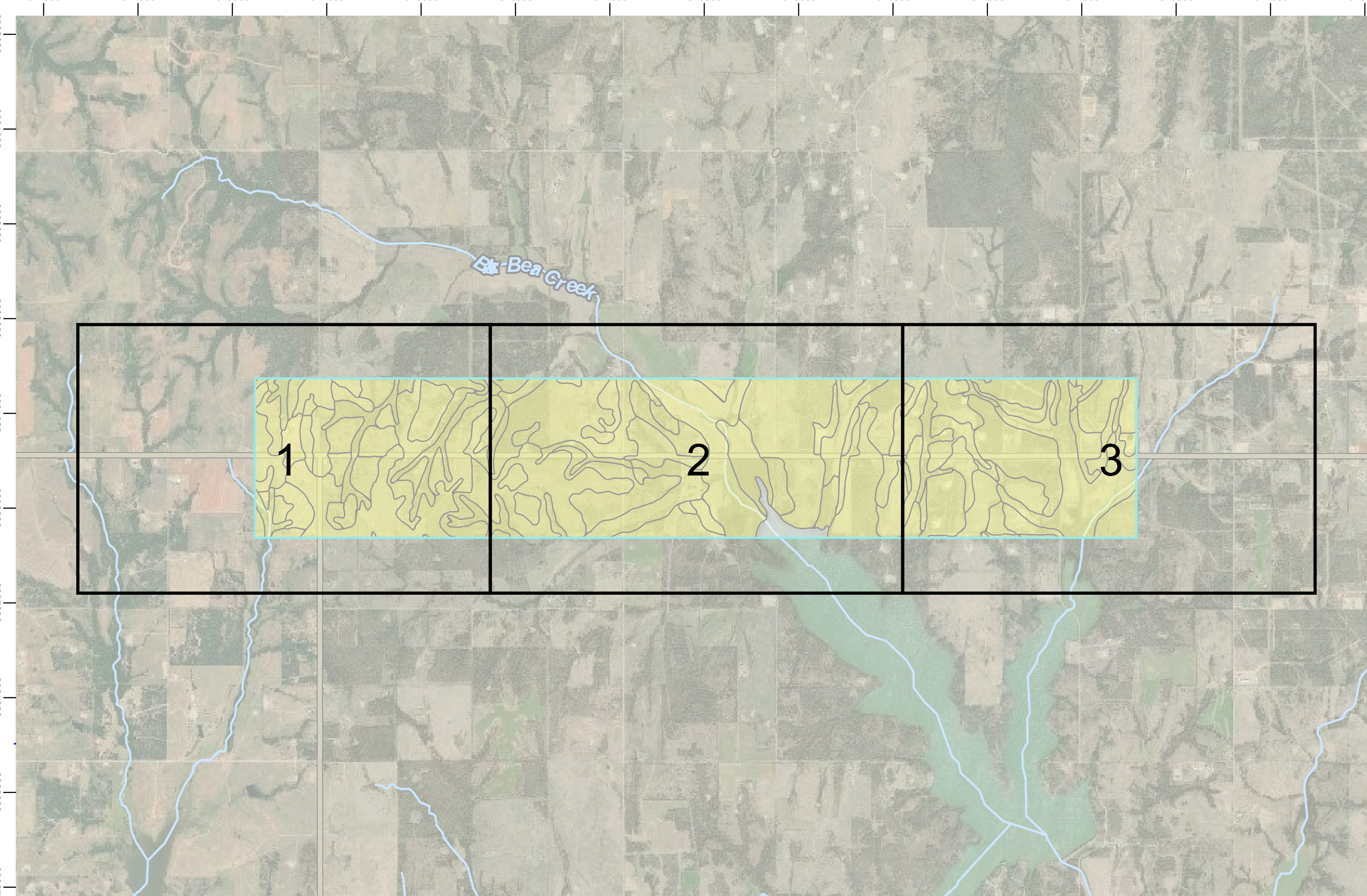
Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



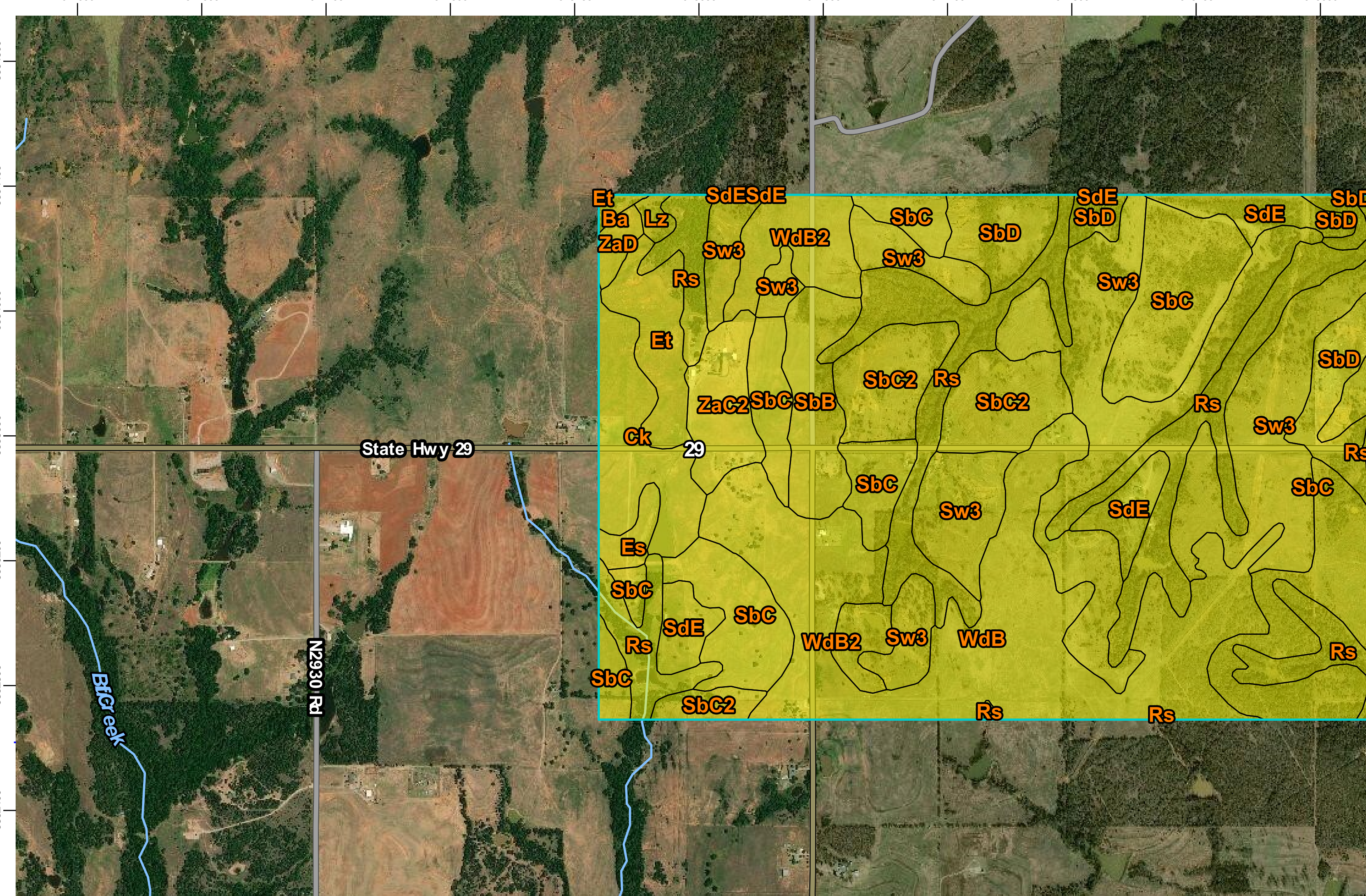
Map Scale: 1:66,000 if printed on A landscape (11" x 8.5") sheet.

N

0 500 1000 2000 3000 Meters

0 3000 6000 12000 18000 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

N

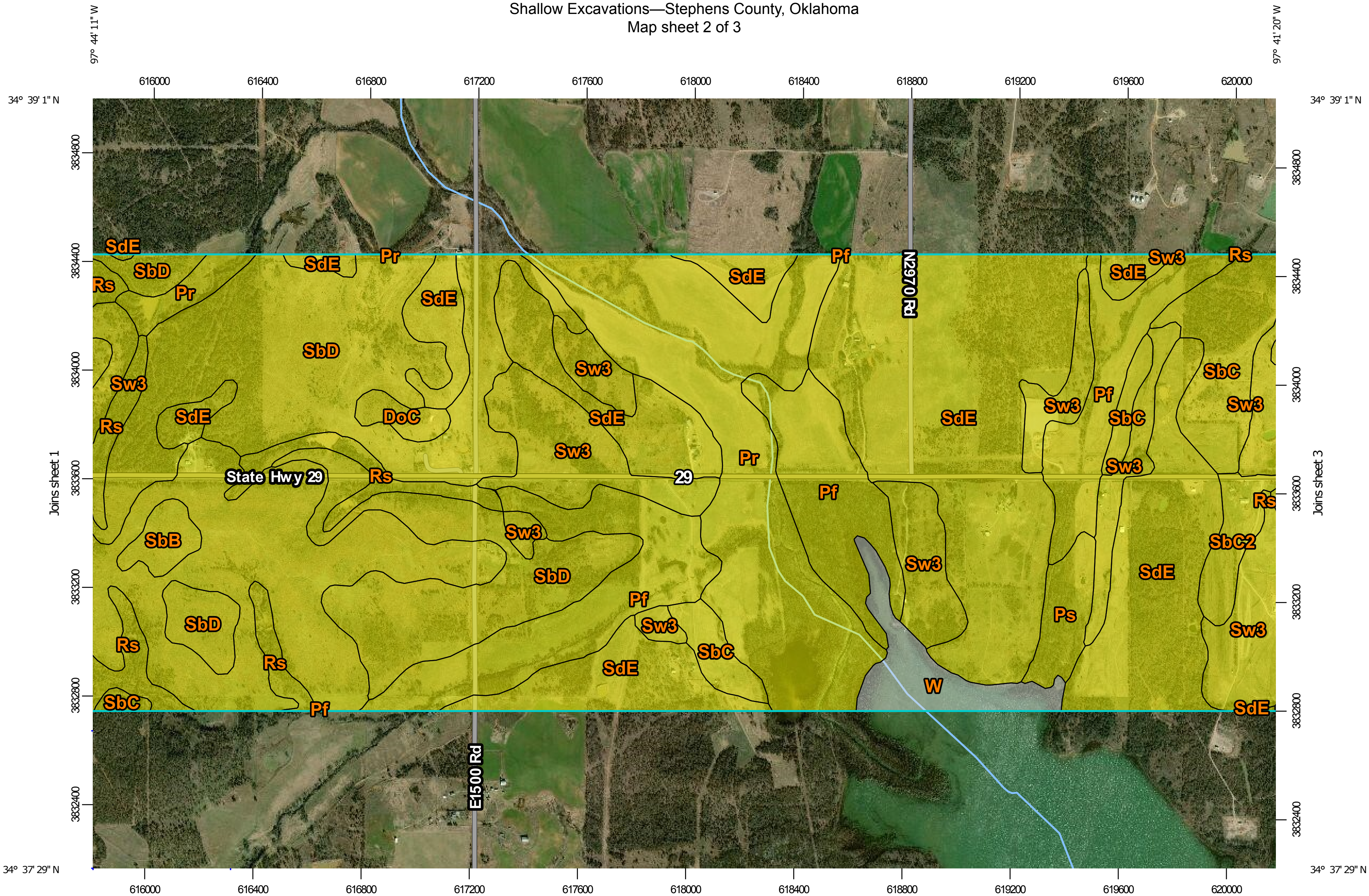
0 250 500 1000 1500 Meters

0 500 1000 2000 3000 Feet

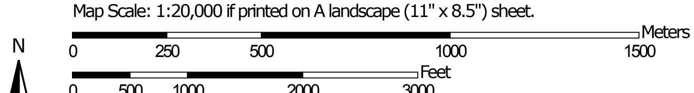
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

1		

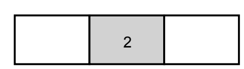
Map Sheet Location



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

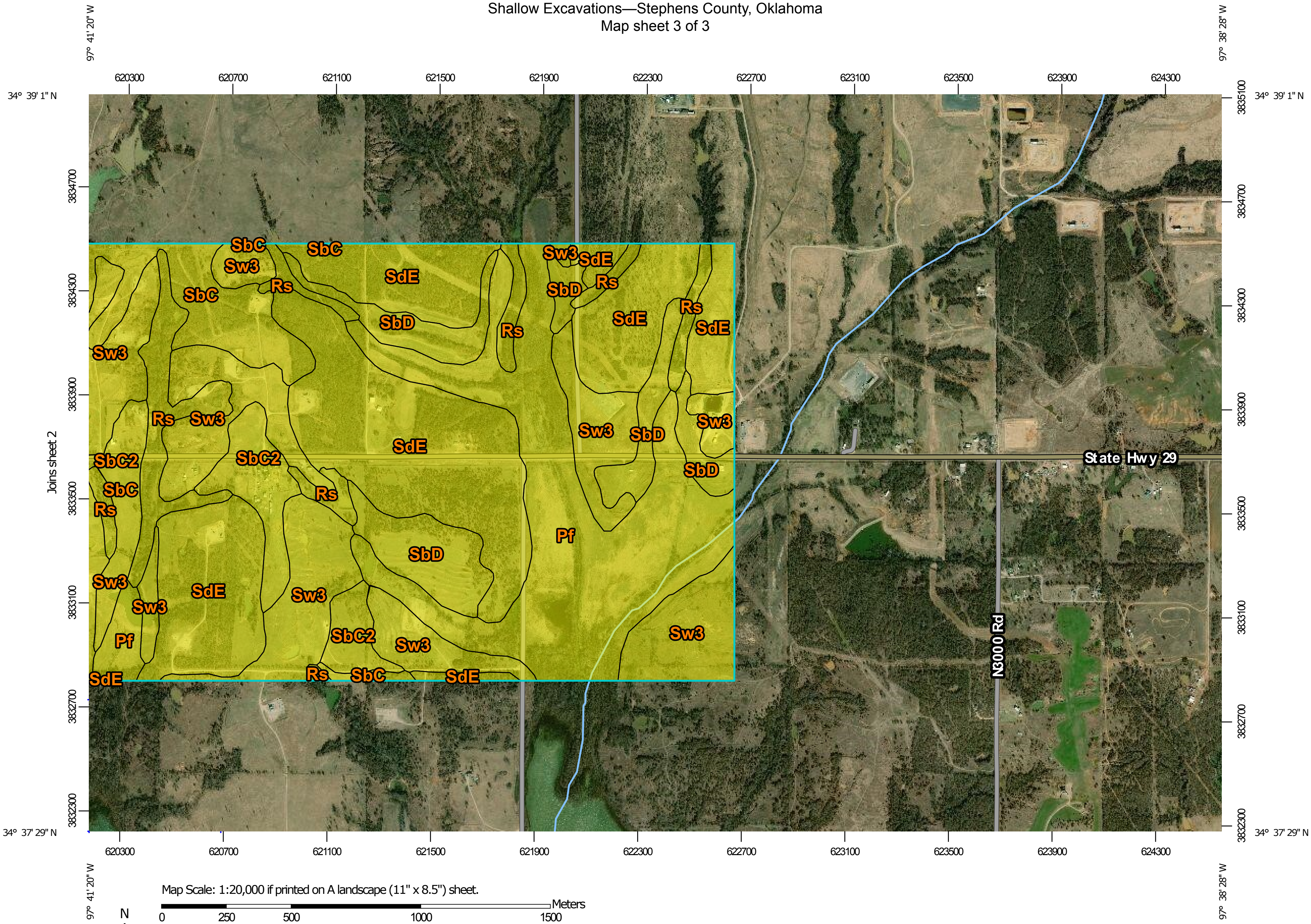


Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84



Map Sheet Location

Shallow Excavations—Stephens County, Oklahoma
Map sheet 3 of 3



Map Scale: 1:20,000 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 250, 500, 1000, 1500

Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 14N WGS84

Map Sheet Location: 3

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Soil Rating Lines
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Soil Rating Points
- Very limited
- Somewhat limited
- Not limited
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Stephens County, Oklahoma
Survey Area Data: Version 12, Sep 21, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 13, 2015—Mar 6, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Shallow Excavations

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Ba	Zaneis-Ashport frequently flooded complex, 0 to 12 percent slopes	Somewhat limited	Zaneis (80%)	Dense layer (0.50)	2.0	0.1%
				Dusty (0.19)		
				Slope (0.04)		
				Unstable excavation walls (0.01)		
			Ashport, frequently flooded (20%)	Flooding (0.80)		
				Dusty (0.33)		
				Unstable excavation walls (0.01)		
Ck	Chickasha-Huska complex, 1 to 3 percent slopes	Somewhat limited	Chickasha (60%)	Dense layer (0.50)	37.8	1.0%
				Dusty (0.20)		
				Unstable excavation walls (0.01)		
			Huska (40%)	Unstable excavation walls (0.51)		
				Dense layer (0.50)		
				Too clayey (0.28)		
				Dusty (0.28)		
DoC	Dougherty and Konawa soils, 3 to 8 percent slopes	Somewhat limited	Dougherty (50%)	Unstable excavation walls (0.01)	9.6	0.2%
			Konawa (35%)	Unstable excavation walls (0.01)		
			Derby (5%)	Unstable excavation walls (0.75)		
			Eufaula (5%)	Unstable excavation walls (0.92)		
Es	Renfrow and Pawhuska soils, 1 to 5 percent slopes,	Somewhat limited	Renfrow, severely eroded (65%)	Unstable excavation walls (0.51)	6.8	0.2%
				Dusty (0.24)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
	severely eroded			Too clayey (0.13)		
			Pawhuska, severely eroded (30%)	Unstable excavation walls (0.51)		
				Dusty (0.33)		
				Too clayey (0.03)		
			Chickasha, severely eroded (5%)	Dense layer (0.50)		
				Dusty (0.21)		
				Unstable excavation walls (0.01)		
Et	Chickasha and Zaneis soils, 1 to 8 percent slopes, severely eroded	Somewhat limited	Chickasha, severely eroded (55%)	Dense layer (0.50)	25.3	0.6%
				Dusty (0.21)		
				Unstable excavation walls (0.01)		
			Zaneis, severely eroded (40%)	Dense layer (0.50)		
				Dusty (0.20)		
				Unstable excavation walls (0.01)		
Lz	Zaneis-Grainola-Lucien complex, 5 to 12 percent slopes	Somewhat limited	Zaneis (60%)	Dense layer (0.50)	3.2	0.1%
				Dusty (0.19)		
				Unstable excavation walls (0.01)		
			Grainola (20%)	Depth to soft bedrock (0.90)		
				Unstable excavation walls (0.51)		
				Dense layer (0.50)		
				Dusty (0.31)		
				Too clayey (0.28)		
Pf	Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded	Somewhat limited	Port, occasionally flooded (93%)	Flooding (0.60)	412.5	10.6%
				Dusty (0.23)		
				Unstable excavation walls (0.01)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
Pr	Port loam, 0 to 1 percent slopes, occasionally flooded	Somewhat limited	Port, occasionally flooded (95%)	Flooding (0.60)	209.7	5.4%
				Dusty (0.19)		
				Unstable excavation walls (0.01)		
Ps	Port-Oscar complex, 0 to 1 percent slopes, occasionally flooded	Somewhat limited	Port, occasionally flooded (68%)	Flooding (0.60)	21.4	0.5%
				Dusty (0.33)		
				Unstable excavation walls (0.01)		
			Oscar, occasionally flooded (25%)	Flooding (0.60)		
				Dusty (0.33)		
				Unstable excavation walls (0.01)		
Rs	Stephenville-Pulaski, frequently flooded, complex, 0 to 20 percent slopes	Somewhat limited	Stephenville (70%)	Dense layer (0.50)	266.2	6.8%
				Depth to soft bedrock (0.20)		
				Slope (0.16)		
				Dusty (0.05)		
				Unstable excavation walls (0.01)		
			Pulaski, frequently flooded (30%)	Flooding (0.80)		
				Dusty (0.02)		
				Unstable excavation walls (0.01)		
SbB	Stephenville and Littleaxe soils, 1 to 3 percent slopes	Somewhat limited	Stephenville (45%)	Depth to soft bedrock (0.06)	43.8	1.1%
				Dusty (0.03)		
				Unstable excavation walls (0.01)		
			Littleaxe (40%)	Dusty (0.05)		
				Unstable excavation walls (0.01)		
SbC	Stephenville and Littleaxe soils, 3 to 5 percent slopes	Somewhat limited	Stephenville (55%)	Dense layer (0.50)	490.9	12.6%
				Dusty (0.06)		
				Depth to soft bedrock (0.01)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Unstable excavation walls (0.01)		
			Littleaxe (40%)	Dense layer (0.50)		
				Dusty (0.03)		
				Unstable excavation walls (0.01)		
SbC2	Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded	Somewhat limited	Stephenville, eroded (55%)	Dense layer (0.50)	125.0	3.2%
				Dusty (0.06)		
				Depth to soft bedrock (0.01)		
				Unstable excavation walls (0.01)		
			Littleaxe, eroded (45%)	Dense layer (0.50)		
				Dusty (0.03)		
				Unstable excavation walls (0.01)		
SbD	Stephenville fine sandy loam, 5 to 8 percent slopes	Somewhat limited	Stephenville (90%)	Dense layer (0.50)	476.2	12.2%
				Dusty (0.05)		
				Depth to soft bedrock (0.01)		
				Unstable excavation walls (0.01)		
SdE	Stephenville-Darnell complex, 5 to 12 percent slopes	Somewhat limited	Stephenville (60%)	Depth to soft bedrock (0.06)	833.7	21.4%
				Dusty (0.03)		
				Unstable excavation walls (0.01)		
Sw3	Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded	Somewhat limited	Stephenville, severely eroded (55%)	Dense layer (0.50)	657.3	16.9%
				Depth to soft bedrock (0.29)		
				Dusty (0.05)		
				Unstable excavation walls (0.01)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
			Newalla, severely eroded (45%)	Too clayey (0.50)		
				Dense layer (0.50)		
				Dusty (0.07)		
				Unstable excavation walls (0.01)		
W	Water	Not rated	Water (100%)		35.1	0.9%
WdB	Newalla fine sandy loam, 1 to 5 percent slopes	Somewhat limited	Newalla (90%)	Too clayey (0.97)	176.5	4.5%
				Unstable excavation walls (0.78)		
				Dusty (0.10)		
WdB2	Newalla fine sandy loam, 1 to 5 percent slopes, eroded	Somewhat limited	Newalla, eroded (95%)	Unstable excavation walls (0.51)	36.2	0.9%
				Too clayey (0.50)		
				Dense layer (0.50)		
				Dusty (0.13)		
			Stephenville, eroded (5%)	Dense layer (0.50)		
				Dusty (0.06)		
				Depth to soft bedrock (0.01)		
				Unstable excavation walls (0.01)		
ZaC2	Zaneis loam, 3 to 5 percent slopes, eroded	Somewhat limited	Zaneis, eroded (85%)	Dusty (0.16)	23.9	0.6%
				Unstable excavation walls (0.01)		
ZaD	Zaneis loam, 5 to 8 percent slopes	Somewhat limited	Zaneis (90%)	Dense layer (0.50)	5.5	0.1%
				Dusty (0.19)		
				Unstable excavation walls (0.01)		
			Grainola (5%)	Depth to soft bedrock (0.71)		
				Unstable excavation walls (0.51)		
				Dense layer (0.50)		

Map unit symbol	Map unit name	Rating	Component name (percent)	Rating reasons (numeric values)	Acres in AOI	Percent of AOI
				Dusty (0.31)		
				Too clayey (0.28)		
Totals for Area of Interest					**3,898.4**	**100.0%**

Rating	Acres in AOI	Percent of AOI
Somewhat limited	3,863.3	99.1%
Null or Not Rated	35.1	0.9%
Totals for Area of Interest	**3,898.4**	**100.0%**

Description

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the specified use. "Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. "Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. "Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The map unit components listed for each map unit in the accompanying Summary by Map Unit table in Web Soil Survey or the Aggregation Report in Soil Data Viewer are determined by the aggregation method chosen. An aggregated rating class is shown for each map unit. The components listed for each map unit are only those that have the same rating class as listed for the map unit. The percent composition of each component in a particular map unit is presented to help the user better understand the percentage of each map unit that has the rating presented.

Other components with different ratings may be present in each map unit. The ratings for all components, regardless of the map unit aggregated rating, can be viewed by generating the equivalent report from the Soil Reports tab in Web Soil Survey or from the Soil Data Mart site. Onsite investigation may be needed to validate these interpretations and to confirm the identity of the soil on a given site.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

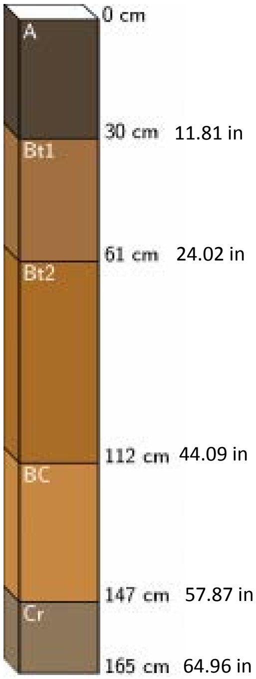
Tie-break Rule: Higher

APPENDIX C

Soil Series Profiles

1. (Ck) **Chickasha-Huska complex, 1 to 3 percent slopes**(SSURGO Export: 2017-09-21) Components within map unit 384855

Chickasha (60%)
Udic Argiustolls



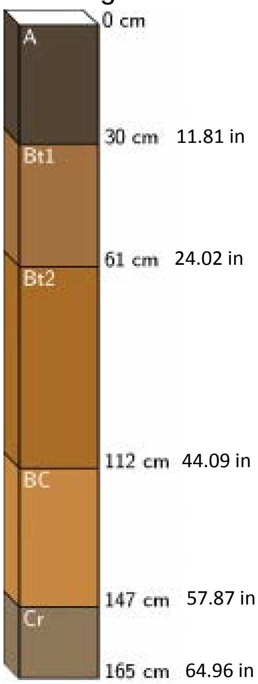
hills
hillslopes / Shoulder

Huska (40%)
Mollic Natrustalfs

hills
hillslopes / Shoulder

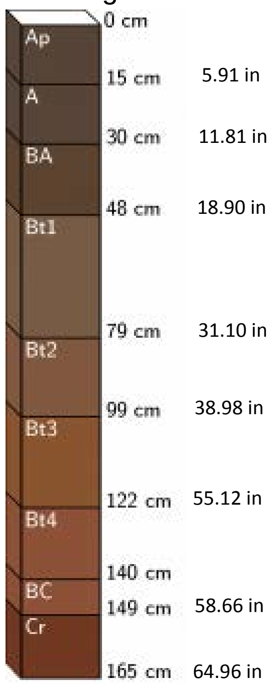
2. (Et) **Chickasha and Zaneis soils, 1 to 8 percent slopes, severely eroded**(SSURGO Export: 2017-09-21) Components within map unit 384861

Chickasha (55%)
Udic Argiustolls



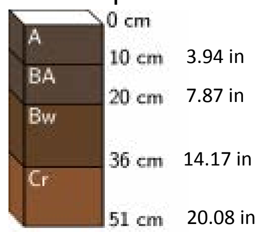
hills
hillslopes / Backslope

Zaneis (40%)
Udic Argiustolls



hills
hillslopes / Backslope

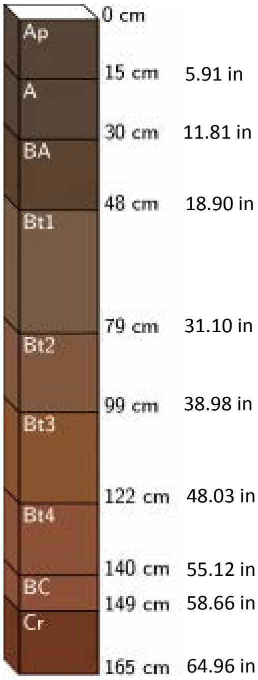
Lucien (5%)
Udic Haplustolls



hillslopes / Backslope
hills

3. (ZaC2) **Zaneis loam, 3 to 5 percent slopes, eroded** (SSURGO Export: 2017-09-21) Components within map unit 384896

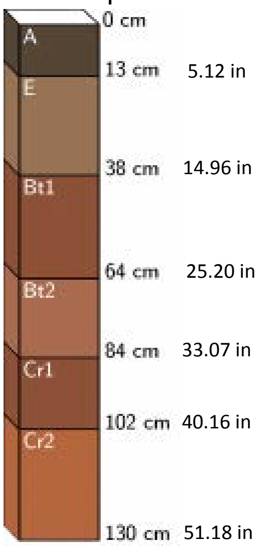
Zaneis (85%)
Udic Argiustolls



low hills / Backslope

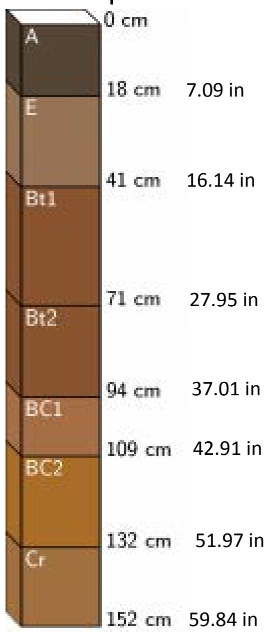
4. (SbC) **Stephenville and Littleaxe soils, 3 to 5 percent slopes** (SSURGO Export: 2017-09-21) Components within map unit 384885

Stephenville (55%)
Ultic Haplustalfs



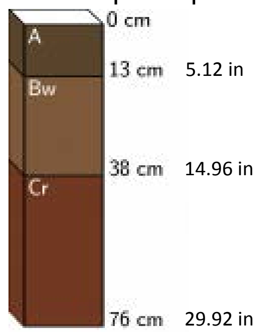
hillslopes / Backslope
hills

Littleaxe (40%)
Ultic Haplustalfs



hills
hillslopes / Backslope

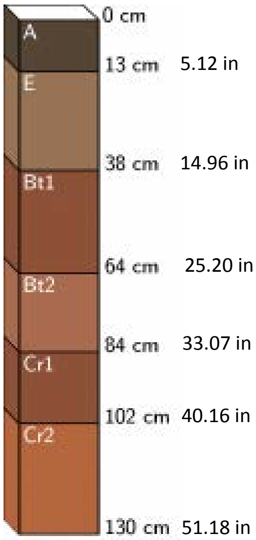
Darnell (5%)
Udic Haplustepts



hills
hillslopes / Backslope

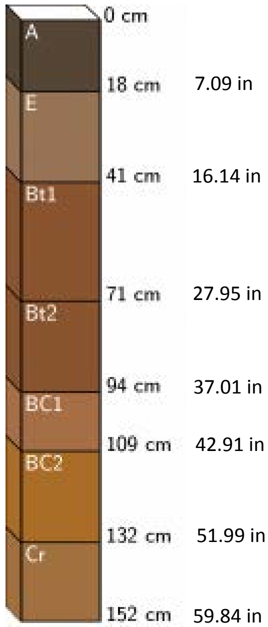
5. (SbB) **Stephenville and Littleaxe soils, 1 to 3 percent slopes** (SSURGO Export: 2017-09-21) Components within map unit 384884

Stephenville (45%)
Ultic Haplustalfs



hillslopes / Backslope

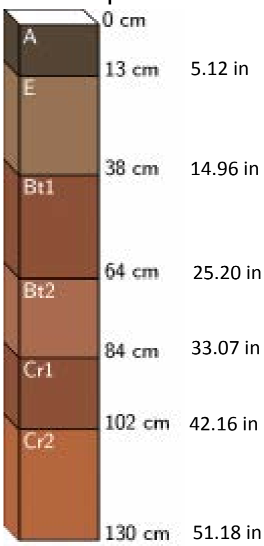
Littleaxe (40%)
Ultic Haplustalfs



hillslopes / Backslope

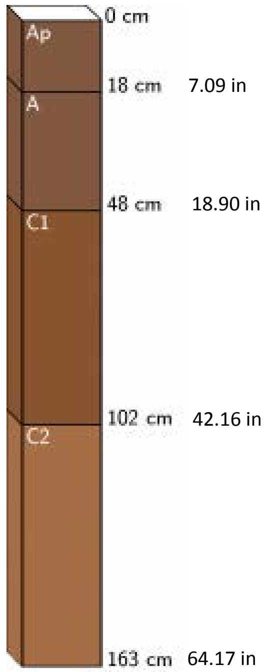
6. (Rs) **Stephenville-Pulaski, frequently flooded, complex, 0 to 20 percent slopes** (SSURGO Export: 2017-09-21) Components within map unit 384882

Stephenville (70%)
Ultic Haplustalfs



hillslopes / Backslope

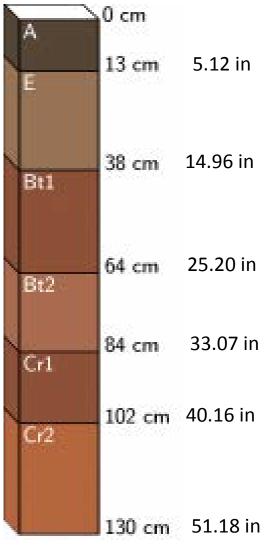
Pulaski (30%)
Udic Ustifluvents



flood plains

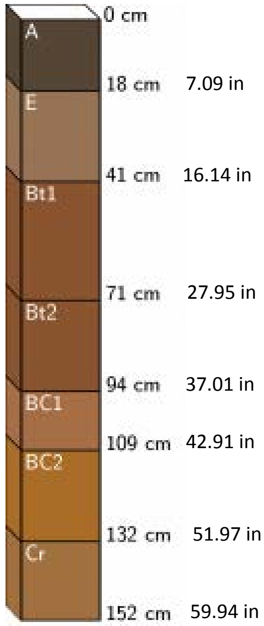
7. (SbC2) **Stephenville and Littleaxe soils, 3 to 5 percent slopes, eroded** (SSURGO Export: 2017-09-21) Components within map unit 384886

Stephenville (55%)
Ultic Haplustalfs



hills
hillslopes / Backslope

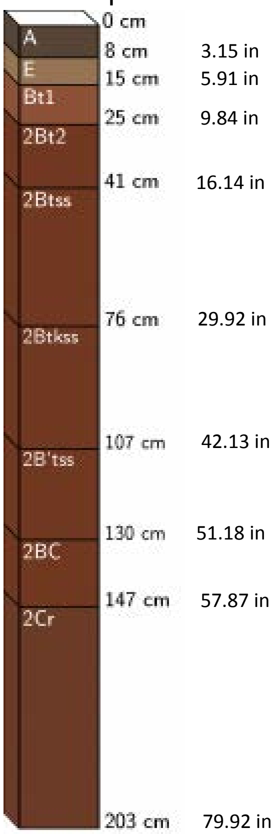
Littleaxe (45%)
Ultic Haplustalfs



hillslopes / Backslope
hills

8. (WdB) **Newalla fine sandy loam, 1 to 5 percent slopes**(SSURGO Export: 2017-09-21) Components within map unit 384891

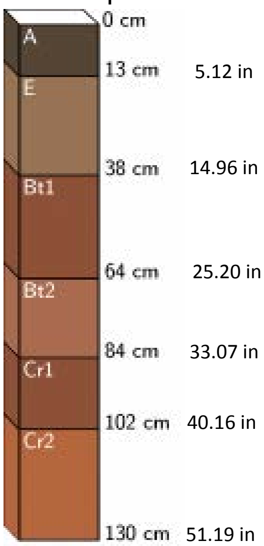
Newalla (90%)
Udic Haplustalfs



hillslopes / Backslope

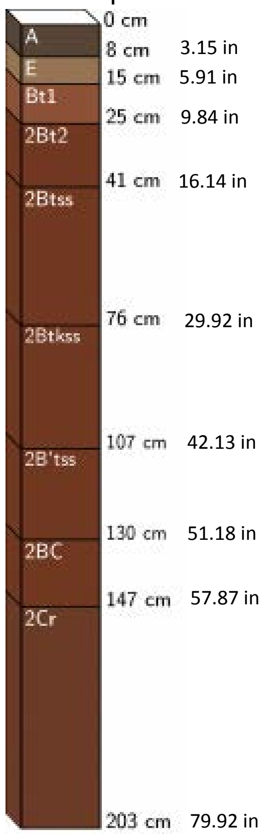
9. (Sw3) **Stephenville and Newalla soils, 1 to 8 percent slopes, severely eroded** (SSURGO Export: 2017-09-21) Components within map unit 384889

Stephenville (55%)
Ultic Haplustalfs



hills
hillslopes / Backslope

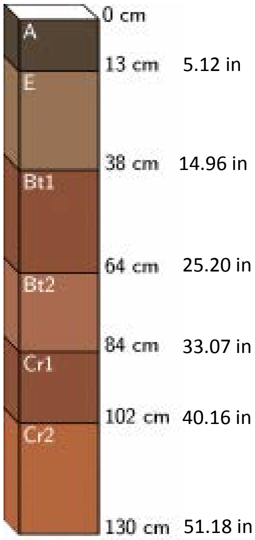
Newalla (45%)
Udic Haplustalfs



hills
hillslopes / Backslope

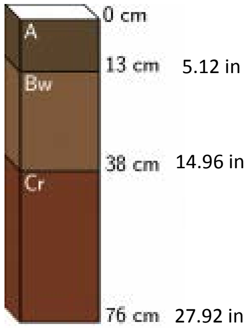
10. (SbD) **Stephenville fine sandy loam, 5 to 8 percent slopes**(SSURGO Export: 2017-09-21) Components within map unit 384887

Stephenville (90%)
Ultic Haplustalfs



hillslopes / Backslope
hills

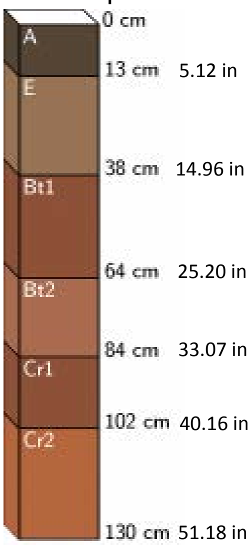
Darnell (10%)
Udic Haplustepts



hills
hillslopes / Backslope

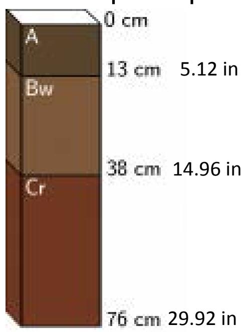
11. (SdE) **Stephenville-Darnell complex, 5 to 12 percent slopes**(SSURGO Export: 2017-09-21) Components within map unit 384888

Stephenville (60%)
Ultic Haplustalfs



hillslopes / Backslope

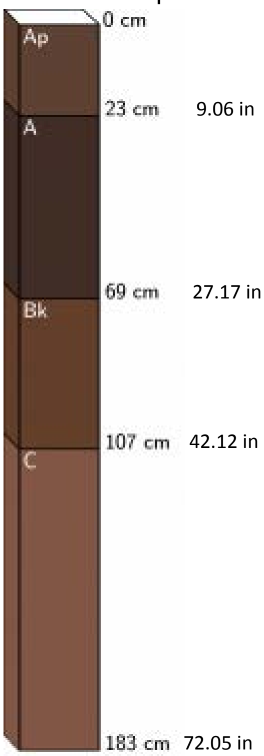
Darnell (30%)
Udic Haplustepts



hillslopes / Summit
hillslopes / Shoulder

12. (Pf) **Port fine sandy loam, 0 to 1 percent slopes, occasionally flooded** (SSURGO Export: 2017-09-21) Components within map unit 384875

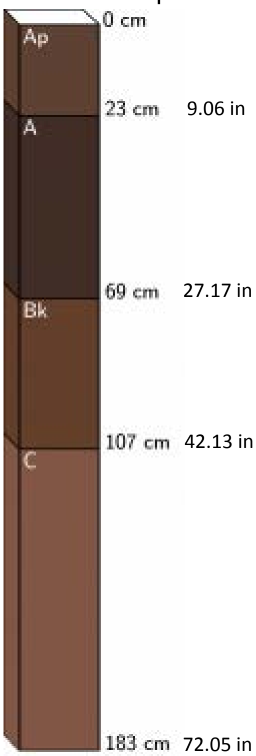
Port (93%)
Cumulic Haplustolls



flood plains

13. (Pr) **Port loam, 0 to 1 percent slopes, occasionally flooded**(SSURGO Export: 2017-09-21) Components within map unit 384877

Port (95%)
Cumulic Haplustolls



flood plains

APPENDIX D

Soil Description

Soil Description

The soil series identified along the CRL of the SH 29 alignment in the order of occurrence beginning from the BOP to the EOP are presented in chronological order in Table 1. Regarding the pedological and geological soil survey, the soil series identified in the project extent are from four soil orders and four suborders; see Table 4 and the Soil Taxonomy statement in Appendix E. For the (Newalla, Huska, Zaneis, Chickasha, Port, and Darnell) soil series not sampled; the official soil description (OSD) depths were used in the following soil descriptions.

The **Stephenville** soil series diagnostic horizons and features include an ochric epipedon, an albic horizon, an argillic horizon, and a paralithic contact. The ochric epipedon is a surface horizon with color values more than 5 dry or 3 moist, contains less than 0.6 percent organic carbon, or is hard to very hard and massive when dry and includes the A horizon from the ground surface to an approximate depth of 5 inches. The albic horizon is a soil material horizon with a white to gray color mainly due to the color of the primary sand and silt particles that is 2.5 inch or thicker and includes the E horizon from approximately 5 to 8 inches. The argillic horizon develops through a process of illuviation where successive horizons with depth develop with increasing clay content at least 1.2 times more clay content as occurring in an overlying horizon and is represented by the lower–case symbol ‘t’ in the subhorizon identification and includes the Bt horizons from approximately 8 to 24 inches. A paralithic contact refers to the boundary between soil and an underlying material that is so hard and consolidated that digging with hand tools is impractical and occurs at an approximate depth of 24 inches at the top of the Cr1 horizon. The Cr1 horizon was found to be weakly cemented in–place sandstone, and a sample was hand augured from 24 to 38 inches. The underlying Cr2 horizon was founded to in–place sandstone that could not be sampled with a hand auger.

The **Littleaxe** soil series diagnostic horizons and features include an ochric epipedon, an albic horizon, an argillic horizon and a paralithic contact. The ochric epipedon as described above for the Stephenville soil series includes the A horizon from the ground surface to an approximate depth of 7 inches. The albic horizon as described above for the Stephenville soil series includes the E horizon from approximately 7 to 16 inches below the ground surface. The argillic horizon as described above for the Stephenville soil series includes the Bt horizons from approximately 16 to 37 inches. The paralithic contact as described above for the Stephenville soil series occurs at a depth of 67 inches, the top of the Cr horizon. The underlying Cr horizon was weakly cemented in−place sandstone interbedded with weakly cemented shale, and a sample was hand augured from 67 to 79 inches.

The **Newalla** soil series diagnostic horizons and features include an ochric epipedon, an albic horizon, an argillic horizon, lithologic discontinuity, an accumulation of secondary calcium carbonate, and a non–paralithic rock contact. The ochric epipedon as described above for the Stephenville soil series includes the A horizon from the ground surface to an approximate depth of 3 inches. The albic horizon as described above for the Stephenville soil series includes the E horizon from an approximate depth of 3 to 6 inches. The argillic horizon as described above for the Stephenville soil series includes the Bt horizons from an approximate depth of 6 to 51 inches. The lithologic discontinuity refers to a contrasting material at an approximate depth of approximately 10 inches at the bottom of the Bt1 horizon where fine sandy loam and sandy clay loam changes clay in the underlying Bt horizons. The accumulation of secondary calcium carbonate refers to the 2Btkss horizon from an approximate depth of 30 to 42 inches where soft masses of calcium carbonate are found. Note the presence of slickensides as indicated in the Btss horizons from an approximate depth of 16 to 51 inches. The non–paralithic contact occurs at the top of the Cr horizon where a non-paralithic material means that it is soft enough to be excavated by hand tools.

The **Huska** soil series diagnostic horizons and features include a mollic epipedon, natric horizon, argillic horizon, and a paralithic contact. The mollic epipedon refers to a dark colored, organic rich surface horizon that is susceptible to subgrade instability when exposed to moisture during construction or increasing moisture with time under a paved surface and includes the A horizon from the ground surface to an approximate depth of 9 inches. The natric horizon meets the requirements of an argillic horizon but also has prismatic or columnar structure and over 15 percent of the cation exchange capacity (at a pH of 8.2) is saturated with sodium ions or has more exchangeable Mg plus Na than Ca plus exchange acidity at pH 8.2. The natric horizon is recognized a soil horizon designated with an 'n' in the description and includes the Btn horizons from an approximate depth of 9 to 50 inches. The argillic horizon as described above for the Stephenville soil series includes the Bt horizons from approximately 9 to 50 inches. The accumulation of salts refers to salts more soluble than gypsum recognized by the 'z' in the Btnz horizons from an approximate depth of 18 to 34 inches. The paralithic contact as described above Stephenville soil series refers to the top of 2Cr horizon where soft sandstone occurs at an approximate depth from 50 to 55 inches.

The **Zaneis** soil series diagnostic horizons and features include a mollic epipedon, argillic horizon, and paralithic contact. The mollic epipedon as described above for the Huska soil series includes the Ap, A, and BA horizons from the ground surface to an approximate depth of 19 inches. The argillic horizon above for the Stephenville soil series includes the Bt horizons from approximately 19 to 55 inches. A paralithic contact as described above Stephenville soil series occurs at the top of the Cr horizon at a depth of approximately of 59 inches. The Cr horizon is recorded from 59 to 65 inches and consists of soft laminated in–place sandstone.

The **Chickasha** soil series diagnostic horizons and features include a mollic epipedon and argillic horizon. The mollic epipedon as described above for the Huska soil series includes the A horizon from the ground surface to an approximate depth of 12 inches. The argillic horizon as described above for the Stephenville soil series includes the Bt horizons from approximately 12 to 44 inches.

The **Port** soil series diagnostic horizons and features include a mollic epipedon and cambic horizon. The mollic epipedon as described above for the Huska soil series includes the Ap and A horizons from the ground surface to an approximate depth of 27 inches. The cambic horizon refers to a subsoil horizon of very fine sand, loamy very fine sand, or finer texture that is 15 cm (5.91 inches) or thicker with some weak indication of alteration in color from the pedogenic processes and includes the Bk horizon from depth of approximately 27 to 42 inches.

The **Pulaski** soil series diagnostic horizons and features include an ochric epipedon, an irregular decrease in organic carbon, and an udic-ustic soil moisture regime. The ochric epipedon as described above for the Stephenville soil series and includes the Ap and A horizons from the ground surface to an approximate depth of 19 inches. The irregular decrease in organic carbon refers to the erratic occurrence of organic carbon due to the alluvial deposition of sediments and occurs in the C1 and C2 horizons approximately 20 to 66 inches from the ground surface. The udic-ustic soil moisture regime means that in most years, this soil series is not dry in any part of the moisture control section (depth to which plant roots penetrate) for as long as 90 cumulative days and at the same time the moisture control section is moist in some part for more than one-half of the days when the soil temperature is 5^{o} C (41^{o}F) at 50 cm (19.69in.).

The **Darnell** soil series soil diagnostic horizons and features include ochric horizon, a cambic horizon, and a paralithic contact. The ochric epipedon as described above for the Stephenville soil series includes the A horizon from the ground surface to an approximate depth of 5 inches. The cambic horizon as described above for the Port soil series includes the Bw horizon from approximately 5 to 15 inches. A paralithic contact as described above as described above for the Stephenville soil series occurs at the top of the Cr horizon at an approximate depth of 15 inches below the ground surface.

APPENDIX E

Soil Taxonomy Statement

Soil Taxonomy

Stephenville Series

Order:	Alfisols The central concept of Alfisols is that of soils that have an argillic horizon and a base saturation of 35 percent or greater. Alfisols have Redoximorphic features in all horizons. Argillic horizons refer to a B horizon that has at least 1.2 times as much clay as does an above horizon. Redoximorphic features refer to the alternation between reducing and oxidizing conditions that are responsible for the release of iron and manganese from primary minerals. This redox condition results in mottled soil colors and generally indicates a fluctuating watertables.
Suborder:	Ustalfs Ustalfs have an ustic moisture regime which implies that in most years part of the moisture control section (depth of root penetration) is dry for more than 90 cumulative days. Ustalfs have calcium carbonate accumulation throughout the horizons.
Great Group:	Haplustalfs Refers to other Haplustalfs that have a sandy or sandy-skeletal particle-size class throughout a layer extending from the mineral soil surface to the top of an argillic horizon at a depth of 50 cm (19.69 in) or more.
Subgroup Modifier:	Ultic Ultic means that the soil horizons have low base saturation.
Particle Size:	Fine-loamy Fine-Loamy refers to a particle class where the soil less than 75 mm (2.95 in) diameter has 15 or more by weight particles with diameters of 0.1 to 75 mm (0.0039 to 2.95 in) [fine sand or coarser, including rock fragments up to 7.5 cm (2.95 in) in diameter] and 18 to 35 percent by dry weight clay
Mineralogy:	Siliceous Siliceous refers to a mineralogical class referring to more 90 percent by weight silica minerals and other extremely durable minerals that are resistant to weathering, in the 0.02 to 2.0 mm (0.0008 to 0.079 in) fraction.
Temperature:	Thermic Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Littleaxe Series

Order: Alfisols
The central concept of Alfisols is that of soils that have an argillic horizon and a base saturation of 35 percent or greater. Alfisols have Redoximorphic features in all horizons. The argillic horizon refers to a B horizon that has at least 1.2 times as much clay as does an above horizon. Redoximorphic features refers to the alternation between reducing and oxidizing conditions that are responsible for the release of iron and manganese from primary minerals. This redox condition results in mottled soil colors and generally indicates a fluctuating watertables.

Suborder: Ustalfs
Ustalfs have an ustic moisture regime which implies that in most years part of the moisture control section (depth of root penetration) is dry for more than 90 cumulative days. Ustalfs have calcium carbonate accumulation throughout the horizons.

Great Group: Haplustalfs
Refers to other Haplustalfs that have a sandy or sandy-skeletal particle-size class throughout a layer extending from the mineral soil surface to the top of an argillic horizon at a depth of 50 cm (19.69 in) or more.

Subgroup Modifier: Ultic
Ultic means that the soil horizons have low base saturation.

Particle Size: Fine-loamy
Fine-Loamy refers to a particle class where the soil less than 75 mm (2.95 in) diameter has 15 or more by weight particles with diameters of 0.1 to 75 mm (0.0039 to 2.95 in) (fine sand or coarser, including rock fragments up to 7.5 cm (2.95 in) in diameter) and 18 to 35 percent by dry weight clay.

Mineralogy: Siliceous
Siliceous refers to a mineralogical class referring to more 90 percent by weight silica minerals and other extremely durable minerals that are resistant to weathering, in the 0.02 to 2.0 mm (0.0008 to 0.08) fraction.

Temperature: Thermic
Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Newalla Series

Order: Alfisols
The central concept of Alfisols is that of soils that have an argillic horizon and a base saturation of 35 percent or greater. Alfisols have Redoximorphic features in all horizons. Argillic horizon refers to a B horizon that has at least 1.2 times as much clay as does an above horizon. Redoximorphic features refers to the alternation between reducing and oxidizing conditions that are responsible for the

release of iron and manganese from primary minerals. This redox condition results in mottled soil colors and generally indicates a fluctuating watertables.

Suborder: Ustalfs
Ustalfs have an ustic moisture regime which implies that in most years part of the moisture control section (depth of root penetration) is dry for more than 90 cumulative days. Ustalfs have calcium carbonate accumulation throughout the horizons.

Great Group: Haplustalfs
Refers to other Haplustalfs that have a sandy or sandy-skeletal particle-size class throughout a layer extending from the mineral soil surface to the top of an argillic horizon at a depth of 50 cm (19.69 in) or more.

Subgroup Modifier : Udic
Udic refers to the udic soil moisture regime which means in normal years that these soils are not dry in any part of the moisture control section (depth of root penetration) for as long as 90 cumulative days.

Particle Size: Fine-loamy over clayey
Fine loamy as described above over clayey which refers to a particle class where the soil has 35 percent or more (by weight) clay.

Mineralogy: Mixed
Mixed refers to a mineralogical class where no one clay mineral is predominates.

Temperature: Thermic
Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Huska Series

Order: Alfisols
The central concept of Alfisols is that of soils that have an argillic horizon and a base saturation of 35 percent or greater. Alfisols have Redoximorphic features in all horizons. Argillic horizons refer to a B horizon that has at least 1.2 times as much clay as does an above horizon. Redoximorphic features refers to the alternation between reducing and oxidizing conditions that are responsible for the release of iron and manganese from primary minerals. This redox condition results in mottled soil colors and generally indicates a fluctuating water tables.

Suborder: Ustalfs
Ustalfs have an ustic moisture regime which implies that in most years part of the moisture control section (depth of root penetration) is dry for more than 90 cumulative days. Ustalfs have calcium carbonate accumulation throughout the horizons.

Great Group: Natrustalfs
Natrustalfs have a natric horizon which have sodium, calcium, and magnesium cations. These horizons may be dispersive.

Subgroup Modifier: Mollic
Mollic refers the soil series having an mollic epipedon which is a deep organic rich soil zone.

Particle Size: Fine
Fine refers to a textural classification that have (by weight average) less than 60 percent (by weight) clay in the fine-earth fraction.

Mineralogy: Mixed
Mixed refers to a mineralogy class indicating that no one clay mineral type predominates.

Temperature: Thermic
Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Zaneis Series

Order: Mollisols
Mollisols are formed in a grassland setting and have a mollic epidedon that is a soft, dark, and organic rich surface horizon. The Mollisol also have a thick, illuvial, and argillic 'B' horizon. This horizon is typically very clayey and neutral to moderately alkaline.

Suborder: Ustolls
Ustolls are the more or less freely drained Mollisols formed in Holocene to mid-Plesitocene geological deposits. Ustolls are found in sub-humid to semi-arid climates and are associated with regions where rainfall is erratic but often occurs in heavy rains. Drought is frequent and may be severe. During drought conditions wind erosion becomes a problem. Ustolls have mollic epipedon and a calcium or lime rich horizon. The mollic epipedon refers to a surface horizon (typically the A and parts of the B horizon) that is soft and has substantial organic matter.

Great Group: Argiustolls
Argiustolls have an argillic horizon. In the argiustolls horizons soil materials are transported from one horizon to another by eluviation (removal) or illuviation (accumulation) through predominantly leaching chemical constituents.

Subgroup Modifier: Udic
Udic refers to the udic soil moisture regime which means in normal years that these soils are not dry in any part of the moisture control section (depth of root penetration) for as long as 90 cumulative days.

Particle Size: Fine-Loamy
Fine-Loamy refers to a particle class where the soil less than 75 mm (2.95 in) diameter has 15 or more by weight particles with diameters of 0.1 to 75 mm (0.039

to 2.95 in) [fine sand or coarser, including rock fragments up to 7.5 cm (2.95 in) in diameter] and 18 to 35 percent by dry weight clay.

Mineralogy: Siliceous
Siliceous refers to a mineralogical class referring to more 90 percent by weight silica minerals and other extremely durable minerals that are resistant to weathering, in the 0.02 to 2.0 mm (0.0008 to 0.08) fraction.

Temperature: Thermic
Thermic refers to a soil temperature classification that ranges from 59 to 72° F. Soil series supports good plant growth.

Chickasha Series

Order: Mollisols
Mollisols are formed in a grassland setting and have a mollic epidedon that is a soft, dark, and organic rich surface horizon. The Mollisol also have a thick, illuvial, and argillic 'B' horizon. This horizon is typically very clayey and neutral to moderately alkaline.

Suborder: Ustolls
Ustolls are the more or less freely drained Mollisols formed in Holocene to mid-Plesitocene geological deposits. Ustolls are found in sub-humid to semi-arid climates and are associated with regions where rainfall is erratic but often occurs in heavy rains. Drought is frequent and may be severe. During drought conditions wind erosion becomes a problem. Ustolls have mollic epipedon and a calcium or lime rich horizon. The mollic epipedon refers to a surface horizon (typically the A and parts of the B horizon) that is soft and has substantial organic matter.

Great Group: Argiustolls
Argiustolls have an argillic horizon. In the argiustolls horizons soil materials are transported from one horizon to another by eluviation (removal) or illuviation (accumulation) through predominantly leaching chemical constituents.

Subgroup Modifier: Udic
Udic refers to the udic soil moisture regime which means in normal years that these soils are not dry in any part of the moisture control section (depth of root penetration) for as long as 90 cumulative days.

Particle Size: Fine-Loamy
Fine-Loamy refers to a particle class where the soil less than 75 mm (2.95 in) diameter has 15 or more by weight particles with diameters of 0.1 to 75 mm (0.039 to 2.95 in) [fine sand or coarser, including rock fragments up to 7.5 cm (2.95 in) in diameter] and 18 to 35 percent by dry weight clay.

Mineralogy: Mixed
Mixed refers to a mineralogy class indicating that no one clay mineral type predominates.

Temperature: Thermic

Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Port Series

Order: Mollisols

Mollisols are formed in a grassland setting and have a mollic epidedon that is a soft, dark, and organic rich surface horizon. The Mollisol also have a thick, illuvial, and argillic 'B' horizon. This horizon is typically very clayey and neutral to moderately alkaline.

Suborder: Ustolls

Ustolls are the more or less freely drained Mollisols formed in Holocene to mid-Plesitocene geological deposits. Ustolls are found in sub-humid to semi-arid climates and are associated with regions where rainfall is erratic but often occurs in heavy rains. Drought is frequent and may be severe. During drought conditions wind erosion becomes a problem. Ustolls have mollic epipedon and a calcium or lime rich horizon. The mollic epipedon refers to a surface horizon (typically the A and parts of the B horizon) that is soft and has substantial organic matter.

Great Group: Haplustolls

Haplustolls are Ustolls that have a cambic horizon which refers to a subsoil horizon of very fine sand, loamy fine sand, or finer texture. Haplustolls have a horizon in which carbonates or soluble salts have accumulated.

Subgroup Modifier: Cumulic

Cumulic is a term that refers to deposition of mineral material on the surface by water (flooding in this case).

Particle Size: Fine-Silty

Fine-Silty refers to a particle size class where the soil has in the fraction less than 75 mm (2.95 in) in diameter, less than 15 percent by weight particles with diameters of 0.1 to 75 mm (0.039 to 2.95 in) [fine sand or coarser, including rock fragments up to 7.5 cm (2.95) in diameter] and in the fine earth fraction 18 to 35 percent by weight clay.

Mineralogy: Mixed

Mixed refers to a mineralogy class indicating that no one clay mineral type predominates.

Temperature: Thermic

Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

Pulaski Series

Order: Entisols

The central concept of Entisols is that of soils that have little or no evidence of pedogenic horizon development. Typical of entisols is an ochric epipedon, a surface horizon that is light in color.

Suborder: Fluvents

Fluvents are loamy and clayey (finer in texture than loamy fine sand) alluvial soils with very simple profiles. Irregularity of content of organic matter with depth is diagnostic. Stratification is common is common in alluvium and soils derived from alluvium.

Great Group: Ustifluvents

Ustifluvents have ustic moisture regimes. In most years, part of the moisture control section of these soils is dry for more than 90 cumulative days but moist in some part more than one-half the days that the soil temperature is above 5° C at 50 cm (19.69 in).

Subgroup Modifier: Udic

Udic refers to the udic soil moisture regime which means in normal years that these soils are not dry in any part of the moisture control section (depth of root penetration) for as long as 90 cumulative days.

Particle Size: Coarse-Loamy

Coarse-Loamy refers to a particle size class where the soil in the fraction less than 75 mm (2.95 in) in diameter has 15 percent or more by weight particles with diameters of 0.1 to 75 mm (0.0039 to 2.95 in) [fine sand or coarser, including rock fragments up to 7.5 cm (2.95 in) in diameter] and in the fine earth fraction, less than 18 percent by weight clay.

Mineralogy: Mixed

Mixed refers to a mineralogy class indicating that no one clay mineral type predominates.

Temperature: Thermic

Thermic refers to a soil temperature classification that ranges from 59 to 72° F. Soil series supports good plant growth.

Darnell Series

Order: Inceptisols

The central concept of Inceptisols is that of soils of humid and subhumid regions that have altered horizons that have lost bases or iron and aluminum but retain some weatherable minerals. They do not have an illuvial horizon enriched with either silicate clay or with an amorphous mixture of aluminum and organic carbon.

Suborder: Ustepts
Ustepts have a duripan that has its upper boundary within 100 cm of the mineral soil surface. A duripan is a subsurface horizon that is cemented by illuvial silica (rock).

Great Group: Haplustepts
The Haplustepts have a lithic contact within 50 cm of the mineral surface. The lithic contact is a boundary between soil and continuous coherent underlying material (rock).

Subgroup Modifier: Udic
Udic refers to the udic soil moisture regime which means in normal years that these soils are not dry in any part of the moisture control section (depth of root penetration) for as long as 90 cumulative days.

Particle Size: Loamy
Loamy refers to a textural class where the soil has a texture of loamy fine sand, very fine sand, or finer, including less than 35 percent by weight clay in the fine fraction.

Mineralogy: Mixed
Mixed refers to a mineralogy class indicating that no one clay mineral type predominates.

Temperature: Thermic
Thermic refers to a soil temperature classification that ranges from 59 to 72^{o} F. Soil series supports good plant growth.

APPENDIX F

Pedological Soil Logs and Test Data

Surveyed By: James B. Nevels
Date Surveyed : 05/07/2018

RED ROCK CONSULTING

RRC Project No: 18028
Project No: 29657(04)
Location: Stephens County, OK

Pedological & Geological Soils Survey

Field No.	Soil Group	Station	Description	Depth (inches)	L.L.	P.I.	% Passing 3 in	3/4 in	#4	#10	#40	#200	OSI	pH	Resistivity (Ω-Cm)	Soluble Sulfates (ppm)	Soil Group Name
		671+01, 11.3' RT	Stephenville Series														
1A	A-4(0)		A Horizon	0 - 5	NV	NP	100	100	100	99	99	44.5	0.0	6.8	4110	<200	silty sand
1B	A-4(0)		E Horizon	5 - 8	23	6	100	100	99	99	98	45.5	3.0	6.5	3550	<200	silty, clayey sand
1C	A-6(4)		Bt1 Horizon	8 - 24	28	13	100	100	99	99	98	54.2	7.9	6.6	3320	<200	sandy lean clay
1D	A-4(0)		Cr1 Horizon	24 - 38	NV	NP	100	100	100	100	99	35.1	0.0	6.4	5120	<200	silty sand
1E	A-6(4)		B Composite	8 - 24	29	13	100	100	100	100	99	51.6	7.5				sandy lean clay
		800+72.7, 23.2' RT	Littleaxe Series														
2A	A-2-4		A Horizon	0 - 7	NV	NP	100	100	100	100	99	16.4	0.0	6.8	3960	<200	silty sand
2B	A-2-4		E Horizon	7 - 16	NV	NP	100	100	98	98	97	14.5	0.0	6.8	4180	<200	silty sand
2C	A-2-4		Bt1 Horizon	16 - 28	NV	NP	100	100	100	100	99	15.6	0.0	6.9	4410	<200	silty sand
2D	A-2-4		Bt2 Horizon	28 - 37	NV	NP	100	100	100	99	98	14.9	0.0	7.1	4550	<200	silty sand
2E	A-2-4		BC1 Horizon	37 - 49	NV	NP	100	100	100	100	98	15.7	0.0	6.9	4670	<200	silty sand
2F	A-2-4		BC2 Horizon	49 - 67	NV	NP	100	100	99	98	95	22.9	0.0	7.2	2970	<200	silty sand
2G	A-4(0)		Cr Horizon	67 - 79	22	6	100	100	91	85	78	38.9	1.9	6.7	3830	<200	silty, clayey sand
2H	A-2-4		B Composite	16 - 67	NV	NP	100	100	100	99	98	15.8	0.0				silty sand
		616+79.3, 105.7' RT	Pulaski Series														
3A	A-4(0)		Ap Horizon	0 - 7	NV	NP	100	100	100	99	99	47.2	0.0	6.6	2020	<200	silty sand
3B	A-2-4		A Horizon	7 - 19	20	3	100	100	100	98	97	34.6	0.6	6.9	2600	<200	silty sand
3C	A-4(0)		C1 Horizon	19 - 40	20	4	100	100	100	98	96	43.4	2.0	6.9	2830	276	silty, clayey sand
3D	A-6(1)		C2 Horizon	40 - 65	25	11	100	100	99	98	97	43.6	5.4	6.9	2730	<200	clayey sand
3E	A-4(0)		C Composite	19 - 65	21	4	100	100	100	98	95	39.5	1.5				silty, clayey sand

SUMMARY OF LABORATORY RESULTS

RED ROCK CONSULTING
PO Box 30591
Edmond, OK 73003
405-562-3328

Project No: 18028

Project Name: SH 29 Pedological West
Client: SRB

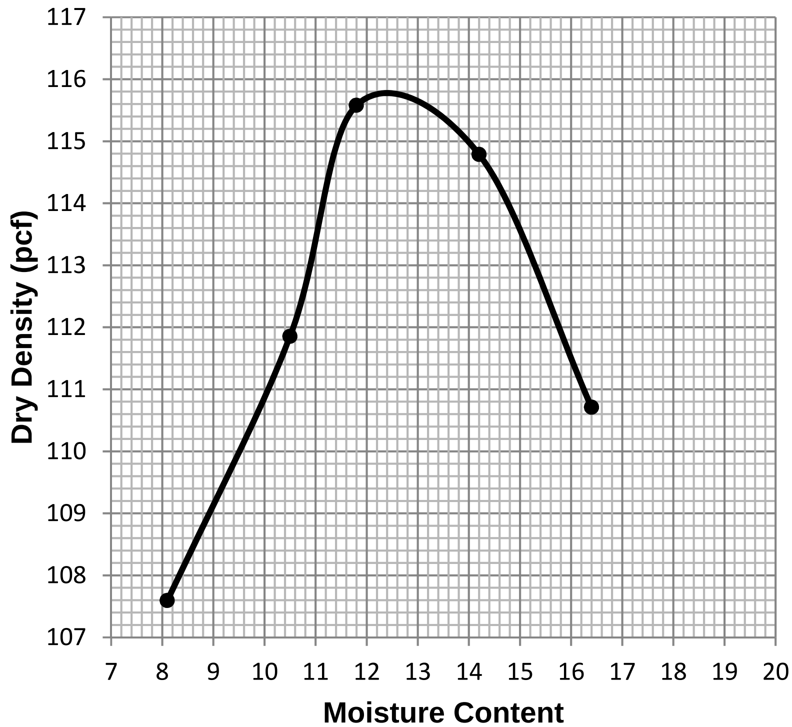
Borehole	Depth (In)	Liquid Limit	Plastic Limit	Plastic Index	-3" Sieve	-3/4" Sieve	-1/2" Sieve	-4 Sieve	-10 Sieve	-40 Sieve	-200 Sieve	pH	Resistivity (Ω-cm)	Sulfates (ppm)
STEPHENVILLE														
A	0-5"	NV	NP	NP	100	100	100	100	99	99	44.5	6.8	4110	<200
E	5-8"	23	17	6	100	100	100	99	99	98	45.5	6.5	3550	<200
Bt1	8-24"	28	15	13	100	100	100	99	99	98	54.2	6.6	3320	<200
Cr1	24-38"	NV	NP	NP	100	100	100	100	100	99	35.1	6.4	5120	<200
COMP. B	8"-24"	29	16	13	100	100	100	100	100	99	51.6			
LITTLEAXE														
A	0-7"	NV	NP	NP	100	100	100	100	100	99	16.4	6.8	3960	<200
E	7-16"	NV	NP	NP	100	100	100	98	98	97	14.5	6.8	4180	<200
Bt1	16-28"	NV	NP	NP	100	100	100	100	100	99	15.6	6.9	4410	<200
Bt2	28-37"	NV	NP	NP	100	100	100	100	99	98	14.9	7.1	4550	<200
BC1	37-49"	NV	NP	NP	100	100	100	100	100	98	15.7	6.9	4670	<200
BC2	49-67"	NV	NP	NP	100	100	100	99	98	95	22.9	7.2	2970	<200
Cr	67-79"	22	16	6	100	100	94	91	85	78	38.9	6.7	3830	<200
COMP. B	16-67"	NV	NP	NP	100	100	100	100	99	98	15.8			
PULASKI														
Ap	0-7"	NV	NP	NP	100	100	100	100	99	99	47.2	6.6	2020	<200
A	7-19"	20	17	3	100	100	100	100	98	97	34.6	6.9	2600	<200
C1	19-40"	20	16	4	100	100	100	100	98	96	43.4	6.9	2830	276
C2	40-65"	25	14	11	100	100	100	99	98	97	43.6	6.9	2730	<200
COMP. C	19-65"	21	17	4	100	100	100	100	98	95	39.5			

Proctor

Project #: 18028 Project Name: Stephenville

Tested By: CP Test Date: 1.5.18 Client: SRB Other

Weight of Hammer: 5.5 No. of Blows: 25



Maximum Dry Density (pcf) 115.8

Optimum Moisture Content (%) 12.4

Liquid Limit: 29 USCS CL

Plasticity Index: 13 AASHTO A-6(4)

Method: A Soil Classification: Sandy Lean Clay

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number	SH29 West - 18028
2. County//State Name	Stephens County/ Oklahoma
3. Test Date	7/16/2018
4.Sample Number	Stephenville (Compacted @ OMC)
5. Material Type	2
6. Soil Series	n/a
7. Horizon	B

9. Soil Properties

Optimum Moisture Content, (%)	12.40
Maximum Dry Density, pcf	115.80
95% MDD (pcf)	110.01

8. Specimen Properties

Compaction Water content, wc, %	12.45
Compaction Dry Density, pcf	112.3
Moisture Content After Mr Test, w(%)	12.34
Permanent Deformation (in)	0.065

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	24.74	22.48	2.26	1.97	1.79	0.18	0.0012	0.0014	0.0013	0.00016	11023
Sequence 2	6	4	50.62	45.09	5.53	4.03	3.59	0.44	0.0025	0.0028	0.0026	0.00033	10948
Sequence 3	6	6	75.74	68.33	7.41	6.03	5.44	0.59	0.0041	0.0046	0.0043	0.00054	10018
Sequence 4	6	8	99.22	89.05	10.17	7.90	7.09	0.81	0.0057	0.0064	0.0060	0.00075	9434
Sequence 5	6	10	125.85	113.17	12.69	10.02	9.01	1.01	0.0074	0.0084	0.0079	0.00099	9123
Sequence 6	4	2	25.25	22.36	2.89	2.01	1.78	0.23	0.0012	0.0014	0.0013	0.00017	10674
Sequence 7	4	4	51.12	45.09	6.03	4.07	3.59	0.48	0.0026	0.0029	0.0028	0.00035	10345
Sequence 8	4	6	75.86	68.45	7.41	6.04	5.45	0.59	0.0042	0.0047	0.0045	0.00056	9775
Sequence 9	4	8	99.22	89.30	9.92	7.90	7.11	0.79	0.0059	0.0066	0.0062	0.00078	9102
Sequence 10	4	10	125.60	112.91	12.69	10.00	8.99	1.01	0.0078	0.0087	0.0082	0.00103	8746
Sequence 11	2	2	25.62	22.73	2.89	2.04	1.81	0.23	0.0014	0.0015	0.0015	0.00018	9983
Sequence 12	2	4	50.99	45.47	5.53	4.06	3.62	0.44	0.0029	0.0033	0.0031	0.00039	9342
Sequence 13	2	6	75.11	67.70	7.41	5.98	5.39	0.59	0.0045	0.0050	0.0048	0.00060	9018
Sequence 14	2	8	98.97	89.18	9.80	7.88	7.10	0.78	0.0064	0.0071	0.0067	0.00084	8463
Sequence 15	2	10	125.98	113.29	12.69	10.03	9.02	1.01	0.0086	0.0094	0.0090	0.00113	8012

* Reported results are based on the average of the last 5 cycles of each load sequence

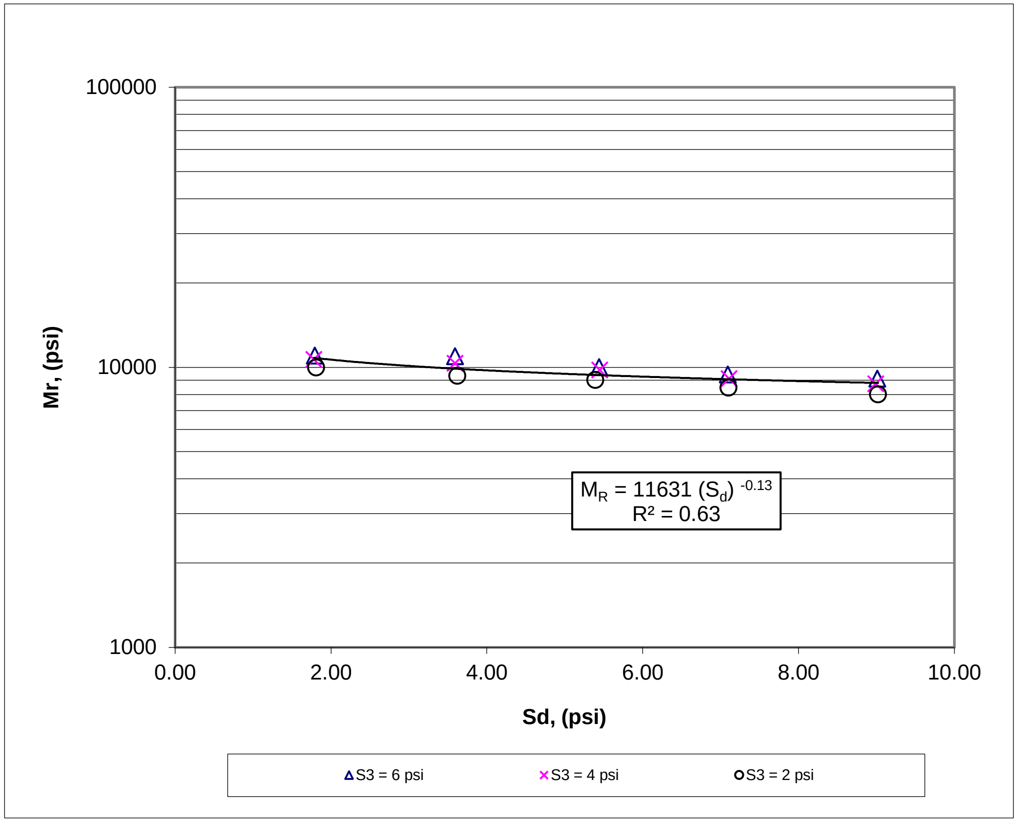
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Stephenville (Compacted @ OMC)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	B
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.79	11023	**10794**
Sequence 2	6	**3.60**	3.59	10948	**9884**
Sequence 3	6	**5.40**	5.44	10018	**9388**
Sequence 4	6	**7.20**	7.09	9434	**9051**
Sequence 5	6	**9.00**	9.01	9123	**8798**
Sequence 6	4	**1.80**	1.78	10674	**10794**
Sequence 7	4	**3.60**	3.59	10345	**9884**
Sequence 8	4	**5.40**	5.45	9775	**9388**
Sequence 9	4	**7.20**	7.11	9102	**9051**
Sequence 10	4	**9.00**	8.99	8746	**8798**
Sequence 11	2	**1.80**	1.81	9983	**10794**
Sequence 12	2	**3.60**	3.62	9342	**9884**
Sequence 13	2	**5.40**	5.39	9018	**9388**
Sequence 14	2	**7.20**	7.10	8463	**9051**
Sequence 15	2	**9.00**	9.02	8012	**8798**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; $Mr = K1 \times Sd^{K2}$

S3 (psi)	K1	K2	R^2
6	12215	-0.12	0.86
4	11751	-0.12	0.90
2	10953	-0.13	0.95
All	11631	-0.13	0.63

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number SH29 West - 18028
2. County//State Name Stephens County/ Oklahoma
3. Test Date 7/16/2018

4.Sample Number Stephenville (Compacted @ Wetter than OMC)
5. Material Type 2
6. Soil Series n/a
7. Horizon B

8. Specimen Properties

Compaction Water content, wc, %	16.98
Compaction Dry Density, pcf	112.3
Moisture Content After Mr Test, w(%)	16.94
Permanent Deformation (in)	0.38

9. Soil Properties

Optimum Moisture Content, (%)	12.40
Maximum Dry Density, pcf	115.80
95% MDD (pcf)	110.01

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	25.12	22.36	2.76	2.00	1.78	0.22	0.0022	0.0022	0.0022	0.00027	6474
Sequence 2	6	4	51.12	45.09	6.03	4.07	3.59	0.48	0.0050	0.0051	0.0051	0.00063	5674
Sequence 3	6	6	74.61	67.70	6.91	5.94	5.39	0.55	0.0083	0.0085	0.0084	0.00106	5109
Sequence 4	6	8	99.22	89.05	10.17	7.90	7.09	0.81	0.0114	0.0117	0.0116	0.00145	4893
Sequence 5	6	10	125.98	113.29	12.69	10.03	9.02	1.01	0.0149	0.0154	0.0151	0.00189	4767
Sequence 6	4	2	24.87	22.23	2.64	1.98	1.77	0.21	0.0024	0.0025	0.0025	0.00031	5748
Sequence 7	4	4	50.11	45.22	4.90	3.99	3.60	0.39	0.0056	0.0057	0.0056	0.00071	5098
Sequence 8	4	6	74.86	67.95	6.91	5.96	5.41	0.55	0.0091	0.0092	0.0091	0.00114	4736
Sequence 9	4	8	99.35	89.18	10.17	7.91	7.10	0.81	0.0129	0.0134	0.0131	0.00164	4320
Sequence 10	4	10	125.98	113.17	12.81	10.03	9.01	1.02	0.0171	0.0179	0.0175	0.00219	4122
Sequence 11	2	2	25.12	22.48	2.64	2.00	1.79	0.21	0.0026	0.0027	0.0026	0.00033	5481
Sequence 12	2	4	49.61	44.71	4.90	3.95	3.56	0.39	0.0064	0.0065	0.0064	0.00081	4421
Sequence 13	2	6	75.86	68.20	7.66	6.04	5.43	0.61	0.0106	0.0109	0.0108	0.00134	4039
Sequence 14	2	8	98.72	88.92	9.80	7.86	7.08	0.78	0.0148	0.0152	0.0150	0.00188	3772
Sequence 15	2	10	126.10	113.42	12.69	10.04	9.03	1.01	0.0195	0.0199	0.0197	0.00247	3662

* Reported results are based on the average of the last 5 cycles of each load sequence

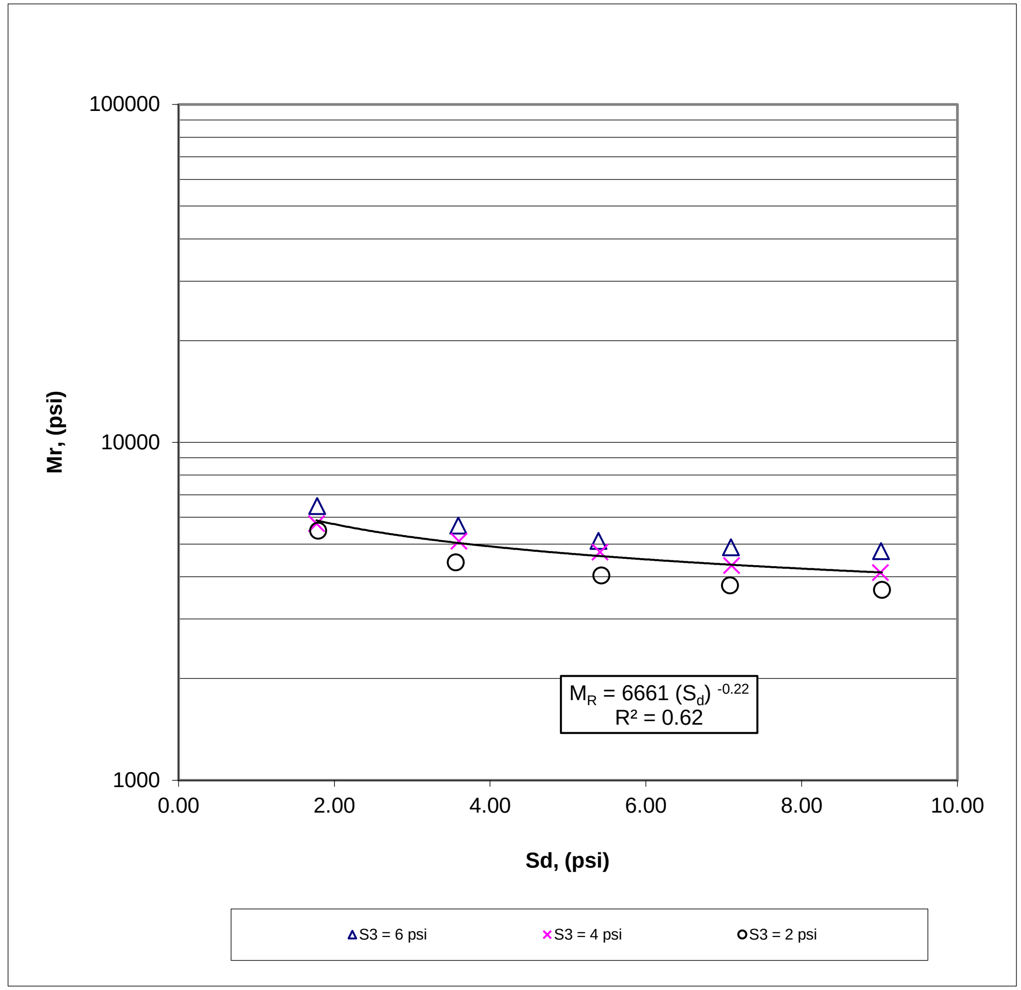
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Stephenville (Compacted @ Wetter than OMC)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	B
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.78	6474	**5860**
Sequence 2	6	**3.60**	3.59	5674	**5037**
Sequence 3	6	**5.40**	5.39	5109	**4611**
Sequence 4	6	**7.20**	7.09	4893	**4330**
Sequence 5	6	**9.00**	9.02	4767	**4125**
Sequence 6	4	**1.80**	1.77	5748	**5860**
Sequence 7	4	**3.60**	3.60	5098	**5037**
Sequence 8	4	**5.40**	5.41	4736	**4611**
Sequence 9	4	**7.20**	7.10	4320	**4330**
Sequence 10	4	**9.00**	9.01	4122	**4125**
Sequence 11	4	**1.80**	1.79	5481	**5860**
Sequence 12	4	**3.60**	3.56	4421	**5037**
Sequence 13	4	**5.40**	5.43	4039	**4611**
Sequence 14	4	**7.20**	7.08	3772	**4330**
Sequence 15	4	**9.00**	9.03	3662	**4125**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; $Mr = K1 \times Sd^{K2}$

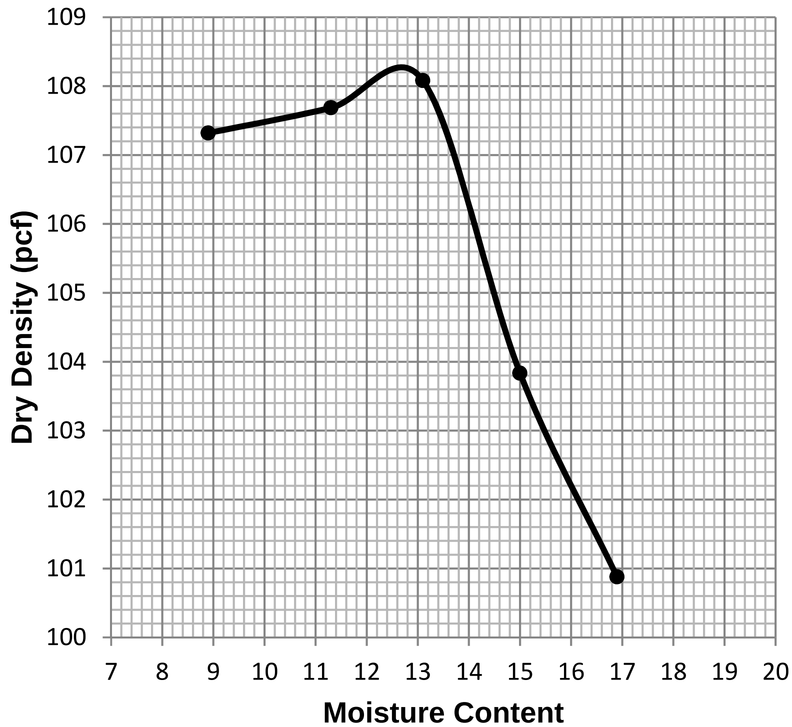
S3 (psi)	K1	K2	R^2
6	7234	-0.20	0.99
4	6547	-0.21	0.98
4	6240	-0.25	0.99
All	6661	-0.22	0.62

Proctor

Project #: 18028 Project Name: Littleaxe

Tested By: CP Test Date: 06.19.18 Client: SRB Other

Weight of Hammer: 5.5 No. of Blows: 25



Maximum Dry Density (pcf) 108.3

Optimum Moisture Content (%) 12.8

Liquid Limit: NV USCS SM

Plasticity Index: NP AASHTO A-2-4

Method: A Soil Classification: Silty Sand

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number SH29 West - 18028
2. County//State Name Stephens County/ Oklahoma
3. Test Date 7/16/2018

4.Sample Number Littleaxe (Compacted @ OMC)
5. Material Type 2
6. Soil Series n/a
7. Horizon B

8. Specimen Properties

Compaction Water content, wc, %	12.67
Compaction Dry Density, pcf	103.24
Moisture Content After Mr Test, w(%)	12.45
Permanent Deformation (in)	<1/16

9. Soil Properties

Optimum Moisture Content, (%)	12.80
Maximum Dry Density, pcf	108.30
95% MDD (pcf)	102.89

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	26.00	22.86	3.14	2.07	1.82	0.25	0.0014	0.0014	0.0014	0.00017	10537
Sequence 2	6	4	50.87	45.47	5.40	4.05	3.62	0.43	0.0028	0.0027	0.0028	0.00035	10435
Sequence 3	6	6	76.49	68.58	7.91	6.09	5.46	0.63	0.0043	0.0042	0.0042	0.00053	10324
Sequence 4	6	8	99.60	89.68	9.92	7.93	7.14	0.79	0.0059	0.0057	0.0058	0.00072	9914
Sequence 5	6	10	125.73	113.29	12.43	10.01	9.02	0.99	0.0075	0.0074	0.0074	0.00093	9720
Sequence 6	4	2	26.00	22.98	3.01	2.07	1.83	0.24	0.0015	0.0015	0.0015	0.00019	9769
Sequence 7	4	4	51.37	45.59	5.78	4.09	3.63	0.46	0.0031	0.0031	0.0031	0.00039	9384
Sequence 8	4	6	76.49	68.70	7.79	6.09	5.47	0.62	0.0048	0.0047	0.0048	0.00060	9174
Sequence 9	4	8	99.35	89.05	10.30	7.91	7.09	0.82	0.0064	0.0062	0.0063	0.00079	8980
Sequence 10	4	10	125.85	113.42	12.43	10.02	9.03	0.99	0.0082	0.0080	0.0081	0.00101	8931
Sequence 11	2	2	26.25	22.98	3.27	2.09	1.83	0.26	0.0016	0.0016	0.0016	0.00020	8985
Sequence 12	2	4	51.37	45.59	5.78	4.09	3.63	0.46	0.0034	0.0033	0.0034	0.00042	8664
Sequence 13	2	6	76.49	68.33	8.16	6.09	5.44	0.65	0.0052	0.0051	0.0051	0.00064	8509
Sequence 14	2	8	100.10	89.80	10.30	7.97	7.15	0.82	0.0070	0.0069	0.0069	0.00087	8242
Sequence 15	2	10	125.73	113.42	12.31	10.01	9.03	0.98	0.0091	0.0089	0.0090	0.00112	8030

* Reported results are based on the average of the last 5 cycles of each load sequence

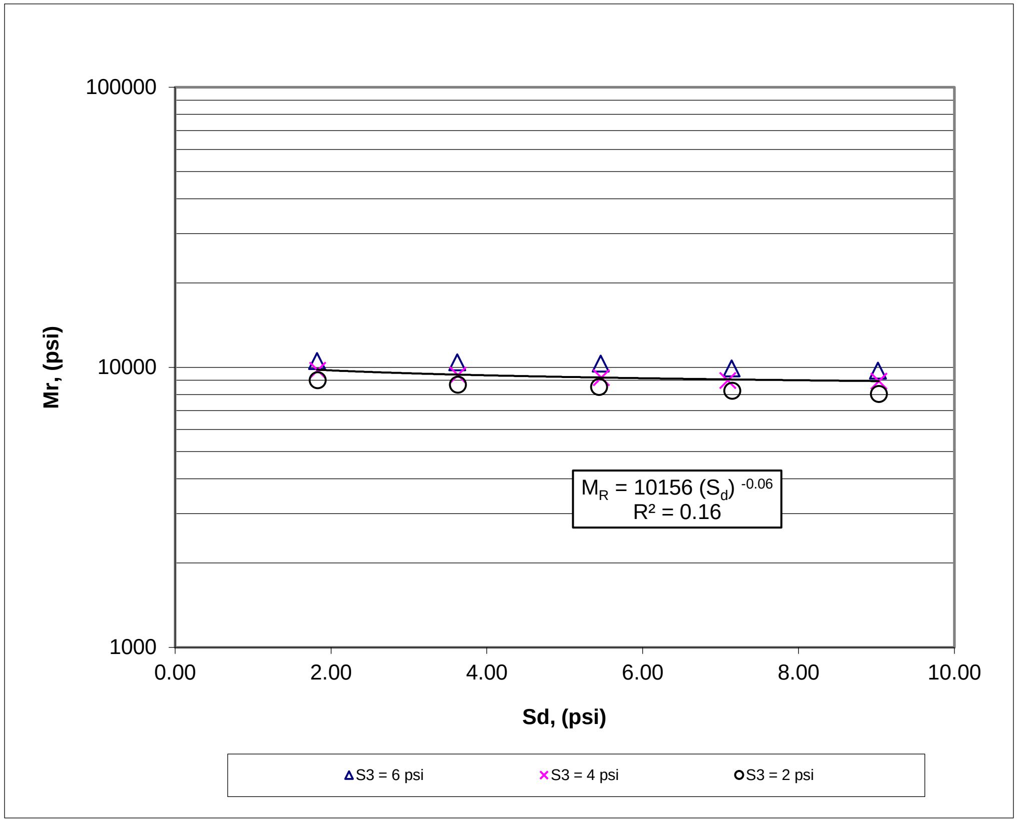
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Littleaxe (Compacted @ OMC)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	B
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.82	10537	**9812**
Sequence 2	6	**3.60**	3.62	10435	**9423**
Sequence 3	6	**5.40**	5.46	10324	**9202**
Sequence 4	6	**7.20**	7.14	9914	**9048**
Sequence 5	6	**9.00**	9.02	9720	**8931**
Sequence 6	4	**1.80**	1.83	9769	**9812**
Sequence 7	4	**3.60**	3.63	9384	**9423**
Sequence 8	4	**5.40**	5.47	9174	**9202**
Sequence 9	4	**7.20**	7.09	8980	**9048**
Sequence 10	4	**9.00**	9.03	8931	**8931**
Sequence 11	2	**1.80**	1.83	8985	**9812**
Sequence 12	2	**3.60**	3.63	8664	**9423**
Sequence 13	2	**5.40**	5.44	8509	**9202**
Sequence 14	2	**7.20**	7.15	8242	**9048**
Sequence 15	2	**9.00**	9.03	8030	**8931**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; Mr = K1 x Sd ^{K2}

S3 (psi)	K1	K2	R^2
6	10988	-0.05	0.80
4	10114	-0.06	0.99
2	9420	-0.07	0.96
All	10156	-0.06	0.16

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number SH29 West - 18028
2. County//State Name Stephens County/ Oklahoma
3. Test Date 7/16/2018

4.Sample Number Littleaxe (Compacted @ OMC+2%)
5. Material Type 2
6. Soil Series n/a
7. Horizon B

9. Soil Properties

Optimum Moisture Content, (%)	12.80
Maximum Dry Density, pcf	108.30
95% MDD (pcf)	102.89

8. Specimen Properties

Compaction Water content, wc, %	14.94
Compaction Dry Density, pcf	103.4
Moisture Content After Mr Test, w(%)	14.67
Permanent Deformation (in)	0.39

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	25.25	22.98	2.26	2.01	1.83	0.18	0.0023	0.0023	0.0023	0.00029	6328
Sequence 2	6	4	50.99	45.47	5.53	4.06	3.62	0.44	0.0045	0.0043	0.0044	0.00055	6574
Sequence 3	6	6	74.98	67.95	7.03	5.97	5.41	0.56	0.0064	0.0061	0.0063	0.00078	6895
Sequence 4	6	8	99.22	89.30	9.92	7.90	7.11	0.79	0.0080	0.0078	0.0079	0.00099	7203
Sequence 5	6	10	125.60	113.17	12.43	10.00	9.01	0.99	0.0100	0.0096	0.0098	0.00123	7345
Sequence 6	4	2	25.75	22.98	2.76	2.05	1.83	0.22	0.0030	0.0028	0.0029	0.00036	5093
Sequence 7	4	4	50.87	45.34	5.53	4.05	3.61	0.44	0.0055	0.0053	0.0054	0.00068	5342
Sequence 8	4	6	75.23	68.20	7.03	5.99	5.43	0.56	0.0081	0.0078	0.0079	0.00099	5478
Sequence 9	4	8	99.35	89.43	9.92	7.91	7.12	0.79	0.0098	0.0095	0.0097	0.00121	5896
Sequence 10	4	10	123.97	112.79	11.18	9.87	8.98	0.89	0.0122	0.0117	0.0120	0.00150	6001
Sequence 11	2	2	25.62	22.86	2.76	2.04	1.82	0.22	0.0031	0.0030	0.0031	0.00038	4748
Sequence 12	2	4	49.74	44.59	5.15	3.96	3.55	0.41	0.0059	0.0057	0.0058	0.00072	4898
Sequence 13	2	6	76.11	68.70	7.41	6.06	5.47	0.59	0.0086	0.0084	0.0085	0.00107	5130
Sequence 14	2	8	99.48	89.18	10.30	7.92	7.10	0.82	0.0111	0.0106	0.0109	0.00136	5234
Sequence 15	2	10	125.22	112.91	12.31	9.97	8.99	0.98	0.0125	0.0119	0.0122	0.00153	5894

* Reported results are based on the average of the last 5 cycles of each load sequence

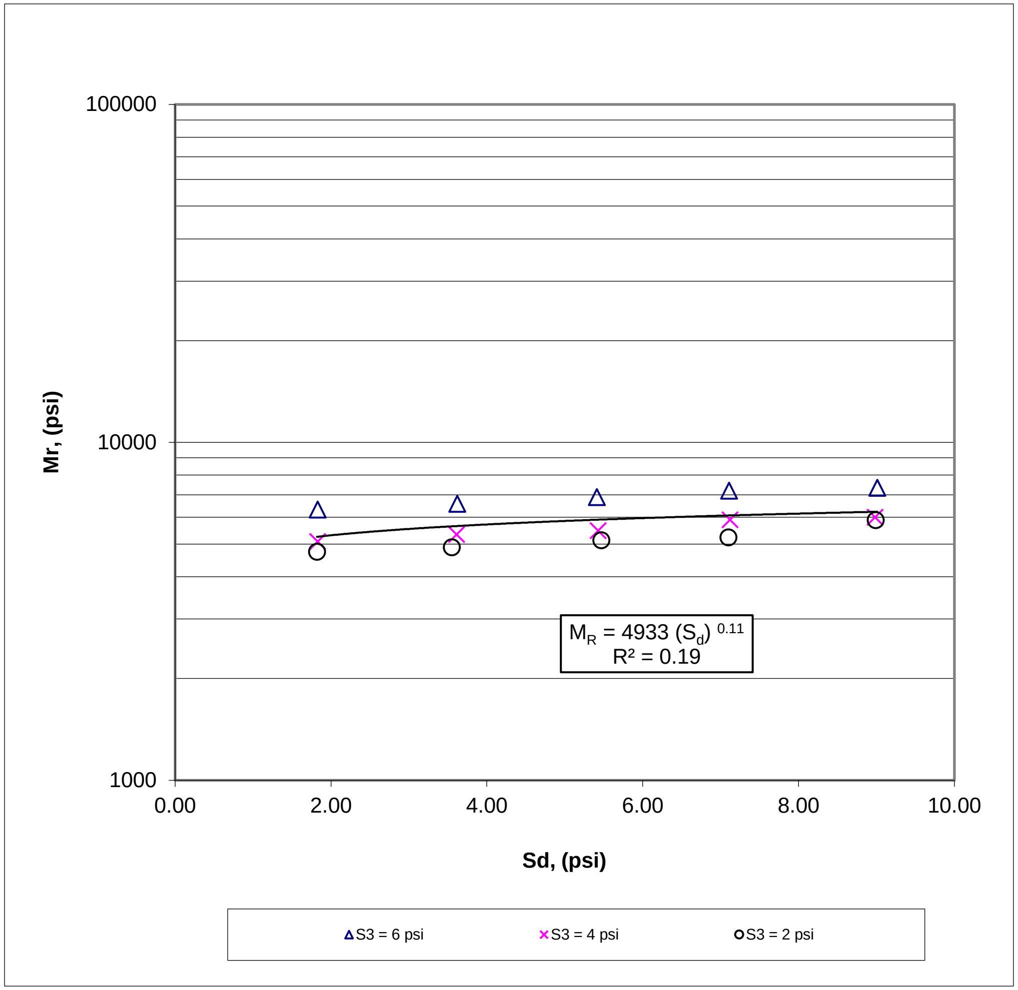
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Littleaxe (Compacted @ OMC+2%)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	B
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.83	6328	**5251**
Sequence 2	6	**3.60**	3.62	6574	**5654**
Sequence 3	6	**5.40**	5.41	6895	**5903**
Sequence 4	6	**7.20**	7.11	7203	**6087**
Sequence 5	6	**9.00**	9.01	7345	**6233**
Sequence 6	4	**1.80**	1.83	5093	**5251**
Sequence 7	4	**3.60**	3.61	5342	**5654**
Sequence 8	4	**5.40**	5.43	5478	**5903**
Sequence 9	4	**7.20**	7.12	5896	**6087**
Sequence 10	4	**9.00**	8.98	6001	**6233**
Sequence 11	4	**1.80**	1.82	4748	**5251**
Sequence 12	4	**3.60**	3.55	4898	**5654**
Sequence 13	4	**5.40**	5.47	5130	**5903**
Sequence 14	4	**7.20**	7.10	5234	**6087**
Sequence 15	4	**9.00**	8.99	5894	**6233**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; $Mr = K1 \times Sd^{K2}$

S3 (psi)	K1	K2	R^2
6	5902	0.10	0.96
4	4719	0.10	0.92
4	4319	0.12	0.78
All	4933	0.11	0.19

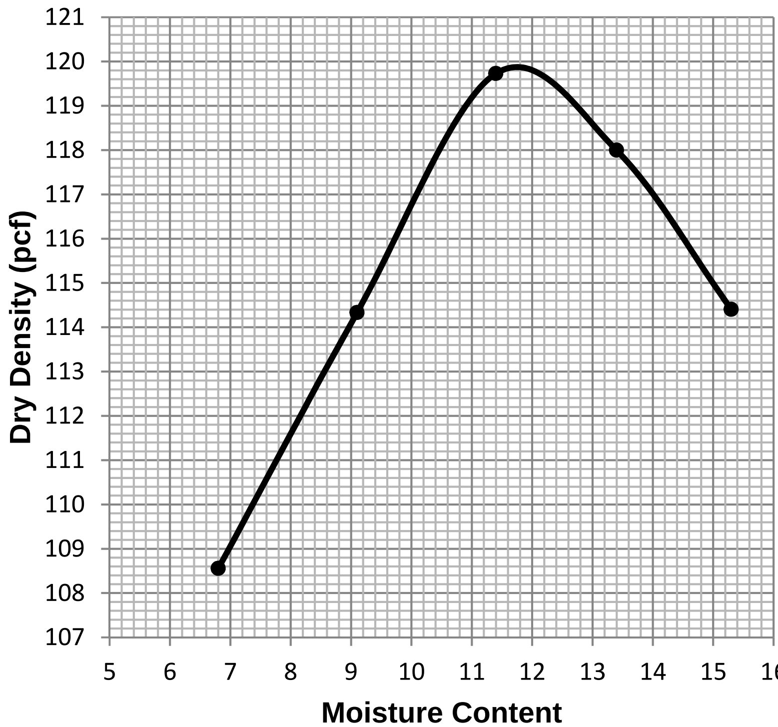
RED ROCK CONSULTING

Proctor

Project #: 18028 Project Name: Pulaski

Tested By: CP Test Date: 06.19.18 Client: SRB Other

Weight of Hammer: 5.5 No. of Blows: 25



Maximum Dry Density (pcf) 119.9

Optimum Moisture Content (%) 11.8

Liquid Limit: 21 USCS SC-SM

Plasticity Index: 4 AASHTO A-4(0)

Method: A Soil Classification: Silty, Clayey Sand

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number SH29 West - 18028
2. County//State Name Stephens County/ Oklahoma
3. Test Date 7/16/2018

4.Sample Number Pulaski (Compacted @ OMC)
5. Material Type 2
6. Soil Series n/a
7. Horizon C

9. Soil Properties

Optimum Moisture Content, (%)	11.80
Maximum Dry Density, pcf	119.90
95% MDD (pcf)	113.91

8. Specimen Properties

Compaction Water content, wc, %	12.01
Compaction Dry Density, pcf	114.87
Moisture Content After Mr Test, w(%)	11.98
Permanent Deformation (in)	0.065

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	25.25	22.86	2.39	2.01	1.82	0.19	0.0012	0.0012	0.0012	0.00015	12094
Sequence 2	6	4	50.37	45.47	4.90	4.01	3.62	0.39	0.0024	0.0024	0.0024	0.00030	11984
Sequence 3	6	6	75.36	68.45	6.91	6.00	5.45	0.55	0.0038	0.0036	0.0037	0.00046	11758
Sequence 4	6	8	99.10	89.18	9.92	7.89	7.10	0.79	0.0051	0.0050	0.0051	0.00063	11203
Sequence 5	6	10	125.73	113.29	12.43	10.01	9.02	0.99	0.0066	0.0064	0.0065	0.00081	11093
Sequence 6	4	2	25.12	22.48	2.64	2.00	1.79	0.21	0.0013	0.0013	0.0013	0.00016	11234
Sequence 7	4	4	51.24	45.47	5.78	4.08	3.62	0.46	0.0027	0.0026	0.0026	0.00033	10989
Sequence 8	4	6	75.11	68.20	6.91	5.98	5.43	0.55	0.0041	0.0040	0.0040	0.00050	10786
Sequence 9	4	8	99.22	89.05	10.17	7.90	7.09	0.81	0.0054	0.0053	0.0053	0.00067	10655
Sequence 10	4	10	125.47	113.17	12.31	9.99	9.01	0.98	0.0071	0.0070	0.0070	0.00088	10233
Sequence 11	2	2	25.25	22.48	2.76	2.01	1.79	0.22	0.0014	0.0013	0.0013	0.00017	10657
Sequence 12	2	4	50.62	44.96	5.65	4.03	3.58	0.45	0.0029	0.0028	0.0028	0.00035	10209
Sequence 13	2	6	75.61	67.95	7.66	6.02	5.41	0.61	0.0044	0.0043	0.0044	0.00055	9898
Sequence 14	2	8	99.73	89.30	10.42	7.94	7.11	0.83	0.0059	0.0057	0.0058	0.00073	9786
Sequence 15	2	10	125.22	112.79	12.43	9.97	8.98	0.99	0.0075	0.0073	0.0074	0.00093	9689

* Reported results are based on the average of the last 5 cycles of each load sequence

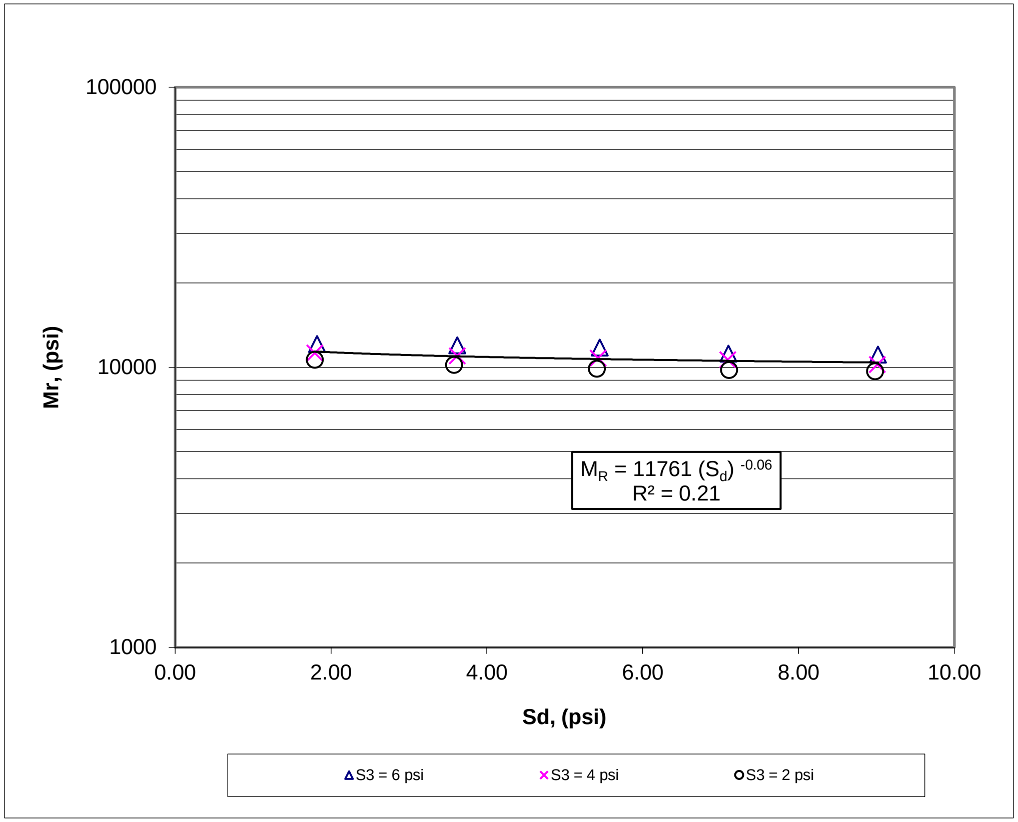
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Pulaski (Compacted @ OMC)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	C
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.82	12094	**11383**
Sequence 2	6	**3.60**	3.62	11984	**10952**
Sequence 3	6	**5.40**	5.45	11758	**10707**
Sequence 4	6	**7.20**	7.10	11203	**10537**
Sequence 5	6	**9.00**	9.02	11093	**10407**
Sequence 6	4	**1.80**	1.79	11234	**11383**
Sequence 7	4	**3.60**	3.62	10989	**10952**
Sequence 8	4	**5.40**	5.43	10786	**10707**
Sequence 9	4	**7.20**	7.09	10655	**10537**
Sequence 10	4	**9.00**	9.01	10233	**10407**
Sequence 11	2	**1.80**	1.79	10657	**11383**
Sequence 12	2	**3.60**	3.58	10209	**10952**
Sequence 13	2	**5.40**	5.41	9898	**10707**
Sequence 14	2	**7.20**	7.11	9786	**10537**
Sequence 15	2	**9.00**	8.98	9689	**10407**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; $Mr = K1 \times Sd^{K2}$

S3 (psi)	K1	K2	R^2
6	12681	-0.06	0.82
4	11670	-0.05	0.88
2	11023	-0.06	0.99
All	11761	-0.06	0.21

Resilient Modulus of Subgrade Soils (Recompacted Samples)

1. Project Number SH29 West - 18028
2. County//State Name Stephens County/ Oklahoma
3. Test Date 7/16/2018

4.Sample Number Pulaski (Compacted @ OMC+2%)
5. Material Type 2
6. Soil Series n/a
7. Horizon C

9. Soil Properties

Optimum Moisture Content, (%)	11.80
Maximum Dry Density, pcf	119.90
95% MDD (pcf)	113.91

8. Specimen Properties

Compaction Water content, wc, %	13.83
Compaction Dry Density, pcf	115.32
Moisture Content After Mr Test, w(%)	13.65
Permanent Deformation (in)	0.28

10. Test Information

Preconditioning-Permanent Strain>5%	No
Testing-Permanent Strain >5%	No
Number of Load Sequences Completed	15
Quick Shear Test	No

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	25.75	22.86	2.89	2.05	1.82	0.23	0.0017	0.0016	0.0017	0.00021	8784
Sequence 2	6	4	50.99	45.47	5.53	4.06	3.62	0.44	0.0037	0.0037	0.0037	0.00046	7847
Sequence 3	6	6	75.23	67.95	7.28	5.99	5.41	0.58	0.0058	0.0058	0.0058	0.00072	7463
Sequence 4	6	8	99.22	89.30	9.92	7.90	7.11	0.79	0.0081	0.0080	0.0080	0.00100	7098
Sequence 5	6	10	125.47	113.17	12.31	9.99	9.01	0.98	0.0107	0.0105	0.0106	0.00133	6787
Sequence 6	4	2	25.50	22.73	2.76	2.03	1.81	0.22	0.0020	0.0020	0.0020	0.00025	7203
Sequence 7	4	4	50.49	45.34	5.15	4.02	3.61	0.41	0.0043	0.0043	0.0043	0.00054	6746
Sequence 8	4	6	74.86	67.70	7.16	5.96	5.39	0.57	0.0071	0.0070	0.0070	0.00088	6138
Sequence 9	4	8	99.35	89.43	9.92	7.91	7.12	0.79	0.0097	0.0096	0.0097	0.00121	5894
Sequence 10	4	10	126.10	113.42	12.69	10.04	9.03	1.01	0.0134	0.0131	0.0132	0.00165	5457
Sequence 11	2	2	25.62	22.86	2.76	2.04	1.82	0.22	0.0021	0.0021	0.0021	0.00026	6883
Sequence 12	2	4	50.24	44.96	5.28	4.00	3.58	0.42	0.0043	0.0042	0.0042	0.00053	6764
Sequence 13	2	6	75.74	68.33	7.41	6.03	5.44	0.59	0.0072	0.0070	0.0071	0.00089	6138
Sequence 14	2	8	99.98	89.55	10.42	7.96	7.13	0.83	0.0102	0.0100	0.0101	0.00126	5674
Sequence 15	2	10	125.98	113.54	12.43	10.03	9.04	0.99	0.0143	0.0139	0.0141	0.00176	5139

* Reported results are based on the average of the last 5 cycles of each load sequence

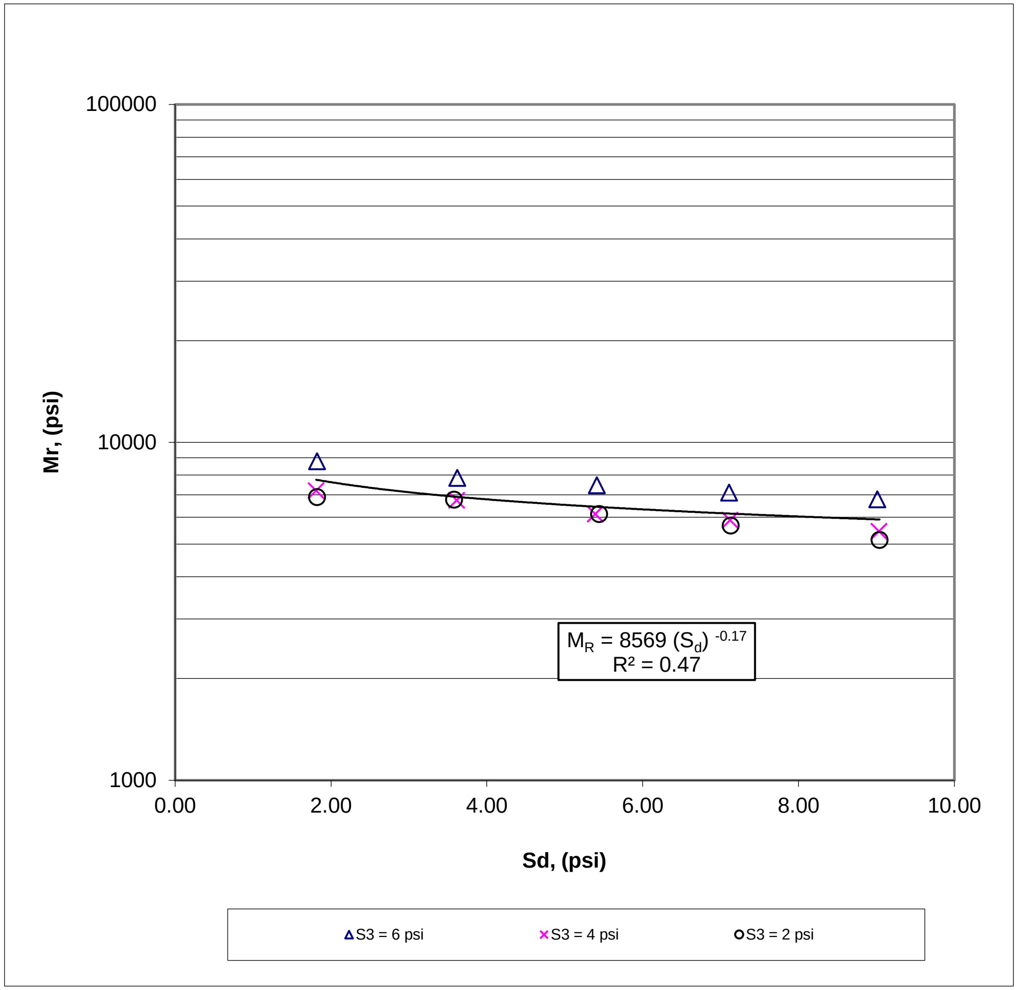
Resilient Modulus of Subgrade Soils (Recompacted Samples)

(Plot)

1. Sample Number	Pulaski (Compacted @ OMC+2%)
2. Material Type	2
3. Soil Series	n/a
4. Horizon	C
5. Test Date	7/16/2018

Column #	1	**2**	3	4	**5**
Parameter	Chamber Confining Pressure	**Desired Applied Cyclic Stress**	Actual Applied Cyclic Stress	Actual Resilient Modulus	**Predicted Resilient Modulus***
Designation	S3	**Scyclic**	Scyclic	Mr	**Mr**
Unit	psi	**psi**	psi	psi	**psi**
Precision	—	**—**	—	—	**—**
Sequence 1	6	**1.80**	1.82	8784	**7761**
Sequence 2	6	**3.60**	3.62	7847	**6905**
Sequence 3	6	**5.40**	5.41	7463	**6450**
Sequence 4	6	**7.20**	7.11	7098	**6144**
Sequence 5	6	**9.00**	9.01	6787	**5918**
Sequence 6	4	**1.80**	1.81	7203	**7761**
Sequence 7	4	**3.60**	3.61	6746	**6905**
Sequence 8	4	**5.40**	5.39	6138	**6450**
Sequence 9	4	**7.20**	7.12	5894	**6144**
Sequence 10	4	**9.00**	9.03	5457	**5918**
Sequence 11	4	**1.80**	1.82	6883	**7761**
Sequence 12	4	**3.60**	3.58	6764	**6905**
Sequence 13	4	**5.40**	5.44	6138	**6450**
Sequence 14	4	**7.20**	7.13	5674	**6144**
Sequence 15	4	**9.00**	9.04	5139	**5918**

*Predicted Mr values at the desired applied cyclic stresses using Model



Model #1; $Mr = K1 \times Sd^{K2}$

S3 (psi)	K1	K2	R^2
6	9661	-0.16	1.00
4	8132	-0.17	0.95
4	8010	-0.18	0.84
All	8569	-0.17	0.47

APPENDIX G

Abrasion and Corrosion Rating Table

CORROSION STRESS MAP

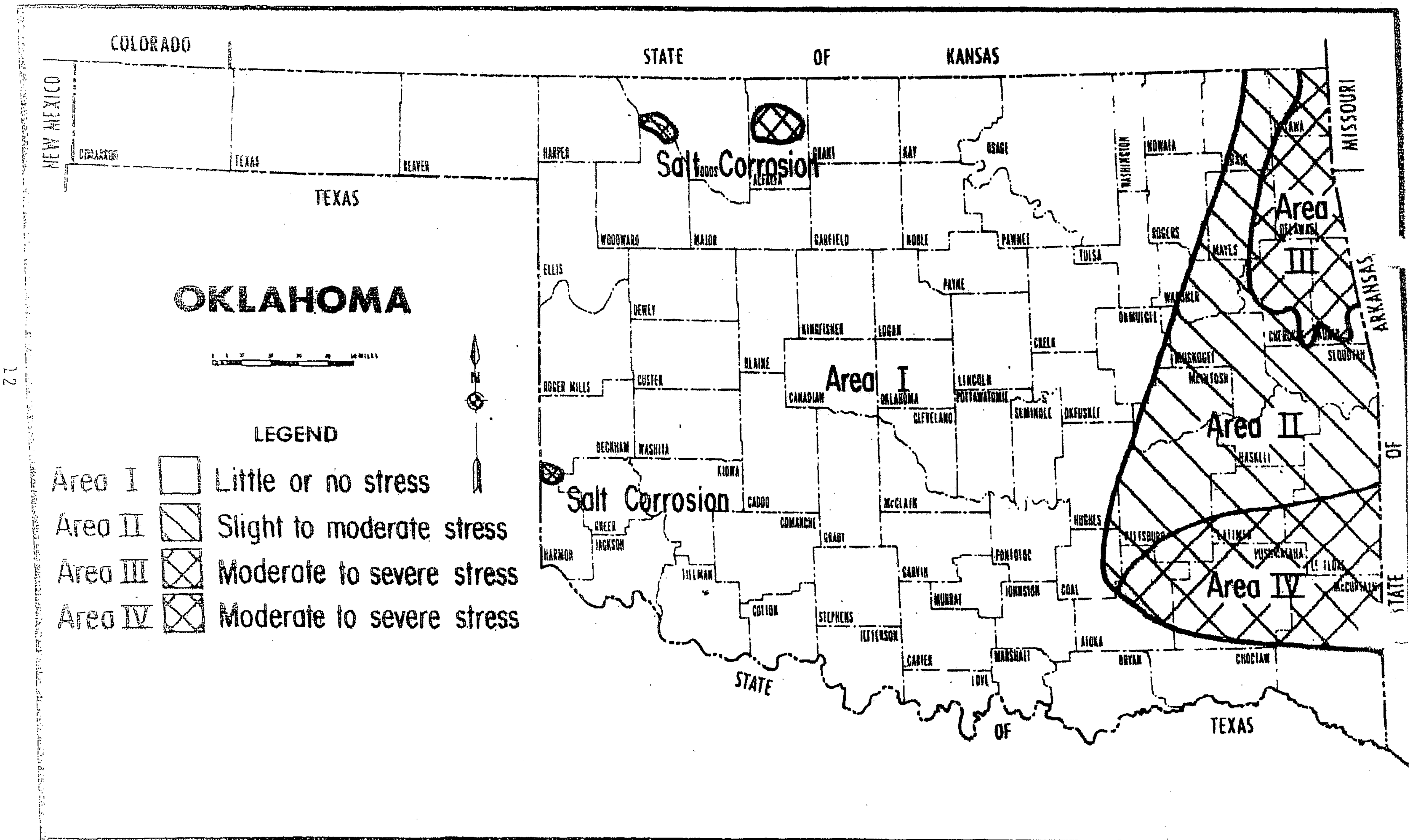


Figure 1. Map showing areas in Oklahoma where potential steel pipe culvert corrosion exists.

PIPE ALTERNATIVES

The following procedure should be used when determining the types of pipe allowed for each use:

(1) Evaluate a) Soil type at the structure, b) Abrasion characteristics of the stream bed, c)Area of the state for Corrosion Regions

(2) Enter the Abrasion / Corrosion Rating Chart with this data and pick the rating which best depicts the site conditions. (Note: When (a) and (c) are in conflict, use the more conservative ratings)

(3) Enter the Allowable Pipe Types Chart and obtain the types of pipes allowed for each catagory of the Abrasion / Corrosion Rating.

(4) When more than one type of pipe is allowable, show these structures as one type but include payitem notes stating which other types may be substituted and the special requirements for such a substitution. Example note: "corrugated Polyethylene Pipe may be substituted for Reinforced Concrete Pipe. Construction shall be in accordance with the 'Flexible Pipe Installation' detail sheet."

ABRASION / CORROSION RATING

SOIL TYPE	SITE ABRASION CHARACTERISTICS: NONABRASIVE V = VERY LOW NO BED LOAD	LOW ABRASIVE V < 5 F.P.S. MINOR BED LOADS OF SAND	MODERATELY ABRASIVE V = 5 - 15 F.P.S. MODERATE BED LOADS OF SAND OR GRAVEL	SEVERELY ABRASIVE V > 15 F.P.S. HEAVY BED-LOADS OF SAND, GRAVEL, OR ROCK	CORROSION REGION (AS DEPICTED IN FIGURE 1a OF TECH MANUAL)
(RESISTIVITY > 6,000 Ω/CM) LITTLE OR NO CORROSION 1) SANDS OR SANDY LOAMS 2) LIGHT TEXTURED SILT LOAMS 3) POROUS OR CLAY LOAMS (OXIDIZED) W/GOOD DRAINAGE CHARACTERISTICS	1	2	3	4	AREA I
(RESIST.=4,500 Ω/CM - 6,000 Ω/CM) SLIGHT CORROSION 1) SANDY LOAMS 2) SILT LOAMS 3) CLAY LOAMS W/FAIR DRAINAGE CHARACTERISTICS	5	6	7	8	AREA I
(RESIST.=2,000 Ω/CM - 4,500 Ω/CM) MODERATE CORROSION 1) CLAY LOAMS 2) CLAYS W/POOR DRAINAGE CHARACTERISTICS	9	10	11	12	AREA II
(RESISTIVITY < 2,000 Ω/CM) SEVERE CORROSION 1) MUCK 2) PEAT 3) CLAYS & ORGANIC SOILS W/VERY POOR DRAINAGE CHARACTERISTICS	13	14	15	16	AREA III & IV

Table 1 – Typical Soil Resistivities

Classification	Resistivity Ohm-cm
Clay	750 - 2000
Loam	2000 - 10000
Gravel	10000 - 30000
Sand	30000 - 50000
Rock	50000 - Infinity*

* Theoretical

Table 2 – Corrosiveness of Soils

Soil Type	Description of Soil	Aeration	Drainage	Color	Water Table
I - Lightly Corrosive	1. Sands or Sandy Loams 2. Light Textured Silt Loams 3. Porus Loams or Clay Loams Thoroughly Oxidized to Great Depths	Good	Good	Uniform Color	Very Low
II - Moderately Corrosive	1. Sandy Loams 2. Silt Loams 3. Clay Loams	Fair	Fair	Slight Mottling	Water Table
III - Badly Corrosive	1. Clay Loams 2. Clays	Poor	Poor	Heavy Texture Moderate Mottling	Water Table
IV - Unusually Corrosive	1. Muck 2. Peat 3. Tidal Marsh 4. Clays and Organic Soils	Very Poor	Very Poor	Bluish-Gray Mottling	Water Table

FIGURE 1

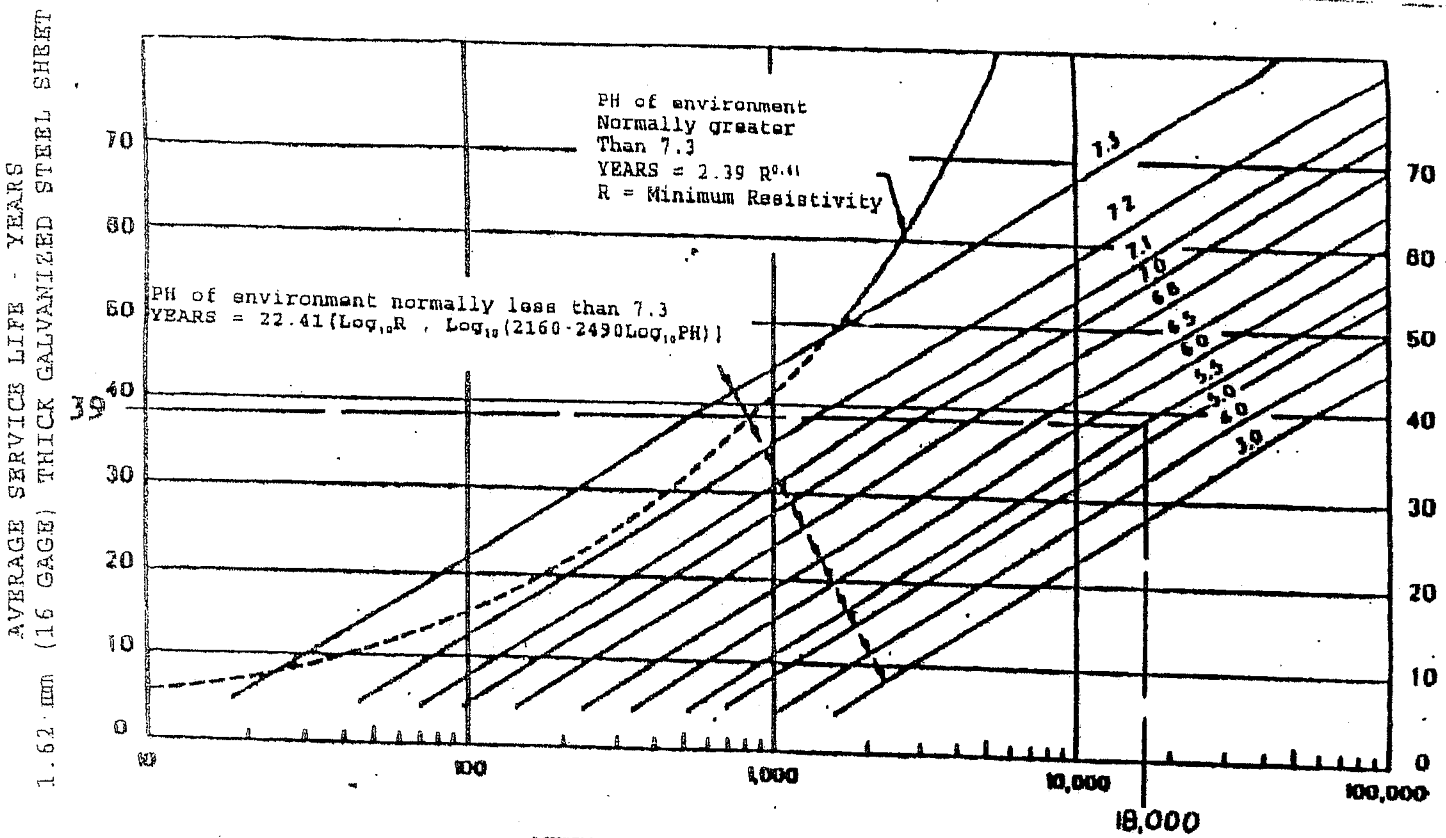


FIGURE 1 - FOR ESTIMATING AVERAGE SERVICE LIFE OF PLAIN GALVANIZED CULVERTS

Thickness, mm	.321	1.62	2.00	2.77	3.50	4.27
Thickness, in	0.052	0.064	0.079	0.109	0.138	0.168
Gage	18	16	14	12	10	8
Factor*	0.8	1.0	1.2	1.7	2.2	2.6

Notes:

1. The curves in this graph are based on the data in FHWA-FLP-91-006 which uses the factors in California Test 643, "Method for Estimating the Service Life of Steel Culverts". These factors increased the estimated service life by 25% after first perforation.

2. The graph has also been modified to reflect a minimum metal thickness of 1.62 mm (16 gaga).

3. Under conditins with 5<PH<9, and R≥1500 Ω-cm, the average service life determined for plain galvanized culverts should be multiplied by 2.0 for aluminized type II.