July 16, 2015

Holloway, Updike, and Bellen, Inc.
818 East Side Boulevard
P.O. Box 1543
Muskogee, Oklahoma 74402

Attn: Mr. Terry Eddings, P.E.

Re: Geotechnical Engineering Report
SH-9 Bridge over Wewoka Creek
Hughes County, Oklahoma
Job Piece No. 28857(04)
Terracon Project Number: 04125055

Dear Mr. Eddings:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with our proposal number P04110389 dated August 24, 2011. This report presents the findings of the subsurface exploration and provides geotechnical recommendations for the design and construction of bridge foundations as related to the subsurface conditions encountered at the borings.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,

Terracon Consultants, Inc.

Cert. of Auth. #CA-4531 exp. 6/30/17

Vaughn Rupnow, P.E.
Oklahoma No. 25692

Michael H. Homan, P.E.
Regional Manager

VR/MHH:lo
Enclosures
Addressee (3 via US Mail and 1 via email)
TABLE OF CONTENTS

1.0 INTRODUCTION ................................................................................................. 1

2.0 PROJECT INFORMATION .................................................................................... 1
   2.1 Project Description ....................................................................................... 1
   2.2 Site Location and Description ..................................................................... 1

3.0 SUBSURFACE CONDITIONS ............................................................................ 2
   3.1 Geology ......................................................................................................... 2
   3.2 Soil and Rock Conditions ............................................................................ 2
   3.3 Groundwater ................................................................................................ 2

4.0 BRIDGE FOUNDATION CONSIDERATIONS .................................................... 3
   4.1 Driven Piles ................................................................................................. 3
   4.2 Drilled Piers .............................................................................................. 4

5.0 GENERAL COMMENTS .................................................................................... 4

APPENDIX A – FIELD EXPLORATION
   Exhibit A-1 Site Location Map
   Exhibit A-2 Boring Location Plan
   Exhibit A-3 Field Exploration Description
   Exhibit A-4 to A-8 Boring Logs
   Exhibit A-9 Subsurface Profile

APPENDIX B – SUPPORTING INFORMATION
   Exhibit B-1 Laboratory Testing

APPENDIX C – SUPPORTING DOCUMENTS
   Exhibit C-1 General Notes
   Exhibit C-2 Unified Soil Classification System
   Exhibit C-3 General Notes – Description of Rock Properties
1.0 INTRODUCTION

This geotechnical engineering report has been completed for the proposed SH-9 Bridge over Wewoka Creek in Hughes County, Oklahoma. Five borings were extended to depths of approximately 44 to 64 feet below existing ground surface. The boring logs and boring location plan showing the approximate boring locations are found in Appendix A.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil and rock conditions
- groundwater conditions
- bridge foundations

2.0 PROJECT INFORMATION

2.1 Project Description

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site layout</td>
<td>See Appendix A, Figure A-2 Boring Location Diagram</td>
</tr>
<tr>
<td>Proposed Construction</td>
<td>New three-span bridge along an offset alignment south of the existing bridge. The interior bent locations will be supported on drilled piers, and the abutments will be supported on driven piles.</td>
</tr>
</tbody>
</table>

2.2 Site Location and Description

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>SH-9 at Wewoka Creek crossing in Hughes County, Oklahoma</td>
</tr>
</tbody>
</table>
3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on the results of our borings and information published in the Oklahoma Department of Transportation manual, “Engineering Classification of Geologic Materials: Division 8”, manual maps this project as Alluvium soil deposits underlain by the Calvin Unit. The Calvin Unit is comprised of an upper sandstone formation, a middle shale sequence, and a lower sandstone complex.

3.2 Soil and Rock Conditions

The subsurface conditions encountered in the borings are shown on the boring logs and are briefly described below. The stratification lines shown on the boring logs represent the approximate boundary between soil and rock types; in-situ, the transition between materials may be gradual and indistinct. Classification of bedrock materials was made from disturbed samples and rock cores. Petrographic analysis may reveal other rock types.

<table>
<thead>
<tr>
<th>Description</th>
<th>Approximate Depth to Bottom of Stratum</th>
<th>Material Encountered</th>
<th>Consistency/Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratum 1</td>
<td>13 to 33 feet</td>
<td>Fat clay, lean clay, and silty clay with varying amounts of sand, clayey sand, silty sand</td>
<td>Clay: Very soft to very stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sand: Medium dense</td>
</tr>
<tr>
<td>Stratum 2</td>
<td>Boring termination depths of 44 to 64 feet</td>
<td>Interbedded shale and sandstone</td>
<td>Shale: Soft to Hard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sandstone: Well cemented</td>
</tr>
</tbody>
</table>

Laboratory tests were conducted on selected soil and rock core samples. The test results are presented on the boring logs in Appendix A.

3.3 Groundwater

Below depths of about 10 to 18.6 feet, we advanced the borings using wet rotary drilling techniques. After completion of the borings, water was bailed from the boreholes. We observed groundwater at the following depths and times:
Long-term monitoring with observation wells, sealed from the influence of surface water, would be required to accurately define the potential range of groundwater conditions. Fluctuations in the groundwater level should be expected due to seasonal variations in the amount of rainfall, runoff, water level in the creek and other factors not apparent at the time the borings were drilled. The possibility of groundwater level fluctuations and the presence of perched water should be considered when designing and developing the construction plans for the project.

4.0 BRIDGE FOUNDATION CONSIDERATIONS

Driven pile foundations can be used to support the bridge abutments and drilled piers can be used to support the interior bents.

The bedrock bearing materials were encountered at the following depths/elevations:

<table>
<thead>
<tr>
<th>Boring</th>
<th>Top of Bedrock Bearing Material (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth</td>
</tr>
<tr>
<td>B-1</td>
<td>33</td>
</tr>
<tr>
<td>B-2</td>
<td>33</td>
</tr>
<tr>
<td>B-3</td>
<td>18.5</td>
</tr>
<tr>
<td>B-3A</td>
<td>18</td>
</tr>
<tr>
<td>B-4</td>
<td>13</td>
</tr>
</tbody>
</table>

4.1 Driven Piles

Driven steel HP piles driven to practical refusal in the shale or sandstone bedrock can be used to support the abutments. According to AASHTO’s LRFD Bridge Design Specifications, the nominal resistance of piles driven to bear on hard rock where pile penetration into the rock formation is minimal is controlled by the structural limit state of the pile. Pile capacity will
depend on the cross-section and the steel grade. The piles could be designed using a maximum working stress in the pile of 25 percent of the steel's yield strength.

Pile driving through the native overburden soils is not expected to be difficult based on the results of the borings. However, variations can occur in the density and strength of the soil and the depth and quality of the bedrock. Because of the high driving resistance anticipated in the bedrock materials, we recommend that the piles be equipped with driving tips that can endure high driving stresses.

Piles should be installed in accordance with Section 514 of ODOT’s Standard Specifications for Highway Construction. All piles should be driven until satisfactory driving resistance is developed for the design load bearing capacity using an appropriate pile driving formula approved by ODOT. In the event sufficient driving resistance is encountered before reaching the anticipated tip elevations, pile driving could be terminated provided it appears the pile has penetrated approximately 1 foot into the bedrock.

Driven pile foundations designed and constructed as recommended above are expected to experience total settlements less than 1 inch.

### 4.2 Drilled Piers

We recommend drilled piers bear in the shale or sandstone bedrock. We understand a bridge engineer will design drilled piers based on the Texas Cone penetrometer values provided on the attached boring logs.

A heavy-duty drill rig equipped with a rock auger will be required to penetrate the bedrock. Cemented sandstone layers may require special drilling methods such as coring.

Based on the results of the borings, casing will be required to maintain open pier excavations and control water inflow. To facilitate pier construction, concrete should be on-site and ready for placement as pier excavations are completed. A sufficient head of concrete should be maintained in the casing as it is being pulled to prevent an influx of soft soil or water into the excavations. Also, concrete having a slump of at least 5 inches should be used to prevent the concrete from arching in the casing.

### 5.0 GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide observation and
testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

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

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.
APPENDIX A
FIELD EXPLORATION
SITE LOCATION MAP

GEOTECHNICAL EXPLORATION

SH-9 OVER WEOWOCA CREEK

HUGHES COUNTY, OKLAHOMA

APPROXIMATE SITE LOCATION

APPROXIMATE SCALE IN FEET
Field Exploration Description

The borings were performed at the approximate locations shown on the Boring Location Plan in this Appendix. The borings locations and elevations were provided in the field by Holloway, Updike, and Bellen.

The borings were advanced with an all-terrain rotary drill rig using wash boring techniques. Temporary casing was used to support the side walls of the upper portion of the bore holes. Representative samples were obtained by the split-barrel sampling procedure in which a standard 2-inch, O.D. split-barrel sampling spoon that is driven into the bottom of the boring with a 140-pound drive hammer falling 30 inches. The number of blows required to advance the sampling spoon the last 12 inches, or less, of an 18-inch sampling interval or portion thereof, is recorded as the standard penetration resistance value, N. The N value is used to estimate the in-situ relative density of granular soils and, to a lesser degree of accuracy, the consistency of cohesive soils and the hardness of weathered bedrock. The sampling depths, penetration distances, and N values are reported on the boring logs. The samples were tagged for identification, sealed to reduce moisture loss and returned to the laboratory for further examination, testing and classification.

The bedrock in the borings was tested using the Texas Highway Department (THD) cone penetrometer test. The THD cone penetrometer test is a standard test developed by the Texas Highway Department to determine the strength and hardness of foundation materials in bridge foundation exploration work. The test is performed by attaching a 3-inch diameter penetrometer cone to the drill stem and lowering it to the bottom of the borehole. The cone is seated, and then driven 12 inches with a 140-pound drive hammer falling 30 inches. The number of blows required for each 6-inch increment is recorded. If more than 100 blows are required for 12 inches of penetration, the penetration per 50 blows are recorded to the nearest 1/16 inch. The results of this test are shown on the boring logs.

An automatic drive hammer was used to advance the split-barrel and THD cone penetrometer. A greater efficiency is achieved with the automatic drive hammer compared to the conventional safety drive hammer operated with a cathead and rope.

Core samples of bedrock materials were obtained using an NX-size diamond-bit core barrel. The percentages of rock core recovered (%REC) and Rock Quality Designation (RQD) per length of core run are shown on the boring logs. The RQD is an index obtained by summing the lengths of rock core pieces that are 4 inches in length or longer divided by the total length of core run. The percent recovery and RQD values are shown on the boring logs in Appendix A.

The drilling operation was supervised by a field engineer, who prepared field logs. The boring logs include visual classifications of the materials encountered during drilling and the engineer’s interpretation of subsurface conditions between samples. Based on the material’s texture, the soil samples were described according to the attached General Notes and classified in
accordance with the Unified Soil Classification System. A brief description of the Unified System is included in Appendix C. Rock descriptions are in general accordance with the General Notes for Sedimentary Rock. Petrographic analysis may reveal other rock types.

As required by the Oklahoma Water Resources Board, any borings deeper than 20 feet, or borings which encounter groundwater or contaminated materials must be grouted or plugged in accordance with Oklahoma State statutes. One boring log must also be submitted to the Oklahoma Water Resources Board for each 10 acres of project site area. Terracon backfilled the borings to comply with the Oklahoma Water Resources Board requirements.
FAT CLAY, dark yellowish-brown (10YR,3/6), medium stiff
- becoming stiff, trace fine sand below 5 feet

SANDY LEAN CLAY, dark yellowish-brown (10YR,4/4), soft to medium stiff

CLAYEY SAND, gray (10YR,6/1) and yellowish-brown (10YR,5/6), medium dense, fine-grained

SANDY SILTY CLAY, gray (5/N,GLEY1), soft

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 165+75</td>
<td>Offset: 0'</td>
</tr>
<tr>
<td>Surface Elev.: 707.8 (FL)</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>GRAPHIC LOG</th>
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</thead>
<tbody>
<tr>
<td>689.5</td>
<td>18.5</td>
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<tr>
<td>684.5</td>
<td>23.5</td>
</tr>
<tr>
<td>699.5</td>
<td>3.5</td>
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<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>ELEVATION (FL)</th>
</tr>
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<tbody>
<tr>
<td>699.5</td>
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<thead>
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<th>WATER LEVEL OBSERVATIONS</th>
<th>RECOVERY (In.)</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
</tr>
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<tbody>
<tr>
<td>1-2-4 N=6</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>1-2-4 N=6</td>
<td>39</td>
<td>92-28-64 98</td>
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<tr>
<td>2-6-8 N=14</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>4-4-4 N=8</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>0-2-2 N=4</td>
<td>24</td>
<td>36-14-22 66</td>
</tr>
<tr>
<td>5-7-5 N=12</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>2-2-2 N=4</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERCENT FINES</th>
<th>LL-PL-PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>66</td>
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<tr>
<td>39</td>
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<tr>
<td>33</td>
<td>66</td>
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<tr>
<td>15</td>
<td>66</td>
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<td>24</td>
<td>66</td>
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<tr>
<td>25</td>
<td>66</td>
</tr>
<tr>
<td>21</td>
<td>66</td>
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</tbody>
</table>

Stratification lines are approximate. In-situ, the transition may be gradual.

<table>
<thead>
<tr>
<th>EXHIBIT: A-3</th>
<th>Description of field procedures.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-4</td>
<td>See Appendix B for description of laboratory procedures and additional data (if any).</td>
</tr>
<tr>
<td>A-4</td>
<td>See Appendix C for explanation of symbols and abbreviations.</td>
</tr>
</tbody>
</table>

Notes:

Advancement Method:
- Power Auger to 10 feet
- Wash Boring below 10 feet
- Rock Bit below 33.5 feet

Abandonment Method:

Hammer Type: Automatic
+ Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Terriacan
9228 East 47th Place, Unit D
Tulsa, Oklahoma

Project No.: 04125055
Exhibit: A-4

Boring Started: 6/11/2015
Boring Completed: 6/11/2015
Drill Rig: ATV 910
Driller: AS
**BORING LOG NO. B-1**

**PROJECT:** SH-9 over Wewoka Creek  
**SITE:** Hughes County, Oklahoma

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>SAMPLE TYPE</th>
<th>RECOVERY (in.)</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMpressive STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>33.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LOCATION**  
Station: 165+75  
Offset: 0’

**DEPTH**  
Surface Elev.: 707.8 (Ft.)

**SANDY SILTY CLAY**, gray (5/N, GLEY1), soft (continued)

**SILTY SAND**, light brownish-gray (10YR, 6/2), medium dense, fine-grained

**INTERBEDDED SHALE AND SANDSTONE**, dark gray (4/N, GLEY1), soft, well cemented

**Notes:**
- Advancement Method:  
  - Power Auger to 10 feet  
  - Wash Boring below 10 feet  
  - Rock Bit below 33.5 feet

- Abandonment Method:
  - 9522 East 47th Place, Unit D  
  - Tulsa, Oklahoma

- Hammer Type: Automatic  
  - Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

- Stratification lines are approximate. In-situ, the transition may be gradual.

**Hammer Type:** Automatic

**Exhibit:** A-3 for description of field procedures.  
See Appendix B for description of laboratory procedures and additional data (if any).  
See Appendix C for explanation of symbols and abbreviations.

**FIELD TEST RESULTS**

- WATER CONTENT (%)
- ATTERBERG LIMITS
- PERCENT FINES

**PERCENT FINES**

- LL-PL-PI

**WATER CONTENT (%)**

- N=17
- 22

**ATTERBERG LIMITS**

- 50/6°
- 15

**FIELD TEST RESULTS**

- UNCONFINED COMpressive STRENGTH (psi)

- 50/13/16°
- 50/3/16°

- 50/11/16°
- 50/1/4°

- 50/9/16°
- 50/1/16°

- 50/3/16°
- 50/3/8°

- 50/3/8°

**WATER LEVEL OBSERVATIONS**

- Not encountered to 10 feet while drilling

- 14 ft After Boring

**Boring Started:** 6/11/2015  
**Boring Completed:** 6/11/2015

**Drill Rig:** ATV 910  
**Driller:** AS

**Project No.:** 04125055  
**Exhibit:** A-4

**GEO SMART LOG-NO WELL 04125055 - 2015.GPJ**
INTERBEDDED SHALE AND SANDSTONE+, dark gray
(4/N,GLEY1), soft, well cemented (continued)
- becoming hard below 53.5 feet

Boring Terminated at 64 Feet

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>SAMPLE TYPE</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
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<tbody>
<tr>
<td>50/1/2&quot;</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>50/1/8&quot;</td>
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<td>50/7/16&quot;</td>
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</table>

Surface Elev.: 707.8 (Ft.)

Notes:
Abandonment Method:
- Power Auger to 10 feet
- Wash Boring below 10 feet
- Rock Bit below 33.5 feet

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.
### BORING LOG NO. B-2

**PROJECT:** SH-9 over Wewoka Creek  
**CLIENT:** Holloway, Updike & Bellen

**SITE:** Hughes County, Oklahoma

#### GRAPHIC LOG

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
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<tbody>
<tr>
<td>Station: 167+15 Offset: 21' RT</td>
<td>Surface Elev.: 678.4 (Fl)</td>
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</table>

<table>
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<tr>
<th>DEPTH (Ft)</th>
<th>ELEVATION (Fl)</th>
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</thead>
<tbody>
<tr>
<td>2.0</td>
<td>676.5</td>
</tr>
<tr>
<td>5.0</td>
<td>673.5</td>
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<td>13.5</td>
<td>665</td>
</tr>
<tr>
<td>18.5</td>
<td>660</td>
</tr>
<tr>
<td>23.5</td>
<td>655</td>
</tr>
</tbody>
</table>

#### WATER LEVEL OBSERVATIONS

- **FAT CLAY** dark yellowish-brown (10YR,4/6) and dark brown (10YR,3/6), medium stiff
- **LEAN CLAY** trace fine sand, dark yellowish-brown (10YR,4/4), stiff to very stiff
- **LEAN CLAY** with sand, brown (10YR,4/3), medium stiff
- **LEAN CLAY** trace fine sand, yellowish-brown (10YR,5/4) and strong brown (7.5YR,5/6), stiff
- **SANDY LEAN CLAY** gray (5/1,5y), very soft

#### FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>RECOVERY (in.)</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
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<tbody>
<tr>
<td>1-2-4</td>
<td>N=6</td>
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<tr>
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<td>N=1</td>
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</tbody>
</table>

#### Notes:
- Advancement Method: Power Auger to 10 feet, Wash Boring below 10 feet, Rock Bit below 33 feet.
- Abandonment Method: 9522 East 47th Place, Unit DT, Tulsa, Oklahoma.
- Hammer Type: Automatic, +Classification estimated from disturbed samples, Core samples and petrographic analysis may reveal other rock types.
- Stratification lines are approximate. In-situ, the transition may be gradual.

#### WATER LEVEL OBSERVATIONS

- Not encountered to 10 feet while drilling
- 12 ft After Boring

---

**THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEC SMART LOG NO. WELL 04125055 - 2015.GPJ**

---

**PROJECT:** SH-9 over Wewoka Creek  
**SITE:** Hughes County, Oklahoma

---

**DRILLER:** AS  
**DRILL RIG:** ATV 910  
**BORING COMPLETED:** 6/11/2015

---

**TERRA CON**

**9222 East 47th Place, Unit D**  
**Tulsa, Oklahoma**

**Project No:** 04125055  
**Exhibit:** A-5
**SANDY LEAN CLAY**, gray (5/1,5y), very soft (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (Ft.)</th>
<th>Sample Type</th>
<th>Field Test Results</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>LL-PL-PI</th>
<th>Per cent Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.5</td>
<td>650</td>
<td></td>
<td>4-7-29 N=36</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SAND**, light brownish-gray (10YR,6/2), dense, fine to medium-grained

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (Ft.)</th>
<th>Sample Type</th>
<th>Field Test Results</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>LL-PL-PI</th>
<th>Per cent Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.0</td>
<td>645.5</td>
<td></td>
<td>50/3&quot;</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INTERBEDDING SHALE AND SANDSTONE**, dark gray (4/N, GLEY1), soft to hard, well cemented

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth (Ft.)</th>
<th>Sample Type</th>
<th>Field Test Results</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>LL-PL-PI</th>
<th>Per cent Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/7/16&quot;</td>
<td>50/1/16&quot;</td>
<td></td>
<td>50/9/16&quot;</td>
<td>50/3/16&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Stratification lines are approximate. In-situ, the transition may be gradual.
- Hammer Type: Automatic
- Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**FIELD TEST RESULTS**

- **PERCENT FINES**
- **WATER CONTENT (%)**
- **ATTERBERG LIMITS**

**WATER LEVEL OBSERVATIONS**
- Not encountered to 10 feet while drilling
- 12 ft After Boring

**ADVANCEMENT METHOD:**
- Power Auger to 10 feet
- Wash Boring below 10 feet
- Rock Bit below 33 feet

**ABANDONMENT METHOD:**
- Boring Started: 6/10/2015
- Boring Completed: 6/11/2015
- Drill Rig: ATV 910
- Driller: AS

**HOLLOWAY, UPDIKE & BELLON**
- Hughes County, Oklahoma
- Site: 678.4 (Ft.)
- Location: See Exhibit A-2

**PROJECT:** SH-9 over Wewoka Creek

**CLIENT:** Holloway, Updike & Bellen
LOCATION
Station: 167+15 Offset: 21' RT
Surface Elev.: 678.4 (Ft.)

DEPTH
ELEVATION (FT)
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0

INTERBEDDED SHALE AND SANDSTONE+, dark gray
(4/N.GLEY1), soft to hard, well cemented (continued)

Boring Terminated at 64 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
Power Auger to 10 feet
Wash Boring below 10 feet
Rock Bit below 33 feet

Abandonment Method:

Notes:
See Exhibit A-3 for description of field procedures.
See Appendix B for description of laboratory procedures and additional data (if any).
See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS
Not encountered to 10 feet while drilling
12 ft After Boring
**BORING LOG NO. B-3**

**PROJECT:** SH-9 over Wewoka Creek

**SITE:** Hughes County, Oklahoma

**LOCATION**
- Station: 168+54 Offset: 21' LT
- Surface Elev.: 691.6 (Fl)

**SANDY LEAN CLAY**
- dark yellowish-brown (10YR,4/4), very soft to soft

**SILTY CLAY**
- trace fine sand, dark yellowish-brown (10YR,4/4), very soft

**SILTY CLAY**
- trace fine sand, grayish-brown (10YR,5/2), soft

**WEATHERED SHALE+**
- dark gray (4/N,GLEY1), hard

**SHALE+**
- with gray (5/N,GLEY1) sandstone seams, dark gray (4/N,GLEY1), soft to hard

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>RECOVERY (IN)</th>
<th>UNDRAINED COMpressive STRENGTH (PSI)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>50/1&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-0-1</td>
<td>1-0-0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-0-0</td>
<td>0-0-0</td>
<td>N=0</td>
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<td></td>
<td></td>
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<tr>
<td>0-1-1</td>
<td>0-1-1</td>
<td>N=2</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>20</td>
<td>RECOVERY (IN)</td>
<td></td>
<td>UNDRAINED COMpressive STRENGTH (PSI)</td>
<td>WATER CONTENT (%)</td>
<td>ATTERBERG LIMITS</td>
<td>LL-PL-PI</td>
<td>PERCENT FINES</td>
</tr>
<tr>
<td>0-0-1</td>
<td>1-0-0</td>
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</tr>
<tr>
<td>2.0</td>
<td>10 ft After One Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.5</td>
<td>678</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.5</td>
<td>673</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>RECOVERY (IN)</td>
<td></td>
<td>UNDRAINED COMpressive STRENGTH (PSI)</td>
<td>WATER CONTENT (%)</td>
<td>ATTERBERG LIMITS</td>
<td>LL-PL-PI</td>
<td>PERCENT FINES</td>
</tr>
<tr>
<td>25</td>
<td>10 ft After One Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>10 ft After One Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>10 ft After One Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Notes:**
- Advancement Method:
  - Power Auger to 18.6 feet
  - Rock Bit below 18.6 feet
  - Diamond bit below 20 feet
- Abandonment Method:
  - See Exhibit A-3 for description of field procedures.

**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>WATER LEVEL OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5</td>
<td>9.5 ft While Drilling</td>
</tr>
<tr>
<td>13.5</td>
<td>10 ft After One Day</td>
</tr>
<tr>
<td>18.5</td>
<td>10 ft After One Day</td>
</tr>
</tbody>
</table>

**Field Test Results**

- Water Level
  - 9.5 ft After Boring
  - 10 ft After One Day

**Hammer Type:** Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Notes:**
- Advancement Method:
  - Power Auger to 18.6 feet
  - Rock Bit below 18.6 feet
  - Diamond bit below 20 feet
- Abandonment Method:
  - See Exhibit A-3 for description of field procedures.

**WATER LEVEL OBSERVATIONS**

- Water Level
  - 9.5 ft While Drilling
  - 10 ft After One Day

**Hammer Type:** Automatic
+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Notes:**
- Advancement Method:
  - Power Auger to 18.6 feet
  - Rock Bit below 18.6 feet
  - Diamond bit below 20 feet
- Abandonment Method:
  - See Exhibit A-3 for description of field procedures.
### BORING LOG NO. B-3

**PROJECT:** SH-9 over Wewoka Creek  
**CLIENT:** Holloway, Updike & Bellen

**SITE:** Hughes County, Oklahoma

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAPHIC LOG</td>
<td>Depth (ft.)</td>
</tr>
<tr>
<td>STATION: 168+54 Offset: 21' LT</td>
<td>Surface Elev.: 691.6 (ft.)</td>
</tr>
<tr>
<td><strong>SHALE</strong>+, with gray (5/N,GLEY1) sandstone seams, dark gray (4/N,GLEY1), soft to hard (\text{(continued)})</td>
<td>REC = 100% RQD = 80%</td>
</tr>
<tr>
<td>30.0</td>
<td>661.5</td>
</tr>
<tr>
<td><strong>SANDSTONE</strong>+, with dark gray (4/N,GLEY1) shale seams and laminae, gray (5/N,GLEY1), well cemented</td>
<td>REC = 100% RQD = 97%</td>
</tr>
<tr>
<td>32.0</td>
<td>659.5</td>
</tr>
<tr>
<td><strong>SHALE</strong>+, with gray (5/N,GLEY1) sandstone seams and laminae, dark gray (4/N,GLEY1), hard</td>
<td>REC = 100% RQD = 97%</td>
</tr>
<tr>
<td>35.0</td>
<td>656.5</td>
</tr>
<tr>
<td><strong>SANDSTONE</strong>+, with dark gray (4/N,GLEY1) shale seams and laminae, gray (5/N,GLEY1), well cemented</td>
<td>REC = 100% RQD = 97%</td>
</tr>
<tr>
<td>50.0</td>
<td>641.5</td>
</tr>
</tbody>
</table>

Hammer Type: Automatic  
Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Stratification lines are approximate. In-situ, the transition may be gradual.**

**Advance Method:** Power Auger to 18.6 feet  
Rock Bit below 18.6 feet  
Diamond bit below 20 feet

**Abandonment Method:**

**Notes:**

**WATER LEVEL OBSERVATIONS**

- **8 ft While Drilling**
- **9.5 ft After Boring**
- **10 ft After One Day**

---

**Terracon**  
9222 East 47th Place, Unit D  
Tulsa, Oklahoma  
Drill Rig: ATV 910  
Driller: AS

**PROJECT NO.: 04125055**  
**Exhibit:** A-6  
**Boring Started:** 6/9/2015  
**Boring Completed:** 6/10/2015
**BORING LOG NO. B-3**

**PROJECT:** SH-9 over Wewoka Creek  
**CLIENT:** Holloway, Updike & Bellen

**SITE:** Hughes County, Oklahoma

<table>
<thead>
<tr>
<th>GRAPHIC LOG LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 168+54</td>
<td>Offset: 21' LT</td>
</tr>
<tr>
<td>Depth</td>
<td>Surface Elev.: 691.6 (Fl)</td>
</tr>
</tbody>
</table>

**Boring Terminated at 50 Feet**

Stratification lines are approximate. In-situ, the transition may be gradual.

---

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>WATER CONTENT (%)</th>
<th>UNCONFINED COMPRESSION STRENGTH (psi)</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
</table>

**FREQUENCY OF WATER CONTENT AND UNCONFINED COMPRESSIVE STRENGTH**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Water Content (%)</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>LL-PL-PI</th>
<th>Percent Finest</th>
</tr>
</thead>
</table>

**Notes:**

- Advancement Method:
  - Power Auger to 18.6 feet
  - Rock Bit below 18.6 feet
  - Diamond bit below 20 feet

- Abandonment Method:
  - See Exhibit A-3 for description of field procedures.
  - See Appendix B for description of laboratory procedures and additional data (if any).
  - See Appendix C for explanation of symbols and abbreviations.

- Hammer Type: Automatic
  + Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

---

**WATER LEVEL OBSERVATIONS**

- After Boring: 9.5 ft
- After One Day: 8 ft

---

**Boring**

- Started: 6/9/2015
- Completed: 6/10/2015

**Drill Rig:** ATV 910
**Driller:** AS

**Project No.: 04125055**  
**Exhibit:** A-6
see boring log for B-3

WEATHERED SHALE+: dark gray (4/N, GLEY1), soft to moderately hard

SHALE+: with gray (5/N, GLEY1) sandstone seams, dark gray (4/N, GLEY1), soft to hard

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

---

FIELD TEST RESULTS

PERCENT FINES

WATER CONTENT (%)

ATTERBERG LIMITS

ULL-PL-PI

---

PROJECT: SH-9 over Wewoka Creek

SITE: Hughes County, Oklahoma

CLIENT: Holloway, Updike & Bellen

LOCATION

GRAPHIC LOG

Station: 168+54     Offset: 26' LT

DEPTH

ELEVATION (FT)

DEPTH (FT)

WATER LEVEL OBSERVATIONS

RECOVERY (IN.)

UNCONFINED COMPRESSIVE STRENGTH (PSI)

---

Notes:

See Exhibit A-3 for description of field procedures.

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix C for explanation of symbols and abbreviations.

Advancement Method:
Power Auger to 10 feet
Wash Boring below 10 feet
Rock Bit below 33.5 feet

Abandonment Method:

---

WATER LEVEL OBSERVATIONS

9 ft While Drilling
10 ft After Boring

---

Boring Started: 6/10/2015
Boring Completed: 6/10/2015

Drill Rig: ATV 910
Driller: AS

Project No.: 04125055
Exhibit: A-7
SHALE+, with gray (5/N, GLEY1) sandstone seams, dark gray (4/N, GLEY1), soft to hard (continued)

SANDSTONE+, with dark gray (4/N, GLEY1) shale seams and laminae, gray (5/N, GLEY1), well cemented

SHALE+, with gray (5/N, GLEY1) sandstone seams and laminae, gray (4/N, GLEY1), hard

SANDSTONE+, with dark gray (4/N, GLEY1) shale seams and laminae, gray (5/N, GLEY1), well cemented

Boring Terminated at 49 Feet

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
- Power Auger to 10 feet
- Wash Boring below 10 feet
- Rock Bit below 33.5 feet

Abandonment Method:
- 9 ft While Drilling
- 10 ft After Boring

Notes:
- See Exhibit A-3 for description of field procedures.
- See Appendix B for description of laboratory procedures and additional data (if any).
- See Appendix C for explanation of symbols and abbreviations.

WATER LEVEL OBSERVATIONS

- 9 ft While Drilling
- 10 ft After Boring

Hammer Type: Automatic

ADVANCEMENT METHOD:
- Power Auger to 10 feet
- Wash Boring below 10 feet
- Rock Bit below 33.5 feet

ABANDONMENT METHOD:
- 9 ft While Drilling
- 10 ft After Boring

Notes:
- See Exhibit A-3 for description of field procedures.
- See Appendix B for description of laboratory procedures and additional data (if any).
- See Appendix C for explanation of symbols and abbreviations.

FIELD TEST RESULTS

PERCENT FINES
WATER CONTENT (%)
ATTERBERG LIMITS

ELEVATION (Ft.)

SAMPLE TYPE
RECOVERY (In.)
UNCONFINED COMPRESSIVE STRENGTH (psi)

DEPTH (Ft.)

DEPTH LEVEL OBSERVATIONS

- 9 ft While Drilling
- 10 ft After Boring

Hammer Type: Automatic

DATA QUALITY:
- 9 ft While Drilling
- 10 ft After Boring

Notes:
- See Exhibit A-3 for description of field procedures.
- See Appendix B for description of laboratory procedures and additional data (if any).
- See Appendix C for explanation of symbols and abbreviations.
## BORING LOG NO. B-4

### PROJECT: SH-9 over Wewoka Creek

### CLIENT: Holloway, Updike & Bellen

### SITE:

Hughes County, Oklahoma

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>GRAPHIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Exhibit A-2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTH (FL)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
<th>WATERTIGHTNESS</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
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<td></td>
<td>N=5</td>
<td>16</td>
</tr>
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<td>3.5</td>
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<td></td>
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</tbody>
</table>

**Notes:**

- Stratification lines are approximate. In-situ, the transition may be gradual.
- Hammer Type: Automatic
- Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Advancement Method:**
Wash Boring below 10 feet

**Abandonment Method:**

**HOLLOW LEAN CLAY**, with sandstone mix, yellowish-brown (10YR,5/8), medium stiff

**FAT CLAY**, brown (10YR,4/3), stiff

with yellowish-brown (10YR,5/8) sandstone seams below 5 feet

**SHALEY LEAN CLAY**, gray (5Y,5/1) and olive-yellow (2.5Y,6/8), very stiff

**INTERBEDDED SHALE AND SANDSTONE**, dark gray (4/N,GLEY1), soft to moderately hard, well cemented

---

**WATER LEVEL OBSERVATIONS**

- 9 ft While Drilling
- 9 ft After Boring
- 10 ft After One Day

---

**Exhibit:** A-2

---

**Notes:**

- See Exhibit A-3 for description of field procedures.
- See Appendix B for description of laboratory procedures and additional data (if any).
- See Appendix C for explanation of symbols and abbreviations.

---

**Driller:** AS

**Drill Rig:** ATV 910

**Exhibit:** A-8

**Boring Started:** 6/10/2015

**Boring Completed:** 6/10/2015

**Project No.: 04125055**

---

**Terracon**

9222 East 47th Place, Unit D Tulsa, Oklahoma
**BORING LOG NO. B-4**

**PROJECT:** SH-9 over Wewoka Creek

**SITE:** Hughes County, Oklahoma

**CLIENT:** Holloway, Updike & Bellen

---

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 169+94 Offset: 23' RT</td>
<td>Surface Elev.: 700.5 (Ft.)</td>
</tr>
</tbody>
</table>

**INTERBEDDED SHALE AND SANDSTONE:** dark gray
(4/N, GLEY1), soft to moderately hard, well cemented (continued)

**Boring Terminated at 44 Feet**

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

+Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

---

**WEATHERED WASH BORING BELOW 10 FEET**

**Abandonment Method:**

See Exhibit A-3 for description of field procedures.

See Appendix B for description of laboratory procedures and additional data (if any).

See Appendix C for explanation of symbols and abbreviations.

---

**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Recovery (In.)</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/11/16”</td>
<td>11</td>
<td>50/1/4”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
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</tr>
<tr>
<td>50/7/16”</td>
<td>50/5/16”</td>
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</tbody>
</table>

---

**Notes:**

---

**PROJECT:** SH-9 over Wewoka Creek

**WATER LEVEL OBSERVATIONS**

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Recovery (In.)</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/11/16”</td>
<td>11</td>
<td>50/1/4”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/5/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Notes:**

---

**Abandonment Method:**

---

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>Depth (Ft.)</th>
<th>Recovery (In.)</th>
<th>Unconfined Compressive Strength (psi)</th>
<th>Water Content (%)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/11/16”</td>
<td>11</td>
<td>50/1/4”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/1/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/7/16”</td>
<td>50/5/16”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Notes:**

---

**Advance Method:**

---

**Exhibit:** A-8

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**Driller:** AS

---

**Drill Rig:** ATV 910

---

**Boring Started:** 6/10/2015

---

**Boring Terminated:** 6/10/2015

---

**Boring Completed:** 6/10/2015

---

**Exhibit:** A-8
Laboratory Testing

Samples retrieved during the field exploration were taken to the laboratory for further observation by the project geotechnical engineer and were classified in accordance with the Unified Soil Classification System (USCS) described in Appendix A. After the testing was completed, the field descriptions were confirmed or modified as necessary.

Selected soil and bedrock samples obtained from the site were tested for the following engineering properties:

- Water content
- Atterberg limits
- Sieve analysis
- Unconfined compressive strength of rock cores
APPENDIX C
SUPPORTING DOCUMENTS
**GENERAL NOTES**

**DESCRIPTION OF SYMBOLS AND ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th>Water Level After a Specified Period of Time</th>
<th>Field Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auger</td>
<td>Water Initially Encountered</td>
<td>(HP) Hand Penetrometer</td>
</tr>
<tr>
<td>Shelby Tube</td>
<td>Water Level After a Specified Period of Time</td>
<td>(T) Torvane</td>
</tr>
<tr>
<td>Ring Sampler</td>
<td>Water Level After a Specified Period of Time</td>
<td>(b/f) Standard Penetration Test (blows per foot)</td>
</tr>
<tr>
<td>Grab Sample</td>
<td></td>
<td>(PID) Photo-Ionization Detector</td>
</tr>
<tr>
<td>No Recovery</td>
<td></td>
<td>(OVA) Organic Vapor Analyzer</td>
</tr>
</tbody>
</table>

**DESCRIPTIVE SOIL CLASSIFICATION**

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

**LOCATION AND ELEVATION NOTES**

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

**RELATIVE DENSITY OF COARSE-GRAINED SOILS**

(50% or more passing the No. 200 sieve.)

<table>
<thead>
<tr>
<th>Strength Terms</th>
<th>Descriptive Term (Density)</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
<th>Ring Sampler Blows/Ft.</th>
<th>Descriptive Term (Consistency)</th>
<th>Unconfined Compressive Strength, Qu, psi</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
<th>Ring Sampler Blows/Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very Loose</td>
<td>0 - 3</td>
<td>0 - 6</td>
<td>Very Soft</td>
<td>less than 500</td>
<td>0 - 1</td>
<td>&lt; 3</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>4 - 9</td>
<td>7 - 18</td>
<td>Soft</td>
<td>500 to 1,000</td>
<td>2 - 4</td>
<td>3 - 4</td>
</tr>
<tr>
<td></td>
<td>Medium Dense</td>
<td>10 - 29</td>
<td>19 - 58</td>
<td>Medium-Stiff</td>
<td>1,000 to 2,000</td>
<td>4 - 8</td>
<td>5 - 9</td>
</tr>
<tr>
<td></td>
<td>Dense</td>
<td>30 - 50</td>
<td>59 - 98</td>
<td>Stiff</td>
<td>2,000 to 4,000</td>
<td>8 - 15</td>
<td>10 - 18</td>
</tr>
<tr>
<td></td>
<td>Very Dense</td>
<td>&gt; 50</td>
<td>&gt; 99</td>
<td>Very Stiff</td>
<td>4,000 to 8,000</td>
<td>15 - 30</td>
<td>19 - 42</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hard</td>
<td>&gt; 8,000</td>
<td>&gt; 30</td>
<td>&gt; 42</td>
</tr>
</tbody>
</table>

**RELATIVE PROPORTIONS OF SAND AND GRAVEL**

**GRAIN SIZE TERMINOLOGY**

**RELATIVE PROPORTIONS OF FINE- GRAVEL**

<table>
<thead>
<tr>
<th>Descriptive Term(s) of other constituents</th>
<th>Percent of Dry Weight</th>
<th>Major Component of Sample</th>
<th>Particle Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace</td>
<td>&lt; 15</td>
<td>Boulders</td>
<td>Over 12 in.</td>
</tr>
<tr>
<td>With</td>
<td>15 - 29</td>
<td>Cobble Ord.</td>
<td>(300 mm)</td>
</tr>
<tr>
<td>Modifier</td>
<td>&gt; 30</td>
<td>Gravel</td>
<td>12 in. to 3 in.</td>
</tr>
</tbody>
</table>

**RELATIVE PROPORTIONS OF FINE**

<table>
<thead>
<tr>
<th>Descriptive Term(s) of other constituents</th>
<th>Percent of Dry Weight</th>
<th>Term</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace</td>
<td>&lt; 5</td>
<td>Non-plastic</td>
<td>0</td>
</tr>
<tr>
<td>With</td>
<td>5 - 12</td>
<td>Low</td>
<td>1 - 10</td>
</tr>
<tr>
<td>Modifier</td>
<td>&gt; 12</td>
<td>Medium</td>
<td>11 - 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>&gt; 30</td>
</tr>
</tbody>
</table>
### UNIFIED SOIL CLASSIFICATION SYSTEM

#### Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests

<table>
<thead>
<tr>
<th>Soil Classification</th>
<th>Group Symbol</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Gravels: More than 5% fines C</td>
<td>Cu ≥ 4 and 1 ≤ Cc ≤ 3</td>
<td>GW</td>
</tr>
<tr>
<td></td>
<td>Cu &gt; 4 and/or 1 &gt; Cc &gt; 3</td>
<td>GP</td>
</tr>
<tr>
<td>Gravels with Fines: More than 12% fines C</td>
<td>Fines classify as ML or MH</td>
<td>GM</td>
</tr>
<tr>
<td></td>
<td>Fines classify as CL or CH</td>
<td>GC</td>
</tr>
<tr>
<td>Clean Sands: Less than 5% fines D</td>
<td>Cu ≥ 6 and 1 ≤ Cc ≤ 3</td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td>Cu &lt; 6 and/or 1 &gt; Cc &gt; 3</td>
<td>SP</td>
</tr>
<tr>
<td>Sands with Fines: More than 12% fines D</td>
<td>Fines classify as ML or MH</td>
<td>SM</td>
</tr>
<tr>
<td></td>
<td>Fines classify as CL or CH</td>
<td>SC</td>
</tr>
</tbody>
</table>

#### Coarse Grained Soils:

- More than 50% retained on No. 200 sieve

- **Gravels:**
  - More than 50% of coarse fraction retained on No. 4 sieve

- **Sands:**
  - 50% or more of coarse fraction passes No. 4 sieve

#### Fine-Grained Soils:

- 50% or more passes the No. 200 sieve

- **Sands and Clays:**
  - Liquid limit less than 50

- **Sands and Clays:**
  - Liquid limit 50 or more

#### Highly organic soils:

- Primarily organic matter, dark in color, and organic odor

---

**A** Based on the material passing the 3-in. (75-mm) sieve

**B** If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.

**C** Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

**D** Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

**E** $Cu = D_{60}/D_{10}$, $Cc = (D_{30})^2 / D_{10}^2$ $D_{60}$

**F** If soil contains ≥ 15% sand, add “with sand” to group name.

**G** If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

---

**For classification of fine-grained soils and fine-grained fraction of coarse-grained soils**

**Equation of “A”** - line
- Horizontal at PI=4 to LL=25.5.
- Then PI=0.73 (LL=20)

**Equation of “U”** - line
- Vertical at LL=16 to PI=7.
- Then PI=0.9 (LL=8)

---

**Exhibit C-2**
GENERAL NOTES
Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIMESTONE</td>
<td>Light to dark colored, crystalline to fine-grained texture, composed of CaCO₃, reacts readily with HCl.</td>
</tr>
<tr>
<td>DOLOMITE</td>
<td>Light to dark colored, crystalline to fine-grained texture, composed of CaMg(CO₃)₂, harder than limestone, reacts with HCl when powdered.</td>
</tr>
<tr>
<td>CHERT</td>
<td>Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz (SiO₂), brittle, breaks into angular fragments, will scratch glass.</td>
</tr>
<tr>
<td>SHALE</td>
<td>Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.</td>
</tr>
<tr>
<td>SANDSTONE</td>
<td>Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.</td>
</tr>
<tr>
<td>CONGLOMERATE</td>
<td>Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (1/2 inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.</td>
</tr>
</tbody>
</table>

PHYSICAL PROPERTIES:

<table>
<thead>
<tr>
<th>DEGREE OF WEATHERING</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>Slight decomposition of parent material on joints. May be color change.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Some decomposition and color change throughout.</td>
</tr>
<tr>
<td>High</td>
<td>Rock highly decomposed, may be extremely broken.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HARDNESS AND DEGREE OF CEMENTATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone and Dolomite:</td>
<td></td>
</tr>
<tr>
<td>Hard</td>
<td>Difficult to scratch with knife. Can be scratched easily with knife, cannot be scratched with fingernail.</td>
</tr>
<tr>
<td>Moderately Hard</td>
<td>Can be scratched with fingernail.</td>
</tr>
<tr>
<td>Soft</td>
<td>Can be scratched with fingernail.</td>
</tr>
<tr>
<td>Shale, Siltstone and Claystone</td>
<td></td>
</tr>
<tr>
<td>Hard</td>
<td>Can be scratched easily with knife, cannot be scratched with fingernail. Can be easily dented but not molded with fingers.</td>
</tr>
<tr>
<td>Moderately Hard</td>
<td>Can be scratched with fingernail.</td>
</tr>
<tr>
<td>Soft</td>
<td>Can be scratched with fingernail.</td>
</tr>
<tr>
<td>Sandstone and Conglomerate</td>
<td></td>
</tr>
<tr>
<td>Well</td>
<td>Capable of scratching a knife blade.</td>
</tr>
<tr>
<td>Cemented</td>
<td>Can be scratched with knife.</td>
</tr>
<tr>
<td>Poorly Cemented</td>
<td>Can be broken apart easily with fingers.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BEDDING AND JOINT CHARACTERISTICS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed Thickness</td>
<td>Joint Spacing</td>
</tr>
<tr>
<td>Very Thick</td>
<td>Very Thick</td>
</tr>
<tr>
<td>Thick</td>
<td>Wide</td>
</tr>
<tr>
<td>Medium</td>
<td>Moderately Close</td>
</tr>
<tr>
<td>Thin</td>
<td>Close</td>
</tr>
<tr>
<td>Very Thin</td>
<td>Very Close</td>
</tr>
<tr>
<td>Laminated</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOLUTION AND VOID CONDITIONS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>Contains no voids. Rock having small solution pits or cavities up to 1/2 inch diameter, frequently with a mineral lining.</td>
</tr>
<tr>
<td>Vuggy (Pitted)</td>
<td>Contains numerous voids, pores, or other openings, which may or may not interconnect.</td>
</tr>
<tr>
<td>Porous</td>
<td>Contains cavities or caverns, sometimes quite large.</td>
</tr>
<tr>
<td>Cavernous</td>
<td></td>
</tr>
</tbody>
</table>