Geotechnical Engineering Report

Turner Turnpike Widening – Bridge B
Bridge Crossing: South 257th West Avenue
Creek County, Oklahoma

June 1, 2016
Terracon Project No. 04155197

Prepared for:
Garver, LLC
Tulsa, Oklahoma

Prepared by:
Terracon Consultants, Inc.
Tulsa, Oklahoma
June 1, 2016

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

Attn: Ms. Jenny E. Sallee, P.E.  
JESallee@GarverUSA.com

Re: Geotechnical Engineering Report  
Turner Turnpike Widening – Bridge B  
Bridge Crossing: West 151st Street South  
Creek County, Oklahoma  
Terracon Project Number: 04155197

Dear Ms. Sallee:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with our Geotechnical Scope of Work, Terracon proposal number P04150620 dated January 6, 2016. 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

[Signatures]

Vaughn Rupnow, P.E.  
Oklahoma No. 25692

Norman Tan  
Senior Engineer

VER:NKT:ej  
Enclosures  
Addressee (3 via US Mail and 1 via email)
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- Exhibits B-2 to B-3 Grain Size Distribution
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- Exhibit C-2 Unified Soil Classification System
- Exhibit C-3 AASHTO Soil Classification System
- Exhibit C-4 General Notes – Description of Rock Properties
GEOTECHNICAL ENGINEERING REPORT
TURNER TURNPIKE WIDENING – BRIDGE C
BRIDGE CROSSING: SOUTH 257TH WEST AVENUE
CREEK COUNTY, OKLAHOMA

Terracon Project No. 04155197
June 1, 2016

1.0 INTRODUCTION

This geotechnical engineering report has been completed for the proposed bridge along South 257th West Avenue over the Turner Turnpike Widening in Creek County, Oklahoma (Appendix A, Exhibit A-1). Six borings, designated B-1, B-2, B-2A, B-3, B-4, and B-5 were drilled for the project to depths of approximately 35 to 55.5 feet below the existing ground surface. The boring logs and a boring location plan showing the approximate boring locations are provided in Appendix A of this report.

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

- subsurface soil and rock conditions
- bridge foundations
- groundwater conditions
- LPILE parameters for lateral analysis

2.0 PROJECT INFORMATION

2.1 Project Description

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring Layout</td>
<td>See Appendix A, Figure A-2 Boring Location Diagram.</td>
</tr>
<tr>
<td>Proposed Construction</td>
<td>Bridge B will be a 4-span bridge to be constructed along South 257th West Avenue over the proposed Turner Turnpike Widening in Creek County, Oklahoma. We understand that the interior bridge bent locations as well as Abutment No. 1 will be supported on drilled shafts and the Abutment No. 2 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>South 257th West Avenue crossing over I-44 (Turner Turnpike) in Creek County, Oklahoma.</td>
</tr>
</tbody>
</table>

3.0 SUBSURFACE CONDITIONS

3.1 Geology

Based on information published in the Oklahoma Department of Transportation manual, “Engineering Classification of Geologic Materials: Division Eight”, the geology of the bridge location consists of the Nellie Bly Unit. This unit consists predominantly of yellowish-brown shale and sandy shale with sandstone and siltstone. The shale ranges from clay shale in lower portion to silty and sandy shale upward. The total thickness of this unit ranges from about 80 to 280 feet.

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>Surface 1 ¹</td>
<td>4 inches</td>
<td>Topsoil</td>
<td>N/A</td>
</tr>
<tr>
<td>Surface 2 ²</td>
<td>10 inches</td>
<td>Asphalt</td>
<td>N/A</td>
</tr>
<tr>
<td>Stratum 1 ²</td>
<td>3 feet</td>
<td>Fill: Silty, clayey sand with gravel</td>
<td>N/A</td>
</tr>
<tr>
<td>Stratum 2 ³</td>
<td>5 to 6 feet</td>
<td>Fat clay, shaley lean clay, sandy silt, silty sand, sandy silty clay</td>
<td>Sand: Loose to medium dense Clay: Medium stiff to very stiff</td>
</tr>
<tr>
<td>Stratum 3 ⁴</td>
<td>8.5 feet</td>
<td>Highly weathered sandstone</td>
<td>Poorly cemented</td>
</tr>
<tr>
<td>Stratum 4 ³</td>
<td>Encountered to boring termination depths of about 35 to 55.5 feet</td>
<td>Shale, sandstone</td>
<td>Shale: Soft to hard Sandstone: Poorly cemented to cemented</td>
</tr>
</tbody>
</table>
Responsive  ■  Resourceful  ■  Reliable

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

The following table indicates the ground surface elevations and the approximate top of competent bedrock depth and elevation at the respective boring locations. The depth to the top of competent bedrock encountered in the borings corresponds to the depths at which the penetration from a Standard Penetration test (SPT), conducted in accordance to ASTM D 1586, was less than or equal to 6 inches with 50 blows. Based on current “State of Oklahoma Department of Transportation Specifications for the Geotechnical Investigations of Bridges and Related Structures”, we understand that the required rock penetration does not begin until competent bedrock is encountered. The rock penetration consists of seven continuous passing Texas Cone Penetrometer (TCP) tests spaced at 5-foot intervals for a total of 30 feet of bedrock penetration in accordance with the ODOT Specifications for Geotechnical Investigations. Thus, depths to top of competent rock and the corresponding elevations shown in table do not necessarily coincide with the depths to top of weathered rock and the corresponding elevations shown on the boring logs.

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Ground Elevation (feet)</th>
<th>Competent Bedrock Material</th>
<th>Depth to Top of Competent Rock (feet)</th>
<th>Elevation of Top of Competent Rock (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>802.9</td>
<td>Shale</td>
<td>24</td>
<td>779</td>
</tr>
<tr>
<td>B-2</td>
<td>764.3</td>
<td>Sandstone</td>
<td>5</td>
<td>759.5</td>
</tr>
<tr>
<td>B-2A</td>
<td>764.5</td>
<td>Sandstone</td>
<td>5</td>
<td>759.5</td>
</tr>
<tr>
<td>B-3</td>
<td>767.7</td>
<td>Sandstone</td>
<td>9</td>
<td>758.5</td>
</tr>
<tr>
<td>B-4</td>
<td>773.8</td>
<td>Shale</td>
<td>9</td>
<td>765</td>
</tr>
<tr>
<td>B-5</td>
<td>808.5</td>
<td>Shale</td>
<td>8.5</td>
<td>768.5</td>
</tr>
</tbody>
</table>
3.3 Groundwater

The boreholes were observed while drilling and 24 hours after boring completion for the presence and level of groundwater. Below depths of about 1.5 to 9 feet, we advanced the borings using wet rotary drilling techniques. We observed groundwater at the following depths and times:

<table>
<thead>
<tr>
<th>Boring</th>
<th>While Drilling</th>
<th>After Drilling</th>
<th>24 hours After Drilling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth</td>
<td>Elevation</td>
<td>Depth</td>
</tr>
<tr>
<td>B-1</td>
<td>Not encountered to 1.5 feet</td>
<td>Not encountered to 801.5 feet</td>
<td>18.5</td>
</tr>
<tr>
<td>B-2</td>
<td>Not encountered to 5 feet</td>
<td>Not encountered to 759.5 feet</td>
<td>34</td>
</tr>
<tr>
<td>B-2A</td>
<td>Not encountered to 5 feet</td>
<td>Not encountered to 759.5 feet</td>
<td>34</td>
</tr>
<tr>
<td>B-3</td>
<td>Not encountered to 9 feet</td>
<td>Not encountered to 758.5 feet</td>
<td>6</td>
</tr>
<tr>
<td>B-4</td>
<td>Not encountered to 5 feet</td>
<td>Not encountered to 769 feet</td>
<td>35</td>
</tr>
<tr>
<td>B-5</td>
<td>Not encountered to 5 feet</td>
<td>Not encountered to 772 feet</td>
<td>29</td>
</tr>
</tbody>
</table>

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 Abutment No. 2 and drilled shafts can be used to support the interior bents and Abutment No. 1. Shale and sandstone was encountered in the bridge borings. The shale and sandstone will adequately support the bridge structure. Specific recommendations regarding the design and construction of driven pile and drilled shaft
foundations are presented in the following sections. The tables attached in Appendix B present design parameters to be used in LPILE analyses.

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>24</td>
</tr>
<tr>
<td>B-2</td>
<td>5</td>
</tr>
<tr>
<td>B-2A</td>
<td>5</td>
</tr>
<tr>
<td>B-3</td>
<td>9</td>
</tr>
<tr>
<td>B-4</td>
<td>9</td>
</tr>
<tr>
<td>B-5</td>
<td>8.5</td>
</tr>
</tbody>
</table>

4.1 Driven Piles

Driven steel HP piles driven to practical refusal in the 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 should 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. Pre-drilling will be required in order to achieve minimum pile lengths.

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

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

A heavy-duty drill rig equipped with a rock auger or core barrel will be required to penetrate the bedrock. Based on the Texas Cone Penetrometer values measured in our borings, the drilling contractor should anticipate difficult drilling in the shale bedrock.

Based on the results of the borings, casing may 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.

4.3 Seismic Considerations

<table>
<thead>
<tr>
<th>Reference</th>
<th>Site Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 AASHTO LRFD Bridge Design Specifications ¹</td>
<td>C</td>
</tr>
</tbody>
</table>

1. In general accordance with the 2012 AASHTO LRFD Bridge Design Specifications, Table 3.10.3.1-1 – Site Class Definitions.

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.
<table>
<thead>
<tr>
<th>BORING</th>
<th>STATION</th>
<th>OFFSET</th>
<th>ELEV. (FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>547+23</td>
<td>202' RT</td>
<td>802.9</td>
</tr>
<tr>
<td>B-2</td>
<td>547+85</td>
<td>55' RT</td>
<td>764.3</td>
</tr>
<tr>
<td>B-2A</td>
<td>547+93</td>
<td>53' RT</td>
<td>764.5</td>
</tr>
<tr>
<td>B-3</td>
<td>548+70</td>
<td>6' LT</td>
<td>767.7</td>
</tr>
<tr>
<td>B-4</td>
<td>549+15</td>
<td>83' LT</td>
<td>773.8</td>
</tr>
<tr>
<td>B-5</td>
<td>549+67</td>
<td>95' LT</td>
<td>777.0</td>
</tr>
</tbody>
</table>

LEGEND

BORING LOCATION

STATIONS AND OFFSETS BASED ON I-44

BASE DRAWING PROVIDED BY GARVER

LEGEND

BORING LOCATION

APPROXIMATE SCALE IN FEET

Project No.: 04155197

Designed By: JM

Drawn By: VER

Checked By: VER

Approved By: MHH

Date: APRIL 2016

BORING LOCATION PLAN

GEOTECHNICAL EXPLORATION

TURNER TURNPIKE WIDENING - BRIDGE B

MILE POST 203 TO 210

CREEK COUNTY, OKLAHOMA

EXHIBIT NO. A-2
Field Exploration Description
The borings were performed at the approximate locations shown on the Boring Location Plan, Exhibit A-2, in this Appendix. Terracon’s drill crew laid out the borings with a hand-held GPS unit. Surface elevations and Oklahoma North Modified State Plane Coordinates (NAVD 88) at the boring locations were obtained by Anderson Surveying, Inc. Surface elevations and stations were referenced to the 3/8” rebar for benchmarks BM #102 and BM #103 (see Exhibit A-2, Boring Location Plan) with elevations of 801.79 and 778.53 feet, respectively. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

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 at boring B-2 using a 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 log. 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 log 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.
**BORING LOG NO. B-1**

**PROJECT:** Turner Turnpike Widening - Bridge B  
**SITE:** Creek County, Oklahoma  
**CLIENT:** Garver, LLC.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 547+23 Offset: 202' RT</td>
<td>Surface Elev.: 802.9 (Ft.)</td>
</tr>
</tbody>
</table>

---

### WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>ELEVATION (Ft.)</th>
<th>Surface Elev.: 802.9 (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.5</td>
<td>784.5</td>
</tr>
<tr>
<td>24.0</td>
<td>779</td>
</tr>
</tbody>
</table>

---

### 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>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>50/2&quot;</td>
<td>50/3/16&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50/1/4&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>10-15-17</td>
<td>22</td>
<td>54-23-31</td>
<td>96</td>
</tr>
<tr>
<td>16</td>
<td>21-50/6&quot;</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50/1 1/2&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### ADVANCEMENT METHOD

- Power Auger to 1 foot
- Wash Boring below 1 foot

### ABANDONMENT METHOD

- Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

---

**NOT ENCOUNTERED TO 1.5 FEET WHILE DRILLING**

- 18.5 ft After Boring
- 5.5 ft After 24 Hours

---

**Notes:**

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

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**See Appendix C for explanation of symbols and abbreviations.**

---

**See Exhibit A-3 for description of field procedures.**

---

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

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

---

**Client:** Garver, LLC

---

**Project No.: 04155197**

---

**Exhibit:** A-4

---

**Boring Started:** 3/29/2016  
**Boring Completed:** 3/29/2016  
**Drill Rig:** ATV  
**Driller:** AS  
**Terracon 9522 E 47th Pl Ste B Tulsa, OK**  
**Project No.: 04155197**  
**Exhibit:** A-4
**SHALE+**, reddish-brown (5YR,4/4), soft to hard (continued)

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

**LOCATION**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station:</td>
<td>547+23</td>
</tr>
<tr>
<td>Offset:</td>
<td>202' RT</td>
</tr>
<tr>
<td>Surface Elevation:</td>
<td>802.9 (ft)</td>
</tr>
</tbody>
</table>

**GRAPHIC LOG**

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>ELEVATION (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>25</td>
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</tr>
<tr>
<td>45</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- **DEPTH:**
  - 0 ft: **50/9/16"**
  - 5 ft: **50/12"**
  - 10 ft: **50/3/16"**
  - 15 ft: **50/3/16"**
  - 20 ft: **50/1/16"**
  - 25 ft: **50/0"**
  - 30 ft: **50/1/16"**
  - 35 ft: **50/1/8"**
  - 40 ft: **50/1/16"**
  - 45 ft: **50/1/8"**
  - 50 ft: **50/1/16"**

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>PERCENT FINES</th>
<th>WATER CONTENT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**UNCONFINED COMpressive STRENGTH (psi)**

- **ELEVATION (Ft.):**
  - **Surface Elev.: 802.9 (Ft.)**

**Notes:**

- **Advancement Method:** Power Auger to 1 feet
  - Wash Boring below 1 feet
- **Abandonment Method:**
  - Backfilled with cuttings above 4'; grouted 4' to 14';
  - backfilled with cuttings from 14' to termination depth.

**Exhibit:**

- **See Exhibit A-3 for description of field procedures.**
- **See Appendix C for explanation of symbols and abbreviations.**
- **Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.**

**Driller:** AS

**Drill Rig:** ATV

**Boring Started:** 3/29/2016

**Boring Completed:** 3/29/2016

**Project No.: 04155197**

**Exhibit:** A-4-
### Boring Log No. B-1

**PROJECT:** Turner Turnpike Widening - Bridge B  
**CLIENT:** Garver, LLC.

**SITE:**  
Creek County, Oklahoma

---

**Graphical Log**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 547+23</td>
<td>Offset: 202' RT</td>
</tr>
<tr>
<td>Surface Elev.: 802.9 (Ft.)</td>
<td></td>
</tr>
</tbody>
</table>

**Depth**  
- Boring Terminated at 55.5 Feet

**Shale**+, reddish-brown (5YR,4/4), soft to hard  
(continued)

- Becoming gray (10YR,5/1) below 54.5 feet

---

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

---

**Advancement Method:**  
Power Auger to 1 feet  
Wash Boring below 1 feet

**Abandonment Method:**  
Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

**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 1.5 feet While Drilling

- 18.5 ft After Boring
- 5.5 ft After 24 Hours

---

**Hammer Type:**  
Automatic

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

---

**Field Test Results**

<table>
<thead>
<tr>
<th>Water Content (%)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/3/16</td>
<td>LL-PL-PI</td>
</tr>
<tr>
<td>50/3/8</td>
<td>50/1/8</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

---

**Unconfined Compressive Strength (psi)**

<table>
<thead>
<tr>
<th>Water Content (%)</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/3/16</td>
<td>LL-PL-PI</td>
</tr>
<tr>
<td>50/3/8</td>
<td>50/1/8</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

---

**Location:** Creek County, Oklahoma  
**Site:** Turner Turnpike Widening - Bridge B  
**Water Level Observations:**

- Not Encountered to 1.5 feet While Drilling
- 18.5 ft After Boring
- 5.5 ft After 24 Hours

---

**Notes:**

- Project No.: 04155197  
- Drill Rig: ATV  
- Driller: AS  
- Boring Completed: 3/29/2016  
- Exhibit: A-4-
PROJECT: Turner Turnpike Widening - Bridge B

SITE: Creek County, Oklahoma

LOCATION
Station: 547+85 Offset: 55' RT
Surface Elev.: 764.3 (Ft.)

DEPTH
ELEVATION (Ft.)

4" Topsoil
FAT CLAY (CH), brown (7.5YR,4/3), stiff
2.0 762.5

SHALEY LEAN CLAY (CL), with sandstone fragments, greenish-gray (GLEY1,5/10GY), stiff
5.0 759.5

SANDSTONE+, strong brown (7.5YR,6/4), cemented
with shale seams, gray (10YR,5/1) at 6 feet
11.0 753.5

SHALE+, gray (10YR,5/1), moderately hard to hard

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

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

LOCATION
DEPTH (Ft.)

FIELD TEST RESULTS
WATER CONTENT (%)

PERCENT FINES

WATER LEVELOBSERVATIONS
Not Encountered to 5 feet While Drilling

34 ft After Boring

4.5 ft After 24 Hours

Exhibit: A-5
Boring Terminated at 35 Feet

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

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

LOCATION

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>RECOVERY (%)</th>
<th>FIELD TEST RESULTS</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>REC = 97%</td>
<td>RQD = 80%</td>
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<tr>
<td>30</td>
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<td>REC = 88%</td>
<td>RQD = 63%</td>
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<td>3</td>
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<td></td>
</tr>
</tbody>
</table>

## WATER LEVEL OBSERVATIONS

Not Encountered to 5 feet While Drilling

### Advancement Method:
- Power Auger to 5 feet
- Diamond Core Bit below 5 feet

### Abandonment Method:
- Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

### Notes:
- Boring Completed: 3/29/2016
- Drill Rig: ATV
- Driller: AS
- Project No.: 04155197
- Exhibit: A-5

---

Creek County, Oklahoma

---

35 ft After Boring

4.5 ft After 24 Hours
**BORING LOG NO. B-2A**

**PROJECT:** Turner Turnpike Widening - Bridge B  
**CLIENT:** Garver, LLC.

**SITE:**  
Creek County, Oklahoma

### GRAPHIC LOG

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 547+93</td>
<td>Offset: 53’ RT</td>
</tr>
</tbody>
</table>

**DEPTH**  
Surface Elev.: 764.5 (Ft.)

### WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>ELEVATION (Ft.)</th>
<th>799.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPTH (Ft.)</td>
<td>5</td>
</tr>
</tbody>
</table>

**SANDSTONE+,** strong brown (7.5YR,6/4), cemented  
with shale seams, gray (10YR,5/1) at 6 feet

<table>
<thead>
<tr>
<th>ELEVATION (Ft.)</th>
<th>753.5</th>
</tr>
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<tbody>
<tr>
<td>DEPTH (Ft.)</td>
<td>11</td>
</tr>
</tbody>
</table>

**SANDSTONE+,** strong brown (7.5YR,6/4), cemented  
with shale seams, gray (10YR,5/1) at 6 feet

### FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>PERCENT FINES</th>
<th>WATER CONTENT (%), ATTERBERG LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL-PL-PI</td>
<td></td>
</tr>
</tbody>
</table>

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

**Notes:**

- Advancement Method: Power Auger to 5 feet  
- Wash Boring below 5 feet  
- Abandonment Method: Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

### WATER LEVEL OBSERVATIONS

- Not Encountered to 5 feet While Drilling
- 34 ft Not Encountered After Boring

**Exhibit:** See Exhibit A-2 for Soil Stratification.
**BORING LOG NO. B-2A**

**PROJECT:** Turner Turnpike Widening - Bridge B  
**CLIENT:** Garver, LLC.

**SITE:**  
Creek County, Oklahoma

**LOCATION**  
See Exhibit A-2

<table>
<thead>
<tr>
<th>STATION</th>
<th>OFFSET</th>
<th>DEPTH</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>FIELD TEST RESULTS</th>
<th>UNDRAINED COMPRESSION STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>547+93</td>
<td>53' RT</td>
<td>35.5</td>
<td>50/7/16&quot; 50/3/16&quot;</td>
<td>50/3/8&quot; 50/1/16&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**SHALE+**, gray (10YR,5/1), moderately hard to hard  
(continued)

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

---

**Advancement Method:**  
Power Auger to 5 feet  
Wash Boring below 5 feet

**Abandonment Method:**  
Backfilled with cuttings above 4'; grouted 4" to 14"; backfilled with cuttings from 14' to termination depth.

**Hammer Type:** Automatic

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

---

**NOT ENCOUNTERED AFTER BORING**

---

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**WATER LEVEL OBSERVATIONS**

- Not Encountered to 5 feet While Drilling
- 34 ft Not Encountered After Boring

---

**PROJECT:** Turner Turnpike Widening - Bridge B

---

**notes:**

---

**Boring Started:** 3/29/2016  
**Boring Completed:** 3/29/2016

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

**Project No.: 04155197**  
**Exhibit:** A-6
**LOCATION**
See Exhibit A-2

<table>
<thead>
<tr>
<th>DEPTH (FT.)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>FIELD TEST RESULTS</th>
<th>UNCOMPRESSED COMCOMPRESSIVE STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>18</td>
<td>15-13-13</td>
<td>N=26</td>
<td>9</td>
<td>19-13-6</td>
<td>37</td>
</tr>
<tr>
<td>9.0</td>
<td>18</td>
<td>15-19-20</td>
<td>N=39</td>
<td>12</td>
<td></td>
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<tr>
<td>14.5</td>
<td>9</td>
<td>17-50/3&quot;</td>
<td>N=50/3&quot;</td>
<td>13</td>
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<td></td>
</tr>
</tbody>
</table>

**SITE:**
Creek County, Oklahoma

**LOCATION**
Station: 548+70 Offset: 6' LT
Surface Elev.: 767.7 (Ft.)

**FIELD TEST RESULTS**

**PERCENT FINES**

**WATER CONTENT (%)**

**ATTERBERG LIMITS**

**ELEVATION (Ft.)**

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

**Advancement Method:**
Power Auger to 5 feet
Wash Boring below 5 feet

**Abandonment Method:**
Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

**FIELD TEST RESULTS**

**WATER LEVEL OBSERVATIONS**

**Not Encountered to 9 feet While Drilling**

**6 ft After Boring**

**WATER LEVELOBSERVATIONS**

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.

**Notes:**
Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

**Hammer Type:**
Automatic

**Boring Started:** 3/24/2016
**Boring Completed:** 3/24/2016

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

**Project No.:** 04155197
**Exhibit:** A-7
SHALE+, gray (2.5Y,5/1) to dark gray (2.5Y,4/1), moderately hard to hard (continued)

Boring Terminated at 40 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.

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 9 feet While Drilling

6 ft After Boring

Boring Started: 3/24/2016
Boring Completed: 3/24/2016
Drill Rig: ATV
Driller: AS
Project No.: 04155197
Exhibit: A-7-
## BORING LOG NO. B-4

**PROJECT:** Turner Turnpike Widening - Bridge B  
**SITE:** Creek County, Oklahoma

### GRAPHIC LOG

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>See Exhibit A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station: 549+15</td>
<td>Offset: 83’ LT</td>
</tr>
<tr>
<td>Surface Elev.: 773.8 (ft.)</td>
<td></td>
</tr>
</tbody>
</table>

### DEPTH ELEVATION (FL.)

<table>
<thead>
<tr>
<th>DEPTH (Ft.)</th>
<th>ELEVATION (FL.)</th>
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</thead>
<tbody>
<tr>
<td>6.0</td>
<td>7.65</td>
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<td>5.0</td>
<td>7.69</td>
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<td>7.73</td>
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<td>2.0</td>
<td>7.75</td>
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### WATER LEVEL OBSERVATIONS

<table>
<thead>
<tr>
<th>ELEVATION (Ft.)</th>
<th>Surface Elev.: 773.8 (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 ft After Boring</td>
<td></td>
</tr>
<tr>
<td>14 ft After 24 Hours</td>
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</tr>
</tbody>
</table>

### FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
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<td>2.2</td>
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<td>5.0</td>
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<td>9.0</td>
</tr>
<tr>
<td>17.0</td>
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<tr>
<td>19.5</td>
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</table>

### UNCONFINED COMPRESSIVE STRENGTH (psi)

<table>
<thead>
<tr>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103-5-10</td>
</tr>
<tr>
<td>156-16-18</td>
</tr>
<tr>
<td>50/5/16*</td>
</tr>
<tr>
<td>50/5/12*</td>
</tr>
</tbody>
</table>

### FIELD TEST RESULTS

<table>
<thead>
<tr>
<th>FIELD TEST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>18</td>
</tr>
</tbody>
</table>

### WATER CONTENT (%)

<table>
<thead>
<tr>
<th>WATER CONTENT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>16</td>
</tr>
</tbody>
</table>

### ATTERBERG LIMITS

<table>
<thead>
<tr>
<th>ATTERBERG LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL-PL-PI</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LL-PL-PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
</tr>
<tr>
<td>65</td>
</tr>
</tbody>
</table>

### Hammer Type: Automatic

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

### Advancement Method:
- Power Auger to 5 feet
- Wash Boring below 5 feet

### Abandonment Method:
- Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14’ to termination depth.

### 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 5 feet While Drilling
- 35 ft After Boring
- 14 ft After 24 Hours

### Project No.: 04155197  
**Exhibit:** A-8-
Boring Terminated at 39.8 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.

Notes:

WATER LEVEL OBSERVATIONS
Not Encountered to 5 feet While Drilling

35 ft After Boring
14 ft After 24 Hours

LOCATION
Station: 549+15 Offset: 83' LT
Surface Elev.: 773.8 (ft.)

DEPTHS
DEPTH (Ft.) ELEVATION (Ft.)
30
35
39.8
734

BORING TERMINATION

SHALE+, gray (2.5Y,5/1) to dark gray (2.5Y,4/1), moderately hard to hard (continued)

FIELD TEST RESULTS

PERCENT FINES
WATER CONTENT (%)
ATTERBBERG LIMITS

ELEVATION (Ft.)
Surface Elev.: 773.8 (Ft.)

ADVANCEMENT METHOD
Power Auger to 5 feet
Wash Boring below 5 feet

ABANDONMENT METHOD
Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

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-5

**PROJECT:** Turner Turnpike Widening - Bridge B  
**SITE:** Creek County, Oklahoma  
**CLIENT:** Garver, LLC.

#### Location
- Station: 549+67  
- Offset: 95' LT  
- Surface Elev.: 777.0 (ft.)

#### Description of Materials
- **6" Topsoil**
  - **Silty Sand (SM)**, brownish-yellow (10YR,6/6), loose to medium dense
  - Depth: 3.0  
  - Elev: 774

- **4.0 Sandy Silty Clay (CL-ML)**, with sandstone fragments, yellow (10YR,7/6) with brownish-yellow (10YR,6/6), medium stiff
  - Depth: 4.0  
  - Elev: 773

- **6.0 Shaley Lean Clay (CL)**, light gray (2.5Y,7/1) with olive-yellow (2.5Y,6/6), soft
  - Depth: 6.0  
  - Elev: 771

- **8.5 Shale+**, pale olive (5Y,6/3), soft

- **19.0 Sandstone+**, light gray (2.5Y,7/1) to gray (2.5Y,6/1), cemented
  - Depth: 19.0  
  - Elev: 758

- **24.0 Shale+**, gray (2.5Y,5/1) to dark gray (2.5Y,4/1), hard
  - Depth: 24.0  
  - Elev: 753

#### Notes
- Advancement Method: Power Auger to 5 feet  
- Wash Boring below 5 feet  
- Abandonment Method: Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

#### Water Level Observations
- **Surface Elev.: 777.0 (Ft.)**
- **DEPTH (Ft.)**
- **RECOVERY (In.)**
- **UNCONFINED COMRESSIVE STRENGTH (psi)**
- **WATER CONTENT (%)**
- **LL-PL-PI**
- **PERCENT FINES**

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

#### Advancement Method
- Power Auger to 5 feet  
- Wash Boring below 5 feet

#### Abandonment Method
- Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

#### WATER LEVEL OBSERVATIONS
- **Not Encountered to 5 feet While Drilling**
- **29 ft Not Encountered After Boring**
- **29 ft After 24 Hours**
**BORING LOG NO. B-5**

**PROJECT:** Turner Turnpike Widening - Bridge B  
**CLIENT:** Garver, LLC.

**SITE:**  
Creek County, Oklahoma

**LOCATION**  
See Exhibit A-2

**Station:** 549+67  
Offset: 95' LT  
Surface Elev.: 777.0 (Ft.)

**SHALE+**  
gray (2.5Y,5/1) to dark gray (2.5Y,4/1), hard
(continued)

**Boring Terminated at 39.2 Feet**

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

**Advancement Method:** Power Auger to 5 feet  
Wash Boring below 5 feet

**Abandonment Method:** Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

**FIELD TEST RESULTS**

<table>
<thead>
<tr>
<th>DEPTH (FL)</th>
<th>WATER LEVEL OBSERVATIONS</th>
<th>SAMPLE TYPE</th>
<th>RECOVERY (%)</th>
<th>PERCENT FINES</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (psi)</th>
<th>WATER CONTENT (%)</th>
<th>LL-PL-PI</th>
<th>ATTERBERG LIMITS</th>
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</table>

**Notes:**

- Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.
- Hammer Type: Automatic
- Advancement Method:
  - Power Auger to 5 feet
  - Wash Boring below 5 feet
- Abandonment Method:
  - Backfilled with cuttings above 4'; grouted 4' to 14'; backfilled with cuttings from 14' to termination depth.

**WATER LEVEL OBSERVATIONS**

- Not Encountered to 5 feet While Drilling
- Not Encountered After Boring
- 29 ft Not Encountered After 24 Hours

**Exhibit:**

- See Exhibit A-2 for description of field procedures.
- See Exhibit A-3 for description of field procedures.
- See Exhibit B for description of laboratory procedures and additional data (if any).

**Project No.:** 04155197  
**Exhibit:** A-10-
Based on information published in the Oklahoma Department of Transportation manual, "Engineering Classification of Geologic Materials: Division Eight", the geology of the bridge location consists of the Nellie Bly Unit. This unit consists predominantly of yellowish-brown shale and sandy shale with sandstone and siltstone. The shale ranges from clay shale in lower portion to silty and sandy shale upward. The total thickness of this unit ranges from about 80 to 280 feet.

**Boring No. B-1**
SPT = Splitspoon Sampler
LL = Liquid Limit
TCP = Texas Consolidation Index
RQD = Rock Quality Designation
SOIL REC = Soil Recovery
UCS = Unconfined Compressive Strength (psi)

**Boring No. B-2**
SPT = Splitspoon Sampler
LL = Liquid Limit
TCP = Texas Consolidation Index
RQD = Rock Quality Designation
SOIL REC = Soil Recovery
UCS = Unconfined Compressive Strength (psi)

**Boring No. B-2A**
SPT = Splitspoon Sampler
LL = Liquid Limit
TCP = Texas Consolidation Index
RQD = Rock Quality Designation
SOIL REC = Soil Recovery
UCS = Unconfined Compressive Strength (psi)
Based on information published in the Oklahoma Department of Transportation manual, "Engineering Classification of Geologic Materials: Division Eight," the geology of the bridge location consists of the Nellie Bly Unit. This unit consists predominantly of yellowish-brown shale and sandy shale with sandstone and siltstone. The shale ranges from clay shale in lower portion to silty and sandy shale upward. The total thickness of this unit ranges from about 80 to 280 feet.
Boring B-2

Depth: 5’ to 11’

Boring B-2

Depth: 11’ to 21’
Boring B-2

Depth: 21' to 31'

Boring B-2

Depth: 31' to 35'
APPENDIX B
SUPPORTING INFORMATION
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 C. Bedrock materials were classified according to the General Notes and described using commonly accepted geotechnical terminology. 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 (ASTM D2216)
- Atterberg limits (ASTM D4318)
- Sieve analysis (ASTM D422)
- Unconfined compressive strength of rock cores (ASTM D2938)

Procedural standards noted above are for reference to methodology in general. In some cases variations to methods are applied as a result of local practice or professional judgment.
### Table: Grain Size Distribution

<table>
<thead>
<tr>
<th>Boring ID</th>
<th>Depth</th>
<th>USCS Classification</th>
<th>AASHTO Classification</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>Cc</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>18.5-20</td>
<td>FAT CLAY (CH)</td>
<td>A-7-6(33)</td>
<td>54</td>
<td>23</td>
<td>31</td>
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<td>B-2</td>
<td>0.5-2</td>
<td>FAT CLAY (CH)</td>
<td>A-7-6(35)</td>
<td>55</td>
<td>22</td>
<td>33</td>
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<tr>
<td>B-3</td>
<td>1-2.5</td>
<td>SILTY, CLAYEY SAND with GRAVEL (SC-SM)</td>
<td>A-4(0)</td>
<td>19</td>
<td>13</td>
<td>6</td>
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<td>B-4</td>
<td>0.5-2</td>
<td>SANDY SILT (ML)</td>
<td>A-4(0)</td>
<td>NP</td>
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### Calculations

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<th>D₅₀</th>
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<th>%Gravel</th>
<th>%Sand</th>
<th>%Silt</th>
<th>%Clay</th>
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**Project:** Turner Turnpike Widening - Bridge B  
**Site:** Creek County, Oklahoma  
**Client:** Garver, LLC  
**Exhibit:** B-2  

---

**LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT.**

**GRAIN SIZE DISTRIBUTION**

**ASTM D422 / ASTM C136**

**PERCENT FINER BY WEIGHT**

**GRAIN SIZE IN MILLIMETERS**

**COBBLES**
- coarse
- fine

**GRAVEL**
- coarse
- medium
- fine

**SAND**
- coarse
- fine

**SILT OR CLAY**
- coarse
- fine

---

**Diagram:**
- U.S. SIEVE OPENING IN INCHES
- U.S. SIEVE NUMBERS
- HYDROMETER
### Grain Size Distribution

**ASTM D422 / ASTM C136**

#### U.S. Sieve Opening in Inches

| 100 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 50 | 45 | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5  | 0  |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 6   | 4  | 3  | 2  | 1  | 3/4 | 1 | 1/2 | 3/8 | 3  | 4  | 6  | 10 | 14 | 16 | 20 | 30 | 40 | 50 | 60 | 100 |

#### U.S. Sieve Numbers

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<th>AASHTO Classification</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>Cc</th>
<th>Cu</th>
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#### Hydrometer

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#### Boring ID: B-5

- **Depth**: 0.5 - 2
- **USCS Classification**: SILTY SAND (SM)
- **AASHTO Classification**: A-2-4(0)
- **LL**: NP
- **PL**: NP
- **PI**: NP
- **Cc**: NP
- **Cu**: NP

#### Grain Size Distribution

<table>
<thead>
<tr>
<th>Boring ID</th>
<th>Depth</th>
<th>D₉₀₀</th>
<th>D₄₀₀</th>
<th>D₁₀₀</th>
<th>D₁₀</th>
<th>%Gravel</th>
<th>%Sand</th>
<th>%Silt</th>
<th>%Clay</th>
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**Project Information**

- **Project Number**: 04155197
- **Project**: Turner Turnpike Widening - Bridge B
- **Site**: Creek County, Oklahoma
- **Client**: Garver, LLC.
- **Exhibit**: B-3
- **Lab Test**: Laboratory tests are not valid if separated from original report.
- **Report Date**: 4/20/16
- **Address**: 9522 E 47th Pl Ste D
- **City**: Tulsa, OK

---
## TABLE B.1

### B-1

**LATERAL CAPACITY ANALYSES**

**DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS**

**Turner Turnpike Widening - Bridge B**

**Terracon Project No. 04155197**

**Creek County, Oklahoma**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Layer</th>
<th>Soil Type</th>
<th>Top (feet)</th>
<th>Bottom (feet)</th>
<th>$k^2$ (pci)</th>
<th>Weight (pcf)</th>
<th>Strength (psf)</th>
<th>Angle (degrees)</th>
<th>RQD (%)</th>
<th>$\varepsilon_{50}/k_{rm}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak Rock</td>
<td>1</td>
<td>(8)</td>
<td>0</td>
<td>5.5</td>
<td>10,000</td>
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<td>63</td>
<td>0.0005</td>
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<tr>
<td>Weak Rock</td>
<td>2</td>
<td>(8)</td>
<td>5.5</td>
<td>18.5</td>
<td>10,000</td>
<td>68</td>
<td>100</td>
<td>0</td>
<td>63</td>
<td>0.0005</td>
</tr>
<tr>
<td>Weak Rock</td>
<td>3</td>
<td>(8)</td>
<td>18.5</td>
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<tr>
<td>Weak Rock</td>
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<td>(8)</td>
<td>24</td>
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<td>30,000</td>
<td>68</td>
<td>300</td>
<td>0</td>
<td>79</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Design depth to subsurface water is about 5.5 feet.
2. Value given for **Weak Rock** is $E_{ri}$ in psi.
3. Uniaxial compressive strength for rock, in psi.
4. Value given for RQD estimated from field data and sample examination.
## TABLE B.2

**LATERAL CAPACITY ANALYSES**
**DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS**

**Turner Turnpike Widening - Bridge B**
**Terracon Project No. 04155197**
**Creek County, Oklahoma**

<table>
<thead>
<tr>
<th>Soil</th>
<th>LPILE Soil Type</th>
<th>Depth to Soil Layer (feet)</th>
<th>Modulus $k^2$ (pci)</th>
<th>Effective Weight Strength (pcf)</th>
<th>Undrained Shear (psf)</th>
<th>Internal Friction Angle (degrees)</th>
<th>RQD Factor (%)</th>
<th>Strain $\varepsilon_{50}/k_{fr}$</th>
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<td>0.0075</td>
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<td>4.5</td>
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<td>68</td>
<td>300</td>
<td>0</td>
<td>79</td>
<td>0.0005</td>
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**NOTES:**

1. Design depth to subsurface water is about 4.5 feet.
2. Value given for **Weak Rock** is $E_{ri}$ in psi.
3. Uniaxial compressive strength for rock, in psi.
4. Value given for RQD estimated from field data and sample examination.
### TABLE B.3

**B-3**

**LATERAL CAPACITY ANALYSES**

**DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS**

Turner Turnpike Widening - Bridge B  
Terracon Project No. 04155197  
Creek County, Oklahoma

<table>
<thead>
<tr>
<th>Layer</th>
<th>Soil Type</th>
<th>Top Layer Depth (feet)</th>
<th>Bottom Layer Depth (feet)</th>
<th>Effective Modulus $k^2$ (pci)</th>
<th>Weight Strength $p$ (pcf)</th>
<th>Undrained Shear $t$ (psf)</th>
<th>Friction Angle $\phi$ (degrees)</th>
<th>RQD $%$</th>
<th>Factor $\epsilon_{50}k_{rm}$</th>
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<tr>
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<td>(5)</td>
<td>0</td>
<td>3</td>
<td>25</td>
<td>115</td>
<td>0</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Stiff Clay without Free Water</td>
<td>(3)</td>
<td>3</td>
<td>6</td>
<td>1,008</td>
<td>120</td>
<td>4,000</td>
<td>0</td>
<td>0.00048</td>
</tr>
<tr>
<td>3</td>
<td>Stiff Clay without Free Water</td>
<td>(3)</td>
<td>6</td>
<td>9</td>
<td>1,008</td>
<td>58</td>
<td>4,000</td>
<td>0</td>
<td>0.00048</td>
</tr>
<tr>
<td>4</td>
<td>Weak Rock</td>
<td>(8)</td>
<td>9</td>
<td>14.5</td>
<td>40,000</td>
<td>68</td>
<td>400</td>
<td>0</td>
<td>0.0005</td>
</tr>
<tr>
<td>5</td>
<td>Weak Rock</td>
<td>(8)</td>
<td>14.5</td>
<td>40</td>
<td>30,000</td>
<td>68</td>
<td>300</td>
<td>0</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Design depth to subsurface water is about 6 feet.
2. Value given for **Weak Rock** is $E_{ri}$ in psi.
3. Uniaxial compressive strength for rock, in psi.
4. Value given for RQD estimated from field data and sample examination.

Exhibit B-6
### TABLE B.4

**B-4**

LATERAL CAPACITY ANALYSES

DESIGN SOIL PARAMETERS FOR

UNDRAINED CONDITIONS

Turner Turnpike Widening - Bridge B

Terracon Project No. 04155197

Creek County, Oklahoma

| Soil Type                        | LPILE Soil | Layer Depth to Soil Layer (feet) | Top k^2 (pci) | Bottom Strength^3 (psf) | Angle (degrees) | RQD^
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (5)</td>
<td>LPILE</td>
<td>0</td>
<td>25</td>
<td>115</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>Stiff Clay without Free Water (3)</td>
<td>LPILE</td>
<td>2</td>
<td>9</td>
<td>1,008</td>
<td>120</td>
<td>2,500</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>LPILE</td>
<td>9</td>
<td>14</td>
<td>10,000</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>LPILE</td>
<td>14</td>
<td>17</td>
<td>10,000</td>
<td>68</td>
<td>100</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>LPILE</td>
<td>17</td>
<td>19.5</td>
<td>40,000</td>
<td>68</td>
<td>400</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>LPILE</td>
<td>19.5</td>
<td>39.8</td>
<td>30,000</td>
<td>68</td>
<td>300</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Design depth to subsurface water is about 14 feet.
2. Value given for **Weak Rock** is $E_{ri}$ in psi.
3. Uniaxial compressive strength for rock, in psi.
4. Value given for RQD estimated from field data and sample examination.
### TABLE B.5

#### B-5

**LATERAL CAPACITY ANALYSES**

**DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS**

Turner Turnpike Widening - Bridge B  
Terracon Project No. 04155197  
Creek County, Oklahoma

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Layer</th>
<th>Soil Type</th>
<th>Top Depth (feet)</th>
<th>Bottom Depth (feet)</th>
<th>Soil Modulus (k&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Unit Weight (pci)</th>
<th>Soil Shear Strength (psf)</th>
<th>Internal Friction (degrees)</th>
<th>70% RQD (%)</th>
<th>Factor ε&lt;sub&gt;50/k&lt;sub&gt;rm&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (4)</td>
<td>1</td>
<td>Sand (4)</td>
<td>0</td>
<td>4</td>
<td>25</td>
<td>115</td>
<td>0</td>
<td>28</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>Stiff Clay without Free Water (3)</td>
<td>2</td>
<td>Stiff Clay without Free Water (3)</td>
<td>4</td>
<td>8.5</td>
<td>1,008</td>
<td>120</td>
<td>4,000</td>
<td>0</td>
<td>79</td>
<td>0.0048</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>3</td>
<td>Weak Rock (8)</td>
<td>8.5</td>
<td>19</td>
<td>10,000</td>
<td>130</td>
<td>100</td>
<td>0</td>
<td>79</td>
<td>0.0005</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>4</td>
<td>Weak Rock (8)</td>
<td>19</td>
<td>24</td>
<td>40,000</td>
<td>130</td>
<td>400</td>
<td>0</td>
<td>63</td>
<td>0.0005</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>5</td>
<td>Weak Rock (8)</td>
<td>24</td>
<td>29</td>
<td>30,000</td>
<td>130</td>
<td>300</td>
<td>0</td>
<td>79</td>
<td>0.0005</td>
</tr>
<tr>
<td>Weak Rock (8)</td>
<td>6</td>
<td>Weak Rock (8)</td>
<td>29</td>
<td>39.2</td>
<td>30,000</td>
<td>68</td>
<td>300</td>
<td>0</td>
<td>79</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Design depth to subsurface water is greater than about 29 feet.
2. Value given for **Weak Rock** is $E_{ri}$ in psi.
3. Uniaxial compressive strength for rock, in psi.
4. Value given for RQD estimated from field data and sample examination.
APPENDIX C
SUPPORTING DOCUMENTS
**GENERAL NOTES**

**DESCRIPTION OF SYMBOLS AND ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Descriptive Term(s) of other constituents</th>
<th>Percent of Dry Weight</th>
<th>Major Component of Sample</th>
<th>Particle Size</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>(HP)</td>
<td>Hand Penetrometer</td>
<td></td>
<td>Boulders</td>
<td>Over 12 in. (300 mm)</td>
<td>0</td>
</tr>
<tr>
<td>(T)</td>
<td>Torvane</td>
<td></td>
<td>Cobbles</td>
<td>12 in. to 3 in. (300mm to 75mm)</td>
<td>1 - 10</td>
</tr>
<tr>
<td>(b/f)</td>
<td>Standard Penetration Test (blows per foot)</td>
<td></td>
<td>Gravel</td>
<td>3 in. to #4 sieve (75mm to 4.75 mm)</td>
<td>11 - 30</td>
</tr>
<tr>
<td>(PID)</td>
<td>Photo-Ionization Detector</td>
<td></td>
<td>Sand</td>
<td>#4 to #200 sieve (4.75mm to 0.075mm)</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>(OVA)</td>
<td>Organic Vapor Analyzer</td>
<td></td>
<td>Silt or Clay</td>
<td>Passing #200 sieve (0.075mm)</td>
<td></td>
</tr>
<tr>
<td>(TCP)</td>
<td>Texas Cone Penetrometer</td>
<td></td>
<td></td>
<td></td>
<td></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.
### UNIFIED SOIL CLASSIFICATION SYSTEM

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

<table>
<thead>
<tr>
<th>Coarse Grained Soils: More than 50% retained on No. 200 sieve</th>
<th>Fine-Grained Soils: 50% or more passes the No. 200 sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravels: More than 50% of coarse fraction retained on No. 4 sieve</td>
<td>Silts and Clays: Liquid limit less than 50</td>
</tr>
<tr>
<td>Sands: 50% or more of coarse fraction passes No. 4 sieve</td>
<td>Silts and Clays: Liquid limit 50 or more</td>
</tr>
</tbody>
</table>

#### Gravels:
- More than 50% of coarse fraction
- More than 5% fines

#### Sands:
- 50% or more of coarse fraction
- Less than 5% fines

#### Gravels with Fines:
- More than 12% fines
- Fines classify as ML or MH

#### Sands with Fines:
- More than 12% fines
- Fines classify as ML or MH

#### Silts and Clays:
- Liquid limit less than 50
- Liquid limit 50 or more

#### Inorganic:
- PI > 7 and plots on or above “A” line
- PI < 4 or plots below “A” line

#### Organic:
- Liquid limit - oven dried
- Liquid limit - not dried

#### Highly organic soils:
- Primarily organic matter, dark in color, and organic odor

#### Soil Classification

<table>
<thead>
<tr>
<th>Group Symbol</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW</td>
<td>Well-graded gravel</td>
</tr>
<tr>
<td>GP</td>
<td>Poorly graded gravel</td>
</tr>
<tr>
<td>GM</td>
<td>Silty gravel</td>
</tr>
<tr>
<td>GC</td>
<td>Clayey gravel</td>
</tr>
<tr>
<td>SW</td>
<td>Well-graded sand</td>
</tr>
<tr>
<td>SP</td>
<td>Poorly graded sand</td>
</tr>
<tr>
<td>SM</td>
<td>Silty sand</td>
</tr>
<tr>
<td>SC</td>
<td>Clayey sand</td>
</tr>
<tr>
<td>CL</td>
<td>Lean clay</td>
</tr>
<tr>
<td>ML</td>
<td>Silt</td>
</tr>
<tr>
<td>OL</td>
<td>Organic clay</td>
</tr>
<tr>
<td>CH</td>
<td>Fat clay</td>
</tr>
<tr>
<td>MH</td>
<td>Elastic Silt</td>
</tr>
<tr>
<td>OH</td>
<td>Organic silt</td>
</tr>
</tbody>
</table>

- **Cu** = \( \frac{D_{60}}{D_{10}} \)  
- **Cc** = \( \frac{(D_{60})^2}{D_{10} \times D_{60}} \)
- **Pi** = Plasticity Index

---

**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**
### AASHTO SOIL CLASSIFICATION SYSTEM

<table>
<thead>
<tr>
<th>GENERAL CLASSIFICATION</th>
<th>GRANULAR MATERIALS (35% OR LESS PASSING 0.075 SIEVE)</th>
<th>SILT-CLAY MATERIALS (MORE THAN 35% PASSING 0.075 SIEVE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIEVE ANALYSIS, PERCENT PASSING:</td>
<td>≤ 50</td>
<td>≤ 50</td>
</tr>
<tr>
<td>2.00 mm (No. 10)</td>
<td>≤ 30</td>
<td>≤ 50</td>
</tr>
<tr>
<td>0.425 mm (No. 40)</td>
<td>≤ 15</td>
<td>≤ 25</td>
</tr>
<tr>
<td>0.075 mm (No. 200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHARACTERISTICS OF FRACTION PASSING:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.425 SIEVE (No. 40):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIQUID LIMIT</td>
<td>6 max</td>
<td>NP</td>
</tr>
<tr>
<td>PLASTICITY INDEX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USUAL TYPES OF CONSTITUENT MATERIALS</td>
<td>STONE FRAGMENTS, GRAVEL, SAND</td>
<td>FINE SAND</td>
</tr>
</tbody>
</table>

**GENERAL RATING AS A SUBGRADE**

<table>
<thead>
<tr>
<th></th>
<th>EXCELLENT TO GOOD</th>
<th>FAIR TO POOR</th>
</tr>
</thead>
</table>

*Plasticity index of A-7-5 subgroup is equal to or less than LL-30. Plasticity index of A-7-6 subgroup is greater than LL-30.

NP = Non-plastic (use ‘0’). Symbol ‘—’ means that the particular sieve analysis is not considered for the classification.

If the soil classification is A4-A7, then calculate the group index (GI) as shown below and report with classification. The higher the GI, the less suitable the soil. Example: A-6 with GI = 15 is less suitable than A-6 with GI = 10.

\[
GI = (F - 35) \times 0.2 + 0.005 \times (LL - 40) + 0.01 \times (F - 15) \times (PI - 10)
\]

where:  
F = Percent passing No. 200 sieve, expressed as a whole number. This percentage is based only on the material passing the No. 200 sieve.
LL = Liquid limit
PI = Plasticity index

If the computed value of GI < 0, then use GI = 0.
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.

LIMESTONE
Light to dark colored, crystalline to fine-grained texture, composed of CaCO₃, reacts readily with HCl.

DOLOMITE
Light to dark colored, crystalline to fine-grained texture, composed of CaMg(CO₃)₂, harder than limestone, reacts with HCl when powdered.

CHERT
Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz (SiO₂), brittle, breaks into angular fragments, will scratch glass.

SHALE
Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The un laminated equivalent is frequently referred to as siltstone, claystone or mudstone.

SANDSTONE
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.

CONGLOMERATE
Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

PHYSICAL PROPERTIES:

DEGREE OF WEATHERING

Slight
Slight decomposition of parent material on joints. May be color change.

Moderate
Some decomposition and color change throughout.

High
Rock highly decomposed, may be extremely broken.

HARDNESS AND DEGREE OF CEMENTATION

Limestone and Dolomite:

Hard
Difficult to scratch with knife.

Moderately
Can be scratched easily with knife, cannot be scratched with fingernail.

Hard
Can be scratched with fingernail.

Shale, Siltstone and Claystone

Hard
Can be scratched easily with knife, cannot be scratched with fingernail.

Moderately
Can be scratched with fingernail.

Soft
Can be easily dented but not molded with fingers.

Sandstone and Conglomerate

Well
Capable of scratching a knife blade.

Cemented
Can be scratched with knife.

Poorly
Can be broken apart easily with fingers.

BEDDING AND JOINT CHARACTERISTICS

<table>
<thead>
<tr>
<th>Bed Thickness</th>
<th>Joint Spacing</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Thick</td>
<td>Very Wide</td>
<td>&gt; 10'</td>
</tr>
<tr>
<td>Thick</td>
<td>Wide</td>
<td>3' - 10'</td>
</tr>
<tr>
<td>Medium</td>
<td>Moderately Close</td>
<td>1' - 3'</td>
</tr>
<tr>
<td>Thin</td>
<td>Close</td>
<td>2' - 1'</td>
</tr>
<tr>
<td>Very Thin</td>
<td>Very Close</td>
<td>.4' - 2&quot;</td>
</tr>
<tr>
<td>Laminated</td>
<td>—</td>
<td>.1' - .4&quot;</td>
</tr>
</tbody>
</table>

Bedding Plane
A plane dividing sedimentary rocks of the same or different lithology.

Joint
Fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.

Seam
Generally applies to bedding plane with an unspecified degree of weathering.

SOLUTION AND VOID CONDITIONS

Solid
Contains no voids.

Vuggy (Pitted)
Rock having small solution pits or cavities up to ½ inch diameter, frequently with a mineral lining.

Porous
Containing numerous voids, pores, or other openings, which may or may not interconnect.

Cavernous
Containing cavities or caverns, sometimes quite large.