Geotechnical Engineering Report

Bridge No. 15 over Mud Creek Tributary
Pawnee County, Oklahoma
November 7, 2014
Terracon Project No. 04145205

Prepared for:
Guy Engineering Services, Inc.
Tulsa, Oklahoma

Prepared by:
Terracon Consultants, Inc.
Tulsa, Oklahoma
November 7, 2014

Guy Engineering Services, Inc.
10759 East Admiral Place
Tulsa, Oklahoma 74116-3012

Attn: Ms. Rebecca Alvarez, P.E.
Rebecca@guyengr.com

Re: Geotechnical Engineering Report
Bridge 15 over Mud Creek Tributary
Pawnee County, Oklahoma
Terracon Project Number: 04145205

Dear Ms. Alvarez:

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 P04130748 dated November 25, 2013. 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. 6/30/15

[Signatures]

Vaughn Rupnow, P.E.
Oklahoma No. 25692

Michael H. Homan, P.E.
Regional Manager

VR-MHH io
Enclosures
Addressee (3 via US Mail and 1 via email)
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1.0 INTRODUCTION

This geotechnical engineering report has been completed for Bridge No. 15 over Mud Creek Tributary in Pawnee County, Oklahoma. Two borings, designated B-1 and B-2, were drilled to depths of approximately 24 feet below the existing ground surface for the proposed bridge. Logs of the borings along with a site location map and a boring location plan are included 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
- backfill compaction

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, Exhibit A-2: Boring Location Plan.</td>
</tr>
<tr>
<td>Proposed Construction</td>
<td>New steel arch structure with footing elevation near 892 feet.</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>NS 34600 Road crossing over Mud Creek tributary in Pawnee County, Oklahoma.</td>
</tr>
<tr>
<td>Existing improvements</td>
<td>Existing bridge.</td>
</tr>
</tbody>
</table>
3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

Based on the results of the borings, subsurface conditions at the project site can be generalized as follows:

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Approximate Depth to Bottom of Stratum</th>
<th>Material Description</th>
<th>Consistency/ Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>6 inches</td>
<td>Gravel</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>17 to 18.5 feet</td>
<td>Clayey sand, silty sand, sandy silty clay, sandy lean clay with sandstone fragments</td>
<td>Sand: Medium dense Clay: Stiff to very stiff</td>
</tr>
<tr>
<td>2</td>
<td>Encountered to boring termination depths of about 24 feet</td>
<td>Shale with sandstone seams</td>
<td>Moderately hard to hard</td>
</tr>
</tbody>
</table>

Conditions encountered at the boring locations are indicated on the boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil and rock types; in situ, the transition between materials may be gradual. Classification of bedrock materials was made from disturbed samples. Core samples and petrographic analysis may reveal other rock types. Details for the borings can be found on the boring logs in Appendix A of this report.

3.2 Groundwater

The boreholes were observed while drilling and immediately after completion for the presence and level of groundwater. No groundwater was observed at these times. Long-term monitoring in piezometers or cased holes, sealed from the influence of surface water, would be required to evaluate longer-term groundwater conditions. During some periods of the year, perched water could be present within the overburden soils and within cracks and fissures within the bedrock. Fluctuations in groundwater levels should be expected throughout the years depending upon the water level in the creek, variations in the amount of rainfall, runoff, evaporation, and other hydrological factors not apparent at the time the borings were performed.
4.0  RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1  Geotechnical Considerations

The steel arch structure can be supported on a shallow foundation system. The structure will bear on shale bedrock at the proposed footing elevation.

Based on our experience, rock formations that can be penetrated by the flight augers used in our drilling operation can sometimes be excavated using large, heavy-duty equipment equipped with rock excavation attachments. However, the contractor should anticipate the need for hydraulic hoe rams or special rock excavation techniques to penetrate the well cemented sandstone seams within the shale bedrock at this site. Recommendations regarding the design and construction of bridge foundations are provided below.

4.2  Foundations

The bedrock bearing material was encountered at the bridge location 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>17</td>
</tr>
<tr>
<td>B-2</td>
<td>18.5</td>
</tr>
</tbody>
</table>

4.2.1  Footing Foundation Design Recommendations

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Design Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net allowable bearing pressure (^1)</td>
<td>15,000 psf</td>
</tr>
<tr>
<td>Minimum width</td>
<td>18 inches</td>
</tr>
<tr>
<td>Minimum embedment (below lowest exterior grade) (^2)</td>
<td>24 inches</td>
</tr>
<tr>
<td>Estimated total and differential settlement</td>
<td>1 inch or less</td>
</tr>
</tbody>
</table>

1. The net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation for footings founded in bedrock. Footing excavation should be free of loose and disturbed material, debris, and water when concrete is placed.

2. Minimum depth will help provide frost protection.

4.2.2  Footing Foundation Construction Considerations

Footing excavations should be free of water, loose soil, loose rock, and debris when concrete is placed. Concrete should be placed soon after excavating to reduce bearing material disturbance. Should the materials at bearing level become frozen, excessively wetted or dry, or otherwise disturbed, the affected material should be removed prior to placing concrete.
Based on our experience, rock formations that can be penetrated by the flight augers used in
our drilling operation can sometimes be excavated using large, heavy-duty equipment equipped
with rock excavation attachments. However, the contractor should anticipate the need for
hydraulic hoe rams or special rock excavation techniques to penetrate the well cemented
sandstone seams within the shale bedrock at this site.

To evaluate that suitable bearing materials are encountered, we recommend the base of all
footing excavations be observed and evaluated by the geotechnical engineer prior to placing
reinforcing steel and concrete.

### 4.3 Seismic Considerations

<table>
<thead>
<tr>
<th>Code Used</th>
<th>Site Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 International Building Code (IBC)¹</td>
<td>C</td>
</tr>
</tbody>
</table>

1. In general accordance with the *2009 International Building Code*, Table 1613.5.2.

### 4.4 Lateral Earth Pressures

The steel arch walls will be subject to lateral earth pressures from the surrounding soils. The
magnitude of lateral earth pressure would depend on the height of the wall, stiffness of the wall,
and the backfill and existing soil conditions behind the wall. We understand that ODOT Type A
aggregate base material will be used as backfill for the structure. The backfill will extend to at
least 4 feet away from the wall.

Assuming the culvert is rigid and cannot move sufficiently to mobilize the shear strength of the
soil, and has no mechanism for relieving hydrostatic pressure, we recommend designing for an
at-rest earth pressure condition. The culvert can be designed using an equivalent fluid pressure
of 60 pounds per cubic foot to represent the at-rest earth pressure. Where the walls can move
sufficiently to fully mobilize the shear strength of the retained soil (wing walls), we recommend
designing the walls based on an active earth pressure condition. The walls should be designed
using an equivalent fluid pressure of at least 45 pounds per cubic foot for active pressure
conditions.

The at-rest and active pressures assume a triangular stress distribution, no surcharge loads
behind the walls, and the walls will retain native soils and backfill materials consisting of ODOT
Type A aggregate base material. These values do not include any stress transmitted to the
culvert from adjacent pavement loading. An increased equivalent fluid pressure value should be
used to represent any pavement loading.
Backfill adjacent to the walls should be placed in uniform 9-inch thick loose lifts and compacted to at least 95 percent of the material's maximum laboratory dry density, determined in accordance with AASHTO T-99.

To develop resistance to lateral movement, we recommend using an allowable passive earth pressure of 750 psf (rectangular distribution) and a coefficient of friction of 0.4 between the footing and underlying bedrock or crushed stone fill. The upper 2 feet of material should not be assumed to provide lateral resistance because of the potential strength loss of these materials due to freeze/thaw cycles.

4.5 Earthwork

4.5.1 Backfill Material Types
Engineered fill should meet the following material property requirements:

<table>
<thead>
<tr>
<th>Fill Type</th>
<th>USCS Classification</th>
<th>Acceptable Location for Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered Fill Material</td>
<td>CL or SC (PI ≤ 20)</td>
<td>All locations and elevations</td>
</tr>
<tr>
<td>On-Site Soils</td>
<td>Varies</td>
<td>All locations and elevations</td>
</tr>
<tr>
<td>ODOT Type A Aggregate Base</td>
<td>---</td>
<td>All locations and elevations</td>
</tr>
</tbody>
</table>

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris and contain maximum rock size of 3 inches. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the geotechnical engineer for evaluation.

2. Low plasticity cohesive soil or granular soil having a plasticity index (PI) of 20 or less and containing at least 15% fines (material passing the No. 200 sieve, based on dry weight).

4.5.2 Compaction Requirements
The backfill should be moisture conditioned and compacted using recommendations in the following table:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill Lift Thickness</td>
<td>9-inches or less in loose thickness</td>
</tr>
<tr>
<td>Compaction Requirements</td>
<td>At least 95% of the material's maximum standard Proctor dry density (AASHTO T-99)</td>
</tr>
</tbody>
</table>
Moisture Content

Soil: -2 to +2% of the optimum moisture content
ODOT Type A Aggregate Base: workable moisture content

1. We recommend that backfill be tested for moisture content and compaction. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

The recommended moisture content should be maintained until fills are completed and pavements are constructed.

4.5.3 Earthwork Construction Considerations

Upon completion of filling and grading, care should be taken to maintain the recommended subgrade moisture content prior to construction. Construction traffic over the completed subgrade should be avoided to the extent practical. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become frozen, excessively wetted or dried, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

Temporary excavations will be required during grading operations. The grading contractor, by his contract, is usually responsible for designing and constructing stable, temporary excavations and should shore, slope or bench the sides of the excavations as required, to maintain stability of both the excavation sides and bottom. All excavations should comply with applicable local, state and federal safety regulations, including the current OSHA Excavation and Trench Safety Standards.

Terracon should be retained during the construction phase of the project to provide observation and testing during earthwork.

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 or biological (e.g., mold, fungi, bacteria) 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
**BORING LOCATION PLAN**

**GEOTECHNICAL EXPLORATION**

**BRIDGE 15 OVER TRIBUTARY OF MUD CREEK**

Pawnee County, Oklahoma

**BASE DRAWING PROVIDED BY GUY ENGINEERING SERVICES, INC.**

**LEGEND**

- **BORING LOCATION**

**BORING LOCATION PLAN**

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

**BORING** | **STATION** | **OFFSET** | **ELEV. (FT)**
---|---|---|---
B-1 | 16+66 | 20' LT | 911.7
B-2 | 17+30 | 20' LT | 911.4

**OFFSETS BASED ON ROAD**

**APPROXIMATE SCALE IN FEET**

**VER 04145205**

**SEE BAR SCALE**

**VER 04145205**

**MHH**

NOV 2014
Field Exploration Description

Terracon established the boring locations in the field by taping distances from existing site features. We measured the ground surface elevation at the boring locations using an engineer’s level. We used benchmark #4 as indicated on the General Plan & Elevation sheet provided by Guy Engineering, which had a reported elevation of 914.06 feet. The elevations are shown near the top of the logs and have been rounded to the nearest 0.1 foot. The boring locations and elevations should be considered accurate only to the degree implied by the methods used to define them.

We advanced the borings with our all-terrain rotary drill rig using the power auger technique. Representative soil samples were obtained using the split-barrel sampling procedure.

Disturbed samples of the overburden soils were obtained by the split-barrel sampling procedure by driving a 2-inch O.D. split-barrel sampling spoon into the ground using a 140-pound, automatic hammer falling 30 inches. The number of blows required to advance the sampling spoon were recorded in the field and are shown on the boring logs as the standard penetration resistance (N) value. The number of blows required to advance the sampling spoon the final 12 inches or less of a standard 18-inch sampling interval indicate the consistency of cohesive soils and, to a lesser degree of accuracy, the hardness of weathered rock. The sampling depths, penetration distances, and the 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 and classification.

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

A field log of each boring was prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller’s interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer’s interpretation of the field logs and include modifications based on laboratory observation and tests of the samples. A brief description of the Unified System is included in the appendix. Rock descriptions are in general accordance with the General Notes for Sedimentary Rock. Petrographic analysis of the rock cores 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 grouted the borings in order to comply with the Oklahoma Water Resources Board requirements.
**BORING LOG NO. B-1**

**PROJECT:** Bridge 15 over Mud Creek Tributary

**SITE:** Pawnee County, Oklahoma

---

**LOCATION**

- **Graphical Log:** See Exhibit A-2
  - **Station:** 16+66
  - **Offset:** 20’ LT
  - **Surface Elev.:** 911.7 (Ft.)

---

**DEPTH (Ft.)**

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Recovery</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>6&quot; Gravel</td>
<td>18</td>
<td>5-6-6 N=11</td>
<td>24-17-7</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Silty Clayey Sand (SC-SM), light reddish-brown, medium dense</strong></td>
<td>18</td>
<td>5-6-7 N=13</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>18</td>
<td>4-5-6 N=11</td>
<td>24-18-6</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sandy Silty Clay (CL-ML), brown, stiff</strong></td>
<td>12</td>
<td>5-8-9 N=17</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td>18</td>
<td>5-7-5 N=12</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sandy Lean Clay (CL), with sandstone fragments, light brownish-gray, very stiff</strong></td>
<td>5</td>
<td>50/5”</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td>2</td>
<td>50/2”</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shale+, with sandstone seams, gray, moderately hard to hard</strong></td>
<td>5</td>
<td>50/5”</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.9</td>
<td>5</td>
<td>50/5”</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Boring Terminated at 23.9 Feet**

---

**WATER LEVEL OBSERVATIONS**

- **not encountered while drilling**
- **not encountered after boring**

---

**Notes:**

- **Hammer Type:** Automatic
- **Advancement Method:** Power Auger
- **Abandonment Method:**
- **Data:**
- **Classification estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.**
- **Site:** Pawnee County, Oklahoma

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**PROJECT:** Bridge 15 over Mud Creek Tributary

**DRILLER:** T

**Drill Rig:** ATV 840

**Boring Started:** 10/29/2014

**Boring Completed:** 10/29/2014

**Driller:** TS

**Project No.:** 04145205

**Exhibit:** A-4
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DEPTH (Ft.)</th>
<th>RECOVERY (ft.)</th>
<th>FIELD TEST RESULTS</th>
<th>UNDRAINED CON amph tide (psi)</th>
<th>WATER CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>LL-PL-PI</th>
<th>PERCENT FINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; Gravel SILTY SAND (SM), brown, medium dense</td>
<td>5.0</td>
<td>10</td>
<td>6-10-1</td>
<td>N=11</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>4-4-6</td>
<td>N=10</td>
<td>7</td>
<td>NP</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>SANDY LEAN CLAY (CL), brown, stiff</td>
<td>13.5</td>
<td>16</td>
<td>6-4-5</td>
<td>N=9</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>4-4-4</td>
<td>N=8</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SANDY LEAN CLAY (CL), with sandstone fragments, dark brown, stiff</td>
<td>18.5</td>
<td>8</td>
<td>7-5-4</td>
<td>N=9</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHALE+, with sandstone seams, brownish-gray, moderately hard to hard</td>
<td>23.8</td>
<td>5</td>
<td>50/5</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>50/3</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Boring Terminated at 23.8 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.

**Advancement Method:** Power Auger

**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.

**PROJECT:** Bridge 15 over Mud Creek Tributary

**SITE:** Pawnee County, Oklahoma

**CLIENT:** Guy Engineering Services, Inc.

**LOCATION** See Exhibit A-2

**DEPTH**

<table>
<thead>
<tr>
<th>Station: 17+30 Offset: 20' LT</th>
<th>Surface Elev.: 911.4 (Ft.)</th>
<th>6-10-1N=114-4-6N=10</th>
<th>6-4-5N=9</th>
<th>7-5-4N=9</th>
<th>50/5</th>
<th>50/3</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/5</td>
<td>906.5</td>
<td>908</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>911.4</td>
<td>898</td>
<td></td>
<td></td>
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<tr>
<td>12</td>
<td>911.4</td>
<td>893</td>
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<tr>
<td>14</td>
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<td>16</td>
<td>911.4</td>
<td>893</td>
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</tr>
<tr>
<td>2.5</td>
<td>911.4</td>
<td>887.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIELD TEST RESULTS**

**UNCONFINED COMPRESSIVE STRENGTH (psi)**

**PERCENT FINES**

**WATER CONTENT (%)**

**WATER LEVEL OBSERVATIONS**

- not encountered while drilling
- not encountered after boring

**Boring Started:** 10/29/2014

**Boring Completed:** 10/29/2014

**Drill Rig:** ATV 840

**Driller:** TS

**Project No.:** 04145205

**Exhibit:** A-5

Guy Engineering Services, Inc.

**LOCATION:**

**DEPTH (Ft.)**

<table>
<thead>
<tr>
<th>ELEVATION (Ft.)</th>
<th>6-10-1N=114-4-6N=10</th>
<th>6-4-5N=9</th>
<th>7-5-4N=9</th>
<th>50/5</th>
<th>50/3</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/5</td>
<td>906.5</td>
<td>908</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>911.4</td>
<td>898</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>911.4</td>
<td>893</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>911.4</td>
<td>893</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>911.4</td>
<td>893</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>911.4</td>
<td>887.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WATER LEVEL OBSERVATIONS**

- not encountered while drilling
- not encountered after boring

**Boring Started:** 10/29/2014

**Boring Completed:** 10/29/2014

**Drill Rig:** ATV 840

**Driller:** TS

**Project No.:** 04145205

**Exhibit:** A-5
APPENDIX B
LABORATORY TESTING
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. Samples of bedrock were classified in accordance with the general notes for Sedimentary Rock Classification. At that time, the field descriptions were confirmed or modified as necessary and an applicable laboratory testing program was formulated to determine engineering properties of the subsurface materials. The laboratory test results are reported on the boring logs in Appendix A.

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

- Water Content
- Atterberg Limits
- Sieve Analysis
**GENERAL NOTES**

**DESCRIPTION OF SYMBOLS AND ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th>Water Initially Encountered</th>
<th>Water Level After a Specified Period of Time</th>
<th>Water Level After a Specified Period of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Split Spoon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shelby Tube</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macro Core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring Sampler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock Core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grab Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Recovery</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIELD TESTS**

- (HP) Hand Penetrometer
- (T) Torvane
- (b/f) Standard Penetration Test (blows per foot)
- (PID) Photo-Ionization Detector
- (OVA) Organic Vapor Analyzer

**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.) Density determined by Standard Penetration Resistance Includes gravels, sands and silts.

<table>
<thead>
<tr>
<th>STRENGTH TERMS</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
<th>Ring Sampler Blows/Ft.</th>
<th>Descriptive Term (Density)</th>
<th>Descriptive Term (Consistency)</th>
<th>Unconfined Compressive Strength, Qu, psf</th>
<th>Standard Penetration or N-Value Blows/Ft.</th>
<th>Ring Sampler Blows/Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<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>
<td></td>
</tr>
<tr>
<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>
<td></td>
</tr>
<tr>
<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>
<td></td>
</tr>
<tr>
<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>
<td></td>
</tr>
<tr>
<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>
<td></td>
</tr>
<tr>
<td>Hard</td>
<td></td>
<td></td>
<td>Hard</td>
<td>&gt; 8,000</td>
<td>&gt; 30</td>
<td>&gt; 42</td>
<td></td>
</tr>
</tbody>
</table>

**CONSISTENCY OF FINE-GRAINED SOILS**

(50% more or passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance.

**RELATIVE PROPORTIONS OF SAND AND 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. (300 mm)</td>
</tr>
<tr>
<td>With</td>
<td>15 - 29</td>
<td>Cobble</td>
<td>12 in. to 3 in. (300mm to 75mm)</td>
</tr>
<tr>
<td>Modifier</td>
<td>&gt; 30</td>
<td>Gravel</td>
<td>3 in. to #4 sieve (75mm to 4.75 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>#4 to #200 sieve (4.75mm to 0.075mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt or Clay</td>
<td>Passing #200 sieve (0.075mm)</td>
</tr>
</tbody>
</table>

**RELATIVE PROPORTIONS OF FINE SOILS**

<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>

**PLASTICITY DESCRIPTION**

**GRAIN SIZE TERMINOLOGY**

**LOCATION AND ELEVATION NOTES**

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</tr>
<tr>
<td>Modifier</td>
<td>&gt; 30</td>
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</tr>
<tr>
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<td>Sand</td>
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<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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<tr>
<td>With</td>
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</tr>
<tr>
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<td>11 - 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High</td>
<td>&gt; 30</td>
</tr>
</tbody>
</table>

**PLASTICITY DESCRIPTION**

**GRAIN SIZE TERMINOLOGY**

Exhibit C-1
## 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><strong>Coarse Grained Soils:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 50% retained on No. 200 sieve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravels:</td>
<td>Cu ≥ 4 and 1 ≤ Cc ≤ 3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>GW</td>
</tr>
<tr>
<td>More than 50% of coarse fraction retained on No. 4 sieve</td>
<td>Cu ≥ 4 and/or 1 &gt; Cc &gt; 3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>GP</td>
</tr>
<tr>
<td>Gravels with Fines:</td>
<td>Fines classify as ML or MH</td>
<td>GM</td>
</tr>
<tr>
<td>More than 12% fines</td>
<td>Fines classify as CL or CH</td>
<td>GC</td>
</tr>
<tr>
<td>Sands:</td>
<td>Cu ≥ 6 and 1 ≤ Cc ≤ 3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>SW</td>
</tr>
<tr>
<td>50% or more of coarse fraction passes No. 4 sieve</td>
<td>Cu ≥ 6 and/or 1 &gt; Cc &gt; 3&lt;sup&gt;E&lt;/sup&gt;</td>
<td>SP</td>
</tr>
<tr>
<td>Sands with Fines:</td>
<td>Fines classify as ML or MH</td>
<td>SM</td>
</tr>
<tr>
<td>More than 12% fines</td>
<td>Fines classify as CL or CH</td>
<td>SC</td>
</tr>
</tbody>
</table>

### Fine-Grained Soils:

- Liquid limit less than 50
- Liquid limit 50 or more

<table>
<thead>
<tr>
<th>Group Symbol</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic:</td>
<td>PI &gt; 7 and plots on or above “A” line&lt;sup&gt;J&lt;/sup&gt;</td>
</tr>
<tr>
<td>Organic:</td>
<td>PI &lt; 4 or plots below “A” line</td>
</tr>
<tr>
<td>Liquid limit - oven dried</td>
<td>&lt; 0.75</td>
</tr>
<tr>
<td>Liquid limit - not dried</td>
<td></td>
</tr>
<tr>
<td>Inorganic:</td>
<td>PI plots on or above “A” line</td>
</tr>
<tr>
<td>Organic:</td>
<td>PI plots below “A” line</td>
</tr>
<tr>
<td>Liquid limit - oven dried</td>
<td></td>
</tr>
<tr>
<td>Liquid limit - not dried</td>
<td></td>
</tr>
</tbody>
</table>

### Highly Organic Soils:

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

---

<sup>A</sup> Based on the material passing the 3-in. (75-mm) sieve
<sup>B</sup> If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.
<sup>C</sup> 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.
<sup>D</sup> 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.
<sup>E</sup> Cu = D<sub>60</sub>/D<sub>10</sub> Cc = (D<sub>60</sub>)<sup>2</sup> / D<sub>10</sub> x D<sub>60</sub>
<sup>F</sup> If soil contains ≥ 15% sand, add “with sand” to group name.
<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
<sup>H</sup> If fines are organic, add “with organic fines” to group name.
<sup>I</sup> If soil contains ≥ 15% gravel, add “with gravel” to group name.
<sup>J</sup> If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
<sup>K</sup> If soil contains 15 to 29% plus No. 200, add “with sand” or “with gravel,” whichever is predominant.
<sup>L</sup> If soil contains ≥ 30% plus No. 200 predominantly sand, add “sandy” to group name.
<sup>M</sup> If soil contains ≥ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.
<sup>N</sup> PI ≥ 4 and plots on or above “A” line.
<sup>O</sup> PI < 4 or plots below “A” line.
<sup>P</sup> PI plots on or above “A” line.
<sup>Q</sup> PI plots below “A” line.
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 unlamelated 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.

CONGLERATE
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.

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

Soft
Can be scratched with fingernail.

Shale, Siltstone and Claystone
Hard
Can be scratched easily with knife, cannot be scratched with fingernail.

Moderately Hard
Can be scratched with fingernail.

Soft
Can be easily dented but not molded with fingers.

Sandstone and Conglomerate
Well Cemented
Capable of scratching a knife blade.

Cemented
Can be scratched with knife.

Poorly Cemented
Can be broken apart easily with fingers.

BEDDING AND JOINT CHARACTERISTICS

Bed Thickness

<table>
<thead>
<tr>
<th>Hard</th>
<th>Medium</th>
<th>Very Thin</th>
<th>Laminated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Thick</td>
<td>Thick</td>
<td>Moderate Close</td>
<td>Very Close</td>
</tr>
<tr>
<td>Very Wide</td>
<td>Wide</td>
<td>Close</td>
<td>Very Close</td>
</tr>
</tbody>
</table>

Joint Spacing

<table>
<thead>
<tr>
<th>Very Thick</th>
<th>Medium</th>
<th>Very Thin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Wide</td>
<td>Moderately Close</td>
<td>Very Close</td>
</tr>
<tr>
<td>3' - 10'</td>
<td>1' - 3'</td>
<td>.4&quot; - .2&quot;</td>
</tr>
</tbody>
</table>

Dimensions

<table>
<thead>
<tr>
<th>Hard</th>
<th>Medium</th>
<th>Very Thin</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10'</td>
<td>2&quot; - 1'</td>
<td>.1&quot; - .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.