# Geotechnical Engineering Report

**Russellville Substation Cut In**
**Russellville, Pope County, Arkansas**
December 12, 2018
Terracon Project No. 35185126

**Prepared for:**
Entergy Services, Inc.
New Orleans, Louisiana

**Prepared by:**
Terracon Consultants, Inc.
Little Rock, Arkansas

December 12, 2018

Terracon GeoReport

Entergy Services, Inc.
639 Loyola Avenue
L-ENT-8D
New Orleans, Louisiana 70113

Attn: Mr. Justin Richard, E.I.
Transmission Line Design, Engineer I
P: (504) 576 7221
E: jrich18@entergy.com

Re: Proposal for Geotechnical Engineering Services
Russellville Substation Cut In
Russellville, Pope County, Arkansas
Terracon Proposal No. P35185108

Dear Mr. Richard:

We have completed the Geotechnical Engineering services for the above-referenced project. This study was performed in general accordance with Terracon Proposal No. P35185108 dated October 18, 2018. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations for the proposed project.

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.**

*Certificate of Authorization #223, Expires 12/31/2019*

Kimberly A. Daggitt, P.E.
Project Engineer

Christopher S. Handley, P.E.
Geotechnical Department Manager

Greg J. Klein, P.E.
National Director

STATE OF ARKANSAS
12/13/18
LICENSED PROFESSIONAL ENGINEER
No. 16398
KIMBERLY A. DAGGITT

## REPORT TOPICS



**Note:** This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the ***GeoReport*** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

## ATTACHMENTS



**Note:** Refer to each individual Attachment for a listing of contents.

# Geotechnical Engineering Report

**Russellville Substation Cut In**
**Tyler Road and East 6th Street**
**Russellville, Pope County, Arkansas**
**Terracon Project No. 35185126**
**December 12, 2018**

## INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed substation to be located near the southeast corner of the Tyler Road and East 6th Street intersection in Russellville, Pope County, Arkansas. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Site preparation and earthwork
- Foundation design and construction
- Seismic site classification per IBC
- Lateral earth resistance

The geotechnical engineering Scope of Services for this project included the advancement of six test borings to varying depths of about 9.5 to 16 feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs and/or as separate graphs in the **Exploration Results** section.

## SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

| Item | Description |
|---|---|
| **Parcel Information** | The site is located near the southeast corner of the Tyler Road and East 6th Street intersection in Russellville, Arkansas.<br>See **Site Location** |
| **Existing Improvements** | The site is currently on an undeveloped parcel of land. Overhead transmission lines and tower structures are present along the northern edge of the project site. |

| Item | Description |
|---|---|
| **Current Ground Cover** | Exposed soil and grass in the proposed substation and transmission line easement |
| **Existing Topography** | The ground surface appeared to be relatively level across the site. |

## PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

| Item | Description |
|---|---|
| **Proposed Structures** | Transmission line structures supported on drilled shaft foundations or direct-embedded poles<br>The substation structures could consist of bus supports, switch supports, small equipment pads, transformers and dead-end structures.<br>Substation foundation types are not known at this time but are expected to include shallow footings, mat foundations, and deep foundations which could include drilled shafts. |
| **Maximum Loads** | Typical reactions for bus and switch supports<br>■ 1 to 6 kips vertical<br>■ 1 to 6 kips shear<br>■ 10 to 120 kip-ft ground line moment due primarily wind<br>Typical reactions for small equipment pads<br>■ 5 to 25 kips in compression<br>Typical reactions for control house and transformer foundations<br>■ 50 to 400 kips in compression<br>Typical reactions for dead-end structures<br>■ 10 to 30 kips shear<br>■ 50 to 200 kips compression<br>■ 50 to 200 kips uplift<br>■ 200 to 600 kip-ft ground line moment |
| **Grading/Slopes** | We expect final grade will remain at or near existing grade for the proposed substation and transmission line structures |
| **Below-Grade Structures** | None anticipated |
| **Free-Standing Retaining Walls** | None anticipated |
| **Pavements** | None anticipated |
| **Estimated Start of Construction** | 2019 |

# GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section and the GeoModel can be found in the **Figures** section of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

| Model Layer | Layer Name | General Description |
|---|---|---|
| **1** | **Overburden Soils** | Lean clay with varying amounts of sand and shale fragments |
| **2** | **Weak Rock** | Highly weathered and soft shale bedrock |
| **3** | **Moderately Hard Rock** | Moderately hard shale bedrock |

# GEOTECHNICAL OVERVIEW

The soil stratigraphy at this site generally consisted of stiff to hard lean clay soils with varying amounts of sand and shale fragments overlying shale bedrock. Upper portions of the shale bedrock in some borings were classified as highly weathered or soft. Moderately hard shale bedrock was typically observed underlying the soft strata at depths of about 5 feet to 11 feet below the existing ground surface. All of the borings terminated in the moderately hard shale layer at depths varying between 9.5 feet and 16 feet below the existing surface.

The results of our study indicate that the sites can be developed for the planned substation and transmission line structures. We understand that the substation structures are typically supported on shallow foundations, mat foundations, and deep foundations which could include drilled shafts or driven piles. Transmission line structures are typically supported on deep foundations. During our study, the following geotechnical conditions were identified:

- Moisture-sensitive soils
- Presence of bedrock

The following discussion addresses these items and provides the basis for design recommendations presented in the subsequent report sections. Additional construction-related concepts are provided in the following sections of this report.

### Moisture-Sensitive Soils

The lean clay soils observed at the project site are moisture-sensitive and prone to strength loss with increased moisture content. These soils could become unstable with typical earthwork and construction traffic, especially after precipitation events; therefore, effective drainage should be completed early in the construction sequence and maintained after construction. If possible, the grading should be performed during the warmer and drier times of the year. If grading or construction is performed during the winter months, an increased risk for possible treatment of unstable subgrade will persist.

### Presence of Bedrock

Highly weathered to unweathered shale was observed in all of the borings, typically from 3 to 7.5 feet below the ground surface and extended to the termination depth of each respective boring. Highly weathered shale was observed at ground surface in Boring Sub-1. Borings were terminated after 5 to 10 feet of rock coring was performed in each boring. Rock excavation considerations are discussed in the **Deep Foundations** section.

The **Shallow Foundations** section addresses support of the substation structures bearing on native soils or bedrock. The **Deep Foundations** section of the report addresses the support of substation and transmission line structures on drilled shaft foundations. The design soil parameters, allowable bearing pressures for footing and mat foundations, and associated settlement were estimated based on the results of the field and laboratory testing. The **General Comments** section provides an understanding of the report limitations.

## EARTHWORK

Earthwork is anticipated to include clearing and grubbing, excavations, and fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria, as necessary, to render the site in the state considered in our geotechnical engineering evaluation for foundations and equipment slabs.

### Site Preparation

Surface vegetation and topsoil should be removed from the construction areas. Close observation and testing should be performed by Terracon after clearing to evaluate the exposed soils and to provide recommendations if subgrade improvement is needed.

After stripping the surface materials and completing required cuts for grading, but prior to placing new fill, the subgrade should be proof-rolled to aid in locating soft areas. A Terracon geotechnical engineer or a qualified senior technician should observe each site to confirm that the site has been effectively stripped of unsuitable materials. They should also monitor proof-rolling procedures to evaluate and approve the stability of the exposed subgrade materials. Proof-rolling can be performed with a rubber-tired construction vehicle weighing at least 25 tons, such as a loaded scraper or tandem-axle dump truck. If proof-rolling is not practical, the subgrade should be evaluated by Terracon using other methods.

Unstable soils identified by proof-rolling or evaluation should be scarified, moisture conditioned, and compacted or removed and replaced full-depth with new structural fill. The appropriate method of improvement, if required, would depend on factors such as schedule, weather, the size of the area to be improved, and the nature of the instability.

After proof-rolling and improving any unstable soils, and just prior to placing fill in areas below design grade, the top 9 inches of the subgrade should be scarified, moisture conditioned and compacted to the density recommended in the **Compaction Requirements** table below.

Close monitoring of the site preparation operations outlined herein will be critical in providing proper subgrade support for fill placement. We therefore recommend that the geotechnical engineer be retained to monitor this portion of the work. Furthermore, it may be prudent to have the geotechnical engineer at the site during initial critical phases of the earthwork to observe the actual site conditions and make necessary recommendations.

## Fill Material Types

Fill required to achieve design grade should be classified as structural fill and general fill. Structural fill is material used below or within 10 feet of structures. General fill is material used to achieve grade outside of these areas. Earthen materials used for structural and general fill should meet the following material property requirements:

| Soil Type [1] | USCS Classification | Acceptable Location for Placement |
|---|---|---|
| **Imported structural fill material** | CL, GC, SC<br>LL ≤ 45 and<br>PI ≤ 20 | All locations and elevations |
| **On site soils [2]** | CL | General fill outside of structural areas |
| **Well-graded granular** | GW/GM [3] | Beneath foundations or equipment slabs |

1. Structural and general fill should consist of approved materials free of organic matter and debris. 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 prior to use on this site.
2. The on-site lean clay soils have a PI greater than 20; therefore they are not recommended for use as engineered fill.

## Fill Compaction Requirements

Structural and general fill should meet the following compaction requirements.

| Item | Structural Fill | General Fill |
|---|---|---|
| **Maximum Lift Thickness** | 8 inches or less in loose thickness when heavy, self-propelled compaction equipment is used<br>4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used | Same as Structural fill |
| **Minimum Compaction Requirements** [1, 2] | 95 percent of material's standard Proctor maximum dry density (ASTM D 698) | 92 percent of material's standard Proctor maximum dry density (ASTM D 698). |
| **Water Content Range** [1] | Cohesive soils: Between 1 percentage point below and 3 percentage points above the material's optimum moisture content value as determined by the standard Proctor test at the time of placement and compaction<br>Granular: workable moisture levels | As required to achieve min. compaction requirements |

1. Maximum density and optimum water content as determined by the standard Proctor test (ASTM D 698).
2. High plasticity cohesive fill should not be compacted to more than 100% of standard Proctor maximum dry density.

### Utility Trench Backfill

All trench excavations should be made with sufficient working space to permit construction including backfill placement and compaction.

### Grading and Drainage

Effective surface drainage during construction will be necessary to control and divert the surface runoff away from the substation structures and pads. Finished exterior grades should be sloped to provide effective drainage away from the equipment structures and any buildings to reduce surface water infiltration into the foundation subgrade materials.

### Earthwork Construction Considerations

Unstable subgrade conditions are may develop during general construction operations, particularly where the soils are wetted and/or subjected to repetitive construction traffic.  Unstable soils, where encountered, should be improved in-place prior to placing new structural fill. In some areas, it may be necessary to strip and/or undercut the rutted and wet surface soils prior to performing ground improvement. Subgrade improvement techniques should be discussed with our Geotechnical Engineer at the time of construction for appropriate recommendations.

Terracon should be retained during construction to observe earthwork and to perform necessary tests and observations during subgrade preparation; proof-rolling; placement and compaction of Structural fills; and just prior to construction of building floor slabs and foundations.

## Excavations

We anticipate the soils will be excavatable using conventional back-hoes, front-end loaders and motorized scrapers. Temporary excavations will likely be required during grading and site development operations. The 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 the excavation sides and bottom. All excavations should comply with applicable local, state and federal safety regulations, including the current Occupational Safety and Health Administration (OSHA) Excavation and Trench Safety Standards.

## Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation and topsoil, proofrolling, and mitigation of areas delineated by the proof-roll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked, as necessary, until approved by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 2,500 square feet of compacted fill in structure areas. One density and water content test should be performed for every 50 linear feet of compacted utility trench backfill.

In areas of foundation excavations, the bearing subgrade should be evaluated under the direction of the Geotechnical Engineer. If unanticipated conditions are encountered, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer’s evaluation of subsurface conditions, including assessing variations and associated design changes.

## SHALLOW FOUNDATIONS

If the site has been prepared in accordance with the requirements noted in **Earthwork**, the following design parameters are applicable for shallow foundations.

### Design Parameters – Compressive Loads

| Description | Columns | Continuous |
|---|---|---|
| **Recommended bearing stratum** | Native undisturbed soil or weathered shale<br>Bearing stratum to be verified by Terracon | |
| **Maximum net allowable bearing pressure** [1]<br>■ Native lean clay soils<br>■ Weathered shale bedrock | 2,000 psf<br>4,000 psf | 2,000 psf<br>4,000 psf |
| **Minimum width** | 30 inches | 16 inches |
| **Minimum embedment below finished grade for frost protection** [2] | 24 inches | 24 inches |
| **Approximate total movement** [3]<br>■ Native lean clay soils<br>■ Weathered shale bedrock | 1 inch<br>½ inch | 1 inch<br>½ inch |
| **Estimated differential movement** [3]<br>■ Native lean clay soils<br>■ Weathered shale bedrock | <1 inch between columns<br>< ½ inch | <1 inch over 40 feet<br>< ½ inch |
| **Allowable passive pressure** [4]<br>■ Native lean clay soils<br>■ Weathered shale bedrock | 1,000 psf<br>3,000 psf | |
| **Coefficient of sliding friction** [4]<br>■ Native lean clay soils<br>■ Weathered shale bedrock | 0.3 (ultimate)<br>0.4 (ultimate) | |

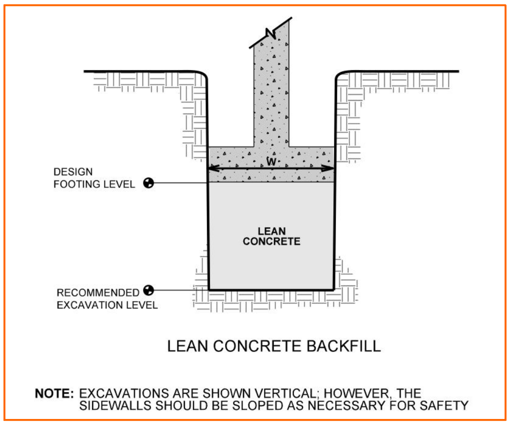
| Description | Columns | Continuous |
|---|---|---|

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation based on a maximum 5-foot by 5-foot foundation. Assumes any unsuitable or soft soils observed will be undercut and replaced with structural fill.
2. For perimeter footings.
3. Actual foundation settlement will depend upon variations within the subsurface soil profile, the structural loading conditions, the embedment depth of the footings, the thickness of compacted fill and the quality of earthwork operations.
4. The sides of the footing excavation must be nearly vertical and the concrete should be placed neat against the excavation sides for the passive earth pressure value to be valid. The allowable passive pressure is also applicable for backfill placed adjacent to formed foundations and constructed as discussed in the **Compaction Requirements** table. Passive resistance for exterior footings should be neglected in the upper 2 feet of the soil profile. If passive resistance is used to resist lateral loads, then base friction should be neglected. No factor of safety has been applied to the coefficient of sliding friction.

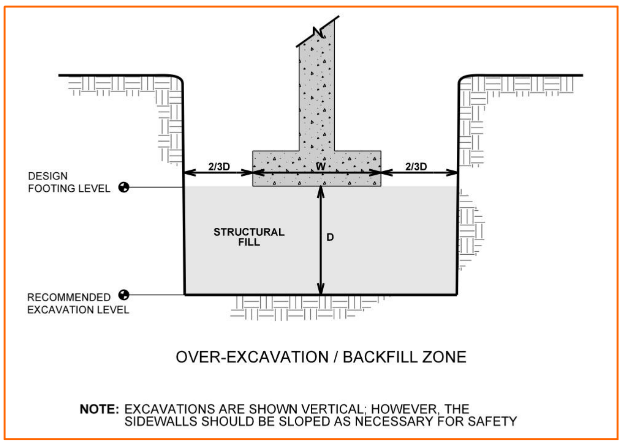
### Shallow Foundation Construction Considerations

As noted in **Earthwork**, the footing and mat foundation excavations should be evaluated under the direction of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the foundation excavations should be removed/reconditioned before foundation concrete is placed.

If unsuitable bearing soils are encountered at the base of the planned foundation excavation, the excavation should be extended deeper to suitable soils, and the foundations could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. This is illustrated on the sketch below.




Over-excavation for structural fill placement below foundations should be conducted as shown below. The over-excavation should be backfilled up to the footing base elevation, with structural fill placed, as recommended in the **Earthwork** section.




## DEEP FOUNDATIONS

Based on the subsurface conditions observed in the borings, the substation structures could be supported on straight-shaft drilled shaft foundations. Design soil parameters for drilled shaft foundations, representing the subsurface conditions observed at the borings, are presented on the Drilled Concrete Shaft Design Soil Parameters table included at the end of this section. The values given in the table are based on conditions observed in the borings, limited laboratory data, published values, and our experience. These values should therefore be considered approximate.

### Lateral Capacity

Axial compression or tension loads will most likely not control the depth or diameter of the shaft; lateral loads from overturning moments on the shaft typically control the design length of the drilled shafts for these structures. Recommended soil parameters (total strength parameters for soil and effective strength parameters for the rock mass) for performing shaft capacity analyses using MFAD 5.0 are presented in the Drilled Concrete Shaft Design Soil Parameters tables included at the end of this section. The MFAD parameters were developed from the subsurface conditions encountered at the individual borings. Due to construction disturbance and other seasonal factors, we recommend that the lateral resistance obtained from the top 2 feet of soil be ignored. A reduction in the lateral resistance of the shadowed shaft in a foundation designed with a shaft group (the lead shaft is not affected) should be considered when the shaft spacing in the direction of loading is less than eight shaft diameters.

### Settlement

Shafts properly designed using the recommended soil parameters installed into undisturbed soil, and constructed as recommended in this report should experience axial compression and uplift movements of less than 1 inch. These movements are associated with the loading from the structure. The quality of drilled shaft construction can also have a significant influence on the total movement that an individual shaft can experience.

### Drilled Shaft Construction Considerations

The drilling contractor should be experienced in the subsurface conditions observed at the site, and the excavations should be performed with equipment capable of providing a clean bearing area. The drilled straight-shaft foundation should be installed in general accordance with the procedures presented in “Standard Specification for the Construction of Drilled Piers,” ACI Publication No. 336.1.

Highly weathered to slightly weathered shale was observed in all the borings typically at depths ranging from about 3 to 7.5 feet below the existing ground surface. Highly weathered shale was observed at the surface in Boring Sub-1. We expect that rock auger and or/coring bit will be required to penetrate the shale or interbedded sandstone and shale bedrock. Auger refusal was encountered in our borings at depths ranging from 4.5 feet to 7.5 feet below the existing ground surface in the substation footprint and at a depth of about 7 feet in the transmission line boring. We expect a core barrel will be needed to extend the pier foundation excavation into rock below this depth. Difficult rock excavation for drilled piers and challenging pier construction conditions should be expected.

Groundwater was not observed in any of the borings during the subsurface investigation, but this does not necessarily mean that groundwater will not be encountered when constructing drilled pier foundations, especially at the soil-rock interface. Casing should be available at the time of construction to seal into the rock. Care should be taken that the sides and bottom of the pier excavation are not disturbed during construction. The bottom of the shaft should be free of soft or loose material prior to reinforcing steel and concrete placement.

For construction consideration, where the spacing between adjacent shafts is less than a center-to-center distance of three times the larger shaft diameter, we recommend waiting at least 24 hours after placing concrete in a shaft before starting to drill an adjacent shaft.

Because the subsurface conditions could likely vary away from the boring locations, we recommend that the geotechnical engineer or his representative observe the shaft installations to evaluate the intended bearing material is observed and sufficiently penetrated.

## SEISMIC CONSIDERATIONS

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Based on the soil properties encountered at the site and as described on the exploration logs and results, it is our professional opinion that the **Seismic Site Classification is C**. Subsurface explorations at this site were extended to a maximum depth of 16 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

## GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations 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. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services 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.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

## PRELIMINARY DRILLED CONCRETE SHAFT DESIGN SOIL PARAMETERS

### Generalized Substation Boring (Sub-1, Sub-3. Sub-4, and Sub-5)

| Layer type | USCS | Consistency / Rock Hardness | Bottom Depth[1] (ft) | Total Unit Weight (pcf) | Modulus of Deformation (ksi) | Friction Angle[2] Φ' (degrees) | Undrained shear Strength or Rock Cohesion (psf) | Rock Bond Strength (ksf) |
|---|---|---|---|---|---|---|---|---|
| Sandy lean clay / highly weathered shale | CL | Very stiff to hard / soft rock | 3 | 120 | 1.3 | 0 | 2,000 | N/A |
| Sandy lean clay / highly weathered shale | CL | Hard / soft rock | 6 | 120 | 2.6 | 0 | 4,000 | N/A |
| Shale | -- | Moderately hard rock | 10.5 | 125 | 735 | 35 | 3,000 | 7 |

1. Approximate depth is below the existing ground surface
2. Soil cohesion and angle of internal friction values are based on SPT $N_{60}$-values and laboratory test results averaged over the layer thickness. For shale bedrock effective parameters are presented, c' and φ'.
3. Free water was not observed in the borings after completion of drilling by dry auger. Water was injected during the rock coring process, so groundwater levels could not be obtained after completion of rock coring.

## PRELIMINARY DRILLED CONCRETE SHAFT DESIGN SOIL PARAMETERS

### Substation Boring Sub-2

| Layer type | USCS | Consistency / Rock Hardness | Bottom Depth[1] (ft) | Total Unit Weight (pcf) | Modulus of Deformation (ksi) | Friction Angle[2] Φ' (degrees) | Undrained shear Strength or Rock Cohesion (psf) | Rock Bond Strength (ksf) |
|---|---|---|---|---|---|---|---|---|
| Sandy lean clay | CL | Stiff to very stiff | 3 | 120 | 1.0 | 0 | 1,500 | N/A |
| Sandy lean clay with shale pieces | CL | Hard | 6 | 120 | 2.6 | 0 | 4,000 | N/A |
| Highly weathered shale | -- | Soft rock | 11 | 125 | 100 | 0 | 2,000 | 7 |
| Shale | -- | Moderately hard rock | 16 | 125 | 1,500 | 36 | 3,200 | 7 |

1. Approximate depth is below the existing ground surface
2. Soil cohesion and angle of internal friction values are based on SPT $N_{60}$-values and laboratory test results averaged over the layer thickness. For shale bedrock effective parameters are presented, c' and φ'.
3. Free water was not observed in the borings after completion of drilling by dry auger. Water was injected during the rock coring process, so groundwater levels could not be obtained after completion of rock coring.

## PRELIMINARY DRILLED CONCRETE SHAFT DESIGN SOIL PARAMETERS

### Transmission Line Boring TL-1

| Layer type | USCS | Consistency / Rock Hardness | Bottom Depth[1] (ft) | Total Unit Weight (pcf) | Modulus of Deformation (ksi) | Friction Angle[2] Φ' (degrees) | Undrained shear Strength or Rock Cohesion (psf) | Rock Bond Strength (ksf) |
|---|---|---|---|---|---|---|---|---|
| Lean clay | CL | Medium stiff to very stiff | 3 | 120 | 0.7 | 0 | 1,000 | N/A |
| Highly weathered shale | -- | Soft rock | 7 | 125 | 2.6 | 0 | 4,000 | N/A |
| Interbedded sandstone and shale | -- | Moderately hard rock | 11 | 125 | 595 | 34 | 2,800 | 7 |
| Shale | -- | Moderately hard rock | 16 | 125 | 735 | 36 | 3,000 | 7 |

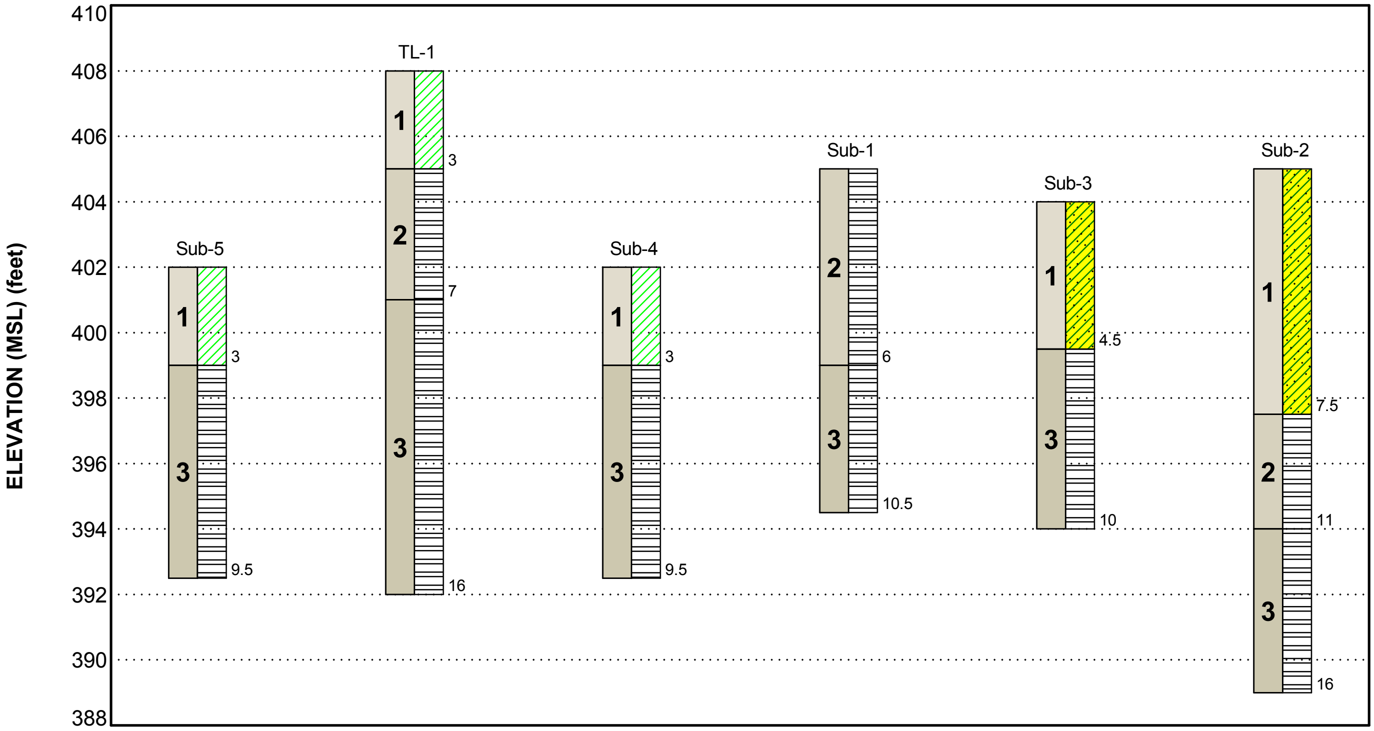
1. Approximate depth is below the existing ground surface
2. Soil cohesion and angle of internal friction values are based on SPT $N_{60}$-values and laboratory test results averaged over the layer thickness. For shale bedrock effective parameters are presented, c' and φ'.
3. Free water was not observed in the borings after completion of drilling by dry auger. Water was injected during the rock coring process, so groundwater levels could not be obtained after completion of rock coring.

# FIGURES

**Contents:**

## GEOMODEL

**Russleville Substation Cut In ■ Russleville, Arkansas**
**12/6/2018 ■ Terracon Project No. 35185126**




This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

| Model Layer | Layer Name | General Description |
|---|---|---|
| 1 | **overburden soils** | lean clay with varying amounts of sand and shale fragments |
| 2 | **Weak Rock** | Highly weathered and soft shale bedrock |
| 3 | **Moderately Hard Rock** | Moderately hard shale bedrock |

## LEGEND

- Shale
- Sandy Lean Clay
- Lean Clay

- First Water Observation
- Second Water Observation
- Final Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time. Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project. Numbers adjacent to soil column indicate depth below ground surface.

# ATTACHMENTS

## SITE LOCATION PLAN

Russellville Substation Cut In ■ Russellville, Arkansas

December 7, 2018 ■ Terracon Project No. 35185126

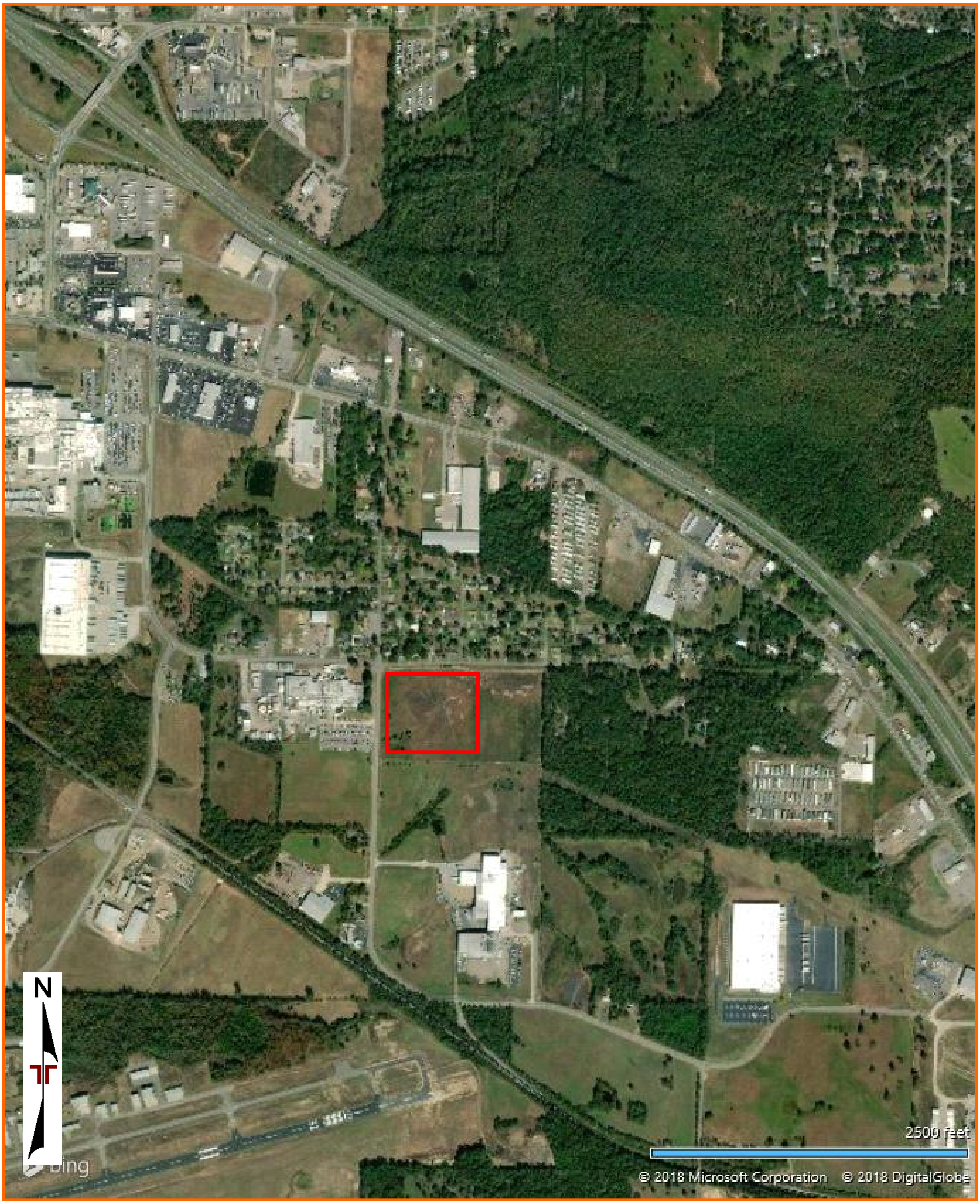



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

## EXPLORATION PLAN

Russellville Substation Cut In ■ Russellville, Arkansas
December 7, 2018 ■ Terracon Project No. 35185126


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

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

# EXPLORATION AND TESTING PROCEDURES

## Field Exploration

| Number of Borings | Boring Depth (feet) | Planned Location |
|---|---|---|
| 5 | 9.5 to 16 | Substation |
| 1 | 16 | Transmission Line |

**Boring Layout and Elevations:** The location of the field exploration points (borings) were established in the field by Terracon's exploration team using a measuring tape and a hand-held GPS unit to measure the boring locations with reference to known points. The accuracy of the exploration point is usually within about 10 feet of the noted location when using the GPS.

**Subsurface Exploration Procedures:** We advanced the borings with a track-mounted, ATV-mounted rotary drill rig using continuous flight augers (solid stem and/or hollow stem) and rock coring techniques. Samples were obtained continuously until auger refusal. We obtained representative samples primarily by the split-barrel sampling procedure. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. We observed and recorded groundwater levels during drilling and sampling.

Upon encountering bedrock or refusal-to-drilling conditions, rock coring (using NQ rock core barrel) was performed at the borings. Rock coring was performed at each boring to depths of 5 to 10 feet beyond auger refusal. Water was used as a drilling fluid for rock coring and the spent water was discharged onsite.

We backfilled the borings with auger cuttings, bentonite chips and a plastic "spider plug: upon completion. Excess auger cuttings were dispersed in the general vicinity of the borehole. Because backfill material often settles below the surface after a period, we recommend boreholes to be periodically checked and backfilled, if necessary. We can provide this service or grout the boreholes for additional fees, at your request.

The sampling depths, penetration distances, and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the

Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

As requested, an electrical earth resistivity survey (EERS) was performed at the substation using the 4-point Wenner array method. The “a” spacing was 5, 10, 20, 30, 40, 60, 80 and 100 feet or as accessible to the testing equipment and permitted by site boundaries.

## Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil strata, as necessary, for this project. Procedural standards noted below are for reference to methodology in general. In some cases, variations to methods were applied because of local practice or professional judgment. Standards noted below include reference to other, related standards. Such references are not necessarily applicable to describe the specific test performed.

- Laboratory Determination of Water (moisture) Content of Soil by Mass
- Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- Particle-Size Analysis of Soils
- Determining the Amount of Material Finer than 75-μm (No. 200) Sieve in Soils by Washing

The laboratory testing program often included examination of soil and rock samples by an engineer. Based on the material’s texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System. Rock classification was conducted using locally accepted practices for engineering purposes.

# EXPLORATION RESULTS

**Contents:**

Boring Logs (Sub-1 through Sub-5 and TL-1 through TL-4)
Earth Electrical Resistivity Results (EERs)

Note: All attachments are one page unless noted above.

# BORING LOG NO. Sub-1



**PROJECT:** Russellville Substation Cut In

**CLIENT:** Entergy Services, Inc.
New Orleans, Louisiana

**SITE:** Tyler Rd and E 6th Street
Russleville, Arkansas

LOCATION See Exhibit A-2

Latitude: 35.2696° Longitude: -93.0833°

| DEPTH | Description | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|
| | **HIGHLY WEATHERED SHALE**, with sandstone fragments, brown and gray, soft rock | | | | SPT | 5-8-17 N=25 | 13 | | | |
| | | | | | SPT | 27-39-29 N=68 | 16 | | | |
| | | | | | SPT | 11-23-29 N=52 | 10 | | | |
| 6.0 | | | 5 | | SPT | 25-50/3" | 10 | | | |
| | **SHALE**, dark gray, slightly fractured, slightly weathered, moderately hard, laminated | | | | Rock core | REC: 98% RQD: 76% | | | | |
| 10.5 | | | 10 | | | | | | | |

***Boring Terminated at 10.5 Feet***

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

Hammer Type: Automatic

Advancement Method:
0 to 6 feet: Solid-stem auger
6 to 10.5 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-22-2018 | Boring Completed: 10-22-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-1 |

# BORING LOG NO. Sub-2



**PROJECT: Russellville Substation Cut In**

**CLIENT: Entergy Services, Inc.**
**New Orleans, Louisiana**

**SITE: Tyler Rd and E 6th Street**
**Russleville, Arkansas**

LOCATION See Exhibit A-2

Latitude: 35.2692° Longitude: -93.0831°

| DEPTH | Description | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|
| | **SANDY LEAN CLAY (CL)**, brown, stiff to hard | | | | | 3-5-6 N=11 | 21 | | | |
| | | | | | | 4-5-18 N=23 | 18 | | 45-21-24 | 65 |
| | - with shale fragments at about 3 feet | | | | | 40-50/4" | 8 | | | |
| | | | 5 | | | 24-26-50/6" | 13 | | | |
| 7.5 | **HIGHLY WEATHERED SHALE**, brown and dark gray, extremely fractured, highly weathered, soft rock, laminated | | 10 | | | REC: 50% RQD: 19% | | | | |
| 11.0 | **SHALE**, gray, slightly fractured, slightly weathered, moderately hard rock, laminated | | 15 | | | REC: 100% RQD: 93% | | | | |
| 16.0 | ***Boring Terminated at 16 Feet*** | | | | | | | | | |

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

Hammer Type: Automatic

Advancement Method:
0 to 7.5 feet: Solid-stem auger
7.5 to 16 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-23-2018 | Boring Completed: 10-23-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-2 |

# BORING LOG NO. Sub-3



**PROJECT: Russellville Substation Cut In**

**CLIENT: Entergy Services, Inc.
New Orleans, Louisiana**

**SITE: Tyler Rd and E 6th Street
Russleville, Arkansas**

LOCATION See Exhibit A-2

Latitude: 35.2693° Longitude: -93.0834°

| GRAPHIC LOG | DEPTH | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|
| | **SANDY LEAN CLAY (CL)**, with shale fragments, brown and gray, very stiff to hard | | | | | 4-6-11 N=17 | 12 | | 47-19-28 | 64 |
| | | | | | | 12-17-32 N=49 | 10 | | | |
| | | | | | | 26-44-50/1" | 9 | | | |
| | 4.5 | | | | | 50/4" | 4 | | | |
| | **SHALE**, dark gray, slightly fractured, slightly weathered, moderately hard rock, laminated | | 5 | | | REC: 98% RQD: 90% | | | | |
| | 10.0 | | 10 | | | | | | | |

***Boring Terminated at 10 Feet***

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

Hammer Type: Automatic

Advancement Method:
0 to 6 feet: Solid-stem auger
6 to 10 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-23-2018 | Boring Completed: 10-23-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-3 |

# BORING LOG NO. Sub-4



**PROJECT: Russellville Substation Cut In**

**CLIENT: Entergy Services, Inc.**
**New Orleans, Louisiana**

**SITE: Tyler Rd and E 6th Street**
**Russleville, Arkansas**

LOCATION See Exhibit A-2

Latitude: 35.2693° Longitude: -93.0838°

| GRAPHIC LOG | DEPTH | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEAN CLAY (CL)**, with shale fragments, brown and gray, very stiff to hard | | | | | 5-11-14 N=25 | 12 | | | |
| | | | | | | 15-50/6" | 9 | | | |
| | 3.0 | | | | | | | | | |
| | **SHALE**, gray, slightly fractured, slightly weathered, soft to moderately hard rock, laminated | | | | | 50/5" | 8 | | | |
| | | | 5 | | | REC: 100% RQD: 76% | | | | |
| | 9.5 | | | | | | | | | |
| | ***Boring Terminated at 9.5 Feet*** | | | | | | | | | |

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

Hammer Type: Automatic

Advancement Method:
0 to 4.5 feet: Solid-stem auger
4.5 to 9.5 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-23-2018 | Boring Completed: 10-23-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-4 |

# BORING LOG NO. Sub-5



**PROJECT:** Russellville Substation Cut In

**CLIENT:** Entergy Services, Inc.
New Orleans, Louisiana

**SITE:** Tyler Rd and E 6th Street
Russleville, Arkansas

LOCATION See Exhibit A-2

Latitude: 35.2696° Longitude: -93.0839°

| DEPTH | Description | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|
| | **LEAN CLAY (CL)**, with shale fragments, brown and gray, very stiff to hard | | | | SPT | 4-11-17 N=28 | 9 | | | |
| 3.0 | | | | | SPT | 26-24-27 N=51 | 14 | | | |
| | **SHALE**, dark gray and reddish-brown, slightly fractured, slightly weathered, moderately hard rock, laminated | | | | SPT | 50/5" | 7 | | | |
| | | | 5 | | Core | REC: 100% RQD: 68% | | | | |
| 9.5 | ***Boring Terminated at 9.5 Feet*** | | | | | | | | | |

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

Hammer Type: Automatic

Advancement Method:
0 to 4.5 feet: Solid-stem auger
4.5 to 9.5 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-23-2018 | Boring Completed: 10-23-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-5 |

# BORING LOG NO. TL-1

**PROJECT:** Russellville Substation Cut In

**CLIENT:** Entergy Services, Inc.
New Orleans, Louisiana

**SITE:** Tyler Rd and E 6th Street
Russleville, Arkansas

LOCATION See Exhibit A-2

Latitude: 35.2703° Longitude: -93.0836°

| GRAPHIC LOG | DEPTH | Material Description | INSTALLATION DETAILS | DEPTH (Ft.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | FIELD TEST RESULTS | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI | PERCENT FINES |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **LEAN CLAY (CL)**, with shale fragments, reddish-brown, medium stiff to very stiff | | | | | 1-3-3 N=6 | 24 | | 42-19-23 | 91 |
| | 3.0 | | | | | | 7-7-10 N=17 | 21 | | | |
| | | **HIGHLY WEATHERED SHALE**, gray, soft rock | | | | | 21-33-44 N=77 | 10 | | | |
| | | | | 5 | | | 10-29-50/4" | 8 | | | |
| | 7.0 | | | | | | 40-50/6" | 15 | | | |
| | | **INTERBEDDED SANDSTONE AND SHALE**, light gray and dark gray, slightly fractured, slightly weathered, moderately hard rock, laminated | | 10 | | | REC: 77% RQD: 54% | | | | |
| | 11.0 | **SHALE**, with sandstone seams, light gray, slightly fractured, unweathered, moderately hard rock | | 15 | | | REC: 99% RQD: 85% | | | | |
| | 16.0 | ***Boring Terminated at 16 Feet*** | | | | | | | | | |

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

Hammer Type: Automatic

Advancement Method:
0 to 7 feet: Solid-stem auger
7 to 16 feet: Diamond-bit NQ core barrel

Abandonment Method:
Borings backfilled with auger cuttings, bentonite chips, and plastic spider plug

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:

**WATER LEVEL OBSERVATIONS**

*No free water observed while drilling by dry auger*

Terracon
25809 I 30
Bryant, AR

| | |
|---|---|
| Boring Started: 10-22-2018 | Boring Completed: 10-22-2018 |
| Drill Rig: Acker #679 | Driller: TF |
| Project No.: 35185126 | Exhibit: A-6 |

# ELECTRICAL EARTH RESISTIVITY SURVEY
## Russellville Substation Cut In
## Russellville Arkansas
## Terracon Project No. 35185126
## TEST NO. 1 (North-South Line)

**STATION NAME:** Russellville Substation Cut In

**STATION LOCATION:** 35.2694, -93.0836

**DATE:** 11/8/2018

**TEMPERATURE:** 50°

**SOIL MOISTURE:** Wet

**SURFACE SOIL TYPE:** Lean clay with shale

**TEST INSTRUMENT TYPE:** Wenner 4 Electrode

**TESTED BY:** DT

| TEST NO. | ELECTRODE SPACING "C" (FEET) | TEST PROBE DEPTH (INCHES) | METER READING, "C" TEST (OHMS) | MULTIPLIER | EARTH RESISTIVITY (OHM-CM) |
|---|---|---|---|---|---|
| 1 | 5 | 12 | 5.06 | 958 | 4,846 |
| 2 | 10 | 12 | 3.08 | 1,916 | 5,900 |
| 3 | 20 | 12 | 1.58 | 3,831 | 6,053 |
| 4 | 30 | 12 | 1.23 | 5,747 | 7,068 |
| 5 | 40 | 12 | 1.02 | 7,662 | 7,815 |
| 6 | 60 | 12 | 0.67 | 11,490 | 7,701 |
| 7 | 80 | 12 | 0.47 | 15,320 | 7,202 |
| 8 | 100 | 12 | 0.37 | 19,160 | 7,088 |

Notes:

Terracon
Consulting Engineers & Scientists

**ELECTRICAL EARTH RESISTIVITY SURVEY**
**Russellville Substation Cut In**
**Russellville Arkansas**
**Terracon Project No. 35185126**
**TEST NO. 2 (East - West Line)**

**STATION NAME:** Russellville Substation Cut In

**STATION LOCATION:** 35.2694, -93.0836

**DATE:** 11/8/2018

**TEMPERATURE:** 50°

**SOIL MOISTURE:** Wet

**SURFACE SOIL TYPE:** Lean clay with shale

**TEST INSTRUMENT TYPE:** Wenner 4 Electrode

**TESTED BY:** DT

| TEST NO. | ELECTRODE SPACING "C" (FEET) | TEST PROBE DEPTH (INCHES) | METER READING, "C" TEST (OHMS) | MULTIPLIER | EARTH RESISTIVITY (OHM-CM) |
|---|---|---|---|---|---|
| 1 | 5 | 12 | 2.05 | 958 | 1,963 |
| 2 | 10 | 12 | 0.92 | 1,916 | 1,762 |
| 3 | 20 | 12 | 0.54 | 3,831 | 2,069 |
| 4 | 30 | 12 | 0.42 | 5,747 | 2,414 |
| 5 | 40 | 12 | 0.34 | 7,662 | 2,605 |
| 6 | 60 | 12 | 0.26 | 11,490 | 2,988 |
| 7 | 80 | 12 | 0.21 | 15,320 | 3,218 |
| 8 | 100 | 12 | 0.16 | 19,160 | 3,065 |

Notes:

Terracon
Consulting Engineers & Scientists

# SUPPORTING INFORMATION

**Contents:**



Note: All attachments are one page unless noted above.

# GENERAL NOTES

## DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

| SAMPLING | | WATER LEVEL | | FIELD TESTS | |
|---|---|---|---|---|---|
| | Rock Core; Standard Penetration Test | | Water Initially Encountered<br>Water Level After a Specified Period of Time<br>Water Level After a Specified Period of Time<br>Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations. | | N — Standard Penetration Test Resistance (Blows/Ft.)<br>(HP) — Hand Penetrometer<br>(T) — Torvane<br>(DCP) — Dynamic Cone Penetrometer<br>(PID) — Photo-Ionization Detector<br>(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.

**STRENGTH TERMS**

| RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance | | CONSISTENCY OF FINE-GRAINED SOILS (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance | | |
|---|---|---|---|---|
| **Descriptive Term (Density)** | **Standard Penetration or N-Value Blows/Ft.** | **Descriptive Term (Consistency)** | **Unconfined Compressive Strength Qu, (psf)** | **Standard Penetration or N-Value Blows/Ft.** |
| Very Loose | 0 - 3 | Very Soft | less than 500 | 0 - 1 |
| Loose | 4 - 9 | Soft | 500 to 1,000 | 2 - 4 |
| Medium Dense | 10 - 29 | Medium Stiff | 1,000 to 2,000 | 4 - 8 |
| Dense | 30 - 50 | Stiff | 2,000 to 4,000 | 8 - 15 |
| Very Dense | > 50 | Very Stiff | 4,000 to 8,000 | 15 - 30 |
| | | Hard | > 8,000 | > 30 |

### RELATIVE PROPORTIONS OF SAND AND GRAVEL

| Descriptive Term(s) of other constituents | Percent of Dry Weight |
|---|---|
| Trace | < 15 |
| With | 15 - 29 |
| Modifier | > 30 |

### GRAIN SIZE TERMINOLOGY

| Major Component of Sample | Particle Size |
|---|---|
| Boulders | Over 12 in. (300 mm) |
| Cobbles | 12 in. to 3 in. (300mm to 75mm) |
| Gravel | 3 in. to #4 sieve (75mm to 4.75 mm) |
| Sand | #4 to #200 sieve (4.75mm to 0.075mm |
| Silt or Clay | Passing #200 sieve (0.075mm) |

### RELATIVE PROPORTIONS OF FINES

| Descriptive Term(s) of other constituents | Percent of Dry Weight |
|---|---|
| Trace | < 5 |
| With | 5 - 12 |
| Modifier | > 12 |

### PLASTICITY DESCRIPTION

| Term | Plasticity Index |
|---|---|
| Non-plastic | 0 |
| Low | 1 - 10 |
| Medium | 11 - 30 |
| High | > 30 |

# UNIFIED SOIL CLASSIFICATION SYSTEM

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A] | | | | | Soil Classification: Group Symbol | Soil Classification: Group Name [B] |
|---|---|---|---|---|---|---|
| **Coarse-Grained Soils:** More than 50% retained on No. 200 sieve | **Gravels:** More than 50% of coarse fraction retained on No. 4 sieve | **Clean Gravels:** Less than 5% fines [C] | Cu ³ 4 and 1 £ Cc £ 3 [E] | | GW | Well-graded gravel [F] |
| | | | Cu < 4 and/or [Cc<1 or Cc>3.0] [E] | | GP | Poorly graded gravel [F] |
| | | **Gravels with Fines:** More than 12% fines [C] | Fines classify as ML or MH | | GM | Silty gravel [F, G, H] |
| | | | Fines classify as CL or CH | | GC | Clayey gravel [F, G, H] |
| | **Sands:** 50% or more of coarse fraction passes No. 4 sieve | **Clean Sands:** Less than 5% fines [D] | Cu ³ 6 and 1 £ Cc £ 3 [E] | | SW | Well-graded sand [I] |
| | | | Cu < 6 and/or [Cc<1 or Cc>3.0] [E] | | SP | Poorly graded sand [I] |
| | | **Sands with Fines:** More than 12% fines [D] | Fines classify as ML or MH | | SM | Silty sand [G, H, I] |
| | | | Fines classify as CL or CH | | SC | Clayey sand [G, H, I] |
| **Fine-Grained Soils:** 50% or more passes the No. 200 sieve | **Silts and Clays:** Liquid limit less than 50 | **Inorganic:** | PI > 7 and plots on or above “A” line [J] | | CL | Lean clay [K, L, M] |
| | | | PI < 4 or plots below “A” line [J] | | ML | Silt [K, L, M] |
| | | **Organic:** | Liquid limit - oven dried | < 0.75 | OL | Organic clay [K, L, M, N] |
| | | | Liquid limit - not dried | | | Organic silt [K, L, M, O] |
| | **Silts and Clays:** Liquid limit 50 or more | **Inorganic:** | PI plots on or above “A” line | | CH | Fat clay [K, L, M] |
| | | | PI plots below “A” line | | MH | Elastic Silt [K, L, M] |
| | | **Organic:** | Liquid limit - oven dried | < 0.75 | OH | Organic clay [K, L, M, P] |
| | | | Liquid limit - not dried | | | Organic silt [K, L, M, Q] |
| **Highly organic soils:** | Primarily organic matter, dark in color, and organic odor | | | | PT | Peat |

[A] Based on the material passing the 3-inch (75-mm) sieve.

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

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

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

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ³ 15% sand, add “with sand” to group name.

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

[H] If fines are organic, add “with organic fines” to group name.

[I] If soil contains ³ 15% gravel, add “with gravel” to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add “with sand” or “with gravel,” whichever is predominant.

[L] If soil contains ³ 30% plus No. 200 predominantly sand, add “sandy” to group name.

[M] If soil contains ³ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[N] PI ³ 4 and plots on or above “A” line.

[O] PI < 4 or plots below “A” line.

[P] PI plots on or above “A” line.

[Q] PI plots below “A” line.