ARKANSAS DEPARTMENT OF TRANSPORTATION

SUBSURFACE INVESTIGATION

STATE JOB NO. 009916

FEDERAL AID PROJECT NO. NHPP-0045(34)

MISSOURI & NORTHERN ARKANSAS RR STR. & APPRS. (SUMMIT) (S)

STATE HIGHWAY 14 **SECTION** 2

IN MARION **COUNTY**

The information contained herein was obtained by the Department for design and estimating purposes only. It is being furnished with the express understanding that said information does not constitute a part of the Proposal or Contract and represents only the best knowledge of the Department as to the location, character and depth of the materials encountered. The information is only included and made available so that bidders may have access to subsurface information obtained by the Department and is not intended to be a substitute for personal investigation, interpretation and judgment of the bidder. The bidder should be cognizant of the possibility that conditions affecting the cost and/or quantities of work to be performed may differ from those indicated herein.

Revised Geotechnical Engineering Report

Job No. 009916, Missouri & Northern Arkansas Railroad Structures and Approaches
Summit, Marion County, Arkansas
March 2, 2023
Terracon Project No. 35225058

Prepared for:
Arkansas Department of Transportation
Little Rock, Arkansas

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

March 2, 2023

Arkansas Department of Transportation
11301 Baseline Road
Little Rock, Arkansas 72209

Attn: Mr. Paul Tinsley
P: (501) 569-2186
E: Paul.Tinsley@ardot.gov

Re: Revised Geotechnical Engineering Report
Job No. 009916, Missouri & Northern Arkansas Railroad Structures and Approaches
Arkansas Highway 14/ North Main Street
Summit, Marion County, Arkansas
Terracon Project No. 35225058

Dear Mr. Tinsley:

We have completed a Revised Geotechnical Engineering evaluation for the referenced project. This study was performed in general accordance with Task Order Number G025, dated July 21, 2022. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning the proposed bridge replacement.

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 12/31/2023

Kimberly A. Daggitt, P.E.
Project Engineer

Christopher S. Handley. P.E.
Principal

STATE OF ARKANSAS ★ ★ ★ LICENSED PROFESSIONAL ENGINEER ★ ★ ★ No. 16398 KIMBERLY A. DAGGITT

REPORT TOPICS

Note: This report was originally delivered in a web-based format. 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.

Revised Geotechnical Engineering Report

Job No. 009916, Missouri & Northern Arkansas Railroad Structures and Approaches

Arkansas Highway 14/ North Main Street

Summit, Marion County, Arkansas

Terracon Project No. 35225058

March 2, 2023

INTRODUCTION

This report presents the results of our subsurface investigation and geotechnical engineering services performed for the proposed bridge replacement (Structure No. 01483) over The Missouri and Northern Arkansas Railroad along Arkansas Highway 14/ North Main Street in Summit, Marion County, Arkansas. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and rock conditions
- Groundwater conditions
- Site preparation and earthwork
- Bridge foundation design and construction
- Embankment slope stability
- Embankment settlement
- Seismic site class per AASHTO

The geotechnical engineering Scope of Services for this project included the advancement of three bridge borings to depths ranging from approximately 43 to 58 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 investigation 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 investigation and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	Structure Number 01483 over the Missouri and Northern Arkansas Railroad along Arkansas 14 (north Main Street) in Summit, Arkansas. See **Site Location**
Existing Improvements	Existing bridge over Missouri and Northern Arkansas Railroad

Item	Description
Current Ground Cover	Existing bridge structure with asphalt pavement approaches and vegetated embankments
Existing Topography	From a provided boring request plan, the replacement bridge is planned along an offset alignment to the east of the existing bridge. Existing grade at the planned bridge location appears to range from 892 to 896 feet. We understand that the fill embankments are planned, with planned heights ranging from 10 to 20 feet.

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
Project Description	ARDOT is proposing to replace the existing bridge. The replacement bridge is planned along an offset alignment to the east of the existing bridge.
Bridge Construction	Based on conference call between Terracon, Jacobs, and ARDOT on July 7, 2022 we understand that end bents will be supported on H-piles founded in rock. Intermediate Bent 2 is planned to be supported by a shallow spread footing and intermediate Bent 3 will also be supported on H-pile foundations founded in rock.
Maximum Loads	Maximum bridge loads were not provided at the time of the report. We should be notified if any uplift or lateral load resistance is required by design.
Approach Embankments	Based on the provide boring request plan dated May 6, 2022, embankments on the order of 10 to 20 feet are planned.
Pavements	Pavement section recommendations are not in the scope of work for this project.

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 evaluation. Conditions encountered at each boring location 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	Overburden soils consisting of fat and lean clay soils containing varying amounts of sand and chert gravel
2	Dolomite Bedrock	Poorly cemented to cemented dolomite bedrock.

Competent dolomite bedrock was observed at elevations ranging from 844 to 868 feet along the alignment. Although top of rock was observed at an elevation of 879 in boring B-4, an apparent clay seam was observed within the bedrock several feet below the rock surface, between approximately elevations 868 and 872.

The boreholes were observed for groundwater while drilling by dry auger. Groundwater was not observed in the borings during auger drilling. Rock coring was performed in the borings to advance the borings into the bedrock to the termination depths. The rock coring procedure utilizes water as a drilling fluid; therefore, groundwater readings taken after the introduction of water into the borehole are not representative of the groundwater conditions. Though groundwater was not observed during the subsurface exploration; does not mean groundwater is not present at the site. Because of the low permeability of the overburden soils observed in the borings, a longer period of time may be necessary to observed groundwater at the site.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or at other times in the life of the structures may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

GEOTECHNICAL OVERVIEW

The Arkansas Department of Transportation is proposing a bridge replacement along Highway 14 in Marion County, Arkansas. The overburden soils observed at the boring locations included lean and fat clay soils containing varying amounts of sand and chert gravel. Bedrock was observed underlying the native overburden soils and consisted of highly weathered to unweathered dolomite bedrock. The results of our study indicate that the site can be developed for the proposed bridge replacement and approach embankment construction. During our study the following geotechnical concerns were identified:

- Presence of bedrock
- Moisture-sensitive soils

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

Presence of Bedrock

Based on conversations with the design consultant, we understand that H-piles are being considered for the support of the end bents and Bent 3 at the bridge replacement. Shallow foundations are being considered for the support of the intermediate Bent 2. Competent dolomite bedrock was observed at elevations varying between 844 to 866 feet at the boring locations.

Excavations for footings into the dolomite could encounter significant construction difficulties. Given the high strength of the bedrock, some cost increases above normal excavation costs should be anticipated. Some of the dolomite is broken, while other parts are massive. Both will be very difficult to excavate or grade with conventional excavation equipment and will require other special excavation techniques. Contractors should also be made aware of the relative strength of the dolomite bedrock, which exhibits intact unconfined strengths of up to 22,000 psi, which will cause significant wear and damage to conventional excavation equipment. In our opinion and our experience on past projects, the variability of the overall stratum and the hardness of bedrock will incur significantly higher excavation and foundation construction costs compared to normal construction. The **Shallow Foundations** section addresses the support of the interior bridge bent B-2 on shallow foundations.

Moisture-Sensitive Soils

The lean clay soils that were observed at or near the ground surface at some of the boring locations are moisture-sensitive and prone to further strength loss with increased moisture content. These soils could become unstable with typical earthwork and construction traffic, especially after precipitation events; therefore, effective site drainage should be developed early in the construction sequence and maintained during and after construction. If possible, the construction should be performed during warmer and drier times of the year. If construction is performed during the winter months, an increased risk for unstable subgrade conditions will occur.

Predrilling may be required at the bridge abutments where driven piles are planned. The **Shallow Foundations** section addresses the support of the bridge abutments on shallow foundations. The **Deep Foundations** section addresses the support of the bridge abutments on driven piles and drilled shafts. The **General Comments** section provides an understanding of the report limitations.

EARTHWORK

Earthwork should be performed as required in the most recent ARDOT Standard Specification for Highway Construction. The following recommendations for site preparation, excavation, subgrade preparation and placement of engineered fills on the project are considered general recommendations for earthwork on-site. The evaluation of earthwork should include observation and testing of engineered fill, subgrade preparation, and other geotechnical conditions during construction of the project.

Site Preparation

We understand that both shallow and deep rock-bearing foundations are being utilized for the support of the bridge. Because of this, we anticipate that preparation of the subgrade may not be necessary in the bridge foundation areas. Where site preparation and grading are necessary for the roadway and approach aprons to the bridge, surface vegetation, topsoil, pavements and any other surface and subsurface structures should be removed from the construction areas. Unstable subgrade conditions will likely develop during site clearing operations, particularly near the creek and if the soils are wet and/or subjected to repetitive construction traffic. Using low ground pressure (tracked or balloon tired) construction equipment would aid in reducing subgrade disturbance. Even with using low ground pressure equipment, difficult conditions should be expected if the ground surface is disturbed and wetted.

After stripping, completing grading operations, and prior to placing fill, the subgrade should be proof-rolled to aid in locating loose or soft areas. Proof-rolling can be performed with a loaded tandem axle dump truck. Where unstable soils are identified by proof-rolling, stabilization could include scarification, moisture-conditioning and compaction; or removal of unstable materials and replacement with aggregate. The appropriate method of improvement, if required, would depend on factors such as schedule, weather, the size of the area to be treated, and the nature of the instability. More detailed recommendations can be provided during construction. Construction during warm, dry periods would help reduce the amount of subgrade stabilization required.

Fill Material Types

Fill materials should be free of organic matter and debris. Based on the limited lab testing performed, the clayey gravel soils sampled appear to be suitable for use as engineered fill. Though on-site soils appear suitable, we recommend thorough testing prior to reuse. Materials with plasticity indices greater than 20 should not be used within the upper 2 feet of the finished pavement subgrade.

While ARDOT has no specific requirement for borrow materials, they do require that the material be capable of forming and maintaining a stable embankment when compacted. Therefore, we recommend specifically avoiding elastic silts (MH) and organic soils (OL, OH and PT) when considering materials for use as borrow.

We suggest that approved imported borrow soils meet the following material property requirements:

Sieve Size	Percent Finer by Weight (ASTM C136)
3 inches	100
No. 4	50-100
No. 200	15-50

- Plasticity Index………………………………………………………..20(max)

Fill Placement

Where fill is placed on existing slopes steeper than 4H:1V, benches should be cut into the existing slopes prior to fill placement. The benches should have a minimum vertical face height of 1 foot and a maximum vertical face height of 3 feet and should be cut wide enough to accommodate the compaction equipment. This benching will help provide a positive bond between the fill and natural soils and reduce the possibility of failure along the fill/natural soil interface. We recommend that fill slopes be filled beyond the planned final slope face and then be cut back to develop an adequately compacted slope face.

Earthwork Construction Considerations

Unstable subgrade conditions are likely to 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 engineered fill. If the in-place soils cannot be sufficiently improved, it may be necessary to undercut the rutted and wet surface soils prior to performing subgrade improvement. Subgrade improvement techniques are discussed in detail in the following paragraphs.

The near-surface clays observed at this site are moisture-sensitive and susceptible to disturbance from construction activity, particularly when the soil has a high natural moisture content or is wetted by surface water or seepage. During wetter periods of the year, these soils will pump and rut under the weight of heavy construction equipment, especially rubber-tired vehicles. The contractor should consider using track-mounted (low ground pressure) equipment to reduce subgrade disturbance and/or instability.

If unstable subgrade conditions are encountered, the methods described below can be considered to improve subgrade strength. Common methods include scarification, moisture conditioning and compaction, and removal of unstable materials and replacement with granular fill (with or without geosynthetics). The appropriate method of improvement, if required, depends on factors such as schedule, weather, the size of area to be stabilized, and the nature of the instability.

If the exposed subgrade becomes unstable, methods outlined below can be considered.

- **Scarification and Compaction –** It may be feasible to scarify, dry and compact the exposed soils. The success of this procedure would depend primarily upon favorable weather and enough time to dry the soils. Stable subgrades likely would not be achievable if the thickness of the unstable soil is greater than about 1 foot, if the unstable soil is at or near the groundwater levels, or if construction is performed during a period of wet or cool weather when drying is difficult.

- **Crushed Stone –** The use of crushed stone or crushed gravel is the most common procedure to improve subgrade stability. Typical undercut depths would be expected to range from about 6 to 30 inches below the finished subgrade elevation. The use of high modulus geosynthetics (i.e., geotextile or geogrid) can also be considered after underground work such as utility construction is completed. Prior to placing the geotextile or geogrid, we recommend that all below-grade construction, such as utility line installation, be completed to avoid damaging the geosynthetics. Equipment should not be operated above the geosynthetics until one full lift of crushed stone fill is placed above it. The maximum particle size of granular material placed over the geosynthetics should conform to the manufacturer's recommendations and generally should not exceed 1½ inches.

Further evaluation of the need for subgrade stabilization should be provided by a qualified geotechnical engineer during construction as the subgrade conditions are exposed on a broad scale.

Temporary excavations will probably be required during grading operations. As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming any responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

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.

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

We understand that shallow foundations may be used to support interior bridge bent B-2 on Structure No. 01483. Design parameters for shallow foundations were evaluated in accordance with Federal Highway Administration Report No. FHWA-SA-02-054, Geotechnical Engineering Circular No. 6, Shallow Foundations as well as AASHTO LRFD Section 10. The values provided in the table below were developed based on our analysis of the rock mass quality, degree of alteration, degree of interbedding and our interpretation of the stratigraphy at interior bent B-2 (Terracon Boring B-4). Suggested resistance factors for the structural limit state for the rock types observed at this project are included in the table.

Shallow Foundation Design Parameters – Compressive Loads

Design Parameter	Value/Description
Nominal End Bearing	20 ksf
Resistance Factor for Footing on Rock [1]	0.45
Required Bearing Stratum [2]	Gary and light brown dolomite bedrock Bedrock was observed at an approximately elevation of 868 feet near Boring B-4 underlying an apparent clay seam. We recommend allowing an additional 2 feet at the bedrock surface to account for weathering so that competent bedrock can be realized.
Minimum Embedment below Competent Rock [3]	24 inches
Estimated Total Settlement from Structural Loads	Less than 1 inch
Estimated Differential Settlement	About 2/3 of total settlement

1. AASHTO Table 10.5.5.2.2-1
2. Any soils and any unsuitable, loose, or soft rock should be over-excavated to expose solid competent rock. We anticipate that this will require the removal of 1 to 2 feet of weathered, fractured rock.
3. Embedment necessary to minimize the effects of frost and/or seasonal water content variations. For sloping ground, maintain depth below the lowest adjacent exterior grade within 5 horizontal feet of the structure.

Terracon must be notified if any of the Service, Structural or Extreme Limit states for the bridge structure will require uplift or lateral resistance. Low-strength overburden soils observed above the existing bedrock will not provide adequate resistance; therefore, to resist uplift and lateral loads, a deeper socket into the bedrock may be necessary.

Foundation Construction Considerations

Excavations into the dolomite bedrock may encounter significant construction difficulties. Given the high unconfined strengths, some cost increases above normal excavation costs should be anticipated. Some of the dolomite is broken, while other parts are massive. Both will be very difficult to excavate or grade, with conventional excavation equipment and will require other special excavation techniques. Contractors should also be made aware of the relative strength of the dolomite bedrock, which exhibits intact unconfined strengths in excess of 20,000 psi, which will cause significant wear and damage to conventional excavation equipment. In our opinion and based on our experience on past projects, the variability of the overall stratum and the hardness of the dolomite will incur significantly higher excavation and foundation construction costs compared to normal construction.

The shallow foundations should be constructed under the observation of experienced Terracon personnel. The base of all foundation excavations should be free of water and loose, broken or soft rock prior to placing concrete. Concrete should be placed soon after excavating to reduce foundation bearing disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry materials or any loose/disturbed material in the bottom of the foundation excavations should be removed before foundation concrete is placed. We recommend that a thin concrete seal slab (mud mat) be constructed to protect the foundation and facilitate placement of reinforced steel.

DEEP FOUNDATIONS

Driven Pile Design Parameters

We understand steel HP piles could be used to support the end bents of the replacement bridge. Driven piles will develop their resistance from end bearing in the dolomite bedrock. Based on the above information, we recommend that the driven piles at the bridge abutments tip out in the observed dolomite bedrock. Based on Section 10.7.3.2.3 of the AASHTO LRFD Bridge Design Specification, the nominal resistance of piles driven to point bearing on competent bedrock is controlled by the structural limit state of the pile. As a result, the nominal compressive resistance of the pile for various limit states should be designed in accordance with the referenced AASHTO specifications. We understand that the piles will be pre-drilled; therefore, according to Section 6.5.4.2 of the AASHTO Specifications, a structural resistance factor of 0.6 should be applied to the H-piles.

Since variation may occur in depth and strength of bedrock due to the distance away from the performed borings, all piles should be driven until satisfactory driving resistance is developed. Considering the above information, the approximate elevations of top of rock observed at borings performed at the end bents are listed below.

Pile Location	Approximate Elevation at Top of Competent Dolomite Bedrock[1,2,3]
Boring B-1	844
Boring B-2	857
Boring B-4	868

Pile Location	Approximate Elevation at Top of Competent Dolomite Bedrock[1,2,3]

1. Based on observations of cores of the bedrock from the borings performed on-site. Conditions can vary away from these performed borings. We recommend predrilling through the upper 3 to 4 feet of dolomite bedrock to realize competent bedrock.
2. Nominal resistances are applicable if the center to center spacing of the piles is equal to or greater than 3 times the maximum pile section diameter.
3. The factored resistance values can be calculated by multiplying the nominal resistance by the structural resistance factor (phi) of 0.6.

Driven Pile Lateral Loading

Recommended soil and bedrock parameters for analyzing lateral deflection of pile foundations under design loading conditions utilizing the computer program LPILE are present below. The values given in the tables are based on our analysis of the existing subsurface conditions and were estimated using generally accepted engineering correlations.

General Material Description	LPILE Material Type	Unit Weight [1]	Internal Angel of Friction	Undrained Shear Strength (psf)	Static Soil Modulus Parameter, k (pci)	Strain, ε_{50}
Imported fill and overburden soils	Stiff clay without free water	120	--	2,500	1,00	0.005
Dolomite	Strong Rock	140	--	12,000 psi [2]	--	--

1. Effective unit weight is input to LPILE. Select appropriate groundwater level and subtract 62 lb/ft^3 from the given total unit weight to get effective unit weight below the groundwater table.
2. For the strong rock model, the unconfined compressive strength (given here in psi) is input instead of the undrained shear strength.

Driven Pile Construction Considerations

We understand the driven piles will be pre-drilled to reduce the potential for pile damage. We recommend welding reinforced high strength cast steel tips to the bottom of the H-piles to help key the end of the pile into the dolomite bedrock formation and reduce the potential for pile damage.

We anticipate that the long-term settlement of driven piles designed as recommended in this report, constructed in accordance with ARDOT requirements, and observed during construction, would be about ½ inch in addition to elastic shortening of the pile materials for the Service I Limit State Loading.

Pile driving refusal in bedrock is likely to be achieved with limited penetration (+/- 1 to 2 feet) into the bedrock. For refusal criteria when driving piles into bedrock, we recommend the piles be driven to the ultimate bearing capacity with penetration per blow equivalent to or less than a rate of 20 blows per 1 inch. The pile hammer should be sized and operated to maintain driving stresses less than 90 percent of the yield stress of steel. Driving should stop immediately when these criteria are met to avoid damage to the pile.

EMBANKMENT SETTLEMENT

We anticipate embankments up to 20 feet in height for the bridge replacement (Structure No. 01483). Top of bedrock was observed at depths of 5 to 30 feet below the existing ground surface. Embankment settlements on the order of about 2 to 3 inches can be expected at the southern embankments of the planned bridge (embankments heights of 10 feet). Embankment settlements on the order of 3 to 5 inches on the northern embankments of the planned bridge (embankment heights of up to 20 feet). We expect the majority of the settlement to occur within 2 to 3 months of construction.

FILL EMBANKMENT SLOPE CONSIDERATIONS

We understand that bridge approach embankments are planned for this project. Borrow sources for the embankment fill materials have not yet been identified. We assume soils in the embankment will be comparable to the observed on-site soils. The following recommendations may be considered prior to the identification of the embankment borrow source. The recommendations do not account for seepage or potential flooding that may dictate the use of flatter slopes. Detailed evaluation of the proposed borrow source materials should be undertaken prior to the final design and the results incorporated in the final slope stability and settlement recommendations.

General Description	Silts and silty or clayey sands	Low plasticity clays	High plasticity clays	Clayey gravels
ASTM Classification	**ML, SM, SC[1]**	**CL**	**CH[2]**	**GC**
Fill Side Slope**	2.5:1	2.5:1	3:1	2:1
Fill Spill Slope** (H* ≤20 feet)	2:1	2:1	2.5:1	2:1
Fill Spill Slope** (H* > 20 feet)[3]	2.5:1	2.5:1	3:1	2:1
Embankment compression (H* ≤20 feet)	1.5%	1.4%	2.6%	1.2%
Embankment compression (H* > 20 feet)	2.8%	2.6%	3.9%	2.4%

General Description	Silts and silty or clayey sands	Low plasticity clays	High plasticity clays	Clayey gravels
ASTM Classification	ML, SM, SC[1]	CL	CH[2]	GC

H* is the total height between the toe of the slope and grade at top of slope/grade at the end of structure

Slope** is the horizontal to vertical slope

1. Erosion control may be required for soil types other than SC
2. High Plasticity index materials (PI > 50) should be used with caution and require project specific analysis of slope stability and compression.
3. Steeper slopes for low spill slopes (H* ≤ 20 feet) assume some form of slope protection to control erosion and cyclic moisture changes.

SEISMIC CONSIDERATIONS

Code Reference	Site Classification
AASHTO LRFD Bridge Design Specifications [1]	C [1]

1. In general accordance with *AASHTO LRFD Bridge Design Specifications*. Site class determination is based on average properties of the subsurface profile within 100 feet of the ground surface. The exploratory borings extended to maximum depths of about 43 to 58 feet and terminated in dolomite bedrock. Terracon's opinion of site class is based on data from the borings and our knowledge of geotechnical and geologic conditions at this locale.

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 investigation. Natural variations will occur between boring 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, cost estimating, 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.

FIGURES

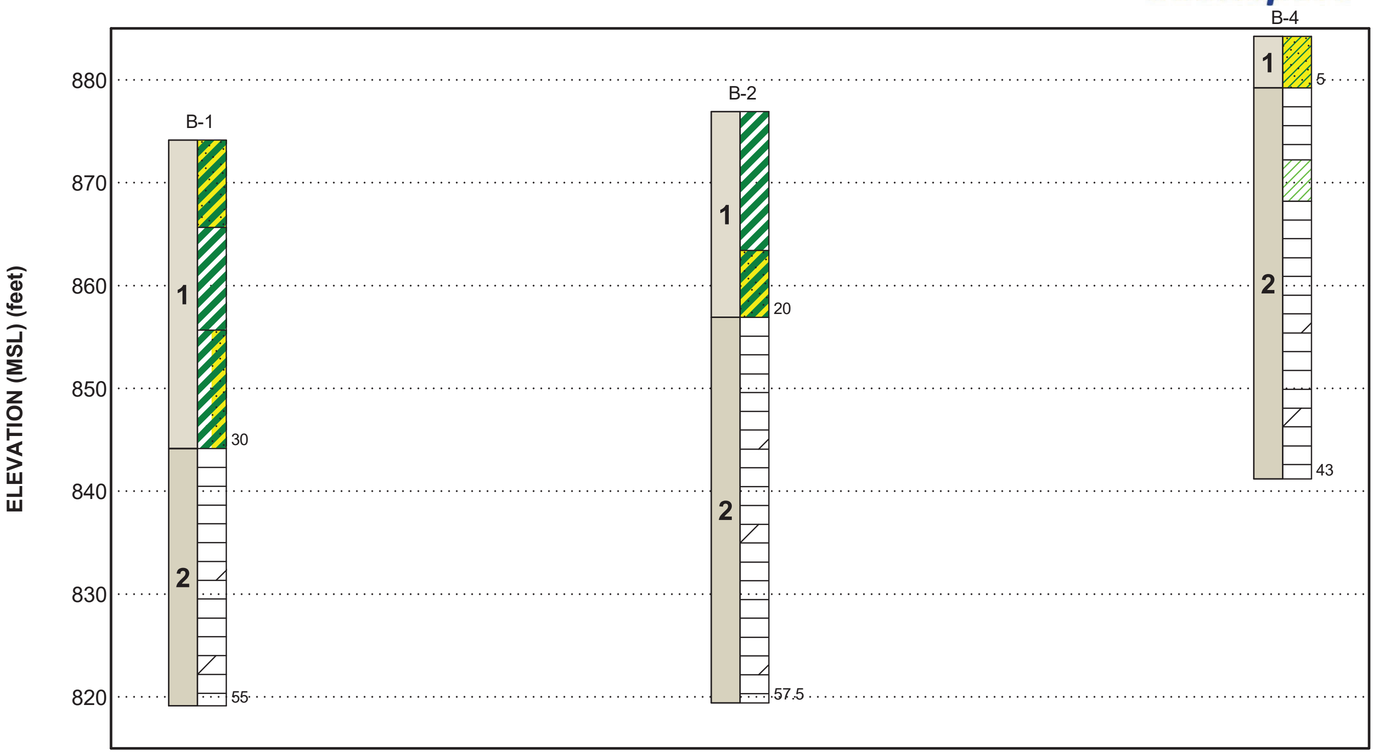
Contents:

GeoModel

GEOMODEL

ARDOT Job No. 009916 ■ Yelleville, AR

Terracon Project No. 35225058



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**	Overburden soils consisting of fat and lean clay soils containing varying amounts of sand and chert gravel
2	**Dolomite bedrock**	Poorly cemented to cemented dolomite bedrock.

LEGEND

- Sandy Fat Clay
- Fat Clay
- Fat Clay with Sand
- Dolomite
- Sandy Lean Clay
- Lean Clay

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

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Boring Layout and Elevations: The locations of the field exploration (borings) were measured in the field by Terracon's exploration team using a hand-held GPS unit to measure the latitude and longitude coordinates. The accuracy of the boring locations is usually within about +/- 20 feet horizontally of the noted location. After completion of the borings, Terracon subcontracted Crafton Tull to survey the performed borings. The latitude and longitude and northing and easting coordinates as well as the ground surface elevations of the borings are provided on the boring logs.

Subsurface Exploration Procedures: We advanced the borings with a track-mounted, drill rig using continuous flight augers to auger refusal. Upon encountering bedrock or refusal-to-drilling conditions, rock coring (using an NQ rock core barrel) was performed. Rock coring was performed in the borings to depths of at least 20 feet beyond auger refusal. Water was used as a drilling fluid for rock coring and the spent water was discharged onsite. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. For the rock cores, the percent recovered and rock quality designation (RQD) were measured in the field and are also reported on the boring logs. We observed and recorded groundwater levels during auger drilling and sampling. For safety purposes, all borings were backfilled with auger cuttings after their completion.

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. The final boring logs included with this report represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

Representative soil samples were tested in the laboratory to measure their natural water content, gradation and Atterberg limits. The test results are provided on the appended boring logs and laboratory test reports.

The soil samples were classified in the laboratory based on visual observation, texture, plasticity, and the laboratory testing described above. The soil descriptions presented on the boring logs are in accordance with the enclosed General Notes and Unified Soil Classification System (USCS). The estimated USCS group symbols for native soils are shown on the boring logs, and a brief description of the USCS is included in this report.

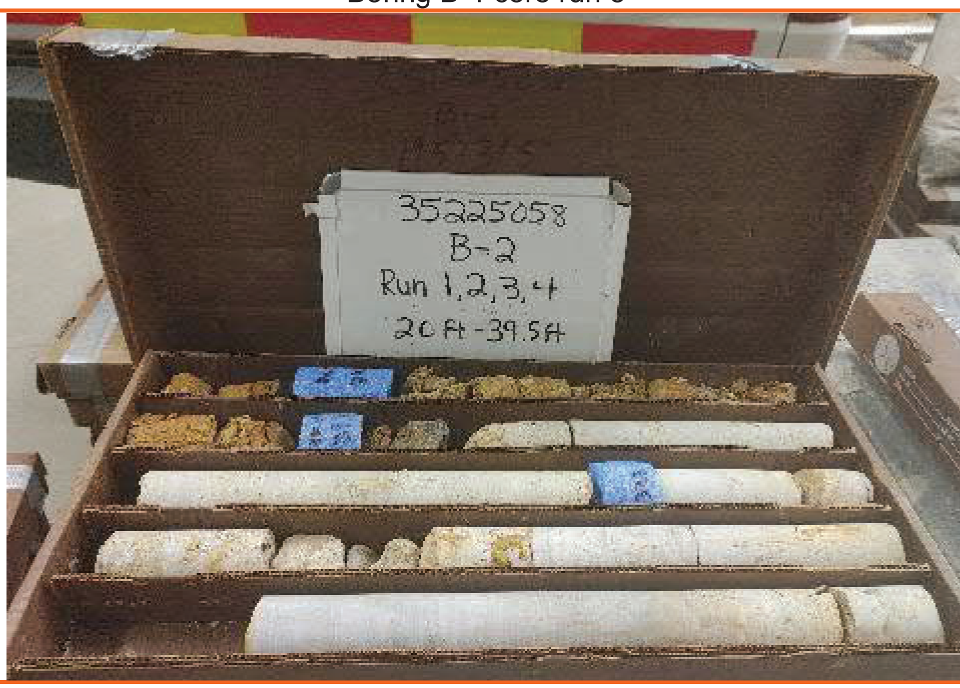
The bedrock materials encountered in the borings were described in accordance with the appended Description of Rock Properties on the basis of visual classification of disturbed auger cuttings and drilling characteristics. Core samples and petrographic analysis may indicate other rock types.

PHOTOGRAPHY LOG

Boring B-1 Core run 1 and 2

Boring B-1 core run 3 and 4

Boring B-1 core run 5

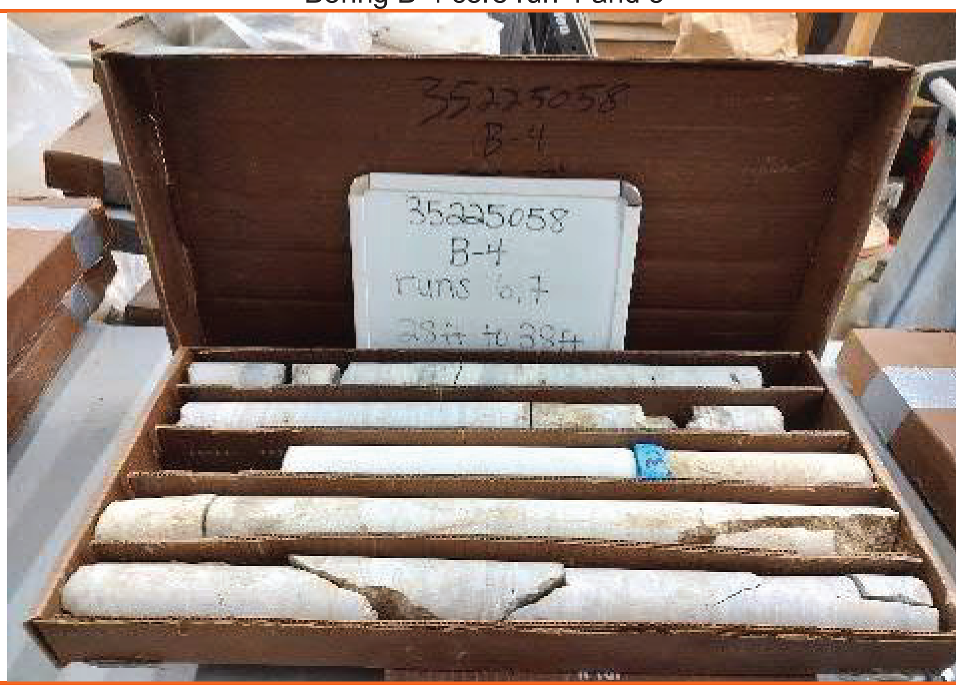


Boring B-2 Core runs 1, 2, 3 and 4

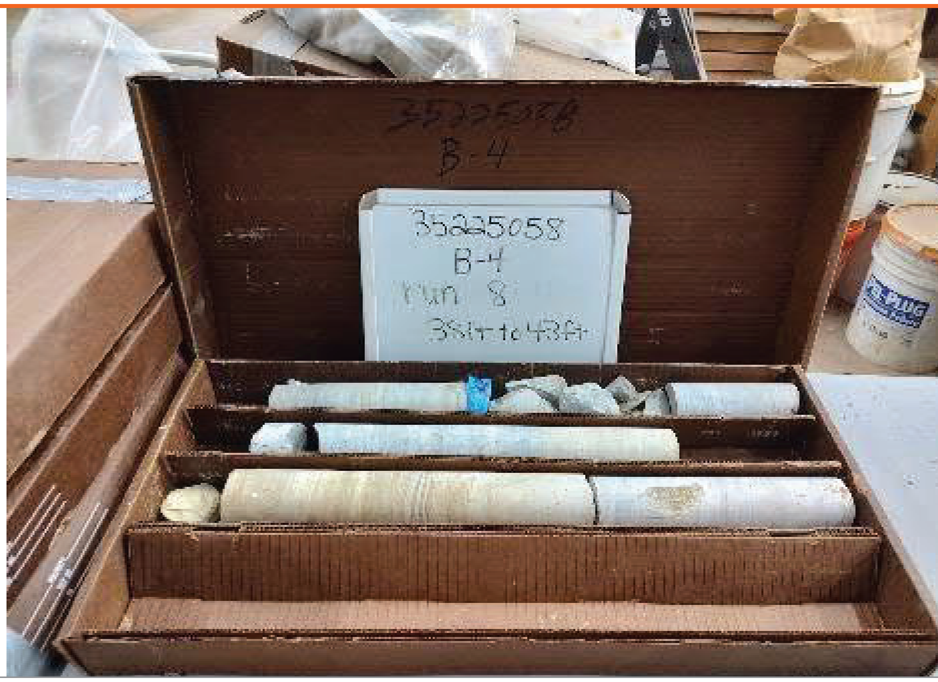
Boring B-2 core runs 5 and 6

Boring B-4 core runs 1, 2 and 3

Boring B-4 core run 4 and 5



Boring B-4 core runs 6 and 7



Boring B-4 core run 8

SITE LOCATION AND EXPLORATION PLANS

Contents:

Note: All attachments are one page unless noted above.

SITE LOCATION

Job No. 009916, Missouri & Northern Arkansas Railroad Structures and Approaches ■ Summit, M
Arkansas

March 2, 2023 ■ Terracon Project No. 35225058

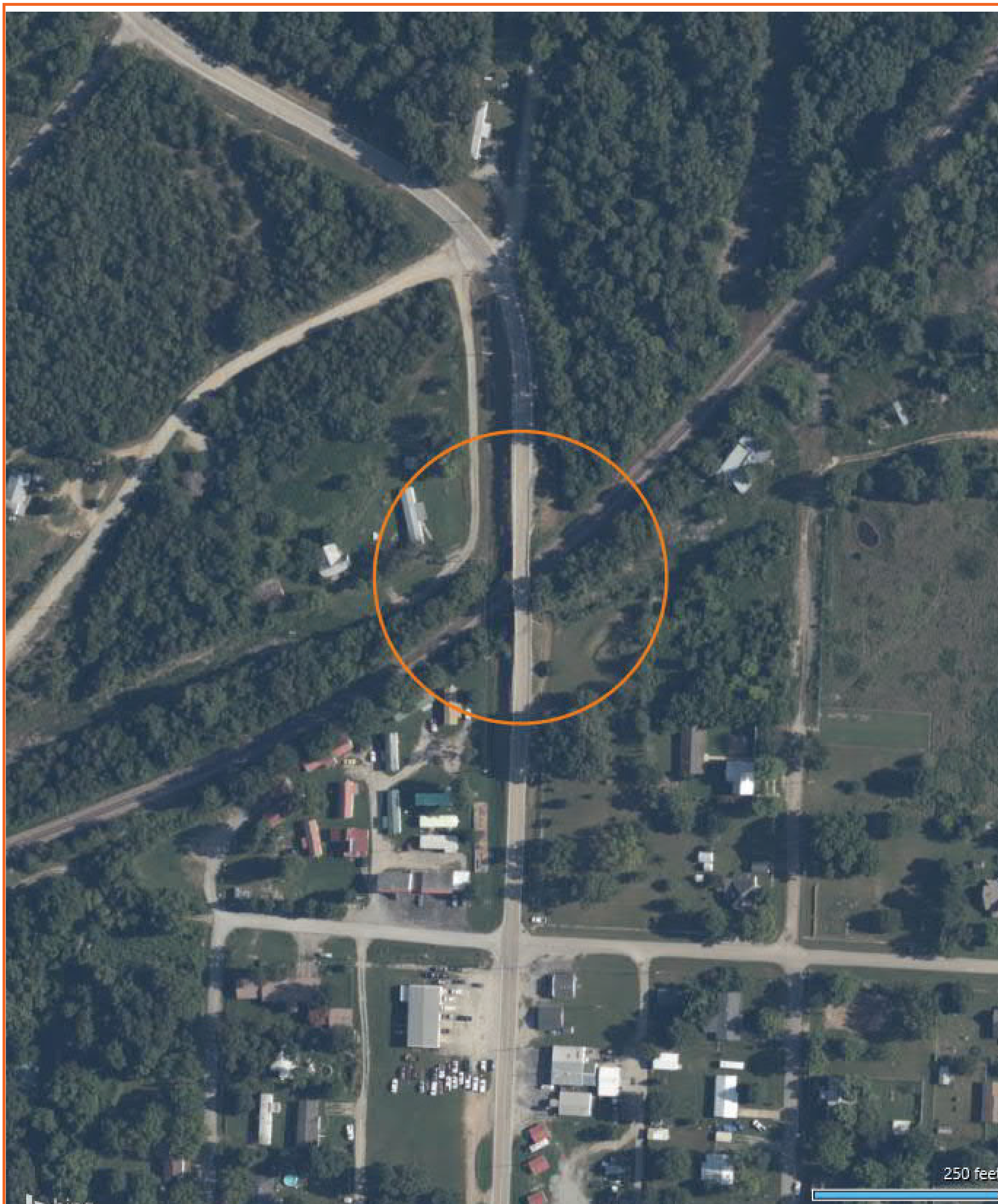


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

ARDOT Job No. 009916 ■ Marion County, Arkansas
July 26, 2022 ■ Terracon Project No. 35225058

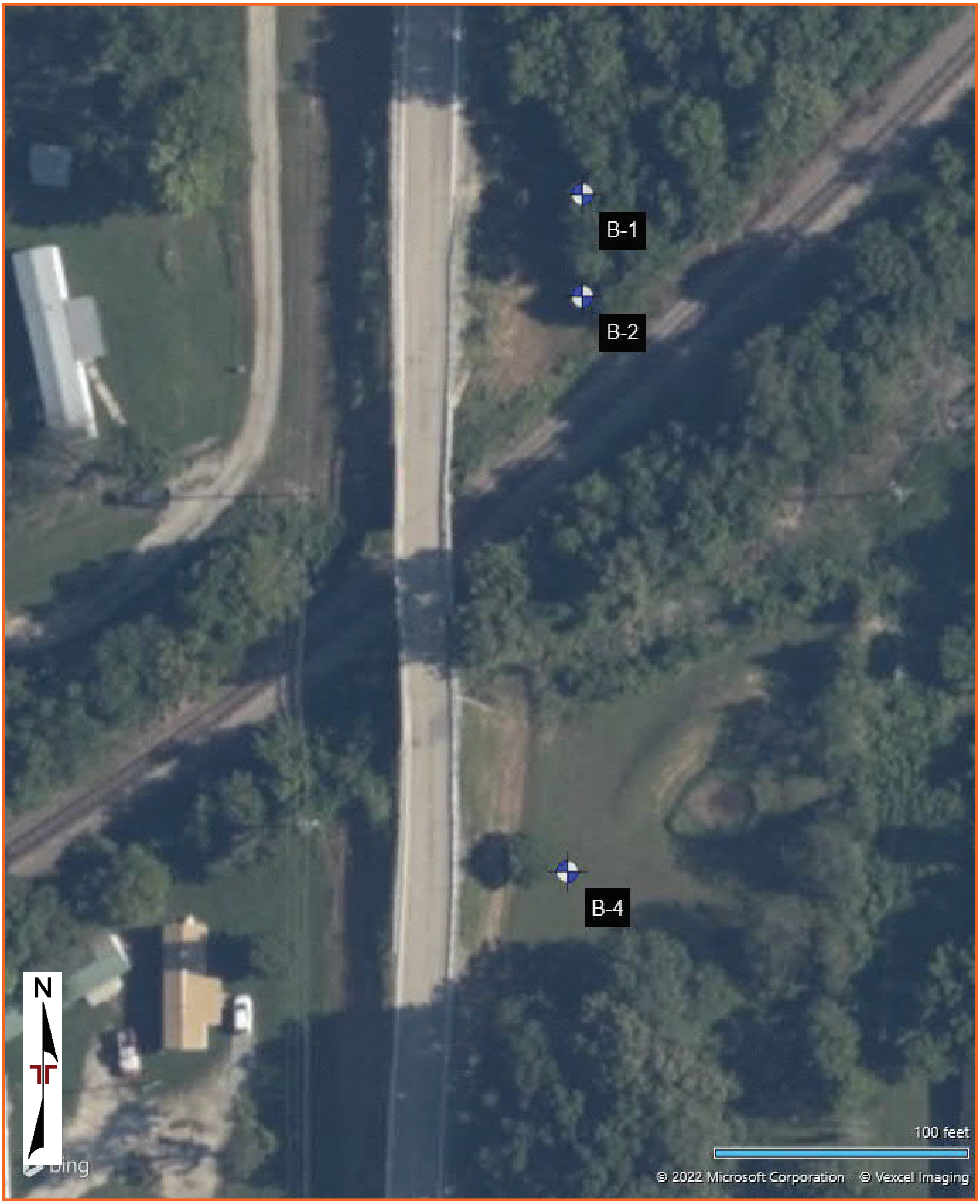


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Boring Logs (B-1, B-2 and B-4)

Note: All attachments are one page unless noted above.

BORING LOG NO. B-1

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation
Little Rock, AR

SITE: Highway 14
Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2530° Longitude: -92.6905°
Northing: 699450.801 Easting: 1108734.334

Surface Elev.: 874.152 (Ft.)

MODEL LAYER	DEPTH / ELEVATION (Ft.)	Description	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1		**SANDY FAT CLAY (CH)**, with chert gravel, brown, stiff to hard			X	3-4-8 N=12				20.8	74-28-46	57
					X	8-9-16 N=25				35.3		
					X	10-14-17 N=31				29.7		
			5		X	14-18-43 N=61				28.2		
	8.5 / 865.5	**FAT CLAY (CH)**, with chert gravel, brown, very stiff to hard			X	6-8-12 N=20				38.0	83-33-50	90
			10									
					X	12-15-29 N=44				36.2		
			15									
	18.5 / 855.5	**FAT CLAY WITH SAND (CH)**, with chert gravel, brown, medium stiff to very stiff			X	5-7-10 N=17				55.1		
			20									
					X	8-3-4 N=7				61.3		76
			25									

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

Hammer Type: Automatic

Advancement Method:
0 to 8.5 feet: Solid-stem auger
8.5 to 30 feet: Mud rotary drilling
30 to 55 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-25-2022	Boring Completed: 06-25-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-1

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation Little Rock, AR

SITE: Highway 14 Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2530° Longitude: -92.6905°
Northing: 699450.801 Easting: 1108734.334

Surface Elev.: 874.152 (Ft.)

MODEL LAYER	DEPTH / DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	TEST TYPE	COMPRESSIVE STRENGTH (psi)	STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1	**FAT CLAY WITH SAND (CH)**, with chert gravel, brown, medium stiff to very stiff *(continued)*				SPT	2-3-11 N=14				88.7		
	30.0	844	30									
2	**DOLOMITE**, with chert seams, gray and light brown, cemented, slightly fractured, moderate spacing				Rock core	REC = 95% RQD = 80%	UC	14198				
			35		Rock core	REC = 93% RQD = 78%						
			40		Rock core	REC = 100% RQD = 98%	UC	12149				
			45		Rock core	REC = 100% RQD = 83%						
			50									

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

Hammer Type: Automatic

Advancement Method:
0 to 8.5 feet: Solid-stem auger
8.5 to 30 feet: Mud rotary drilling
30 to 55 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-25-2022	Boring Completed: 06-25-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-1

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation Little Rock, AR

SITE: Highway 14 Yelleville, AR

MODEL LAYER	GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 36.2530° Longitude: -92.6905° Northing: 699450.801 Easting: 1108734.334 Surface Elev.: 874.152 (Ft.) DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2		**DOLOMITE**, with chert seams, gray and light brown, cemented, slightly fractured, moderate spacing *(continued)* 55.0 / 819	55			REC = 100% RQD = 97%	UC	18429				
		Boring Terminated at 55 Feet										

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

Hammer Type: Automatic

Advancement Method:
0 to 8.5 feet: Solid-stem auger
8.5 to 30 feet: Mud rotary drilling
30 to 55 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-25-2022	Boring Completed: 06-25-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-2

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation
Little Rock, AR

SITE: Highway 14
Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2529° Longitude: -92.6905°
Northing: 699409.483 Easting: 1108734.005

Surface Elev.: 876.917 (Ft.)

MODEL LAYER	DEPTH	DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1		**FAT CLAY (CH)**, with chert gravel, brown and gray, very stiff to hard				SPT	7-9-11 N=20				13.2		
						SPT	5-7-9 N=16				30.0	80-18-62	92
						SPT	6-8-12 N=20				24.8		
				5		SPT	6-9-12 N=21				33.5		
				10		SPT	17-41-20 N=61				31.7		
	13.5	**SANDY FAT CLAY (CH)**, with chert gravel, brown and gray, very stiff to hard	863.5			SPT	15-8-11 N=19				27.5	72-22-50	66
				15		SPT	6-9-21 N=30				38.5		
2	20.0	**DOLOMITE**, with chert seams, gray and light brown, cemented, extremely to slightly fractured, very close to close fracture spacing	857	20		Rock core	REC = 7% RQD = 0%						
				25									

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

Hammer Type: Automatic

Advancement Method:
0 to 6.5 feet: Solid-stem auger
6.5 to 20 feet: Mud rotary drilling
20 to 67.5 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-24-2022	Boring Completed: 06-24-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-2

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation, Little Rock, AR

SITE: Highway 14, Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2529° Longitude: -92.6905°
Northing: 699409.483 Easting: 1108734.005

Surface Elev.: 876.917 (Ft.)

MODEL LAYER	DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2	**DOLOMITE**, with chert seams, gray and light brown, cemented, extremely to slightly fractured, very close to close fracture spacing *(continued)*				REC = 38% RQD = 0%						
		30			REC = 50% RQD = 50%	UC	20380				
		35			REC = 83% RQD = 68%						
		40			REC = 99% RQD = 47%	UC	21036				
		45			REC = 100% RQD = 100%						
		50									

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

Hammer Type: Automatic

Advancement Method:
0 to 6.5 feet: Solid-stem auger
6.5 to 20 feet: Mud rotary drilling
20 to 67.5 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-24-2022	Boring Completed: 06-24-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-2

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation Little Rock, AR

SITE: Highway 14 Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2529° Longitude: -92.6905°
Northing: 699409.483 Easting: 1108734.005

Surface Elev.: 876.917 (Ft.)

MODEL LAYER	GRAPHIC LOG	DEPTH / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2		**DOLOMITE**, with chert seams, gray and light brown, cemented, extremely to slightly fractured, very close to close fracture spacing *(continued)*				REC = 94% RQD = 81%	UC	12026				
			55			REC = 100% RQD = 88%						
		57.5 / 819.5										
		Boring Terminated at 57.5 Feet										

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

Hammer Type: Automatic

Advancement Method:
0 to 6.5 feet: Solid-stem auger
6.5 to 20 feet: Mud rotary drilling
20 to 67.5 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-24-2022	Boring Completed: 06-24-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-4

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation Little Rock, AR

SITE: Highway 14 Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2522° Longitude: -92.6905°
Northing: 699184.183 Easting: 1108725.725

Surface Elev.: 884.211 (Ft.)

MODEL LAYER	DEPTH / DESCRIPTION / ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1	**SANDY LEAN CLAY (CL)**, with chert gravel, brown, stiff to hard				7-6-7 N=13				6.0		
					16-20-10 N=30				14.4		
					6-9-6 N=15				20.4	49-20-29	62
	5.0 — 879	5			50/4"				28.0		
2	**HIGHLY WEATHERED DOLOMITE**, with chert veins, light brown and gray, poorly cemented, extremely fractured, close fracture spacing				REC = 75% RQD = 14%						
		10			REC = 33% RQD = 15%						
	12.0 — 872										
	APPARENT CLAY SEAM WITHIN HIGHLY WEATHERED DOLOMITE, brown	15			REC = 15% RQD = 15%						
	16.0 — 868										
	DOLOMITE, gray and light brown, cemented, slightly fractured, moderate spacing	20			REC = 92% RQD = 73%	UC	6627				
		25									

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

Hammer Type: Automatic

Advancement Method:
0 to 8 feet: solid-stem
8 to 43 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-23-2022	Boring Completed: 06-23-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

BORING LOG NO. B-4

PROJECT: ARDOT Job No. 009916

CLIENT: Arkansas Department of Transportation Little Rock, AR

SITE: Highway 14 Yelleville, AR

LOCATION See Exploration Plan

Latitude: 36.2522° Longitude: -92.6905°
Northing: 699184.183 Easting: 1108725.725

Surface Elev.: 884.211 (Ft.)

MODEL LAYER	DEPTH / DESCRIPTION	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (psi)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2	**DOLOMITE**, gray and light brown, cemented, slightly fractured, moderate spacing *(continued)*				Rock core	REC =95% RQD =88%						
			30		Rock core	REC = 99% RQD = 75%	UC	4740				
			35		Rock core	REC = 88% RQD = 83%						
			40		Rock core	REC = 100% RQD = 100%	UC	1838				
	43.0	841										
	Boring Terminated at 43 Feet											

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

Hammer Type: Automatic

Advancement Method:
0 to 8 feet: solid-stem
8 to 43 feet: Rock coring

Abandonment Method:
Boring backfilled with Auger Cuttings

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Elevations were provided by others.

Notes:

WATER LEVEL OBSERVATIONS

No free water observed during augering

Terracon
25809 I 30
Bryant, AR

Boring Started: 06-23-2022	Boring Completed: 06-23-2022
Drill Rig: 576	Driller: JC
Project No.: 35225058	

SUPPORTING INFORMATION

Contents:

Note: All attachments are one page unless noted above.

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

ARDOT Job No. 009916 ■ Yelleville, AR

Terracon Project No. 35225058

SAMPLING

Rock Core

Standard Penetration Test

WATER LEVEL

- **Water Initially Encountered**
- **Water Level After a Specified Period of Time**
- **Water Level After a Specified Period of Time**
- **Cave In Encountered**

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.

FIELD TESTS

N	**Standard Penetration Test Resistance (Blows/Ft.)**
(HP)	**Hand Penetrometer**
(T)	**Torvane**
(DCP)	**Dynamic Cone Penetrometer**
UC	**Unconfined Compressive Strength**
(PID)	**Photo-Ionization Detector**
(OVA)	**Organic Vapor Analyzer**

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

LOCATION AND ELEVATION NOTES

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. 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, (psi)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 3.50	0 - 1
Loose	4 - 9	Soft	3.5 to 7.0	2 - 4
Medium Dense	10 - 29	Medium Stiff	7.0 to 14.0	4 - 8
Dense	30 - 50	Stiff	14.0 to 28.0	8 - 15
Very Dense	> 50	Very Stiff	28.0 to 55.5	15 - 30
		Hard	> 55.5	> 30

RELEVANCE OF SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.

UNIFIED SOIL CLASSIFICATION SYSTEM

Terracon GeoReport

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 ≥ 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 ≥ 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 / Liquid limit - not dried < 0.75	OL	Organic clay [K, L, M, N]
					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 / Liquid limit - not dried < 0.75	OH	Organic clay [K, L, M, P]
					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 ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

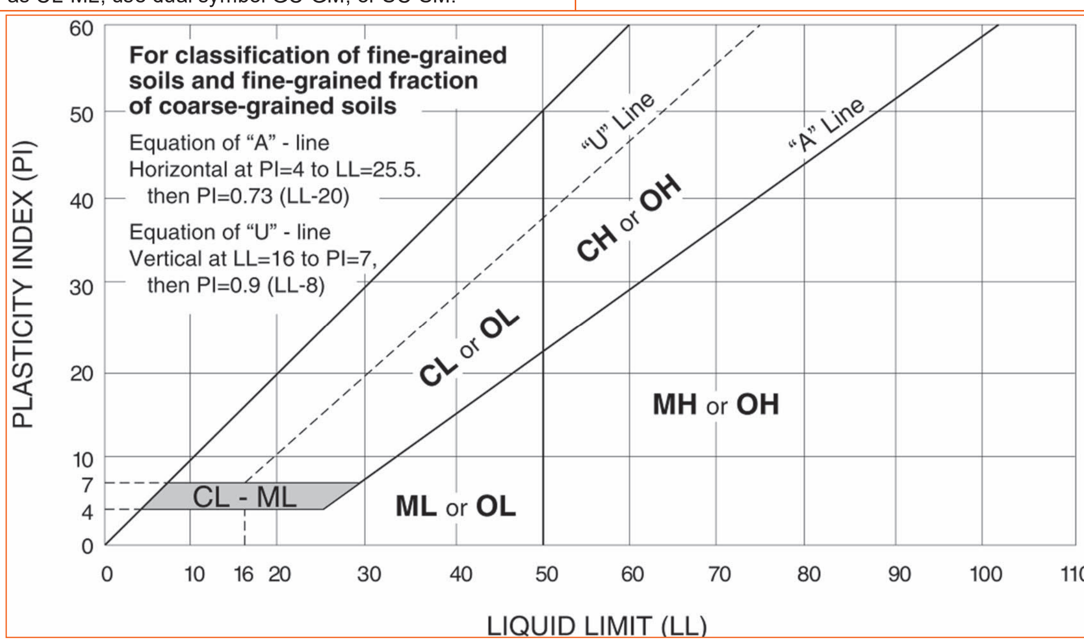
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 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.



DESCRIPTION OF ROCK PROPERTIES

Terracon GeoReport

WEATHERING	
Fresh	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil". Rock "fabric" no discernible or discernible only in small, scattered locations. Quartz may be present as dikes or stringers.

HARDNESS (for engineering description of rock – not to be confused with Moh's scale for minerals)	
Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to ¼ in. deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Medium	Can be grooved or gouged 1/16 in. deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1-in. maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1-in. or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

Joint, Bedding, and Foliation Spacing in Rock [1]

Spacing	Joints	Bedding/Foliation
Less than 2 in.	Very close	Very thin
2 in. – 1 ft.	Close	Thin
1 ft. – 3 ft.	Moderately close	Medium
3 ft. – 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick

1. Spacing refers to the distance normal to the planes, of the described feature, which are parallel to each other or nearly so.

Rock Quality Designator (RQD) [1]

RQD, as a percentage	Diagnostic description
Exceeding 90	Excellent
90 – 75	Good
75 – 50	Fair
50 – 25	Poor
Less than 25	Very poor

1. RQD (given as a percentage) = length of core in pieces 4 inches and longer / length of run

Joint Openness Descriptors

Openness	Descriptor
No Visible Separation	Tight
Less than 1/32 in.	Slightly Open
1/32 to 1/8 in.	Moderately Open
1/8 to 3/8 in.	Open
3/8 in. to 0.1 ft.	Moderately Wide
Greater than 0.1 ft.	Wide

References: American Society of Civil Engineers. Manuals and Reports on Engineering Practice - No. 56. Subsurface Investigation for Design and Construction of Foundations of Buildings. New York: American Society of Civil Engineers, 1976. U.S. Department of the Interior, Bureau of Reclamation, Engineering Geology Field Manual.