Geotechnical Engineering Report

Sheriff's Building Communications Tower
Union, Missouri
November 7, 2014
Terracon Project No. 15145158

Prepared for:
Franklin County
Union, Missouri

Prepared by:
Terracon Consultants, Inc.
St. Louis, Missouri

terracon.com

Terracon

Environmental ▪ Facilities ▪ Geotechnical ▪ Materials

November 7, 2014

Terracon

Franklin County
400 East Locust
Union, Missouri 63085

Attn: Mr. John Griesheimer
E: commision@franklinmo.net

Re: Geotechnical Engineering Report
Sheriff's Building Communications Tower
1 Bruns Lane
Union, Missouri
Terracon Project Number: 15145158

Dear Mr. Griesheimer:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. 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.

FOR:
Adam S. Christy, P.E.
Staff Geotechnical Engineer

Jonathan D. Bruner, P.E.
Senior Geotechnical Engineer

STATE OF MISSOURI
JONATHAN D.
E-2001004566
11-07-2014
REGISTERED PROFESSIONAL ENGINEER

Enclosures
Copies: 1 – Client (.pdf)
1 – File

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GEOTECHNICAL ENGINEERING REPORT
SHERRIFF'S BUILDING COMMUNICATIONS TOWER
UNION, MISSOURI

Terracon Project No. 15145158
November 7, 2014

1.0 INTRODUCTION

A geotechnical engineering report has been completed for the proposed self-support telecommunication tower to be located at 1 Bruns Lane in Union, Missouri. One (1) boring, labeled B-1, was performed to a depth of approximately 28 feet below the existing ground surface at the proposed tower location. A log of the boring along with a Site Location Map and a Boring Location Diagram are included in Appendix A of this report.

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

- subsurface soil conditions
- groundwater conditions
- earthwork
- foundation design and construction
- seismic considerations

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Figure A-2, Boring Location Diagram
Tower	Self-support
Maximum loads (estimated by Terracon)	Vertical: 100 kips per leg
Grading	Assumed to be less than 5 feet of cuts or fills
Cut and fill slopes	Assumed to be no steeper than 3H:1V (horizontal to vertical) and no more than 5 feet tall
Retaining walls	None anticipated
Below-grade levels	None anticipated

2.2 Site Location and Description

Item	Description
Location	The project will be located at 1 Bruns Lane in Union, Missouri. Latitude: 38.458645° N, Longitude: 90.991495° W
Existing improvements	Several buildings, two communication towers, parking and drives, and landscaping
Current ground cover	Grass
Existing topography	Relatively flat

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

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

Stratum	Approximate Depth to Bottom of Stratum (feet)	Material Description	Consistency/ Density
Surface	0.3	Topsoil	N/A
1	16	Fat clay (CH) with trace amounts of silt and varying amounts of gravel	Stiff
2	Undetermined	Limestone	N/A

Conditions encountered at each boring location are indicated on the individual boring logs in Appendix A of this report. Stratification boundaries on the boring logs represent the approximate location of changes in soil types; in-situ, the transition between materials may be gradual.

3.2 Groundwater

The borehole was observed while drilling and after completion for the presence and level of groundwater. Groundwater was encountered at approximately 6 feet while drilling. Water introduced during rock coring obscured further water observations in the borehole. The groundwater measurements are not necessarily stable groundwater levels. Due to the low permeability of the soils encountered in the boring, a relatively long period of time may be necessary for a groundwater level to develop and stabilize in a borehole in these materials.

Long-term observations in piezometers or observation wells sealed from the influence of surface water are often required to define groundwater levels in materials of this type.

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. In addition, perched water can develop over low permeability soil strata. Therefore, groundwater levels during construction or at other times in the life of the structures may be different from 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.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Based on the subsurface conditions encountered in the boring, we recommend the proposed communication tower be supported either on shallow foundations or drilled pier foundations.

We recommend that the exposed subgrade be thoroughly evaluated after stripping of topsoil and at the base of all cut areas, but prior to the start of any fill operations. We recommend that the geotechnical engineer be retained to evaluate the bearing material for the foundations and subgrade soils. Subsurface conditions, as identified by the field and laboratory testing programs, have been reviewed and evaluated with respect to the proposed project plans known to us at this time.

4.2 Earthwork

4.2.1 Site Preparation

Prior to placing fill, all vegetation, topsoil, and any otherwise unsuitable materials should be removed from the construction areas. Excessively wet or dry material should either be removed or moisture conditioned and recompacted. After stripping and grubbing, the subgrade should be proofrolled where possible to aid in locating loose or soft areas. Proofrolling can be performed with a loaded, tandem-axle dump truck. Soft, excessively wet or dry, or low-density soil should be removed or compacted in place prior to placing fill.

4.2.2 Soil Stabilization

Methods of subgrade improvement could include scarification, moisture conditioning and recompaction, removal of unstable materials and replacement with granular fill (with or without geosynthetics) and chemical stabilization. The appropriate method of improvement, if required, would be dependent on factors such as schedule, weather, the size of the area to be stabilized, and the nature of the instability. More detailed recommendations can be provided during construction as the need for subgrade stabilization occurs. Performing site grading operations during warm seasons and dry periods would help to reduce the amount of subgrade stabilization required.

Further evaluation of the need and recommendations for subgrade stabilization can be provided during construction as the geotechnical conditions are exposed.

4.2.3 Material Requirements

Compacted structural fill should meet the following material property requirements:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Moderate to High Plasticity Material [2]	CH (LL≥50) or CL (LL≥45 or PI≥25)	Below upper 2 feet of floor slabs and any other lightly-loaded structures
Granular Material [3]	GM, GC, SM, or SC	All locations and elevations
Low Plasticity Material [4]	CL (LL<45 & PI<25) or Granular Material [3]	

1. Compacted structural fill should consist of approved materials that are 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 Terracon for evaluation. On-site soils generally appear suitable for use as fill, although treatment of high plasticity soils will be required.
2. Delineation of moderate to high plasticity clays should be performed in the field by a qualified geotechnical engineer or their representative, and could require additional laboratory testing.
3. Crushed limestone aggregate, limestone screenings or granular material such as sand, gravel or crushed stone containing at least 15% low plasticity fines.
4. Low plasticity cohesive soil or granular soil having low plasticity fines. Material should be approved by the geotechnical engineer.

4.2.4 Compaction Requirements

Item	Description
Fill Lift Thickness	9 inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6 inches in loose thickness when hand-guided equipment (i.e. jumping jack or plate compactor) is used
Compaction Requirements [1]	At least 95% of the material's maximum standard Proctor dry density (ASTM D 698)
Moisture Content – Cohesive Soil	-1 to +3% of the optimum moisture content value as determined by the standard Proctor test
Moisture Content – Granular Material	Workable moisture levels [2]

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

2. Specifically, moisture levels should be maintained low enough to allow for satisfactory compaction to be achieved without the cohesionless fill material pumping when proofrolled.

4.2.5 Utility Trench Backfill

All trench excavations should be made with sufficient working space to permit construction including backfill placement and compaction. If utility trenches are backfilled with relatively clean granular material, they should be capped with at least 18 inches of cohesive fill in non-pavement areas to reduce the infiltration and conveyance of surface water through the trench backfill.

4.2.6 Earthwork Construction Considerations

In periods of dry weather, the surficial soils may be of sufficient strength to allow fill construction on the stripped and grubbed ground surface. However, unstable subgrade conditions could develop during general construction operations, particularly if the soils are wet or subjected to repetitive construction traffic. The use of light construction equipment would aid in reducing subgrade disturbance. The use of remotely operated equipment, such as a backhoe, would be beneficial to perform cuts and reduce subgrade disturbance. Should unstable subgrade conditions be encountered, stabilization measures will need to be employed. Further evaluation of the need and recommendations for subgrade stabilization can be provided during construction as the geotechnical conditions are exposed on a broad scale.

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

Temporary excavations will be required during construction. 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 both 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.

The geotechnical engineer should be retained during the construction phase of the project to observe earthwork and to perform necessary tests and observations during subgrade preparation; proofrolling; placement and compaction of controlled compacted fills; backfilling of excavations into the completed subgrade; and just prior to construction of building floor slabs.

4.3 Foundation Recommendations

The self-support tower can be supported by shallow foundations bearing on stiff native clay or newly placed compacted structural fill. Alternately, the tower can be supported on a drilled pier foundation system bearing on the underlying limestone. Design recommendations are presented in the following sections.

4.3.1 Spread Footing Design Recommendations

Description	Value
Net allowable bearing pressure [1] ■ **Native soil or structural fill**	2,500 psf
Minimum footing width	36 inches
Minimum embedment below finished grade [2]	30 inches
Estimated total settlement [3]	<1 inch
Estimated differential settlement [3]	<¾ inch over 40 feet
Ultimate passive pressure [4]	250 pcf (equivalent fluid density)
Ultimate coefficient of sliding friction [4]	0. 30

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation, and can be increased by 1/3 for transient loads (e.g., wind or seismic). Assumes the bearing material consists of suitable stiff native soil or structural fill.
2. For frost protection and to reduce the effects of seasonal moisture variations in the subgrade soils. For perimeter footings and footings beneath unheated areas.
3. Foundation settlement will depend upon variations within the subsurface soil profile, the structural loading conditions, the embedment depth of the footings, the width of the footings, the thickness of compacted fill, and the quality of the earthwork operations.
4. The sides of the spread footing foundation excavations must be nearly vertical and the concrete should be placed neat against the vertical faces for the passive earth pressure values to be valid. If the loaded side is sloped or benched, and then backfilled, the allowable passive pressure will be significantly reduced. Passive resistance in the upper 2½ feet of the soil profile should be neglected. If passive resistance is used to resist lateral loads, base friction should be neglected.

Uplift resistance for spread footing foundations may be computed as the sum of the weight of the foundation element and the weight of the soil overlying the foundation. We recommend using a soil unit weight of 115 pcf for compacted structural fill overlying the footing placed as described in section **4.2 Earthwork**. A unit weight of 150 pcf could be used for reinforced footing concrete. We recommend a minimum factor of safety of 1.5 be utilized for uplift calculations.

4.3.2 Spread Footing Construction Considerations

The base of all foundation excavations should be free of water and loose soil and rock prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. If the soils at bearing level become excessively dry, disturbed, saturated, or frozen, the affected soil should be removed prior to placing concrete. A lean concrete mud-mat should be placed over the bearing soils if the excavations must remain open for an extended period of time. It is recommended that the geotechnical engineer be retained to observe and test the soil foundation bearing materials.

Groundwater was encountered in the boring, and may be encountered during foundation excavation. In addition, some surface and/or perched groundwater may enter foundation excavations during construction. It is anticipated that any water entering foundation excavations from these sources can be removed using sump pumps or gravity drainage.

If unsuitable bearing soils are encountered in footing excavations, the excavations should be extended deeper to suitable soils. The footings could then bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. The footings could also bear on properly compacted backfill extending down to the suitable soils. Overexcavation for compacted backfill placement below footings should extend laterally beyond all edges of the footings at least 8 inches per foot of overexcavation depth below footing base elevation. The overexcavation should then be backfilled up to the footing base elevation in accordance with section **4.2 Earthwork**. The overexcavation and backfill procedure is illustrated in the following figure.

Lean Concrete Backfill **Overexcavation / Backfill**

NOTE: Excavations in sketches shown vertical for convenience. Excavations should be sloped as necessary for safety

4.3.3 Drilled Pier Design Recommendations

Based on the borings the following design parameters were developed for drilled piers.

Approximate Depth/ Material (feet) [1]	Allowable Skin Friction (psf)	Allowable End Bearing Pressure (psf) [2]	Allowable Passive Pressure (psf)	Cohesion (psf)	Internal Angle of Friction (Degrees)	Strain ε_{50} [3]	Lateral Subgrade Modulus (pci) [3]
0 – 3	Ignore	Ignore	Ignore	Ignore	Ignore	Ignore	Ignore
3 – 16 (cohesive soil)	325	--	1,250	1,250	---	0.010	375
Below 16 (limestone)	1,200	20,000	6,500	6,500	--	0.004	2,000

1. Pier observation is recommended to adjust pier length if variable soil conditions are encountered.
2. Minimum pier length of 4 diameters required. Terracon should be contacted if the pier length is less than four times the pier diameter as modifications to our design parameters may be warranted. The drilled pier must extend at least 3 feet, or one pier diameter, whichever is greater, into the bearing strata to achieve the full listed capacity.
3. Lateral subgrade modulus and ε_{50} values provided above are to be used with LPILE^{plus} software.

The above-indicated cohesions are ultimate values without factors of safety. The end bearing and passive resistance are allowable parameters with a factor of safety of 3. The skin friction values are allowable with a factor of safety of 2. The values given in the above table are based on our borings and past experience with similar soil types. Lateral resistance and friction in the upper 3 feet should be ignored due to the potential effects of frost action, desiccation, and drilling disturbance.

Long-term settlement of a drilled shaft foundation designed and constructed in accordance with the recommendations presented in this report, should be less than ½ inch.

4.3.4 Drilled Pier Construction Considerations

Pier drilling into the bedrock will be difficult and concentrated effort and/or core barrels may be necessary to advance the shaft excavation through zones of gravel, cobbles, boulders, and/or weathered bedrock overlying competent bedrock. Groundwater was encountered in the boring, should be expected during drilled pier excavation. Therefore, temporary casing may be needed to advance drilled pier excavations. Temporary casing should be installed if personnel will enter the shafts.

The bottom of the pier excavations should be cleaned of any water and loose material before placing reinforcing steel and concrete. A minimum shaft diameter of at least 30 inches is required for entry of personnel, and to facilitate clean-out and possible dewatering of the pier excavation.

Concrete should be placed soon after excavating to reduce bearing surface disturbance. Any water accumulating in the pier excavation should be pumped from the excavation or the water level should be allowed to stabilize and then concrete should be placed using the tremie method.

If concrete will be placed as the temporary casing is being removed, we recommend the concrete mixture be designed with a slump of about 5 to 7 inches to reduce the potential for arching when removing the casing. While removing the casing from a pier excavation during concrete placement, the concrete inside the casing should be maintained at a sufficient level to resist any earth and hydrostatic pressures outside the casing during the entire casing removal procedure.

We recommend that a representative of Terracon be present during drilling activities to observe the materials removed from the drilled pier excavations to evaluate when adequate capacity has been developed, to observe the base of the drilled pier to evaluate that the cuttings have been adequately removed, to probe the pilot holes, and also to observe concrete placement.

Although obvious signs of harmful gases such as methane, carbon monoxide, etc., were not noted in the borings during the drilling operations, gas could be encountered in the drilled shaft excavations during construction. The contractor should check for gas and/or oxygen deficiency prior to any workers entering the excavation.

4.4 Seismic Considerations

Code Used	Site Classification
2009 International Building Code (IBC) [1]	C [2]

1. In general accordance with the *2009 International Building Code,* Table 1613.5.2.
2. The 2009 International Building Code (IBC) requires a site soil profile determination extending to a depth of 100 feet for seismic site classification. The boring performed for this report extended to a depth of approximately 28 feet, and this seismic site class assignment considers that similar or stiffer material continues below the maximum depth of the subsurface exploration. Additional exploration to greater depths could be considered to confirm the conditions below the current depth of exploration. Alternatively, a geophysical exploration could be utilized in order to attempt to justify a more favorable seismic site class.

5.0 GENERAL COMMENTS

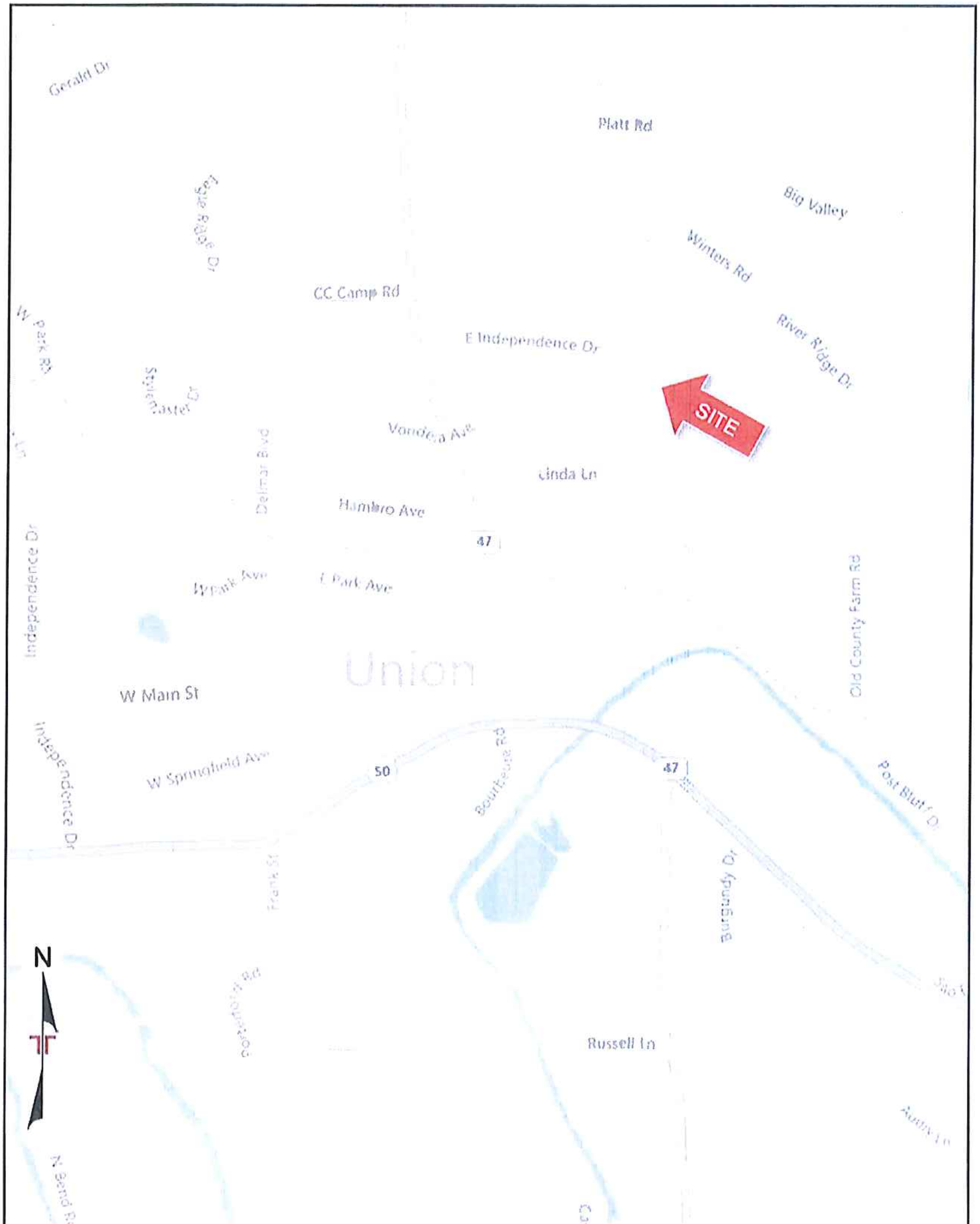
Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon should also be retained to provide observation and testing services during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

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

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

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

APPENDIX A
FIELD EXPLORATION



MAP PROVIDED BY MICROSOFT BING MAPS

Project Manager: JDB	Project No. 15145158	Terracon	SITE LOCATION MAP	Exhibit
Drawn by: ASC	Scale: N.T.S.	11600 Lilburn Park Rd. St. Louis, MO	Sheriff's Building Communications Tower 1 Bruns Lane Union, Missouri	A-1
Checked by: JDB	File Name: 15145158_A-1-2			
Approved by: JDB	Date: 11/7/2014			

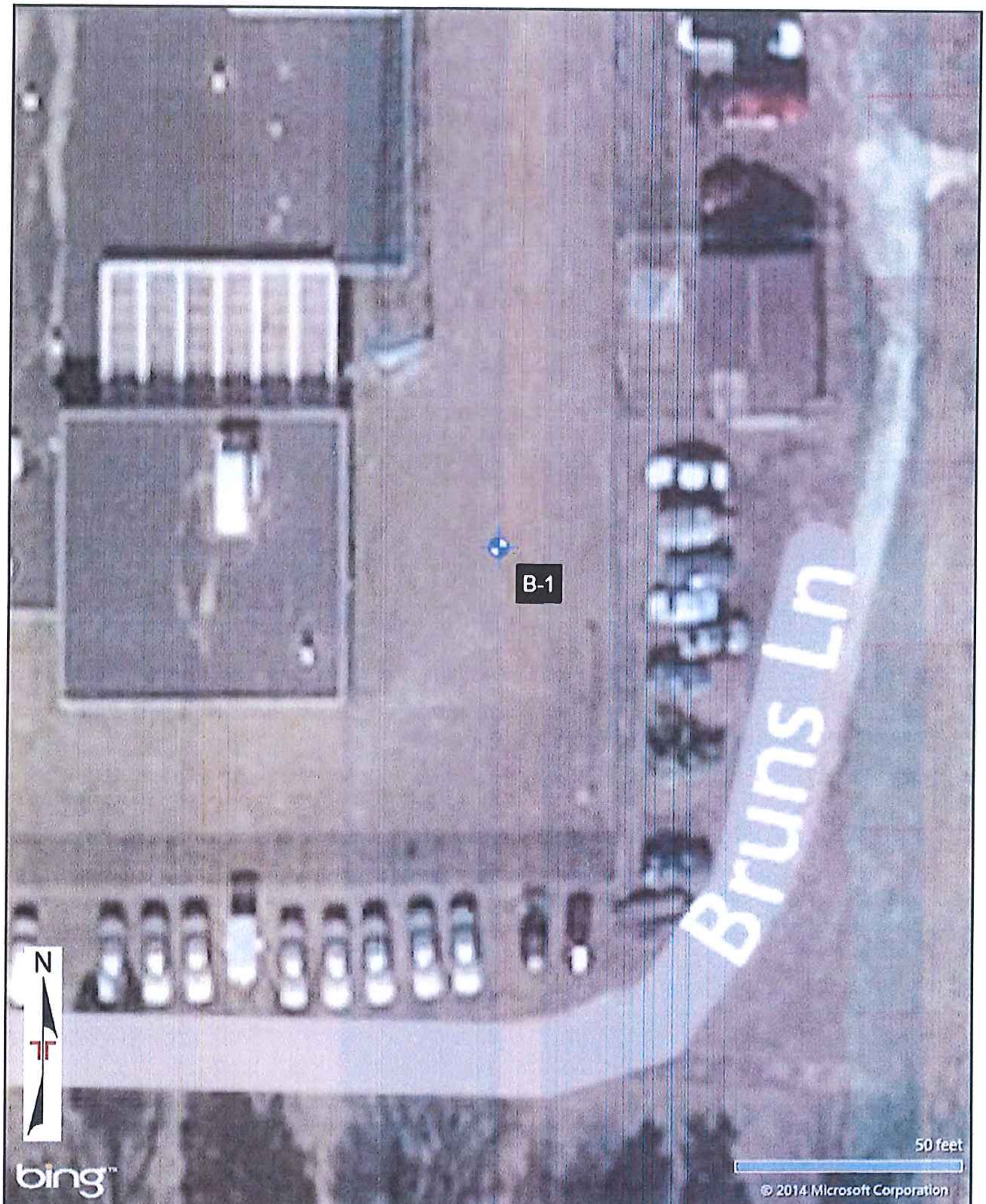


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED BY MICROSOFT BING MAPS

Project Manager: JDB	Project No. 15145158	Terracon	BORING LOCATION DIAGRAM	Exhibit
Drawn by: ASC	Scale: AS SHOWN	11600 Lilburn Park Rd. St. Louis, MO	Sheriff's Building Communications Tower 1 Bruns Lane Union, Missouri	A-2
Checked by: JDB	File Name: 5145158_A-1-2			
Approved by: JDB	Date: 11/7/2014			

Field Exploration Description

The boring location located in the field by the drill crew using a hand-held GPS unit and reference to site features. The elevation indicated on the boring log was measured in the field using an engineer's level and grade rod, and is referenced to the finished floor elevation of the existing building. This benchmark was assigned an elevation of 100 feet. The location and elevation of the boring should be considered accurate only to the degree implied by the means and methods used to define them.

The boring was drilled with a CME-850, ATV-mounted, rotary drill rig using continuous-flight, hollow-stem augers to advance the borehole. Samples of the soils encountered in the boring were obtained using the split-barrel sampling procedures. Samples below practical auger refusal were obtained using NQ-2 diamond coring techniques.

In the split-barrel sampling procedure, the number of blows required to advance a standard 2-inch O.D. split-barrel sampler the last 12 inches of the typical total 18-inch penetration by means of a 140-pound hammer with a free fall of 30 inches, is the standard penetration resistance value (SPT N-value). This value is used to estimate the in-situ relative density of cohesionless soils and the consistency of cohesive soils.

A CME automatic SPT hammer was used to advance the split-barrel sampler in the boring performed on this site. A greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. This higher efficiency has an appreciable effect on the SPT N-value. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further observation, testing, and classification. Information provided on the boring log attached to this report includes soil descriptions, consistency evaluations, boring depth, sampling intervals, and groundwater conditions. The boring was backfilled with auger cuttings prior to the drill crew leaving the site.

A field log of the boring was prepared by the drill crew. This log included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. The final boring log included with this report represents the engineer's interpretation of the field log and includes modifications based on laboratory observation and tests of the samples.

BORING LOG NO. B-1

PROJECT: Sherriff's Building Communications Tower | **CLIENT: Franklin County, Union, Missouri**

SITE: 1 Bruns Lane, Union, Missouri

LOCATION See Exhibit A-2

Latitude: 38.458645° Longitude: -90.991495°

Approximate Surface Elev: 99.5 (Ft.) +/-

DEPTH	Description	ELEVATION (Ft.)	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	RECOVERY (In.)	FIELD TEST RESULTS	LABORATORY TORVANE/HP (psf)	UNCONFINED COMPRESSIVE STRENGTH (psf)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)
0.3	**3" topsoil**	99+/-									
	FAT CLAY (CH), trace silt, brown and gray, stiff					10	4-8-7 N=15	6000 (HP)		19	
	trace gravel					8	3-5-4 N=9	1500 (HP)		28	
			5	▽							
			10			10	2-4-7 N=11	7000 (HP)		19	
			15			8	4-6-9 N=15	6000 (HP)		24	
16.0	**WEATHERED LIMESTONE**, gray, highly weathered	83.5+/-									
18.0	Auger refusal at 18 feet	81.5+/-									
	LIMESTONE, gray, slightly weathered, moderately hard		20				REC=85% RQD=35%				
	Unconfined Compressive Strength = 11,620 psi		25				REC=100% RQD=61%				
28.0		71.5+/-									
	Boring Terminated at 28 Feet		30								

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

Hammer Type: Automatic SPT Hammer

Advancement Method:
0-18' Hollow Stem Auger
18-28' NQ-2 Diamond Bit

Abandonment Method:
Boring backfilled with soil cuttings upon completion.

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.
Elevations were measured in the field using an engineer's level and grade rod.

Notes:

WATER LEVEL OBSERVATIONS

▽ *While drilling*

Terracon
11600 Lilburn Park Road
St. Louis, Missouri

Boring Started: 11/5/2014	Boring Completed: 11/5/2014
Drill Rig: CME-850	Driller: DB
Project No.: 15145158	Exhibit: A-4

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO LOG-DEPTH TO BOTTOM OF PAGE 15145158.GPJ TEMPLATE UPDATE 3-31-14.GPJ 11/7/14

APPENDIX B
SUPPORTING INFORMATION

Laboratory Testing

Soil samples were tested in the laboratory to measure their natural water content (ASTM D4959). A hand penetrometer was used to estimate the unconfined compressive strength of some cohesive samples. The hand penetrometer has been correlated with unconfined compression tests and provides a better estimate of soil consistency than visual examination alone. The test results are provided on the boring logs included in Appendix A.

As part of the testing program, samples were examined in our laboratory and classified in accordance with the General Notes and the Unified Soil Classification System (USCS) based on the material's texture and plasticity (ASTM D2487 and ASTM D2488). The USCS group symbol is shown on the boring logs, and a brief description of the USCS is included with this report in Appendix C.

Procedural standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING			WATER LEVEL		FIELD TESTS	
	Auger	Split Spoon		Water Initially Encountered	(HP)	Hand Penetrometer
	Shelby Tube	Macro Core		Water Level After a Specified Period of Time	(T)	Torvane
	Ring Sampler	Rock Core		Water Level After a Specified Period of Time	(b/f)	Standard Penetration Test (blows per foot)
	Grab Sample	No Recovery			(PID)	Photo-Ionization Detector
					(OVA)	Organic Vapor Analyzer

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.

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 Includes gravels, sands and silts.			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.	Ring Sampler Blows/Ft.	Descriptive Term (Consistency)	Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-Value Blows/Ft.	Ring Sampler Blows/Ft.
	Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3
	Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4
	Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	4 - 8	5 - 9
	Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 15	10 - 18
	Very Dense	> 50	≥ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42
				Hard	> 8,000	> 30	> 42

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

Terracon

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]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]		GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [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]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]		SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [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] $Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[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.

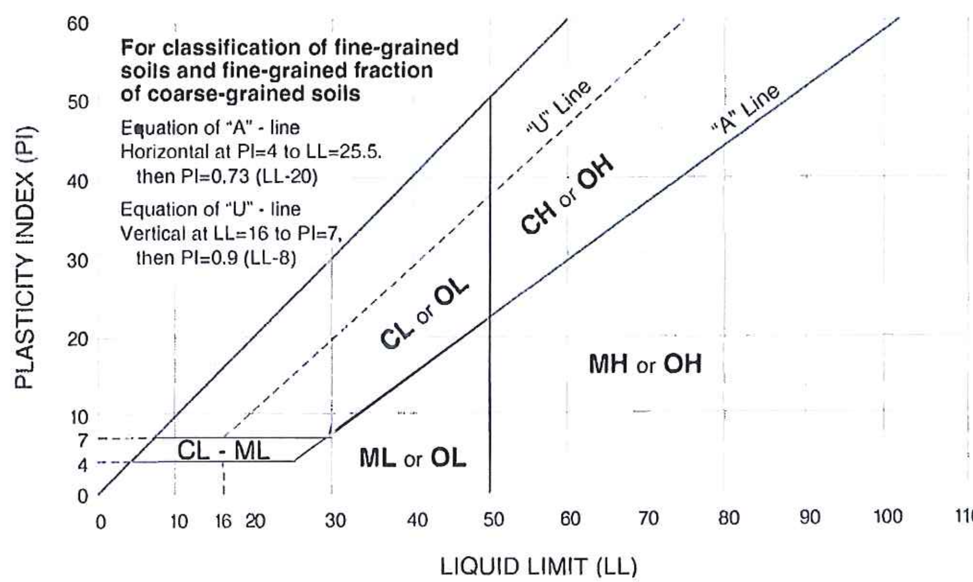
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[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.



Terracon

Exhibit C-2

DESCRIPTION OF ROCK PROPERTIES

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" not discemible 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 [a]

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

a. 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) a

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

a. RQD (given as a percentage) = length of core in pieces 4 in. 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.