# Geotechnical Engineering Report

**County Bridge SH-15**
**Stillwell Road over Tributary to Stanger Creek**
**Leavenworth County, KS**

January 13, 2014
Terracon Project No. 02135230

**Prepared for:**
Leavenworth County
Leavenworth, KS

**Prepared by:**
Terracon Consultants, Inc.
Lenexa, KS

Offices Nationwide Employee-Owned
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Terracon
Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

January 13, 2014

Terracon

Leavenworth County
300 Walnut, Suite 7
Leavenworth, KS 66048

Attn: Mr. Mickey G. Schwartzkopf
E: mschartzkopf@leavenworthcounty.org

Re: Geotechnical Engineering Report
County Bridge SH-15
Stillwell Road over Tributary to Stranger Creek
Leavenworth County, KS
Terracon Project Number: 02135230

Dear Mr. Schwartzkopf:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the planned replacement of County Bridge SH-15 over a tributary to Stranger Creek in Leavenworth County, KS. This study was performed in general accordance with our proposal number P02131053. 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 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.**

BRETT W. LARSEN
LICENSED
21707
KANSAS
PROFESSIONAL ENGINEER
1/13/2014

Brett W. Larsen, P.E.
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Enclosures
cc: 1 – Client (PDF)
1 – File

## TABLE OF CONTENTS

# GEOTECHNICAL ENGINEERING REPORT
# COUNTY BRIDGE SH-15
# STILLWELL ROAD OVER TRIBUTARY OF STRANGER CREEK
# LEAVENWORTH COUNTY, KS

**Terracon Project No. 02135229**
**January 13, 2014**

## 1.0 INTRODUCTION

Terracon Consultants, Inc. (Terracon) has completed a subsurface exploration for the proposed County Bridge SH-15 over tributary of Stranger Creek in Leavenworth County, KS. Two (2) borings were performed at this site to depths ranging from 25 to 39 feet. The boring location diagram, a site location diagram, site aerial and logs of borings 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
- lateral earth pressures
- seismic considerations

## 2.0 PROJECT INFORMATION

### 2.1 Project Description

| Item | Description |
|---|---|
| **Site layout** | See Appendix A, Exhibit A-3: Boring Location Diagram |
| **Replacement bridge structure** | The replacement structure is expected to be a single-span precast concrete bridge (Conspan or Old Castle). These type of replacement bridges are usually supported on footing foundations. If driven pile foundations are required, a steel girder bridge will be planned. |
| **Grading** | We do not expect changes to the horizontal and vertical alignment of Stillwell Road. |
| **Cut and fill slopes** | We understand that no instability of existing side slopes has been reported and that no significant alterations to the existing grades are planned. |

## 2.2 Site Location and Description

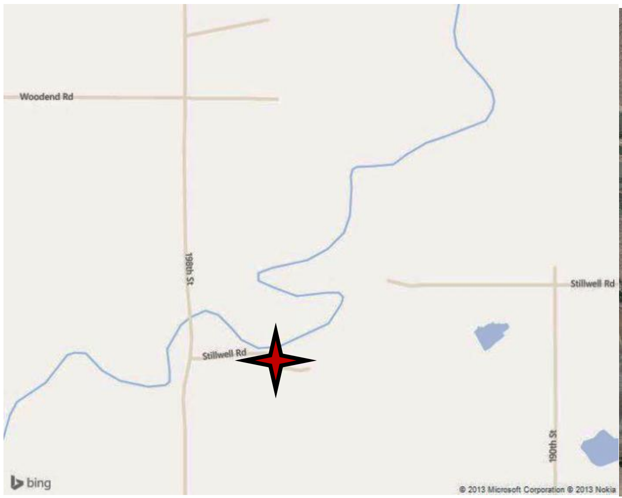



**Figure 1. Site Location**

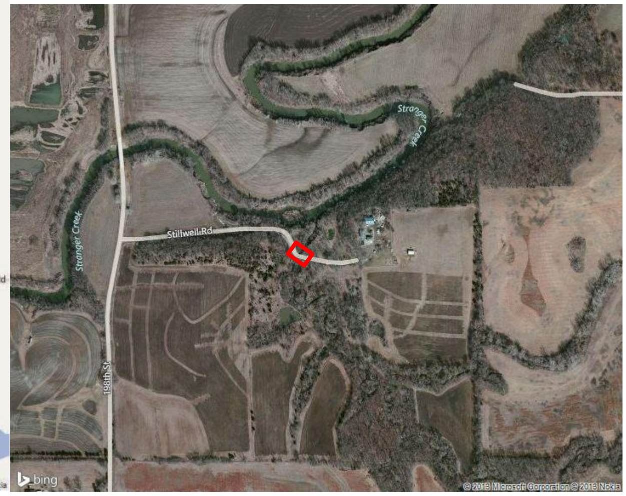



**Figure 2. Aerial of Site**

| Item | Description |
|---|---|
| **Location** | The bridge site is located on Stillwell Road over a tributary of Stranger Creek in Leavenworth County, KS. |
| **Existing conditions** | Stillwell Road is a gravel road in the vicinity of the existing county Bridge. The existing bridge spans approximately 35 feet across the tributary and the bridge deck is approximately 14 feet above the flowline of the creek. |

# 3.0 SUBSURFACE CONDITIONS

## 3.1 Typical Profile

Subsurface conditions at the borings can be generalized as follows:

| Stratum | Approximate Depth to Bottom of Stratum[1] | Material Description | Comments |
|---|---|---|---|
| 1 | 10 feet at B-1<br>15 feet at B-2 | Fill | Lean clay, with gravel, trace roots and wood, dark brown |
| 2 | 24.5 feet at B-2 | Lean clay[2] | trace gravel, stiff, yellow-brown |

| Stratum | Approximate Depth to Bottom of Stratum[1] | Material Description | Comments |
|---|---|---|---|
| 3 | Not determined[3,4] | Bedrock | Gray, hard, moderately weathered shale at B-2<br><br>Gray, hard, moderately weathered limestone, with occasional shale seams at B-1 |

1. Depth as measured below the existing ground surface at the time the borings were conducted.
2. Lean clay was not encountered below the existing fill at Boring B-1.
3. Boring B-1 was terminated at a depth of 25 feet in limestone bedrock.
4. Boring B-2 was terminated at a depth of 39 feet in shale bedrock.

Subsurface conditions encountered at the boring locations are indicated on the attached boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil and rock types; in situ, the transition between materials may be gradual.

### 3.2 Groundwater

The borings were observed while drilling and after completion for the presence of groundwater. Groundwater was not observed at Borings B-1 and B-2 during drilling. Long term observations in piezometers or observation wells sealed from influence of surface water would be required to develop additional groundwater information.

Groundwater levels fluctuate due to seasonal variations in the amount of rainfall, runoff, the water level in the tributary of Stranger Creek and other factors not evident at the time the borings were performed. Therefore, groundwater conditions at other times may be different than indicated on the boring logs.

## 4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

### 4.1 Geotechnical Considerations

The deck of the existing bridge is approximately 14 feet above the flow line of the existing creek. We anticipate that the foundations for the new bridge will bear at about 17 to 20 feet below existing grade at our borings. At Boring B-1, hard limestone bedrock was encountered at 10 feet, so some excavation of bedrock may be required to extend footings to the design bearing level. At Boring B-2, footings are anticipated to bear on stiff lean clay soils. In our opinion, the proposed bridge replacement could be supported on footing foundations that bear on stiff native clay on one side of the creek and limestone bedrock on the other side. Recommendations have been provided in subsequent sections of this report.

## 4.2 Bridge Foundation Design and Construction Considerations

We do not expect horizontal and vertical alignments of Stillwell Road will be altered for this project. The flow line of the stream was approximately 14 feet below existing bridge deck at the time of the subsurface exploration, so we have considered that typical strip footings or slab footings that will support the bridge and wing walls would bear approximately 17 feet to 20 feet below the existing roadway surface. Based on the estimated footing bearing depth and the conditions encountered in the borings, we anticipate the west side footing will bear on limestone bedrock and on the east side footing will bear on stiff clay soils. Recommendations for design of shallow foundations bearing on limestone bedrock and stiff clay are provided in the following sections.

### 4.2.1 Foundation Design Recommendations – Limestone Bearing

| Description | Wall |
|---|---|
| **Net allowable bearing pressure** [1] | 5,000 psf |
| **Continuous footing minimum width** | 12 inches |
| **Minimum embedment below finished grade** | N/A[2] |
| **Approximate total settlement** | Less than ½ inch |
| **Allowable coefficient of sliding friction** | 0.65 |

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. The recommended bearing value considers the foundations bear on competent limestone or a relatively thin (12 inches thick or less) layer of crushed aggregate placed directly on the limestone bedrock.
2. Footings that bear directly on limestone do not need to meet the minimum embedment requirements.

### 4.2.2 Foundation Design Recommendations – Clay Bearing

| Description | Wall |
|---|---|
| **Net allowable bearing pressure** [1] | 2,500 psf |
| **Continuous footing minimum width** | 30 inches |
| **Minimum embedment below finished grade**[2] | 36 inches |
| **Approximate total settlement** | Less than 1 inch |
| **Allowable coefficient of sliding friction** | 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. The recommended bearing value considers the foundations bear on stiff lean clay soils below the scour depth.
2. The embedment depth is for frost protection and to reduce the effects of seasonal moisture variations in the subgrade soils.

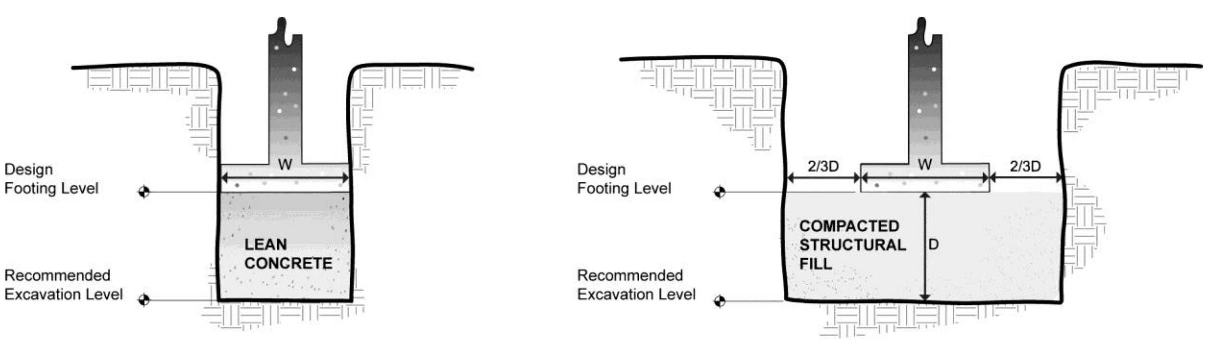
### 4.2.3 Settlement Considerations

Footings that bear on limestone bedrock are not expected to settle appreciably; and footings that bear on clay may settle up to 1 inch. Therefore there is a potential for up to 1-inch of differential settlement across the bridge structure. The structural engineer should consider the impact of the possible differential settlement on the proposed structure. If the proposed structure cannot tolerate the anticipated settlements and/or settlement differential, the proposed structure should be supported on foundations that extend to bedrock.

### 4.2.4 Foundation 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 surface disturbance. Should the material at the bearing level become disturbed the affected material should be removed prior to placing concrete. The contractor could consider placement of a lean concrete mud-mat over the bearing surfaces if the excavations must remain open over night or for an extended period of time. It is recommended that the geotechnical engineer be retained to observed and test the soil foundation bearing material.

If unsuitable bearing soils or bedrock are encountered in the footing excavations, the excavation could be extended deeper to suitable soils or bedrock and the footing could bear directly on these soils or bedrock at the lower level or on lean concrete backfill placed in the excavations. As an alternative, the footings could also bear on properly compacted engineered backfill extending down to the suitable soils. Overexcavation for compacted engineered fill 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 with engineered fill material placed in lifts of 9 inches or less in loose thickness (6 inches or less if using hand-guided compaction equipment) and compacted to at least 95 percent of the material's standard effort maximum dry density (ASTM D 698). The overexcavation and backfill procedure is described in the following figure.

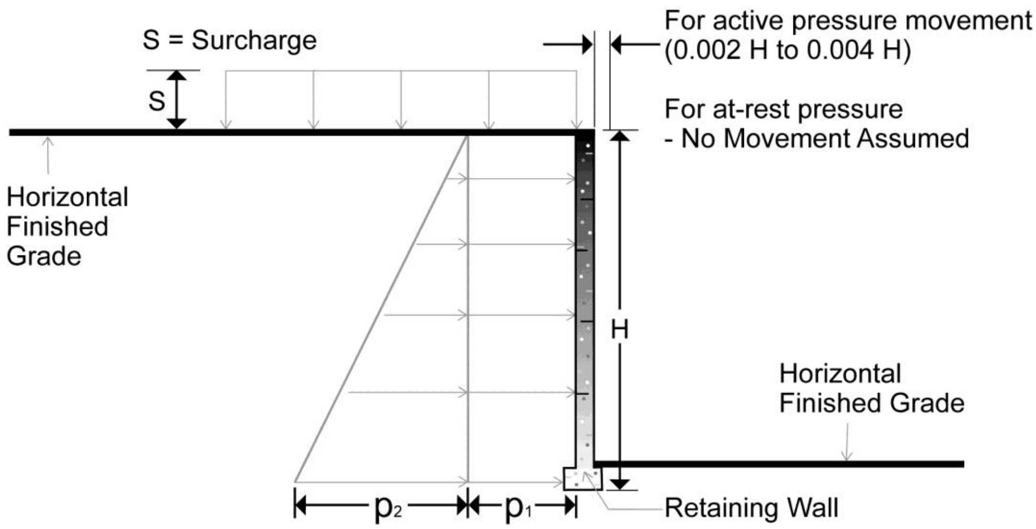



**Lean Concrete Backfill** **Overexcavation / Backfill**

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

## 4.3 Lateral Earth Pressures

Abutment and wing walls with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to those indicated in the following table. Earth pressures will be influenced by structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown. Active earth pressure considers wall movement is permitted whereas, the at-rest condition considers wall movement is not permitted. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls. In our opinion, at-rest parameters should be used to design abutment walls. If wing walls will connect to abutment walls such that movement is restricted, at-rest parameters should also be used to design wing walls.




**EARTH PRESSURE COEFFICIENTS**

| EARTH PRESSURE CONDITIONS | COEFFICIENT FOR BACKFILL TYPE | EQUIVALENT FLUID DENSITY (pcf) | SURCHARGE PRESSURE, $p_1$ (psf) | EARTH PRESSURE, $p_2$ (psf) |
|---|---|---|---|---|
| Active (Ka) | Granular - 0.33 | 40 | (0.33)S | (40)H |
| | Lean Clay - 0.42 | 50 | (0.42)S | (50)H |
| At-Rest (Ko) | Granular - 0.42 | 50 | (0.42)S | (50)H |
| | Lean Clay - 0.58 | 70 | (0.58)S | (70)H |

<u>Applicable conditions to the above include:</u>

- For active earth pressure, wall must rotate about base, with top lateral movements of about 0.002 **H** to 0.004 **H**, where **H** is wall height
- Uniform surcharge, where S is surcharge pressure

- In-situ soil backfill weight a maximum of 120 pcf
- Horizontal backfill, compacted between 95 and 98 percent of standard Proctor maximum dry density
- Loading from heavy compaction equipment not included
- No hydrostatic pressures acting on wall
- No dynamic loading
- No safety factor included in soil parameters

Backfill placed against structures should consist of granular soils or on-site cohesive soils. For the granular values to be valid, the granular backfill must extend out from the base of the wall at an angle of at least 45 degrees from vertical for the active and at at-rest cases.

To control hydrostatic pressure behind the walls we recommend a continuous subsurface drain line be installed behind the walls that drains freely to down gradient outlets and/or weep holes be installed through the walls. If backfill drainage is not possible, then walls should be designed to resist the combined hydrostatic and lateral earth pressures.

## 4.4 Seismic Considerations

| Code Reference | Site Classification |
|---|---|
| **2009 International Building Code (IBC)** | C [1] |

1. The 2009 International Building Code (IBC) site profile determination is based on average properties of the subsurface profile to a depth of 100 feet. Borings extended to a maximum depth of approximately 40 feet. Our opinion of site classification is based on our knowledge of local geologic and geotechnical conditions.

## 4.5 Backfill and Compaction

Fills used to backfill behind the bridge abutments and wing walls should consist of approved materials, which are free of organic matter and debris. In general, the lean clay soils that will likely be excavated to accommodate construction of the bridge replacement could be used to construct engineered fills, provided any organic matter and debris is removed. Wet clay soils will likely need to be dried in order to achieve the recommended degree of compaction. Samples of all proposed fill materials (site soils and imported materials) should be tested and approved prior to being incorporated into the work.

In our opinion, engineered fill should be placed and compacted as recommended in the table below.

| 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 small hand-guided equipment (i.e. jumping jack or plate compactor) is used |
| **Compaction Requirements** [1] | 95% of the materials maximum standard Proctor dry density (ASTM D-698) |
| **Moisture Content – Cohesive Soil** | Within the range of -2% to +2% optimum moisture content as determined by the standard Proctor test. |
| **Moisture Content – Granular Material** | Sufficient to achieve satisfactory compaction without pumping when proof-rolled |

1. We recommend that engineered 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.

## 5.0 GENERAL COMMENTS

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

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

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

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

# APPENDIX A
# FIELD EXPLORATION

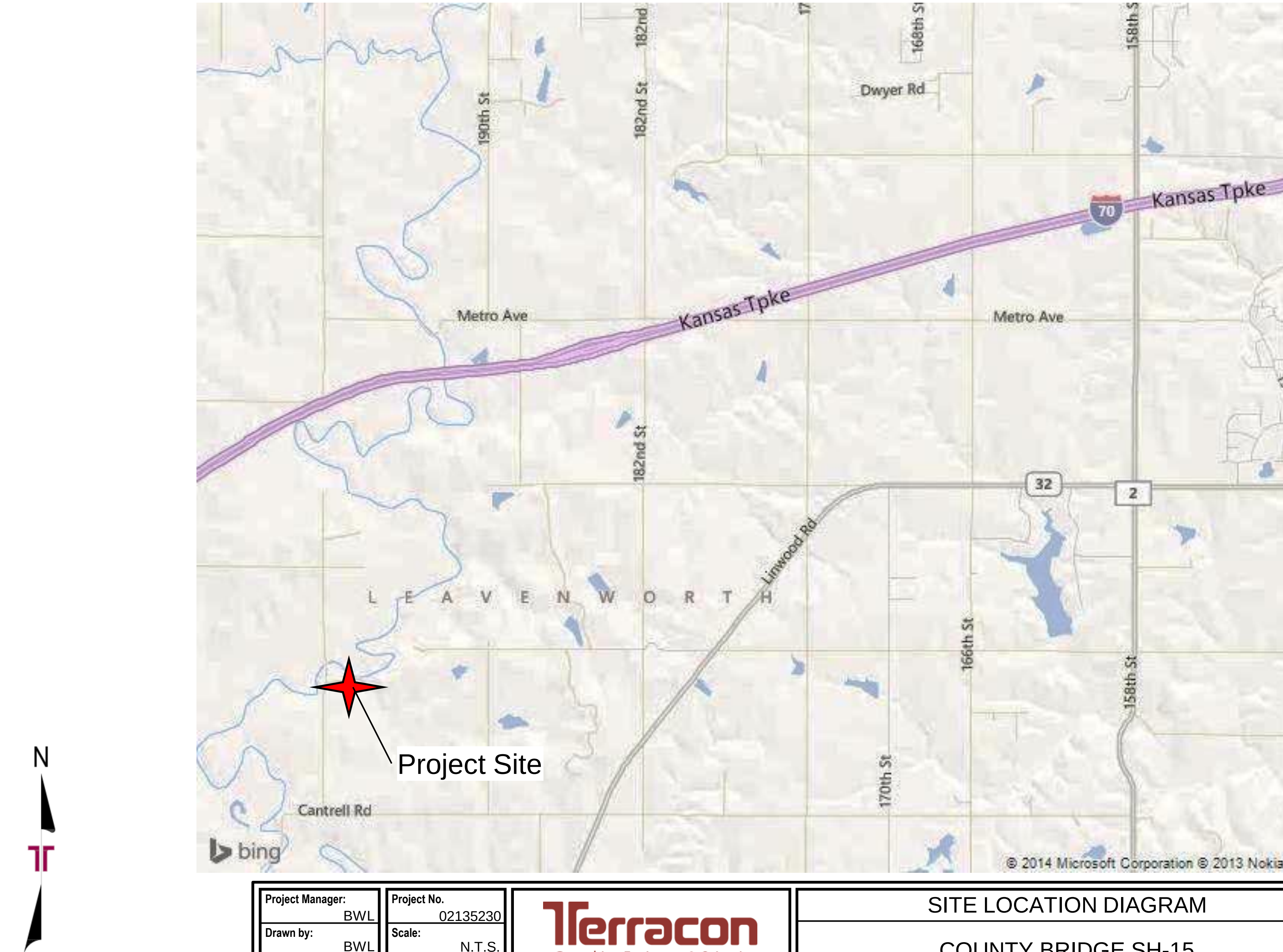



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

| | |
|---|---|
| Project Manager: BWL | Project No. 02135230 |
| Drawn by: BWL | Scale: N.T.S. |
| Checked by: BWL | File Name: Boring Location (11x8.5).ppt |
| Approved by: BWL | Date: 1/07/2013 |

Terracon
Consulting Engineers & Scientists
13910 West 96th Terrace Lenexa, Kansas 66215
PH. (913) 492-7777 FAX. (913) 492-7443

# SITE LOCATION DIAGRAM

## COUNTY BRIDGE SH-15

Stillwell Road
LEAVENWORTH, KS

Exhibit
A-1



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

| | | | | |
|---|---|---|---|---|
| Project Manager: BWL | Project No. 02135230 | Terracon Consulting Engineers & Scientists | BORING LOCATION DIAGRAM | Exhibit |
| Drawn by: BWL | Scale: N.T.S. | | COUNTY BRIDGE SH-15<br>Stillwell Road<br>LEAVENWORTH, KS | A-2 |
| Checked by: BWL | File Name: Boring Location (11x8.5).ppt | 13910 West 96th Terrace Lenexa, Kansas 66215 | | |
| Approved by: BWL | Date: 1/07/2014 | PH. (913) 492-7777 FAX. (913) 492-7443 | | |

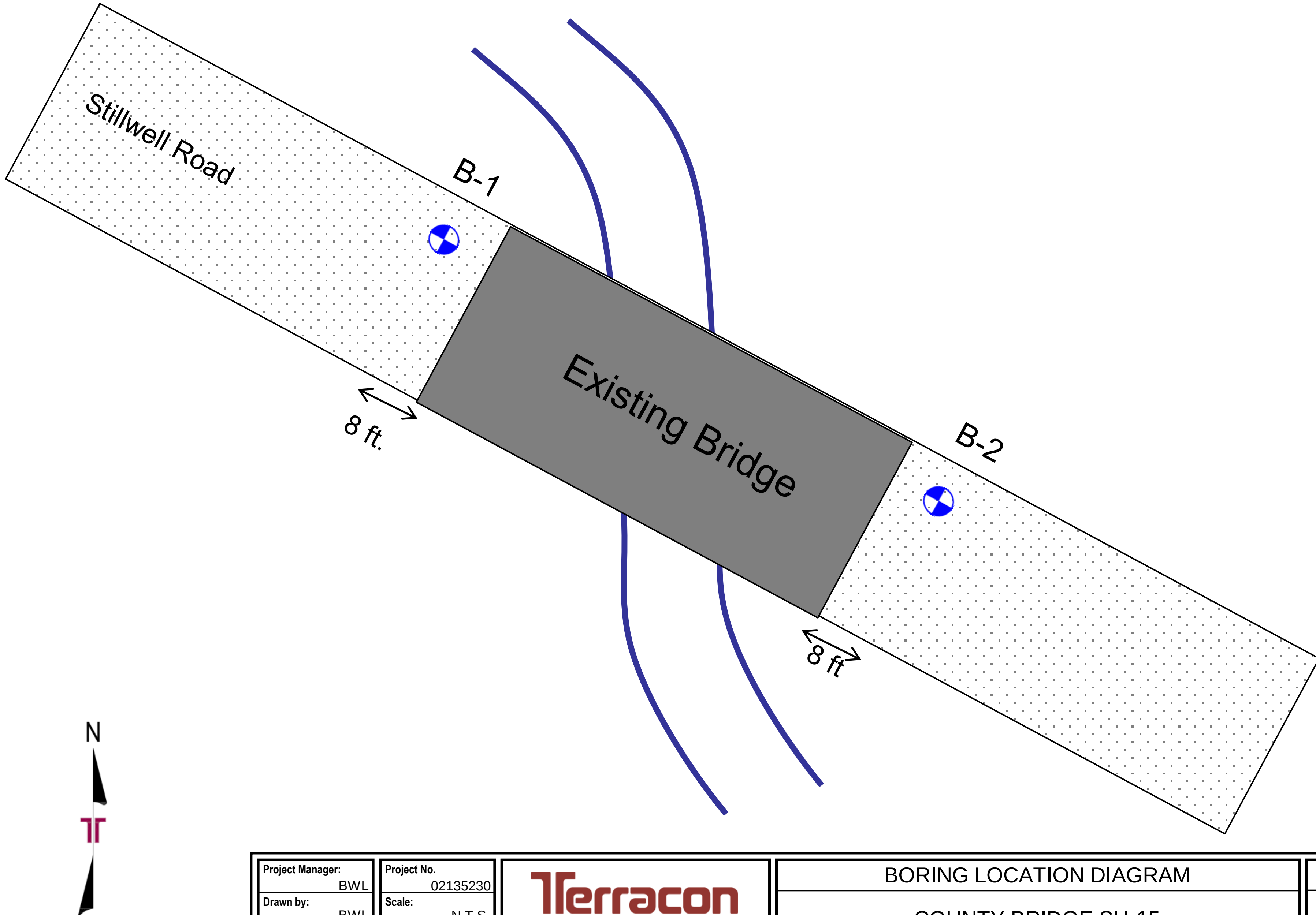



DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

| | | | | | |
|---|---|---|---|---|---|
| Project Manager: BWL | Project No. 02135230 | Terracon Consulting Engineers & Scientists | BORING LOCATION DIAGRAM | Exhibit |
| Drawn by: BWL | Scale: N.T.S. | 13910 West 96th Terrace Lenexa, Kansas 66215 | COUNTY BRIDGE SH-15 | A-3 |
| Checked by: BWL | File Name: Boring Location (11x8.5).ppt | PH. (913) 492-7777 FAX. (913) 492-7443 | Stillwell Road | |
| Approved by: BWL | Date: 1/07/2014 | | LEAVENWORTH, KS | |

# BORING LOG NO. B-1



**PROJECT:** Leavenworth County Bridge SH-15

**CLIENT:** Leavenworth County

**SITE:** Stillwell Road, Leavenworth County, KS

LOCATION See Exhibit A-3

Surface Elev.: 100.5 (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) | ATTERBERG LIMITS LL-PL-PI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | **FILL - 12" Gravel and Sand** | 99.5 | | | | | | | | | | |
| | **FILL - LEAN CLAY**, with gravel and sand,, dark brown | | | | | 18 | | +900 (HP) | | 10 | 98 | |
| | | | | | | 19 | | 5000 (HP) | | 15 | 87 | |
| | | | 5 | | | | | | | | | |
| 10.0 | | 90.5 | | | | | | | | 12 | | |
| | **LIMESTONE**, gray, hard, moderately weathered, with occasional shale seams | | 10 | | | | | | | | | |
| | | | | | | | REC: 100 RQD: 100 | | | | | |
| | | | 15 | | | | REC: 100 RQD: 100 | | | | | |
| | | | 20 | | | | REC: 100 RQD: 100 | | | | | |
| 25.0 | | 75.5 | 25 | | | | | | | | | |

***Boring Terminated at 25 Feet***

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Advancement Method:
0-12': Hollow-stem auger
12'-25': NX-series core barrel

Abandonment Method:
Boring backfilled with soil cuttings and bentonite chips upon completion.

See Exhibit A-6 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**

*No free water observed*

Terracon
13910 West 96th Terrace
Lenexa, Kansas

| | |
|---|---|
| Boring Started: 12/16/2013 | Boring Completed: 12/16/2013 |
| Drill Rig: CME 550 | Driller: SS |
| Project No.: 02135230 | Exhibit: A-3 |

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 02135230.GPJ TERRACON_STD_TEMPLATE.GDT 1/8/14

# BORING LOG NO. B-2



**PROJECT: Leavenworth County Bridge SH-15**

**CLIENT: Leavenworth County**

**SITE: Stillwell Road, Leavenworth County, KS**

LOCATION See Exhibit A-3

Surface Elev.: 100.5 (Ft.)

| DEPTH | Description | ELEVATION (Ft.) |
|---|---|---|
| 1.0 | **FILL - 12" Gravel and Sand** | 99.5 |
| 5.0 | **FILL - LEAN CLAY**, with gravel and roots, dark brown | 95.5 |
| 15.0 | **FILL - LEAN CLAY**, with gravel, brown | 85.5 |
| 24.5 | **LEAN CLAY**, trace gravel, yellow-brown, stiff | 76 |
| 39.0 | **SHALE**, gray, hard, moderately weathered | 61.5 |
| | ***Boring Terminated at 38.9 Feet*** | |

| DEPTH (Ft.) (approx.) | WATER LEVEL OBSERVATIONS | SAMPLE TYPE | RECOVERY (In.) | FIELD TEST RESULTS | LABORATORY TORVANE/HP (psf) | UNCONFINED COMPRESSIVE STRENGTH (psf) | WATER CONTENT (%) | DRY UNIT WEIGHT (pcf) | ATTERBERG LIMITS LL-PL-PI |
|---|---|---|---|---|---|---|---|---|---|
| 3-5 | | Shelby tube | 16 | | +9000 (HP) | | 19 | 82 | |
| 8-10 | | Shelby tube | 5 | | | 15197 | 15 | 109 | |
| 13-15 | | Shelby tube | 9 | | | 543 | 15 | 109 | 48-21-27 |
| 18.5-20 | | Split spoon | 18 | 6-6-6 N=12 | | | 13 | | |
| 23.5-25 | | Split spoon | 15 | 6-7-50/3" N=57/9" | | | 16 | | |
| 28.5-30 | | Split spoon | 8 | 40-50/2" N=50/2" | | | 12 | | |
| 33.5-35 | | Split spoon | 5 | 50/5" N=50/5" | | | 9 | | |
| 38.5-38.9 | | Split spoon | 5 | 50/5" N=50/5" | | | 9 | | |

Stratification lines are approximate. In-situ, the transition may be gradual.
Classification of rock estimated from disturbed samples. Core samples and petrographic analysis may reveal other rock types.

Hammer Type: Automatic SPT Hammer

Advancement Method:
0-39': Hollow-stem auger

Abandonment Method:
Boring backfilled with soil cuttings and bentonite chips upon completion.

See Exhibit A-6 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**

*No free water observed*

Terracon
13910 West 96th Terrace
Lenexa, Kansas

| | |
|---|---|
| Boring Started: 12/16/2013 | Boring Completed: 12/16/2013 |
| Drill Rig: CME 550 | Driller: SS |
| Project No.: 02135230 | Exhibit: A-4 |

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 02135230.GPJ TERRACON_STD_TEMPLATE.GDT 1/8/14

## Field Exploration Description

The proposed boring locations were laid out in the field by a Terracon representative. Distances from existing site features were measured with a calibrated measuring wheel and right angles were estimated. Ground surface elevations indicated on the boring logs were measured in the field using a surveyor's level and grade rod. The elevations were referenced to the bridge abutment elevation at the southwest corner of the bridge and are rounded to the nearest ½ foot. This temporary benchmark was assigned an arbitrary elevation of 100.0 feet. The locations and elevations of the borings should be considered accurate only to the degree implied by the means and methods used to define them.

The borings were drilled with a truck-mounted rotary drill rig using flight augers to advance the boreholes. Samples of the soil encountered in the borings were obtained using the thin-walled tube and split-barrel sampling procedures.

In the thin-walled tube sampling procedure, a 2-inch diameter, steel-tube with a sharp cutting edge is pushed hydraulically into the soil to obtain a relatively undisturbed sample. In the split-barrel sampling procedure, a standard 2-inch O.D. split-barrel sampling spoon is driven into the ground by a 140 pound hammer falling a distance of 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18 inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. The borings were backfilled with auger cuttings upon completion.

A field log of each boring was prepared by the drill crew to record data including visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's interpretation of the subsurface conditions based on field laboratory data and observation of the samples.

# APPENDIX B
# SUPPORTING INFORMATION

## Laboratory Testing

Representative soil samples were tested in the laboratory to measure their natural water content, dry unit weight and unconfined compressive strength. A calibrated penetrometer was used to estimate the approximate unconfined compressive strength of other samples. The test results are provided on the boring logs included in Appendix A.

Descriptions of the soils indicated on the boring logs are in accordance with the enclosed General Notes and the Unified Soil Classification System. A Unified Soil Classification Group Symbol is shown for each sample. A brief description of this classification system is in Appendix C. All classification was by visual manual procedures.

# APPENDIX C
# SUPPORTING DOCUMENTS

# GENERAL NOTES

## DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

**SAMPLING**

| | |
|---|---|
| Auger | Split Spoon |
| Shelby Tube | Macro Core |
| Ring Sampler | Rock Core |
| Grab Sample | No Recovery |

**WATER LEVEL**

- Water Initially Encountered
- Water Level After a Specified Period of Time
- Water Level After a Specified Period of Time

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**

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

## DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

## LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

**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 | | | | BEDROCK | | |
|---|---|---|---|---|---|---|---|---|---|
| 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. | Ring Sampler Blows/Ft. | Standard Penetration or N-Value Blows/Ft. | Descriptive Term (Consistency) |
| Very Loose | 0 - 3 | 0 - 6 | Very Soft | less than 500 | 0 - 1 | < 3 | < 30 | < 20 | Weathered |
| Loose | 4 - 9 | 7 - 18 | Soft | 500 to 1,000 | 2 - 4 | 3 - 4 | 30 - 49 | 20 - 29 | Firm |
| Medium Dense | 10 - 29 | 19 - 58 | Medium-Stiff | 1,000 to 2,000 | 4 - 8 | 5 - 9 | 50 - 89 | 30 - 49 | Medium Hard |
| Dense | 30 - 50 | 59 - 98 | Stiff | 2,000 to 4,000 | 8 - 15 | 10 - 18 | 90 - 119 | 50 - 79 | Hard |
| Very Dense | > 50 | $\geq$ 99 | Very Stiff | 4,000 to 8,000 | 15 - 30 | 19 - 42 | > 119 | >79 | Very Hard |
| | | | 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

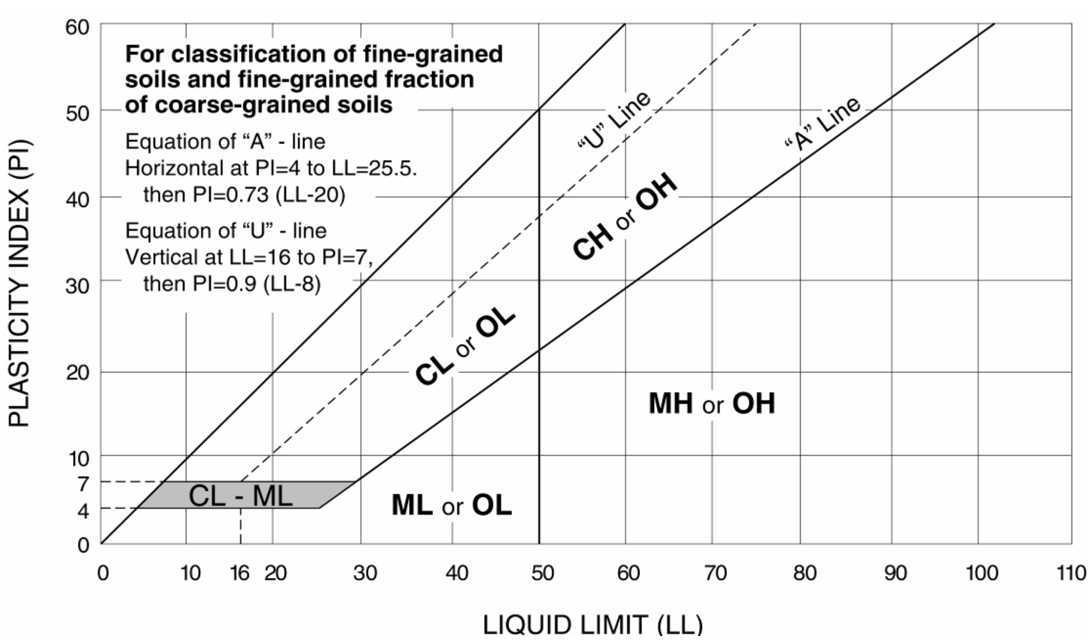
# UNIFIED SOIL CLASSIFICATION SYSTEM

| 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 ≥ 4 and 1 ≤ Cc ≤ 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 ≥ 6 and 1 ≤ Cc ≤ 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

# 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 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 [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.