GEOTECHNICAL ENGINEERING REPORT
STATE HIGHWAY 105 OVER HEADQUARTERS CREEK
CONSTRUCTION STATE J/P NO. 27060(04)
LINCOLN COUNTY, OKLAHOMA
KLF Project No. 20151682

September 2, 2014

KLEINFELDER
Bright People. Right Solutions.

September 2, 2014
Project No.: 20151682

Mr. Brad Smith, PE
Oklahoma Department of Transportation
200 N.E. 21st Street, Room 3-C9
Oklahoma City, OK 73105

Subject: Geotechnical Engineering Report
State Highway 105 Over Headquarters Creek
Construction State J/P No. 27060(04)
Lincoln County, Oklahoma

Dear Mr. Smith:

Kleinfelder has completed the authorized subsurface exploration and geotechnical engineering evaluation for the above referenced project. The purpose of the geotechnical study was to explore and evaluate the subsurface conditions at the proposed bridge site and develop geotechnical design and construction considerations for the bridge foundations. The attached Kleinfelder report contains a description of the findings of our field exploration and laboratory testing program, our engineering interpretation of the results with respect to the design of bridge foundations and potential construction issues for the planned project.

Recommendations provided herein are contingent on the provisions outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report. The project Owner should become familiar with these provisions in order to assess further involvement by Kleinfelder and other potential impacts to the proposed project.

We appreciate the opportunity to be of service to you on this project and are prepared to provide the recommended additional services. Please call us if you have any questions concerning this report.

Sincerely,
KLEINFELDER, INC.
Certificate of Authorization #3036, Expires 06/30/15

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STATE HIGHWAY 20 OVER HEADQUARTERS CREEK
CONSTRUCTION STATE J/P NO. 27060(04)
LINCOLN COUNTY, OKLAHOMA

1. INTRODUCTION

1.1 GENERAL

Kleinfelder has completed the authorized subsurface exploration and geotechnical engineering evaluation for the proposed bridge replacement on State Highway 105 (SH 105) over Headquarters Creek in Lincoln County, Oklahoma. These services were provided in general accordance with our proposal (No.TUL14P01272) dated June 23, 2014. This report includes our recommendations related to the geotechnical aspects of the bridge foundation design and construction. Conclusions and recommendations presented in the report are based on the subsurface information encountered at the locations of our exploration and the provision and requirements outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report. In addition, an article prepared by The Association of Engineering Firms Practicing in the Geosciences (ASFE), *Important Information about Your Geotechnical Engineering Report*, has been included in APPENDIX C. We recommend that all individuals read the report limitations along with the included ASFE document.

1.2 PROPOSED CONSTRUCTION

The subject site is located on the existing SH 105 alignment approximately 2.0 miles west of City of Tryon in Lincoln County, Oklahoma at the Headquarters Creek crossing. The proposed improvement includes replacing the existing bridge on the existing alignment. The proposed bridge will be a three span (45'-55'-45') bridge structure with Rolled Beams, with a 40-foot clear roadway, and TR-4 traffic rails. Based on the General Plan and Elevation drawing provided by Oklahoma Department of Transportation, the proposed bridge is approximately 45 feet longer and 16 feet wider than the existing bridge. The proposed roadway elevation is approximately level with the existing alignment on both the east and west approaches.

The magnitude of the foundation loads for the proposed bridge was not known at the time our report was prepared. We anticipate that the new bridge abutments and intermediate bents will be supported on driven steel H-Piles and straight-sided drilled shafts, respectively.

The scope of the exploration and engineering evaluation for this study, as well as the conclusions and recommendations in this report, are based on our understanding of the project as described above. If pertinent details of the project change or otherwise differ from our descriptions, we must be notified and engaged to review the changes and modify our recommendations, as necessary.

2. SITE CONDITIONS

2.1 SITE DESCRIPTION

The general location of the site is shown on Figure 1, Site Location Diagram. The existing bridge is a two-span structure with concrete deck with asphalt overlay, and metal guardrails. Design plans of the existing bridge were not available at the time of this report. The concrete deck supports a 24-foot clear, asphalt paved roadway with two driving lanes and no shoulders. The existing roadway slopes downward from the east and west towards Headquarters Creek. The existing east bridge approach was constructed on embankment. Trees and bushes were observed along the edges of the existing right of way. Boulders/Ripraps were observed underneath the existing bridge over the existing east and west abutments face. The areas surrounding the proposed bridge site are undeveloped farm land.

Existing utilities noted within the current right-of-way include overhead power lines, telephone lines, and gas lines. Additional utilities may be present within the proposed construction area. All area utilities should be located and properly marked prior to commencement of construction.

2.2 GENERAL SITE GEOLOGY

According to the "Engineering Classification of Geologic Materials – Division Three" from the Oklahoma Highway Department, 1968, the bridge location appears to be located in an area of **Wellington-Admire (Pwa) Unit**.

Wellington-Admire Unit (Pwa): This unit consists dominantly of shale, but includes considerable amounts of sandstone. Conglomerates are prominent locally.

The shales are thick and varied in color, with red predominating. The sandstones are mostly soft, massive (up to 40 feet thick), and buff in color. The base of the unit is a limy, buff to reddish purple, cross-bedded sandstone.

Conglomerates are prominent in two locales. A dark chert conglomerate is persistent from two miles east of Asher, Pottawatomie County, northeastward to about a mile west of Maud. This conglomerate (commonly called the Maud conglomerate) consists of green, blue, red, and gray chert pebbles and cobbles and occurs in thicknesses up to 20 feet. The other conglomerate (commonly called the Jarvis Church conglomerate) is persistent for a distance of about four miles north of US 270, Sec. 26, T10N, R5E, and western Seminole County. It occurs in thicknesses up to 10 feet and buff chert pebbles predominate although a few green, red, gray, and banded cherts are present. The two conglomerate exposures vary from loose gravel to moderately hard well cemented beds. The total thickness of the Wellington-Admire Unit is about 1100 feet.

The Wellington-Admire Unit outcrops in a 15 mile-wide, north-south band in Pottawatomie and western Seminole Counties of Division 3. South of the Canadian River the rock strata are mapped within the Graber-Wellington Unit.

Topographically, the unit generally forms gently rolling prairie plains. Locally, where the sandstones are thick, rolling hills covered with blackjack and oak trees interrupt the prairies.

2.3 SUBSURFACE CONDITIONS

Kleinfelder explored the subsurface conditions at the site by drilling five borings, including one constructability boring, between July 16 and July 20, 2014. Approximate locations of the borings (designated B-1 through B-4) are shown on Figure 2, Boring Location Diagram. The field exploration and laboratory testing programs are presented in APPENDIX A and APPENDIX B, respectively. Drilling was performed with an ATV-mounted (CME 550X) drilling rig.

The following presents a general summary of the major strata encountered during our subsurface exploration and includes a discussion of the results of the field and laboratory tests conducted. Specific subsurface conditions encountered at the boring locations are presented on the respective boring logs in APPENDIX A. The Subsurface Cross-Section, Figure A-1 in APPENDIX A, depicts the generalized subsurface profile across the project site based on the information obtained from the borings. The stratification lines shown on the logs and Subsurface Cross-Section represent the approximate boundaries between material types. The actual transitions may vary or be more gradual than those depicted.

Fill Materials: Boulders (nominal size up to 10 feet) were encountered on both side of abutment face. Clearing of boulders was performed and fill materials was brought in to build a pad using a bulldozer to access boring locations B-2, B-2C, and B-3. Fill materials comprised of silty sand, clayey sand, silty clayey sand and sandy silt were encountered in each boring, and extended to approximate depths ranging from 5.0 to 17.0 feet (El ±898.7 to El ±886.8).

Native Materials: Native materials comprised of lean clay with various amounts of sand, silty sand, sandy silt, and poorly graded sand with various amount of silt were encountered in each boring, and extended to approximate depths ranging from 41.0 to 61.0 feet (El ±853.7 to El ±850.3). The native materials are various combinations of reddish brown and brown in color. The cohesive soils are generally very soft to firm in consistency and the relative densities of the cohesionless soils are very loose to medium dense.

Bedrock: Bedrock comprised of weathered shale, weathered sandstone and sandstone underlain by shale was encountered in each boring at an approximate depth ranging from 41.0 to 61.0 feet (El ±853.7 to El ±850.3). The upper one to five feet of the shale and sandstone bedrock were generally weathered. The sandstone bedrock continued to depths ranging from approximately 56.5 to 78.0 feet (El±845.8 to El ±832.7). Shale bedrock was encountered beneath sandstone bedrock at approximate depths ranging from 56.5 to 78.0 feet (El±845.8 to El ±832.7) and continued to the boring termination depths of approximately 30 feet into bedrock (El±821.4 to El ±818.8).

Depth to competent bedrock is defined as the depth at which the penetration from a Standard Penetration test (SPT), conducted in accordance to ASTM D1586, was less than or equal to 6 inches of penetration with 50 blows. Table 1 indicates the ground surface elevations and the approximate top of competent bedrock depth and elevation at the respective boring locations. Based on current "State of Oklahoma Department of Transportation Specifications for the Geotechnical Investigations of Bridges and Related Structures", we understand that the required rock penetration does not begin until competent bedrock is encountered. The rock penetration consists of seven continuous passing Texas Cone Penetrometer (TCP) tests spaced at 5-foot intervals for a total of 30 feet of bedrock. A passing TCP test consists of two consecutive sets of 50 blows with less than or equal to 6 inches of penetration per 50 blow set. A failing TCP test would consist of the penetration of 6 inches before 50 blows are applied. Thus, depths to top of competent rock and the corresponding elevations shown in Table 2-1 do not necessarily coincide with the depths to the top of weathered rock and the corresponding elevations shown on the boring logs.

Table 2-1. Approximate Competent Bedrock Depth and Elevation				
Boring No.	**Ground Elevation (feet)**	**Competent Bedrock Material**	**Depth to Top of Competent Rock (feet)**	**Elevation of Top of Competent Rock (feet)**
B-1	910.7	Sandstone	58.5	852.2
B-2	897.7	Sandstone	46.5	851.2
B-2C	897.9	Sandstone	46.0	851.9
B-3	891.8	Sandstone	42.0	849.8
B-4	911.3	Sandstone	61.0	850.3

Table 2-2 provides specific information for the rock coring that was performed within the competent bedrock in Boring B-2C. This table includes the ground surface elevation, the test number, the starting and ending depth at which the test was performed, the starting and ending elevation at which the test was performed, and the results of each test.

Table 2-2. Rock Coring Sample Intervals and Results							
Boring No.	**Ground Elev. (feet)**	**Rock Coring Test No.**	**Coring Depth (feet)**	**Coring Elevation (feet)**	**Recovery (inches)**	**RQD (%)**	**Rock Unconfined Compression Test (psi) @ Approx. Depth/Elev. (feet)**
B-2C	897.9	12	46.5 – 51.5	851.4 – 846.4	17	7	2,420 psi @ 50/868.7
		13	51.5 – 56.5	846.4 – 841.4	60	33	3,620 psi @ 55/857.6 feet
		14	56.5 – 61.5	841.4 – 836.4	57	7	2,590 psi @ 60/872.1
		15	61.5 – 66.5	836.4 – 831.4	59	67	N/A
		16	66.5 – 71.5	831.4 – 826.4	60	95	N/A
		17	71.5 – 76.5	826.4 – 821.4	60	78	N/A

N/A : Materials are too soft to perform unconfined compression test

Table 2-3 provides specific information for TCP tests taken within competent bedrock. This table includes the ground surface elevation at the boring location, test number, starting depth at which the test was performed, starting elevation at which the test was performed, and the result of each test.

Table 2-3. TCP Test Intervals and Results					
Boring No.	**Ground Elevation (feet)**	**Test No.**	**Depth (feet)**	**Elevation (feet)**	**TCP Results (blow/inch)**
B-1	910.7	13	59.0	851.7	100/0.69
		14	64.0	846.7	100/0.44
		15	69.0	841.7	100/0.57
		16	74.0	836.7	100/0.94
		17	79.0	831.7	100/0.81
		18	84.0	826.7	100/6.63
		19	89.0	821.7	100/0.44
B-2	897.7	2	47.0	850.7	100/0.51
		3	52.0	845.7	100/0.44
		4	57.0	840.7	100/0.69
		5	62.0	835.7	100/1.44
		6	67.0	830.7	100/2.75
		7	72.0	825.7	100/5.88
		8	77.0	820.7	100/0.50
B-3	891.8	2	42.5	849.3	100/0.51
		3	47.5	844.3	100/4.76
		4	52.5	839.3	100/0.38
		5	57.5	834.3	100/0.63
		6	62.5	829.3	100/6.25
		7	67.5	824.3	100/0.32
		8	72.5	819.3	100/0.38
B-4	911.3	14	61.0	850.3	100/0.63
		15	66.0	845.3	100/9.50
		16	71.0	840.3	100/6.44
		17	76.0	835.3	100/7.38
		18	81.0	830.3	100/9.75
		19	86.0	825.3	100/0.75
		20	91.0	820.3	100/0.44

2.4 GROUNDWATER OBSERVATIONS

Due to the soft and loose soil conditions wash bore operations began at a depth of ten feet to prevent borehole collapse and improve testing results. No groundwater was encountered in the borings prior to the introduction of drilling fluids. Introduction of water as drilling fluid was required during wash bore operations, thus limiting further observation of groundwater conditions until the water level in the boring could equalize with the groundwater depth.

Table 3-1 summarizes the depths and elevations of the groundwater encountered in borings B-2 and B-2C at completion of drilling and approximately 24 hours after the completion of the drilling. Next day readings were not taken from the remaining borings due to the need to backfill at the completion of drilling. The groundwater depths at completion of drilling presented in Table 3 may have been influenced by the drilling fluid.

Table 3-1 Approximate Groundwater Levels					
Boring No.	**Ground Elevation (feet)**	**Groundwater Depth ACR (feet)**	**Groundwater Elevation ACR (feet)**	**Groundwater Depth @ 24 hours (feet)**	**Groundwater Elev. @ 24 hours (feet)**
B-2	897.7	14.5	883.2	13.5	884.2
B-2C	897.9	15.8	882.1	13.0	884.9

N/A: Boring backfilled at completion of drilling

The materials encountered in the test borings may have a wide range of permeability and observations over an extended period of time through use of piezometers or cased borings would be required to better define groundwater conditions. Fluctuations of groundwater levels can occur due to seasonal variations in the amount of rainfall, runoff, creek level, and other factors not evident at the time the borings were performed. Water was noted within the creek at the time of the field exploration. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

2.5 LABORATORY TESTING

Atterberg limits tests performed on selected soil samples indicated liquid limit (LL) values ranging from non-plastic to 39, plastic limit (PL) values ranging from non-plastic to 17, and plasticity index (PI) values ranging from non-plastic to 22. Grain size analysis results indicated that the fines content (percentage by weight passing the #200 sieve) of the soil ranged from approximately 9 to 93 percent. The moisture content of the samples ranged from approximately 7.0 to 28.6 percent. A more detailed discussion about the laboratory testing program is presented in APPENDIX B.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 GENERAL

Based on the information obtained from the borings, the bridge abutments and interior bents could be supported on driven steel H-Piles and straight-sided drilled shafts, respectively, extending into the competent bedrock. Recommendations regarding the geotechnical aspects of the project design and construction are presented below.

The recommendations submitted herein are based, in part, upon data obtained from our subsurface exploration. The nature and extent of subsurface variations that may exist at the proposed project site will not become evident until construction. If variations appear evident, then the recommendations presented in this report should be evaluated. In the event that any changes in the nature, design, or location of the proposed project are planned, the conclusions and recommendations contained in this report will not be considered valid unless the changes are reviewed and our recommendations modified in writing.

3.2 FOUNDATIONS

3.2.1 General

The subsurface conditions appear suitable to support the proposed bridge abutments on driven steel H-piles and interior bents on straight sided drilled shafts extending into the competent sandstone bedrock. Design and construction recommendations for both types of foundations are included in the following paragraphs.

3.2.2 Driven Steel H-piles

Based on the preliminary plan provided by Oklahoma Department of Transportation, the bridge abutments will be supported on structural HP 10x42 steel H-piles (Grade 50). The contractor should review the boring logs to assess the potential problems with completing the pile driving in the subsurface materials encountered at this site. Recommendations for design and construction of the driven steel H-piles are presented in the following paragraphs. The influence of the approach embankments is not included in our analysis of the piling parameters.

Based on previous experience and subsurface conditions, we expect that the HP 10x42 steel H-piles will penetrate through the overburden soils and weathered bedrock, and achieve "practical" refusal (ODOT 2009 Standard Specification Section, 514.04E) in the competent sandstone bedrock at the both the east and west bridge abutments. Estimated pile tip depth and elevation are provided in Table 3-1. Estimated pile tip depth is based on axial loads only. Other factors including lateral loads, scour, or uplift were not taken into consideration when estimating the pile tip depths.

Table 3-1. Estimated HP Pile Depths/Elevations

Location	Ground Surface Elevation, feet	Competent Bedrock Depth (BEG), feet	Competent Bedrock Elevation, feet	Estimated Pile Tip Depth (BEG), feet	Estimated Pile Tip Elevation, feet
West Abutment Boring B-1	910.7	58.5	852.2	60.5*	850.2*
East Abutment Boring B-4	911.3	61.0	850.3	68.0**	843.3**

BEG: Below existing ground
***Estimated 2 feet embedment into competent bedrock at West Abutment (B-1)**
****Estimated 7 feet embedment into competent bedrock at East Abutment (B-4)**

The capacity of piles driven to practical refusal will be controlled by the structural resistance of the steel H-piles. Nominal and Factored capacities for the piles are outlined in Table 3-2.

Table 3-2. Structural Steel (Grade 50) HP Pile Capacities (Abutments)

Section	Area (in^2)	Geotechnical Nominal Compression Resistance (kips)	Geotechnical Factored Compression Resistance (kips) ϕ_{-side}=0.35 / ϕ_{-end} =0.45	Structural Nominal Compression Resistance (kips)	Structural Factored Compression Resistance (kips) ($\phi_{structural}$ =0.5)
HP 10x42	12.4	1,040*	380*	620	310

*** Estimated 5' Embedment into competent bedrock at West Abutment (B-1) and 8' Embedment into competent bedrock at East Abutment (B-4)**

3.2.2.1 Estimated Settlements

Long-term structural settlement for driven pile foundations designed and constructed as outlined above should be 1/2 inch or less.

3.2.2.2 Construction Considerations

Installation: Close monitoring of the driven H-piles will be required to evaluate whether the H-piles are terminated at the correct bearing elevation. It is recommended that the piles be equipped with cast steel-driving tips. The driving tip is intended to protect the pile tip during driving procedures, to maintain the pile integrity, and to allow the pile to be driven to design depths. In addition, compression failure of the pile tip is less likely to occur.

It is recommended that all piles be installed in accordance with the latest version of the Oklahoma Department of Transportation "Standard Specifications for Highway Construction." For the type and size of piling being considered for this project, the driving hammer should have a minimum rated energy as shown in Table 514:2 "Minimum Energy for Pile Hammers" in Section 514.03.A.(3) of ODOT "2009 Standard Specifications for Highway Construction". Pile driving resistance should be closely monitored and the pile capacity should be assessed according to Section 514.04.E of ODOT "2009 Standard Specifications for Highway Construction", practical refusal is defined as four consecutive sets of 10 blows having no more than 0.5 inch of penetration per each 10-blow set.

Variations in the refusal depth and elevation should be anticipated due to variations in weathering and size of hammer used. Because the depth to refusal could vary across the site, especially between the abutment locations, the piling contractor should be prepared for piles being shorter or longer than indicated by the borings.

Pile Spacing: Piles should be installed with a minimum center-to-center spacing of three diameters. No reduction in individual axial pile capacity for group action is needed for the spacing of three diameters. Lateral capacity of the piles should be reduced for center-to-center spacing of less than six diameters. Once pile spacing is determined, reduction factors can be developed that reflect the spacing(s).

3.2.3 Drilled Shaft Foundations

Subsurface conditions encountered in the borings are also suitable for support of the intermediate bents of the proposed bridge on straight-sided drilled shafts. The drilled shafts should extend through the weathered bedrock and be founded in the competent sandstone bedrock. Competent bedrock was encountered in the intermediate bent borings at approximate depths ranging from 42.0 to 46.5 feet below the existing ground surface (El ±872.0 to El ±870.6 feet) in Borings B-2, and B-3. The straight-sided drilled shafts should be founded at a depth that provides a minimum penetration of at least 5 feet or 1.5 drilled shaft diameters, whichever is greater, into the competent shale bedrock.

Drilled shafts founded as recommended in the competent shale may be sized using a factored end bearing resistance as shown in Table 3-3. No side resistance should be assigned to the overlying weathered bedrock and soils.

Table 3-3. Drilled Shaft Design Parameters

Elevation (feet)	Material	End Bearing Resistance (ksf)[2]		Side Resistance (ksf)		
		Nominal[1]	Factored ($\phi_{r\text{-}end}$=0.5)	Nominal[1]	Compression Factored ($\phi_{r\text{-}side\ comp}$=0.55)	Uplift Factored ($\phi_{r\text{-}side\ uplift}$=0.40)
Intermediate Pier 1 (Boring B-2)						
851.2-848.2	Sandstone	N/A	N/A	18.0	9.9	7.2
848.2-845.7	Sandstone	120	60	18.0	9.9	7.2
845.7-834.7	Sandstone	40	20	18.0	9.9	7.2
834.7-830.2	Shale	40	20	15.6	8.6	6.2
Intermediate Pier 2 (Boring B-3)						
849.8-846.8	Sandstone	N/A	N/A	18.0	9.9	7.2
846.8-839.8	Sandstone	51	26	15.0	8.3	6.0
839.8-835.3	Sandstone	39	20	18.0	9.9	7.2
835.3-829.8	Shale	39	20	15.6	8.6	6.2

[1] Based on THD Cone Penetrometer Correlation Bearing & Frictional (PCBF) Curves for Drilled Shaft Foundation Design. Nominal End Bearing determined using a FOS=2.0 and Nominal Skin friction determined using a FOS=3.0.

[2] Assume development of 50% of nominal end bearing resistance at ½ inch deformation for bedrock, based on cohesive soil load transfer distribution with settlement (ONeill and Reese, 1999) for drilled shaft sizes of 4 to 6 feet in diameter.

3.2.3.1 Estimated Settlements

Long-term structural settlement for drilled shafts designed and constructed as outlined above should be 1/2 inch or less.

3.2.3.2 Construction Considerations

Discussions on various construction methods are presented below:

Dry Excavation Method: Conventional drilling equipment should be able to penetrate the soils and weathered bedrock. Based on the TCP penetration results, excavation for the drilled shafts into the competent bedrock may be difficult. Drilling equipment, such as a core barrel with rock teeth, may be required to penetrate this material. The drilled shaft contractor should be given the opportunity to review the attached boring logs to assess the appropriate drilling technique.

Water seepage will be encountered during the installation of drilled shafts in the dry, and casing will be required to advance drilled shaft operations. If the drilled shaft excavations are performed in the dry, the drilled shaft excavations should have depth of groundwater seepage less than 6 inches and no caving, sloughing, or swelling conditions should exist. Shafts completed in the dry should be observed by an experienced geotechnical engineer to evaluate the suitability of the bearing materials. The contractor should use the alternative method approved by the engineer. The dry excavation method should be in accordance with ODOT "2009 Standard Specifications for Highway Construction", Section 516.04.C (a).

Wet Excavation Method: Use the wet construction method or casing construction method for shafts that do not meet the requirements for dry construction. For the wet method, use water or slurry to maintain the stability of the shaft excavation while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft. The wet excavation method should be performed in accordance with ODOT "2009 Standard Specifications for Highway Construction", Section 516.04.C (b).

Casing Method: The casing should not be advanced to the bottom of the shaft, and should be discontinued at the top of the founding stratum as shown on the plans. Excavation below the casing can be advanced with either the dry or wet method. The use of the casing method should be in accordance with ODOT "2009 Standard Specifications for Highway Construction", Section 516.04.C (c).

Concrete Placement: To minimize disturbance to the bearing surfaces caused by ponding of water, it is recommended that concrete be placed the same day that the drilled shafts are completed. The bottom of the drilled shaft excavation should be cleaned of water and loose material before placing reinforcing steel and concrete. Concrete placement should be continuous from the bottom to the top elevation of the shaft. The placement of concrete should be performed with either tremie or concrete pump method.

Shaft Size/Spacing: Drilled shafts should have a minimum diameter of 3 feet and should be installed at a minimum center-to-center spacing of three diameters. No reduction in individual shaft axial capacity for group action is needed for this spacing. Adjacent drilled shafts should not be constructed on the same day. Lateral capacity of the drilled shafts should be reduced for a center-to-center spacing of less than six diameters. Once the final spacing is determined, reduction factors can be developed that reflect the final configuration.

3.3 SEISMIC HAZARDS DETERMINATION

We have evaluated the seismic hazard based on the 2010 Interim Revisions to AASHTO LRFD Bridge Design Specifications. Based on our subsurface information and evaluation of the data, we recommend a Site Class "E" be used in design.

4. ADDITIONAL SERVICES

4.1 PLANS AND SPECIFICATIONS REVIEW

We recommend that Kleinfelder conduct a general review of the final plans and specifications to evaluate that our foundation recommendations have been properly interpreted and implemented during design. In the event Kleinfelder is not retained to perform this recommended review, we will assume no responsibility for misinterpretation of our recommendations.

4.2 CONSTRUCTION OBSERVATION AND TESTING

We recommend that all earthwork and foundation installation be monitored by a representative from Kleinfelder, including site preparation, placement of all engineered fill, and pile driving operations. The purpose of these services would be to provide Kleinfelder the opportunity to observe the subsurface conditions encountered during construction, evaluate the applicability of the recommendations presented in this report to the subsurface conditions encountered, and recommend appropriate changes in design or construction procedures if conditions differ from those described herein.

5. LIMITATIONS

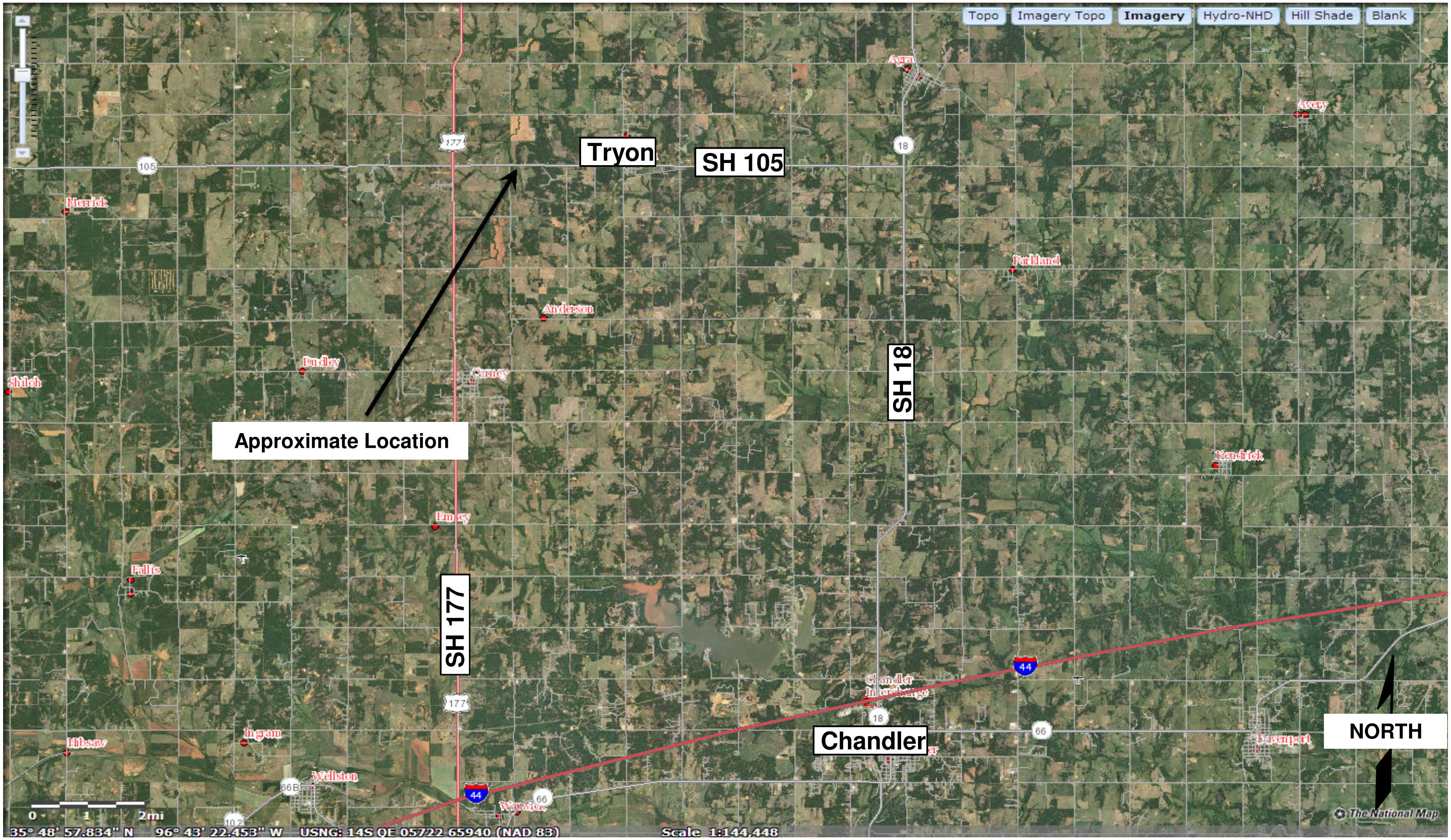
Recommendations contained in this report are based on our field observations and subsurface explorations, limited laboratory tests, and our present knowledge of the proposed construction. It is possible that subsurface conditions could vary between or beyond the points explored. If subsurface conditions are encountered during construction that differ from those described herein, we should be notified immediately in order that a review may be made and any supplemental recommendations provided. If the scope of the proposed construction, including the proposed loads or structural locations, changes from that described in this report, our recommendations should also be reviewed.

We have prepared this report in substantial accordance with the generally accepted geotechnical engineering practice as it exists in the site area at the time of our study. No warranty is expressed or implied. The recommendations provided in this report are based on the assumption that an adequate program of tests and observations will be conducted by Kleinfelder during the construction phase in order to evaluate compliance with our recommendations. The scope of our services did not include any environmental assessment or exploration for the presence of hazardous or toxic materials in the soil, surface water, groundwater or air, on, below or around this site.

This report may be used only by the client and only for the purposes stated, within a reasonable time from its issuance, but in no event later than three years from the date of report. Land use, site conditions (both on-site and off-site), regulations, or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify Kleinfelder of such intended use. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party and client agrees to defend, indemnify and hold harmless Kleinfelder from any claim or liability associated with such unauthorized or non-compliance.

FIGURES

TULSA, OKLAHOMA



Source: USGS

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DRAWN:	8/5/2014
DRAWN BY:	SYW
CHECKED BY:	HML
FILE NAME:	
20151682	

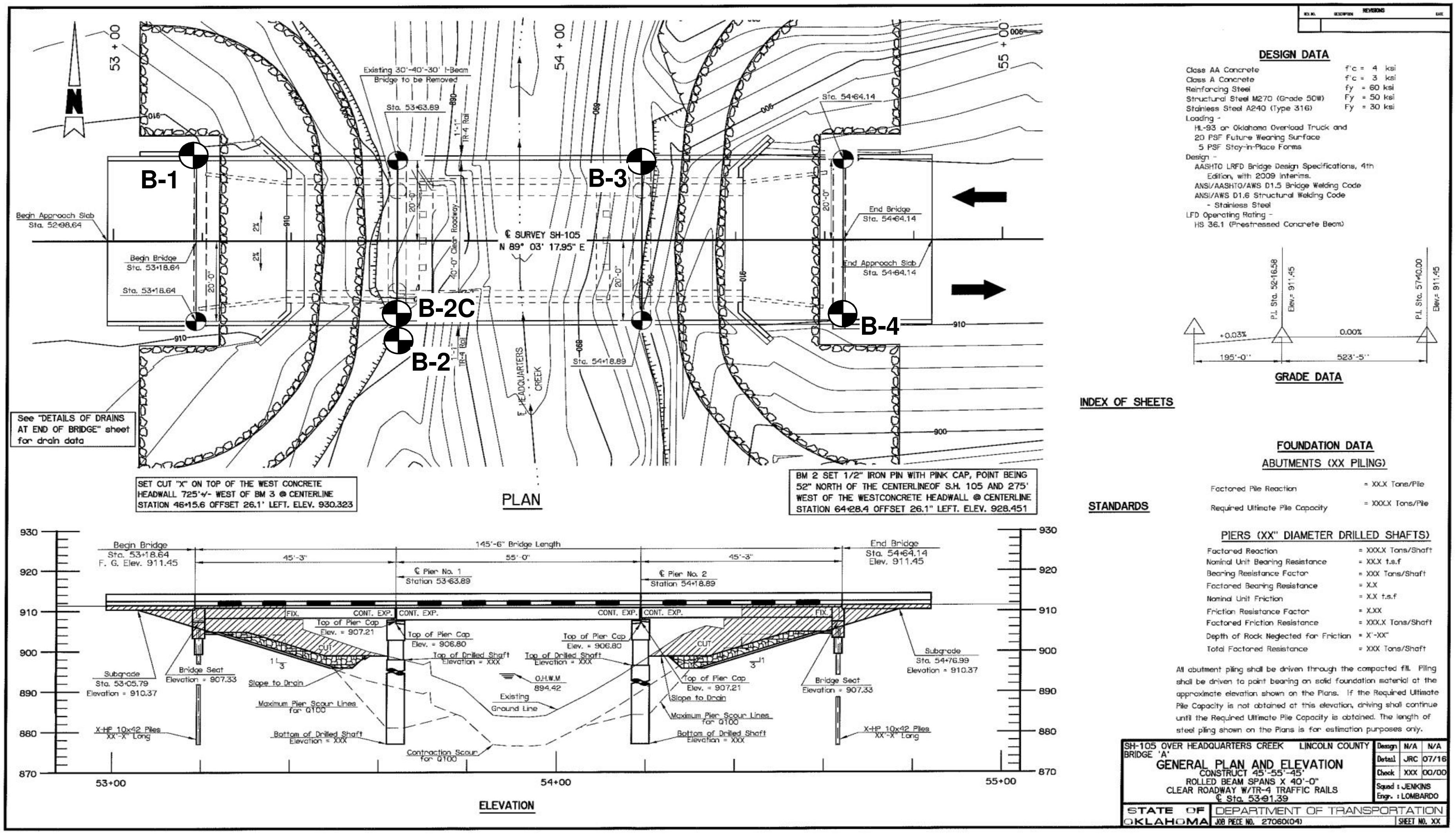
SITE LOCATION DIAGRAM

STATE HIGHWAY 105
OVER HEADQUARTERS CREEK
STATE J/P NO.: 27060(04)
LINCOLN COUNTY, OKLAHOMA

FIGURE

1

TULSA, OKLAHOMA



Source: ODOT

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DRAWN:	8/5/2014
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20151682	

BORING LOCATION DIAGRAM

STATE HIGHWAY 105
OVER HEADQUARTERS CREEK
STATE J/P NO.: 27060(04)
LINCOLN COUNTY, OKLAHOMA

FIGURE

2

TULSA, OKLAHOMA

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20151682	

ROCK CORE PICTURES
B-2C

STATE HIGHWAY 105
OVER HEADQUARTERS CREEK
STATE J/P NO.: 27060(04)
LINCOLN COUNTY, OKLAHOMA

FIGURE

3

TULSA, OKLAHOMA

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FILE NAME:	
20151682	

ROCK CORE PICTURES
B-2C

STATE HIGHWAY 105
OVER HEADQUARTERS CREEK
STATE J/P NO.: 27060(04)
LINCOLN COUNTY, OKLAHOMA

FIGURE

4

TULSA, OKLAHOMA

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PROJECT NO.	20151682
DRAWN:	8/5/2014
DRAWN BY:	SYW
CHECKED BY:	HML
FILE NAME:	
20151682	

ROCK CORE PICTURES
B-2C

STATE HIGHWAY 105
OVER HEADQUARTERS CREEK
STATE J/P NO.: 27060(04)
LINCOLN COUNTY, OKLAHOMA

FIGURE

5

APPENDIX A

FIELD EXPLORATION PROGRAM
FIGURE A-1. SUBSURFACE CROSS-SECTION
FIGURE A-2. GRAPHICS KEY
FIGURE A-3. SOIL DESCRIPTION KEY
FIGURE A-4. ROCK DESCRIPTION KEY
BORING LOGS

Kleinfelder conducted the field work for this study between July 16 and 20, 2014. The exploration consisted of five borings drilled near the locations indicated on Figure 2, Boring Location Diagram. A bulldozer was used to cut in areas accessible for the drill rig. The borings were terminated at approximate depths ranging from 73.0 to 91.5 feet below existing ground surface (El ±821.4 to El ±818.8 feet).

Boring locations were established in the field by a representative of Kleinfelder. A measuring tape was used to measure distances from the existing bridge to the boring locations. Right angles were estimated. Approximate elevations at the boring locations were determined through use of an engineer's level referenced to an existing benchmark. The benchmark was identified as BM #4 which is a cut “X” on top of the southwest corner of the concrete headwall at approximate station 46+15.6, with an offset of 26.1 feet left centerline of survey, with an elevation of 909.5 feet. The benchmark is located approximately 725 feet west of the west end of the bridge. Locations and elevations of the borings should be considered accurate only to the degree implied by the methods used. Table A1 lists the approximate boring locations and the respective ground surface elevations.

Table A1. Approximate Boring Locations and Ground Surface Elevations

Boring No.	Ground Elevation* (feet)	Approximate Location	
		Station	Offset from CL Survey
BM #4	909.5	46+15.6	26.1’ Lt.
B-1	910.7	53+19	23.5’ Lt.
B-2	897.7	53+66	22.5’ Rt.
B-2C	897.9	53+65	19.0’ Rt.
B-3	891.8	54+17	22.0’ Lt.
B-4	911.3	54+62	9.5’ Rt.

*Elevations based on the preliminary plans provided by ODOT.

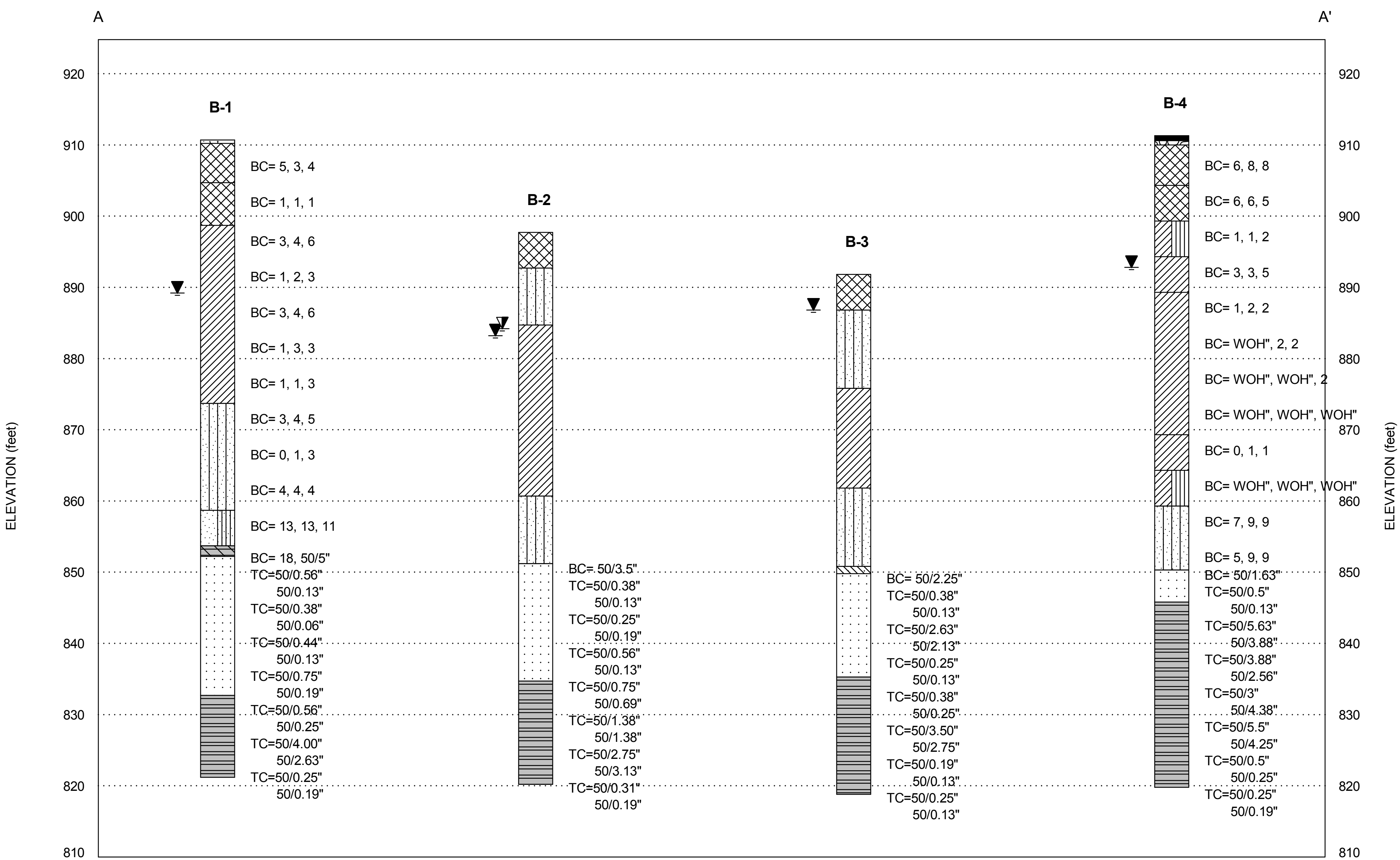
The borings were performed with ATV-mounted (CME-550X) rotary drill rig. The borings were completed using a combination of solid flight augers and wash boring techniques. Borings were extended 10 feet below existing ground surface using wash boring techniques. Samples were obtained by performing a Standard Penetration test (SPT) using a 2-inch O.D. split-barrel sampler. Split-barrel sampling was conducted in general accordance with ASTM D1586 (*Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils*). The split-barrel sampler is driven into the bottom of the boring over an 18-inch sampling interval by a 140-pound hammer that is dropped a distance of 30 inches. A CME automatic SPT hammer with an approximate hammer efficiency of 78.3 percent was used to advance the split-barrel sampler and the TCP. The SPT N-value is the number of blows required to drive the split-barrel sampler the final 12 inches of the 18-inch sampling interval. The samples were sealed and returned to our laboratory for further examination, classification and testing. The borings were backfilled in accordance with the appropriate Oklahoma Water Resources Board Regulations.

The bedrock encountered in Boring B-2C was cored using NQ-diamond bit coring procedures. This diameter core barrel provides a sample having an approximate diameter of 2 inches. Description of the rock core is presented on the boring log in addition to recovery and Rock Quality Designation (RQD) for the core recovered. Recovery is defined as the length of core obtained. Rock Quality Designation is defined as the total length of core pieces, 4 inches or greater in length, expressed as a percentage of the total length cored. Rock Quality Designation provides an indication of the integrity of the rock mass and relative extent of seams and bedding planes.

The bedrock in the rest of borings was evaluated through use of a Dynamic Cone Penetrometer Test (Texas Cone Penetrometer (TCP) test or Texas Highway Department (THD) test). This test utilizes a 3-inch diameter cone with a height of 2.5 inches and an angle of 60 degrees from the horizontal. After seating the cone with 12 blows, the amount of penetration for two consecutive sets of 50 blows is recorded. These values are indicated on the boring logs at the depth of occurrence.

Boring logs included in this APPENDIX A present such data as soil and bedrock descriptions, relative density, consistency, and hardness evaluations, depths, sampling intervals, and observed groundwater conditions. Conditions encountered in each of the borings were monitored and recorded by the drill crew and field professional. Field logs included visual classification of the materials encountered during drilling, as well as drilling characteristics. Our final boring logs represent the engineer's interpretation of the field logs combined with laboratory observation and testing of the samples. Stratification boundaries indicated on the boring logs were based on observations during our field work, an extrapolation of information obtained by examining samples from the borings, and comparisons of soils with similar engineering characteristics. Locations of these boundaries are approximate, and the transitions between material types may be gradual rather than clearly defined.

gINT FILE: PROJECTWISE: 20151682_sh 105 Over Headquarters Creek.gpj
gINT TEMPLATE: PROJECTWISE: KLF_STANDARD_GINT_LIBRARY_2014.GLB [8.5X11 PROFILE] PLOTTED: 09/02/2014 03:59 PM BY: bmooney



NOTE:
REFER TO INDIVIDUAL LOGS FOR DETAILED INFORMATION AND THE GRAPHIC LEGEND KEYS FOR GRAPHICAL SYMBOL INFORMATION.

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PROJECT NO.:	20151682
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DATE:	7/28/2014
REVISED:	-

SUBSURFACE CROSS-SECTION

SH-105 over Headquarters Creek
State J/P No. 27060(04)
Lincoln County, Oklahoma

FIGURE
A-1

SAMPLE/SAMPLER TYPE GRAPHICS

- NQ CORE SAMPLE (1.874 in. (47.6 mm.) core diameter)
- SOLID STEM AUGER
- STANDARD PENETRATION SPLIT SPOON SAMPLER (2 in. (50.8 mm.) outer diameter and 1-3/8 in. (34.9 mm.) inner diameter)
- TEXAS CONE PENETRATION
- WASH BIN

ROCK LITHOLOGY GRAPHICS

- SANDSTONE
- SHALE

GROUND WATER GRAPHICS

- WATER LEVEL (level where first observed)
- WATER LEVEL (level after exploration completion)
- WATER LEVEL (additional levels after exploration)
- OBSERVED SEEPAGE

NOTES

- The report and graphics key are an integral part of these logs. All data and interpretations in this log are subject to the explanations and limitations stated in the report.
- Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual or differ from those shown.
- No warranty is provided as to the continuity of soil or rock conditions between individual sample locations.
- Logs represent general soil or rock conditions observed at the point of exploration on the date indicated.
- In general, Unified Soil Classification System designations presented on the logs were based on visual classification in the field and were modified where appropriate based on gradation and index property testing.
- Fine grained soils that plot within the hatched area on the Plasticity Chart, and coarse grained soils with between 5% and 12% passing the No. 200 sieve require dual USCS symbols, ie., GW-GM, GP-GM, GW-GC, GP-GC, GC-GM, SW-SM, SP-SM, SW-SC, SP-SC, SC-SM.
- If sampler is not able to be driven at least 6 inches
- TCP-Texas Cone Penetrometer

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D 2487)

COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	GRAVELS (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVEL WITH <5% FINES	Cu≥4 and 1≤Cc≤3	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			Cu<4 and/ or 1>Cc>3	GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH 5% TO 12% FINES	Cu≥4 and 1≤Cc≤3	GW-GM	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
				GW-GC	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
			Cu<4 and/ or 1>Cc>3	GP-GM	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE FINES
				GP-GC	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE CLAY FINES
		GRAVELS WITH > 12% FINES		GM	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
				GC-GM	CLAYEY GRAVELS, GRAVEL-SAND-CLAY-SILT MIXTURES
	SANDS (More than half of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH <5% FINES	Cu≥6 and 1≤Cc≤3	SW	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			Cu<6 and/ or 1>Cc>3	SP	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH 5% TO 12% FINES	Cu≥6 and 1≤Cc≤3	SW-SM	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
				SW-SC	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
			Cu<6 and/ or 1>Cc>3	SP-SM	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE FINES
				SP-SC	POORLY GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE CLAY FINES
		SANDS WITH > 12% FINES		SM	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-GRAVEL-CLAY MIXTURES
				SC-SM	CLAYEY SANDS, SAND-SILT-CLAY MIXTURES

FINE GRAINED SOILS (More than half of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid Limit less than 50)	ML	INORGANIC SILTS AND VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, SILTS WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		CL-ML	INORGANIC CLAYS-SILTS OF LOW PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid Limit greater than 50)	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
		CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
		OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY

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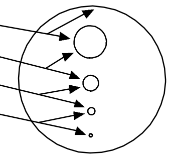
PROJECT NO.: 20151682	GRAPHICS KEY		FIGURE
DRAWN BY: BJM			
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma		A-2
DATE: 7/28/2014			
REVISED: -			

GRAIN SIZE

DESCRIPTION		SIEVE SIZE	GRAIN SIZE	APPROXIMATE SIZE
Boulders		>12 in. (304.8 mm.)	>12 in. (304.8 mm.)	Larger than basketball-sized
Cobbles		3 - 12 in. (76.2 - 304.8 mm.)	3 - 12 in. (76.2 - 304.8 mm.)	Fist-sized to basketball-sized
Gravel	coarse	3/4 -3 in. (19 - 76.2 mm.)	3/4 -3 in. (19 - 76.2 mm.)	Thumb-sized to fist-sized
	fine	#4 - 3/4 in. (#4 - 19 mm.)	0.19 - 0.75 in. (4.8 - 19 mm.)	Pea-sized to thumb-sized
Sand	coarse	#10 - #4	0.079 - 0.19 in. (2 - 4.9 mm.)	Rock salt-sized to pea-sized
	medium	#40 - #10	0.017 - 0.079 in. (0.43 - 2 mm.)	Sugar-sized to rock salt-sized
	fine	#200 - #10	0.0029 - 0.017 in. (0.07 - 0.43 mm.)	Flour-sized to sugar-sized
Fines		Passing #200	<0.0029 in. (<0.07 mm.)	Flour-sized and smaller

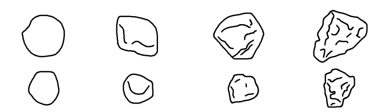


Munsell Color

NAME	ABBR
Red	R
Yellow Red	YR
Yellow	Y
Green Yellow	GY
Green	G
Blue Green	BG
Blue	B
Purple Blue	PB
Purple	P
Red Purple	RP
Black	N

ANGULARITY

DESCRIPTION	CRITERIA
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges



Rounded Subrounded Subangular Angular

PLASTICITY

DESCRIPTION	LL	FIELD TEST
Non-plastic	NP	A 1/8-in. (3 mm.) thread cannot be rolled at any water content.
Low (L)	< 30	The thread can barely be rolled and the lump or thread cannot be formed when drier than the plastic limit.
Medium (M)	30 - 50	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump or thread crumbles when drier than the plastic limit
High (H)	> 50	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump or thread can be formed without crumbling when drier than the plastic limit

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

REACTION WITH HYDROCHLORIC ACID

DESCRIPTION	FIELD TEST
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

APPARENT / RELATIVE DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPT-N_{60} (# blows/ft)	MODIFIED CA SAMPLER (# blows/ft)	CALIFORNIA SAMPLER (# blows/ft)	RELATIVE DENSITY (%)
Very Loose	<4	<4	<5	0 - 15
Loose	4 - 10	5 - 12	5 - 15	15 - 35
Medium Dense	10 - 30	12 - 35	15 - 40	35 - 65
Dense	30 - 50	35 - 60	40 - 70	65 - 85
Very Dense	>50	>60	>70	85 - 100

NOTE: AFTER TERZAGHI AND PECK, 1948

CONSISTENCY - FINE-GRAINED SOIL

CONSISTENCY	UNCONFINED COMPRESSIVE STRENGTH (q_u)(psf)	CRITERIA
Very Soft	< 1000	Thumb will penetrate soil more than 1 in. (25 mm.)
Soft	1000 - 2000	Thumb will penetrate soil about 1 in. (25 mm.)
Firm	2000 - 4000	Thumb will indent soil about 1/4-in. (6 mm.)
Hard	4000 - 8000	Thumb will not indent soil but readily indented with thumbnail
Very Hard	> 8000	Thumbnail will not indent soil

STRUCTURE

DESCRIPTION	CRITERIA
Stratified	Alternating layers of varying material or color with layers at least 1/4-in. thick, note thickness
Laminated	Alternating layers of varying material or color with the layer less than 1/4-in. thick, note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

CEMENTATION

DESCRIPTION	FIELD TEST
Weakly	Crumbles or breaks with handling or slight finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

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PROJECT NO.: 20151682	SOIL DESCRIPTION KEY	FIGURE
DRAWN BY: BJM		
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	A-3
DATE: 7/28/2014		
REVISED: -		

INFILLING TYPE

NAME	ABBR	NAME	ABBR
Albite	Al	Muscovite	Mus
Apatite	Ap	None	No
Biotite	Bi	Pyrite	Py
Clay	Cl	Quartz	Qz
Calcite	Ca	Sand	Sd
Chlorite	Ch	Sericite	Ser
Epidote	Ep	Silt	Si
Iron Oxide	Fe	Talc	Ta
Manganese	Mn	Unknown	Uk

BEDDING CHARACTERISTICS

TERM	Thickness (in.)	Thickness (mm.)
Very Thick Bedded	> 36	> 915
Thick Bedded	12 - 36	305 - 915
Moderately Bedded	4 - 12	102 - 305
Thin Bedded	1 - 4	25 - 102
Very Thin Bedded	0.4 - 1	10 - 25
Laminated	0.1 - 0.4	2.5 - 10
Thinly Laminated	< 0.1	< 2.5

Bedding Planes — Planes dividing the individual layers, beds, or stratigraphy of rocks.
Joint — Fracture in rock, generally more or less vertical or traverse to bedding.
Seam — Applies to bedding plane with unspecified degree of weather.

DENSITY/SPACING OF DISCONTINUITIES

DESCRIPTION	SPACING CRITERIA
Unfractured	> 6 ft. (> 1.83 meters)
Slightly Fractured	2 - 6 ft. (.061 - 1.83 meters)
Moderately Fractured	8 in - 2 ft. (203.20 - 609.60 mm.)
Highly Fractured	2 - 8 in. (50.80 - 203.30 mm.)
Intensely Fractured	< 2 in. (< 50.80 mm.)

APERTURE

DESCRIPTION	CRITERIA [in.(mm.)]
Tight	< 0.04 (< 1)
Open	0.04 - 0.20 (1 - 5)
Wide	> 0.20 (> 5)

ADDITIONAL TEXTURAL ADJECTIVES

DESCRIPTION	RECOGNITION
Pit (Pitted)	Pinhole to 0.03 ft. (3/8 in.) (>1 to 10 mm.) openings
Vug (Vuggy)	Small openings (usually lined with crystals) ranging in diameter from 0.03 ft. (3/8 in.) to 0.33 ft. (4 in.) (10 to 100 mm.)
Cavity	An opening larger than 0.33 ft. (4 in.) (100 mm.), size descriptions are required, and adjectives such as small, large, etc., may be used
Honeycombed	If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form
Vesicle (Vesicular)	Small openings in volcanic rocks of variable shape and size formed by entrapped gas bubbles during solidification

DISCONTINUITY TYPE

DESCRIPTION
Fault
Joint
Shear
Foliation
Vein
Bedding

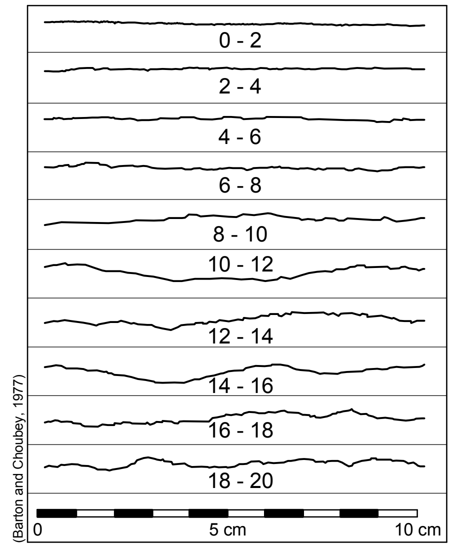
INFILLING AMOUNT

DESCRIPTION
Surface Stain
Spotty
Partially Filled
Filled
None

ROCK QUALITY DESIGNATION (RQD)

DESCRIPTION	RQD (%)
Very Poor	0 - 25
Poor	25 - 50
Fair	50 - 75
Good	75 - 90
Excellent	90 - 100

JOINT ROUGHNESS COEFFICIENT (JRC)



RQD — Rock-quality designation (RQD) Rough measure of the degree of jointing or fracture in a rock mass, measured as a percentage of the drill core in lengths of 10 cm. or more.

DEGREES OF WEATHERING

DESCRIPTION	CRITERIA
Unweathered	No evidence of chemical/mechanical alternation; rings with hammer blow.
Slightly Weathered	Slight discoloration on surface; slight alteration along discontinuities; <10% rock volume altered.
Moderately Weathered	Discoloring evident; surface pitted and alteration penetration well below surface; Weathering "halos" evident; 10-50% rock altered.
Highly Weathered	Entire mass discolored; Alteration pervading most rock, some slight weathering pockets; some minerals may be leached out.
Decomposed	Rock reduced to soil with relict rock texture/structure; Generally molded and crumbled by hand.

RELATIVE HARDNESS / STRENGTH DESCRIPTIONS

GRADE		UCS (MPa)	FIELD TEST
R0	Extremely Weak	0.25 - 1.0	Indented by thumbnail
R1	Very Weak	1.0 - 5.0	Crumbles under firm blows of geological hammer, can be peeled by a pocket knife
R2	Weak	5.0 - 25	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer
R3	Medium Strong	25 - 50	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow of a geological hammer
R4	Strong	50 - 100	Specimen requires more than one blow of geological hammer to fracture it
R5	Very Strong	100 - 250	Specimen requires many blows of geological hammer to fracture it
R6	Extremely Strong	> 250	Specimen can only be chipped with a geological hammer

KLEINFELDER
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PROJECT NO.: 20151682	ROCK DESCRIPTION KEY	FIGURE
DRAWN BY: BJM		A-4
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	
DATE: 7/28/2014		
REVISED: -		

Date Begin - End:	7/18/2014 - 7/19/2014	Drilling Company:	R.C. Drilling			BORING LOG B-1
Logged By:	S. Wang	Drill Crew:	R. Campbell			
Hor.-Vert. Datum:	Not Available	Drilling Equipment:	CME-550X	Hammer Type - Drop:	140 lb. Auto - 30 in.	
Plunge:	-90 degrees	Drilling Method:	Solid Stem Auger	Hammer Efficiency:	78.3%	
Weather:	Not Available	Exploration Diameter:	4.5 in. O.D.	Hammer Cal. Date:	11/13/2012	

FIELD EXPLORATION | LABORATORY RESULTS

Sta. 53+19 Offset 23.5 ft. Lt. of CL Survey
Approximate Ground Surface Elevation (ft.): 910.7

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
910		**TOPSOIL** 910.2											
		DOZER FILL **Clayey SAND**: reddish brown											
		- clay seams below 4.0 feet	1	BC=5 3 4	14"	SC	13.1		91	41	29	15	
905	5	904.7											
		FILL **Sandy SILT**: reddish brown	2	BC=1 1 1	18"	ML	16.6			68	16	NP	
900	10	898.7											
		Lean CLAY with Sand (CL): reddish brown, soft to firm	3	BC=3 4 6	16"	CL	16.9			74	29	14	
895	15												
			4	BC=1 2 3	18"	CL	19.1			71	26	13	
890	20												
			5	BC=3 4 6	18"	CL	21.2			92	39	22	
885	25												
		- soft below 27.0 feet	6	BC=1 3 3	18"	CL	23.2			78	33	18	
880	30												
		- very soft below 32.0 feet	7	BC=1 1 3	18"	CL	26.4			81	32	17	
875	35	- brown and dark brown below 35.0 feet 873.7											
		Silty SAND (SM): reddish brown, loose	8	BC=3 4 5	NR								
870	40												
			9	BC=0 1 3	NR								
865	45												
			10	BC=4 4	8"	SM	22.4			24	NP	NP	

Date Begin - End:	7/18/2014 - 7/19/2014	**Drilling Company:**	R.C. Drilling		**BORING LOG B-1**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 53+19 Offset 23.5 ft. Lt. of CL Survey
Approximate Ground Surface Elevation (ft.): 910.7

Lithologic Description	Bottom Elevation (feet)	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
			4									
Silty SAND (SM): reddish brown, loose	858.7											
Poorly-graded SAND with Silt (SP-SM): medium dense		11	BC=13 13 11	13"	SP-SM	23.8			12	NP	NP	
	853.7											
Weathered SHALE: reddish brown, soft	852.2											
SANDSTONE: reddish brown trace of light bluish gray, poorly to moderately cemented		12	BC=18 50/5"	6"	CL	12.7			76	30	15	
		13	TC=50/0.56" 50/0.13"									
		14	TC=50/0.38" 50/0.06"									
		15	TC=50/0.44" 50/0.13"									
		16	TC=50/0.75" 50/0.19"									
- well cemented below 76.5 feet	832.7											
SHALE: reddish brown, hard												
- sandstone seams from 80.0 to 83.0 feet		17	TC=50/0.56" 50/0.25"									
		18	TC=50/4.00" 50/2.63"									
	821.2	19	TC=50/0.25" 50/0.19"									

The exploration was terminated at approximately 89.5 ft. below ground surface. The exploration was backfilled with bentonite on July 19, 2014.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not encountered prior to introduction of drilling fluid.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 20151682	BORING LOG B-1	B-1
	DRAWN BY: BJM		
	CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	
	DATE: 7/28/2014		
	REVISED: -		PAGE: 2 of 2

Date Begin - End:	7/19/2014	**Drilling Company:**	R.C. Drilling			**BORING LOG B-2**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell			
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.	
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%	
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012	

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 53+66 Offset 22.5 ft. Rt. of CL Survey
Approximate Ground Surface Elevation (ft.): 897.7

Approximate Elevation (feet)	Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Texas Cone(TC)= blows/6 in RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
895			**FILL** **Clayey SAND**: reddish brown												
892.7	5		**Clayey SAND (SM)**: reddish brown - trace of boulders at 8.0 feet												
890															
	10														
884.7 (885)			**Lean CLAY with Sand (CL)**: brown and reddish brown												
	15														
880	20														
875	25														
870	30														
865	35														
860.7 (860)			**Silty SAND (SM)**: reddish brown												
	40														
855	45														
851.2 (850)			**SANDSTONE**: reddish brown, poorly cemented	1 2		BC=50/3.5" TC=50/0.38" 50/0.13"	3"	SM	17.7		94	17	NP	NP	

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 20151682	BORING LOG B-2	
	DRAWN BY: BJM		
	CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	B-2
	DATE: 7/28/2014		
	REVISED: -		PAGE: 1 of 2

Date Begin - End:	7/19/2014	Drilling Company:	R.C. Drilling		**BORING LOG B-2**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION — Sta. 53+66 Offset 22.5 ft. Rt. of CL Survey; Approximate Ground Surface Elevation (ft.): 897.7

LABORATORY RESULTS

Approximate Elevation (feet)	Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Texas Cone(TC)= blows/6 in RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
			SANDSTONE: reddish brown, poorly cemented												
845				3		TC=50/0.25" 50/0.19"									
	55														
840				4		TC=50/0.56" 50/0.13"									
	60														
835			834.7	5		TC=50/0.75" 50/0.69"									
			SHALE: reddish brown, moderately hard												
	65														
830				6		TC=50/1.38" 50/1.38"									
	70		- soft below 70.0 feet												
825				7		TC=50/2.75" 50/3.13"									
	75		- hard below 75.0 feet												
			- trace of sandstone seams below 76.0 feet 820.2	8		TC=50/0.31" 50/0.19"									
820															
	80														
815															
	85														
810															
	90														
805															
	95														
800															

The exploration was terminated at approximately 77.5 ft. below ground surface. The exploration was backfilled with bentonite on July 19, 2014.

GROUNDWATER LEVEL INFORMATION:
▼ Groundwater was not encountered prior to introduction of drilling fluid.
▼ Groundwater was observed at approximately 13.5 ft. below ground surface 24 Hrs. after drilling completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

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PROJECT NO.:	20151682	BORING LOG B-2	B-2
DRAWN BY:	BJM		
CHECKED BY:	SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	
DATE:	7/28/2014		
REVISED:	-		PAGE: 2 of 2

Date Begin - End:	7/16/2014	**Drilling Company:**	R.C. Drilling		**BORING LOG B-2C**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 53+65 Offset 19 ft. Rt. of CL Survey
Approximate Ground Surface Elevation (ft.): 897.9

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		DOZER FILL **Silty Clayey SAND**: reddish brown, medium dense											
892.9	5		1	BC=4 6 7	8"	SC-SM	7.0			48	20	5	
		Silty SAND (SM): reddish brown, very loose - trace of cobbles below 5.0 feet											
		- trace of gravel below 8.5 feet	2	BC=6 2 2	15"	SM	12.3		92	38	NP	NP	
884.9		- trace of gravel below 12.7 feet											
		Sandy Lean CLAY (CL): brown and reddish brown, firm	3	BC=4 5 4	18"	CL	21.5		99	59	22	8	
		- lean clay seams below 18.5 feet	4	BC=2 2 3	18"	CL	28.6			86	33	16	
		- very soft below 22.0 feet											
			5	BC=0 1 0	18"	CL	26.4			62	29	13	
			6	BC=0 0 2	18"	CL	20.7			55	25	11	
865.9		**Sandy SILT (ML)**: reddish brown and brown, soft											
			7	BC=0 4 2	8"	ML	22.3			55	NP	NP	
860.9		**Poorly-graded SAND with Silt (SP-SM)**: reddish brown, medium dense to dense											
			8	BC=8 7 14	12"	SP-SM	21.4		94	10	NP	NP	
			9	BC=15 16 15	12"	SP-SM	21.0			9.0	NP	NP	
851.9		**Weathered SANDSTONE**: reddish brown, poorly cemented	10	BC=15 50/5.25"	6"	SM	15.5		90	18	NP	NP	
			11	RQD=7	17"								**Unc. Comp. Str.-Rock=** q_u: 2420 psi
847.9													

Elevation scale: 895, 890, 885, 880, 875, 870, 865, 860, 855, 850. Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45.

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PROJECT NO.: 20151682	BORING LOG B-2C		B-2C
DRAWN BY: BJM			
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma		
DATE: 7/28/2014			
REVISED: -			PAGE: 1 of 2

Date Begin - End:	7/16/2014	Drilling Company:	R.C. Drilling		**BORING LOG B-2C**
Logged By:	S. Wang	Drill Crew:	R. Campbell		
Hor.-Vert. Datum:	Not Available	Drilling Equipment:	CME-550X	Hammer Type - Drop:	140 lb. Auto - 30 in.
Plunge:	-90 degrees	Drilling Method:	Solid Stem Auger	Hammer Efficiency:	78.3%
Weather:	Not Available	Exploration Diameter:	4.5 in. O.D.	Hammer Cal. Date:	11/13/2012

Sta. 53+65 Offset 19 ft. Rt. of CL Survey
Approximate Ground Surface Elevation (ft.): 897.9

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Texas Cone(TC)= blows/6 in RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		SANDSTONE: brown and gray, medium-grained, moderately to slightly weathered, thickly to very thickly bedded, highly to intensely fractured, weak	11 (cont.)			17" (cont.)								
845			12		RQD=33	60"								**Unc. Comp. Str.-Rock=** q_u: 3620 psi
	55													
840			13		RQD=7	57"								**Unc. Comp. Str.-Rock=** q_u: 2590 psi
	60	835.4	14		RQD=67	59"								
835		**SANDY SHALE**: reddish brown, fine to medium grained, slightly weathered to unweathered, very thickly bedded, moderately to highly fractured, extremely weak to weak												
	65													
830			15		RQD=95	60"								
	70													
825			16		RQD=78	60"								
	75	821.4												
820														
	80													
815														
	85													
810														
	90													
805														
	95													
800														

The exploration was terminated at approximately 76.5 ft. below ground surface. The exploration was backfilled with bentonite on July 16, 2014.

GROUNDWATER LEVEL INFORMATION:
▼ Groundwater was not encountered prior to introduction of drilling fluid.
▽ Groundwater was observed at approximately 13 ft. below ground surface 24 Hrs. after drilling completion.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 20151682	BORING LOG B-2C	B-2C
	DRAWN BY: BJM		
	CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	
	DATE: 7/28/2014		
	REVISED: -		PAGE: 2 of 2

PLOTTED: 08/27/2014 02:25 PM BY: BMooney

Date Begin - End:	7/20/2014	**Drilling Company:**	R.C. Drilling		**BORING LOG B-3**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION | LABORATORY RESULTS

Sta. 54+17 Offset 22 ft. Lt. of CL Survey
Approximate Ground Surface Elevation (ft.): 891.8

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. Texas Cone(TC)= blows/6 in RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
891.8	0	**DOZER FILL** **Silty Clayey SAND**: reddish brown											
886.8	5	**Silty SAND (SM)**: reddish brown											
875.8	16	**Lean CLAY with Sand (CL)**: dark gray and brown											
861.8	30	**Silty SAND (SM)**: reddish brown and brown											
850.8	41	**Weathered SANDSTONE**: reddish brown and gray, poorly cemented											
849.8	42	**SANDSTONE**: reddish brown and gray, poorly cemented	1	BC=50/2.25"	NR								
			2	TC=50/0.38" 50/0.13"									
			3	TC=50/2.63" 50/2.13"									

Elevation scale: 890, 885, 880, 875, 870, 865, 860, 855, 850, 845
Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45

KLEINFELDER Bright People. Right Solutions.	PROJECT NO.: 20151682	BORING LOG B-3
	DRAWN BY: BJM	
	CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma
	DATE: 7/28/2014	B-3
	REVISED: -	PAGE: 1 of 2

gINT FILE: PROJECTWISE: 20151682_sh 105 Over Headquarters Creek.gpj
gINT TEMPLATE: PROJECTWISE: KLF_STANDARD_GINT_LIBRARY_2014.GLB [KLF_BORING/TEST PIT SOIL LOG]

BORING LOG B-3

Date Begin - End:	7/20/2014	**Drilling Company:**	R.C. Drilling		
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 54+17 Offset 22 ft. Lt. of CL Survey
Approximate Ground Surface Elevation (ft.): 891.8

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
840		**SANDSTONE**: reddish brown and gray, poorly cemented											
			4	TC=50/0.25" 50/0.13"									
	55	- moderately cemented below 54.5 feet											
835.3													
835		**SHALE**: reddish brown, hard											
			5	TC=50/0.38" 50/0.25"									
	60	- soft below 59.0 feet											
830													
			6	TC=50/3.50" 50/2.75"									
	65	- hard below 64.0 feet											
825													
			7	TC=50/0.19" 50/0.13"									
	70												
820													
818.8			8	TC=50/0.25" 50/0.13"									

The exploration was terminated at approximately 73 ft. below ground surface. The exploration was backfilled with bentonite on July 20, 2014.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not encountered prior to introduction of drilling fluid.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

KLEINFELDER
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PROJECT NO.: 20151682	BORING LOG B-3	B-3	
DRAWN BY: BJM			
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma		
DATE: 7/28/2014			
REVISED: -		PAGE: 2 of 2	

Date Begin - End:	7/18/2014	**Drilling Company:**	R.C. Drilling		**BORING LOG B-4**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 54+62 Offset 9.5 ft. Rt. of CL Survey
Approximate Ground Surface Elevation (ft.): 911.3

Approximate Elevation (feet)	Depth (feet)	Lithologic Description	Sample Number	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
910.6		**ASPHALT**: 8.0 inches											
910.0		**AGGREGATE BASE**: 7.0 inches											
904.3		**FILL** **Silty Clayey SAND**: reddish brown	1	BC=6 8 8	8"	SC-SM	13.9		100	44	19	5	
899.3		**FILL** **Silty SAND**: reddish brown	2	BC=6 6 5	14"	SM	11.5			47	NP	NP	
894.3		**Sandy Silty CLAY (CL-ML)**: reddish brown, very soft	3	BC=1 1 2	13"	CL-ML	15.9			57	22	6	
889.3		**Lean CLAY (CL)**: reddish brown, soft	4	BC=3 3 5	15"	CL	18.8		100	93	36	20	
		Lean CLAY with Sand (CL): reddish brown, very soft	5	BC=1 2 2	18"	CL	20.2			81	35	20	
			6	BC=WOH 2 2	18"	CL	24.0			84	34	19	
		- loosing water circulation at 30.0 feet											
		- brown and reddish brown below 33.0 feet	7	BC=WOH WOH 2	18"	CL	28.0			82	32	15	
869.3		- trace of brown below 38.5 feet	8	BC=WOH WOH WOH	18"	CL	25.8			72	29	13	
864.3		**Sandy Lean CLAY (CL)**: reddish brown and brown, very soft	9	BC=0 1 1	18"	CL	24.1			69	29	13	
		Sandy Silty CLAY (CL-ML): reddish brown and brown, ver soft	10	BC=WOH WOH	18"	CL-ML	19.7			62	21	5	

Elevation scale: 910, 905, 900, 895, 890, 885, 880, 875, 870, 865
Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45

KLEINFELDER
Bright People. Right Solutions.

PROJECT NO.: 20151682	BORING LOG B-4		
DRAWN BY: BJM			
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	B-4	
DATE: 7/28/2014			
REVISED: -		PAGE: 1 of 2	

Date Begin - End:	7/18/2014	**Drilling Company:**	R.C. Drilling		**BORING LOG B-4**
Logged By:	S. Wang	**Drill Crew:**	R. Campbell		
Hor.-Vert. Datum:	Not Available	**Drilling Equipment:**	CME-550X	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Solid Stem Auger	**Hammer Efficiency:**	78.3%
Weather:	Not Available	**Exploration Diameter:**	4.5 in. O.D.	**Hammer Cal. Date:**	11/13/2012

FIELD EXPLORATION / LABORATORY RESULTS

Sta. 54+62 Offset 9.5 ft. Rt. of CL Survey
Approximate Ground Surface Elevation (ft.): 911.3

Lithologic Description

Approximate Elevation (feet)	Lithologic Description	Bottom Elevation
—	**Sandy Silty CLAY (CL-ML)**: reddish brown and brown, ver soft	859.3
859.3	**Silty SAND (SM)**: reddish brown, medium dense	850.3
850.3	**SANDSTONE**: gray and brown, poorly cemented - well cemented below 63.0 feet	845.8
845.8	**SHALE**: reddish brown, soft - hard below 85.5 feet	819.8

Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. / Texas Cone(TC)= blows/6 in / RQD=%	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
		WOH									
11		BC=7 9 9	13"	SM	21.0			15	NP	NP	
12		BC=5 9 9	12"	SM	22.2		99	13	NP	NP	
13		BC=50/1.63"	1"	SM	19.0		96	23	NP	NP	
14		TC=50/0.5" 50/0.13"									
15		TC=50/5.63" 50/3.88"									
16		TC=50/3.88" 50/2.56"									
17		TC=50/3" 50/4.38"									
18		TC=50/5.5" 50/4.25"									
19		TC=50/0.5" 50/0.25"									
20		TC=50/0.25" 50/0.19"									

The exploration was terminated at approximately 91.5 ft. below ground surface. The exploration was backfilled with bentonite on July 18, 2014.

GROUNDWATER LEVEL INFORMATION:
Groundwater was not encountered prior to introduction of drilling fluid.

GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

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PROJECT NO.: 20151682	BORING LOG B-4		
DRAWN BY: BJM			B-4
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma		
DATE: 7/28/2014			
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APPENDIX B

LABORATORY TESTING PROGRAM

LABORATORY TESTING PROGRAM

GENERAL

Laboratory tests were performed on select, representative samples to evaluate pertinent engineering properties of these materials. We directed our laboratory testing program primarily toward classifying the subsurface materials and measuring index values of the on-site materials. Laboratory tests were performed in general accordance with applicable standards. The results of the laboratory tests are presented on the respective boring logs. The laboratory testing program consisted of the following:

- **Moisture content tests**, AASHTO T-265, Standard Test Method for Laboratory Determination of Moisture Content of Soils.
- **Atterberg limits**, ASTM D4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
- **Particle Size Analysis of Soil,** ASTM D422, Standard Test Methods for Particle-Size Analysis of Soils.
- **Visual classification**, ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

Exploration ID	Depth (ft.)	Sample No.	Sample Description	USCS	AASHTO	OKLAHOMA SOIL INDEX (OSI)	Water Content (%)	Atterberg Limits			Sieve Analysis (%)				
								Liquid Limits	Plastic Limits	Plasticity Index	Passing #4	Passing #10	Passing #40	Passing #100	Passing #200
B-1	3.0 - 4.5	1	CLAYEY SAND	SC	A-6(2)	6.0	13.1	29	14	15	91	89	87	48	41
B-1	8.0 - 9.5	2	SANDY SILT	ML	A-4(0)	2.6	16.6	16	16	NP			100	84	68
B-1	13.5 - 15.0	3	LEAN CLAY WITH SAND	CL	A-6(8)	11.3	16.9	29	15	14			100	86	74
B-1	18.5 - 20.0	4	LEAN CLAY WITH SAND	CL	A-6(6)	9.9	19.1	26	13	13		100	98	82	71
B-1	23.5 - 25.0	5	LEAN CLAY	CL	A-6(20)	16.6	21.2	39	17	22		100	98	95	92
B-1	28.5 - 30.0	6	LEAN CLAY WITH SAND	CL	A-6(12)	13.8	23.2	33	15	18		100	99	89	78
B-1	33.5 - 35.0	7	LEAN CLAY WITH SAND	CL	A-6(12)	13.2	26.4	32	15	17		100	97	88	81
B-1	48.5 - 50.0	10	SILTY SAND	SM	A-2-4	0.0	22.4	NP	NP	NP			100	61	24
B-1	53.5 - 55.0	11	POORLY GRADED SAND WITH SILT	SP-SM	A-2-4	0.0	23.8	NP	NP	NP			100	36	12
B-1	58.0 - 58.9	12	LEAN CLAY WITH SAND	CL	A6(9)	12.0	12.7	30	15	15		100	98	82	76
B-2	46.5 - 46.8	1	SILTY SAND	SM	A-2-4	0.0	17.7	NP	NP	NP	94	91	88	22	17
B-2C	3.5 - 5.0	1	SILTY, CLAYEY SAND	SC-SM	A-4	0.0	7.0	20	15	5			100	75	48
B-2C	8.5 - 10.0	2	SILTY SAND	SM	A-4(0)	0.0	12.3	NP	NP	NP	92	90	86	45	38
B-2C	13.5 - 15.0	3	SANDY LEAN CLAY	CL	A-4(2)	5.8	21.5	22	14	8	99	91	79	64	59
B-2C	18.5 - 20.0	4	LEAN CLAY	CL	A-6(13)	13.0	28.6	33	17	16		100	97	91	86
B-2C	23.5 - 25.0	5	SANDY LEAN CLAY	CL	A-6(5)	9.2	26.4	29	16	13			100	85	62
B-2C	28.5 - 30.0	6	SANDY LEAN CLAY	CL	A-6(3)	6.8	20.7	25	14	11			100	77	55
B-2C	33.5 - 35.0	7	SANDY SILT	ML	A-4(0)	0.0	22.3	NP	NP	NP			100	78	55
B-2C	38.5 - 40.0	8	POORLY GRADED SAND WITH SILT	SP-SM	A-3	0.0	21.4	NP	NP	NP	94	92	91	15	10
B-2C	43.5 - 45.0	9	POORLY GRADED SAND WITH SILT	SP-SM	A-3	0.0	21.0	NP	NP	NP			100	15	9.0
B-2C	45.5 - 46.5	10	SILTY SAND	SM	A-2-4	0.0	15.5	NP	NP	NP	90	83	77	20	18
B-4	3.5 - 5.0	1	SILTY, CLAYEY SAND	SC-SM	A-4(0)	2.3	13.9	19	14	5	100	99	97	64	44
B-4	8.5 - 10.0	2	SILTY SAND	SM	A-4(0)	0.0	11.5	NP	NP	NP			100	81	47
B-4	13.5 - 15.0	3	SANDY SILTY CLAY	CL-ML	A-4(1)	4.9	15.9	22	16	6			100	87	57
B-4	18.5 - 20.0	4	LEAN CLAY	CL	A-6(18)	15.2	18.8	36	16	20	100	99	98	97	93
B-4	23.5 - 25.0	5	LEAN CLAY WITH SAND	CL	A-6(15)	15.0	20.2	35	15	20			100	94	81
B-4	28.5 - 30.0	6	LEAN CLAY WITH SAND	CL	A-6(14)	14.4	24.0	34	15	19			100	96	84
B-4	33.5 - 35.0	7	LEAN CLAY WITH SAND	CL	A-6(11)	12.4	28.0	32	17	15		100	97	88	82

Refer to the Geotechnical Evaluation Report or the supplemental plates for the method used for the testing performed above.
NP = Nonplastic
NA = Not Available

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PROJECT NO.:	20151682
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CHECKED BY:	SYW
DATE:	7/28/2014
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LABORATORY TEST RESULT SUMMARY

SH-105 over Headquarters Creek
State J/P No. 27060(04)
Lincoln County, Oklahoma

TABLE

B-1

Exploration ID	Depth (ft.)	Sample No.	Sample Description	USCS	AASHTO	OKLAHOMA SOIL INDEX (OSI)	Water Content (%)	Atterberg Limits			Sieve Analysis (%)				
								Liquid Limits	Plastic Limits	Plasticity Index	Passing #4	Passing #10	Passing #40	Passing #100	Passing #200
B-4	38.5 - 40.0	8	LEAN CLAY WITH SAND	CL	A-6(7)	10.6	25.8	29	16	13		100	98	82	72
B-4	43.5 - 45.0	9	SANDY LEAN CLAY	CL	A-6(7)	10.2	24.1	29	16	13		100	97	83	69
B-4	48.5 - 50.0	10	SANDY SILTY CLAY	CL-ML	A-4(1)	4.9	19.7	21	16	5			100	85	62
B-4	53.5 - 55.0	11	SILTY SAND	SM	A-2-4	0.0	21.0	NP	NP	NP			100	30	15
B-4	58.5 - 60.0	12	SILTY SAND	SM	A-2-4	0.0	22.2	NP	NP	NP	99	98	94	18	13
B-4	61.0 - 61.1	13	SILTY SAND	SM	A-2-4	0.0	19.0	NP	NP	NP	96	92	90	28	23

Refer to the Geotechnical Evaluation Report or the supplemental plates for the method used for the testing performed above.
NP = Nonplastic
NA = Not Available

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PROJECT NO.: 20151682	LABORATORY TEST RESULT SUMMARY	TABLE
DRAWN BY: BJM		B-2
CHECKED BY: SYW	SH-105 over Headquarters Creek State J/P No. 27060(04) Lincoln County, Oklahoma	
DATE: 7/28/2014		
REVISED: -		

APPENDIX C

ASFE DOCUMENT

Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

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