20 December, 2016

Attention: Mr. Professional Engineer

Re: Geotechnical/Foundation Engineering Study

Our Geotechnical/Foundation Engineering Study Report for the referenced project is enclosed. The report includes the results of test drilling, laboratory analyses and recommended criteria for foundation design, and related earthwork.

Should you have any questions about this report, we would be pleased to discuss them with you.

Respectively submitted,

Reviewed by:

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Principal Geotechnical Engineer

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1.0 INTRODUCTION

This is the report of the geotechnical engineering study completed by this firm to evaluate the physical properties of the subsoils underlying the proposed building site and to provide recommendations for foundation design, and related earthwork.

2.0 PROPOSED CONSTRUCTION

We understand that the project consists of a building approximately. Cuts for site grading are not likely to exceed 3 feet in depth; site fills are not likely to exceed 3 feet in height.

Should final design details vary significantly from those outlined above, this firm should be notified for review and possible modification of recommendations.

3.0 INVESTIGATION

3.1 Subsurface Exploration

Two exploratory borings were drilled at the site to depths of 60 feet below existing grades utilizing a truck-mounted CME rotary drill rig equipped with an 8-inch O.D. hollow stem auger. Standard penetration testing and open-end drive sampling were performed at selected intervals in the borings. During the field study, the soils encountered were continuously examined, visually classified, and logged. Results of the field study are presented in Appendix A, which includes a brief description of drilling and sampling equipment and procedures, a site plan showing the boring locations, and logs of the test borings.

3.2 Laboratory Analysis

Moisture content determinations were made on all open-end drive samples recovered. Direct Shear and Consolidation test were conducted on selected relatively undisturbed 2.42-inch I.D. "ring" samples. Results of these tests are shown in the Appendix B.

Grain-size analysis and Atterberg limits tests were performed on selected samples to aid in soil classification, as well as a hydrometer test on a selected clay sample. Test results are presented in Appendix B, along with a brief description of soil mechanics testing procedures.

4.0 SITE CONDITIONS & GEOTECHNICAL PROFILE

4.1 Site Conditions

At the time of the field study, the area surrounding the building location was an ungraded field with a community walking trail around the perimeter of the park (which is utilized) and disc golf baskets. The site has large amounts of native grasses, small yuccas and other vegetation. The building site had not been cleared. Surveying company personnel were on site during drilling.

4.2 Geotechnical Profile

The soils at the site consisted of clay (CL), sandy-clayey silt (SC-SM), silty sand (SM), silty clay and clayey silt (CL-ML). The clay is of medium plasticity, ranging from very stiff to hard in consistency and contains some degree of sand and silt. The sandy-clayey silt is of medium plasticity, fine to medium grained and is medium dense to dense. The silty sand has very low plasticity, is fine to medium grained, contains some trace clay and is dense to very dense. Cemented caliche was encountered at depths between 10 and 30 feet.

4.3 Soil Moisture & Groundwater Conditions

No free groundwater was encountered in the borings. Measured soil moisture contents were generally low ranging from 2 to 32 percent, with an average of 13 percent.

5.0 DISCUSSION & RECOMMENDATIONS

Settlement, bearing capacity and clay activity analyses were run using soil parameters from both boring locations. Laboratory data and SPT correlations were used to calculate soil analysis parameters.

5.1 Analysis of Results

The near surface native soils (0 to 4ft) at the site are of low density. From 5 feet to 20 feet the native soil is medium dense and between 20 and 46 ft the soil is very dense and hard.

The proposed building can be safely supported on a foundation bearing directly on at least 3 feet of structural fill. Site preparation and leveling would consist of overexcavating a portion of the native soils beneath the proposed structure's bearing elevation. Surface materials should be overexcavated to provide compacted structural fill beneath the structure. Detailed recommendations concerning site preparation and foundation design are presented in the following sections of this report.

Post-construction moisture increases in the supporting soils could cause some differential foundation movements and, thus, careful site grading, drainage and moisture protection procedures as outlined in following sections of this report will be critical for the satisfactory performance of the structure.

5.2 Settlement

An analysis of estimated building settlement was performed using the Schmertmann method. Using the data from BH-01, the settlement was calculated to be 1.61 inches and the data from BH-02 was used to calculate settlement of 1.73 inches giving an estimated differential settlement of 0.12 inches between the two borehole locations.

A second settlement analysis was performed using laboratory data from consolidation tests on selected samples. This analysis estimated settlement in selected clay layers. For BH-01 clay layer from 40-41.5ft for a layer thickness of 5ft, a settlement of 0.3 inches was calculated. For BH-02 from 20-21.5ft and a layer thickness of 5ft, a settlement of 0.6 inches was calculated.

For BH-02 from 40-41.5ft and a layer thickness of 5ft, a settlement of 0.3 inches was calculated. These calculations were used to compare to other methods.

A third settlement analysis was calculated using the Janbu method which averages the soil modulus of the soil profile and uses the shape of the footing, the thickness of the soil in question to the width of the base ratio and the depth of embedment to the width of the base ratio to calculate factors that are then used to estimate settlement. Using the soil parameters from BH-01, the settlement was calculated to be 2.2 inches and the soil parameters from BH-02 was calculated to be 2.5 inches with a 0.3 inch differential.

5.3 Bearing Capacity

Bearing capacity was calculated using the Meyerhof ultimate and allowable bearing capacity equation, using bearing capacity factors from the Meyerhof chart in FHWA-SA-96-071. The allowable gross load per unit area is 41.78 tons per square foot (tsf) and the allowable total gross load is 554,653 tons using a factor of safety 3.

5.4 Clay Activity

Clay activity calculated using laboratory hydrometer data from a clay sample taken from BH-02 50-51.5ft is 0.68 which classifies the clay as inactive. Inactive clays are clays that have low swell potential and low long-term creep settlement potential.

5.5 Ring-Wall Foundation

A shallow spread-type ringwall foundation bearing at a uniform depth below finished grade, in conjunction with the recommended site preparation and moisture protection provisions, is recommended for support of the structure. A safe soil bearing pressure of 3,000 psf is recommended for the design of the ring-wall foundation. The foundation bearing should be on a minimum thickness of 3.0 feet of structural fill. Minimum depths of footings should be 2.0 feet below the lowest adjacent finished grade for perimeter footings. Three feet is the minimum recommended width for the ring-wall footing.

In order to minimize the sensitivity of the structure to differential movement, ring wall footings should be reinforced to allow for a degree of load redistribution should a localized zone of the supporting soils become saturated.

The bearing pressure recommended above applies to full service.

5.6 Site Drainage & Moisture Protection

Substantial moisture increase in the subsoils would reduce their support value and increase foundation movements. Therefore, positive site drainage should be provided during construction and maintained thereafter. Where pavements, sidewalks or slabs do not immediately adjoin the structure, the ground surface should be sloped away from the structure perimeter in a manner to allow flow along the drainage lines at a minimum grade of 4 percent to points at least 20.0 feet away. A minimum grade of at least 1 percent should be provided from these points to streets or natural water courses. In no case should long-term ponding of water or seepage of water into subsurface support soils be allowed around the perimeter or beneath the structure.

5.7 Construction Considerations

Surface materials should be overexcavated a minimum of 3 feet and structural fill should also extend a minimum distance of 3 feet laterally from the base perimeter. Recommendations presented in previous sections of this report are predicated on the fact that there will be continuous observation and testing by the geotechnical engineer's representative during earthwork operations. Verification of recommended excavation and required degree of compaction should be performed in accordance with "Specifications for Earthwork", Appendix C.

APPENDIX A

Test Drilling Equipment & Procedures

Unified Soil Classification

AASHTO Soil Clasification

Soil Boring Location Plans

Logs of Test Borings

TEST DRILLING EQUIPMENT & PROCEDURES

Drilling Equipment - Truck-mounted drill rigs powered with gasoline or diesel engines are used in advancing test borings. Drilling through soil or softer rock is performed with hollow-stem auger or continuous flight auger. Carbide insert teeth are normally used on the auger bits so they can often penetrate rock or very strongly cemented soils which require blasting or very heavy equipment for excavation. Where refusal is experienced in auger drilling, the holes are sometimes advanced with tricone gear bits and NX rods using water or air as a drilling fluid.

Sampling Procedures - Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 procedures. In most cases, 2-inch O.D., 1-3/8-inch I.D. samplers are used to obtain the standard penetration resistance. "Undisturbed" samples of firmer soils are often obtained with 3-inch O.D. samplers lined with 2.42-inch I.D. brass rings. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free-fall drop hammer required to advance the samplers in 6-inch increments. However, in stratified soils, driving resistance is sometimes recorded in 2 or 3-inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. These values are expressed in blows per foot on the logs. "Undisturbed" sampling of softer soils is sometimes performed with thin-walled Shelby tubes (ASTM D1587). Where samples of rock are required, they are obtained by NX diamond core drilling (ASTM D2113). Tube samples are labeled and placed in water-tight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings.

Boring Records - Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487), with appropriate group symbols being shown on the logs.

TERMINOLOGY USED TO DESCRIBE THE RELATIVE DENSITY, CONSISTENCY OR FIRMNESS OF SOILS

The terminology used on the boring logs to describe the relative density, consistency or firmness of soils relative to the standard penetration resistance is presented below. The standard penetration resistance (N) in blows per foot is obtained by ASTM D1586 procedure using 2" O.D., 1-3/8" I.D. samplers.

1. Relative Density Terms for description of relative density of cohensionless, uncemented sands and sand-gravel mixtures.

N	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium dense
31-50	Dense
50+	Very dense

2. Relative Consistency Terms for the description of clays which are saturated or near saturation.

N	Relative Consistency	Remarks
0-2	Very Soft	Easily penetrated several inches with fist
3-4	Soft	Easily penetrated several inches with thumb
5-8	Medium stiff	Can be penetrated several inches with thumb with moderate effort
9-15	Stiff	Readily indented with thumb, but penetrated only with great effort
16-30	Very stiff	Readily indented with thumbnail
30+	Hard	Indented only with difficulty by thumbnail

3. Relative Firmness Terms for the description of partially saturated and/or cemented soils which commonly occur in the Southwest including clays, cemented granular materials, silts and silty and clayey granular soils:

N	Relative Density
0-4	Very soft
5-8	Soft
9-15	Moderately firm
16-30	Firm
31-50	Very firm
50+	Hard

APPENDIX B

Laboratory Testing Procedures

Classification Test Data

Consolidation Test Data

Direct Shear Test Data

Hydrometer Test Data

Excel Correlations Data

LABORATORY TESTING PROCEDURES

Consolidation Tests   Consolidation apparatus of the "fixed-ring" type are employed for the one-dimensional consolidation tests. They are designed to receive one inch high, 2.5 inch O.D. brass liner rings with soil specimens as secured in the field. Procedures for the tests generally are those outlined in ASTM D2435. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. For soils which are essentially saturated, each increment of load is maintained until the deformation versus log of time curve indicates completion of primary consolidation. For partially saturated soils, each increment of load is maintained until the rate of deformation is equal or less than 1/10,000 inch per hour. Applied loads are such that each new increment is equal to the total previously applied loading. Porous stones are placed in contact with the top and bottom of the specimens to permit free addition or expulsion of water. For partially saturated soils, the tests are normally performed at in situ moisture conditions until consolidation is complete under stresses approximately equal to those which will be imposed by the combined overburden and foundation loads. The samples are then submerged to show the effect of moisture increase and the tests continued under higher loadings. Generally, the tests are continued to about twice the anticipated curve due to overburden and structural loads, with a rebound curve then being established by releasing loads.

Expansion Tests   The same type of consolidometer apparatus described above is used in expansion testing. Undisturbed samples contained in brass liner rings are placed in the consolidometers, subjected to appropriate surcharge loads and submerged. The loads are maintained until the expansion versus log of time curve indicates the completion of "primary swell".

APPENDIX C

Specifications for Earthwork

SPECIFICATIONS FOR EARTHWORK

1.0 SCOPE

Includes all clearing and grubbing, removal of obstructions, general excavating, grading and filling, and any related items necessary to complete the grading for the entire project in accordance with these specifications.

2.0 SUBSURFACE SOIL DATA

Subsurface soil investigations have been made, and the results are available for examination by the contractor. The contractor is expected to examine the site and determine for himself the character of materials to be encountered.

No additional allowance will be made for rock removal, site clearing and grading, filling, compaction, disposal, or removal of any unclassified materials.

3.0 CLEARING & GRUBBING

A. **General**: Clearing and grubbing will be required for all areas shown on the plans to be excavated or on which fill is to be constructed.

B. **Clearing**: Clearing shall consist of removal and disposal of trees and other vegetation as well as down timber, snags, brush, existing foundations, slabs, and rubbish within the areas to be cleared.

C. **Grubbing**: Stumps, matted roots, and roots larger than 2 inches in diameter shall be removed from within 6 inches of the surface of areas on which fills are to be constructed except in roadways. Materials as described above within 18 inches of finished subgrade of roadways in either cut or fill sections shall be removed. Areas disturbed by grubbing will be filled as specified herein for EMBANKMENT.

D. **Grass & Topsoil**: Grass, grass roots, and incidental topsoil shall not be left beneath a fill area, nor shall this material be used as fill material. Grass, grass roots, and topsoil may be stockpiled and later used in the top 6 inches of fills outside roadways and building pads.

4.0 EARTH EXCAVATION

A. Earth excavation shall consist of the excavation and removal of suitable soils for use as embankment, as well as the satisfactory disposal of all vegetation, existing man-made fill, debris, and deleterious materials encountered within the area to be graded and/or in a borrow area.

B. Excavated areas shall be continuously maintained such that the surface shall be smooth and have sufficient slope to allow water to drain from the surface.

5.0 EMBANKMENT

A. General: Embankments shall consist of a controlled fill constructed in areas indicated on the grading plans.

B. Materials:

(1) Physical Characteristics: Embankment fill material shall consist of soils that conform to the following physical characteristics:

Sieve Size (Square Openings)	Percent Passing by Weight
3 inch	100
No. 4	50-100
No. 200	15-50

The plasticity index of the material, as determined in accordance with ASTM D4318, shall not exceed 12. Results of our investigation indicate that some of the on-site soils will meet these requirements, however, some imported fill may be required. The fill materials shall be free from roots, grass, other vegetable matter, clay lumps, rocks larger than 6 inches, or other deleterious materials.

(2) Borrow: When the quantity of suitable material required for embankments is not available within the limits of the jobsite, the contractor shall provide sufficient materials to construct the embankments to the lines, elevations, and cross sections shown on the drawings from borrow areas. The contractor shall obtain from owners of said borrow areas the right to excavate material, shall pay all royalties and other charges involved, and shall pay all expenses in developing the source, including the cost of right-of-way required for hauling the material.

C. Construction:

(1) Structure Area Treatment: The structure area shall be overexcavated to such an extent as to provide for a minimum of 3.0 feet of structural fill beneath the structure ring-wall foundation and structure base. Overexcavation shall extend laterally a minimum distance of 3.0 feet beyond the structure footing's perimeter.

Prior to placement of fill, the structure subgrade area shall be inspected and approved by a representative of the geotechnical engineer to insure satisfactory removal of native soils and the removal of any existing man-made fill.

The exposed cut surface, as well as surfaces to receive fill, shall be scarified and mixed with water added to a minimum depth of 8 inches and watered as necessary to bring the upper 12 inches as close as practicable to optimum moisture content or above. The upper 8 inches of the native soils shall then be compacted to a minimum of 95 percent of maximum dry density as determined in accordance with ASTM D1557.

Where vibratory compaction equipment is used, it shall be the contractor's responsibility to insure that the vibrations do not damage nearby buildings or other adjacent property.

(2) **Compaction**: Fill shall be spread in layers not exceeding 8 inches, watered and mixed `as necessary, and compacted. Moisture content at the time of compaction shall be 2 percent below optimum moisture or higher. A density of not less than 95 percent of maximum dry density within the structure base area and paved areas shall be obtained for the structural fill. Structural fill, as well as the native soils, outside the structure base area and paved areas shall be compacted to 90 percent of maximum dry density.

Optimum moisture content and maximum dry density for each soil type used shall be determined in accordance with ASTM D1557.

(3) **Weather Limitations**: Controlled fill shall not be constructed when the atmospheric temperature is below 35 degrees F. When the temperature falls below 35 degrees, it shall be the responsibility of the contractor to protect all areas of completed work against any detrimental effects of ground freezing by methods approved by the geotechnical engineer. Any areas that are damaged by freezing shall be reconditioned, reshaped, and compacted by the contractor in conformance with the requirements of this specification without additional cost to the owner.

D. **Slope Protection & Drainage**: The edges of the controlled fill embankments shall be graded to the contours shown on the drawings and compacted to the density required in paragraph 5.C(2). Slopes steeper than 1 vertical to 3 horizontal shall be protected from erosion.

6. INSPECTION & TESTS

A. **Field Inspection & Testing**: The owner shall employ the services of a registered, licensed geotechnical engineer to observe and test all controlled earthwork. The geotechnical engineer shall provide continuous on-site observation by experienced personnel during construction of controlled earthwork. The contractor shall notify the engineer at least two working days in advance of any field operations of controlled earthwork, or of any resumption of operations after stoppages. Tests of fill materials and embankments will be made at the following suggested minimum rates:

(1) One field density test for each 500 square yards of original ground surface prior to placing fill or constructing floor slabs.

(2) One field density test for each 250 cubic yards of fill placed or each layer of fill for each work area, whichever is the greater number of tests.

(3) One moisture-density curve for each type of material used, as indicated by sieve analysis and plasticity index.

B. **Report of Field Density Tests**: The geotechnical engineer shall submit, daily, the results of field density tests required by these specifications.

C. **Costs of Tests & Inspection**: The costs of tests, inspection and engineering, as specified in this section of the specifications, shall be borne by the owner.

APPENDIX D

Settlement Calculation

Bearing Capacity Calculation

Activity Calculation