GEOTECHNICAL EXPLORATION
FOR THE PROPOSED RESIDENCE
LOCATED AT 11460 QUEENSBORO CT.
MONTGOMERY, TEXAS

Reported to

MR. ROBERT COREALE
TILE ROOFS OF TEXAS, INC.
HOUSTON, TEXAS

Prepared By

EARTH engineering, inc.

down to earth solutions
for your complex projects

EARTH ENGINEERING, INC.
HOUSTON, TEXAS

THE HOUSTON 100
Spotlighting Houston's Fastest-Growing Private Companies
A program of UH Small Business Development Center
2001 Winner

Project No: EE-1432111-G

December 16, 2014

EARTH ENGINEERING, INC.
Geotechnical, Materials Testing & Environmental Consultants
4877 Langfield Road • Houston, TX 77040 • T: (713) 681-5311 • F: (713) 681-5411 • www.eartheng.com
down to earth solutions for your complex projects

December 16, 2014

Mr. Robert Coreale
Tile Roofs of Texas, Inc.
6614 Del Rio
Houston, TX 77021

Report No.: EE-1432111-G

Subject: **GEOTECHNICAL EXPLORATION FOR THE PROPOSED RESIDENCE AT 11460 QUEENSBORO CT. IN MONTGOMERY, TX.**

Dear Mr. Coreale:

EARTH ENGINEERING, INC. is pleased to submit the results of the geotechnical exploration study for the above-referenced project. This report briefly presents the findings of the study along with our conclusions and recommendations for the design of the foundation for the above project.

We appreciate the opportunity to serve you and look forward to working with you in other future projects. We also look forward to providing the materials testing inspection phase on this project.

Should you have any questions regarding this report or any questions pertaining to soils engineering or materials testing, please do not hesitate to call me at (713) 681-5311 at any time.

Yours very truly,
EARTH ENGINEERING, INC.

Sanjay Dhakal, E.I.T.
Staff Geotechnical Engineer

STATE OF TEXAS
YUQING WU
104862
LICENSED
PROFESSIONAL ENGINEER

12.16/2014

Yuqing (Jack) Wu, P.E. (104862)
Project Manager

MAS/CY

Date: 12/16/14
Yuqing Wu, P.E - # 104862
Earth Engineering, Inc. # F-5045

TABLE OF CONTENTS

Page No

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

Planning is underway for construction of the proposed residence located at 11460 Queensboro Ct in Montgomery, TX.

2.0 SCOPE OF WORK

The specific scope of our services pertaining to the geotechnical study was specified by the client and is presented below:

- Drill and sample a total of two (2) borings within the proposed residential area. Both borings will have a termination depth of twenty (20) feet below existing grades at the site.

- Obtaining continuous soil samples to a depth of twelve (12) feet, and then at three (3) foot intervals thereafter to the respective termination depth of each boring.

- Earth Engineering will perform granular soil sampling utilizing the Standard Penetration Test, which consists of driving a split spoon sampler 18 inches into the ground using a 140-pound weight falling 30 inches (ASTM D-1558). The number of blows necessary to drive the split spoon the final 12 inches will be recorded. Cohesive soils will be sampled using a thin walled sampler (Shelby Tube) hydraulically pushed into the soil (ASTM D-1587).

- Performing laboratory tests on selected representative soil samples to develop the engineering properties of the soil. These tests may include: pocket penetrometers, unconfined compression, present moisture content, percent passing #200 sieves, dry densities, Atterberg Limits, and swell tests, as deemed appropriate.

- Utilizing observations made in the field and the results of limited laboratory tests, Earth Engineering will author a report that will include the following:

    - Soil stratigraphy: soil encountered to a depth of 20 feet

    - Groundwater conditions and groundwater control during construction

    - Boring log information (will include all laboratory and in situ test results)

    - Suitable foundation design options and recommendations for the residence

    - Slab on-grade design criteria, including the need for sub-grade replacement with fill or lime stabilization of the sub-grade.

    - Floor slab recommendations (structural slab or slab on-grade)

- Construction considerations and recommendations, as deemed necessary
- Back-fill material specifications and recommendations

All of the above will be incorporated into a geotechnical engineering report performed under the direction of, and signed by, a professional engineer registered in the State of Texas.

3.0 SUBSURFACE EXPLORATION

3.1 Sampling Techniques

The subsurface conditions were explored by a total of two (2) borings. All borings were drilled by utilizing a truck-mounted drill rig as the boring locations.

Samples in cohesive and semi-cohesive soils (clays, sandy clays, and silty clays) were obtained using a three-inch (two-inch) diameter Shelby Tube sampler advanced hydraulically by one stroke in accordance with the procedures outlined in ASTM D-1587. Samples were extruded in the field, visually classified, and a strength estimate was obtained with a pocket penetrometer. Penetrometer readings are tabulated on the logs of borings. Representative portions of the samples were wrapped with aluminum foil and sealed for transport to the laboratory for further testing.

Cohesionless and semi-cohesionless soils (sands and silts), if encountered, were sampled using the Standard Penetration Test (SPT) split spoon barrel driven 18 inches by a 140-pound hammer falling 30 inches in accordance with procedures outlined in ASTM D-1586. The number of blows (N) required to advance the split-spoon barrel the last 12 inches is recorded for each corresponding sample on the individual log of borings. Samples obtained from the split-spoon barrel were visually classified in the field, wrapped in aluminum foil, and sealed for transportation to the laboratory for further testing.

3.2 Sample Disposal

In general, soil samples (both tested and untested) will be discarded 30 days after the submittal of the final report, unless otherwise notified by the client.

4.0 LABORATORY TESTING

The laboratory-testing program was designed and directed towards evaluating the physical and engineering properties of the subsoils. Physical properties include Atterberg limits (liquid limits and plastic limits), moisture content for clays, and percent passing #200 sieve for sands. Engineering properties include shear strength of the soil, compressibility of the soils, and the swell characteristics of the soils. It should be noted that the testing program varies for each project and depends solely on the project budget and emphasis. Typically, Earth Engineering, Inc. specifies the anticipated testing program in each proposal. The tests undertaken in this program included the following:

Laboratory Tests	Applicable Test Standards	Number of Tests
Liquid Limit, Plastic Limit, and Plasticity Index of Soil	ASTM D-4318 Method B	3
Moisture Content	ASTM D-2216	8

Laboratory test results are presented in the Logs of Borings, Plates 3 and 4. A Key to Log Terms and Symbols is presented in Plate 5. It should be noted that the soils were classified in accordance with the Unified Soil Classification System (ASTM D-2487).

5.0 SUBSURFACE STRATIGRAPHY

5.1 Site Location and Conditions

The site is located at 11460 Queensboro Ct. in Montgomery, TX. At the time of drilling, the proposed site was wooded and boring locations were cleared prior to drilling operations.

Based on our visual observations during drilling operations, it appears that the site and the surrounding area exhibit topographic variations of less than four (4) feet. Surveying map with existing and proposed elevations including the finished floor elevations was not available at this time.

5.2 Subsurface Conditions

The subsurface conditions at the project site were evaluated based on two (2) borings. Soil stratigraphy details are presented on the Log of Borings, Plates 3 and 4. The soil strata listed below are general in nature and highlight major subsurface soils. The boring logs include a summary of soil properties at certain depths.

The soil stratigraphy shown on each boring log represents the conditions and approximate boundaries between strata at that specific boring location only. The actual transitions between strata may be gradual. Variations will occur and should be expected at locations away from each boring location**.** Based on field logs and laboratory test results, the subsoil stratigraphy is approximately as follows:

Stratum No.	Range* of Depth, ft.	Soil Description and Classification (Based on Unified Soil Classification System)
I	0-10 at B-1 and B-2	Loose to medium dense, dark gray to gray brown **SILTY SAND (SM)** with root fibers
II	10-20 at B-1 and B-2	Very stiff, reddish brown to light gray brown **SANDY LEAN CLAY (CL)** ferrous nodules, calcareous nodules and sand seams

*These stratum depths are based on measurements referenced from ground surface at the time of our drilling activities on November 25, 2014. Please note that the depths of the stratum changes vary; please refer to the boring logs presented on Plates 3 and 4 for stratum changes at specific locations.

Stratum I consists of loose to medium dense silty sands. These sands are highly permeable and during inclement weather perched water condition may arise. Please see section 5.4 for further detail for mitigation of perched water conditions.

Stratum II consists of very stiff sandy lean clays. These soils are not expected to experience significant shrink and swell movement caused by seasonal change in water contents.

5.3 Groundwater Conditions

The borings were drilled using a flight auger (dry method) to better assess the groundwater conditions. Ground water was not encountered during drilling operations.

There are several factors that may potentially cause groundwater fluctuations. These factors include seasonal rainfall quantity in the area, the presence of wells near the site, the relative location (upstream or downstream) and proximity of the site to any bayous or streams.

Accurate groundwater measurements can be measured only using piezometers or monitor wells. Piezometer installation was beyond the scope of this project.

The groundwater level should be verified before drilled piers excavation and the commencement of utility construction.

5.4 Potential Settlement and Erosion of Top Soils (Landscape/Flatwork)

Low plastic/cohesion-less soils were encountered at top ten (10) feet at both borings during drilling operations. Less permeable sandy lean clays underlie the permeable silty sands. During inclement (rainy) weather, rainwater permeates through these silty sands and ponds on top of the lean clays, and creates a perched (trapped) groundwater condition.

Perched water tends to soften the lean clays underlying the silty sands, and severely undermines the slab integrity and can result in premature slab failure.

One of the options listed below should be utilized to mitigate the perched groundwater effects in the slab areas during inclement rainy weather (at least top 2-feet):

1. Mix with onsite sandy clay to make final plasticity index in between 10 to 20 (10<PI<20).

2. Chemically stabilize the existing silty sands with 2% lime and 8% fly ash.

3. Positive site drainage should be maintained throughout the lifespan of the structure(s).

6.0 ANALYSIS AND RECOMMENDATIONS

6.1 General

In order to assure a satisfactory foundation performance, foundations should be designed to fulfill the following requirements:

- The imposed structural loads should not exceed the allowable bearing capacity

- The potential total settlement and differential settlement are within tolerable limits of the structure, and

- The potential soil heave is within tolerable limits of the structure.

Foundation design recommendations are presented in the following paragraphs.

6.2 Foundation Types and Associated Risks

Construction of lightly loaded structures is challenging for engineers, architects, developers, and builders. It is our experience that economic considerations usually govern the choice of foundation systems and the associated risks. There are associated risks with all of the foundation systems. However, in general, risks decrease as the cost of the foundation system increases. The foundation systems listed below are commonly used in the Houston and Gulf Coast area for residential projects. *These foundation systems can be used to support the proposed structures. It should be noted that the first option is the least risky while the floating slab (Options 2 and 3) is more risky.*

(1) Drilled Shafts/Piers with a Structural Slab: This type of foundation consists of drilled straight shafts with a structural (self-supporting) slab. A minimum crawl space of six (6) inches should be used beneath the slab and grade beams. *This foundation system entails the least amount of risk because the slab is isolated from the on-site soils.* In the event that the structural slab is used, there will be no need to import any fill to the site.

(2) Drilled Shafts/Piers with a Slab on-Fill/Slab on-grade: **This type of foundation system can be utilized if and only if at least two (2) feet of silty sands are removed and replaced with select structural fill.** This type of foundation consists of drilled and under-reamed piers (bell-bottoms) with a slab-on-fill floor system. In our experience, we have found that properly designed and constructed drilled piers incorporating a slab on-fill floor system function very well in the Houston area, provided certain techniques are implemented. These techniques include maintaining positive drainage (drainage away from the foundation) around the structure and controlling vegetation and tree growth near the structure. Both of these techniques need to be utilized throughout the life of the structure. The Owner, the Architect, the Structural Engineer, the Project Manager, and the Civil Engineer should note with full knowledge that the slab-on-fill floor system may experience differential movements during its life due to changing environmental conditions at the site, including but not limited to altered drainage patterns, sewer leakages, and the addition or removal of trees and shrubs.

(3) Stiffened Slab on-Grade: **This type of foundation system can be utilized if and only if at least two (2) feet of silty sands are removed and replaced with select structural fill.** This type of foundation is typically used for residential projects, including subdivisions and specification houses. This type of foundation is extensively used by homebuilders in the greater Houston metropolitan area. Since these stiffened slabs are supported directly on-grade, they tend to be more sensitive to environmental conditions, such as drainage patterns, trees, and shrubs. Stiffened slab foundations may experience distress ten (10) to fifteen (15) years after they are built if drainage patterns are altered and/or if trees are added or removed from the immediate vicinity of the structure. The slab on-grade system is more prone to distress if the moisture conditions are altered due to negative drainage (drainage toward the slab area), rain, plumbing leakage and/or exposure to external sources of moisture.

6.3 Drilled Straight Shafts/Piers

Based on the subsurface conditions, the most suitable foundation system for support of the proposed structures is drilled straight shafts or piers. Groundwater was not encountered during drilling operations. Foundation recommendations are presented as follows:

Type of Foundation	Depth Below Existing Grade (feet)	Allowable Bearing Capacity (psf) Dead Plus Sustained Live Load Factor of Safety = 3	Allowable Bearing Capacity (psf) Maximum Net Load Factor of Safety = 2
Drilled straight Shafts	12(1)	3,500	5,250
Drilled Piers with Casing	14	4,000	6,000

Notes:

1. **Ground water was not encountered during drilling operation on 11/25/2014. However, in general groundwater table may fluctuate with seasonal rainfall, and proximity of the job site to a bayou or to a stream or a lake.**

2. **At least four (4) test piers should be performed prior to installation of production piers to verify the soil stratigraphy, depth of current ground water level and constructability of the drilled and under-reamed piers**

3. **Casing or slurry method of installation should be utilized during construction if holes are caving in.**

4. Final grade elevation is not available at this time.

As mentioned earlier, drilled straight shafts should be designed to resist both axial and uplift loads. Uplift pressures are applied at the perimeter of the pier. We recommend designing the straight shafts to resist uplift adhesion stresses of 1,300 psf along the upper eight (8) feet of the shaft length. We recommend that each pier be sufficiently reinforced throughout the full length of the shaft to prevent any cracks that may result from the tensile stresses induced by the expansive clays.

We recommend that each footing be sufficiently reinforced throughout the full length of the shaft to prevent any cracks, which may result from the tensile stresses induced by the expansive clays.

Soil stratigraphy and groundwater level may vary within the proposed construction site. Therefore, we recommend installing four (4) corner piers before foundation construction begins to verify the groundwater level and soil stratigraphy. The depths of the other straight shafts may be adjusted accordingly.

6.4 Potential Floor Slabs Associated with Straight shafts/Piers

6.4.1 Structural Slab

Based on the existing soil conditions, a structural floor system with a 6-inch void/crawl space is the most suitable for the structures.

Foundation recommendations and associated risks were discussed in previous paragraphs. ***The structural slab usually entails the least risk because it is isolated from the on-site soils.*** If a structural (suspended) floor system is selected, structural fill will not be required to reduce the Potential Vertical Rise (PVR).

6.4.2 Slab on-grade/Slab on-fill

Although the use of a structural slab is strongly recommended due to the isolation of the slab from the on-site soils, a foundation system incorporating drilled piers with a slab on-fill can be used for this project. Foundation recommendations and associated risks were discussed in previous paragraphs.

The structural slab usually entails the least risk because it is isolated from the on-site soils. However, we understand the cost of such a system is usually cost prohibitive if the area of the slab is large.

Slabs supported on compacted fill have been successfully used in the Houston and Gulf Coast area. This option is usually economically feasible and can be effective if used with positive drainage and vegetation and tree control. Positive drainage entails directing the rainwater away from the structure and not allowing the water to pond or collect near the structure throughout its lifespan.

The potential of a soil to heave is critical in determining the amount of fill necessary for a slab on-fill system. The potential soil heave was estimated using the Potential Vertical Rise (PVR) method. The PVR method was a result of extensive research by the Texas Department of Highways and Public Transportation in 1971 and 1972. Based on this method (TDHPT Method TEX-124-E), PVR was estimated with different fill thickness. A graph showing the potential heave for the amount of fill added above grade is presented below. The points on the y-axis show the amount of heave that the soil would experience if no structural fill were to be added above the existing grade. The graph displays results for the following soil conditions:

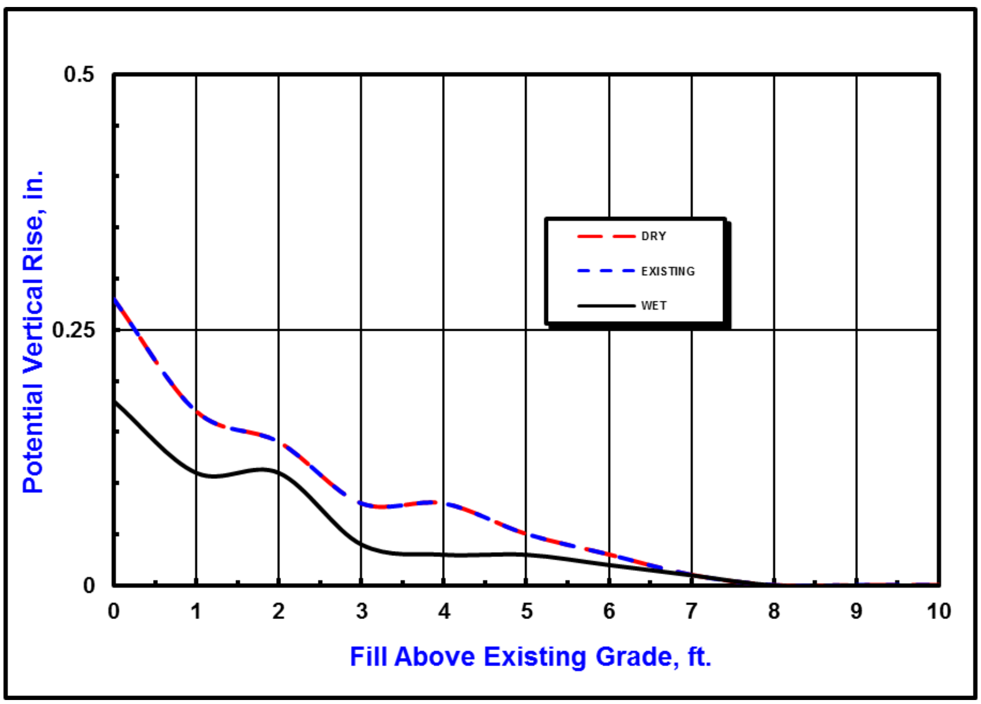
- Existing moisture in the field during the time of drilling on 11/25/2014
- Wet moisture conditions (lower bound envelope) during prolonged rainy season
- Dry moisture conditions (upper bound envelope) during prolonged drought

In order to quantify the risk involved due to expansive soils, Earth Engineering developed a unique in-house program called "**PVR CALC"**. The program is written in Visual Basic code for Windows and uses the TEX-124-E method to compute the Potential Vertical Rise (PVR). The table below shows the input data for the PVR analysis. Four layers were used in the analysis, each two feet thick.

Depth, feet	LL (%)	PL (%)	PI (%)	Existing W (%)	Moisture Condition
0-2	23	15	8	6	Dry
2-4	22	14	8	6	Dry
4-6	25	15	10	6	Dry
6-8	30	16	14	6	Dry

LL: Liquid Limit, PL: Plastic Limit, PI: Plastic Index, W: Moisture Content

The graph below shows the results of the PVR analysis for the soil conditions displayed in the table above. The graph shows the relationship between the amount of fill added above grade and the corresponding value for the PVR. As the amount of structural fill added above grade is increased, the PVR decreases. The points directly on the y-axis show the amount of heave that the on-site soils would experience if no structural fill were to be added above the existing grade.



Note:

1. Potential Vertical Rise (PVR) is a function of the Plasticity Index (PI) and the moisture content of the soils. While plasticity index of the soil is constant, the moisture content varies depending on seasonal rainfall quantity, presence of trees in the vicinity as well as site drainage

2. The site condition was dry, hence the curves for existing moisture condition matches with curve with dry moisture condition.

The general acceptable practice in Houston and the surrounding area is to limit the PVR to one inch or less. The amount of fill required to limit the PVR to one inch can lower the risk of heave to an acceptable level. The one (1) inch tolerable (design) heave is a serviceability index only.

Foundation movements resulting from potential vertical rise (PVR) of one (1) inch or less do not account for the movement criteria required by the owner or occupants of the facility. The operational performance criteria may often be more restrictive than the structural criteria of one (1) inch of PVR. If a more stringent criterion is required of less than one (1) inch of PVR; Earth Engineering should be contacted to revise the recommendations to fit the new movement criteria.

In past projects, the author of this report has observed cracks in slabs that were caused by a heave of about one-fourth (1/4) inch. However, a combination of a sound structural design coupled with sound construction methods, proper drainage, and proper maintenance will reduce the possibility of heave.

The amount of fill required depends primarily on the tolerable slab heave “PVR”. The structural engineer, in collaboration with the owner’s representative, should discuss the costs and risks involved based on the tolerable PVR and amount of fill required to mitigate the heave based on the above graph.

Either the existing or dry condition curve can be used to estimate the amount of heave. The PVR for the site is estimated to be 0.28 inches for dry moisture conditions and for existing moisture conditions respectively. Remedial action will not need to be taken to reduce the PVR to an acceptable level as the estimated PVR is less than one (1) inch.

However, as previously stated at least two (2) feet of existing silty sand from foundation area should be removed and replaced with select structural fill compacted to 95% of proctor density.

We highly recommend over-excavating the existing silty-sands at the site from the foundation areas and replacing these soils with on-site lean clays/structural fill (12<PI<20). The replacement lean clay/fill should extend a minimum of five (5) feet away from the structure on all sides. A layer (20”) of fat clay (PI>30) should be placed on all sides at the interface between the lean clay/ structural fill and the existing soils to protect the foundation from seepage of water from the neighboring silty sands/silty sandy clays.

In the event that the foundation fill soils are not protected by the clays, seepage of rainwater will occur from the silty sands. Migration of water toward the foundation elements can soften the soils supporting the foundation and slab and can undermine the overall stability and performance of the foundation elements. Problems arising from perched water conditions include excessive settlement, tilt, and possible bearing capacity failures.

The fill soils placed (if needed) on the site should consist of low plasticity sandy clays with plasticity indices (PI's) ranging between 12 and 20. Sands, or silts, are not considered fill and, therefore, should not be used in lieu of sandy clays. The fill soils should be placed in loose eight (8) inch lifts and compacted to 95% of the maximum density as determined by ASTM D-698. The moisture contents of the structural fill should be within a ± 2 percent of the optimum moisture content.

The floor slab should be installed as soon the structure pad is prepared. The slab should be protected from inclement weather at all times by providing proper drainage and placing plastic sheeting on top of the slab. If the structure pad is left exposed to rainfall, perched groundwater conditions may develop which will undermine the integrity of the floor slab. Therefore, the floor pad should be covered with a plastic sheet, if the floor slab is not placed immediately.

In the event that the floor slab is not installed as soon as pad is prepared, the in situ slab densities must be retested at several locations within the slab areas prior to slab placement. All densities must be at least 95% of the maximum dry density and the optimum moisture contents should be with ±2% of the optimum moisture content. If the densities fail, then the deeper layers must also be retested. All the failed areas must be excavated, aerated or chemically stabilized, than placed in eight (8) inch loose lift and re-compacted to 95% of maximum dry density and within ±2 of optimum moisture content.

All trenches (sanitary, water, cable, electrical) should be properly backfilled and compacted to 95% of the maximum dry densities. Sand or other permeable materials should not be used as backfill. Improperly backfilled and improperly compacted trenches, if left exposed, can also lead to the development of perched groundwater conditions. In general, perched water tends to be trapped within the fill. The trapped groundwater tends to soften the subgrade. The excess moisture promotes clay expansion (heave) which may be a detriment to the integrity of the slab foundation and structure. Positive drainage should be maintained across the entire structure pad.

Clay plugs must be utilized at the entrance and exit of all pipes under the building area to prevent water intrusion into the slab bedding soils. Plumbing leak tests should be performed periodically to detect any leaks within the system.

6.5 Grade Beams Associated with Drilled Shafts/Piers

We recommend extending the exterior and interior grade beams to a depth of 24 inches below the final grade at the site. A system of grade beams should be incorporated in the design of the slab. The number and the dimension of the grade beams are left to the discretion of the structural engineer.

The project team (Architect, Structural Engineer, Project Manager, Contractor and the Owner) must recognize that poor drainage, plumbing leakages, sanitary sewer leakages, and sprinkler systems around the structures are potential sources of moisture that could easily migrate under the exterior grade beams into the slab area. This type of excess moisture promotes clay expansion (heave), which may be detrimental to the integrity of the slab, foundation, and structure.

6.6 Flatwork

Flatwork (such as sidewalks, ramps etc.) outside the residence areas will be sensitive to movement; therefore, subgrade preparations should be implemented in a similar fashion as for slab area. Proper preparation of the flatwork subgrade will help in minimizing differential movements between the residence(s) and the flatwork adjacent to the residence(s).

If the flatwork subgrade is not installed in a manner similar to the residence slabs, these areas will be susceptible to post-construction movements (larger PVR values), which may then result in reversed drainage patterns that direct run-off towards the structure(s).

6.7 Lifetime Maintenance and Construction Considerations

6.7.1 Site Drainage

The site should be graded in such a manner as to channel all rainwater away from the structure(s). Water should not be allowed to pond around the structure(s). Positive site drainage will reduce the exposure of the on-site clays to moisture, thus eliminating potential swelling of the on-site clays.

The exposed, unpaved ground should be sloped away from the structure(s) at a minimum grade of 5% and should extend at least 10 feet beyond the perimeter of each residence upon completion of construction and landscaping. We recommend verifying the final grades to ensure that effective drainage has been achieved

The grading around the structure(s) should be periodically inspected and adjusted as necessary, as part of the maintenance program. Positive site drainage should be maintained throughout the lifespan of the structure(s).

6.7.2 Plumbing

Installing a watertight plumbing system is critical to the success of a foundation. Water leakage due to poor plumbing will have detrimental effects on the performance of the structure(s) and foundation(s). Clay plugs must be utilized at the entrance and exit of all pipes under the building area to prevent water intrusion into the slab bedding soils. Plumbing leak tests should be performed periodically to detect any leaks within the system.

6.7.3 Roof Gutters and Downspouts

Roof gutters should be utilized to direct roof runoff away from the structure(s). Downspouts should not be allowed to discharge near the structure(s). Downspout extensions should be used to facilitate rapid rainwater discharge away from the structure(s). Ideally, the downspouts should be directly connected to the storm sewer system.

6.7.4 Presence of Trees near the Structure(s)

Trees should be planted a distance away from the structure(s) equivalent to the anticipated height of the mature tree. Tree roots are continually growing and seeking new moisture sources. Trees are capable of withdrawing large quantities of water from the soil, which causes a net volume reduction in the soil matrix. The decrease in water volume within the soil matric can result in excessive settlement. Additionally, if existing trees are removed from an area, heave may occur due to the reallocation of moisture within the soil matrix. This process is known as moisture equilibration and may take as long as ten (10) years.

In general, the drying effects of a tree impact a circular area radiating outwards from the base of the tree with a radius roughly equal to the height of the mature tree. Thus, all trees should be a planted away from the structure(s) at a minimum distance that is equal to the maximum anticipated tree height. If trees are planted in close proximity to the structure(s), the roots will extend below the slab areas and cause distress to the slabs. Root barriers should be constructed around the perimeter of the residence(s) in the event that trees are located a distance away from the structure(s) that is less than the maximum anticipated height of the mature tree. Root barriers should extend at least seven (7) feet below grade.

6.7.5 Landscaping

Landscaping and irrigation should be minimized as much as possible around the structure(s). Plants located within 10 feet of the structure(s) should be self-contained to prevent water from infiltrating into the subgrade soils located beneath the each residence and pavement. The sprinkler mains and spray heads should be installed at a minimum distance of 7-10 feet away from the building lines. Low volume, drip-style irrigation systems should not be used in the vicinity of the residences.

6.7.6 Structural Design Considerations

The floor slabs should be provided with a moisture barrier to prevent migration of the capillary moisture through the slab. Fifteen (15)-mill Visqueen can be used.

7.0 STIFFENED SLAB ON-GRADE

Please note that the existing top two (2) feet of silty sand should be excavated and replaced with the select structural fill compacted to 95% of the maximum proctor density.

The actual soil stratigraphy throughout the lot may be different than that encountered during drilling operations. If the soil encountered consists of deleterious materials or concrete debris or soft organic soils, it is highly recommended to remove these materials and replace with select fill compacted to 95% of the maximum dry density.

It should be noted the following post-tensioned slab design parameters were obtained from the third edition of *Design of Post-Tensioned Slabs-on-Ground* (Post-Tensioning Institute, 2008). The conventional slab on-grade design parameters were based on the 1968 BRAB design manual entitled "Criteria for Selection and Design of Residential Slabs on Ground".

The third edition of this design guideline contains a major change in the method for calculating geotechnical parameters. One of the most significant geotechnical changes is in the determination of the edge moisture variation distant e_m. In previous editions, e_m was primarily related to climatic conditions expressed in the terms of the Thornthwaite Moisture Index. In this edition, e_m is related to both climatic conditions and actual soil properties. Program VOLFLO 1.5 is utilized to analyze geotechnical parameters for the slab-on-grade foundation. VOLFLO 1.5 was developed by Geostructural Tool Kit, Inc following the third edition of the PTI design manual.

The differential soil movement (y_m) was estimated using the Software of VOLFLO 1.5. VOLFLO 1.5 was developed by Geostructural Tool Kit, Inc following the third edition of the PTI design manual. The differential soil movement (y_m) was predicted based on the following soil conditions table. It should be noted that the following input parameters for VOLFLO 1.5 are obtained from the lab testing results along with our engineering experience.

Depth, feet	LL, %	PL, %	PI, %	% Passing #200 Sieve	% Finer than 2 Microns
0-4	24	15	9	49	22
4-8	31	16	15	55	23

LL: Liquid Limit, PL: Plastic Limit, PI: Plastic Index, W: Moisture Content

Below is a summary of design parameters that can be used to design the post-tensioned slab foundation or the conventional slab-on-grade. It should be noted that the post-tensioned slab design parameters were obtained from the Post – Tensioning Institute (PTI) design manual, 2008 edition.

Minimum Embedment Grade Beam Depth[(1)]	24 Inches embedded into the natural soil or compacted fill
Minimum Grade Beam Width	12 Inches
Allowable Net Bearing Capacity[(2)] Dead Load + Sustained Live Load Total Load (Dead + Live)	 600 psf for Existing Silty Sand and 1,000 psf Compacted Structural Fill[(3)] 900 psf for Existing Silty Sand and 1,500 psf Compacted Structural Fill[(3)]
Depth to Constant Suction	7 feet
Constant Suction Value	3.3 pF
Thornthwaite Index	20
Velocity of Moisture	0.7 in/month
Edge Moisture Variation, e_m Edge Lift Center Lift	 4.9 feet 9.0 feet
Differential Swell, y_m Edge Lift Center Lift	 0.95 Inches 0.68 Inches
Type of Clay	Montmorillonite
Percent Fine Clay	45
Effective Plasticity Index (PI)	20
Minimum Fill Undrained Shear Strength	1,000 psf
Slab Subgrade Coefficient Slab on Sand Bedding Sand on Polyethylene over Sand	 1.00 0.75
Climatic Rating, C_w	25
Soil Support Index, C	0.75

Notes:

(1) Grade beams should be embedded at least 24-inches into the natural soil or compacted fill soil

(2) Bearing capacity is based on the assumption that the existing top soil is either stiff to hard natural soil or added select structural fill compacted to 95% of maximum dry density (ASTM D 698).

The slab on grade system is more prone to distress if the moisture conditions are altered. Causes of altered moisture conditions include negative drainage (drainage toward the slab areas), rain, plumbing leaks, and any other general exposure to external sources of moisture. Since these stiffened slabs are supported directly at-grade, they tend to be more sensitive to environmental conditions such as drainage patterns, trees, and shrubs.

Trees should be planted a distance away from the structure(s) equivalent to the anticipated height of the mature tree. Tree roots are continually growing and seeking new moisture sources. Trees are capable of withdrawing large quantities of water from the soil, which causes a net volume reduction in the soil matrix. The decrease in water volume within the soil matric can result in excessive settlement. Additionally, if existing trees are removed from an area, heave may occur due to the reallocation of moisture within the soil matrix. This process is known as moisture equilibration and may take as long as ten (10) years.

In general, the drying effects of a tree impact a circular area radiating outwards from the base of the tree with a radius roughly equal to the height of the mature tree. Thus, all trees should be a planted away from the structure(s) at a minimum distance that is equal to the maximum anticipated tree height. If trees are planted in close proximity to the structure(s), the roots will extend below the slab areas and cause distress to the slabs. Root barriers should be constructed around the perimeter of the residence(s) in the event that trees are located a distance away from the structure(s) that is less than the maximum anticipated height of the mature tree. Root barriers should extend at least seven (7) feet below grade.

8.0 CONSTRUCTION CONSIDERATIONS

8.1 Site Preparation

The following recommendations are applicable to slabs, driveways, pavements and any structures that are supported directly on-grade.

- Soft soils should be removed until firm soil is reached. The soft soils can be aerated and placed back in eight-inch loose lifts and compacted to 95% as specified by ASTM D-698.

- Tree stumps, tree roots, and any existing structures and pavement should be removed from the site area. If the tree stumps and roots are left in place, settlement and termite infestation may occur. Once a root system is removed, a void is created in the subsoil. We recommend filling these voids with structural fill or cement-stabilized sand and compacting the material to 95% as specified by ASTM D-698.

- The presence of organic material varies from site to site, but organic material is often found at depths ranging from 2 to 2.5 feet below the existing grades. All organic materials should be scarified and removed prior to subgrade preparation.

- **Any low-lying areas (including ravines, ditches, swamps, etc.) should be filled with structural fill placed in eight-inch lifts**. Each lift should be compacted to 95% of the maximum dry density as specified by ASTM D-698.

- The exposed subgrade should be scarified to a minimum depth of six (6) inches in the driveway and slab area. The subgrade should then be compacted to 95% of the maximum density as determined by the Standard Moisture Density Relationship (ASTM D-698). A sheep-foot roller should be utilized to compact the fill soils. A smooth-drum compactor should then be utilized to seal the compacted fill. In the event that the upper six-(6) inches cannot be compacted due to excessive moisture, we recommend that these soils be excavated and removed or chemically stabilized to provide a firm base for fill placement.

- Proof rolling should be performed using a heavy tired loaded truck or pneumatic rubber-tired equipment weighting about 15 to 20 tons.

- The fill soils placed on the site should consist of low plasticity sandy clays with plasticity indices ranging between 12 and 20.

- Sands or silts are not considered fill and therefore, should not be used in lieu of sandy clays.

- The fill soils should be placed in loose eight-inch lifts and compacted to 95% of the maximum density as determined by ASTM D-698.

- The floor slab should be placed as soon as possible after the building pad is prepared. If the building pad is left exposed to rainfall, perched groundwater conditions may develop which will undermine the integrity of the floor slab. All trenches (sewer, water, cable, electrical) should be properly backfilled and compacted to 95% of the maximum dry densities. Sand or permeable materials should not be used as backfill. Improperly backfilled and improperly compacted trenches, if left exposed, can result in perched groundwater conditions at the site. Perched groundwater conditions are highly undesirable and result in softening of the subgrade which undermines the stability of the foundation. Positive drainage should be maintained across the entire building pad to prevent perched water conditions from arising.

- A qualified soil technician should monitor all earthwork operations. Field density tests should be conducted on each lift using a nuclear density gauge. The gauge should be calibrated every day.

- Prior to field density tests, a 50-pound sample from the subgrade soils should be obtained. A similar sample should be obtained from the fill soils. A Standard Moisture Density Relationship (ASTM D-698) should be performed on each sample in order to obtain optimum moisture content and a maximum dry density. The field density tests should be compared to these results every time the soils are tested in the field.

8.2 Site Drainage

The site should be graded in such a manner as to channel all rainwater away from the structure(s). Water should not be allowed to pond around the structure(s). Positive site drainage will reduce the exposure of the on-site clays to moisture, thus eliminating potential swelling of the on-site clays.

<u>The exposed, unpaved ground should be sloped away from the structure(s) at a minimum grade of 5% and should extend at least 10 feet beyond the perimeter of each residence upon completion of construction and landscaping. We recommend verifying the final grades to ensure that effective drainage has been achieved.</u>

The grading around the structure(s) should be periodically inspected and adjusted as necessary, as part of the maintenance program. Positive site drainage should be maintained throughout the lifespan of the structure(s).

8.3 As Built Survey Elevations

It is highly recommended to measure elevations of the existing slab, top and bottom of the pool and surrounding areas (if any). Also establish a benchmark elevation for future reference.

8.4 Straight Shaft Installation

Drilled shaft foundations should be augured and constructed in a continuous manner. Concrete should be placed in the shaft excavations immediately following drilling and evaluated for proper bearing stratum, embedment, and cleanliness. In general, drilled shaft installation should conform to the Texas Department of Transportation Item 416.

<u>**In order to keep *the shaft excavation open, either the casing or slurry method of construction should be used for foundations.***</u>

In the event that the slurry method is used, the slurry should consist of commercial bentonite mixed with water. The slurry should be mixed in a large mixing tank adjacent to the excavation. Mixing of the slurry in the shafts is not permitted. The slurry should conform to the following requirements:

Bentonite Content (percent by weight):	2% to 8%
Specific Gravity:	1.02 to 1.15
Viscosity (500 ml funnel):	40 seconds maximum
Sand Content:	10% maximum

For foundations constructed with drilling mud, a visual inspection is not possible. A check on verticality of the shaft should be made to the full depth of dry augering prior to introducing drilling mud. Typically, problems with verticality develop early in the shaft excavation process and can be corrected before the drilling mud is introduced. When the straight-sided shafts are completed to full depth with drilling mud, the bottoms should be probed and sounded before concreting.

The shaft bottoms should be cleaned with a "clean-out" bucket until rotation on the bottom without crud produces little spoil. A final probing after this cleaning operation is essential for shafts that are drilled using the slurry method. Following inspection, the foundation excavation may be filled with concrete placed through a tremie pipe or by pumping. The tremie pipe diameter should be at least as large as eight times the largest concrete aggregate size.

The use of high slump concrete (6"-9" slump) is recommended for placement in slurry conditions. A computation of final concrete volume for each foundation should be made. Shafts exhibiting either excessively high or significantly low volumes of concrete should possibly be cored.

In order to prevent contamination of concrete with slurry during concrete placement using the tremie method, it is recommended to seal the bottom of the tremie with a plug before the tremie is placed in the wet excavation.
Shafts should not be allowed to remain open for an extended period or overnight. If shaft excavation and backfilling with concrete cannot be completed the same day, the shaft should be backfilled with excavated soils and re-excavated when excavation and concrete placement can be completed on the same day.

9.0 DESIGN REVIEW

EARTH ENGINEERING, INC. should be given the opportunity to review the construction design documents prior to release for bid to assure that our recommendations are interpreted as intended in our report. If we are not given the opportunity to review the final documents, EARTH ENGINEERING, INC. will not be responsible for misinterpretations of our recommendations by other parties. The design review is not part of our scope of work and would be an additional charge.

10.0 LIMITATIONS

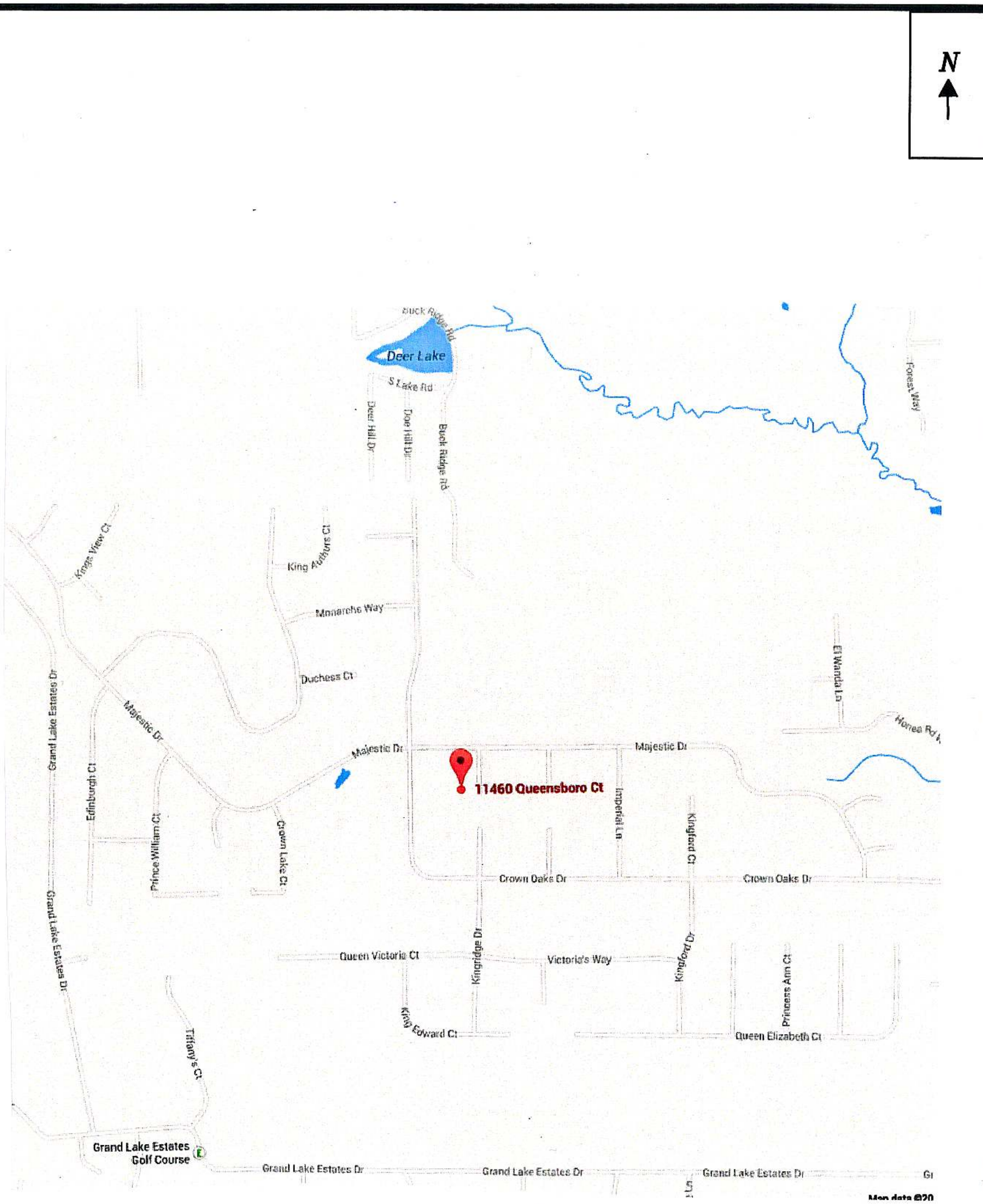
Our site exploration was based on two (2) borings at select locations. Soil stratigraphy may change within the site. In the event that different soil conditions are encountered in the field, EARTH ENGINEERING, INC. should be immediately notified. It should be noted that fault study is not within the scope of work. This study was performed in accordance with generally accepted geotechnical engineering practices for design purposes only under the supervision of a licensed professional engineer in the State of Texas. Foundation recommendations presented herein are valid for one (1) year from the date of the report. After one (1) year, Earth Engineering, Inc. should be contacted to verify the validity of the recommendations prior to construction.

In the event that any changes in the nature, design, or location of the proposed residence are made, the conclusions or recommendations presented in this report are not valid until the changes are reviewed by EARTH ENGINEERING, INC. and the conclusions and recommendations are modified in writing.

11.0 CONSTRUCTION MATERIALS TESTING

Quality control (QC) is extremely important in the construction industry. A quality control program should be initiated at the beginning of the project. The program should be designed by an accredited laboratory to cover all stages of construction from the ground up. EARTH ENGINEERING, INC. would be pleased to provide you with a proposal for these services:

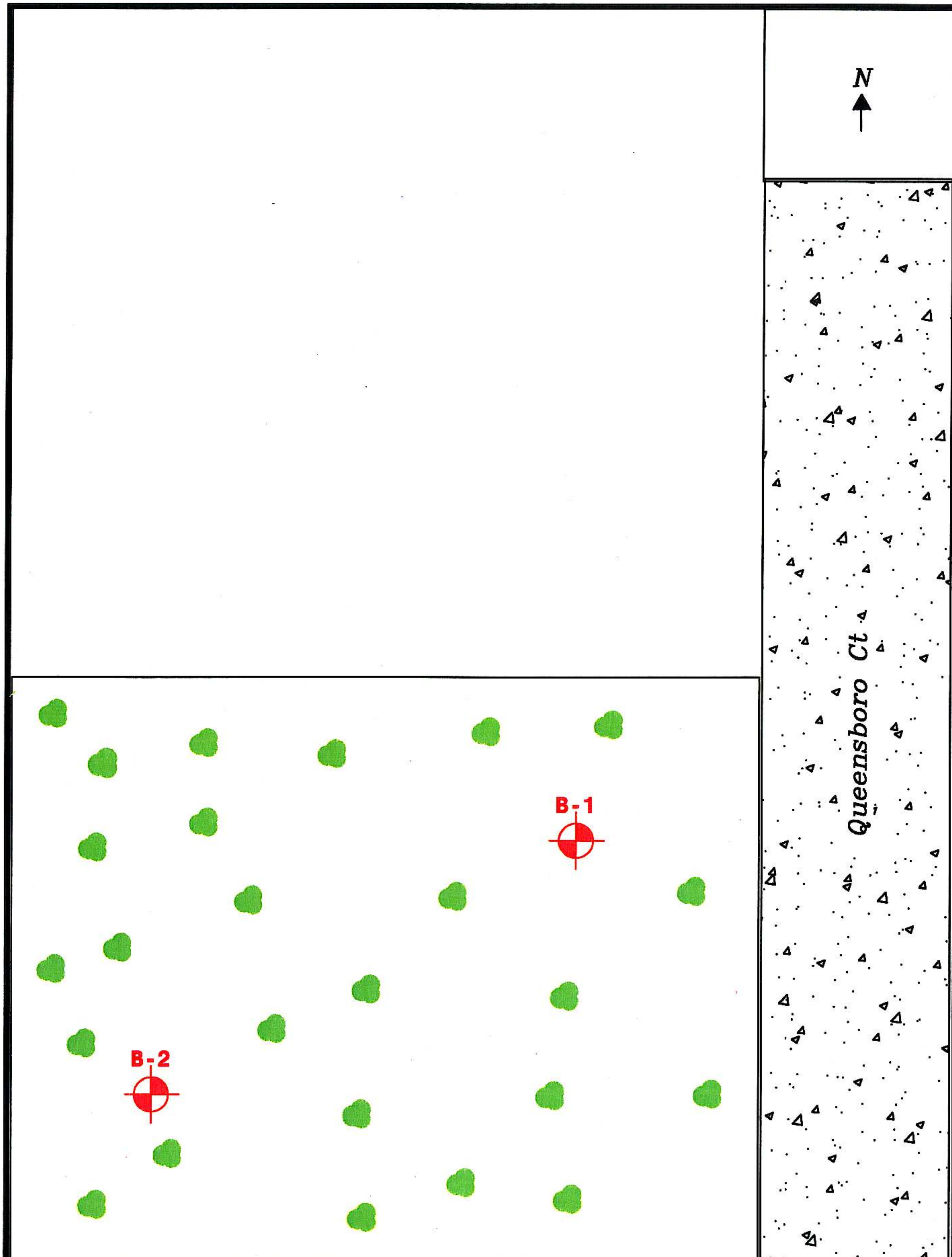
- Soil Compaction (fill under-slab, utility backfill, etc.)
- Soil Stabilization (lime or lime/fly-ash)
- Foundation Inspection and Monitoring (drilled piers, drilled shafts, auger cast piles, spread footings, driven piles and spread footings)
- Concrete Inspection & Monitoring
- Rebar Inspection
- Structural Steel Welding Visual Inspection and Non-Destructive Testing
- Fire-Proofing Inspection
- Floor Flatness
- Maturity Probes and Thermocouplers to Measure Concrete Temperature and Strength



A–Site Address

Site Locaiton Map	**EARTH ENGINEERING, INC.** *Geotechnical, Materials and Environmental Consultants*	
Proposed Residence 11460 Queensboro Ct. Montgomery, TX	*SCALE: N.T.S.*	*DATE: 11/25/14*
	PROJECT: EE–1432111–G	*DWG. 001*

Plate No. 1



Boring Locaiton Map	**EARTH ENGINEERING, INC.** *Geotechnical, Materials and Environmental Consultants*	
Proposed Residence *11460 Queensboro Ct.* *Montgomery, TX*	*SCALE: N.T.S.*	*DATE: 11/25/14*
	PROJECT: EE-1432111-G	*DWG. 002*

Plate No. 2

LOG OF BORING B-1

PROJECT: Proposed Residence at 11460 Queensboro Ct. in Montgomery, TX **ELEVATION:** Existing

BORING LOCATION: See Plate 2 **CLIENT:** Tile Roofs of Texas, Inc. **PROJECT NUMBER:** EE-1432111-G

DEPTH/ ELEVATION (feet)	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	MAX. DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)
0	Loose, brown SILTY SAND with ferrous nodules and roots fibers from 0-4 feet	SM			6				NP			
	--light brown from 2-6 feet		4									
5			5		6				NP			
	--brown gray from 6-8 feet		8									
	--medium dense from 8-10 feet		15		6							
10	Very stiff, reddish brown SANDY LEAN CLAY with sand seams below 10-feet	CL	21									
	--light gray red from 13-15 feet		34		11							
15												
	--reddish from 18-20 feet		33									
20	Boring terminated at 20 ft.											
25												
30												

EARTH engineering, inc.
down to earth solutions for your complex projects

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry ▼ **Final:** Dry

DATE DRILLED: 11/25/14

DRILLER: Ricardo

PLATE NO. 3

LOG OF BORING B-2

PROJECT: Proposed Residence at 11460 Queensboro Ct. in Montgomery, TX **ELEVATION:** Existing

BORING LOCATION: See Plate 2 **CLIENT:** Tile Roofs of Texas, Inc. **PROJECT NUMBER:** EE-1432111-G

DEPTH/ ELEVATION (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	MAX. DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)
0			Loose, dark gray brown SILTY SAND with ferrous stains and roots fibers from 0- 4 feet	SM										
			--brown from 2-4 feet		5		6							
5			--light brown from 4-6 feet		6									
			--medium dense, below 6 feet		11		6							
			--light gray from 8-12 feet		16									
10			Very stiff, reddish brown SANDY LEAN CLAY with sand seams below 10 feet	CL	21		11							
			--ferrous stains from 13-15 feet		38									
15														
			--reddish from 18-20 feet		28		11							
20			Boring terminated at 20 ft.											
25														
30														

EARTH engineering, inc.
down to earth solutions for your complex projects

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry ▼ **Final:** Dry

DATE DRILLED: 11/25/14

DRILLER: Ricardo

PLATE NO. 4

KEY TO LOG TERMS AND SYMBOLS

SOIL TYPE

ROCK | GRAVEL | SAND | SILT | CLAY | PEAT

MODIFIERS

STONE | GRAVELY | SANDY | SILTY | CLAYEY | FILL

SAMPLER TYPE

NO SAMPLE | AUGER SAMPLE | SHELBY TUBE | SPLIT SPOON

NO RECOVERY | ROCK CORE | 2" SHELBY TUBE | TXDOT CONE

UNIFIED SOIL CLASSIFICATION SYSTEM - ASTM D 2487

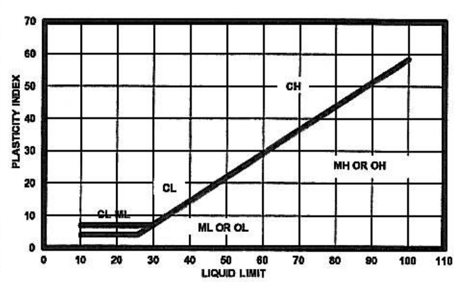
MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS LESS THAN 50% PASSING NO. 200 SIEVE	GRAVEL & GRAVELY SOILS LESS THAN 50% PASSING NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		W/ APPRECIATE-BLE FINES	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS,GRAVEL-SAND-CLAY MIXTURES
	SANDS MORE THAN 50% PASSING NO. 4 SIEVE	CLEAN SANDS LITTLE FINES	SW	WELL GRADED SAND, GRAVELY SAND (LITTLE FINES)
			SP	POORLY GRADED SANDS, GRAVELY SAND (L.FINES)
		SANDS WITH APPREA. FINES	SM	SILTY SANDS, SAND-SILT MIXTURES
			SC	CLAYEY SANDS,SAND-CLAY MIXTURES
FINE GRAINED SOILS LESS THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS & VERY FINE SANDS,ROCK FLOUR SILTY OR CLAYEY FINE SANDS OR CLAYEY SILT W/PI
			CL	INORGANIC CLAY OF LOW TO MEDIUM PI LEAN CLAY GRAVELY CLAYS, SANDY CLAYS, SILTY CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PI
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY FAT CLAYS
			OH	ORGANIC CLAYS OF MED TO HIGH PI, ORGANIC SILT
HIGHLY ORGANIC SOIL			PT	PEAT AND OTHER HIGHLY ORGANIC SOILS
UNCLASSIFIED FILL MATERIALS				ARTIFICIALLY DEPOSITED AND OTHER UNCLASSIFIED SOILS FILL MATERIALS

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNCONFINED COMP. STRENGTH IN TSF
VERY SOFT	0 TO 0.25
SOFT	0.25 TO 1.0
FIRM	1.0 TO 1.75
STIFF	1.75 TO 3
VERY STIFF	3.0 TO 4.5
HARD	4.5+

RELATIVE DENSITY - GRANULAR SOILS

CONSISTENCY	N-VALUE (BLOWS PER FT)
VERY LOOSE	0-4
LOOSE	4-9
MEDIUM DENSE	10-29
DENSE	30-49
VERY DENSE	> 50 OR 50+



CLASSIFICATION OF GRANULAR SOILS

U.S. STANDARD SIEVE SIZE(S)

Sieve: 6"	3"	3/4"	4	10	40	200		
BOUL- -DERS	COBBLES	GRAVEL		SAND			SILT OR CLAY	CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE		
152	76.2	19.1	4.76	2.0	0.42	0.074		0.002

GRAIN SIZE IN MM