GEOTECHNICAL EXPLORATION
FOR THE PROPOSED ASSISTED LIVING CAMPUS
LOCATED AT LAKEVIEW DRIVE
MISSOURI CITY, 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
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2001 Winner

Project No: EE-1227309-G

October 2, 2012

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Report No.: EE-1227309-G

Subject: **GEOTECHNICAL EXPLORATION FOR THE PROPOSED ASSISTED LIVING CAMPUS LOCATED AT LAKEVIEW DRIVE IN MISSOURI CITY, TX.**

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.

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1.0 INTRODUCTION

Planning is underway for construction of the proposed assisted living campus located at Lakeview Drive in Missouri City, Texas. The facility will consist of three buildings (Buildings I, II, and IV), parking areas, and drives.

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 ten borings: three (3) borings to a depth of 20 feet within the proposed building areas, (3) borings to a depth of 25 feet within the proposed building areas, four (4) borings to a depth of 5 feet within the proposed parking areas.

- For the 20-foot and 25-foot borings: obtain continuous soil samples to a depth of twelve (12) feet, and then at pre-designated intervals thereafter to the borings' termination depths.

- For the 5-foot borings: obtain continuous soil samples to a depth of five (5) feet

- 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).

- Perform 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.

- Utilize the results of observations both in the field and in limited laboratory tests to author a report that will include the following subjects:

    - Soil stratigraphy: soil encountered to a depth of 25 feet

    - Groundwater conditions and groundwater control during construction

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

- Recommend suitable foundation design options for the building
- Recommend slab on-grade design criteria, including the need for sub-grade replacement with fill or lime stabilization of the sub-grade
- Calculate the soil heave using the potential vertical rise (PVR) method
- Recommend whether structural slabs are required in lieu of slab on-grade
- Recommend construction considerations, as deemed necessary
- Recommend back-fill material specifications

Earth Engineering will incorporate all of the above 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 ten (10) borings. The borings were drilled by a truck-mounted drill rig. The boring locations are shown on Plate 2.

Samples in cohesive and semi-cohesive soils (clays, sandy clays, and silty clays) were obtained using a three-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 in aluminum foil and sealed for transport to the laboratory for 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	17
Moisture Content	ASTM D-2216	61
Materials in Soils Finer Than No. 200 Sieve	ASTM D-1140	8
Unconfined Compressive Strength of Cohesive Soils	ASTM D-2166	3

Laboratory test results are presented in the Logs of Borings, Plates 3 through 12. A Key to Log Terms and Symbols is presented in Plate 13. 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 Lakeview Drive between Eldridge Road and Gillingham Lane in Missouri City, Texas. Please refer to Plate 1 for a map designating the location of the site. At the time of drilling, the project site contained no existing structures. The site was covered in short grass and other vegetation. Numerous trees were scattered throughout the site.

Based on our visual observations during drilling operations, it appears that the site and the surrounding area exhibit topographic variations of less than two (2) feet. Surveying map with exi sting 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 ten (10) borings. Borings B-1, B-2, B-3, and B-4 were drilled in the proposed parking areas, while B-5, B-6, B-7, B-8, and B-9 were drilled in the proposed building areas (Buildings I, II, and IV). B-10 was drilled in the proposed dumpster pad area. Soil stratigraphy details are presented on the Log of Borings (Plates 3-12). **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 stratifications shown on each boring log represent the conditions and approximate boundaries between strata at that actual boring location only. <u>The actual transitions between strata may be gradual. Variations will occur and should be expected at locations away from each boring location.</u> 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	0-2 at B-1, B-3, B-4, B-6, B-7, B-8 0-8 at B-10	**FILL:** Soft to very stiff, dark gray/ dark brown and gray **FAT CLAY (CH)** with gravel, sand pockets, organic material, root fibers, and ash
II	2-5 at B-1, B-3, B-4 0-5 at B-2 0-25 at B-5 2-10, 13-25 at B-6, B-7 2-10, 13-20 at B-8 0-8 at B-9 8-20 at B-10	Firm to very stiff, dark gray/ reddish-brown/ light gray **FAT CLAY (CH)** with root fibers, ferrous nodules, calcareous nodules, and silt seams
III	10-13 at B-6, B-7, B-8 8-13 at B-9	Very stiff, reddish-brown **SANDY LEAN CLAY (CL)** with sand seams and calcareous nodules
IV	13-20 at B-9	Medium dense, tan **CLAYEY SAND (SC)**

*These stratum depths are based on measurements referenced from ground surface at the time of our drilling activities on September 10 and 11, 2012. Please note that the depths of the stratum changes vary; please refer to the boring logs presented on Plates 3-12 for stratum changes at specific locations.

The soils of Stratum I have been identified as existing fill. The fill soils were encountered at seven of the ten borings. At six of the borings, the fill soils extend from the surface to a depth of approximately two (2) feet below existing grades at the site. At B-10, the fill soils were encountered from the surface to an approximate depth of eight (8) feet below existing grades. The fill materials consist of fat clays with substantial amounts gravel intermixed. At B-10, ash was found mixed with the clay from four (4) to eight (8) feet. The fill soils are very stiff in consistency at B-1, B-3, B-4, B-6, B-7, and B-8, but range from soft to very stiff at B-10. These clays are high in plasticity, with plasticity indices ranging from 33 to 55. Structures supported on these materials may be susceptible to several problems. Please refer to Section 5.4 for more information on the existing fill.

Stratum II consists of fat clays. These clays are high in plasticity, with plasticity indices ranging from 40 to 67. These clays are expected to experience significant shrink and swell movements resulting from changes in moisture conditions. The consistency of these soils ranges from firm to very stiff.

Stratum III consists of sandy lean clays. These clays were only encountered at B-6 and B-9 and are moderate in plasticity, with a plasticity index of 28. These clays are not expected to experience significant shrink and swell movements resulting from changes in moisture conditions. However, some degree of shrink and swell movement is anticipated. These soils are very stiff in consistency.

Stratum IV consists of clayey sands. These sands were only encountered at B-9. These sands are medium dense, with an SPT 'N' value of 34.

5.3 Groundwater Conditions

The borings were drilled using a flight auger (dry method) to better assess the groundwater conditions. Groundwater was not encountered at any of the ten borings during drilling operations. Please refer to the boring logs presented on Plates 3-12 for more information.

Groundwater fluctuations in an area can be caused by several factors including 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 Existing Fill

Existing fill soils were encountered at seven of the ten borings. The fill soils consist of fat clays with gravel intermixed and were encountered at B-1, B-3, B-4, B-6, B-7, B-8, and B-10. Based on the limited number of borings performed, we estimate the fill materials to extend from the surface to approximately two (2) feet below existing grades at the site at six of the borings and from the surface to eight (8) feet below existing grades at B-10.

Boring B-10 was drilled in the proposed dumpster pad area at the site. From four (4) to eight (8) feet at B-10, the fill soils contained substantial amounts of ash and organic material. We suspect that this area was used as a burn pit for trees at some point in the past. The soils are soft and crumbly from four to eight feet.

No information is presently available as to the age, method of placement, compaction, origin, or exact extent and depth of these materials. However, these materials appear to be of high shear strength as indicated by their pocket penetrometer values.

If drilled piers incorporating a slab on-grade floor system is selected, then the recommendations outlined in section 6.4.2 for managing the on-site soils (i.e. removing or adding soils to reduce the PVR) will need to be followed along with the construction considerations presented in section 8.0.

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(s), and
- The potential soil heave is within tolerable limits of the structure(s).

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. *Due to differing subsurface conditions across the site, separate foundation recommendations will be given for the Building I, Building II and IV, and the dumpster pad.*

Foundation Options for Building I:

(1) Drilled Piers/Straight Shafts with a Structural Slab: This type of foundation consists of drilled and under-reamed piers (bell-bottoms) or drilled straight shafts with a structural (self-supporting) slab. A minimum crawl space of eight (8) inches should be used beneath the slab. *This foundation system is considered the least risky because the slab is isolated from the on-site soils.* The use of structural fill is not necessary if a structural slab is selected.

(2) Drilled Piers/Straight Shafts with a Slab-on-Fill: This type of foundation consists of drilled and under-reamed piers (bell-bottoms) or straight shafts with a slab-on-fill floor system. While this foundation system is less expensive than the first option, more risk is entailed compared to option one (1). In our experience, we have found that properly designed and constructed drilled piers or straight shafts 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.

Foundation Options for Building II and IV:

(1) Drilled Piers with a Structural Slab: This type of foundation consists of drilled and under-reamed piers (bell-bottoms) with a structural (self-supporting) slab. A minimum crawl space of eight (8) inches should be used beneath the slab. *This foundation system is considered the least risky because the slab is isolated from the on-site soils.* The use of structural fill is not necessary if a structural slab is selected.

(2) Drilled Piers with a Slab-on-Fill: This type of foundation consists of drilled and under-reamed piers (bell-bottoms) with a slab-on-fill floor system. While this foundation system is less expensive than the first option, more risk is entailed compared to option one (1). 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.

Foundation Options for Dumpster Pad:

(1) Stiffened Slab on-Grade: This type of foundation is typically used for residential projects, including subdivisions and specification houses. This type of foundation is used extensively 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 to fifteen 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 Foundation Recommendations for Building I

Based on the subsurface conditions, either drilled and under-reamed piers founded at a depth of twelve (12) feet or drilled straight shafts founded at a depth of sixteen (16) feet is the best foundation system to be utilized for support of Building I. Groundwater was not encountered at any of the ten borings during drilling operations. Foundation recommendations are presented as follows:

Foundation Type	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 & Underreamed Piers(1)	12	2,500	3,750
Drilled Straight Shafts(1)(2)	16	4,000	6,000

Notes:

1. Clayey sands were encountered at B-9 at a depth of 13 feet below existing grades.
2. The drilled piers/straight shafts should be founded at least two (2) shaft diameters measured center to center.
3. Either slurry method of construction or casing should be used to install the drilled straight shafts to prevent caving.
4. No existing surveying map or proposed final grading plan has been provided to Earth Engineering for the proposed structure.
5. The foundation recommendation are based on our assumption that the finished floor elevation (FFE) for the proposed structure will be at or near (within 1 to 2 feet of) the existing grade.

Soil stratigraphy and groundwater level may vary within the proposed construction site. Therefore, we recommend installing four (4) corner piers/shafts and two (2) center piers/shafts before foundation construction begins to verify the groundwater level and soil stratigraphy at the site. The depths of the other drilled piers or straight shafts may be adjusted accordingly.

6.4 Foundation Recommendations for Building II and IV

Based on the subsurface conditions, drilled and under-reamed piers founded at a depth of sixteen (16) feet is the best foundation system to be utilized for support of Building II and Building IV. Groundwater was not encountered at any of the ten borings during drilling operations. Foundation recommendations are presented as follows:

Foundation Type	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 and Underreamed Piers(1)	16	4,000	6,000

Notes:

1. The drilled piers should be founded at least two (2) shaft diameters measured center to center.
2. No existing surveying map or proposed final grading plan has been provided to Earth Engineering for the proposed structure.
3. The foundation recommendation are based on our assumption that the finished floor elevation (FFE) for the proposed structure will be at or near (within 1 to 2 feet of) the existing grade.

Soil stratigraphy and groundwater level may vary within the proposed construction site. Therefore, we recommend installing four (4) corner piers and two (2) center piers before foundation construction begins to verify the groundwater level and soil stratigraphy at the site. The depths of the other drilled piers may be adjusted accordingly.

6.5 Uplift Pressures from Expansive Soils

As mentioned earlier, drilled piers should be designed to resist both axial and uplift loads. Uplift pressures are applied at the perimeter of the pier/shaft. We recommend designing the drilled piers to resist uplift adhesion stresses of 1,200 psf along the upper eight (8) feet of the shaft length.

We recommend that each pier/shaft 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.

Uplift forces due to expansive soils can be estimated using the following equation:

$$Q_{uf} = 3.142 * Z_a * B_s * f_a \text{ ....(1)}$$

Where:

Q_{uf} = Uplift force due to swelling pressure, kips
Z_a = Depth of Active Zone, feet = 8 feet
Z_a = Depth of Active Zone, feet = 3 feet for paved areas and areas covered with slab
B_s = Shaft diameter, feet
f_a = Uplift adhesion stress, ksf = 1.2 ksf

<u>Uplift Capacity of Drilled and Under-reamed Piers</u>

The uplift capacity of a single drilled and under-reamed pier in clay can be estimated using the following equation:

$$Q_{u\,max} = [N_u * C + \gamma * D_b] * A_u + 0.5\, W_{DL}$$

Where:

Q_u = Maximum uplift capacity in kips
C = Average Shear Strength, kips per square foot (ksf) = 1.0 ksf (Safety Factor =2.0)
N_u = Bearing Capacity Factor for Uplift = $3.5 * (D_b / B_b)$
D_b = $L\text{-}Z_a$, feet
L = Length of Pier, feet
Z_a = Depth of Active Zone, feet = 8 feet; Z_a = 3 feet for paved areas and in slab areas.
B_b = Pier bell diameter, feet
B_s = Shaft Diameter, feet
γ = Design unit weight of soils = 120 pcf
A_u = $0.785 * (B_b^2 - B_s^2)$, square feet
W_{DL} = Dead Load on Column, kips

6.6 Potential Floor Slabs Associated with Drilled Piers and Straight Shafts

<u>6.6.1 Structural Slab</u>

Based on the existing soil conditions, a structural floor system with an 8-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).

6.6.2 Slab on-Fill

Although the use of a structural slab is strongly recommended due to the isolation of the slab from the expansive clay soils at the site, a foundation system incorporating drilled piers or straight shafts 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 structures and not allowing the water to pond or collect near the structures throughout their lifespans.

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:

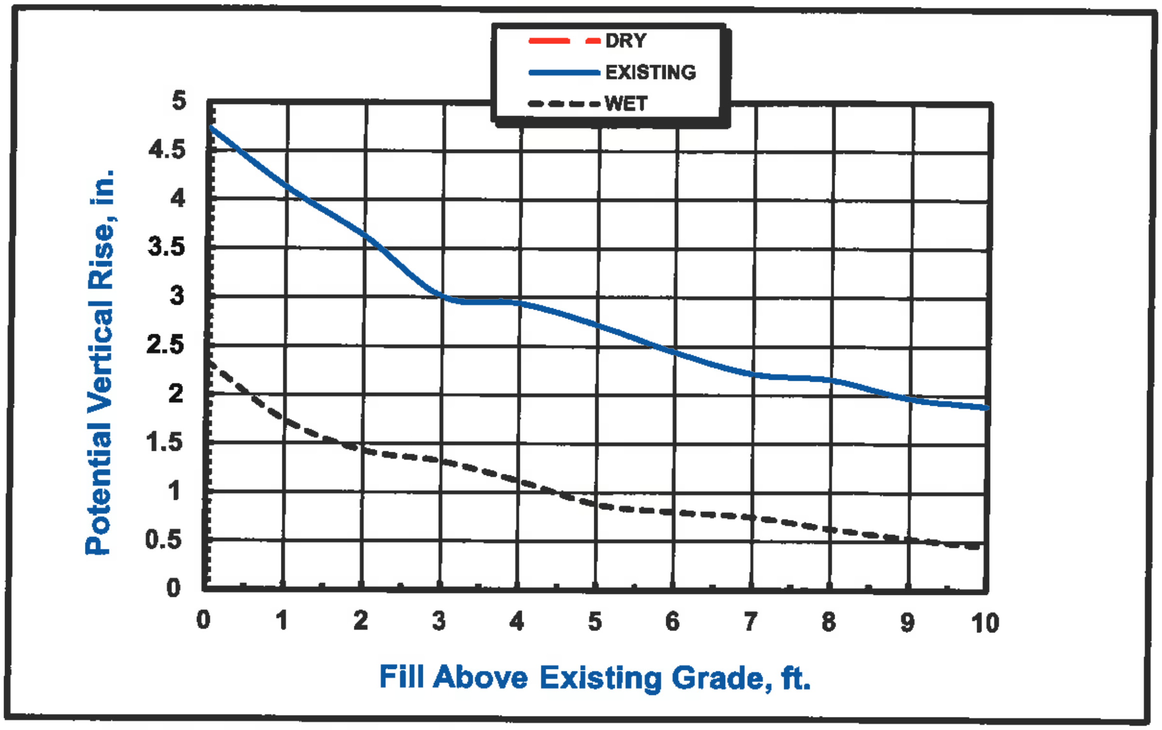
- Existing moisture in the field during the time of drilling on 9/10/2012 and 9/11/2012
- Wet moisture conditions (lower bound) during prolonged rainy season
- Dry moisture conditions (upper bound envelope) during prolonged drought

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. Five layers were used in the analysis, each two feet thick.

Depth, feet	**LL, %**	**PL, %**	**PI, %**	**Existing W,%**	**Moisture Condition**
0-2	72	22	50	17	Dry
2-4	77	23	54	19	Dry
4-6	74	23	51	25	Dry
6-8	78	23	55	26	Dry
8-10	69	22	47	20	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.



Notes:

1. At the time of drilling, the existing moisture conditions of the on-site soils were dry at all depths. This results in the existing and dry curves being identical in the graph shown above.

2. 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.

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.

Either the existing or dry condition curve can be used to estimate the amount of heave. **The PVR is estimated to be 4.74 inches for both existing moisture conditions and dry moisture conditions.** The dry and existing PVR values are equal due to the soil moisture conditions at the site being dry at the time of drilling. Remedial action will need to be taken to reduce the PVR to an acceptable level as the estimated PVR is greater than one (1) inch. Reducing the PVR to an acceptable level can be achieved through the implementation of one of the following methods:

(1) Add select fill above the existing grade at the site. The graph above shows the relationship between the amount of fill added above grade and the corresponding reduction in PVR.

(2) Remove the highly expansive clays present at the site and replace with select fill. This process is known as undercutting. The relationship between estimated PVR and thickness of select fill replacement below existing grade is presented in the following table:

Estimated PVR (Dry Moisture Condition) vs. Thickness of Replacement Fill* (Undercut)	
Thickness of the Structural Fill Below the Existing Grade (ft)	PVR (in)
0	4.74
2	3.88
4	2.46
6	1.64
8	0.93

*Assumed structural fill properties used in undercut analysis: LL: 27, PL: 15 PI: 12, % < #40: 100

If drilled piers or straight shafts with a slab on-grade floor system is selected for support of the structures, we recommend undercutting the upper layer of existing soils at the site (Option 2). More specifically, the upper seven (7) feet of existing soils at the site should be removed and replaced with seven (7) feet of structural fill to reduce the estimated PVR to less than one inch.

After excavation of the native soils and prior to adding the seven (7) feet of structural fill, the native soils from seven (7) to eight (8) feet should be stabilized with lime at a ratio of 7 to 8 percent lime by dry weight of soil, which is typically equivalent to 45 pounds per square yard per 6 inches of depth. If these recommendations are not feasible due to budgetary constraints, then a structural slab should be used. Please refer to section 8.1 for information regarding select fill properties and site preparation.

The fill soils placed 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 as possible after 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.

The in situ slab densities must be retested at least 12 to 20 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.

Do not extend the fill outside of the building areas in order to prevent infiltration of rainwater into the fill soils. Rainwater infiltration through the fill soils will create bath-tub effects (perched water conditions) under the slab. In addition, it is highly recommended to lime stabilize the upper twelve (12) inches around the structures and extend it horizontally five (5) feet beyond the perimeter of each building.

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.

6.7 Grade Beams Associated with Drilled Piers

We recommend extending both the exterior and interior grade beams to a depth of 30 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 structure 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.

6.8 Flatwork

Flatwork (such as sidewalks, ramps etc.) outside the building area 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 building and the flatwork adjacent to the building.
If the flatwork subgrade is not installed in a manner similar to the building slab, 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).

6.9 Lifetime Maintenance and Construction Considerations

6.9.1 Site Drainage

The site should be graded in such a manner as to channel all rainwater away from the structures. Water should not be allowed to pond around the structures. 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 structures at a minimum grade of 5% and should extend at least 10 feet beyond the perimeter of the building 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 should be periodically inspected and adjusted as necessary, as part of the maintenance program. Positive site drainage should be maintained throughout the lifespans of the structures.

6.9.2 Plumbing

Due to the presence of highly expansive clay soils, installing a watertight plumbing system is critical. Water leakage due to poor plumbing will have detrimental effects on the performance of the structures and foundations. Plumbing leakage tests should be performed periodically to detect any leaks within the system before irreversible damage to the foundation is caused.

6.9.3 Roof Gutters and Downspouts

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

6.9.4 Presence of Trees near the Structure

Trees should be planted a distance away from the structure 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 structures at a minimum distance that is equal to the maximum anticipated tree height. If trees are planted in close proximity to the structure, the roots will extend below the slab areas and cause distress to the slabs. Root barriers should be constructed around the perimeter of the building in the event that trees are located a distance away from the structures that is less than the maximum anticipated height of the mature tree. Root barriers should extend at least five (5) feet below grade.

6.9.5 Landscaping

Landscaping and irrigation should be minimized as much as possible around the structures. Plants located within 10 feet of the structure should be self-contained to prevent water from infiltrating into the subgrade soils located beneath the buildings 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 buildings.

6.9.6 Structural Design Considerations

The floor slabs should be provided with a moisture barrier to prevent migration of the capillary moisture through the slab. Ten (10)-mill Visqueen can be used.

6.10 Dumpster Pad Foundation Recommendations

Boring B-10 was drilled in the proposed dumpster pad area at the site. Fill soils were encountered from the surface to a depth of eight (8) feet. The fill soils contained substantial amounts of ash and organic material from four (4) to eight (8) feet. We suspect that this area was used as a burn pit for trees at some point in the past. The soils are soft and crumbly from four to eight feet.

Due to the consistency of the fill soils encountered at B-10, there is a high risk for excessive differential and total settlement at the dumpster pad site. We recommend adding grade beams to the dumpster pad area to increase the stiffness of the slab and prevent problems associated with excessive differential settlement.

Foundation recommendations are presented below:

Minimum Grade Beam Depth	36 Inches Below Final Grade
Minimum Grade Beam Width	12 Inches
Allowable Net Bearing Capacity	
Dead Load + Sustained Live Load	600 psf for Existing Soils and 1,000 Compacted Structural Fill(1)
Total Load (Dead + Live)	900 psf for Existing Soils and 1,500 Compacted Structural Fill(1)

Notes:

(1) Assuming that the existing soils are removed and replaced with structural fill and compacted to 95% of maximum dry density (ASTM D 698).

7.0 PAVEMENT RECOMMENDATIONS

7.1 General

A total of four borings (B-1, B-2, B-3, and B-4) were drilled in the proposed parking areas. The borings were drilled to a depth of five (5) feet below existing grades at the site. Existing fill soils were encountered at B-1, B-3, and B-4. The existing fill soils consist of fat clays with gravel and sand pockets intermixed. As described in Section 5.4, we estimate the fill soils to extend from the surface to approximately two (2) feet below existing grades. The fill soils will not need to be completely removed, but the construction considerations presented in section 8.1 will need to be followed (i.e. remove the upper 6 to 8 inches of soil, proof roll soft soils, remove all organic material from upper 2 feet, etc.)

Selecting the proper pavement system for the soil conditions at the site is critical. In general, a flexible (asphalt) pavement system is more tolerable to differential settlements as compared to a rigid (concrete) system. Pavement design recommendations will be presented for both asphalt and concrete pavements.

7.2 Anticipated Traffic

Traffic counts were not available during this study. However, it is anticipated that the parking area pavement will be exposed to light traffic that consists mainly of passenger cars, delivery vehicles, and garbage trucks.

TRAFFIC DESIGNATION	DESCRIPTION
Light Traffic	Few vehicles heavier than passenger cars, no regular use by heavily loaded two axle trucks or larger vehicles.
Medium Traffic	Similar to light traffic with a maximum of 50 fully loaded two axle trucks per day. No regular use by three axles heavily loaded trucks.
Heavy	Similar to medium traffic with a maximum of 300 heavily loaded two axle trucks or buses and a maximum of 30 heavily loaded trucks with more than three axles per day.

Note that the above assumptions are valid mostly for parking lots and low to medium density streets. These assumptions are not valid for major arterial thoroughfare streets.

Recommendations are presented in the following sections.

7.3 Rigid Pavement

In general, flexible (asphalt) pavement systems are more tolerable to differential settlements as compared to rigid concrete systems. Pavement design recommendations will be presented for both asphalt and concrete pavements.

7.3.1 Pavement Thickness

Pavement design thickness is dependent on several factors. The factors include traffic loading, design reliability, concrete modulus of rupture, load transfer coefficients, effective modulus of subgrade reaction, and drainage provisions. Tabulated below are the assumed traffic frequencies and loads used to design pavement sections of this project:

CONCRETE PAVEMENT			
	Pavement Thickness (inches)		
Pavement Component	Low Traffic (Parking Area)	Medium Traffic (Driveways)	Heavy Traffic (Driveways)
Reinforced Concrete	5.0	6.0	7.0
Stabilized Subgrade	6.0	8.0	8.0

7.3.2 Subgrade Stabilization

The pavement area should be prepared in accordance with the site preparation recommendations presented in this report.

Due to the presence of cohesive soils at the surface, we recommend that the subgrade be stabilized with lime. The upper six (6) inches of the subgrade should be stabilized in light traffic areas and the upper eight (8) inches of subgrade should be stabilized in medium and heavy traffic areas. Both light and medium/heavy traffic areas should be stabilized with **seven percent (7%) lime** by dry weight in accordance with TxDOT 1995 Specification Item 260. This translates to about **45** pounds of dry lime per square yard per 6 inches of depth.

The amount of lime should be determined in the field after the site is stripped of top loose soil and the subgrade soils are exposed. The lime used should be (Type A) hydrated lime or (Type B) commercial slurry conforming to TxDOT Item 264. The subgrade should be compacted to 95% of the Standard Moisture Density Relationship (ASTM D-698) as specified in the Site Preparation Section of this report.

Density Relationship (ASTM D-698) as specified in the Site Preparation Section of this report.

It is recommended to extend the pavement stabilization five feet beyond the perimeter of the pavement in order to preclude edge failure. It is also highly recommended to maintain positive drainage away from the pavement throughout the life of the pavement.

7.3.3 Temperature Steel Reinforcement and Joint Spacing

For concrete pavements that are placed on clay or sandy soils, it is typical to use #4 bars at 18 inches center to center both ways. A ¾ inch dowel, 18 inches in length spaced at 12 inches on centers at each joint can also be utilized.

Maximum control joint spacing of 12 feet is desirable throughout the pavement. If sawcut, control joints should be cut within 12 to 24 hours of concrete placements. However, proper reinforcement, joint spacing, and other pertinent design parameters should conform to ACI or AASHTO methods or standard local practices.

7.3.4 Concrete Strength

Concrete should be designed to exhibit flexural strength (3-point loading) of at least 500 psi at 28 days. The flexural strength (M_r) may be approximated by the following formula from ACI 330R: $M_r = 2.3(f'_c{}^{2/3})$, where f'_c is the compressive strength of concrete. The actual relationship between flexural and compressive strength for the proposed mix should be evaluated in the laboratory.

7.4 Asphalt Pavement

7.4.1 Pavement Thickness

Asphalt pavement thickness is dependent on several factors. The factors include reliability, traffic loads, and the effective subgrade resilient modulus.

ASPHALT PAVEMENT			
	Pavement Thickness (in inches) Not Valid for Major Arterial Thoroughfares		
Pavement Component	Low Traffic (Parking Area)	Medium Traffic (Driveways)	Heavy Traffic (Driveways)
Asphalt Surface	2.0	2.5	3.0
Crushed Limestone Base	8.0	10.0	12.0
Stabilized Subgrade	6.0	8.0	8.0

7.4.2 Subgrade Stabilization

Please refer to section 7.3.2 for details.

7.4.3 Hot Mix Asphaltic Concrete Course

The asphalt surface should be mixed in a batch plant and laid hot (Fine Graded Surface Course) in accordance with TxDOT Item 340 Type D (Hot Mix Asphaltic Concrete Pavement) and specific criteria for the job mix design formula. The mix should be designed for a stability of at least 40 and should be compacted to 95 percent, of the maximum theoretical density as measured by ASTM D 2041. The compacted asphaltic surface should contain air voids between 5% and 9%. The asphalt cement content of total mixture weight should be within ± 0.3 percent asphalt cement from the specific mix.

7.4.4 Crushed Limestone Base

The base material should consist of crushed limestone in accordance with TxDOT item 247 Type A, Grade 1 requirements. The base should be compacted to 95% of the maximum dry density as determined by the modified moisture/density relationship (ASTM D 1557) within –2 to +3 percent of the optimum moisture content.

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. It is recommended to fill these voids with structural fill or cement-stabilized sand and compact to 95% as specified by ASTM D-698.
- Depending on the virgin site conditions, organic is found at depths of 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 and 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 areas. 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 Perched water tends to get trapped within the fill which then leads to softening of the subgrade and undermines the stability of the foundation. Positive drainage should be maintained across the entire building pad.

- 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

Site drainage should be established during the first phase of construction. Water should not be allowed to collect or pond on the construction site. The site should be graded in such a manner to shed all rainwater away from the structures and foundation. *Positive site drainage should be maintained throughout the lifespans of the structures.*

8.3 Drilled Pier Excavations

The field exploration was conducted on September 10 and 11, 2012. Groundwater was not encountered at any of the ten borings during drilling operations. However, it should be noted that the groundwater level usually fluctuates with seasonal moisture conditions. Therefore, it is possible that the groundwater level may rise upward several feet during the rainy season. It is highly recommended to perform six (6) test piers (two in the center and one at each corner) prior to construction to verify the following:

- **the most current groundwater conditions just before construction**
- **the stability of the under-ream and shaft**
- **verify the presence of sand layers or thick sand seams**

An experienced drilling contractor should perform drilled and under-reamed pier excavations. The piers should be checked for levelness in order to prevent eccentric loading conditions. The belling bucket should be checked before the commencement of drilling to assure the right bell size. It is of prime importance that the bells are clear of loose materials and soil cuttings. In order to prevent concrete segregation and bearing area disturbance, it is recommended to use a tremie to pour the concrete if the depth of the pier exceeds eight (8) feet.

Soil stratigraphy and groundwater level may vary within the proposed construction site. Therefore, it is recommended to install four (4) corner piers and two (2) center piers before construction begins to verify the groundwater level and soil stratigraphy. The depths of the other piers may be adjusted accordingly.

Piers should not be allowed to remain open for an extended period or overnight. If pier excavation and backfilling with concrete cannot be completed the same day, the pier should be backfilled with excavated soils and re-excavated when excavation and concrete placement can be completed on the same day.

8.4 Drilled Straight Shaft Installations

As previously stated, groundwater was not encountered during drilling operations. However, the groundwater level usually fluctuates with seasonal moisture conditions. Therefore, it is possible that the groundwater level may rise upward several feet during the rainy season. It is highly recommended to perform a test shaft prior to construction to verify the following:

- the most current groundwater conditions just before construction
- the stability of the under-ream and shaft
- verify the presence of sand layers or thick sand seams

In order to keep the shaft excavation open, the slurry or casing method should be used during construction of the straight shafts.

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.

If casing is used, it should be extracted in a smooth motion by a vibratory hammer when the concrete is within a foot of the ground surface. The level of concrete should not be allowed to fluctuate more than one foot during casing extraction. Abrupt drops in concrete level during extraction should be noted and logged.

Straight shafts should not be excavated within three shaft diameters, edge-to-edge, of shafts that have been concreted 24 hours or earlier. The head elevation of all existing shafts within three shaft diameters of a pier being constructed should be monitored before and after the shaft construction. Differences in elevation should be brought to the attention of the Geotechnical Engineer.

An experienced drilling contractor should perform straight shaft excavations. The shafts should be checked for levelness in order to preclude eccentric loading conditions.

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

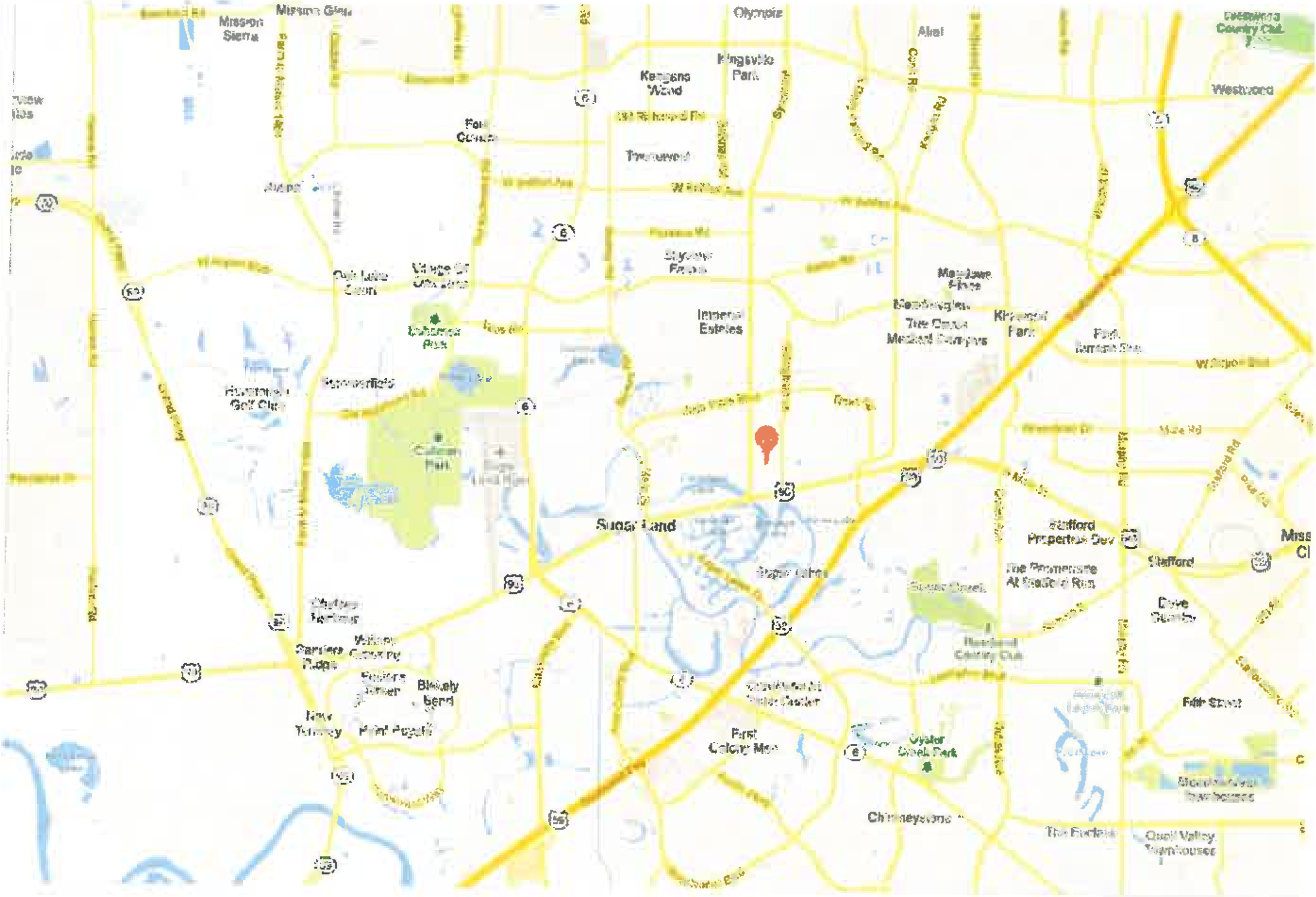
Our site exploration was based on ten (10) borings at select locations. Soil stratigraphy may change within the site. In the event that different soil conditions are encountered in the field, EARTH ENGINEERING, INC. should be immediately notified. It should be noted that fault study is not within the 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 building 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

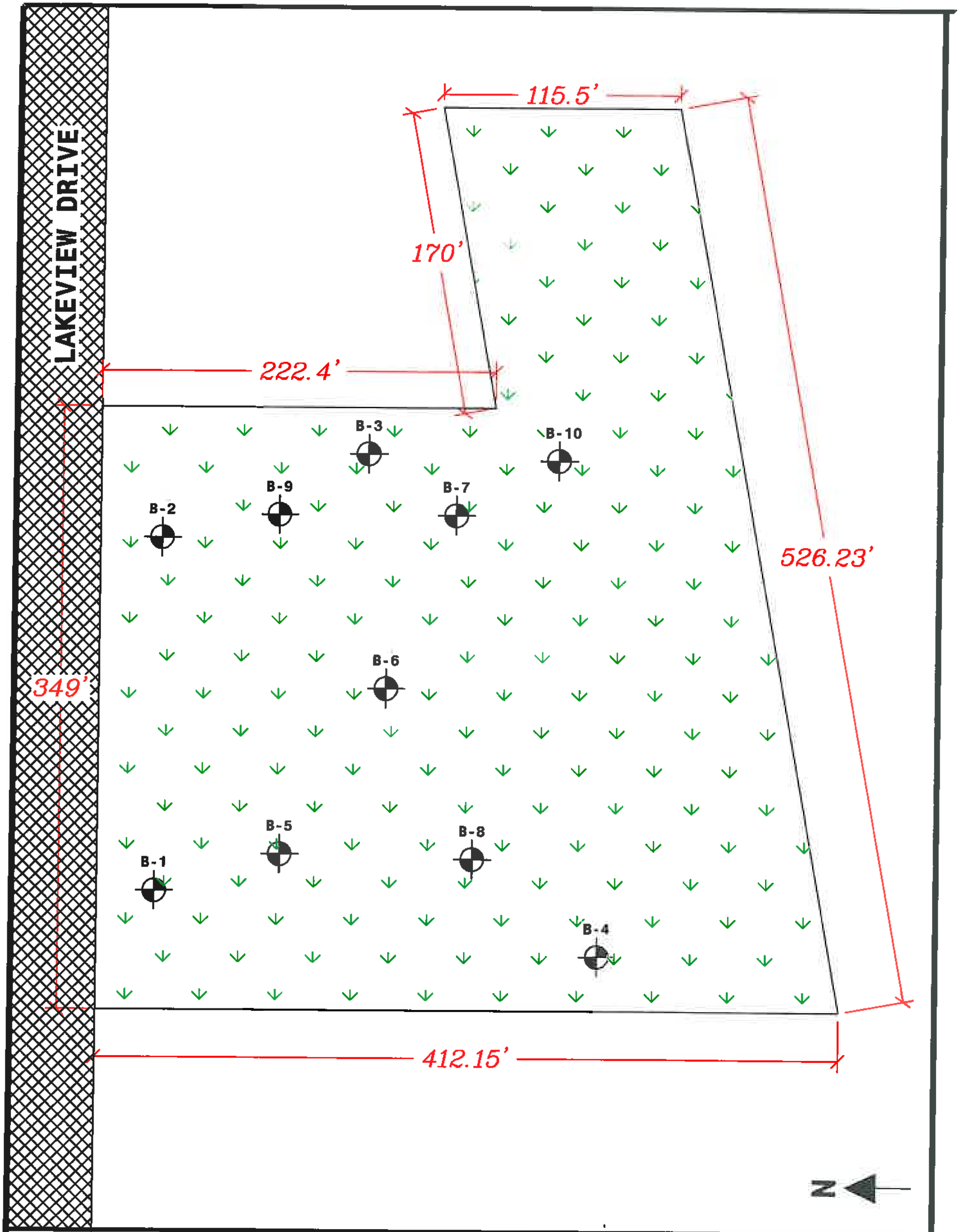
Site Location Map

Proposed Assisted Living Campus
Lakeview Dr.
Missouri City, TX

EARTH ENGINEERING, INC.
Geotechnical, Materials and Environmental Consultants

SCALE: N.T.S.	DATE: 10/2/2012
PROJECT: EE–1227309–G	DWG. 001

Plate No. 1



Boring Location Map

Proposed Assisted Living Campus
Lakeview Dr.
Missouri City, TX

EARTH ENGINEERING, INC.
Geotechnical, Materials and Environmental Consultants

SCALE: N.T.S.
DATE: 9/25/12
PROJECTEE-1227309-G
DWG. 002

Plate No. 2

LOG OF BORING B-1

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▩	■	FILL: Very stiff, dark gray FAT CLAY with sand, gravel, root fibers, and organic material	CH		4.50	17		78	23	55				
2	▨	■	Very stiff, dark gray FAT CLAY with ferrous nodules and root fibers from 2-5 feet	CH		4.50	18					94			
4	▨	■				4.50	20								
			Boring terminated at 5 ft.												
8															
12															
16															
20															
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/11/2012

DRILLER: R.B.

PLATE NO. 3

LOG OF BORING B-2

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▨	■	Very stiff, dark gray FAT CLAY with ferrous nodules and root fibers from 0-5 feet	CH		4.50	17		79	23	56				
						4.50	18								
4						4.50	19								
			Boring terminated at 5 ft.												
8															
12															
16															
20															
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/10/2012

DRILLER: R.B.

PLATE NO. 4

LOG OF BORING B-3

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▦	■	FILL: Very stiff, dark gray FAT CLAY with sand pockets, gravel, root fibers, and organic material	CH		4.50	13					78			
2	▨	■	Very stiff, dark gray FAT CLAY with ferrous nodules and root fibers below 2 feet	CH		4.50	20		64	21	43				
4	▨	■	--stiff from 4-5 feet			2.25	28								
			Boring terminated at 5 ft.												
8															
12															
16															
20															
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/10/2012

DRILLER: R.B.

PLATE NO. 5

EARTH ENGINEERING, INC.

LOG OF BORING B-4

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▩	■	FILL: Very stiff, dark gray FAT CLAY with gravel, root fibers, and organic material	CH		4.50	16								
2	▨	■	Very stiff, dark gray FAT CLAY with ferrous nodules and root fibers below 2 feet	CH		4.50	19		80	24	56				
4	▨	■					21								
			Boring terminated at 5 ft.												
8															
12															
16															
20															
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/11/2012

DRILLER: R.B.

PLATE NO. 6

LOG OF BORING B-5

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0			Very stiff, dark gray FAT CLAY with ferrous nodules from 0-8 feet and root fibers from 0-6 feet	CH		4.50	18		73	22	51				
						4.50	20					94			
5						4.50	22		76	23	53				
						4.50	22								
			--reddish-brown below 8 feet, with calcareous nodules from 8-20 feet			4.50	19		64	21	43				
10			--with silt seams from 10-15 feet			4.50	16								
						4.00	21	105					3.60	6.00	
15															
						4.50	19								
20															
						4.00	23								
25			Boring terminated at 25 ft.												
30															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/11/2012

DRILLER: R.B.

PLATE NO. 7

EARTH ENGINEERING, INC.

LOG OF BORING B-6

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0			FILL: Very stiff, dark brown and gray FAT CLAY with gravel, root fibers, and sand pockets			4.50	12								
2			Very stiff, dark gray FAT CLAY with ferrous nodules below 2 feet and root fibers from 2-8 feet	CH		4.50	19		87	25	62				
						4.50	23					94			
			--gray and dark gray from 6-8 feet			4.25	24		88	25	63				
			--gray and reddish-brown with calcareous nodules from 8-10 feet			4.50	19								
10			Very stiff, reddish-brown SANDY LEAN CLAY with sand seams and calcareous nodules	CL		4.50	12	111					5.40	2.80	
13			Very stiff, reddish-brown FAT CLAY with silt seams from 13-25 feet and calcareous nodules from 13-20 feet	CH		4.00	21								
						4.00	24								
						3.50	20								
25			Boring terminated at 25 ft.												

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/11/2012

DRILLER: R.B.

PLATE NO. 8

EARTH ENGINEERING, INC.

LOG OF BORING B-7

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▩	■	FILL: Very stiff, dark gray FAT CLAY with root fibers, organic material, gravel, and sand pockets	CH		4.50	15		61	21	40				
2	▨	■	Very stiff, dark gray FAT CLAY with root fibers and ferrous nodules from 2-8 feet	CH		4.25	21								
	▨	■	--firm from 4-6 feet			1.50	30		92	25	67				
	▨	■	--stiff, gray from 6-8 feet, with calcareous nodules below 6 feet			2.00	28					92			
	▨	■	--very stiff, reddish-brown from 8-10 feet			4.00	20								
10	▒	■	Very stiff, reddish-brown SANDY LEAN CLAY with calcareous nodules and sand seams	CL		4.25	18								
13	▨	■	Very stiff, reddish-brown FAT CLAY with calcareous nodules and silt seams below 13 feet	CH		4.00	24								
	▨	■	--stiff from 18-20 feet			2.25	26	96					1.35	3.80	
	▨	■	--very stiff, reddish brown and light gray from 23-25 feet			4.00	19								
25			Boring terminated at 25 ft.												

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/10/2012

DRILLER: R.B.

PLATE NO. 9

LOG OF BORING B-8

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0			FILL: Very stiff, dark gray FAT CLAY with gravel and root fibers	CH		4.50	17					91			
2			Very stiff, dark gray FAT CLAY with root fibers from 2-6 feet and ferrous nodules form 2-8 feet	CH		4.50	22		73	22	51				
			--stiff from 4-8 feet			2.50	25								
			--gray from 6-8 feet			2.75	27		69	22	47				
			--very stiff, reddish brown with calcareous nodules from 8-10 feet			3.50	21								
10			Very stiff, reddish-brown SANDY LEAN CLAY with calcareous nodules and sand seams	CL		3.75	19								
13			Very stiff, reddish-brown FAT CLAY with calcareous nodules below 13 feet	CH		4.50	18								
			--with silt seams from 18-20 feet			4.50	22								
20			Boring terminated at 20 ft.												

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/11/2012

DRILLER: R.B.

PLATE NO. 10

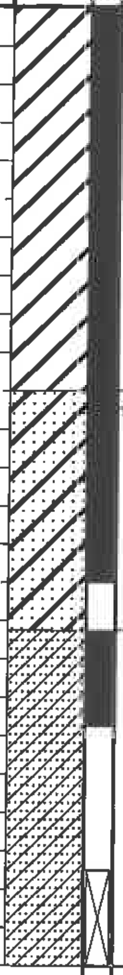
LOG OF BORING B-9

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)



DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0			Very stiff, dark gray FAT CLAY with ferrous nodules from 0-8 feet and root fibers from 0-6 feet	CH		4.50	16								
						4.50	19		81	24	57				
4						4.50	20					90			
			--gray from 6-8 feet			4.50	19								
8			Very stiff, reddish-brown SANDY LEAN CLAY with calcareous nodules and sand seams below 8 ft	CL		4.50	12		46	18	28				
			--stiff from 10-12 feet			2.75	9								
13			Medium dense, tan CLAYEY SAND	SC			7								
					34		4								
20			Boring terminated at 20 ft.												
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

DATE DRILLED: 9/10/2012

DRILLER: R.B.

PLATE NO. 11

LOG OF BORING B-10

PROJECT: Assisted Living Campus at Lakeview Dr. in Missouri City, TX

PROJECT NUMBER: EE-1227309-G

BORING LOCATION: See Plate 2

CLIENT: Optimum Personal Care (Mr. Bobby English)

DEPTH (feet)	GRAPHIC LOG	SAMPLING METHOD	DESCRIPTION Type of Boring: Flight Auger Surface Elevation: Existing	USCS SYMBOL	SPT, BLOWS/FT	POCKET PENETROM. (TSF)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	% < #200	COHESION, 'C' (KSF)	FAILURE STRAIN (%)	CONFINING PRESSURE, (PSI)
0	▩	■	FILL: Very stiff, brown and gray FAT CLAY with gravel, sand pockets, and organic material to 8 feet	CH		4.50	16		67	21	46				
	▩	■				4.50	14					78			
4	▩	■	--firm from 4-6 feet, with ash below 4 feet			1.25	23		52	19	33				
	▩	■	--soft from 6-8 feet			0.75	21								
8	▨	■	Very stiff, reddish-brown FAT CLAY with calcareous nodules from 8-20 feet	CH		4.50	17								
	▨	■	--with silt seams below 10 feet			4.50	18								
12	▨	□													
	▨	■				3.75	23								
16	▨	□													
	▨	■	--reddish-brown and light gray from 18-20 feet			3.00									
20			Boring terminated at 20 ft.												
24															

WATER LEVEL MEASUREMENTS

▽ **Initial:** Dry

▼ **Final:** Dry

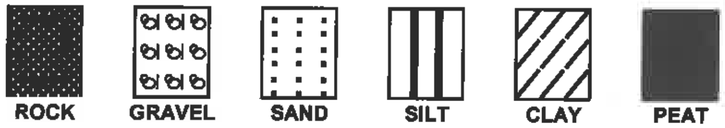
DATE DRILLED: 9/10/2012

DRILLER: R.B.

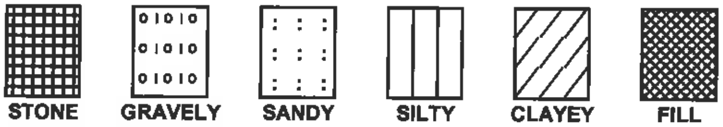
PLATE NO. 12

KEY TO LOG TERMS AND SYMBOLS

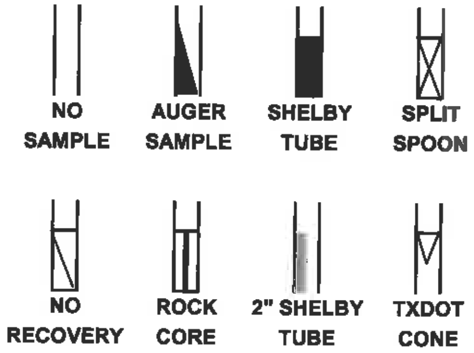
SOIL TYPE



MODIFIERS



SAMPLER TYPE



UNIFIED SOIL CLASSIFICATION SYSTEM - ASTM D 2487

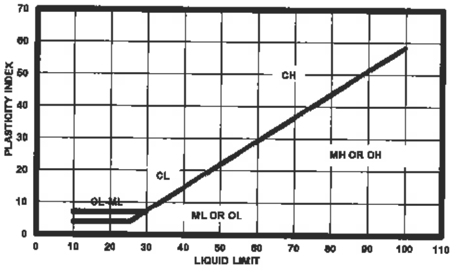
MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS LESS THAN 50% PASSING NO. 200 SIEVE	GRAVEL & GRAVELY SOILS LESS THAN 50% PASSING NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND 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)

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

Project Site Pictures
EE-1227309-G

PROPOSED ASSISTED LIVING CAMPUS AT LAKEVIEW DR. IN MISSOURI CITY, TX

PROPOSED ASSISTED LIVING CAMPUS AT LAKEVIEW DR. IN MISSOURI CITY, TX