PRELIMINARY GEOTECHNICAL STUDY
FOUNDATIONS, UNDERGROUND UTILITIES
DETENTION POND AND PAVING
42.45 ACRES CENTENNIAL OAKS
GALVESTON COUNTY, TEXAS

PROJECT NO. 22-635E

TO

D.R. HORTON
RICHMOND, TEXAS

BY

GEOTECH ENGINEERING AND TESTING

SERVICING

TEXAS, LOUISIANA, NEW MEXICO, OKLAHOMA

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Project No.: 22-635E
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Attention: Ms. Kori Johnston

PRELIMINARY GEOTECHNICAL STUDY
FOUNDATIONS, UNDERGROUND UTILITIES
DETENTION POND AND PAVING
42.45 ACRES CENTENNIAL OAKS
GALVESTON COUNTY, TEXAS

Dear Madam:

Submitted here is Geotech Engineering and Testing (GET) geotechnical study of subsurface conditions for the above-referenced project. This study was authorized by Ms. Kori Johnston on June 30, 2022.

This report presents the results of our field explorations and laboratory testing, together with recommendations for the preliminary design and construction of the proposed post-tensioned slab foundations, underground utilities, detention pond and paving.

We appreciate the opportunity to be of service. Should you have any questions or need additional assistance, please call.

Very truly yours,

GEOTECH ENGINEERING AND TESTING
TBPE Registration Number F-001183

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1.0 SUMMARY

It is planned to develop 42.45 Acres Centennial Oaks, Galveston County, Texas. A site vicinity map of the project site is presented on Plate 1. A review of our subsoil data at the project site indicates the following:

- The subsoils generally consist of naturally occurring Lean Clay (CL), underlain by Lean clay and Fat Clay (CH) soils. These soils are suitable for development of subdivision streets and post-tensioned slab foundations. However, due to the presence of expansive soils on the site, we recommend the post-tensioned slabs be stiffened such that minimum differential movements occur once a portion of the slab is lifted as a result of expansive soils. The foundation system may experience tilt if designed as a stiff slab.

- This site has a potential vertical rise (PVR) of 1.5-inch.

- Our short-term field exploration indicates that groundwater was encountered during and after 0.33-hour of drilling at the depth of 18-ft. Hence, groundwater dewatering system may be required.

- The residential structural loads can be supported on the post-tensioned slab type foundations. The allowable net bearing capacities are 1,000 psf and 1,500 psf for dead load and total load, respectively.

- Recommendations for underground utilities, detention pond and pavement are presented in Sections 8.0, 9.0 and 10.0 of this report, respectively.

- The depth of detention pond is not available at the time of the study. We assume that the detention pond will be approximately 20-ft deep. The slopes of detention pond recommended should be no steeper than 3.5(horizontal) to 1(vertical) [3.5(h):1(v)].

- In general, the development of this site should not pose any additional difficulties compared to similar developments in the area.

- **The foundation recommendations presented in this report are preliminary. They should not be used for final design. We recommend additional studies to be conducted upon completion of the lot development.**

2.0 INTRODUCTION

It is planned to develop 42.45 Acres Centennial Oaks, Galveston County, Texas. A site vicinity map of the project is presented on Plate 1. We understand that the planned facilities will include foundations, underground utilities (waterlines, sanitary and storm sewers), detention pond and paving. A general layout of the proposed site is presented on Plate 2. The planned facilities will consist of followings:

Facility	Description
Post-Tensioned Slab Foundations	Preliminary post-tensioned slab foundation recommendations.
Water, Sanitary and Storm Sewers	The invert depths of underground utilities were not available at the time of this study.
Detention Pond	The depth of detention pond was not available at the time of this study. We assume that the detention pond will be approximately 20-ft deep.
Subdivision Streets	We understand that concrete pavement will be used on this project. The concrete driveway will be subjected to auto and light truck traffic loading. The concrete pavement will consist of subdivision and collector streets.

The purpose of our study was to explore subsurface conditions for the subject project and using the information obtained, develop preliminary recommendations to guide design and construction of the proposed facilities. Since the scope of our work is development of preliminary recommendations, it cannot be used for final design. **The recommendations presented in this report are preliminary. They should not be used for final design. We recommend additional studies to be conducted upon completion of the lot development.**

Our recommendations on underground utilities, site preparation and soil stabilization are in general accordance with Galveston County "Rules, Regulations and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions" dated October 03, 2005 (Ref. 1) and "Subdivision Construction Standards" of City of Texas City (Ref. 2).

3.0 FIELD EXPLORATION

The soil conditions were explored by conducting four (4) soil borings (B-1 through B-4). A general layout of the borings is shown on Plate 2. The number of borings and depths were specified by the client. Soil samples were obtained continuously at each boring location from the ground surface to 10-ft and at five-ft intervals thereafter to the completion depth of the borings at 20-ft. The cohesive soils were generally sampled in general accordance with the ASTM D 1587, using a Shelby tube sampler.

Some cohesive soils were generally sampled with a split-spoon sampler driven in general accordance with the Standard Penetration Test (SPT), ASTM D 1586. This test is conducted by recording the number of blows required for a 140-pound weight falling 30 inches to drive the sampler 12 inches into the soil. Driving resistance for the SPT, expressed as blows per foot of sampler resistance (N), is tabulated on the boring logs.

Soil samples were examined and classified in the field, and cohesive soil strengths were estimated using a calibrated hand penetrometer. This data, together with a classification of the soils encountered and strata limits, is presented on the logs of borings, Plates 3 through 6. A key to the log terms and symbols is shown on Plate 7.

The borings were drilled dry, without the aid of drilling fluids, to more accurately estimate the depth to groundwater. Water level observations made during and after drilling are indicated at the bottom portion of the individual logs.

4.0 LABORATORY TESTS

4.1 General

Soil classifications and shear strengths were further evaluated by laboratory tests on representative samples of the major strata. The laboratory tests were performed in general accordance with ASTM Standards. Specifically, ASTM D 2487 is used for classification of soils for engineering purposes.

4.2 Classification Tests

As an aid to visual soil classifications, physical properties of the soils were evaluated by classification tests. These tests consisted of natural moisture content tests (ASTM D 4643) and Atterberg limit determination (ASTM D 4318, Method B). Similarity of these properties is indicative of uniform strength and compressibility characteristics for soils of essentially the same geological origin. Results of these tests are tabulated on the boring logs at respective sample depths.

4.3 Strength Tests

Undrained shear strengths of the cohesive soils, measured in the field, were verified by calibrated hand penetrometer tests, unconfined compressive strength test (ASTM D 2166) and torvane tests. Natural moisture content and dry unit weight were determined routinely for each unconfined compressive strength test. These test results are also presented on the boring logs.

4.4 Soil Sample Storage

Soil samples tested or not tested in the laboratory will be stored for a period of seven days subsequent to submittal of this report. The samples will be discarded after this period, unless we are instructed otherwise.

5.0 GENERAL SOILS AND DESIGN CONDITIONS

5.1 Site Conditions

A site visit was conducted by Mr. Sonny Ehsaee, B.SC.E. with Geotech Engineering and Testing (GET) on July 7, 2022. Project site pictures were taken during our field exploration and site visit. These pictures are presented on cover page and Plate 8. The following observations were made during our site visit:

- Project site is located at the intersection of N Elm Road and Highway 6 in Galveston County.
- Project site areas are generally undeveloped and covered with grass and some trees.
- The surrounding areas are generally flat and exhibit topographic variation of less than three-ft.
- There are some residentials in vicinity of the project site.
- Some drainage ditches are located within the project site.
- In general, the development of this site should not pose any additional difficulties compared to similar development in the area.

5.2 Review of Aerial Photographs and Topographic Map

5.2.1 Aerial Photographs

Aerial photographs of 2015 and 2022 available at Google Earth website (www.google.com/earth/) were reviewed to evaluate the present and past land use, structural improvements (if any), trees and the surrounding properties of the project site. The aerial photographs are presented in Appendix A. Our review of these aerial photographs is as follows:

Year	Remarks	
2015	Project Site	Generally undeveloped.
	Surrounding Areas	Some residentials in vicinity of the project site.
2021	Project Site	No special changes.
	Surrounding Areas	No special changes.

5.2.2 Topographic Map

Based on the topographic map available at USGS Website (ngmdb.usgs.gov), presented in Appendix A, the subject lots and vicinity are nearly level. The topographic map indicated presence of some drainage ditches within the project site.

5.2.3 Recommendations

The review of the topographic map indicates the presence of some drainage ditches within the project site. We recommend all earthwork, testing and fill placement in the impacted lots be further studied to evaluate potential future foundation problems. All the backfill soils at drainage ditches feature must have records of doing density testing.

5.3 Soil Stratigraphy

Subsurface soils appear to be relatively uniform across the lots. Details of subsurface conditions at each boring location are presented on the respective boring logs. In general, the soils can be grouped into two (2) major strata with depth limits and characteristics as follows:

Stratum No.	Range of Depth, ft.	Soil Description*
I	0 – 20	LEAN CLAY (CL), soft to very stiff, light brown, brown, dark brown, light gray, gray, with root fibers to 20', calcareous and ferrous nodules, gravels, sands
II	13 – 15	FAT CLAY (CH), firm, reddish brown, light gray, with root fibers to 15', ferrous nodules, gravels

* Classification in general accordance with the Unified Soil Classification System (ASTM D 2487)

5.4 Soil Properties

Soil strength and index properties and how they relate to foundation design are summarized below:

Stratum No.	Soil Type	PI(s)	Soil Expansivity	Soil Strength, tsf	SPT
I	Lean Clay (CL)	17 – 28	Non- to Moderately Expansive	0.15 – 1.50	4 –10
II	Fat Clay (CH)	–	–	0.46	–

Legend: PI = Plasticity Index
SPT= Standard Penetration Test

5.5 Water-Level Measurements

The soil borings were dry augered to evaluate the presence of perched or free-water conditions. The levels where free water was encountered in the open boreholes during our field exploration and 0.33 hours after drilling are shown on the boring logs. Our groundwater measurements are as follows:

Boring No.	Groundwater Depth, ft. at the Time of Drilling	Groundwater Depth, ft. at 0.33-Hour Later
B-1 through B-4	18	18

Fluctuations in groundwater generally occur as a function of seasonal moisture variation, temperature, groundwater withdrawal and future construction activities that may alter the surface drainage and subdrainage characteristics of this site.

An accurate evaluation of the hydrostatic water table in the relatively impermeable clays and low permeable silts/sands requires long term observation of monitoring wells and/or piezometers. It is not possible to accurately predict the pressure and/or level of groundwater that might occur based upon short-term site exploration.

The installation of piezometers/monitoring wells was beyond the scope of our study. We recommend that the groundwater level be verified just before construction if any excavations such as construction of underground utilities, etc. are planned.

We recommend that GET be immediately notified if a noticeable change in groundwater occurs from that mentioned in our report. We would be pleased to evaluate the effect of any groundwater changes on our design and construction sections of this report.

6.0 POTENTIAL VERTICAL RISE

A review of the subsoil conditions indicates the presence of moderately expansive soils. The floating slab type foundation, if used, will experience heave. Foundations experiencing tilt as opposed to differential movements will not experience significant distress. Tilt is defined as a planar rotation, measured over the length or width of foundation.

We computed the potential vertical rise (PVR, Ref. 1) at this site. A PVR of about 1.5-inch can be expected during the life of the structure. Additional information on differential movements or tilt can be obtained from Foundation Performance Association Publication “Guidelines for the Evaluation of Foundation Movements for Residential and other Low-Rise Buildings”, (Ref. 2).

A review of American Society of Civil Engineers Guidelines for the Evaluation and Repair of Residential Foundations (Ref. 3) indicates slope of greater than one percent is usually noticeable. The Americans with Disabilities Act considers a two percent slope too large. Slope is defined as differential elevation (rise) between two points divided by the horizontal distance (run) between them.

Foundation tilt can be reduced if several feet of on-site expansive soils are removed and replaced with select structural fill. Alternatively, the select structural fill can be placed on top of existing soils. Additional recommendation on foundation tilt can be developed, if requested.

7.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

7.1 Foundations and Risks

Many lightly loaded foundations are designed and constructed on the basis of economics, risks, soil type, foundation shape and structural loading. Many times, due to economic considerations, higher risks are accepted in foundation design. We recommend that the builder and architect/designer discuss foundations and risks with the owner. The proper foundation system should then be selected by the owner after all risks are discussed. It should be noted that some levels of risk are associated with all types of foundations and there is no such thing as a zero risk foundation. All of these foundations must be stiffened in the areas where expansive soils are present and trees have been removed prior to construction.

It should be noted that these foundations are not designed to resist soil and foundation movements as a result of sewer/plumbing leaks, excessive irrigation, poor drainage and water ponding near the foundation system. The following are the foundation types typically used in the area with increasing levels of risk and decreasing levels of cost:

FOUNDATION TYPE	REMARKS
Structural Slab with Piers	This type of foundation (which also includes a pier and beam foundation with a void/crawl space) is considered to be a low risk foundation, provided it is built and maintained with positive drainage and vegetation control. A minimum space of four-inch or larger is required. Using this foundation, the floor slabs are not in contact with the subgrade soils. This type of foundation is particularly suited for the areas where expansive soils are present and where trees have been removed prior to construction. The drilled footings must be placed below the potential active zone to reduce potential drilled footing upheaval due to expansive clays. In the areas where non-expansive soils are present, spread footings can be used instead of drilled footings.
Slab-On-Fill Foundation Supported on Piers	This foundation system is also suited for the area where expansive soils are present. This system has some risks with respect to foundation distress and movements, where expansive soils are present. However, if positive drainage and vegetation control are provided, this type of foundation should perform satisfactorily. The fill thickness is evaluated such that once it is combined with environmental conditions (positive drainage, vegetation control) the potential vertical rise will be reduced. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating (Stiffened) Slab Supported on Piers. The Slab can either be Conventionally-Reinforced or Post-Tensioned	The risk on this type of foundation system can be reduced if it is built and maintained with positive drainage and vegetation control. Due to presence of piers, the slab cannot move down. However, if expansive soils are present, the slab may move up, behaving like a floating slab. In this case, the steel from the drilled piers should not be dowelled into the grade beams. The structural loads can also be supported on spread footings if expansive soils are not present.
Floating Super-Structural Slab Foundation (Conventionally-Reinforced or Post-Tensioned Slab)	The risk on this type of foundation system can be reduced if it is built and maintained with positive drainage and vegetation control. No piers are used in this type of foundation. Many of the lightly-loaded structures in the state of Texas are built on this type of foundation and are performing satisfactorily. In the areas where trees have been removed prior to construction and where expansive clays exist, these foundations must be stiffened to reduce the potential differential movements as a result of subsoil heave due to tree removal. The advantage of this foundation system is that as long as the grade beams penetrate a minimum of six-inch into the competent natural soils or properly compacted structural fill, no compaction of subgrade soils is required. The subgrade soils should, however, be firm enough to support the floor slab loads during construction. The structural engineer should design the floor slabs such that they can span in between the grade beams. The subsoils within which the grade beams are placed must have a minimum shear strength of 1000 psf and a minimum degree of compaction of 95% standard Proctor density (ASTM D 698) at a moisture content between optimum and +3% of optimum moisture content.
Floating Slab Foundation (Conventionally-Reinforced or Post-Tensioned Slab)	The risk on this type of foundation can be reduced if it is built and maintained with positive drainage and vegetation control. No piers are used in this type of foundation. Many of the lightly-loaded structures in the state of Texas are built on this type of foundation and are performing satisfactorily. In the areas where trees have been removed prior to construction and where expansive clays exist, these foundations must be stiffened to reduce the potential differential movements as a result of subsoil heave due to tree removal. However, foundation tilt can still occur even if the foundation system is designed stiff.

The above recommendations, with respect to the best foundation types and risks, are very general. The best type of foundation may vary as a function of structural loading and soil types. For example, in some cases, a floating slab foundation may perform better than a drilled footing type foundation. More information regarding foundations and risks can be found at the **Foundation Performance Association Document #FPA-SC-01-0** (Ref. 4).

7.2 Foundation Type

Foundations for the proposed residences should satisfy two independent design criteria. First, the maximum design pressure exerted at the foundation base should not exceed allowable net bearing pressure based on an adequate factor of safety with respect to soil shear strength. Secondly, the magnitude of total and differential settlements or heave under sustained foundation loads must be such that the structure is not damaged or its intended use impaired.

We understand that a detention pond could be constructed at the subject site. The scope of our work did not include the evaluation of foundation design due to the close proximity of the detention pond. Our foundation recommendations are valid only if the proposed buildings are located at least 30-ft away from the high banks of the detention pond.

Since the foundation information provided in this report is preliminary, it cannot be used for final design. Additional studies should be conducted to develop the final foundation design recommendations.

We understand that the residential structural loads will be supported on the post-tensioned slab type foundations. Our recommendations for this foundation type are presented in the following report sections.

7.3 Post-Tensioned Slab Foundation

We understand that the structural loads will be supported on a post-tensioned slab foundation. Our recommendation for the design of post-tensioned slabs is in general accordance with the PTI DC10.1-08, Third Edition with 2008 supplement (Ref. 6). Our recommendations for post-tensioned slab based on 12-inch and 30-inch exterior grade beam are presented below:

Minimum Grade Beam Depth Below the Final Grade	:	1.0-ft
Allowable Net Bearing Capacity		
Total (Dead + Live) Loading	:	1,500 psf
Dead + Sustained Live Loads	:	1,000 psf
Slab Subgrade Coefficient		
Slab-on-Vapor Sheeting over Sand	:	0.75
Depth of Deepest Root Fibers	:	20-ft
Edge Moisture Variation, e_m, feet		
Edge Lift	:	4.8
Center Lift	:	8.5
Differential Swell, y_m, inches		
Edge Lift	:	1.2
Center Lift	:	1.4
Effective Plasticity Index (PI)	:	28
Structural Fill Type	:	See Site Preparation Section
The Required Minimum Fill Undrained Shear Strength	:	1,000 psf
Thornthwaite Moisture Index	:	18

Design Suction Envelope	:	Post-Equilibrium
Potential Vertical Rise (PVR)	:	1.5-inch

Grade beams proportioned in accordance with the above bearing capacity values will have a factor of safety of 3.0 and 2.0 with respect to shearing failure for dead and total loading, respectively. Footing weight below final grade can be neglected in the determination of design loading.

The differential movement values presented in this report are based on climate controlled soil conditions and are not valid when influenced by significant other conditions, such as trees, poor drainage, slope, cut and fill sections, etc. Due to the presence of moderately expansive soils on the site, we recommend the post-tensioned slab be stiffened such that minimum differential movements occur once a portion of the slab is lifted as a result of tree removal and the presence of expansive soils. The foundation system may experience tilt if designed as a stiff slab.

A bedding layer of leveling sand, one- to two-inches in thickness, may be planned beneath the floor slab. A moisture barrier should be used above the sands to prevent moisture migration through the slab. The excavations for the grade beams should be free of loose materials prior to concrete placement.

Information was not available on whether fill will be used to raise site grade prior to slab construction. In the event that fill is placed on site, specifications should require placement in accordance with our recommendations given in the "Site Preparation" section. Lack of proper site preparation may result in additional stress and inferior slab performance. The on-site soils, with the exception of sands and silts (if present), free of root organics, are suitable for use as structural fill under a post-tensioned slab foundation. Sands should not be used as structural fill materials at this site (with the exception of top one- to two-inch of leveling sand under the slab).

7.4 Foundation Settlement

A settlement analysis was not within the scope of this study. It is anticipated that grade beams and slabs designed using the recommended allowable bearing pressures will experience small settlements that will be within the tolerable limit for the proposed structures.

7.5 Foundation Maintenance

Long term performance of a residential structure depends not only on the proper design and construction, but also on the proper foundation maintenance program.

A properly designed and constructed foundation may still experience distress from the vegetation and expansive soil which will undergo volume change when correct drainage is not established or incorrectly controlled water source, such as plumbing/sewer leaks, excessive irrigation, water ponding near the foundation becomes available.

Our general recommendations on foundation maintenance are presented in Appendix B of this report. More foundation maintenance information can be found at **Foundation Performance Association Document #FPA-SC-07-0** (Ref. 4).

8.0 UNDERGROUND UTILITIES

8.1 General

We understand that the subsurface utility installations will include storm sewers, sanitary sewers and waterlines. The invert depths for the underground utilities are not available at the time of this study. The borings schedule is presented in the "Field Exploration" section. We understand that either open trench or augering methods of construction will be used for the underground utility installations. Furthermore, the proposed underground utilities will be constructed in accordance with "Subdivision Construction Standards" of City of Texas City (Ref. 2).

8.2 Open-Trench Method

8.2.1 Sanitary and Storm Sewerlines

The sanitary and storm sewer lines shall be installed in accordance with "Subdivision Construction Standards" of City of Texas City, DWG. NO. 3 and 4 of 6.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as soft lean clay soils existing at the borings. A summary of the unsatisfactory soils locations and depths are as follows:

Boring(s)	Depth, ft.
B-2	6 to 8
B-2	13 to 15
B-3	13 to 15
B-4	13 to 20

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented. Furthermore, the contractor may have to over excavate an additional 6 inches and remove unstable or unsuitable materials with approval by geotechnical engineer, then place an equal depth of cement stabilized sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Sand backfill used in the cement-stabilized sand and sand backfill should be free of clay lumps, organic materials, or other deleterious substances, and with a PI less than 4 for the cement-stabilized sand and less than 7 for the sand backfill, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to "Subdivision Construction Standards" of City of Texas City, DWG. NO. 3 and 4 of 6.

8.2.2 Water Lines

Open-trench construction for the underground utilities should be in accordance with "Subdivision Construction Standards" of City of Texas City, DWG. NO. 2 of 6. The bedding and backfill for the proposed water lines should be constructed in accordance with City of Texas City, DWG. NO. 2 of 6. Trenches for the proposed underground utilities must have a width below the top of the pipe of not less than the outside diameter of the pipe plus 24-inch and shall be wide enough to permit making up the joints but shall not be wider than the outside diameter of the pipe plus 36-inch.

In general, twelve-inch of bank sand should be placed above the utility lines. Twelve-inch lifts of bank sand should be placed below the utility lines for dry excavation bottom. In case of wet excavation bottom, geotextile fabrics should be placed at the excavation bottom and along the excavation sides to a height of at least 24-inch.

8.3 Augering and Augering Pits Method

8.3.1 Sewer Lines and Water Lines

We understand that augering method may be used for this project. Augering should be started from approved pit locations. Excavation for pits and shoring installation should conform to "Subdivision Construction Standards" of City of Texas City. If the augering zone is within the cohesionless soils or caving soils, install casing as required by "Subdivision Construction Standards" of City of Texas City, DWG. NO. 3 of 6. Diameter of auger hole should not exceed pipe bell diameter plus 2-inch. The receiving pit distance should conform to the aforementioned City of Texas City. A minimum spacing of 6-inch should be provided between the pipe and walls of bore pit. The maximum allowable width of pit shall be 5-ft unless approved by the engineer. Width of pit at surface shall not be less than the pit width at the bottom.

8.4 Backfilling

8.4.1 Backfilling for Open-Trench

Sand backfill used in the cement-stabilized sand and sand backfill section should be free of clay lumps, organic materials, or other deleterious material, and should have a PI less than 4 for cement-stabilized sand and less than 7 for the sand backfill, and not more than 15% passing the No. 200 sieve. Cement stabilized sand should conform to "Subdivision Construction Standards" of City of Texas City, DWG. NO. 2 of 6.

Random fill for zones above pipe bedding should be placed in loose lifts not exceeding eight-inch and compacted to 100% of the natural soil density. This value will be on the order of 95% of standard density (ASTM D 698) at a moisture content between optimum and +3% of optimum. These values should be verified by testing during construction.

Utility embedment depths may be greater than 10-ft below existing grades. Trench backfill in excess of about 10-ft in thickness is prone to post-construction settlements due to compression of the soils from self-weight, even if these fills are properly placed and compacted. This settlement could be about 1- to 2-percent of the thickness of the fill. The potential for this settlement should be considered when designing pavements over deep utility lines.

To reduce (but not eliminate) the risk of fill settlement, the portion of the fill below a depth of 10-ft below final grade should be compacted to a minimum of 100 percent of the material's maximum standard Proctor dry density (ASTM D-698).

8.4.2 Backfilling for Auger Pits and Auger Holes

Sand used in backfill sections should be free of clay lumps, organic materials, or other deleterious substances, and should have a PI less than 7, and not more than 15% passing the No. 200 sieve. Backfill should be placed in accordance with "Subdivision Construction Standards" of City of Texas City, DWG. NO. 2 of 6.

8.5 Lateral Earth Pressures

In the event that open excavations are not used, the proposed underground utilities can be installed using trench sheeting. The sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate 9. The trenching and shoring operations should follow OSHA Standards. We recommend a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety.

9.0 DETENTION POND

9.1 General

We understand that a detention pond will be constructed at the subjected site. The depth of detention pond is not available at the time of the study. We assume that the proposed detention pond will be approximately 20-ft deep. Furthermore, the proposed detention pond will not be used as an amenity lake, hence, it is our opinion that a clay liner will not be required.

9.2 Recommended Detention Pond Slope Ratio

We recommend that the slopes should be no steeper than 3.5(horizontal) to 1(vertical) [3.5(h):1(v)]. Recommended slope erosion control techniques are further discussed in the following report sections.

9.3 Detention Pond Slope Erosion Protection

Erosion problems are usually associated with embankments of the detention pond. Excessive erosion can lead to a loss of ground and gradual (progressive) sloughing of the slopes. Consequently, progressive slope failures can occur. Dressing of the slopes with erosion control systems should ensure successful long-term performance. The erosion control systems may consist of grass cover.

Grass cover can provide a suitable erosion protection system provided the root systems can sustain the peak velocities from the rainwater. Periodic observation of slopes should be planned to identify areas that may require a more positive erosion protection system.

10.0 PAVEMENT SECTIONS

We understand that concrete paving is planned for the subdivision streets. Our field exploration and laboratory testing data indicate that the surficial soils consist of lean clay (CL). soils. Our recommendations on pavement sections and soil stabilization are developed on the basis of Galveston County "Rules, Regulations and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions" dated October 03, 2005 (Ref. 1) and "Subdivision Construction Standards" of City of Texas City (Ref. 2) and are provided in Appendix C.

11.0 CONSTRUCTION CONSIDERATIONS

11.1 General

1. Our recommendations for the construction and maintenance of the post-tensioned slab foundations should be in accordance with the procedures presented in the publication "Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-on-Ground" (Ref. 7).

2. Grade beams excavations should be free of all loose materials. The bottom of the excavations should be dry and hard.

3. Surficial soils in the floor slab areas should be compacted to a minimum of 95% of standard Proctor density (ASTM D 698). This should be confirmed by conducting a minimum of four field density tests per slab, per lift.

4. Minimum concrete strength should be 1,750 and 2,500 psi at 7 and 28 days, respectively, with a maximum slump of 5-inch. Concrete workability and durability can be improved by adding air to the concrete mix. The slump and strength values of the concrete should be verified by slump tests and compressive strength of concrete cylinder tests, respectively. We recommend three concrete cylinders be made for each slab. These cylinders should be tested after 7 and 28 days from placement date. Furthermore, these tests should be performed in accordance with the applicable ASTM test procedures.

4. A layer of high-performance polyethylene moisture barrier, placed under the floor slabs, should be properly stretched to maximize soil-slab interaction.

6. Tree stumps should not be left under the slabs. This may result in future settlement and termite infestation.

7. Tree roots tend to desiccate the soils. In the event that a tree has been removed prior to building construction, during the useful life of the structure, or if a tree dies, subsoil swelling may occur in the expansive soil areas for several years. Studies (Ref. 8) have shown that this process can take an average of five years in the area where highly expansive clays are present. Depending on availability of water, this time period could be shorter or longer. In this case, the foundation for the structure should be designed for the anticipated maximum heave. In the event that a post-tensioned slab foundation is used, we recommend the slab be stiffened to resist the subsoil movements due to the presence of trees.

In addition, the area within the tree root zone may have to be chemically stabilized to reduce the potential movements. Alternatively, the site should be left alone for several years so that the moisture regime in the desiccated areas of the soils (where tree roots used to be) becomes equal/stabilized to the surrounding subsoil moisture conditions.

It should be noted that the upheaval in the expansive clays (where trees have been removed or trees have died) occurs faster in the areas that poor drainage, excessive irrigation or plumbing/sewer leak is occurring.

The effects of trees on foundations are covered with much more detail in the recommended Homeowner Foundation Maintenance Program for Residential Projects document at the end of this report.

8. We recommend trees not to be planted or left in place (existing trees) closer than half the canopy diameter of mature trees from the grade beams, typically a minimum of 20-ft. Alternatively, root barriers must be placed near the exterior grade beams to minimize tree root movements under the floor slab. This will reduce the risk of possible foundation movements as a result of tree root systems.

9. It is recommended that site drainage be well developed. Surface water should be directed away from the foundation soils (use a slope of about 5% in the grass within 10-feet of foundation). No ponding of surface water should be allowed near the structure.

10. In the event that sprinkler systems are used, we recommend that the sprinkler system be placed all around the residences to provide a uniform moisture condition throughout the year. This will reduce fluctuations in subsoil moisture and corresponding movements.

11. In order to minimize ponding of surface water, site drainage should be established early in project construction so that this condition will be controlled.

11.2 Site Preparation

In general, our recommendations for site preparations in the floor slab and pavement areas are summarized below:

1. In general, remove all vegetation, tree roots, organic topsoil, existing foundations, paved areas and any undesirable materials from the construction area. Tree trunks and tree roots under the floor slabs should be removed to a root size of less than 0.5-inch. We recommend that the stripping depth be evaluated at the time of construction by a soil technician.

2. Any on-site fill soils, encountered in the structure and pavement areas during construction, must have records of successful compaction tests signed by a licensed professional engineer that confirms the use of the fill and record of construction and earthwork testing. These tests must have been performed on all the lifts for the entire thickness of the fill. In the event that no compaction test results are available, the fill soils must be removed, processed and recompacted in accordance with our site preparation recommendations.

Excavation should extend at least two-feet beyond the structure and pavement area. Alternatively, the existing fill soils should be tested comprehensively to evaluate the degree of compaction in the fill soils.

3. The subgrade areas should then be proofrolled with a loaded dump truck or similar pneumatic-tired equipment with loads not be less than 25-tons. The proofrolling serves to compact surficial soils and to detect any soft or loose zones. The proofrolling should be conducted in accordance with The City of Texas City Specifications. Any soils deflecting excessively under moving loads should be undercut to firm soils and recompacted. Any subgrade stabilization should be conducted after site proofrolling is completed and approved by the geotechnical engineer. The proofrolling operations should be observed by an experienced geotechnician.

4. Scarify the subgrade, add moisture, or dry if necessary, and recompact to 95% of the maximum dry density as determined by ASTM D 698 (Standard Proctor). The moisture content at the time of compaction of subgrade soils should be between optimum and +3% of the Proctor optimum value. We recommend that the degree of compaction and moisture in the subgrade soils be verified by field density tests at the time of construction.

5. Structural fill may consist of off-site inorganic lean clays with a liquid limit of less than 40 and a plasticity index between 12 and 20. Other types of structural fill available locally, and acceptable to the geotechnical engineer, can also be used.

   These soils should be placed in loose lifts not exceeding eight-inches in thickness and compacted to 95% of the maximum dry density determined by ASTM D 698 (Standard Proctor). The moisture content of the fill at the time of compaction should be between optimum and +3% of the optimum value. We recommend that the degree of compaction and moisture in the fill soils be verified by field density tests at the time of construction. We recommend that the frequency of density testing be as stated in Item 4.

6. The backfill soils in the trench/underground utility areas and tree root excavation areas should consist of selected structural fill, compacted as described in Item 4. In the event of compaction difficulties, the trenches should be backfilled with cement-stabilized sand or other materials approved by the geotechnical engineer. Due to high permeability of sands and potential surface water intrusion, bank sands should not be used as backfill material in the trench/underground utility areas and tree root excavation areas.

7. In cut areas, the soils should be excavated to grade and the surface soils proofrolled and scarified to a minimum depth of six-inch and recompacted to the previously mentioned density and moisture content.

8. The subgrade and fill moisture content and density must be maintained until paving or floor slabs are completed. We recommend that these parameters be verified by field moisture and density tests at the time of construction.

9. In the areas where expansive soils are present, rough grade the site with structural fill soils to insure positive drainage. Due to their high permeability of sands, sands should not be used for site grading where expansive soils are present.

10. We recommend that the site and soil conditions used in the structural design of the foundation be verified by the engineer's site visit after all of the earthwork and site preparation has been completed and prior to the concrete placement.

11.3 Groundwater Control

11.3.1 General

Our short-term field exploration indicates that groundwater was encountered during and after 0.33-hour of drilling. Hence, groundwater dewatering system may be required. Fluctuations in groundwater can occur as a function of seasonal moisture variation. Groundwater control recommendations are presented in the following report sections.

11.3.2 Dewatering Technique

In the event that groundwater is encountered during construction, it is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or trench sump-pump. Wellpoint system can be used in the area where sandy soils are present.

Piezometers should be installed near the excavation area to further evaluate groundwater levels in the area prior to construction. The piezometers should be left in place during construction to monitor groundwater levels and effectiveness of the dewatering system.

Design of a wellpoint system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of groundwater and surface water should be in accordance with "Subdivision Construction Standards" of City of Texas City, Section 01563 – Control of Groundwater and Surface Water.

11.4 OSHA Soil Classifications

The subsoils can be classified in accordance with Occupational Safety and Health Administration (OSHA) Standards, dated October 31, 1989, of the Federal Register. OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. The description of four (4) types in classification system is summarized in the Appendix D.

Based on our geotechnical exploration and laboratory test results, details of soil classifications at each boring are summarized in the OSHA Soil Classification and Trench Safety Recommendations, presented in Appendix D.

11.5 Excavations

An excavation or trench which is five-ft or deeper must be protected by sheeting/bracing shoring or sloped. Based on soil strength data and OSHA soil classifications, temporary (less than 24 hours) open-trenched, non-surcharged, and unsupported excavations should be made on slopes of about 1.5(h):1(v). Vertical cuts can be constructed, provided shoring and bracing are used for the excavation wall stability. Benched excavation can also be used with average slopes of about 1(h):1(v) and steps should not be higher than five-ft. In all cases, excavations should conform to OSHA guidelines.

Flatter slopes may have to be used if large amounts of sand need to be excavated for deep utility installations. Specifications should require that no water be allowed to pond in the excavations. The surface slopes should be protected from deterioration and weathering if they are to be left open for more than 24 hours.

Excavations should be performed with equipment capable of providing a relatively clean bearing area. Excavation equipment should not disturb the soil beneath the design excavation bottom and should not leave large amounts of loose soil in the excavation.

11.6 Surface Water Drainage

In order to minimize ponding of surface water, site drainage should be established early in project construction so that this condition will be controlled.

11.7 Suitability of On-Site Soils for Use as Fill

11.7.1 General

The on-site soils can be used as fill. There are typically three types of fill at a site. These fills can be classified as described in the following report sections.

11.7.2 Select Structural Fill

This is the type of fill that can be used under the floor slabs, paving, etc. These soils should consist of lean clays, free of root organics, with liquid limit of less than 40 and plasticity indices between 12 and 20.

11.7.3 Structural Fill

This type does not meet the Atterberg limit requirements for select structural fill. This fill should consist of lean clays or fat clays. They can be used under post-tensioned slab or paving.

11.7.4 General Fill

This type of fill consists of sands and silts. These soils are moisture sensitive and are difficult to compact in a wet condition (they may pump). These soils can be used as structural fill on areas with the understating that they can erode easily and if they get wet, they are difficult to compact (they may pump). These soils can result in a perched water table. The owner and the civil engineer must be aware of these potential issues.

11.7.5 Use of On-Site Soils as Fill

The on-site soils can be used as fill materials as described below:

		Use as Fill			
Stratum No.[1]	Soil Type	Select Structural Fill	Structural Fill	General Fill	Notes
I	Lean Clay (CL)	–	✓	✓	2, 3
II	Fat Clay (CH)	–	✓	✓	2, 4

Notes:
1. See soil stratigraphy and design conditions sections of this report for strata description.
2. All fill soils should be free of organics, roots, etc.
3. These soils, once lime modified (4% by dry weight), can be used as select structural fill.
4. These soils, once lime modified (5% by dry weight), can be used as select structural fill.

11.8 Earthwork

Difficult access and workability problems can occur in the surficial clay soils due to poor site drainage, wet season, or site geohydrology. Should this condition develop, drying of the soils for support of pavement and floor slabs may be improved by the addition 4% lime by dry weight. The application rate corresponding to these additive amounts would be approximately 18 pounds per square yard for each six-inch of compacted thickness.

"Subdivision Construction Standards" of City of Texas City, DWG. NO. 1 of 6, shall be used as procedural guides for placing, mixing, and compacting lime stabilizer and the soils.

Our recommendations on subgrade stabilization are preliminary. The actual depth and type of stabilization should be determined in the field at the time of construction just after site stripping and proofrolling. The required amount of lime for stabilization should be determined by ASTM C 977 Method. Furthermore, the type and amount of the stabilizer may vary depending on the final grade elevation and the soil type encountered.

Provided the site work is performed during dry weather and/or project schedules permit aeration of wet soils, the subgrade will be suitable for floor slab and pavement support.

11.9 Construction Surveillance

Construction surveillance and quality control tests should be planned to verify materials and placement in accordance with the specifications. The recommendations presented in this report were based on a discrete number of soil test borings. Soil type and properties may vary across the site. As a part of quality control, if this condition is noted during the construction, we can then evaluate and revise the design and construction to minimize construction delays and cost overruns. We recommend the following quality control procedures be followed by a licensed engineer or technician during the construction of the facility:

- Monitor all phases of trench safety.
- Observe the site stripping and proofrolling.
- Verify the type, depth and amount of stabilizer.
- Verify the compaction of subgrade soils.
- Evaluate the quality of fill and monitor the fill compaction for all lifts.
- Monitor and test the excavations for strength, cleanness, depth, size, etc.
- Observe the make-up prior to concrete placement.

- Observe all excavation operations.

- Conduct after pour observations, including post-tensioned slab cable stress monitoring, if used.

- Monitor concrete placement, conduct slump tests and make concrete cylinders.

It is the responsibility of the client to notify GET when each phase of the construction is taking place so that proper quality control and procedures are implemented.

12.0 RECOMMENDED ADDITIONAL STUDIES

We recommend the following additional studies be conducted:

1. This report has been based on assumed conditions/characteristics of the proposed development where specific information was not available. It is recommended that the architect, civil engineer and structural engineer along with any other design professionals involved in this project carefully review these assumptions to ensure they are consistent with the actual planned development. When discrepancies exist, they should be brought to our attention to ensure they do not affect the conclusions and recommendations provided herein. We recommend that GET be retained to review the plans and specifications to ensure that the geotechnical related conclusions and recommendations provided herein have been correctly interpreted as intended.

2. **Conduct site characterization studies.** These studies will include the following separate studies:

   - Phase I Geologic Fault Study to look for geologic faults at or near the site.

   - Phase I Environmental Site Assessment Study to evaluate the risk of contamination at the site.

   - Conduct a site visit to look for drainage features, slopes, seeps, trees and other vegetation, fence lines, ponds, stock tanks, areas of fill, etc.

3. **The recommendations provided in this report are preliminary and are based on very limited number of soil borings. We recommend additional soil borings to be conducted for the detailed design and construction recommendations for the foundations, underground utilities, paving and detention pond.**

13.0 STANDARD OF CARE

The recommendations described herein were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical engineering profession practicing contemporaneously under similar conditions in the locality of the project. No other warranty or guarantee, expressed or implied, is made other than the work was performed in a proper and workmanlike manner.

14.0 REPORT DISTRIBUTION

This report was prepared for the sole and exclusive use by our client, based on specific and limited objectives. All reports, boring logs, field data, laboratory test results, maps and other documents prepared by GET as instruments of service shall remain the property of GET. Reuse of these documents is not permitted without written approval by GET. GET assumes no responsibility or obligation for the unauthorized use of this report by other parties and for purposes beyond the stated project objectives and work limitations.

14.0 REFERENCES

1. Galveston County "Rules, Regulations and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions" dated October 03, 2005.

2. "Subdivision Construction Standards", City of Texas City. http://www.texas-city-tx.org/page/plan.subdivision

3. "Method for Determining the Potential Vertical Rise, PVR," State Department of Highways and Public Transportation, Test Method Tex 124-E, Austin, Texas.

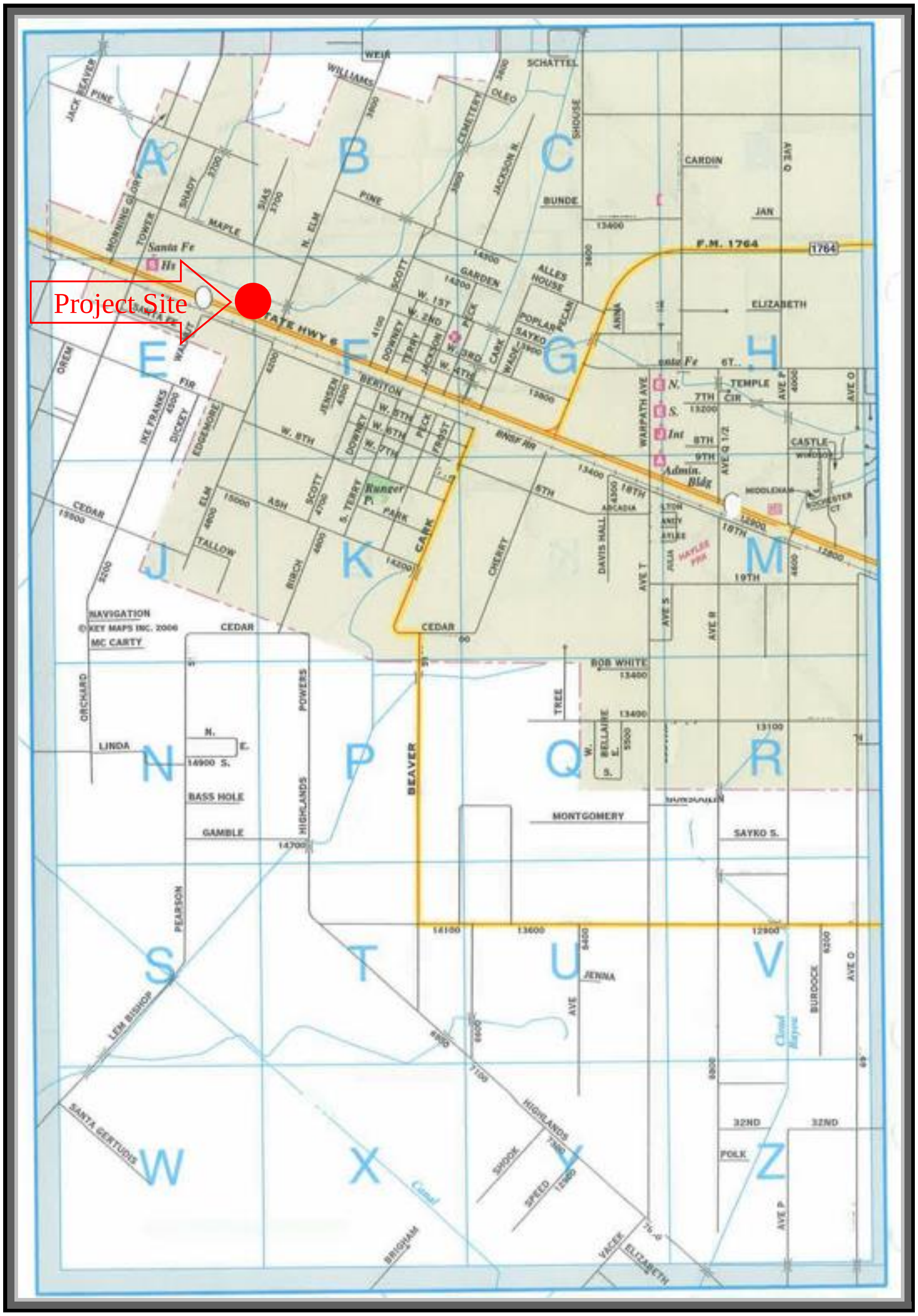
4. Committee Papers from Foundation Performance Association (FPA), see FPA Website: http://www.foundationperformance.org/committee_papers.cfm.

5. "Guidelines for the Evaluation and Repair of Residential Foundations", Version 2, Texas Section of the American Society of Civil Engineers, May 2009.

6. "Design of Post-Tensioned Slab-on-Ground", Post-Tensioning Institute, Phoenix, Arizona, Third Edition, with 2008 Supplement, 2008.

7. "Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-on-Ground", 2nd Edition, Post-Tensioning Institute, Phoenix, Arizona, September 1998.

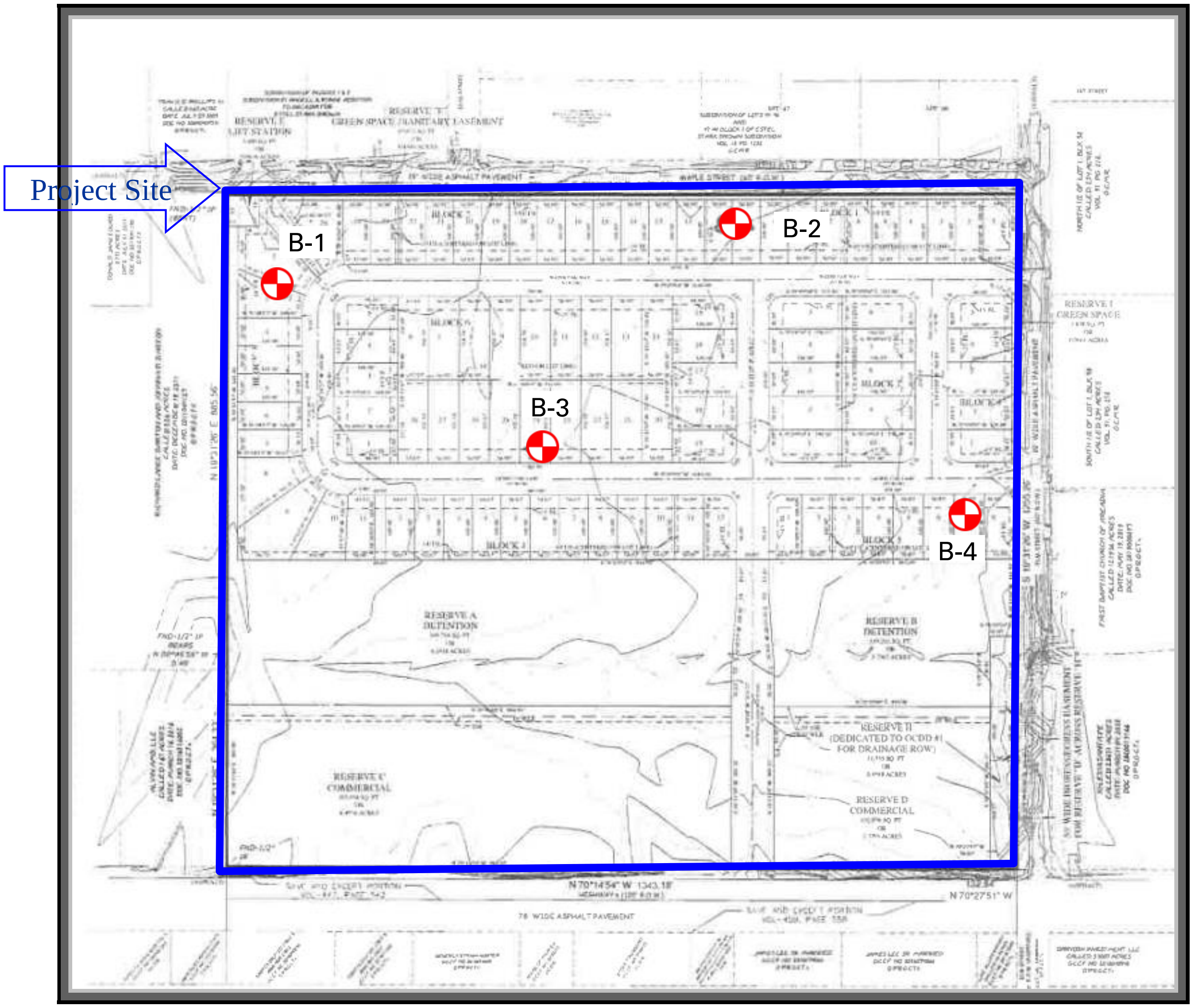
8. Eastwood, et al., "Design of Foundations with Trees in Mind", Presented at the ASCE Texas Section Meeting, 1997.



SITE VICINITY MAP

PROJECT: Preliminary Geotechnical Exploration for 42.45 Acres Centennial Oaks
Galveston County, Texas

SCALE: NOT TO SCALE	DATE: JULY 2022	REPORT NO.: 22-635E



PLAN OF BORINGS (boring locations are approximate)		
PROJECT: Preliminary Geotechnical Exploration for 42.45 Acres Centennial Oaks Galveston County, Texas		
SCALE: NOT TO SCALE	DATE: JULY 2022	PROJECT NO.: 22-635E

NORTH

LOG OF BORING NO. B-1

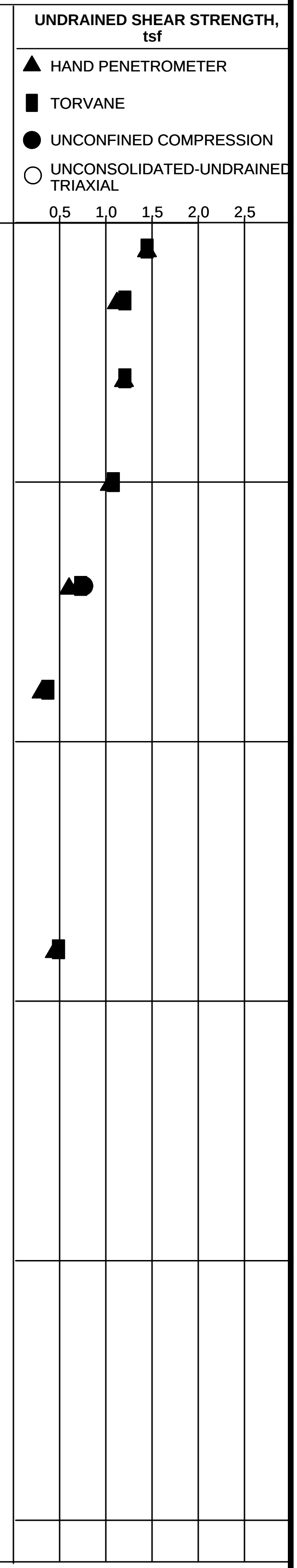
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Preliminary G/S for 42.45 Acres Centennial Oaks
LOCATION: Galveston County, Texas
PROJECT NO.: 22-635E STATION NO.:
DATE: 7-1-22 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			LEAN CLAY (CL), very stiff, dark brown, light brown, with root fibers to 10', ferrous nodules, sands - light brown 1' to 6', gray 1' to 4'	13	36	17	19					
5			- stiff 6' to 8', reddish brown, with calcareous nodules 6' to 10'	20						108		
			- firm 8' to 10'	20	46	18	28					
13			FAT CLAY (CH), firm, reddish brown, light gray, with root fibers to 15', ferrous nodules, gravels									
18	4		LEAN CLAY (CL), firm, reddish brown, light gray, with root fibers to 20', ferrous nodules, gravels, sands									
20												

UNDRAINED SHEAR STRENGTH, tsf



WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 18.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 18.0 ft. AFTER 0.33-HOUR

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ___ TO ___ ft.

DRILLED BY: Joseph (T)
LOGGED BY: Jonathan

OVM2 22-635E.GPJ OVM.GDT 7/12/22

LOG OF BORING NO. B-2

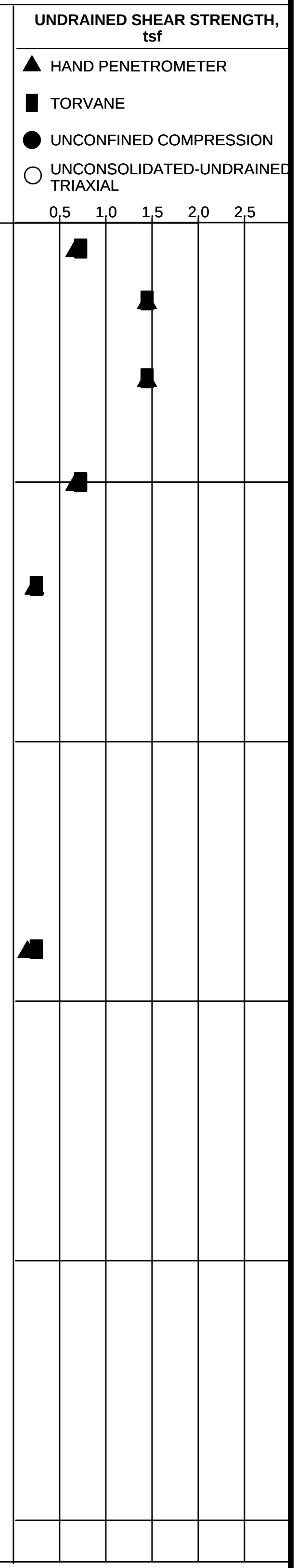
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Preliminary G/S for 42.45 Acres Centennial Oaks
LOCATION: Galveston County, Texas
PROJECT NO.: 22-635E STATION NO.:
DATE: 7-1-22 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			LEAN CLAY (CL), stiff, dark brown, light brown, with root fibers to 20', ferrous nodules, gravels, sands - very stiff 1' to 4', gray 1' to 2'									
5				11	33	16	17					
			- soft 6 ' to 8', reddish brown, light gray 6' to 20', with gravels 6' to 10', with calcareous nodules 6' to 8'									
			- firm 8' to 10'									
	5											
10												
			- soft 13' to 15'									
15												
			- firm 18' to 20'									
	5											
20												
25												

UNDRAINED SHEAR STRENGTH, tsf



WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 18.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 18.0 ft. AFTER 0.33-HOUR

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: Joseph (T)
LOGGED BY: Jonathan

OVM2 22-635E.GPJ OVM.GDT 7/12/22

LOG OF BORING NO. B-3

Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Preliminary G/S for 42.45 Acres Centennial Oaks
LOCATION: Galveston County, Texas
PROJECT NO.: 22-635E STATION NO.:
DATE: 7-1-22 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0			LEAN CLAY (CL), stiff, dark brown, light brown, with root fibers to 20', sands									
			- very stiff 1' to 8', with ferrous nodules 1' to 20'									
			- with gravels 2' to 20'	14	39	17	22					
			- gray 4' to 6'									
5												
			- brown 6' to 8', light gray 6' to 20', with calcareous nodules 6' to 8'	13	38	17	21					
			- firm 8' to 10', reddish brown 8' to 20'									
	7											
10												
			- soft 13' to 15'									
15												
			- firm 18' to 20'									
	7											
20												
25												

UNDRAINED SHEAR STRENGTH, tsf

▲ HAND PENETROMETER
■ TORVANE
● UNCONFINED COMPRESSION
○ UNCONSOLIDATED-UNDRAINED TRIAXIAL

0.5 1.0 1.5 2.0 2.5

WATER OBSERVATIONS:
▽ : WATER ENCOUNTERED AT 18.0 ft. DURING DRILLING
▼ : WATER DEPTH AT 18.0 ft. AFTER 0.33-HOUR

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: Joseph (T)
LOGGED BY: Jonathan

OVM2 22-635E.GPJ OVM.GDT 7/12/22

LOG OF BORING NO. B-4

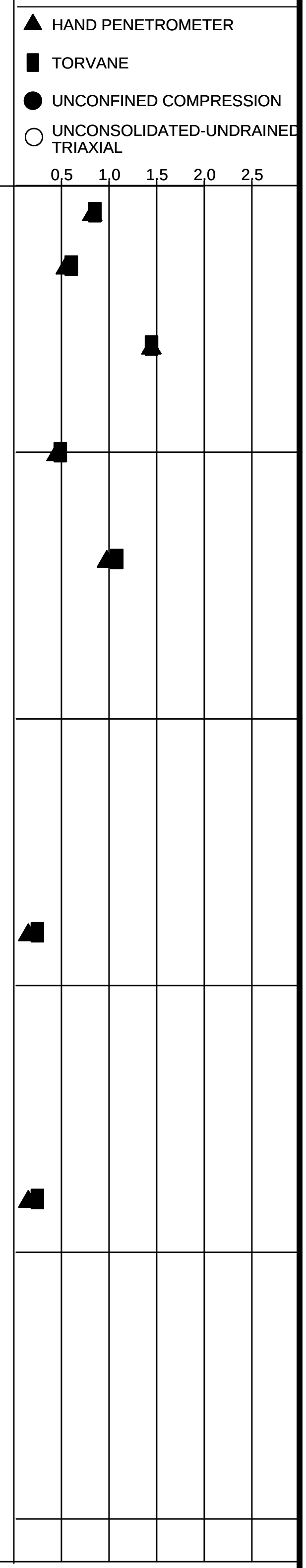
Geotech Engineering and Testing
17407 US Highway 59
Houston, Texas 77396
Phone: 713-699-4000 Fax: 713-699-9200

PROJECT: Preliminary G/S for 42.45 Acres Centennial Oaks
LOCATION: Galveston County, Texas
PROJECT NO.: 22-635E STATION NO.:
DATE: 7-1-22 COMPLETION DEPTH: 20.0 ft.

ELEVATION: Existing Grade

DEPTH, ft	SPT N-VALUE blows per foot	OVM, ppm	SYMBOL	SAMPLES	DESCRIPTION	NATURAL MOISTURE CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	PLASTICITY INDEX, %	PERCENT PASSING NO. 200 SIEVE	SUCTION (pF)	DRY UNIT WEIGHT, pcf	PERCENT COMPACTION	PASSING/FAILING (P/F)
0					LEAN CLAY (CL), stiff, dark brown, light brown, with root fibers to 20' - with ferrous nodules 1' to 2', sands	8	35	16	19					
					- very stiff, gray 2' to 4'									
5					- firm 4' to 6', reddish brown 4' to 20', light gray 4' to 10', with ferrous nodules, calcareous nodules 4' to 8', with gravels 4' to 15' - very stiff 6' to 8'									
	10													
10														
					- soft 13' to 20'									
15														
20														
25														

UNDRAINED SHEAR STRENGTH, tsf



WATER OBSERVATIONS:
▽: WATER ENCOUNTERED AT 18.0 ft. DURING DRILLING
▼: WATER DEPTH AT 18.0 ft. AFTER 0.33-HOUR

DRY AUGER: 0 TO 20 ft.
WET ROTARY: ____ TO ____ ft.

DRILLED BY: Joseph (T)
LOGGED BY: Jonathan

OVM2 22-635E.GPJ OVM.GDT 7/12/22

KEY TO LOG TERMS AND SYMBOLS

UNIFIED SOIL CLASSIFICATIONS

Symbol	Material Descriptions
GW	WELL GRADED-GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GM	SILTY GRAVELS, GRAVEL-SAND SILT MIXTURES
GC	CLAY GRAVELS, GRAVEL-SAND CLAY MIXTURES
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP	POORLY GRADED SANDS, OR GRAVELLY SANDS, LITTLE OR NO FINES
SM	SILTY SANDS, SAND-SILT MIXTURES a
SC	CLAYEY SANDS, SAND-SILT MIXTURES b
ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
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 MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENT
	FILL SOILS

TERMS CHARACTERIZING SOIL STRUCTURE

Slickensided	-	Having incline planes of weakness that are slick and glossy in appearance.
Fissured	-	Containing shrinkage cracks frequently filled with fine sand or silt: usually vertical.
Laminated	-	Composed of thin layers of varying colors and soil sample texture.
Interbedded	-	Composed of alternate layers of different soil types.
Calcareous	-	Containing appreciable quantities of calcium carbonate.
Well Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes.
Poorly Graded	-	Predominantly of one grain size, or having a range of sizes with some intermediate sizes missing.
Pocket	-	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	-	Inclusion less than 1/8-inch thick extending through the sample.
Seam	-	Inclusion 1/8- to 3-inch thick extending through the sample.
Layer	-	Inclusion greater than 3-inch thick extending through the sample.
Interlayered	-	Soils sample composed of alternating layers of different soil types.
Intermixed	-	Soil samples composed of pockets of different soil type and layered or laminated structure is not evident.

COARSE GRAINED SOILS (major portion retained on No. 200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Conditions rated according to standard penetration test (SPT)* as performed in the field.

Descriptive Terms	Blows Per Foot*
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	over 50

* 140 pound weight having a free fall of 30-inch

SOIL SAMPLERS

- SHELBY TUBE SAMPLER
- STANDARD PENETRATION TEST
- AUGER SAMPLING

FINE GRAINED SOILS (major portion passing No. 200 Sieve): Include (1) inorganic or organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength as indicated by hand penetrometer readings or by unconfined compression tests.

Descriptive Term	Undrained Shear Strength Ton/Sq. Ft.	Descriptive Term	Blows Per Foot*
Very Soft	Less than 0.13	Very Soft	< 2
Soft	0.13 to 0.25	Firm	2 – 8
Firm	0.25 to 0.50	Stiff	8 – 15
Stiff	0.50 to 1.00	Very Stiff	15 – 30
Very Stiff	1.00 to 2.00	Hard	> 30
Hard	2.00 or higher		

NOTE: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above because of weakness or cracks in the soil. The consistency ratings of such soils are based on hand penetrometer readings.

* 140 pound weight having a free fall of 30-inch

TERMS CHARACTERIZING ROCK PROPERTIES

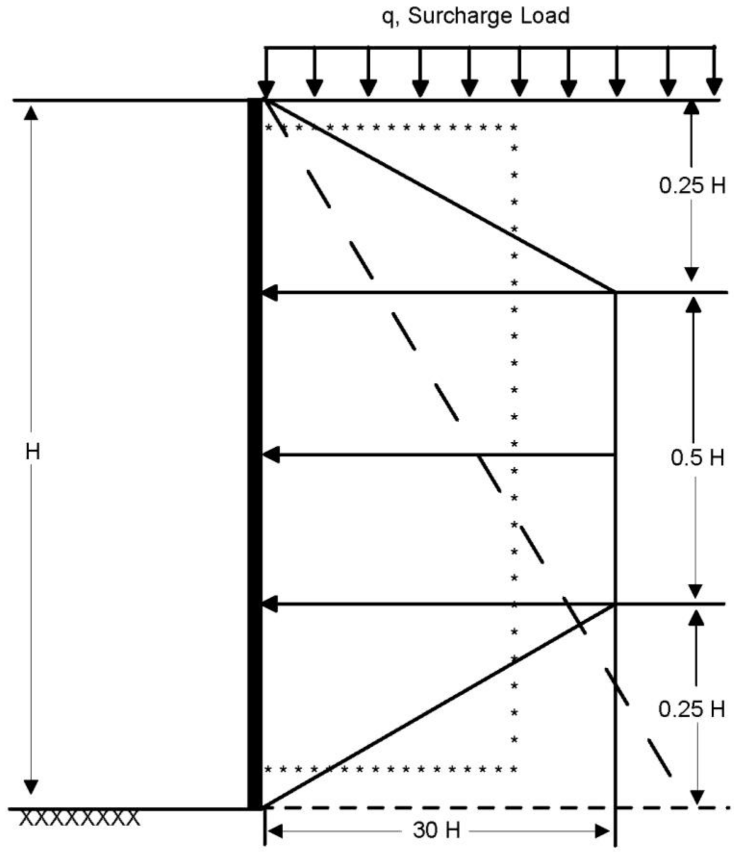
VERY SOFT OR PLASTIC	Can be remolded in hand: corresponds in consistency up to very stiff in soils.
SOFT	Can be scratched with fingernail.
MODERATELY HARD	Can be scratched easily with knife; cannot be scratched with fingernail. Difficult to scratch with knife.
VERY HARD	Cannot be scratched with knife.
POORLY CEMENTED OR FRIABLE	Easily crumbled.
CEMENTED	Bounded Together by chemically precipitated materials.
UNWEATHERED	Rock in its natural state before being exposed to atmospheric agents.
SLIGHTLY WEATHERED	Noted predominantly by color change with no disintegrated zones.
WEATHERED	Complete color change with zones of slightly decomposed rock.
EXTREMELY WEATHERED	Complete color change with consistency, texture, and general appearance or soil.

PROJECT PICTURES

Project No. 22-635E

Note: The above picture(s) indicate a snap shot of the project and the surroundings. We request that the client review the picture(s) and make sure that they represent the project area. We must be contacted immediately if any discrepancy exists.

LATERAL EARTH PRESSURE DIAGRAM



Legend:

——————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - Cantilevered sheeting

Active Pressure:

(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilevered sheeting = 0.7q + 42H + 62.4H

where: q = surcharge load, psf: A value of 250 psf can be assumed.
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.
5. In case of layered soils, active pressure should be calculated based on the dominant or more critical soil conditions.

APPENDIX A

Aerial Photographs from Google Earth Website
(www.google.com/earth/)

AERIAL PHOTOGRAPH 2015			NORTH
PROJECT: Preliminary Geotechnical Exploration for 42.45 Acres Centennial Oaks Galveston County, Texas			
SCALE: NOT TO SCALE	DATE: JULY 2022	PROJECT NO.: 22-635E	

AERIAL PHOTOGRAPH 2022

PROJECT: Preliminary Geotechnical Exploration for 42.45 Acres Centennial Oaks
Galveston County, Texas

SCALE: NOT TO SCALE	DATE: JULY 2022	PROJECT NO.: 22-635E

NORTH

TOPOGRAPHIC MAP

PROJECT: Preliminary Geotechnical Exploration for 42.45 Acres Centennial Oaks
Galveston County, Texas

SCALE: NOT TO SCALE	DATE: JULY 2022	PROJECT NO.: 22-635E

NORTH

APPENDIX B

Foundation Maintenance Program

GEOTECH ENGINEERING and TESTING

Geotechnical, Environmental, Construction Materials, and Forensic Engineering

ACCREDITED
CERTIFICATE #0075-01
#0075-02

RECOMMENDED HOMEOWNER FOUNDATION MAINTENANCE PROGRAM FOR RESIDENTIAL PROJECTS IN THE HOUSTON AREA

BY
DAVID A. EASTWOOD, P.E.

02-16

Introduction

Performance of residential structures depends not only on the proper design and construction, but also on the proper foundation maintenance program. Many residential foundations have experienced major foundation problems as a result of owner's neglect or alterations to the initial design, drainage, or landscaping. This has resulted in considerable financial loss to the homeowners, builders, and designers in the form of repairs and litigation.

A properly designed and constructed foundation may still experience distress from vegetation and expansive soil which will undergo volume change when correct drainage is not established or incorrectly controlled water source becomes available.

The purpose of this document is to present recommendations for maintenance of properly designed and constructed residential projects in Houston. It is recommended that the builder submit this document to his/her client at the time that the owner receives delivery of the house.

Typical Foundations

Foundations for support of residential structures in the Houston area consist of pier and beam type foundation, spread footing foundation, conventionally reinforced slab, or a post-tensioned slab. A soils exploration must be performed before a proper foundation system can be designed.

General Soil Conditions

Variable subsoil conditions exist in the Houston Metro area. Highly expansive soils exist in the West University, Bellaire, Southwest Houston, Clear Lake, Friendswood, Missouri City, and First Colony areas.

Sandy soils with potential for severe perched water table problems as a result of poor drainage are present in the North and West Houston, including portions of Piney Point, Hedwig Village, The Woodlands, Kingwood, Atascocita, Cypresswood, Fairfield, etc.

A perched water table condition can occur in an area consisting of surficial silty sands or clayey sands underlain by impermeable clays. During the wet (rainy) season, water can pond on the clays (due to poor drainage) and create a perched water table condition. The sands become extremely soft, wet, and lose their load carrying capacity.

Drainage

The initial builder/developer site grading (positive drainage) should be maintained during the useful life of the residence. In general, a civil engineer develops a drainage plan for the whole subdivision. Drainage sewers or other discharge channels are designed to accommodate the water runoff. These paths should be kept clear of debris such as leaves, gravel, and trash.

In the areas where expansive soils are present, positive drainage should be provided away from the foundations. Changes in moisture content of expansive soils are the cause of both swelling and shrinking. Positive drainage should also be maintained in the areas where sandy soils are present.

Positive drainage is extremely important in minimizing soil-related foundation problems.

The homeowner's berm the flowerbed areas, creating a dam between the berm and the foundation, preventing the surface water from draining away from the structure. This condition may be visually appealing but can cause significant foundation damage as a result of negative drainage.

The most commonly used technique for grading is a positive drainage away from the structure to promote rapid runoff and to avoid collecting ponded water near the structure which could migrate down the soil/foundation interface. This slope should be about 3 to 5 percent within 10-feet of the foundation.

Should the owner change the drainage pattern, he should develop positive drainage by backfilling near the grade beams with select fill compacted to 90 percent of the maximum dry density as determined by ASTM D 698-91 (standard proctor).

This level of compaction is required to minimize subgrade settlements near the foundations and the subsequent ponding of the surface water. The select fill soils should consist of silty clays and sandy clays with liquid limits less than 40 and plasticity index (PI) between 10 and 20. Bank sand or top soils are not a select fill. The use of Bank sand or top soils to improve drainage away from a house is discouraged; because, sands are very permeable. In the event that sands are used to improve drainage away from the structure, one should make sure the clay soils below the sands have a positive slope (3 - 5 Percent) away form the structure, since the clay soils control the drainage away from the house.

The author has seen many projects with an apparent positive drainage; however, since the drainage was established with sands on top of the expansive soils the drainage was not effective.

Depressions or water catch basin areas should be filled with compacted soil (sandy clays or silty clays not bank sand) to have a positive slope from the structure, or drains should be provided to promote runoff from the water catch basin areas. Six to twelve inches of compacted, impervious, non-swelling soil placed on the site prior to construction of the foundation can improve the necessary grade and contribute additional uniform surcharge pressure to reduce uneven swelling of underlying expansive soil.

Pets (dogs, etc.) sometimes excavate next to the exterior grade beams and created depressions and low spots in order to stay cool during the hot season. This condition will result in ponding of the surface water in the excavations next to the foundation and subsequent foundation movements. These movements can be in the form of uplift in the area with expansive soils and settlement in the areas with sandy soils. It is recommended as a part of the foundation maintenance program, the owner backfills all excavations created by pets next to the foundation with compacted clay fill.

Grading and drainage should be provided for structures constructed on slopes, particularly for slopes greater than 9 percent, to rapidly drain off water from the cut areas and to avoid ponding of water in cuts or on the uphill side of the structure. This drainage will also minimize seepage through backfills into adjacent basement walls.

Subsurface drains may be used to control a rising water table, groundwater and underground streams, and surface water penetrating through pervious or fissured and highly permeable soil. Drains can help control the water table in the expansive soils.

Furthermore, since drains cannot stop the migration of moisture through expansive soil beneath foundations, they will not prevent long-term swelling. Moisture barriers can be placed near the foundations to minimize moisture migration under the foundations. The moisture barriers should be at least five-feet deep in order to be effective.

Area drains can be used around the house to minimize ponding of the surface water next to the foundations. The area drains should be checked periodically to assure that they are not clogged.

The drains should be provided with outlets or sumps to collect water and pumps to expel water if gravity drainage away from the foundation is not feasible. Sumps should be located well away from the structure. Drainage should be adequate to prevent any water from remaining in the drain (i.e., a slope of at least 1/8 inch per foot of drain or 1 percent should be provided).

Positive drainage should be established underneath structural slabs with crawl space. This area should also be properly vented. Absence of positive drainage may result in surface water ponding and moisture migration through the slab. This may result in wood floor warping and tile unsticking.

It is recommended that at least six-inches of clearing be developed between the grade and the wall siding. This will minimize surface water entry between the foundation and the wall material, in turn minimizing wood decay.

Poor drainage at residential projects in North and West Houston can result in saturation of the surficial sands and development of a perched water table. The sands, once saturated, can lose their load carrying capacity. This can result in foundation settlements and bearing capacity failures. Foundations in these areas should be designed assuming saturated subsoil conditions.

In general, roof drainage systems, such as gutters or rain dispenser devices, are recommended all around the roof line when gutters and downspouts should be unobstructed by leaves and tree limbs. In the area where expansive soils are present, the gutters should be connected to flexible pipe extensions so that the roof water is drained at least 10-feet away from the foundations. Preferably the pipes should direct the water to the storm sewers. In the areas where sandy soils are present, the gutters should drain the roof water at least five-feet away from the foundations.

If a roof drainage system is not installed, rain-water will drip over the eaves and fall next to the foundations resulting in subgrade soil erosion, and creating depression in the soil mass, which may allow the water to seep directly under the foundation and floor slabs.

The home owner must pay special attention to leaky pools and plumbing. In the event that the water bill goes up suddenly without any apparent reason, the owner should check for a plumbing leak.

The introduction of water to expansive soils can cause significant subsoil movements. The introduction of water to sandy soils can result in reduction in soil bearing capacity and subsequent settlement. The home owner should also be aware of water coming from the air conditioning drain lines. The amount of water from the condensating air conditioning drain lines can be significant and can result in localized swelling in the soils, resulting in foundation distress.

Landscaping

General. A house with the proper foundation and drainage can still experience distress if the homeowner does not properly landscape and maintain his property. One of the most critical aspects of landscaping is the continual maintenance of properly designed slopes.

Installing flower beds or shrubs next to the foundation and keeping the area flooded will result in a net increase in soil expansion in the expansive soil areas. The expansion will occur at the foundation perimeter. It is recommended that initial landscaping be done on all sides, and that drainage away from the foundation should be provided and maintained. Partial landscaping on one side of the house may result in swelling on the landscaping side of the house and resulting differential swell of foundation and structural distress in a form of brick cracking, windows/door sticking, and slab cracking.

Landscaping in areas where sandy, non-expansive soils are present, with flowers and shrubs should not pose a major problem next to the foundations. This condition assumes that the foundations are designed for saturated soil conditions. Major foundation problems can occur if the planter areas are saturated as the foundations are not designed for saturated (perched water table) conditions. The problems can occur in a form of foundation settlement, brick cracking, etc.

Sprinkler Systems. Sprinkler systems can be used in the areas where expansive soils are present, provided the sprinkler system is placed all around the house to provide a uniform moisture condition throughout the year.

The use of a sprinkler system in parts of Houston where sandy soils are present should not pose any problems, provided the foundations are designed for saturated subsoil conditions with positive drainage away from the structure.

The excavations for the sprinkler system lines, in the areas where expansive soils are present, should be backfilled with impermeable clays. Bank sands or top soil should not be used as backfill. These soils should be properly compacted to minimize water flow into the excavation trench and seeping under the foundations, resulting in foundation and structural distress.

The sprinkler system must be checked for leakage at least once a month. Significant foundation movements can occur if the expansive soils under the foundations are exposed to a source of free water.

The homeowner should also be aware of damage that leaking plumbing or underground utilities can cause, if they are allowed to continue leaking and providing the expansive soils with the source of water.

Effect of Trees. The presence of trees near a residence is considered to be a potential contributing factor to the foundation distress. Our experience shows that the presence or removal of large trees in close proximity to residential structures can cause foundation distress. This problem is aggravated by cyclic wet and dry seasons in the area. Foundation damage of residential structures caused by the adjacent trees indicates that foundation movements of as much as 3- to 5-inches can be experienced in close proximity to residential foundations.

This condition will be more severe in the periods of extreme drought. Sometimes the root system of trees such as willow, elm, or oak can physically move foundations and walls and cause considerable structural damage. Root barriers can be installed near the exterior grade beams to a minimum depth of 60-inches, if trees are left in place in close proximity to foundations. It is recommended that trees not be planted closer than half the canopy diameter of the mature tree, typically 20-feet from foundations. Any trees in closer proximity should be thoroughly soaked at least twice a week during hot summer months, and once a week in periods of low rainfall. More frequent tree watering may be required.

Tree roots tend to desiccate the soils. In the event that the tree has been removed prior to house construction, during the useful life of the house, or if tree dies, subsoil swelling can occur for several years. Studies have shown that this process can last as much as 20 years in the area where highly expansive clays are present. In the areas where sandy soils are present this process does not occur.

In this case the foundation for the house should be designed for the anticipated maximum heave. Alternatively, the site should be left alone for several years so that the moisture regime in the desiccated area of the soils (where roots used to be) become equal/stabilized to the surrounding subsoil conditions.

Tree removal can be safe provided the tree is no older than any part of the house, since the subsequent heave can only return the foundation to its original level. In most cases there is no advantage to a staged reduction in the size of the tree and the tree should be completely removed at the earliest opportunity. The areas where expansive soils exist and where the tree is older than the house, or there are more recent extensions to the house, it is not advisable to remove the tree because the danger of inducing damaging heave; unless the foundation is designed for the total computed expected heave.

In the areas where non-expansive soils are present, no significant foundation distress will occur as a result of the tree removal.

In the areas where too much heave can occur with tree removal, some kind of pruning, such as crown thinning, crown reduction or pollarding should be considered. Pollarding, in which most of the branches are removed and the height of the main trunk is reduced, is often mistakenly specified, because most published advice links the height of the tree to the likelihood of damage. In fact, the leaf area is the important factor. Crown thinning or crown reduction, in which some branches are removed or shortened, is therefore generally preferable to pollarding. The pruning should be done in such a way as to minimize the future growth of the tree, without leaving it vulnerable to disease (as pollarding often does) while maintaining its shape. This should be done only by a reputable tree surgeon or qualified contractor working under the instructions of an arbor culturist.

You may find there is opposition to the removal or reduction of an offending tree; for example, it may belong to a neighbor or the local authority or have a Tree Preservation Order on it. In such cases there are other techniques that can be used from within your own property.

One option is root pruning, which is usually performed by excavating a trench between the tree and the damaged property deep enough to cut most of the roots. The trench should not be so close to the tree that it jeopardizes its stability. In time, the tree will grow new roots to replace those that are cut; however, in the short term there will be some recovery as the degree of desiccation in the soil under the foundations reduces.

Where the damage has only appeared in a period of dry weather, a return to normal weather pattern may prevent further damage occurring. Permission from the local authority is required before pruning the roots of a tree with preservation order on it.

Root barriers are a variant of root pruning. However, instead of simply filling the trench with soil after cutting the roots, the trench is either filled with concrete or lined with an impermeable layer to form a "permanent" barrier to the roots. Whether the barrier will be truly permanent is questionable, because the roots may be able to grow round or under the trench. However, the barrier should at least increase the time it takes for the roots to grow back.

Foundations/Flat Works

Every homeowner should conduct a yearly observation of foundations and flat works and perform any maintenance necessary to improve drainage and minimize infiltrations of water from rain and lawn watering. This is important especially during the first six years of a newly built home because this is usually the time of the most severe adjustment between the new construction and its environment. We recommend that all of the separations in the flat work and paving joints be immediately backfilled with joint sealer to minimize surface water intrusion and subsequent shrink/swell.

Some cracking may occur in the foundations. For example, most concrete slabs can develop hairline cracks. This does not mean that the foundation has failed. All cracks should be cleaned up of debris as soon as possible. The cracks should be backfilled with high-strength epoxy glue or similar materials. If a foundation experiences significant separations, movements, cracking, the owner must contact the builder and the engineer to find out the reason(s) for the foundation distress and develop remedial measures to minimize foundation.

APPENDIX C

PAVEMENT SECTIONS

PAVEMENT SECTIONS

The laboratory data indicates that the upper subsoils are classified as natural lean clay (CL) soils by the Unified Soil Classification System. These soils have subgrade moduli, k, ranging from 80 to 140 pci and CBR values ranging from 3 to 5.

Based on the subgrade soil properties, the recommended pavement thickness for rigid paving is given on Table I. Our recommendations were developed on the basis of Galveston County "Rules, Regulations and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions" dated October 03, 2005 (Ref. 1) and "Subdivision Construction Standards" of City of Texas City (Ref. 2).

It should be noted that our recommendations on subgrade stabilization assume that final paving grade will be at the top of existing subgrade. Alternative subgrade stabilization recommendations will be required if the final subgrade is different from the one assumed in this report. Actual type and quantity of subgrade stabilization should be determined at the time of construction when the pavement subgrade has been exposed.

TABLE I

Rigid Pavement		Minimum Thickness, Inches	
		Single Roadway	Double Roadway
Surface:	Concrete Pavement	6	7
Subgrade:	Lime- Stabilized Subgrade (4% by dry weight) Compact to 95% of Maximum Standard Proctor Density (ASTM D 698) at a moisture content between optimum and +3% of optimum.	6	6

NOTES:

1. The paving should be reinforced with #4 bars at 18-inches on centers each. Steel used for reinforcements should be grade 60. The maximum width between traverse expansion joints shall not exceed 60’-0’’. Control joints shall be saw cut 3/8’’ wide and 1 - 1/2’’ deep (min.) with joint sealant at 20’ maximum spacing between expansion joints.

2. The concrete should have a compressive strength of 3000 psi at 28 days.

3. Use 4% lime by dry weight to stabilize the upper soils. This results in application rates of 18 pounds per square yard per six-inches of compacted thickness and 48 pounds per square yard per eight-inches of compacted thickness

APPENDIX D

OSHA SOIL CLASSIFICATION AND TRENCH SAFETY RECOMMENDATIONS

OSHA SOIL CLASSIFICATION AND TRENCH SAFETY RECOMMENDATIONS

General

Occupational Safety and Health Administration (OSHA) requires a trench protective system for trenches deeper than five-ft. Trenches that are deeper than five-ft, should be shored, sheeted, braced or laid back to a stable slope, or some other appropriate means of protection should be provided where workers might be exposed to moving ground or caving. OSHA developed a soil classification system to be used as a guideline in determining protective requirements for trench excavations.

OSHA classification system categorizes the soil and rock in four types based on shear strength and stability. These classifications are summarized in the following report sections.

Stable Rock

means natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A Soil

means cohesive soils with an unconfined compressive strength of 1.5-ton per square foot (tsf) or greater. Examples of cohesive soils are: clay, silty clay, sandy clay, clay loam, silty clay loam, sandy clay loam, caliche and hardpan. No soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibration from heavy traffic, pile driving or similar effects; or
- The soil has been previously disturbed; or
- The soil is part of a slope, layered system where the layers dip into the excavation on a slope of 4(h): 1(v) or greater; or
- The material is subject to other factors that would require it to be classified as a less stable material.

Type B Soil

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; or
- Granular cohesionless soils including: angular gravel, silt, silt loam, sandy loam, and in some case, silty clay loam and sandy clay loam; or
- Previously disturbed soils except those which would otherwise be classified as Type C soil; or
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or

- Dry rock that is not stable; or
- Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than 4(h): 1(v), but only if the material would otherwise be classified as Type B.

Type C Soil

- Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
- Granular soils including gravel, sand, and loamy sand; or
- Submerged soil or soil from which water is freely seeping; or
- Submerged rock that is not stable; or
- Materials in a sloped, layered system where the layers dip into the excavation on a slope 4 (h) : 1(v) or steeper.

Under the assumption that appropriate groundwater control measures are carried out, and the groundwater table, if present, is lowered and maintained at least 3-ft below the excavation depths, the stable cohesive soils (CL) and (CH), with unconfined compressive strength greater than 0.5 tsf, are classified as OSHA soil Type "B". The granular soils, which are less stable, are classified as OSHA soil Type "C".

Based on our geotechnical exploration and laboratory test results, details of soil classifications at the boring locations are summarized below:

Boring No.	Depth Range [1], ft	Soil Type	OSHA Soil Classification
B-1	0 – 13	Lean Clay (CL)	B
	13 – 18	Fat Clay (CH)	B
	18 – 20	Lean Clay (CL)	B
B-2	0 – 6	Lean Clay (CL)	B
	6 – 8	Lean Clay (CL)	C
	8 – 13	Lean Clay (CL)	B
	13 – 18	Lean Clay (CL)	C
	18 – 20	Lean Clay (CL)	B
B-3	0 – 13	Lean Clay (CL)	B
	13 – 18	Lean Clay (CL)	C
	18 – 20	Lean Clay (CL)	B
B-4	0 – 13	Lean Clay (CL)	B
	13 – 20	Lean Clay (CL)	C

Note: 1. Refer to each boring log of soils stratigraphy

Stockpiling of excavated materials may not be allowed near the banks of excavated areas. Generally, a distance of one-half the excavation depth on both sides of the trench should be kept clear of any excavated material.

Underground utility trenches should be provided with proper trench support system. The trench should be provided with a temporary shoring system on excavations deeper than five-ft. The trenches can be made using shored, sheeted and braced, laid back stable slope or other means of appropriate protection system should be provided where workers are exposed to moving ground or caving. The slopes may be constructed in accordance with Table B-1 and shoring may be constructed in accordance with Table C-1.1, Table C-1.2 and Table C-1.3 of 29 CFR Part 1926 of OSHA.

In the event that trench sheeting is used, the sheeting can be constructed in the form of cantilever sheeting or with bracing. Lateral earth pressures for each method used are summarized on Plate D-1. The trenching and shoring operations should follow OSHA Standards. We recommend that a geotechnical engineer monitor all phases of trench excavation and bracing to assure trench safety.

Timber shoring as outlined in 29 CFR Part 1926 of OSHA recommendation may be used in the construction of trench supporting system.

For trench excavation, it is necessary to maintain the stability of the sides and base and not to disturb the soil below the excavation grade. In braced cuts, if the sheeting is terminated at the base of the cut, the bottom of the excavation can become unstable under certain conditions. The stability of the trench bottom is governed by the shear strength of the soils and the differential hydrostatic head. For cuts in cohesive soils (such as fat clay and lean clay), stability of the bottom can be evaluated in accordance with the procedure outlined on Plate D-2. However, if cohesionless soils are encountered, dewatering will be required to prevent bottom blowup if the groundwater is encountered during construction. Design soil parameters presented on Plate D-3 and D-4 can be used for design.

Groundwater Control

Our short-term field exploration indicates that groundwater was encountered during and after 0.33-hour of drilling Hence, groundwater dewatering may be required. However, fluctuations in groundwater can occur as a function of seasonal moisture variation. Groundwater control recommendations are presented in the following report sections.

In the event that groundwater is encountered during construction, it is our opinion that groundwater should be lowered to a depth of at least three-ft below the deepest excavation grade in order to provide dry working conditions and firm bedding. Any minor water inflow in cohesive soil layers can probably be removed using a sump-pump or trench sump-pump. Wellpoint system can be used in the area where sandy soils are present.

Piezometers should be installed near the excavation area to further evaluate groundwater levels in the area prior to construction. The piezometers should be left in place during construction to monitor groundwater levels and effectiveness of the dewatering system.

Design of a wellpoint system should consider the amount of groundwater to be lowered and the permeability of the affected soils. The selection and proper implementation of an effective groundwater control system is the responsibility of the contractor. The design of groundwater and surface water should be in accordance with “Subdivision Construction Standards” of City of Texas City, Section 01563 – Control of Groundwater and Surface Water.

The results of our field exploration and laboratory testing indicate that unsatisfactory soils for excavation, such as soft lean clay soils existing at the borings. A summary of the unsatisfactory soils locations and depths are as follows:

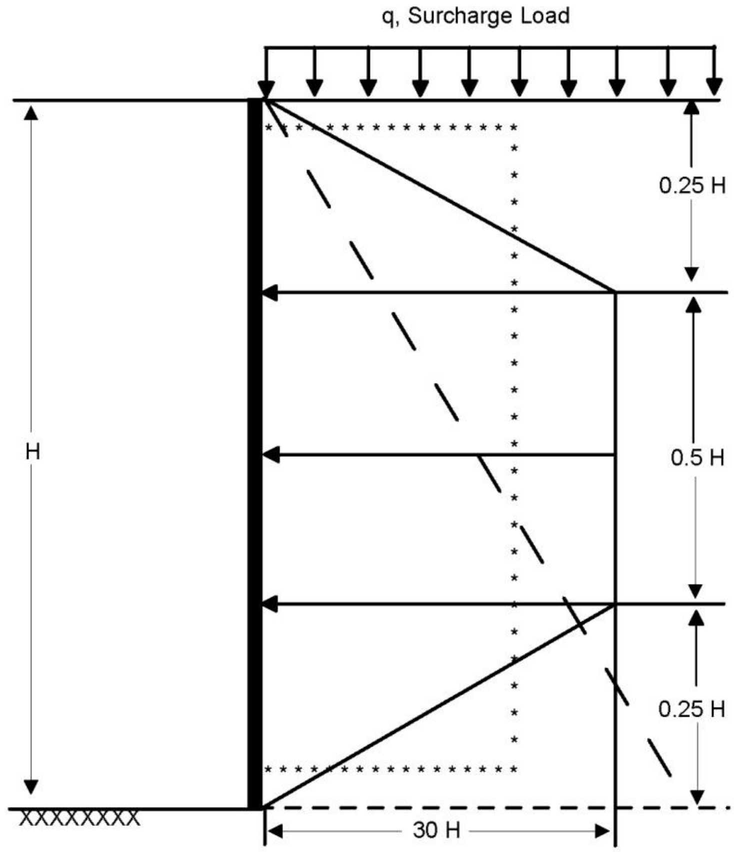
Boring(s)	Depth, ft.
B-2	6 to 8
B-2	13 to 15
B-3	13 to 15
B-4	13 to 20

If these conditions are encountered during the time of construction, suitable groundwater control measures should be implemented in accordance with “Subdivision Construction Standards” of City of Texas City, Section 01563 – Control of Groundwater and Surface Water. Furthermore, the contractor may have to over excavate an additional 6 inches and remove unstable or unsuitable materials with approval by geotechnical engineer, then place an equal depth of cement stabilized sand.

Due to potential variability of the on-site soils, unstable trench conditions may still exist in the areas where we did not conduct borings. If these conditions are encountered during the time of construction, a stable trench should be provided to allow proper bedding and installation.

Our recommendation on trench safety at the project site does not address the effects of excavations on existing buildings/facilities at the project site. This study was outside the scope of our work.

LATERAL EARTH PRESSURE DIAGRAM



Legend:

———————— Braced Excavation (stiff clays)
* * * * * * * * * * * * * * Braced Excavation (sands)
- - - - - - - - - - - - - - - Cantilevered sheeting

Active Pressure:

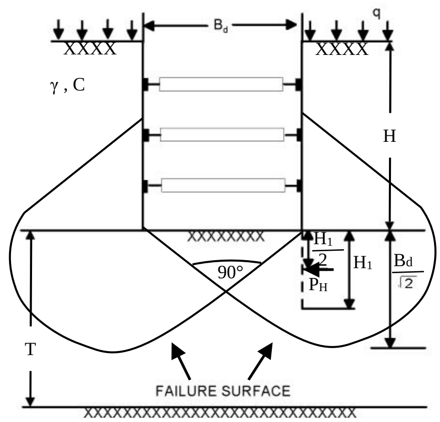
(a) Braced Excavation (stiff clays) = 0.5q + 30H + 62.4H
(b) Braced Excavation (sands) = 0.4q + 18H + 62.4H
(c) Cantilevered sheeting = 0.7q + 42H + 62.4H

where: q = surcharge load, psf: A value of 250 psf can be assumed.
H = wall height, ft.

Notes:

1. The above Active Pressure Equations account for the groundwater at the surface.
2. The final lateral pressures should be reviewed prior to construction.
3. Trench excavation and construction should be observed by a geotechnical engineer.
4. The means and methods for a safe excavation is the responsibility of the contractor.
5. In case of layered soils, active pressure should be calculated based on the dominant or more critical soil conditions.

CUT IN COHESIVE SOIL,
DEPTH OF COHESIVE SOIL UNLIMITED (T > 0.7 B_d)
L= LENGTH OF CUT



If sheeting terminates at base of cut:

Safety Factor, $F_s = \dfrac{N_c c}{\gamma H + q}$

N_c = Bearing capacity factor, which depends on dimensions of the excavation: B_d, L and H (use N_c from graph below)

c = Undrained shear strength of clay in failure zone beneath and surrounding base of cut

γ = Wet unit weight of soil

q = Surcharge (assumed q = 250psf)

If safety factor is less than 1.5, sheeting or soldier piles must be carried below the base of cut to insure stability – (see note)

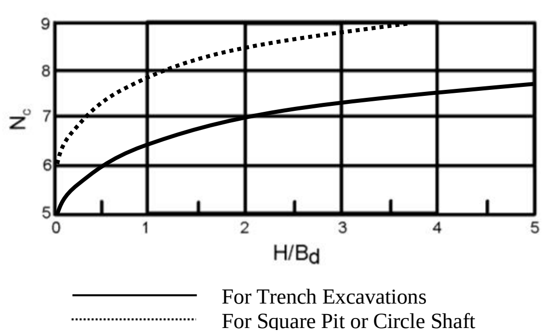
H_1 = Buried length = $\dfrac{B_d}{2} \geq 5$ feet

Note: If soldier piles are used, the center to center spacing should not exceed 3 times the width or diameter of soldier pile.

Force on buried length, P_H:

If $H_1 > \dfrac{2}{3}\dfrac{B_d}{\sqrt{2}}$, $P_H = 0.7\,(\gamma H B_d - 1.4CH - \pi c B_d)$ in lbs/linear foot

If $H_1 < \dfrac{2}{3}\dfrac{B_d}{\sqrt{2}}$, $P_H = 1.5H_1\,(\gamma H - \dfrac{1.4CH}{B_d} - \pi c)$ in lbs/linear foot



STABILITY OF BOTTOM FOR BRACED CUT

SOIL DESIGN PARAMETERS

(BASED ON BORING B-1)

Soil Type	Depth Range, ft.	γ, pcf	c, psf
LEAN CLAY (CL)	0 – 6	115	2,000
LEAN CLAY (CL)	6 – 8	115	1,560
LEAN CLAY (CL)	8 – 13	115	620
FAT CLAY (CH)	13 – 18	105	920
LEAN CLAY (CL)	18 – 20	115	660

(BASED ON BORING B-2)

Soil Type	Depth Range, ft.	γ, pcf	c, psf
LEAN CLAY (CL)	0 – 1	115	1,380
LEAN CLAY (CL)	1 – 4	115	2,000
LEAN CLAY (CL)	4 – 6	115	1,380
LEAN CLAY (CL)	6 – 8	115	460
LEAN CLAY (CL)	8 – 13	115	750
LEAN CLAY (CL)	13 – 18	115	300
LEAN CLAY (CL)	18 – 20	115	750

(BASED ON BORING B-3)

Soil Type	Depth Range, ft.	γ, pcf	c, psf
LEAN CLAY (CL)	0 – 1	115	1,380
LEAN CLAY (CL)	1 – 8	115	2,000
LEAN CLAY (CL)	8 – 13	115	900
LEAN CLAY (CL)	13 – 18	115	300
LEAN CLAY (CL)	18 – 20	115	900

SOIL DESIGN PARAMETERS

(BASED ON BORING B-4)

Soil Type	Depth Range, ft.	γ, pcf	c, psf
LEAN CLAY (CL)	0 – 1	115	1,700
LEAN CLAY (CL)	1 – 2	115	1,120
LEAN CLAY (CL)	2 – 4	115	2,000
LEAN CLAY (CL)	4 – 6	115	920
LEAN CLAY (CL)	6 – 8	115	2,000
LEAN CLAY (CL)	8 – 13	115	1,300
LEAN CLAY (CL)	13 – 20	115	300