Subsurface Exploration and Foundation Analysis
Proposed Residence on The Shores Drive (Lot 519)
Corsicana, Navarro County, Texas

Mr. Gerard Lisee
Helton Homes
121 Prairie Creek Trail
Georgetown, Texas 78633

Terradyne Project No.: D171216 **August 23, 2017**

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TERRADYNE
Engineers, Geologists & Environmental Scientists

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Re: **Subsurface Exploration and Foundation Analysis**
Proposed Residence on The Shores Drive (Lot 519)
Corsicana, Navarro County, Texas
Terradyne Project No.: D171216

Dear Lisee:

Terradyne DFW, Inc. (formerly InTEC of DFW Metro, Inc.) has completed a soil and foundation engineering report at the above referenced project site. The results of the exploration and foundation recommendations are presented in this report.

We appreciate and wish to thank you for the opportunity to service you on this project. Please do not hesitate to contact us if we can be of additional assistance during the Construction Materials Testing and Quality Control phases of construction.

Respectfully Submitted,

Very Truly Yours,
Terradyne DFW, Inc.

Sukanta Chakraborty, M.S., P.E.

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY

The soil conditions at the site of the Proposed Residence on The Shores Drive (Lot 519) in Corsicana, Navarro County, Texas were explored by drilling two borings B-1 and B-2 to a maximum depth of 25 feet. Laboratory tests were performed on selected specimens to evaluate the engineering characteristics of various soil strata encountered in our borings.

The results of our exploration, laboratory testing and engineering evaluation indicate the soils underlying this site have high to very high expansive characteristics. Potential vertical movement on the order of 3 inches was estimated at the existing grade level for average moisture conditions.

The proposed structure may be supported by a) stiffened grid type beam and slab foundations, b) post tensioned beam and slab foundations or c) drilled piers or under-reamed piers. The grade beams, founded at the depths shown in Table No. 4 below the finished grade elevation on proof-rolled in-situ soils or compacted select fill, may be sized for an allowable bearing capacity value of 1,200 or 2,000 pounds per square foot.

Straight shaft piers, founded at minimum depths of 15-feet[1], may be sized for allowable end bearing capacity 4,500 PSF. Piers may need to be extended deeper to provide sufficient resistance for uplift forces. Pier extended below groundwater level, 13½ feet below the existing ground surface may require casing or slurry displacement method.

As an alternative to straight shafts, under-reamed piers may be founded at a minimum depth of 12-feet to stay above the ground water and sized for allowable end bearing capacity 3,500 PSF. However, under reamed pier founded at 12 feet depth, my experience movements slightly more than 1-inch due to expansive soils.

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[1] This pier depth is a guideline and should not be construed as the final pier depth. Please refer to the structural engineers' foundation plans for the actual required pier depth for the site.

Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration.

Detailed descriptions of subsurface conditions, engineering analysis, and design recommendations are included in this report.

1.0 INTRODUCTION

This report presents the results of our subsurface exploration and foundation analysis for the Proposed Residence on The Shores Drive (Lot 519) in Corsicana, Navarro County, Texas. The object of this investigation was to evaluate the physical properties of the soils underlying the site in order to provide recommendations for foundation, and retaining wall design, slab support and related earthwork for the structures.

2.0 PROPOSED CONSTRUCTION

Terradyne understands that the proposed structure will be two or three-story with slab areas ranging from 4,000 to 5,000 square feet. If the final construction plans vary from what has been assumed, please contact Terradyne for further evaluation as the revisions may affect the recommendations provided in this report.

3.0 PURPOSE AND SCOPE OF SERVICES

The purpose of our geotechnical investigation was to evaluate the subsurface and groundwater conditions of the site and provide geotechnical engineering recommendations for the design and construction of the residence. Our scope of services includes the following:

1) Drilling and sampling of two borings B-1 and B-2 to a depth of 25 feet;
2) Evaluation of the in-place conditions of the subsurface soils through field penetration tests;
3) Observation of the groundwater conditions during drilling operations;
4) Performing laboratory tests such as Atterberg limits and moisture content tests;
5) Review and evaluation of field and laboratory tests;

6) Compilation, generalization and analysis of the field and laboratory data according to the project requirements;

7) Estimation of potential vertical movements;

8) Preparation of recommendations for the design and construction of the condominium units;

9) Consultations with Prime Professionals and members of the design team on findings and recommendations and the preparation of a written geotechnical engineering report for their use in the preparation of design and construction documents.

The Scope of Services does not include an environmental assessment of the presence or absence of wetlands and/or hazardous or toxic materials in the soil, surface water, groundwater, or air, in the proximity of this site. Any statements in this report or on the boring logs regarding odors, colors or unusual or suspicious items or conditions are strictly for the information of the client.

4.0 SITE CONDITIONS

The site is located on The Shores Drive (Lot 519) in Corsicana, Navarro County, Texas within an undeveloped area. The site is generally flat, wooded and covered with grass. Boring B-1 and B-2 were drilled at approximate locations shown on the attached boring location plan on Figure 1-A in the Appendix.

5.0 GEOTECHNICAL INVESTIGATION

The field exploration to determine the engineering characteristics of the subsurface materials included a reconnaissance of the project site, drilling the borings, performing standard penetration tests and obtaining disturbed auger samples. Two soil test borings were drilled at the site. Borings

B-1 and B-2 were drilled to a depth of 25 feet. Boring locations at the lots were selected by the client and established in the field by the drilling crew. An approximate boring location plan is shown on Figure 1-B in the Appendix.

The borings were performed with a drilling rig equipped with a rotary head. Conventional solid stem augers were used to advance the holes and samples of the subsurface materials were obtained using a standard 4.0 inch diameter auger. The samples were identified according to boring number and depth, encased in polyethylene plastic wrapping to protect against moisture loss, and transported to our laboratory.

The following samples, presented in Table No. 1, were collected as a part of our field exploration procedure:

Table No. 1

Type of Sample	Number Collected
Auger Samples	2
Standard Penetrometer Test (SPT)	12

5.1 Field Tests and Measurements

Penetration Tests: During the sampling procedures, standard penetration tests were performed in the borings in conjunction with split-barrel sampling (ASTM 1586). The standard penetration value (N) is defined as the number of blows of a 140-pound hammer, falling thirty inches, required to advance the split-spoon sampler one foot into the soil. The sampler is lowered to the bottom of the drill hole and the number of blows recorded for each of the three successive increments of six inches penetration. The "N" value is obtained by adding the second and third incremental numbers.

The results of the standard penetration tests indicate the relative density and comparative consistency of the soils, and thereby provide a basis for estimating the relative strength and compressibility of the soil profile components.

Water Level Measurements: Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration. In relatively pervious soils, such as sandy soils, the indicated elevations are considered reliable groundwater levels. In relatively impervious soils, an accurate determination of the groundwater elevation may not be possible even after several days of observation. Seasonal variations, temperature and recent rainfall conditions may influence the level of the groundwater table and the volume of water encountered will depend on the permeability of the soils.

5.2 Field Logs

A field log was prepared for each boring. Each log includes information concerning the boring method, samples attempted and recovered, the presence of various materials (such as clay, clayey sand, silty sand and sand) and groundwater observations. It also includes an interpretation of the subsurface conditions between samples. Therefore, these logs include both factual and interpretive information.

5.3 Presentation of the Data

The final logs represent our interpretation of the contents of the field logs and laboratory test results for the purpose delineated by our client. The final logs are included on Figures 2 and 3 in the Appendix. A key to classification terms and symbols used on the log is presented on Figure 4.

5.4 Laboratory Testing Program

In addition to field exploration, a supplemental laboratory testing program was conducted to determine additional pertinent engineering characteristics of the subsurface materials that are necessary to evaluate the soil parameters. All phases of the laboratory testing program were performed in general accordance with the indicated applicable ASTM Specifications.

In the laboratory, each sample was examined and classified by a geotechnical engineer. As a part of this classification procedure, the natural water content of selected specimens was determined. Liquid and Plastic Limit tests were performed on representative specimens to determine the plasticity characteristics of the different soil strata encountered. The following tests, presented in Table No. 2, were conducted in the laboratory to evaluate the engineering characteristics of the subsurface materials. The results of these tests are presented on the appropriate boring log.

Table No. 2

Type of Test	Number Conducted
Natural Moisture Content	14
Atterberg Limits	4
% Passing No. 200 Sieve	4

5.5 General Subsurface Conditions

The site is located within the Wilcox Group Formation (EPAwi) and consists of mostly mudstone, coal, sand, clay or mud. At this particular site the soil consists of fat clay and fat clay with sand down to final boring depth of about 25 feet.[2]

[2] Source: Bureau of Economic Geology, 1992, Geologic Map of Texas: University of Texas at Austin, Virgil E. Barnes, project supervisor, Hartmann, B.M. and Scranton, D.F., cartography, scale 1:500,000

The soils underlying the site may be grouped into two generalized strata with similar physical and engineering properties. The logs describe any noticeable changes that occur as depth increases related to soil type, moisture, color and hardness; interface between soil strata represent approximate boundaries. The transition between materials may be gradual. The soil stratigraphy at the boring location is presented on the Boring Logs, Figures 2 and 3. The engineering characteristics of the underlying soils, based on our field and laboratory test results, are summarized and presented in Table No. 3.

Table No. 3

Stratum	Depth Range Feet	Liquid Limit Range	Plasticity Index	Blows Per Foot
1. Dark Grayish Brown Fat Clay (CH)	0 - 8	60-65	43-47	8-14
2. Grayish Brown Fat Clay with Sand (CH)	8 - 25	50	35	10-31

The above description generally highlights the major soil stratification features and soil characteristics. The test boring logs should be consulted for specific information at the boring locations.

Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration. However, groundwater levels will fluctuate with seasonal climatic variations and changes in the land use. The low permeability of the soils may require several days for groundwater to enter and stabilize in the boreholes. It is not unusual to encounter shallow groundwater during or after periods of rainfall. Surface water tends to percolate through the surface until it encounters a relatively imperious layer.

6.0 FOUNDATIONS ON EXPANSIVE SOIL

There are many plastic clays that swell when water is added to them and shrink when water is removed. Foundations constructed on these clays are subjected to large uplifting forces caused by the swelling.

Two factors contribute to potential shrink-swell problems within a building site. Problems can arise if a) the soil has expansive or shrinkage properties or b) environmental conditions cause the moisture levels in the soil to change.

Evaluation of the Shrink-Swell Potential of the Soils: Subsurface sampling, laboratory testing and data analysis is used to evaluate the shrink-swell potential of the soils under the foundations.

The Mechanism of Swelling: The mechanism of swelling in expansive clays is influenced by a number of factors. The expansion in clays is a result of changes in the soil-water system that disturbs the internal stress equilibrium. Clay particles have negative electrical charges on their surfaces and positively charged ends. The negative charges are balanced by actions in the soil-water and give rise to an electrical interparticle force field. In addition, adsorptive forces exist between the clay crystals and water molecules, and Van Der Waals surface forces exist between particles. Thus, there exists an internal electro-chemical force system that must be in equilibrium with the externally applied stresses and capillary tension in the soil water. If the soil-water chemistry is altered, either by changing the amount of water or chemical composition in the soil, the inter-particle force field will change. If the change in internal forces is not balanced by a corresponding change in the state of stress, the particle spacing changes until equilibrium is reached. This change in particle spacing manifests itself as a shrinkage or swelling.

Antecedent Rainfall Ratio: This is defined as the total monthly rainfall for the current and previous months prior to laying the slab, divided by twice the average monthly rate measured for the period. The intent of this ratio is to give a relative measure of ground moisture conditions at the time the slab is placed. Thus, if a slab is placed at the end of a wet period, the slab shall be expected to experience some loss of support around the perimeter as the wet soil begins to dry out and shrink. The opposite effect could be anticipated if the slab is placed at the end of an extended dry period; as the wet season occurs, uplift around the perimeter may occur as the soil at the edge of the slab gains in moisture content.

Age of Slab: The length of time since the slab was cast provides an indication of the type of swelling the soil profile may have beneath the slab.

Initial Moisture Condition and Moisture Variation: A volume change in an expansive soil mass is the result of increases or decreases in water content. The initial moisture content influences the swell and shrink potential of a soil. However, moisture content alone is useless as an indicator or predictor of shrink-swell potential. The relationship between moisture content and other soil characteristics, such as the Plastic Limit and Liquid Limit, must also be known.

If the moisture content is below or near the Plastic Limit, the soils may have a high potential to swell. Expansive soils with Liquidity Index3 in the range of 0.20 to 0.40 tend to experience little additional swell.

The availability of water in an expansive soil profile is influenced by many environmental and manmade factors. Generally, the upper few feet of the profile are subjected to the widest ranges of moisture variation, and are the least restrained from movement by overburden. This upper stratum of the profile is referred to as the active zone. Moisture variation in the active zone of a natural soil profile is affected by climatic cycles at the surface and fluctuating groundwater levels at the lower moisture boundary. The superficial boundary moisture conditions are changed by placing a barrier, such as a building floor slab or pavement, between the soil and atmospheric environment. Other causes of moisture variation result from altered drainage conditions or manmade sources of water, such as irrigation or leaky plumbing. The latter factors are difficult to quantify and incorporate into the analysis, but shall be controlled to the extent possible for each situation. For example, proper drainage and attention to landscaping are simple means of minimizing moisture fluctuations near structures, and shall always be taken into consideration.

Manmade Conditions That Can Be Altered: There are a number of factors that can influence whether a soil might shrink or swell and the magnitude of this movement. For the most part, the owner and/or designer have some control over whether these factors can be avoided, and if not avoided, the degree to which these factors may influence the shrink-swell process.

[3] $$\text{LIQUIDITY INDEX} \equiv \frac{\text{NATURAL WATER CONTENT} - \text{PLASTIC LIMIT}}{\text{LIQUID LIMIT} - \text{PLASTIC LIMIT}}$$

Lot Drainage: How a lot is graded affects the accumulation of surface water around the slab. Most builders are aware of the importance of grading the soil away from the structure so that rainwater does not collect and pond adjacent to the foundation. If allowed to accumulate next to the foundation, water may infiltrate the expansive soils underlying the foundation, which could cause the foundation to settle. Similarly, runoff from surface water drainage patterns and swales must not collect adjacent to the foundation.

Topography: As it swells, soil heaves perpendicularly to the ground surface or slope, but as it shrinks, it recedes in the direction of gravity and gradually moves downslope in a sawtooth fashion over a number of shrink-swell cycles. In addition to this shrink-swell influence, soil will exhibit viscoelastic properties and creep downhill under the steady influence of the weight of the soil. Therefore, to avoid a structure constructed on this slope from moving downhill with the soil, it must be designed to compensate for this lateral soil influence.

Pre-Construction Vegetation: A large amount of vegetation, especially large trees, on a site prior to construction may have desiccation at the site. Constructing over a desiccated soil can produce some dramatic instances of heave and associated structural distress and damage as it becomes wet.

Post-Construction Vegetation: The type, amount, and location of vegetation that has grown since construction can cause localized desiccation. Planting trees or large shrubs near a building can result in the loss of foundation support as the vegetation robs moisture from the foundation soil. Conversely, the opposite effect can occur if flowerbeds or shrubs are planted next to the foundation and these beds are kept well-watered or flooded. This practice can result in swelling of the soil around the perimeter where the soil remains wet.

Summation: It is beyond the scope of this investigation to do more than point out the factors that may influence the amount and type of swell a slab-on-grade foundation may be subjected to during its lifetime. The design engineer must be aware of these factors in developing his design, using his engineering experience and judgment as a guide.

7.0 DESIGN ENGINEERING ANALYSIS

Foundation Design Considerations: Review of the borings and test data indicates that the factors presented on the following page will affect the foundation design and construction at this site:

1) The site is underlain by subsoils of high to very high plasticity at shallow depths. Structures supported at shallow depths will be subjected to potential vertical movements on the order of 3 inches.
2) The strengths of the underlying soils are adequate to support shallow or deep foundations.
3) Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration.
4) Pier may need casing or slurry displacement when extended in to the sand layer.

Structural Information: Based on the information provided, it is understood that the proposed structures will be one or two story structure. These structures are expected to create moderately heavy loads to be carried by the foundation systems. These structures will utilize wood frame construction and brick or stucco exterior walls. It is assumed that the maximum column loads will not exceed 30 kips, while maximum exterior wall loading will be in the range of one kip per foot.

Vertical Movements: The potential vertical rise (PVR) for slab-on grade construction at the location has been estimated using the general guidelines presented in the Texas Department of Transportation Test Method TXDOT-124-E. This method utilizes the liquid limits, plasticity indices, and in-situ moisture contents for soils in the seasonally active zone, estimated to be about twelve to fifteen feet in the project area.

The estimated PVR value provided is based on the proposed floor system applying a sustained surcharge load of approximately one pound per square inch on the subgrade materials. Potential vertical movements on the order of 3 inches may be anticipated for average soil moisture conditions. The finish grade elevation was assumed to be ½ to one foot above the existing grade level.

If the underlying clays are removed to a depth of 2 or 4 or 6-feet and replaced by non-expansive select fill, potential vertical movements on the order of 2 or 1½ or 1-inch, may be anticipated for average soil conditions. If over excavation and select fill replacement is used to reduce potential vertical movements, the bottom of excavation shall be drained properly and any select fill placement outside of the slab perimeter should be covered with at least one foot of relatively impermeable clay. The excavation should not act as a "bathtub" and hold water in the event any accidental source of water enters the excavation.

Alternatively, the installation of a minimum of one foot of non-expansive select fill over a minimum of 10 -feet of moisture conditioned clay should lower the potential vertical movements of 2-inches. It is recommended that moisture conditioning be extended beyond the building line to include entrances and other flatwork areas sensitive to movement. Outside the building, a single lift of select fill should be placed to minimize drying during construction.

A properly engineered and constructed vapor barrier shall be provided beneath slab-on-grade foundations that will be carpeted or receive moisture sensitive coverings or adhesives. The top one foot of the fill or soil replacement outside the building perimeter shall consist of high plastic clay. This clay will limit surface water infiltration into the building pad fill and subgrade soils.

7.1 Moisture Conditioning

Moisture conditioning involves excavating the soils as required to provide 5 or 10-feet of reworked material beneath the non-expansive one foot thick select fill (2^{nd} alternative). The exposed clay subgrade shall be scarified to a minimum depth of 8 inches and recompacted to a minimum of 92 percent of Standard Proctor (ASTM D 698), at a minimum of +3 percentage points above the soil's optimum moisture content. The excavated soils shall be moisture conditioned to water content between optimum +2 and +5 percentage points and cured. The moisture conditioned soils can then be placed in 8-inch maximum thick loose lifts, and uniformly compacted to the same criteria. Care shall be taken that a lift is not allowed to desiccate prior to placing a subsequent lift. The non-expansive select fill shall then be placed above the reworked subgrade within 48 hours of completing the installation of the moisture conditioned soils.

7.2 Water Pressure Injection

The potential vertical movements can be lowered by a) injecting water to a depth of about 10-feet and b) by preparing a building pad of one-foot thickness using compacted select fill placed immediately below the floor slab (3rd alternative). The compacted select fill will help the water injected soil mass retain its' moisture and provide a uniform support for the slab. The injection of water into expansive clay is a method of pre-swelling the clay mass. This pre-swelling processes requires that the moisture content of the injected soils be maintained throughout the construction process and after construction has completed. If pre-swelled clays are allowed to dry, it is likely that much of the benefit achieved by the injection process will be lost. Buildings supported on 10-feet of water-injected clays are expected to move on the order of 2-inches.

Limits of Injection: Injection shall be performed under the building, at 12-inches on-center, and shall be extended a minimum of 5-feet beyond the general building lines. The injection shall be extended 10-feet beyond the building at entrances to limit the potential for differential movement between structures, sidewalks and entrance pavement. ***Quality control inspections and tests shall be performed by Terradyne at the time of water injection.***

Multiple Injections: The number of injection passes required will be dependent upon soil moisture conditions at the time of construction. Even with the best of techniques, average moisture increases of more than 2 to 3 percent are difficult to achieve with a single injection. When the clay soils are dry and dense, multiple injections will be necessary. For estimating purposes, a minimum of four passes shall be anticipated. Multiple injections will help the clays to achieve the desired final moisture content and the corresponding swell abatement.

Final Acceptance Criteria: Satisfactory completion of the injection process is achieved when the desired moisture content and abatement of swell in the injected clays are reached. Preliminary laboratory tests indicate the desired final water content will be about 45 percent of the Liquid Limit of the soil, approximately 20 percent for this sample. Under the applied floor slab loads and sustained final overburden pressure, the free swell shall not exceed one percent. Post injection swell and moisture content test results shall be reviewed; these test results shall be used for the final acceptance or rejection of the injection process. Additional passes of water injection and further sampling and testing will be required (in the case of first rejection).

Adequate Pre-Swelling of the Clays: Concrete for the slab shall not be placed on water-injected areas until at least two weeks following the final water injection. This waiting period allows for adequate pre-swelling of the soils from the injection process. During the two-week period, the surface of the soil mass must be kept moist or covered to prevent moisture loss. About 1½ to 2 inches of heave can be expected in the building pad during and shortly after completion of the injection process.

If the existing grade has to be raised to attain the finish grade elevation, select fill shall be placed, compacted and tested for compaction compliance by Terradyne.

8.0 FOUNDATION RECOMMENDATIONS

The type and depth of foundation suitable for a given structure primarily depends on several factors: the subsurface conditions, the function of the structure, the loads it may carry and the cost of the foundation. Additional considerations may include acceptable performance criteria set by the owner, architect, or structural designer with respect to vertical and differential movements that the structure can withstand without damage. Based on these conditions and our engineering design analysis, a post tensioned beam and slab foundation, or a stiffened grid type beam and slab foundation.

8.1 Stiffened Grid Type Beam and Slab Foundation

A stiffened grid type beam and slab foundation may be considered to support the proposed structures provided the potential vertical movements presented will not impair the performance of the structures.

It is desirable to design the foundation system using an assumption that the beams carry the loads. A maximum allowable bearing capacity of 1,200 or 2,000 pounds per square foot may be used for the beams founded at the depths shown in Table No. 4 within the undisturbed existing soils or compacted select fill, respectively. A minimum beam width of at least 10 inches is recommended. The beams shall intersect at heavy load areas, such as columns. The beam intersection may be widened to act as spread footings and sized for an allowable bearing capacity of 1,200 pounds per square foot. Refer to Table No. 4 for Design Plastic Index values for various soil conditioning methods for the site.

8.2 Post-Tensioned Beam and Slab Foundation

A post-tensioned slab-on-grade foundation may be considered to support the proposed structure provided the potential vertical movements will not impair the performance of the structures. Pertinent design parameters were evaluated and are presented in the following paragraphs.

Differential vertical movements shall be expected for shallow type foundations at this site due to expansive soil conditions that were encountered. Differential vertical movements have been estimated for both the center lift and edge lift conditions for post-tensioned slab-on grade construction at this site. These movements were estimated using the procedures and criteria discussed in the Post-Tensioning Institute Manual entitled "Design and Construction of Post-Tensioned Slabs-on-Ground," 3rd Edition. This procedure uses the soil data obtained from the field and laboratory tests performed on the soil samples.

Differential vertical movements have been estimated for the center lift and edge lift conditions. These values are presented for various Design Plasticity Indices in Table No.4 for 3rd Edition.

Table No. 4 – 3rd Edition PTI Values

Soil Conditioning Method		Minimum Grade Beam Depth (Inches)	PVR (Inches)	Design Plasticity Index	Differential Vertical Movement, (Y_m) Inches		Edge Moisture Variation Distance, (E_m) feet	
Type	Depth				Center Lift	Edge Lift	Center Lift	Edge Lift
Existing Condition	N/A	18	3	43	1.95	2.66	8.7	4.5
Existing Condition	N/A	24	3	43	1.45	1.80	8.7	4.5
Existing Condition	N/A	30	3	43	1.29	1.56	8.7	4.5
Select Fill	2-ft	18	2	36	1.29	1.56	8.7	4.5
Select Fill	4-ft	18	1½	28	0.81	0.98	8.7	4.4
Select Fill	6-ft	18	1	21	0.61	0.83	8.7	4.4
Moisture Cond.	10-ft	18	2	43	1.62	2.07	7.0	3.8
Water Injection	10-ft	18	2	43	1.62	2.07	7.0	3.8

Grade beams, founded at the depths shown in Table No. 4 below finish grade elevation within the undisturbed existing soil or compacted select fill, may be sized for an allowable bearing capacity value of 1,200 or 2,000 pounds per square foot, respectively.

8.3.1 Drilled Piers

Drilled straight shaft piers are used in areas where relatively soft or expansive soil strata overlie a firm foundation soil. The soil conditions at the site and the magnitude of the loads of the proposed structures indicate that drilled piers will be a suitable foundation system for the structures. Grade beams could be supported on the drilled piers where required to support wall loads. The floor slab, utilized with the drilled pier foundation system, should consist of a structurally suspended floor system.

The piers will utilize a combination of end bearing and skin friction to develop load carrying capacity. Piers should be founded at a minimum 15 feet below the existing ground surface. Piers founded 15 feet below the existing ground surface may be designed with a maximum allowable end bearing capacity of 4,500 pounds per square foot based on dead load plus design live load considerations. Piers may need to be extended deeper to provide sufficient resistance for uplift forces. Upper 15 feet of embedment pier into the soil should be neglected for skin friction resistance as shown in Table No. 5. In no case should piers be designed with a shaft diameter less than 12 inches.

Table No. 5

Depth, Feet	Allowable Skin Friction Value, PSF
15-25	275

Uplift Forces: Moisture variation in the expansive soils at this site can cause vertical movements of the subsurface soils. This potential vertical movement can mobilize an uplift force along the shaft of a drilled pier. The uplift force acting on the shaft may be estimated by using Equation No. 1.

$$\mathbf{F_u = 37d \text{ - - - - - } (1)}$$

where F_u = uplift force in kips

d = Diameter of the shaft in feet

Tension steel will be required in each pier shaft to withstand a net force equal to the uplift force, minus the sustained compressive load carried by that footing. We recommend that each pier be reinforced with tension steel to withstand this net force or one percent of the cross-sectional area of the shaft, whichever is greater.

Pier Spacing: The minimum clear spacing between any two piers should not be less than 3*d*, where *d* is the pier diameter. If the spacing between the piers is closer than 3*d*, stress concentrations will occur between the two piers. The concentrated stress may be higher than the allowable bearing capacity. Hence, these piers should be designed for a lower bearing capacity than the maximum allowable. For construction purposes, the minimum pier spacing may be as close as 3 feet, provided the first pier has been drilled and concreted and the concrete has achieved its final set prior to drilling the adjacent pier.

8.3.2 Under-reamed piers:

As an alternative to straight shafts, under-reamed piers may be founded at a minimum depth of 12-feet to stay above the ground water. Piers founded in the referenced materials may be proportioned assuming a maximum allowable end bearing capacity of 3,500 pounds per square foot based on dead load plus design live load considerations. However, under reamed pier founded at 12 feet depth, my experience movements slightly more than 1-inch due to expansive soils.

The under-reamed piers should have a minimum bell diameter to shaft diameter ratio of 2.5 to resist uplift forces, associated with shrinking and swelling of the site soils that may be created by soil-to-pier adhesion in the zone of expansive clays. A maximum bell diameter to shaft diameter ratio of 3.0 is also recommended. The under-reamed piers should have a minimum clear spacing at least equal to or larger than the diameter of the end bearing area of the bells.

Settlements on the order of one inch with differential settlements (between adjacent piers) on the order of 0.5 inches should be considered. The piers should be reinforced for their full depth to resist potential, tensile forces, which may develop due to swelling of the site soils, and due to structural loads. Uplift forces due to swelling soils can be approximated by assuming an uplift adhesion value of 1,200 pounds per square foot over the perimeter of the shaft for a depth of 10 feet.

It is recommended that the design and construction of drilled piers should generally follow methods outlined in the manual titled Drilled Shafts: Construction Procedures and Design Methods (Publication No: FHWA-IF-99-025, August 1999).

Detailed inspection of pier construction should be made to verify that the piers are vertical and founded in the proper bearing stratum, and to verify that all loose materials have been removed prior to concrete placement. Temporary casing must be used where necessary to stabilize pier holes and to control water inflow.

Any accumulated water must be removed prior to the placement of concrete. A hopper and tremie should be utilized during concrete placement to control the maximum free fall of the wet concrete to less than five feet unless the mix is designed so that it does not segregate during free fall and provided the pier excavation is dry.

If the pier hole has been cased, sufficient concrete should remain in the casing as the casing is withdrawn to prevent any discontinuities from forming within the concrete section. Concrete placed in drilled piers should be placed at slumps between six to eight inches. Concrete, which is placed in piers at a slump less than six inches, increases the potential for honeycombing. Concrete used in piers should be designed to achieve the required strength at the higher slumps as referenced above. For any given pier, excavation, placement of steel and concreting should be completed within the same workday. Where water inflow or caving soils are encountered, excavation of piers and placement of concrete within a very short time frame will frequently aid in proper pier construction.

Structurally supported grade beams, and pier caps if required, should be isolated from the subgrade soils by providing a minimum 6-inch positive void beneath the floor slab, grade beams and pier caps. Void forms will not be required for pier supported monolithic slab on grade foundation system. Voids can be produced using compressible cardboard carton forms specially manufactured for this purpose. Care should be exercised so that the forms are not crushed, damaged or saturated prior to placement of the concrete. In addition, barriers that will not rapidly decay should be placed or constructed along the sides of the cardboard carton forms to prevent soil intrusion into the void after the carton forms decay.

Grade Beams: A minimum 6-inch void space should be provided beneath the grade beams to prevent uplift should the underlying soils expand.

Floor Slabs: Two alternatives are available for constructing floor slabs with a drilled pier foundation. The owner may select the alternative best satisfying the required performance criteria.

Alternative No. 1: Floor slabs, or portions of the floor slab, which have high performance criteria and are movement sensitive in nature, should be structurally suspended above grade because of the anticipated ground movements. A positive void space of at least 6 inches should be provided beneath the floor slab. The crawl space should be designed with a positive drainage flow so that water will not accumulate in the crawl space. Excavated on-site material may be used to raise the grade in the crawl space area. This material should be compacted to 95 percent of the ASTM D-698 maximum density and tested. Select fill need not be used to raise the grade in the crawl space area.

Alternative No. 2: Floor Slabs within the superstructure may be ground supported provided the potential vertical movements will not impair performance of the floor system. Ground supported floor slabs could be doweled to the perimeter grade beams. Doweled slabs that are subjected to heaving will typically crack and develop a plastic hinge along a parallel line located approximately 5 to 10 feet inside the grade beams.

The floor slab may be cast independent of the grade beams, interior columns and partitions. These slabs should experience cracking of lower magnitude, but may create difficulties at critical entry points, such as doors. A "trip hazard" could result due to resulting differential movements at entryways and difficulty in opening and closing doors could develop.

We recommend placement of a polyethylene moisture barrier underground supported floor slabs to reduce the possibility of moisture migration through the slab.

8.4 Utilities

Utilities that project through slab-on-grade floors shall be designed with either some degree of flexibility or with sleeves in order to prevent damage to these lines should vertical movements occur.

8.5 Contraction, Control and/or Expansion Joints

Contraction, control and/or expansion joints shall be designed and placed in various portions of the structure. Properly planned placement of these joints will assist in controlling the degree and location of material cracking that occurs due to soil movements, material shrinkage, thermal affects and other related structural conditions.

8.6 Lateral Earth Pressure

Some retaining walls may be needed at this site. The equivalent fluid density values were evaluated for various backfill materials. These values are presented in Table No. 6.

Table No. 6

Backfill Material	Equivalent Fluid Density, PCF		
	Active Condition	At Rest Condition	Passive Condition
a. Crushed Limestone	40	60	530
b. Clean Sand	40	60	360
c. Select Fill (PI ≤ 15)	65	85	265

These equivalent fluid densities do not include the effect of seepage pressures, surcharge loads such as construction equipment, vehicular loads or future storage near the walls.

If the basement wall or cantilever retaining wall can tilt forward to generate “active earth pressure” condition, the values under active condition shall be used. For rigid non-yielding walls which are part of the building, the values” at rest condition” shall be used. The compactive effort shall be controlled during backfill operations. Over compaction can produce lateral earth pressures in excess of at rest magnitudes. Compaction levels adjacent to below-grade walls shall be maintained between 95 and 98 percent of standard Proctor (ASTM D698) maximum dry density.

The backfill behind the wall shall be drained properly. The simplest drainage system consists of a drain located near the bottom of the wall. The drain collects the water that enters the backfill and this may be disposed of through outlets along the base of the wall. To insure that the drains are not clogged by fine particles, they shall be surrounded by a granular filter. In spite of a well-constructed toe drain, substantial water pressure may develop behind the wall if the backfill consists of clays or silts. A more satisfactory drainage system, consisting of a back drain of 12 inches to 24 inches width gravel may be provided behind the wall to facilitate to drainage.

The maximum toe pressure for wall footings founded a minimum depth of 12 inches into the clay soils shall not exceed 1,200 pounds per square foot. An adhesion value of 290 pounds per square foot shall be used to check against sliding for wall footings bearing on clay.

9.0 CONSTRUCTION GUIDELINES

9.1 Construction Monitoring

As Geotechnical Engineer of Record for this project, Terradyne, shall be involved in monitoring the foundation installation and earthwork activities. The performance of any foundation system is not only dependent on the foundation design, but is strongly influenced by the quality of construction. Prior to construction, please contact our office so that a Foundation and Earthwork Monitoring Plan can be incorporated into the Project Quality Control Program.

9.2 Site Preparation

In any areas where soil-supported floor slabs or pavement are to be constructed, vegetation and all loose or organic material shall be stripped and removed from the site. Subsequent to stripping operations, the subgrade shall be proofrolled to identify soft zones. Any soft zone detected shall be removed to a firm subgrade soils and replaced with compacted suitable soils to reach subgrade level. Upon the acceptance of proofrolling operations the subgrade shall be scarified to a minimum depth of 8 inches, moisture conditioned and compacted to a 95 percent of maximum dry density as determined by ASTM D 698, between optimum and 4 percentage points above of optimum moisture content. The exposed subgrade shall not be allowed to dry out prior to placing structural fill.

9.3 Drainage

Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration. However, minor groundwater seepage may be encountered within the proposed building foundation and grading excavations at the time of construction, especially after periods of heavy precipitation. Small quantities of seepage may be removed by conventional sump and pump methods of dewatering.

9.4 Temporary Drainage Measures

Temporary drainage provisions shall be established to minimize water runoff into construction areas. If standing water does accumulate, it shall be removed by pumping as soon as possible. Adequate protection against sloughing of soils shall be provided for workers and inspectors entering the excavations. This protection shall meet OSHA and other applicable building codes.

9.5 Temporary Construction Slopes

Temporary slopes on the order of 1H to 1V may be provided for excavations through clays. Fill slopes on the order of 1H to 1V may be used provided a) the fill materials are compacted, as recommended, and b) the slopes are temporary. Fill slopes shall be compacted. Compacting operations shall be continued until the slopes are stable but not too dense for planting on the slopes. Compaction of the slopes may be done in increments of 4 to 6-feet in fill height or for shallow fills, until fill reaches its' total height.

9.6 Select Structural Fill

Select fill material used at this site shall be clayey sand (SC), lean clay with gravel (CL) or clayey gravel (GC) with maximum liquid limit of 35 percent and plasticity index (PI) between 5 and 20. The fill shall be compacted to at least 95 percent of the maximum dry density as determined by ASTM D698, within ± 2 percentage points of optimum moisture content

9.7 Groundwater

In areas where significant cuts (2-feet or more) are made to establish final grades for building pads, attention shall be given to possible seasonal water seepage that could occur through natural cracks and fissures in the newly exposed stratigraphy. Subsurface drains may be required to intercept seasonal groundwater seepage. The need for these, or other dewatering devices, on building pads shall be carefully addressed during construction. Our office could be contacted to visually inspect final pads to evaluate the need for such drains.

Groundwater seepage may occur several years after construction if the rainfall rate or drainage changes in the vicinity of the project site. If seepage runoff occurs towards the building, an engineer shall be contacted to evaluate its' effect and determine whether French drains are required at the location.

9.8 Control Testing and Field Observation

Subgrade preparation and select structural fill placement shall be monitored by the project geotechnical engineer or his representative. As a guideline, at least one in-place density test shall be performed for each 2,500 square feet of compacted surface lift. A minimum of three density tests shall be performed on the subgrade or per lift of compaction. Any areas not meeting the required compaction shall be re-compacted and retested until compliance is met.

9.9 Earthwork and Foundation Acceptance

Exposure to the environment may weaken the soils at the foundation bearing level if the excavation remains open for long periods of time. Therefore, it is recommended that all foundation excavations be extended to final grade and the footings constructed as soon as possible to minimize potential damage to bearing soils. The foundation bearing level shall be free of loose soil, ponded water or debris sand, and shall be inspected and approved by the geotechnical engineer or his representative prior to concreting.

Foundation concrete shall not be placed on soils that have been disturbed by rainfall or seepage. If the bearing soils are softened by surface water intrusion during exposure or by desiccation, the unsuitable soils must be removed from the foundation excavation and replaced prior to placement of concrete.

Subgrade preparation and fill placement operations shall be monitored by the geotechnical engineer or his representative. As a guideline, at least one in-place density test shall be performed for each 2,500 square feet of compacted surface lift. Any areas not meeting the required compaction shall be recompacted and retested until compliance is met.

9.10 Drilled Piers

Field Observations: Each drilled pier excavation must be monitored by a qualified individual of Terradyne who is familiar with the geotechnical aspects of the soil stratigraphy, structural configuration and foundation design details and assumptions. This is to observe that:

(1) The footing has been drilled to the specific dimensions at the correct depth established by the previously mentioned criteria;
(2) The bottom of the footing is concentric to the pier shaft;
(3) The pier shaft has been drilled plumb within specified tolerances along its total length;
(4) Excessive cuttings, build-up and soft compressible material have been moved from the bottom of the excavation.

Concrete shall be placed for each footing, as soon as possible, to reduce changes in the moisture content or the state of stress of the foundation soils. No footings should be concreted without the approval of the project geotechnical engineer. No completed footing excavation should be left overnight without concreting.

Surface runoff and/or groundwater seepage accumulating in the excavation should be pumped and the condition of the bearing surface should be evaluated immediately prior to placing concrete.

Casing: Groundwater seepage was encountered at a depth of about 13½ feet in our borings at the time of our field exploration. However, minor groundwater seepage may be encountered at the time of pier construction, especially after periods of heavy rainfall at some pier locations. Zones of sloughing soils may occur during pier construction. We recommend that the bid documents require the foundation contractor to specify unit costs for different lengths of casing that may be required.

If groundwater seepage occurs, the use of casing should help minimize groundwater inflow into the pier excavation, although it may not alleviate seepage from the soils. If seepage persists even after casing installation, the water should be pumped from the excavation prior to placing concrete. If groundwater inflow is too severe to be controlled by pumping, the concrete shall be tremied to the full depth of the excavation to effectively displace the water. In this case, a "clean-out" bucket shall be used to remove the soil from the pier bottom before placing steel and concrete.

If casing is used, removal of the casing should be performed with extreme care and proper supervision to minimize mixing of the surrounding soil and water with the concrete.

Drilling Equipment: High power and high torque drilling equipment **may** be required to drill through the hard clays encountered at this site.

10.0 DRAINAGE AND MAINTENANCE

Final drainage is important for the performance of the proposed structures and pavement. Landscaping, plumbing, and downspout drainage is also important. It is vital that all roof drainage be transported away from the building so that water does not pond around it, which can result in a soil volume change underneath the building. Plumbing leaks shall be repaired as soon as possible in order to minimize the magnitude of a moisture change under the slab. **Large trees and shrubs shall not be planted in the immediate vicinity of the structures, since root systems can cause a substantial reduction in soil volume in the vicinity of the trees during dry periods.**

Adequate drainage shall be provided to reduce seasonal variations in moisture content of foundation soils. All pavement and sidewalks within 10-feet of the structures shall be sloped away from the structures to prevent ponding of water around the foundations. Final grades within 10-feet of the structure shall be adjusted to slope away from structures preferably at a minimum slope of 3 percent. Maintaining positive surface drainage throughout the life of the structure is essential.

In areas with pavement or sidewalks adjacent to the new structure, a positive seal must be provided and maintained between the structures and the pavement or sidewalk to minimize seepage of water into the underlying supporting soils. Post-construction movement of pavement and flat-work is not uncommon. Maximum grades practical shall be used for paving and flatwork to prevent areas where water can pond. In addition, allowances in final grades shall take into consideration post construction movement of flatwork, particularly if such movement would be critical. Normal maintenance shall include inspection of all joints in paving and sidewalks, etc. as well as re-sealing where necessary.

There are several factors related to civil and architectural design and/or maintenance that can significantly affect future movements of the foundation and floor slab systems.

1. Where positive surface drainage cannot be achieved by grading the ground surface adjacent to the buildings, a complete system of gutters and downspouts shall carry runoff water a minimum of 10-feet from the completed structures.

2. Planters located adjacent to the structures shall preferably be self-contained. Sprinkler mains shall be located a minimum of five feet from the building line.

3. Planter box structures placed adjacent to the building shall be provided with a means to assure concentrations of water do not infiltrate the subsoils stratigraphy.

4. Large trees and shrubs shall not be planted closer to the foundations than a horizontal distance equal to roughly their mature height due to their significant moisture demand upon maturing.

5. Moisture conditions shall be maintained "constant" around the edge of the slabs. Ponding of water in planters, in unpaved areas, and around joints in paving and sidewalks can cause slab movements beyond those predicted in this report.

6. Roof drains shall discharge on pavement or be extended away from the structures. Ideally, roof drains shall discharge to storm sewers by closed pipe.

Trench backfill for utilities shall be properly placed and compacted, as outlined in this report, and in accordance with the requirements of local City, County and/or State Standards. Since granular bedding backfill is used for most utility lines, the backfilled trench shall be prevented from becoming a conduit and allowing an access for surface or subsurface water to travel toward the new structures. Concrete cut-off collars or clay plugs shall be provided where utility lines cross building lines to prevent water from traveling in the trench backfill and entering beneath the structures.

The PVR values estimated and stated under "Vertical Movements" are based on the provision that positive drainage shall be maintained to divert water away from the building and adjacent pavement. If the this drainage is not maintained, the wetted front may occur below the assumed fifteen feet depth, and the resulting PVR may be 2 to 3 times greater than the stated values shown in this report. Utility leaks may also cause similar high movements to occur.

11.0 LIMITATIONS

The analysis and recommendations submitted in this report are based upon the data obtained from the two borings drilled at the site. This report may not reflect the exact variations of the soil conditions across the site. The nature and extent of variations across the site may not become evident until construction commences. If variations appear evident, it will be necessary to re-evaluate our recommendations after performing on-site observations and tests to establish the engineering significance of any variations. The project geotechnical engineer should review the final plan for the proposed building so that he may determine if changes in the foundation recommendations are required. The project geotechnical engineer declares that the findings, recommendations or professional advice contained herein have been made and this report prepared in accordance with generally accepted professional engineering practice in the fields of geotechnical engineering and engineering geology. No other warranties are implied or expressed.

This report is valid until site conditions change due to disturbance (cut and fill grading) or changes to nearby drainage conditions or for 3 years from the date of this report, whichever occurs first. Beyond this expiration date, Terradyne shall not accept any liability associated with the engineering recommendations in the report, particularly if the site conditions have changed. If this report is desired for use for design purposes beyond this expiration date, we highly recommend drilling additional borings so that we can verify the subsurface conditions and validate the recommendations in this report.

This report has been prepared for the exclusive use of Helton Homes for the specific application to the Proposed Residence on The Shores Drive (Lot 519) in Corsicana, Navarro County, Texas.

APPENDIX

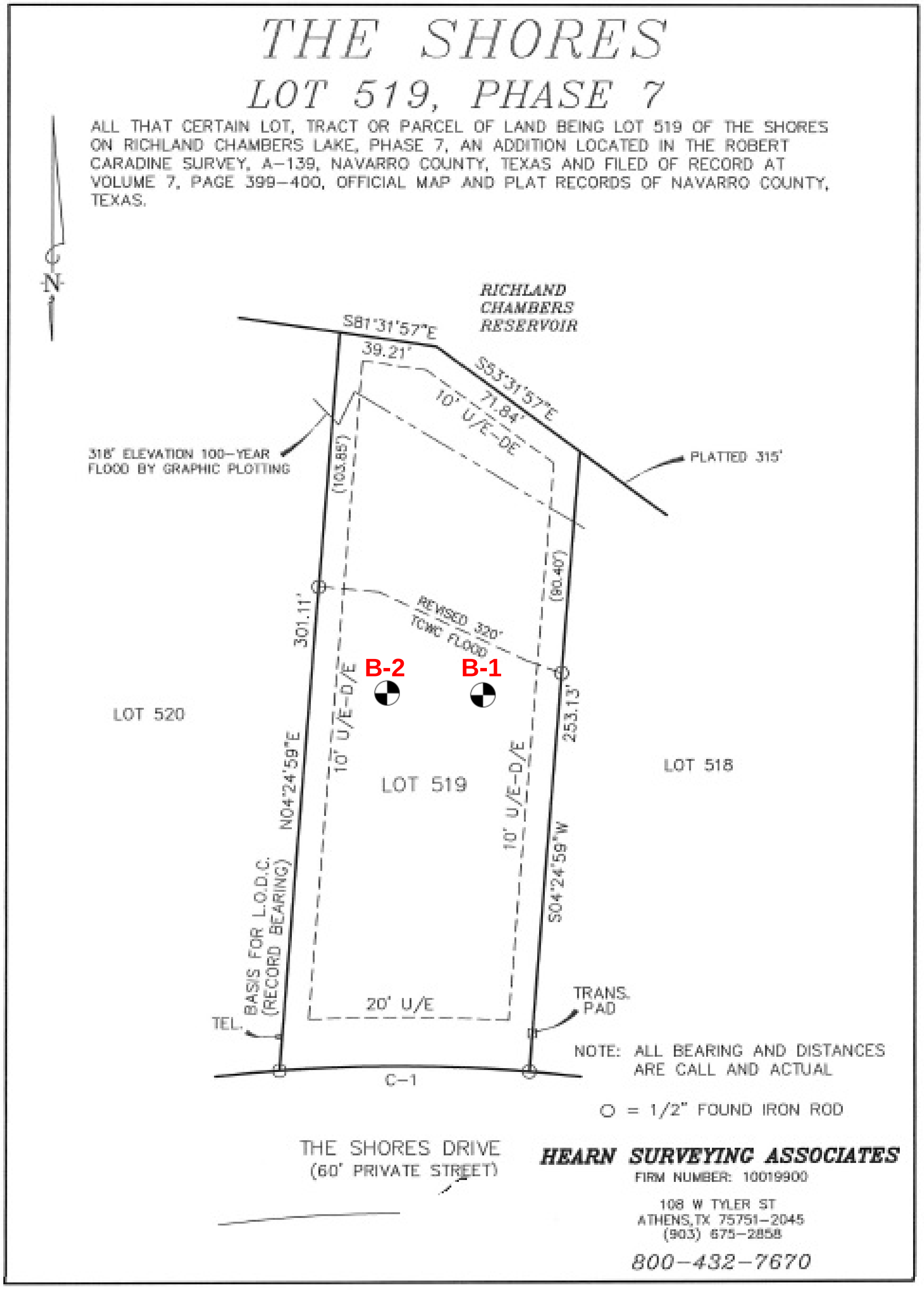
*Terradyne drill rigs are equipped with a GPS tracking system which provides us with latitude and longitudinal co-ordinates of sites.

Site Latitude and Longitude

Proposed Residence on The Shores Drive (Lot 519)
Corsicana
Navarro County, Texas

TERRADYNE
EULESS, TEXAS

Prepared By: GDR	Scale: See Scale Bar	Project # D171216
Verified By: Google Earth	Date: August 2017	Figure # 1-A



*Boring locations are approximate.

Boring Location Plan Proposed Residence on The Shores Drive (Lot 519) Corsicana Navarro County, Texas	TERRADYNE Engineers, Geologists & Environmental Scientists	TERRADYNE EULESS, TEXAS	
	Prepared By: GDR	Scale: Not to Scale	Project # D171216
	Base Plan By: Hearn Surveying Associates	Date: August 2017	Figure # 1-B

Project: **Proposed Residence on**

Project Location: **The Shores Drive (Lot 519), Corsicana, Navarro County, TX**

Terradyne Project Number: **D171216**

Log of Boring B-1

Sheet 1 of 1

Date(s) Drilled **August 11, 2017**		
Drilling Method **Continous Flight Auger**		Total Depth of Borehole **25 feet bgs**
Drill Rig Type **Simco**		Approximate Surface Elevation **Existing Ground Surface**
Groundwater Level and Date Measured **Encountered at 13.5'**	Sampling Method(s) **Grab, SPT**	
Borehole Backfill **Soil Cuttings**	Location **See Figure 1-B**	

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, tsf	REMARKS AND OTHER TESTS
0	SPT	11			FAT CLAY, stiff, moist, dark grayish brown, (CH)	14		96	65	20	45		
	SPT	14				19							
5						19		92	61	14	47		
					FAT CLAY WITH SAND, stiff to very stiff, moist, grayish brown, (CH)								
10	SPT	12				22							
					- becomes light brownish gray ▽								
15	SPT	12				20							
20	SPT	27				25							
25	SPT	29				22							
					End of Borehole								
30													

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TERRADYNE
Engineers, Geologists & Environmental Scientists

Project: **Proposed Residence on**
Project Location: **The Shores Drive (Lot 519), Corsicana, Navarro County, TX**
Terradyne Project Number: **D171216**

Log of Boring B-2
Sheet 1 of 1

Date(s) Drilled: **August 11, 2017**			
Drilling Method: **Continous Flight Auger**		Total Depth of Borehole: **25 feet bgs**	
Drill Rig Type: **Simco**		Approximate Surface Elevation: **Existing Ground Surface**	
Groundwater Level and Date Measured: **Encountered at 13.5'**	Sampling Method(s): **Grab, SPT**		
Borehole Backfill: **Soil Cuttings**	Location: **See Figure 1-B**		

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, tsf	REMARKS AND OTHER TESTS
0	SPT	8			FAT CLAY, medium stiff to stiff, moist, dark grayish brown, (CH)	12							
	SPT	11				14		96	60	17	43		
5	Grab					20							
					FAT CLAY WITH SAND, stiff to medium stiff to stiff, moist, grayish brown, (CH)								
	SPT	10				20		78	50	15	35		
10													
					▽ (groundwater)								
	SPT	12				23							
15													
					- becomes light brownish gray - becomes very stiff								
	SPT	24				26							
20													
	SPT	31			- becomes hard	24							
25					End of Borehole								
30													

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TERRADYNE Engineers, Geologists & Environmental Scientists

Figure 3

Project: **Proposed Residence on**

Project Location: **The Shores Drive (Lot 519), Corsicana, Navarro County, TX**

Terradyne Project Number: **D171216**

Key to Log of Boring

Sheet 1 of 1

Depth (feet)	Sample Type	N=blows/ft (SPT) T=inches/100 blows (THD)	PP (tsf)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	Passing #200 Sieve, %	LL, %	PL, %	PI, %	UC, tsf	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14

COLUMN DESCRIPTIONS

1 Depth (feet): Depth in feet below the ground surface.
2 Sample Type: Type of soil sample collected at the depth interval shown.
3 N=blows/ft (SPT) T=inches/100 blows (THD): N: Number of blows to advance SPT sampler 12 inches or distance shown, OR T: Penetration in inches of THD Cone for 100 blows
4 PP (tsf): The Relative Consistency of the soil, measured by Pocket Penetrometer in tons/square foot
5 Graphic Log: Graphic depiction of the subsurface material encountered.
6 MATERIAL DESCRIPTION: Description of material encountered. May include consistency, moisture, color, and other descriptive text.
7 Water Content, %: Water content of the soil sample, expressed as percentage of dry weight of sample.
8 Dry Unit Weight, pcf: Dry weight per unit volume of soil sample measured in laboratory, in pounds per cubic foot.
9 Passing #200 Sieve, %: The percent fines (soil passing the No. 200 Sieve) in the sample.
10 LL, %: Liquid Limit, expressed as a water content
11 PL, %: Plastic Limit, expressed as a water content.
12 PI, %: Plasticity Index, expressed as a water content.
13 UC, tsf: Unconfined compressive strength.
14 REMARKS AND OTHER TESTS: Comments and observations regarding drilling or sampling made by driller or field personnel.

FIELD AND LABORATORY TEST ABBREVIATIONS

SPT: Standard Penetration Test
THD: Texas Dept. of Transportation Cone Penetrometer Test
LL: Liquid Limit, percent
PL: Plastic Limit, percent
PI: Plasticity Index, percent
PP: Pocket Penetrometer
UC: Unconfined compressive strength test, Qu, in ksf

TYPICAL MATERIAL GRAPHIC SYMBOLS

Fat CLAY, CLAY w/SAND, SANDY CLAY (CH)

TYPICAL SAMPLER GRAPHIC SYMBOLS

Grab Sample
Rock Core
2-inch-OD unlined split spoon (SPT)
THD Cone
Shelby Tube (Thin-walled, fixed head)

OTHER GRAPHIC SYMBOLS

Water level (at time of drilling, ATD)
Water level (after waiting)
Minor change in material properties within a stratum
Inferred/gradational contact between strata
? Queried contact between strata

GENERAL NOTES

1: Soil classifications are based on the Unified Soil Classification System. Descriptions and stratum lines are interpretive, and actual lithologic changes may be gradual. Field descriptions may have been modified to reflect results of lab tests.
2: Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

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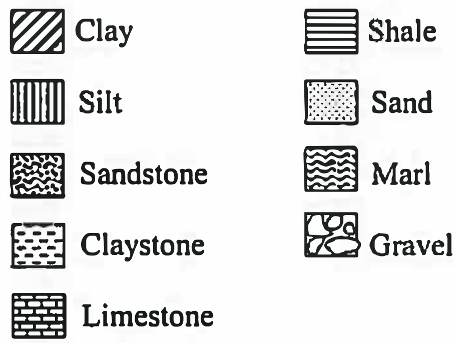
Figure B-1

Key to Classification and Symbols

Soil Fractions

Component	Size Range
Boulder	Greater than 12"
Cobbles	3"- 12"
Gravel	3"- #4 (4.75 mm)
Coarse	3"- ¾"
Fine	¾"- #4
Sand	#4 - #200 (0.074 mm)
Coarse	#4 - #10 (2.00 mm)
Medium	#10 - #40 (0.042 mm)
Fine	#40 - #200 (0.074 mm)
Silt and Clay	Less than #200 (0.074 mm)



Consistency of Fine-Grained Soils

Consistency	Blows/Foot Std. Pen. Test	Unconfined Compressive Strength (TSF)
Very Soft	<2	0.25
Soft	2-4	0.25-0.50
Firm	4-8	0.50-1.00
Stiff	8-15	1.00-2.00
Very Stiff	15-30	2.00-4.00
Hard	>30	>4.00

Consistency of Coarse-Grained Soils

Consistency	Blows/Foot Std. Pen. Test
Very Loose	0-4
Loose	4-10
Medium	10-30
Medium Dense	30-50
Very Dense	50

SOIL STRUCTURE

Calcareous	Containing deposits of Calcium Carbonate, generally modular.
Slickensided	Having inclined planes of weakness that are slick and glossy in appearance.
Laminated	Composed of thin layers of varying colors and textures.
Fissured	Containing shrinkage cracks frequently filled with fine sand or silt usually more or less vertical.
Interbedded	Composed of alternate layers of different soil types.
Jointed	Consisting of hair cracks that fall apart as soon as the confining pressure is removed.
Stratified	Composed of, or arranged in layers (usually 1 inch or more).
Well-graded	Having a wide range og grain size and substantial amounts of all intermediate particle sizes.
Poorly or Gap-graded	Having a range of sizes with some intermediate sizes missing.
Uniformly graded	Predominantly of one grain size