MTEC COMPANIES, LLC

Report of Geotechnical Evaluation
Proposed Residence and Workshop
238 Sky Oak Lane
Huntsville, Texas 77340

MTEC Project 2024-004-018

February 2, 2024

Prepared for:

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MTEC Project Number: 2024-004-018

Subject: **GEOTECHNICAL EVALUATION**
Proposed Residence and Workshop
238 Sky Oak Lane
Huntsville, Texas 77340

Submitted herein is our report of geotechnical evaluation for the proposed Residence and Workshop to be located at 238 Sky Oak Lane, Huntsville, Texas.

This geotechnical report documents the recommendations for the design of the proposed Residence and Workshop foundations. **This report recommends a post-tension slab**. However, we have provided **parameters for drilled and underream piers.**

Respectfully Submitted,
MTEC Companies, LLC (MTEC)
MTEC Engineering Firm Number: F 18063

The seal appearing on this page was authorized by Raghunath Dass P.E. # 90119 on February 2, 2024.

Raghunath Dass, P.E.
Chief Engineer
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Johnny Tatum
Chairman of the Board

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TABLE OF CONTENTS

FIGURES

FIGURE

APPENDIX

BORINGS (B-1 and B-2)

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

TERMS USED ON BORING LOGS

TABLES 1 THROUGH 6

TEXAS. DROUGHT MONITOR MAP

TEXAS DROUGHT CONDITIONS

FLOOD INFORMATION

1.0 INTRODUCTION

In accordance with your request, MTEC Companies, LLC. (MTEC) has completed a geotechnical evaluation for the construction of the proposed Residence and Workshop to be located at 238 Sky Oak Lane, Huntsville, Texas. The project SITE VICINITY MAP is shown in FIGURE 1. The purpose of this study was:

- Evaluate the subsurface conditions at the project site, and
- Provide geotechnical recommendations for the design and construction of the proposed Residence and Workshop.

This report presents the findings of the geotechnical study and presents evaluations, conclusions and recommendations for earthwork and foundation design.

1.1 PROJECT DESCRIPTION

This evaluation was performed for Built Green Custom Homes (Client). MTEC understands that the proposed project will consist of the construction of a new Residence and Workshop in Huntsville, Texas. MTEC has not been advised of any additional future structures including retaining walls, basement, or swimming pool.

1.2 SITE DESCRIPTION

The site is described as sloping with dense brush/tree cover. Land use in the immediate vicinity of the proposed project site is residential.

1.3 PRESUMED LOAD CRITERIA

Although MTEC has not been provided with the anticipated structural loads, for the purposes of this evaluation, we have presumed the following load criteria:

- Walls: About 1.0 to 1.5 kips/ ft
- Floors: About 100 to 125 lbs/ sq ft

1.4 PREVIOUS INVESTIGATIONS

MTEC is not aware of any previous evaluation for the target property.

2.0 SCOPE OF SERVICES

Based upon on-going discussions with the Client, Built Green Custom Homes, MTEC included the following services to provide our Report of Geotechnical Evaluation:

- Geotechnical site reconnaissance to provide an overall approach to the services provided;
- Delineation of test boring locations to represent the underlying site conditions;
- Drilling, logging and sampling three small-diameter geotechnical soil test borings:
  - Test exploratory borings drilled and sampled within the boundary of the property to a depth of about 20 feet, and 15 feet each below ground surface;

TABLE 1. EXPLORATORY TEST BORING PROGRAM

AREA / GENERAL LOCATION	TEST BORING NUMBER(S)	TEST BORING DEPTH (feet)
See Figure 2	B-1	20
See Figure 2	B-2	15
See Figure 2	B-3	20

- Collection of soil samples and transport to the MTEC laboratory for visual classification and laboratory testing of selected soil samples to evaluate the geotechnical engineering properties of the intercepted soils underlying the project site;
- Engineering analyses and evaluation of the collected data:
  - Evaluation of general subsurface conditions and approximate descriptions of types, distributions, and engineering characteristics of intercepted and identified subsurface soils;
  - Evaluation and suitability of on-site soils for foundation support;
  - General recommendations for site grading and subgrade preparation;
  - Recommendations for design of foundations including allowable bearing capacity, and estimated settlement, as appropriate for the proposed building; and

  - Recommendations for subgrade preparation for the floor slab and slab-on-grade support, including design recommendations.

- Developing recommendations to reduce foreseeable construction problems.

- Preparation of this report presenting the work performed and data acquired, as well as summarizing MTEC's conclusions and geotechnical recommendations for the design and construction of the proposed project.

3.0 FIELD EXPLORATION AND LABORATORY TESTING

3.1 FIELD EXPLORATION

The field activities consisted of drilling and sampling three exploratory borings at approximate locations. The borings were located in the field by MTEC designated representatives. The field activities were performed on January 9, 2024.

Equipment. Three three-inch nominal diameter borings were advanced with a mobile drilling apparatus using continuous solid-stem flight augers. The boring depths of about 20 feet, and 15 feet each were measured from the existing ground surface at the time of our field exploration.

Penetrometer Tests. Generally, pocket penetrometer tests are normally performed on selected portions of the predominately cohesive soil samples in the field to provide a general measure of consistency.

The presence of sands tends to obscure the penetration test results.

Field Test Boring Logs. Field test boring logs were prepared by a MTEC representative. These logs included visual classifications of the materials encountered during drilling and initial interpretation of the subsurface conditions and assessment of free water, as applicable.

In this instance, no free water was intercepted nor identified.

Final Test Boring Logs. Final test boring logs, included with this report, represent an interpretation of the field test boring logs and include modifications based on laboratory observations and testing of the soil samples. The Logs of Borings are shown in the Appendix attached to this report.

A description of the *Classification of Soils for Engineering Purposes* and *Terms Used on Boring Logs* are presented at the end of the Appendix.

3.2 LABORATORY TESTING PROGRAM

Soil samples obtained during the field program were visually classified in the laboratory by the geotechnical engineer according to procedures outlined in ASTM D 2488 (Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)).

A testing program was conducted on selected samples, as directed by the geotechnical engineer, to aid in the classification and evaluation of the engineering properties required for analyses.

Laboratory tests were performed in accordance with the indicated standard procedure, and shown on TABLE 2.

TABLE 2. LABORATORY TEST PROCEDURES

LABORATORY TEST	APPLICABLE TEST STANDARD
Liquid and Plastic Limit to determine Plasticity Indices of Soil	ASTM D 4318
Amount of Material in Soils Finer than the No. 200 Sieve	ASTM D 1140
Intact Moisture Content	ASTM D 2216

Results of the laboratory tests are presented on the test boring logs provided in the Appendix. Laboratory test results were used to classify on-site soils according to the Unified Soil Classification System (ASTM D 2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)).

3.3 SOIL SAMPLE DISPOSAL

Soil samples were returned to the MTEC laboratory in Pinehurst, Texas. Soil samples will be stored for a period of 60 days subsequent to submittal of this MTEC report.

These soil samples will be discarded after this period, unless we are notified otherwise in writing by the Client.

4.0 SURFACE AND SUBSURFACE CONDITIONS

4.1 FILL SOILS

Fill soils were not identified at this site. In addition, no construction debris or other material was noted at the site.

4.2 SUBSURFACE SOIL STRATIGRAPHY

The subsurface stratigraphy, as determined from the MTEC field activities and laboratory program, is shown in greater detail on the attached exploratory test boring logs (Borings B-1 and B-2), presented in the Appendix. The test boring logs include descriptions of the various strata encountered and identified, their approximate depths, and the soil consistencies and relative densities, as appropriate.

A brief summary of the soil stratigraphy indicated on the boring logs is given below. Boundaries between the various soil types are approximate and may vary among the borings. The primary soils that were intercepted and identified during our drilling and sampling activities were the following:

- **Borings B-1 to 20 feet:**
  - **Silty Sand (SM),** overlaying
  - **Sandy Fat Clay (CH),** overlaying
  - **Fat Clay with Sand (CH).**
- **Borings B-2 to 15 feet:**
  - **Silty Sand (SM),** overlaying
  - **Sandy Fat Clay (CH),** overlaying
  - **Fat Clay with Sand (CH).**
- **Borings B-3 to 20 feet:**
  - **Sandy Fat Clay (CH),** overlaying
  - **Fat Clay with Sand (CH).**

The surficial soils are very sensitive to varying moisture conditions. The soils are very similar across the site.

4.3 FAULT DISCUSSION

The project site is outside the area of published faults of which we are aware. We did not observe any adverse conditions based upon faults. Therefore, we do not anticipate major concerns regarding fault interaction with the new structure.

4.4 FREE WATER OR GROUNDWATER

Free water was not encountered or intercepted at the site of the exploratory borings to the termination depths of the borings.

If more detailed water level information is required, observation wells or piezometers could be installed at the site, and water levels could be monitored over one or more seasons. However, we do not believe that this is necessary for this project.

Fluctuations in the short-term and long-term groundwater level should be expected throughout the years, depending upon variations in hydrological conditions and other factors not apparent at the time the borings were drilled.

Free water and groundwater level fluctuations may occur due to:

- Seasonal and climatic variations,
- Alteration of drainage patterns,
- Leaking utilities,
- Land usage, and
- Ground cover.

4.5 HUNTSVILLE DROUGHT CONDITIONS

Historically, the Huntsville area is within moderate drought to severe drought conditions as expressed in the Texas Drought Monitor Map.

5.0 DESIGN RECOMMENDATIONS

Recommendations for the design and construction of the foundation for the proposed Residence and Workshop are presented in the following report sections.

5.1 GENERAL DESIGN CONSIDERATIONS

Presumed Loadings. Although we have no information of the design loading conditions, for the purposes of this evaluation, we have presumed the following load criteria:

- The estimated structural loads are:

Walls:	About 1.0 to 1.5 kips/ ft
Floors:	About 100 to 125 lbs./ sq ft

- The floor slab of the building will probably be a slab-on-grade.

Potential Vertical Rise. Based upon the test results and field observations, the Potential Vertical Rise **<u>(PVR) of about 2.8 inches was estimated</u>** for this site under **existing "average" and "dry" moisture conditions** using the Texas Department of Transportation method (Test Procedure TEX-124-E).

If entirely "dry", the Potential Vertical Rise will increase to <u>about 3.8 inches.</u>

One inch of PVR is generally accepted as the maximum allowable value for design and construction in the geographical area. However, structural engineers do design structures atop PVR material in excess of one inch.

For information, one approach to mitigating this is to remove at least 1 foot of existing soils and replace with at least 1 foot of properly compacted and moisture-controlled select fill and install 27 inches of properly compacted and moisture-controlled select fill above the new earthen pad to achieve a PVR of about 2.5 inches.

For information, another approach to mitigating this is to remove at least 6 feet of existing soils and replace with at least 6 feet of properly compacted and moisture-controlled select fill and install 27 inches of properly compacted and moisture-controlled select fill above the new earthen pad to achieve a PVR of about 1.0 inches. *We do not necessarily recommend this approach*.

We generally do not like the alternatives of removing and replacing soil. The major reasons for this are the following:

- **The solution is rather expensive;**
- **We sometimes discover that the site, once excavated, does not have an engineered proof-roll;**
- **We sometimes discover that the replacement soils at the site are not placed in maximum of 8-inch loose lifts; instead, the lifts are 12 to 18 inches or more in thickness.**

Instead, we prefer that the Design Team approach the problem in the following manner:

1. **PVR is related to increased moisture to the underlying soil, so try to inhibit moisture filtration into the underlying soils**
    - **Use flexible connections below ground for water transmitting pipe,**
    - **Seal concrete joints with waterproof sealant,**
    - **Install French drains around the building to capture and redirect surface water,**
    - **Eliminate landscaping requiring watering,**
    - **Grade the site to avoid ponding at the building and in the parking and drive areas.**
    - **Maintain the surface area to prevent water infiltration into cracks.**

2. **Encase water pipes in cement stabilized sand to prevent leaking pipes allowing water to seep into the underlying soils.**

However, these economic decisions are left to the Design Team.

It has been reported that Texas has been subjected to three 500-year precipitation events in the last three years.

In addition, Texas has had several drought conditions in the past.

Based on the observed soil data, the surficial soils encountered by the borings are considered to be silty sands and sandy fat clays. The state of in situ soil moisture appears to be "average" and "dry" at the exploratory borings within the appropriate boring locations. The soil-moisture conditions were evaluated using the following empirical formulae (TxDOT Procedure 124-E).

Dry Soil:	In situ moisture content ≤ (0.2 Liquid Limit + 9)
Average Soil:	In situ moisture content is between dry and wet conditions.
Wet Soil:	In situ moisture content ≥ (0.47 Liquid Limit + 2)

Excessive foundation movement should not occur if customary measures are taken to reduce and control moisture variations beneath the structure.

5.2 SETTLEMENT

Total settlement, after initial foundation loading, is estimated to be about 1 inch or less for foundation units designed in accordance with recommendations provided herein and control of underground moisture, **unless the site becomes inundated**. Differential settlements for the slab/foundation are estimated to be on the order of 1/2 inches or less.

5.3 FOUNDATION DESIGN RECOMMENDATIONS

Typically, specific foundations are recommended for specific projects based upon several criteria. The intercepted and identified underlying soils at the project area are predominately "dry" sandy fat clays, and fat clays with sand.

5.3.1 STIFFENED" POST-TENSION SLAB

A "stiffened" post-tensioned slab-on-grade foundation system may be utilized to support the planned Residence and Workshop. The foundation slab should be designed to sustain the estimated soil movements.

"Stiffened" Post-Tensioned Slab Design. A "stiffened" post-tensioned slab-on-grade may be used and designed in accordance with the publication *Design of Post-Tensioned Slabs-on-Ground 3rd Edition*, Post-Tensioning Institute (PTI). TABLE 3 provides post-tension slab parameters.

TABLE 3. MTEC STIFFENED POST-TENSIONED SLAB DESIGN PARAMETERS

(Design of Post-Tensioned Slabs-on-Ground, 3rd Edition PTI)

Designed Shear Strength	1,000 psf	
Allowable Soil Bearing Pressure	Minimum bearing depth into in situ soils = 12 inches	
Total Load	**Say 2,700 psf** FS ≥ 2.0	
Dead Load + Sustained Live Load	**Say 1,800 psf** FS ≥ 3.0	
Thornthwaite Index, I_M	About 30	
Weighted BRAB Plasticity Index	**Less than 40**	
Potential Vertical Rise, "dry"	**About 3.8 inches**	
MTEC RECOMMENDED VALUES		
	Center Lift	**Edge Lift**
e_m	**4.9 feet**	**5.4 feet**
y_m	**0.7 inches**	**1.2 inches**
(Alternate Foundations include spread footings or strip footings; Section 3.2.3 Non-Active Sites, PTI 3rd Edition)		
Slab Subgrade Friction Coefficient	Stable Soils: Uniform Thickness Slabs cast on Polyethylene Sheeting: Range of values of 0.5 to 0.6 (PTI Section 2.2, page 5); Stable Soils: Slabs cast directly on a Sand Layer: Range of values = 0.75 to 1.0 (PTI Section2.2, page 5) ; Ribbed Slabs cast on Polyethylene Sheeting or Sand; Range of values = 0.75 to 1.0, respectively.	

Allowable soil bearing pressures based upon a minimum penetration of the foundations (grade beams, etc.) into the underlying undisturbed in situ soils to an embedment depth of at least 12-inches.

The design and construction of the post-tensioned slab should be performed by structural engineers and contractors experienced in such work. In addition, MTEC has provided a guide line for the design and construction of "stiffened" slab in the Appendix.

5.3.2 OTHER DESIGN PARAMETERS

The following paragraphs address the subgrade, and the use of leveling sand atop the building pad.

Dry Subgrade. Permeable dry subgrade, with a smooth, low-friction surface should be provided beneath the building slabs.

- **The slabs should not be constructed on a saturated subgrade; and**
- The slabs should not be constructed on a subgrade with standing water.

Leveling Sand. **MTEC recommends the avoidance of sands as final grading and/or leveling material.**

5.3.3 FOUNDATION CONSTRUCTION CONSIDERATIONS

Predominately "dry" soils were observed during the drilling and soil sampling activities below the existing ground surface, January 9, 2024.

Foundation construction should be as follows:

- Foundations may be founded in a variety of soil types.
- Excavations for foundations should be clean and free of loose, weak or pumping soils prior to the placement of concrete.
- Concrete should be placed in the foundation excavations as soon as practical after excavating and placement of reinforcing steel.

Allowable net bearing pressures provided in this report are based on proper construction procedures.

Observation of post-tensioned foundation construction should be performed by a qualified technician to ensure compliance with design assumptions, and to verify that:

- Foundations have the specified dimensions,
- Foundations are excavated to the specified depth,
- Foundation excavations are dry prior to concreting,
- Loose soil cuttings, or weak or pumping soils are removed, or remediated, and
- Concrete is placed properly.

5.3.4 GRADE BEAMS

Grade beams for the proposed building should be founded on similar soils throughout with a minimum depth of 12-inches.

> *The base of the grade beams should be supported by similar soils across the site, whether in situ soils or moisture- and compaction-controlled select fill.*

> ***The allowable bearing pressure is 1,800 psf with a Factor of Safety of at least 3.***

5.3.5 FLOOR SLABS

MTEC recommends that the finished floor slab elevation be constructed above existing grade; at least six inches.

Design elements that reduce the potential for moisture content changes in the supporting soils include the following:

- Absence of landscaping directly adjacent to the Residence and Workshop, and
- Drainage away from the building that will not be modified during structural life by landscaping.

The absence of landscaping removes a common water source for changes in induced moisture content. A major source of water that could promote adverse soil activity is from leaking building utilities.

The impacts of potential utility leaks can be lessened by selection of pipe bedding, pipe backfill, use of chemically treated (stabilized) subgrade, and building pad fill material that does not promote water movement.

5.3.6 DRILLED AND UNDERREAM PIERS

MTEC recommends that the design and construction of the drilled and underream piers generally follow the methods outlined in the manual *Drilled Shafts: Construction Procedures and Design Methods*, Publication No. FHWA-IF-99-025, August 1999. Table 4, overleaf, provides design parameters for drilled and underream piers.

TABLE 4a. DEEP FOUNDATION DESIGN PARAMETERS

PARAMETER	RECOMMENDATION	COMMENTS
Foundation Type	Drilled-and-Underreamed Piers	-------------------------------
Bearing Depth below existing ground	16 feet	Below existing grade.
Assumed Design Shear Strength	1,500 psf	-------------------------------
Net allowable bearing pressure*, qall		
Total Load, ksf	6.0	Includes safety factor of 2
D. L. + Sustained Live Load, ksf	4.0	Includes safety factor of 3
Pier Spacing	At least three underream diameters for underream piers	Measured center-to-center
Bell to Shaft Ratio for Underream Piers	**2:0 to 2.5:1**	**Do not use 3:1 Bell to Shaft Ratio**

TABLE 4b. DEEP FOUNDATION DESIGN PARAMETERS, with 27 Inch Earthen Pad

PARAMETER	RECOMMENDATION	COMMENTS
Foundation Type	Drilled-and-Underreamed Piers	-------------------------------
Bearing Depth	15 feet	**Below the top of 27-inch earthen pad placed above the proof-rolled existing grade.**
Assumed Design Shear Strength	1,500 psf	-------------------------------
Net allowable bearing pressure*, qall		
Total Load, ksf	6.0	Includes safety factor of 2
D.L. + Sustained Live Load, ksf	4.0	Includes safety factor of 3
Pier Spacing	At least three underream diameters for underream piers	Measured center-to-center
Bell to Shaft Ratio for Underream Piers	**2:0 to 2.5:1**	**Do not use 3:1 Bell to Shaft Ratio**

Note: * May be increased 33% for transient loading conditions such as wind

Detailed inspection of drilled shaft construction should be made to verify that the shaft is vertical and verify that all loose materials have been removed prior to concrete placement. In addition, the underreams and/or shafts should be checked to verify their integrity and size as per the specifications.

Accumulated water should 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 5 feet.

When drilling operations and inspections are complete, ***concrete should be placed inside the shaft and/or underream within a maximum of six hours.*** In no instance should the shaft excavation, and/or underream cavity remain open overnight. Placement of the drilled shaft concrete immediately following underream operations may be necessary to reduce the potential for caving.

Design values are based on footings spaced, center-to-center, at least equal to three times the adjacent or subject underream diameter, whichever is greater.

Closer footing spacing may warrant reductions in allowable bearing values, because of increased (overlapping) vertical stresses imposed in the soils, to limit foundation settlements to within acceptable limits

Uplift Heave Capacity **With the 27-inch earthen pad addition,** MTEC anticipates that the soils within the surficial 10 feet of soil will be subject to heave. The heave should be calculated as:

(Pier shaft diameter) times (π) times (9 feet) times (1,700 pdf)*Factor of Safety

With the 27-inch earthen pad addition, the allowable underream uplift capacity may be calculated as:

(0.67) X (underream diameter) X (π) X (14 feet) X (1,700 pdf)/ 3

Construction Considerations. There is a possibility that perched water seepage may be encountered during shaft excavation, especially if construction is performed during wet weather. Construction of the drilled shafts may require the use of temporary casing if excessive seepage water infiltration occurs.

Concrete. Concrete for the drilled shafts should be constructed in accordance with American Concrete Institute Specification ACI 336. The concrete should be placed in a manner to avoid striking the reinforcing steel and walls of the shaft during placement.

Document Review. MTEC should be retained to observe and document the drilled shaft construction.

The geotechnical engineer, or a representative of the geotechnical engineer, should document the following:

- Shaft and/or underream diameter,
- Excavation depth,
- Excavation cleanliness,
- Plumbness of the shaft, and the
- Type of bearing material.

Inspection. The drilled shaft excavation should be observed to check that the bottom of the hole is dry and thoroughly cleaned of cuttings.

No build-up of cuttings in the base of the excavation should be allowed.

Moisture induced movements are influenced by:

- Soil properties,
- Overburden pressures,
- Soil moisture content at the time of construction, and
- Changes in the underlying soil moisture contents.

5.4 VAPOR RETARDER

ACI 302.1R-96, *Guide for Concrete Floor and Slab Construction* (ACI Committee 302) recommends that a vapor retarder with:

- Permeance of less than 0.3 US perms (ASTM E 96, "Standard Test Methods for Water Vapor Transmission of Materials"), and
- Thickness not less than 10-mils be placed under the concrete floor slab on ground to reduce the transmission of water vapor from the supporting soil through the concrete slab and to function as a slip sheet to reduce subgrade drag friction.

MTEC recommends that at least a minimum 10-mil polyethylene sheet be used as the moisture retarder.

MTEC recommends placing the concrete floor directly on the vapor retarder. The vapor retarder should be installed according to ASTM E 1643 ("Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill Under Concrete Slabs").

6.0 GENERAL SITE GRADING RECOMMENDATIONS

6.1 SITE GRADING AND DRAINAGE

Site Preparation. Initial site grading should include general preparation of the site for the proposed residential development. Included in this activity are clearing, stripping and grubbing the site to remove the surficial (organic) soils and tree roots in excess of ¼ inch in diameter, if any.

***The exposed soils at the residential pad must pass proof-rolling by suitable equipment, prior to installation of 27-inch earthen pad*.**

Grading. Grading should provide positive drainage away from the residential structure, and should prevent water from collecting or discharging near the foundations. Water should not be permitted to pond adjacent to the building during, or after, construction.

Surface Drainage. Surface drainage gradients should be designed to divert surface water away from the building and edges of pavements and towards suitable collection and discharge facilities.

Unpaved areas and permeable surfaces, if any, should be provided with steeper gradients than paved areas. Surface drainage gradients of sidewalks and pavements within 15 feet of the structure should be constructed with maximum slopes allowed by local code.

Roof Drainage. Roofs, as applicable, should not allow the formation of standing water along side of the building foundations during and after precipitation.

- Downspouts should discharge directly onto drainage areas or drainage swales, and
- Roof downspout and surface drain outlets should discharge into erosion-resistant areas.

Flat Grades. Flat grades should be avoided.

Concrete Joints. Where concrete pavement is used, joints should also be sealed to prevent the infiltration of water. Joints should be periodically inspected and resealed where necessary.

Cut/Fill Considerations. Constructing foundation elements **bearing partially on cut and partially on fill is *not recommended within the same building and should be avoided*.** If fill is placed beneath the structures, then the depth of fill should be somewhat consistent beneath the entire structure to reduce the possibility of differential settlement.

Structures constructed partially on cut and partially on fill typically may exhibit differential movements in excess of normal due to the fill portion of the building settling more rapidly and a greater amount than that portion of the structure constructed on a cut area.

Designated fill areas for bearing purposes may be required to provide a level and increased elevation building pad.

- These fill areas should be composed of density controlled select fill (compacted to 95% Standard Proctor ASTM D 698).
- These constructed fills, even though placed in a density-controlled and monitored-manner, can be expected to settle between ½% and 1-½% throughout the fill thickness. {This contribution to settlement can be significant on sites with constructed fill depths exceeding several feet, and should be accounted for in the design of the building}.
- Usually, the most effective means to reduce and control deleterious effects of this settlement is to simply provide a relatively constant fill thickness, or accommodate a gradual transition from cut to fill.

6.2 SITE PREPARATION

We do not know the grade of the existing site parcel, nor the design finished grade of the building earthen platform and the pavement grade.

Presumably, after the initial site preparation, soil will be either cut out, brought in, or a combination of these two, or simply processed in place.

Site preparation within the building footprint area should consist of clearing, stripping and grubbing operations will probably remove at least four to six inches of the top soil.

To achieve a working building platform, or to accommodate soils to increase the ground elevation, **the building area may require remediation:**

- After grubbing and stripping, the building area plus 5 feet beyond the building area **must be proof-rolled** to identify loose, soft, or pumping areas and any areas containing looser soft soils. These loose, soft, or weak areas should be **hand-probed** (on an approximate 5-foot grid) to delineate the extent of the loose, soft, or pumping areas or areas of construction debris previously identified.
  - Construction area of exposed soils should be compacted with suitable equipment.
  - Compaction equipment should make at least 3 passes in each of two perpendicular directions.

- Proof-rolling should proceed using a heavy, loaded pneumatic-tired vehicle such as a 20-to-25-ton roller, loaded dump truck, or scraper.

  (Track vehicles are not suitable for this activity).

- **Unacceptable areas** identified during the proof-rolling and hand-probing activities should be remediated in one of the following methods:
  - Overexcavation and recompacted to at least 95% Standard Proctor maximum dry density throughout the buildings/pavement subgrade areas.
  - Reprocessing to adjust moisture;
  - Chemical modification with lime, lime-fly ash, cement, or cementitious mixture; or
  - Installing geosynthetics such as geotextiles, geogrids, or geogrid-rock “mattresses”.

- **If select fill placement** is necessary to provide grade adjustments, the select fill should have the following attributes:
  - Free of surficial vegetation, organics, any other deleterious materials;
  - Free of debris and relatively homogeneous mixture;
  - Maximum particle size is less than 3 inches;
  - Liquid limit less than 38; and
  - Plasticity index between 7 and 18.
  - ***Note: The on-site soils are not suitable for use as select fill.***

6.3 SELECT FILL PLACEMENT IN BUILDING AREA

If required to modify grade, the fill materials should be spread in loose lifts, less than 8 inches thick, and uniformly compacted between - 2 and + 2 percentage points of optimum moisture content to a minimum of 95% Standard Proctor maximum dry density.

Each layer shall be leveled and compacted with approved equipment. After spreading, each layer should be thoroughly manipulated by plowing, dicing, or other approved methods to the full depth of the layer being placed to ensure uniform density and moisture distribution for proper compaction.

The moisture content at the time of compaction shall be within the range specified in this report.

- If the material is too dry, it shall be moistened by watering, before placement, and before and during manipulation, to properly condition the material for compaction.

- If the material is too wet, the moisture content must be reduced to within satisfactory compaction range by windrows, chemical treatment (i.e., addition of fly-ash), or other approved methods.

Construction Monitoring. We recommend that MTEC perform the observation services during the placement of select fill within the building pad and pavement areas.

6.4 SANDS AS ENGINEERED FILL

Silty sand (SM) is frequently proposed for use as select fill. However, our experience is that many contractors encounter major difficulty in working with silty sands and sands, depending on the seasonal moisture and groundwater conditions.

Although silty sands may satisfy moisture and compaction test requirements at the time of placement, sands typically:

- Require re-working prior to further construction due to subsequent moisture variations, surficial degradation, and loss of structure, especially under construction traffic, which affects the density of the material.
- Do not usually allow “formless” utility and foundation trenches to remain stable.
- Are relatively pervious, and tend to allow upward migration of shallow groundwater or perched water during processing and compaction.

For these reasons, this material will not satisfy the recommended requirements listed herein for select fill.

MTEC recommends avoidance of sands to be used as leveling or final grading, unless the existing sands remain in place.

6.5 FILL TESTING FREQUENCY

Each lift of compacted soil (select fill or engineered fill) should be tested and inspected by the geotechnical engineer or his representative prior to placement of subsequent lifts. As a guideline, MTEC recommends the testing frequency noted on TABLE 5.

TABLE 5. FILL TESTING FREQUENCY

FILL LOCATION	TEST FREQUENCY RECOMMENDATIONS
Building Area	Not less than 1 test per 2,500 square feet of surface areas per lift, or Minimum of 4 tests per lift for each tested area.
Utility Areas	Not less than 1 test per 500 linear feet of utility line placement.

6.6 LANDSCAPING AND TREES

The effects of evapotranspiration from nearby trees, and recently removed trees, can have a severely negative impact on underlying and neighboring soils.

Tree roots can continue to reduce moisture in the underlying soils over time, causing shrinkage or subsidence, or the abundance of water (perhaps through storm events) can cause realignment of soil particles and greater shrinkage upon drying.

Once the trees are removed, the roots dry and the underlying soils have a tendency to absorb water from the surrounding areas to regain an equilibrium condition.

- MTEC recommends that the trees near the structures, if any, should be no closer than 100 percent of the mature height of the tree, and
- MTEC recommends that buildings not be positioned within the vertical projection of mature tree canopies to reduce their future impact on the structures.
- Alternatively, trees closer than these recommendations should have vertical root barriers along the structure perimeter no shallower than 3 feet below finished grade to impede tree roots from growing beneath the foundation in search of water.

  The root barrier may be earth formed from trenching or excavating and filled with a lean concrete mixture. Steel reinforcement is not required within the root barriers.

The clay soils at the site can be desiccated by the presence of previous current trees. Water control in this area is important as a means of preventing adverse heave from these soils. In general, MTEC recommends essentially the same proximity considerations as tree removal, and as a further stipulation, MTEC recommends the planting of low to moderate water demand plants/trees. (See TABLE 6, overleaf).

Tree Additions. Similar to tree removal, not all trees have the same water demand characteristics. Since the tree roots can have a detrimental effect on structure through opening of rock or geomaterial joints, or a positive effect on some slopes, great care must be exercised in designating the new plantings as part of the overall landscaping scheme.

6.7 AREA DESICCATION, PAST SHRINKAGE AND REHYDRATION

In general, as a tree grows over time, they will remove moisture from the underlying soils and if the soils are shrinkable (i.e., clays), the soil will develop low permeability.

- The soil can cause a persistent moisture deficiency to develop.

TABLE 6. SUMMARY OF TREES WITH VARYING WATER DEMANDS

WATER DEMANDS	TYPICAL TREES
High Water Demand Trees	Oak (all varieties) Elm Poplar Willow, and Some Cypress Trees
Moderate Water Demand Trees	Ash Sycamore Cherry Douglas Fir Pine, and Leyland Cypress
Low Water Demand Trees	Beech Birch

- The soil does not fully re-hydrate during the appropriate seasons before the soil undergoes another condition of clay shrinkage subsidence during the next growing season.

It can easily take many years for rehydration to occur. The time period usually depends upon the degree of desiccation already established by the surrounding trees and the permeability of the underlying clays.

Desiccation. Reviewing the laboratory test data, many of the soils to the depths tested have intact moisture contents **less than 50 %** of the associated liquid limits.

According to Richard Driscoll (1983), the state of desiccation can be predicted by intact moisture contents **less than 50 % of the liquid limit**. Therefore, **the soils identified and observed are generally in a state of desiccation and susceptible to rehydration as trees in the area are removed.**

6.8 FREE WATER OR GROUNDWATER CONTROL

Based on our experience, attaining adequate compaction of clayey soils can become problematic if underlying moisture mitigates to the working surface.

It is reasonable to anticipate that groundwater conditions may vary, and there is a possibility of intercepting perched water at the time of construction.

- Some dewatering through shaping of work areas to shed water, and construction of temporary ditches with sumps and pumping may be necessary to remove the loose soils and allow placement of imported select fill in a dry manner.
- Excavated soils intended for re-use as select fill may require special methods in order to dry the soil to suitable moisture content prior to re-placing the soil as select fill.

Perched Water Conditions. Precipitation and surface water may collect atop the underlying soil layers and seep or pour into open excavations during construction. This condition should be expected, and is usually controlled by sumps and pumps.

Water should not be allowed to accumulate into excavations waiting on evaporation to dry the area. Instead, the contractor should take positive measures to remove the water accumulation.

Pumping Subgrades. Pumping subgrades are possible at this site, especially if work is conducted during wet periods. If these conditions are encountered during construction, it may be advisable to consider replacement of wet, unstable material with a material that is less porous than the existing material, installation of “bleeder” ditches, French drains, and other measures.

Bleeder Ditches and De-Watering Pits. “Bleeder ditches” (temporary excavated de-watering ditches maximum four feet deep) are not anticipated but may be required as an integral part of the contractor’s base bid, if viewed as incidental or subsidiary to the other bid items. The temporary construction of “de-watering pits” or wells may be useful during certain phases at this site.

7.0 DESIGN REVIEW AND CONSTRUCTION MONITORING

Geotechnical review of plans and specifications is of significant importance in engineering practice. The poor performance of many structures has been attributed to inadequate geotechnical review of construction documents.

Additionally, observation and testing of the subgrade will be important to the performance of the proposed development. The following sections present our recommendations relative to the review of construction documents and the monitoring of construction activities.

7.1 PLANS AND SPECIFICATIONS

The design plans and specifications should be reviewed and approved by MTEC prior to bidding and construction, as the geotechnical recommendations may need to be reevaluated in the light of the actual design configuration and loads.

This review is necessary to evaluate whether the recommendations contained in this report and future reports have been properly incorporated into the project plans and specifications. Based on the work already performed, MTEC is best qualified to provide such a review.

7.2 CONSTRUCTION MONITORING

Site preparation, removal of unsuitable soils, assessment of imported fill material, fill placement, foundation installation, and other site grading operations should be observed and tests, as appropriate.

The soil substrata, exposed during the construction and project development, may differ from that encountered and identified in the limited soil test borings.

Continuous observation by a representative of MTEC during site preparation and foundation construction allows for the evaluation of the soil conditions as they are encountered, and allows the opportunity to recommend appropriate revisions, where necessary.

8.0 LIMITATIONS

The recommendations and opinions expressed in this report are based on information obtained from field activities on January 9, 2024.

Due to the limited nature of our field explorations, surface and/or subsurface conditions not observed and described in this report may be present on the site. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration.

However, it is common practice for these types of projects that only a very limited amount of soil exploration is performed for the engineering evaluation. Additional subsurface evaluation and laboratory testing can be performed upon request.

Conditions different from those anticipated in this report may be encountered during site grading operations such that additional effort may be required to mitigate them.

Recommendations provided in this report have been developed from information provided by a limited number of test borings. These test borings depict subsurface conditions only at specific test boring locations and at the particular dates designated on the logs. Subsurface conditions may vary between test boring locations. The nature and extent of variations between test borings may not become evident until construction begins.

If subsurface conditions encountered during construction differ from what we have obtained from test borings, our office should be notified immediately so that the effects of these conditions on design and construction can be addressed.

Site conditions, including groundwater elevation, can change with time as a result of natural processes or the activities of man at the subject site or nearby sites.

Changes to the applicable laws, regulations, codes, and standards of practice may occur as a result of government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which MTEC has no control.

Construction Monitoring. MTEC's recommendations for this site and this project are, to a high degree, dependent upon appropriate quality control of subgrade preparation, fill placement, and foundation construction. Accordingly, the recommendations are made contingent upon the opportunity for MTEC to observe grading operations and foundation excavations for the proposed construction.

If parties other than MTEC are engaged to provide such services, or such services are un-provided, such parties, as appropriate, must be notified that they will be required to assume complete responsibility as the geotechnical engineer or record for the geotechnical phase of the project by concurring with the recommendations on this report and/or by providing alternative recommendations.

Standard of Practice. Professional services provided for this geotechnical evaluation has been performed, findings obtained, and recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices.

Items Not Covered By MTEC Services. The scope of services of MTEC provided herein does not include:

- Geologic fault study,
- Environmental assessment of the site, or investigation for the presence or absence of hazardous materials in the soil, surface water, and groundwater, or
- Flood elevation considerations.

Report Use. This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. MTEC should be contacted if the reader requires additional information or has questions regarding the content, interpretation presented, or completeness of this document.

The reproduction of this report or any part thereof, in plans or other documents supplied to persons other than the owner, should bear language indicating that the information contained therein is for foundation design purposes.

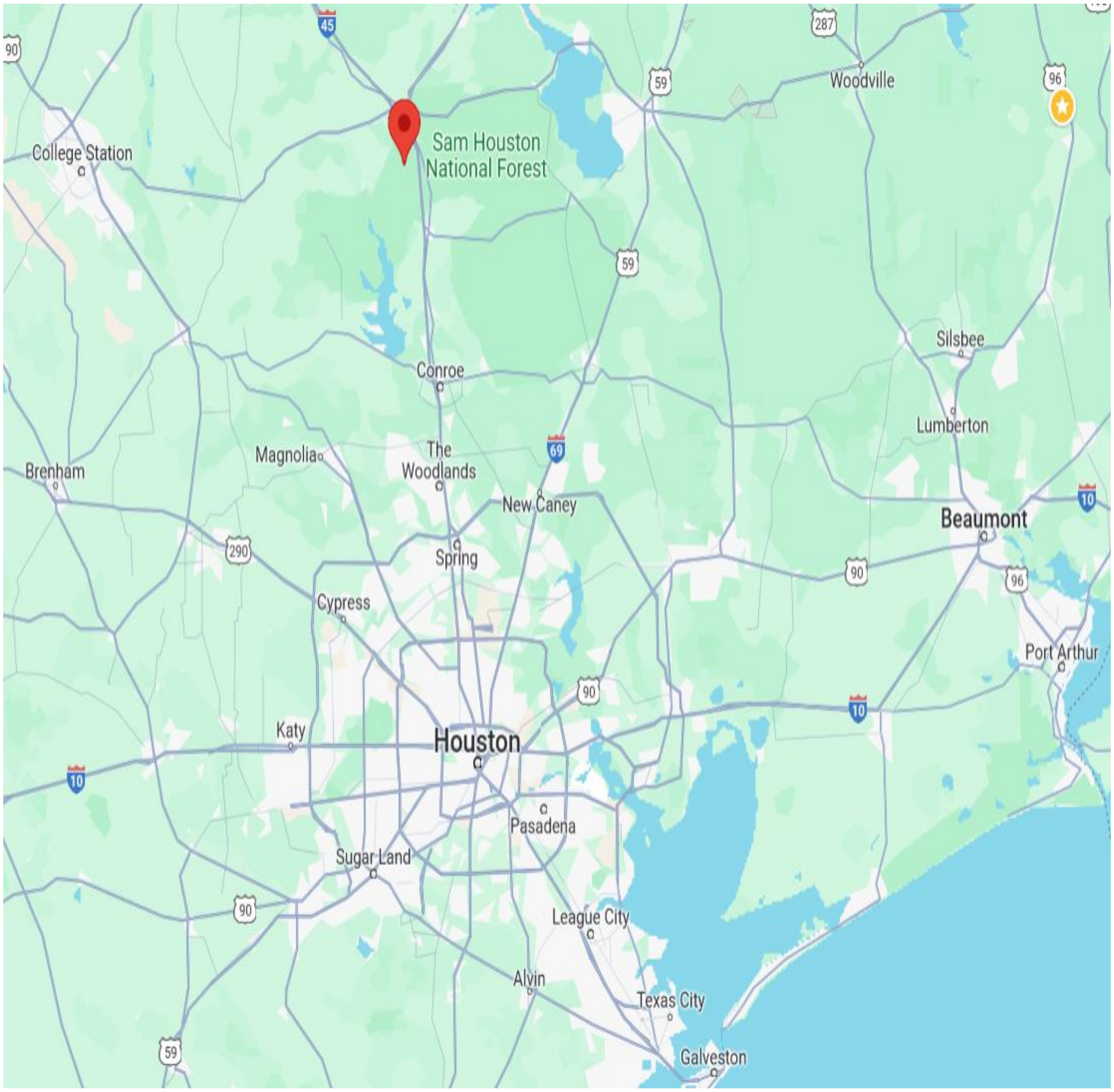
Report Certification. This report has been certified to Built Green Custom Homes by MTEC Companies, LLC. All contractors referring to this geotechnical report should draw their own conclusions regarding excavations, trafficability, etc., for bidding purposes.

MTEC is not responsible for conclusions, opinions, or recommendations made by others based on these data.

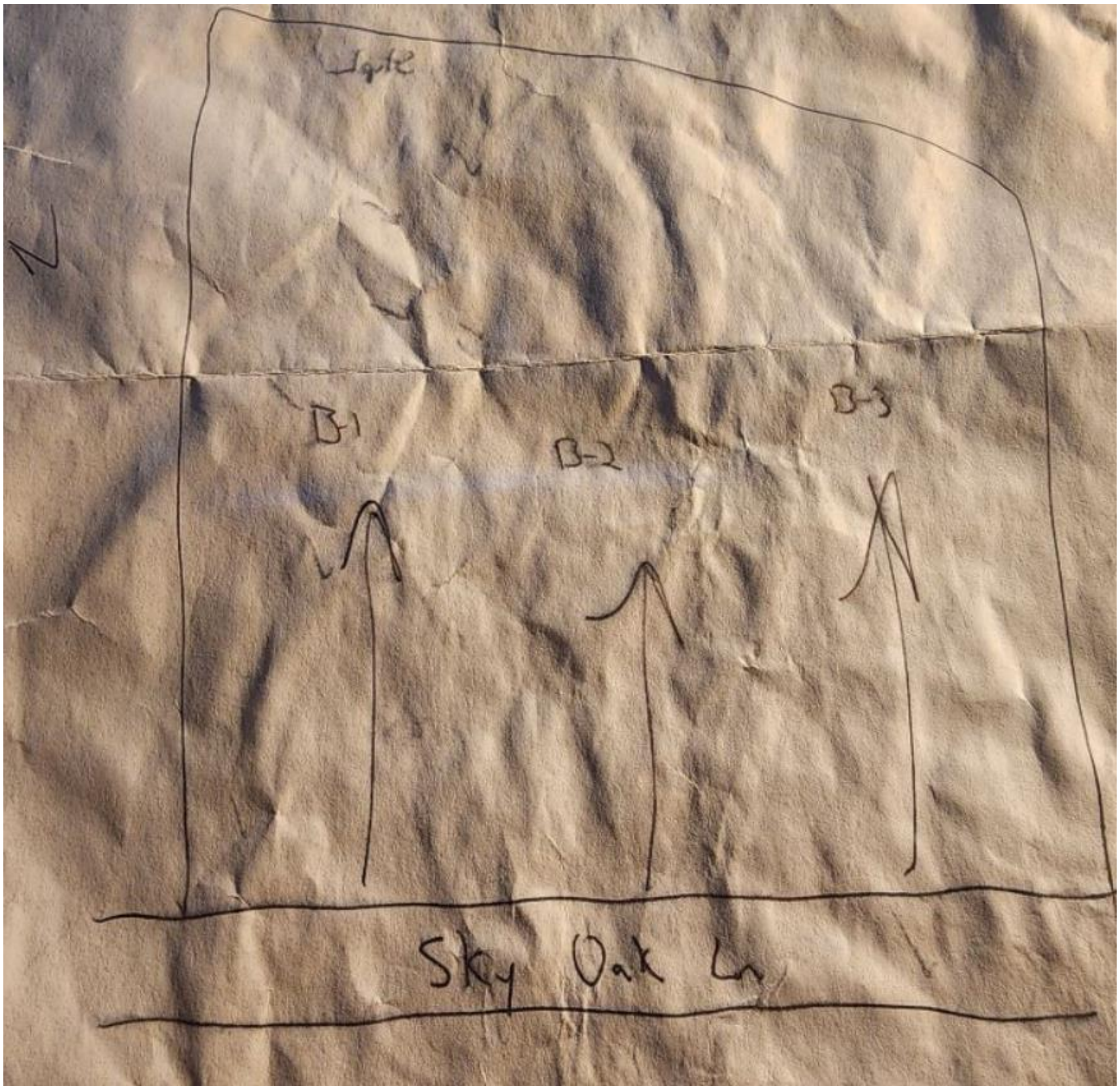
Warranty. MTEC has endeavored to perform our evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical professionals with experience in this area in similar soil conditions.

No other warranty, either expressed or implied, is made as to the conclusions and recommendations contained in this report.

FIGURES



Proposed Residence and Workshop 238 Sky Oak Lane HUNTSVILLE, Texas 77340	MTEC Project Number: 2024-004-018	**FIGURE 1** **SITE VICINITY MAP**



Not to Scale

Proposed Residence and Workshop 238 Sky Oak Lane HUNTSVILLE, Texas 77340	MTEC Project Number: 2024-004-018	**FIGURE 2** **PLAN OF BORINGS**

APPENDIX

BORING LOGS (Borings B-1 and B-2)

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

TERMS USED ON BORING LOGS

TABLES 1 THROUGH 6

TEXAS DROUGHT MONITOR MAP

TEXAS DROUGHT CONDITIONS

FLOOD INFORMATION

,

MTEC Companies LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC Companies LLC

Project No.: MTEC 2023-004-018 **Date:** January 9, 2024

Project Name: Residence and Workshop at 238 Sky Oak Lane, Huntsville, Texas 77340

Specifics:

BORING B-1

Depth	Samples	Penetron.	Soil Description(s)	w %	LL	PL	PI	Pass - 200
				Lab Tests				
	B	–	**Silty Sand (SM),** Brown	10	Non-Plastic			12
		2.50	**Sandy Fat Clay (CH),** Brown, Lt. Gray, Red, and Orange, Stiff	18	51	20	31	66
5		2.50		17	53	19	34	69
		3.00	**Fat Clay with Sand (CH),** Lt. Gray, Red, and Orange, Stiff	19	61	18	43	79
10		3.50		22	67	20	47	81
15		3.50		18	65	20	45	84
20	B	2.75		20	55	22	33	74
25			**Boring Terminated At 20 Feet.**					

Drilling Company: Hou-Tex Drilling Company
Water: Initial Contact Depth: ________ feet.
Depth after ________ minutes: ________ feet.
Termination Depth of Boring: 20 feet.
Additional Comments:

MTEC Companies LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC Companies LLC

Project No.: MTEC 2023-004-018 **Date:** January 9, 2024

Project Name: Residence and Workshop at 238 Sky Oak Lane, Huntsville, Texas 77340

Specifics:

BORING B-2

Depth	Samples	Penetron.	Soil Description(s)	w %	LL	PL	PI	Pass - 200
				Lab Tests				
	B	–	**Silty Sand (SM),** Brown	10	Non-Plastic			12
		2.25	**Sandy Fat Clay (CH),** Brown, Lt. Gray, Red, and Orange, Stiff	17	52	19	33	67
5		2.50		20	56	21	35	68
		3.50	**Fat Clay with Sand (CH),** Lt. Gray, Red, and Orange, Stiff	18	64	19	45	80
10		3.50		20	66	22	44	84
15		3.00		20	58	21	37	78
			Boring Terminated at 15 feet.					
20	B							
25								

Drilling Company: Hou-Tex Drilling Company
Water: Initial Contact Depth: ________ feet.
Depth after ________ minutes: ________ feet.
Termination Depth of Boring: 15 feet.
Additional Comments:

MTEC Companies LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC Companies LLC

Project No.: MTEC 2023-004-018 **Date:** January 9, 2024

Project Name: Residence and Workshop at 238 Sky Oak Lane, Huntsville, Texas 77340

Specifics:

BORING B-3

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	Pass - 200
	B	2.50		**Sandy Fat Clay (CH),** Brown, Lt. Gray, Red, and Orange, Stiff	20	54	20	34	66
		2.50			20	57	22	35	67
5		2.25			19	51	21	30	64
		3.00		**Fat Clay with Sand (CH),** Lt. Gray, Red, and Orange, Stiff	18	62	20	42	83
10		3.00			18	60	20	40	80
15		3.50			21	65	22	43	81
20	B	2.75			20	59	22	37	79
				Boring Terminated At 20 Feet.					
25									

Drilling Company: Hou-Tex Drilling Company

Water: Initial Contact Depth: ______ feet.

Depth after ______ minutes: ______ feet.

Termination Depth of Boring: 20 feet.

Additional Comments:

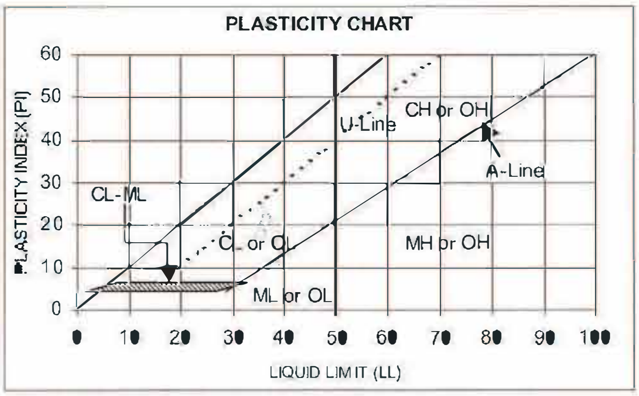
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

After, ASTM Designation D 2487 (Standard Test Method for Classification of Soils for Engineering Purposes)

MAJOR DIVISIONS				GROUP SYMBOL	TYPICAL NAMES
COARSE –GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (Less than 50% of coarse fraction passes NO. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200)		GW	Well-graded gravel, well-graded gravel with sand
				GP	Poorly graded gravel, poorly graded gravel with sand
		GRAVELS WITH FINES (More than 12 % passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	GM	Silty gravel, silty gravel with sand
			Limits plot above "A" line & hatched zone on plasticity chart	GC	Clayey gravel, clayey gravel with sand
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well-graded sand, Well-graded sand with gravel
				SP	Poorly graded sand, poorlygraded sand with gravel
		SAND WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	SM	Silty sand, silty sand with gravel
			Limits plot above "A" line & hatched zone on plasticity chart	SC	Clayey sand, clayey sand with gravel
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)		SILTS AND CLAYS (Liquid limit less than 50)		ML	Silt, silt with sand or with gravel, sandy silt, sandy silt with gravel, gravelly silt, gravelly silt with sand
				CL	Lean clay, lean clay with sand or with gravel, sandy lean clay, sandy lean clay with gravel, gravelly lean clay, gravelly lean clay with sand
				OL	Organic clay, organic clay with sand or with gravel, sandy organic clay, sandy organic clay with gravel, gravelly organic clay, gravelly organic clay with sand, organic silt, organic silt with sand or with gravel, sandy organic silt, sandy organic silt with gravel, gravelly organic silt, gravelly organic silt with sand
		SILTS AND CLAYS (Liquid limit 50 or more)		MH	Elastic silt, elastic silt with sand or with gravel, sandy elastic silt, sandy elastic silt with gravel, gravelly elastic silt, gravelly elastic silt with sand
				CH	Fat clay, fat clay with sand or with gravel, sandy fat clay, sandy fat clay with gravel, gravelly fat clay, gravelly fat clay with sand
				OH	Organic clay, organic clay with sand, sandy organic, clay organic silt, sandy organic silt

NOTE: Gravels and Sands with 5% to 12% fines require dual symbols (i.e. GW-GM {well-graded gravel with silt}, GW-GC {well-graded gravel with clay}, SW-SM {well-graded sand with silt}, SW-SC {well graded sand with clay, SP-SM {poorly graded sand with silt}).

PLASTICITY CHART



Equation of A-Line: Horizontal at PI = 4 to 25.5, then PI = 0.73(LL-20)

Equation of U-Line: Vertical at LL = 16 to PI = 7, then PI = 0.9(LL-8)

DEGREE OF PLASTICITY OF COHESIVE SOIL

Degree of Plasticity	Plasticity Index
None	0 to 4
Slight	5 to 10
Medium	11 to 20
High	21 to 40
Very High	> 40

C_U = Coefficient of Uniformity = D_{60}/D_{10}
C_C = Coefficient of Curvature = $(D_{30})^2/(D_{10} \times D_{60})$

SOIL SYMBOLS

	Fill		Sand
	Clay (CH)		Silt
	Clay (CL)		

NOTES:
If soil (GW, GP, GM, GC) contains ≥ 15 % sand, add "**with sand**" to Group Name.
If soil fines (in GM, GC, SM, SC) classify as CL-ML, use **GC-GM** or **SC-SM** as Group Name.
If soil fines (in GM, GC, SM, SC) are organic, add "**with organic fines**" with Group Name.
If soil (SP, SM, SC) contains ≥ 15 % gravel, add "**with gravel**" to Group Name.
If CL or ML Atterberg Limits plot in hatched area, soil is a **CL-ML**, silty clay.
If soil (CL, ML, OL, CH, MH, OH) contains 15 to 29 % plus No.200, add "**with sand**" or "**with gravel**", whichever is appropriate.
If soil (CL, ML, OL, CH, MH, OH) contains ≥ 30 % plus No.200, predominately sand, add "**sandy**" to Group Name.

TERMS USED ON BORING LOGS

SOIL GRAIN SIZE IN US STANDARD SIEVE

12"	3"	¾"	#4	#10	#40	#200	
BOULDER	COBBLES	GRAVEL		SAND			CLAY or SILT
		Coarse	Fine	Coarse	Medium	Fine	Clay exhibits plasticity Silt is non-plastic or very slightly plastic
300 mm	75.0	19.0	4.75	2.00	0.425	0.075	

SOIL GRAIN SIZE IN MILLIMETERS

STRENGTH OF COHESIVE SOILS
(After, Hunt's Geotechnical Engineering Investigation Manual, 1984)

Consistency	Undrained Shear Strength, ksf
Very Soft	< 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	> 4.00

RELATIVE DENSITY OF COHESIONLESS SOILS FROM STANDARD PENETRATION TEST (ASTM D 1586)
(After, Hunt's Geotechnical Engineering Investigation Manual, 1984)

Relative Density	SPT
Very Loose	< 4 bpf
Loose	5 to 10 bpf
Medium Dense	11 to 30 bpf
Dense	31 to 50 bpf
Very Dense	> 50 bpf
	(bpf = blow per foot)

SPLIT BARREL SAMPLER DRIVING RECORD (SPT) (After ASTM D 1586)

Blows per 6-inches	Description
5, 7, 6	5 hammer blows to seat device and SPT N = 13 thereafter.
5, 50/7	5 hammer blows to seat device and 50 blows for 7-inches thereafter.
50/3	50 blows driving sampler 3 inches during initial 6-inch seating interval

Notes: SPT driving should be stopped under the following circumstances:

a. Split spoon device is advanced 6-inches for seating, and another two-sets of 6-inches for N-value;
b. 50 hammer blows during any one of the 6-inch increments;
c. Total of 100 hammer blows have been reached prior to advancing through three 6-inch increments; or
d. No sample advance during application of 10 successive hammer blows.

DRY STRENGTH (ASTM D 2488)	
None	Dry specimen crumbles into powder with mere pressure of handling.
Low	Dry specimen crumbles into powder with some finger pressure.
Medium	Dry specimen breaks into pieces or crumbles with considerable pressure.
High	Dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and hard surface.
Very High	Dry specimen cannot be broken between the thumb and a hard surface.

CRITERIA FOR MOISTURE CONDITION (ASTM D 2488)	
Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table.

CRITERIA FOR DESCRIBING CONSISTENCY (ASTM D 2488)

Consistency	Descriptive Criteria
Very Soft	Thumb will penetrate soil more than 1-inch.
Soft	Thumb will penetrate soil about 1-inch.
Firm	Thumb will indent soil about ¼-inches.
Hard	Thumb will not indent soil but readily indented with thumbnail.
Very Hard	Thumbnail will not indent soil.

CRITERIA FOR DESCRIBING SOIL STRUCTURE AND CEMENTATION (After, ASTM D 2488)

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick
Laminated	Alternating layers of varying material or color with layers less than 6 mm thick
Fissured	Breaks along definite planes of fracture with little resistance to fracturing. Shrinkage or relief cracks are often filled with fine sand or silt; usually more or less vertical.
Slickensided	Fracture planes appear polished, slick or glossy, sometimes striated. The degree of slickensidedness depends upon the spacing of slickensides and the ease of breaking along these planes.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Weakly Cemented	Crumbles or breaks with handling or little finger pressure.
Moderately Cemented	Crumbles or breaks with considerable finger pressure.
Strongly Cemented	Will not crumble or break with finger pressure.

TABLE 1A – STIFFENED SLABS ON ACTIVE SOILS

DESIGN OF STIFFENED SLABS ON GRADE ON SHRINK-SWELL SOILS – A NEW APPROACH

Phillip G. King, P.E. (Vice President, Geo Institute)
April 30, 2011 – ASCE Web Seminar – Part 1 of 2
- A Summary -

Residential Damage (year 2000)	No. 1 – Hurricanes No. 2 – Floods **No. 3 – Expansive Soils** No. 4 - Tornados No. 5 – Earthquakes No. 6 - Landslides	About $ 4.8 Billion About $ 4.7 Billion **About $ 4.6 Billion** About $ 3.5 Billion About $ 2.0 Billion About $ 0.8 Billion

The purpose of this presentation is to present recommended practices for the **design of residential foundations to augment current building codes** to help reduce foundation related problems on shrink-swell soils.

Successful application of methods to control undue distress to slabs on grade requires experienced engineering judgment; **only following guidelines may not achieve a satisfactory result.**

This information does not, of itself, comprise the standard of care which engineers are required to uphold.

Change in soil moisture content causes changes in the volume of expansive soils.

Swelling Potential in Soils:	Swelling Potential	Plasticity Index
	Low	0 to 15
	Medium	10 to 35
	High	20 to 55
	Very High	35 and above

Soils beneath a residential slab on grade are frequently wetter than soils at the same depth away from the slab.

Seasonal drying can cause shrinkage at edges of residential slab and distressing the perimeter of the residential slab and walls.

Leaking utility lines and excessive watering of soil adjacent to the structure can also result in foundation heave.

Runoff directed toward residential foundation (producing swelling soils) and seasonal drying can cause foundation and structure distress by "pump handle" (up and down vertical movement of soils) movement of foundation.

Trees can cause shrinkage to portion of residential slab in proximity because of water demands of tree roots (roots absorb water out of the soil system leading to localized soil shrinkage.

Typical tree root drying zone = dimensional height of tree as a radius around the tree trunk
New construction – Recent tree removal –
- Moisture will change
- Roots no longer absorbing water; soil will increase in moisture content and swell

Existing construction – Add trees for landscaping – Decrease ground moisture by tree roots; Decrease moisture will cause soil to shrink causing slab distress

TABLE 1B – STIFFENED SLABS ON ACTIVE SOILS
(continued)

Design Procedures:

Texas- ASCE Guidelines – Recommended Practice for the Design of Residential Foundations, Volume 1

BRAB (1968) – Building Research Advisory Board – Report No. 33

Criteria for Selection and Design of Residential Slabs-on-Ground

Based on reinforced concrete design theory and cracked section theory
Required parameters: Climatic Rating, Cw, of site
Weighted Plasticity Index
Bearing Capacity of the soil

Beam analysis length should be limited to a maximum of 50 feet, regardless of actual beam length
Use maximum long-term creep factor as provided in ACI 318, Section 9.5.2.5

WRI (1981, 1996) – The Wire Reinforcement Institute

Mostly based upon plain (uncracked section) concrete design theory.
Method developed by Walter L. Snowden, P.E., Austin
Empirically derived by observing reinforced concrete slab performance and writing and modifying equations to provide results approximating the foundations that had been determined to give satisfactory results

WRI uses the same approach as the BRAB method;
WRI can be considered as a modified version of BRAB.

Requires parameters: Climatic Rating, Cw, of site
Weighted Plasticity Index
Bearing Capacity of the soil, and
Consolidation Correction Coefficient, Co
Slope Correction Coefficient, Cs

Beam analysis length should be limited to a maximum of 50 feet, regardless of actual beam length
The minimum design length, Lc, shall be 6 feet

PTI – Post Tensioning Institute – Design and Construction of Post-Tensioned Slabs-On-Ground

Based on initial research work by Wray (1978)
Based on analysis of a plate resting on a semi-infinite elastic continuum.
Mostly based on plain (uncracked section) concrete design theory

The e_m and y_m terms are based upon average climatic controlled soil movements and the design analysis should take into account the added effect of trees and other environmental effects (i.e., effect of vegetation and roof drip lines, early stage of growth of trees and/or future trees, middle and later years of growth) as noted in the PTI design manual.
Slab corners may require special attention with additional ribs or diagonals; stiffen slab corners for active soil slab corners.

Design example: Slab Dimensions: 36 x 72 ft qall = 1,500 psf
Edge Lift: e_m = 5.5 feet y_m = 1 inch
Center Lift: e_m = 4.5 feet y_m = 1 inch
Foundation Design: Current PTI Method 10 x 24 inches with slab strands at 5 ft oc
PTI with ASCE 10 x 28 inches with slab strands at 5 ft oc

TABLE 1C – STIFFENED SLABS ON ACTIVE SOILS
(Continued)

General Recommendations to stiffen slab in presence of active soils:

If Slab Shape Factor > 20 or slab extensions > 12 feet:
Note: Shape Factor = Perimeter Squared / Area

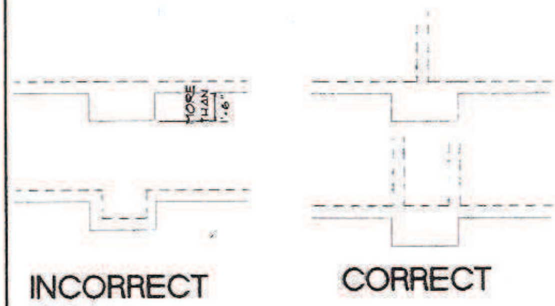
Provide deeper or more beams
Revise floor plan
Chemically treat soil to reduce movement potential (lime, lime fly ash, fly ash, cement, etc.)
Use structurally suspended floor slab

Stiffen slab offsets when offsets > 18 inches
Use continuous beams at reentrant corners
Add additional beams to stiffen slab
Generally, use judgment to design requirements to "stiffen" beams.

Section 5.2.3.3 – Interior Beams

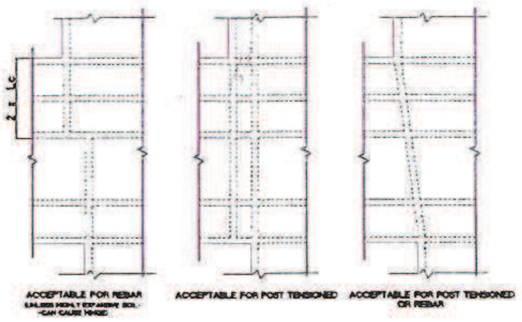
Continuous Beams at Reentrant Corners

Section 5.2.3.4 – Interior Beams Stiffening Beams Perpendicular to Offsets



Properly Stiffen Offsets when Offset exceeds 18 inches

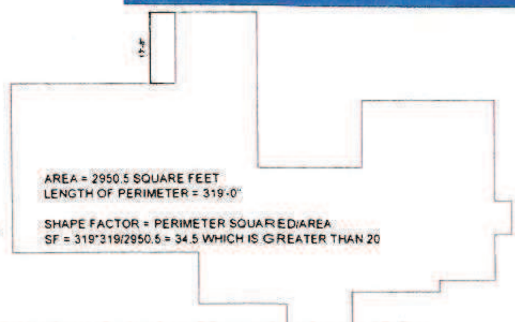
Section 5.2.3.3 – Interior Beams



Post Tensioned – Use only continuous beams

Conventional Rebar – Beams to be at least twice the Lc distance

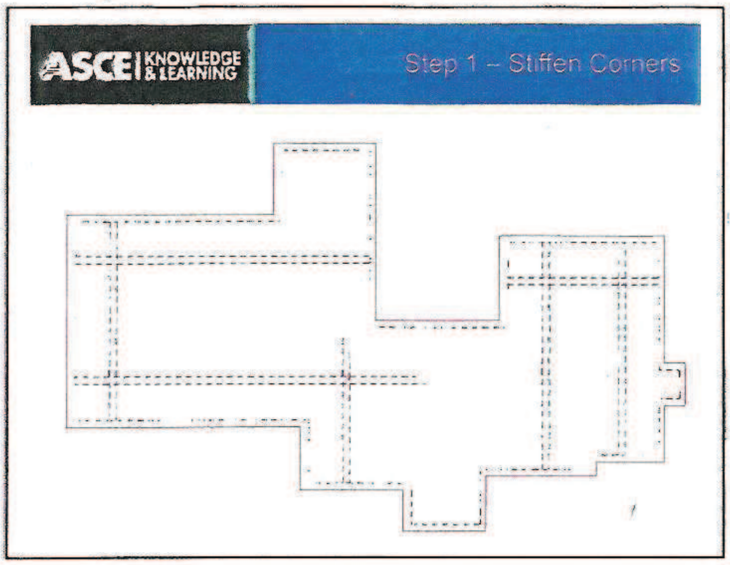
Section 5.2.3.6 – Interior Beams Shape Factor and Extensions

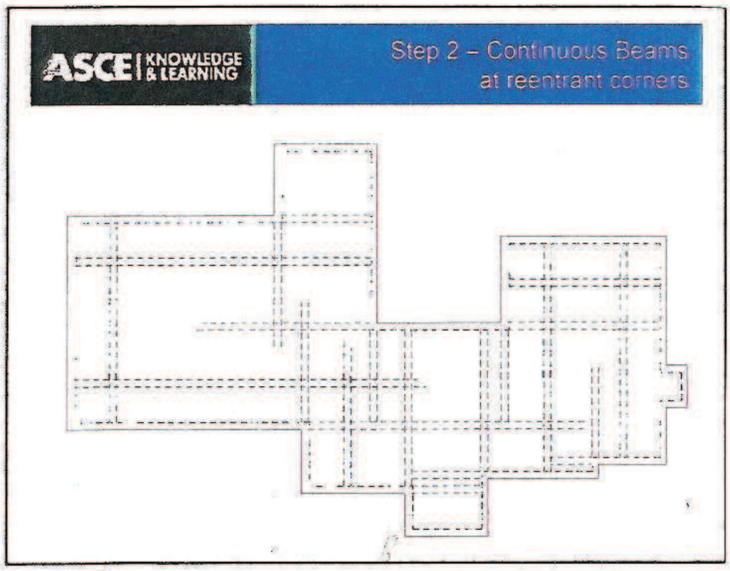


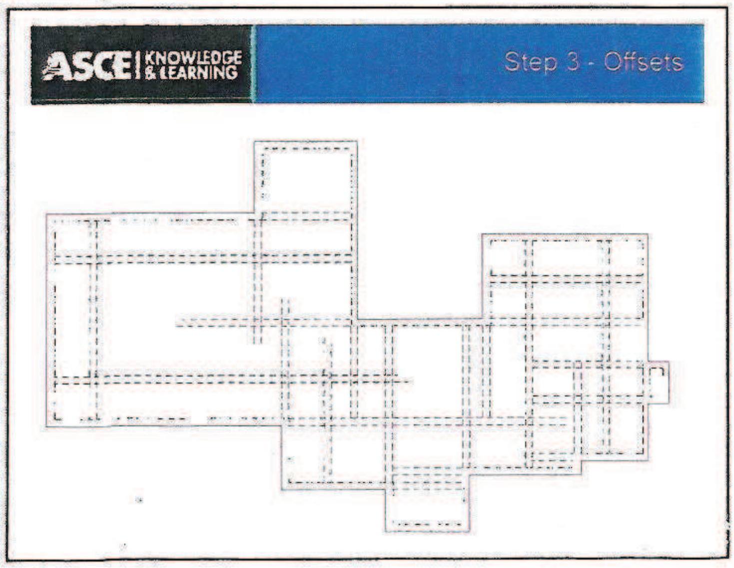
Options if the shape factor is > 20 or extensions > 12 ft:

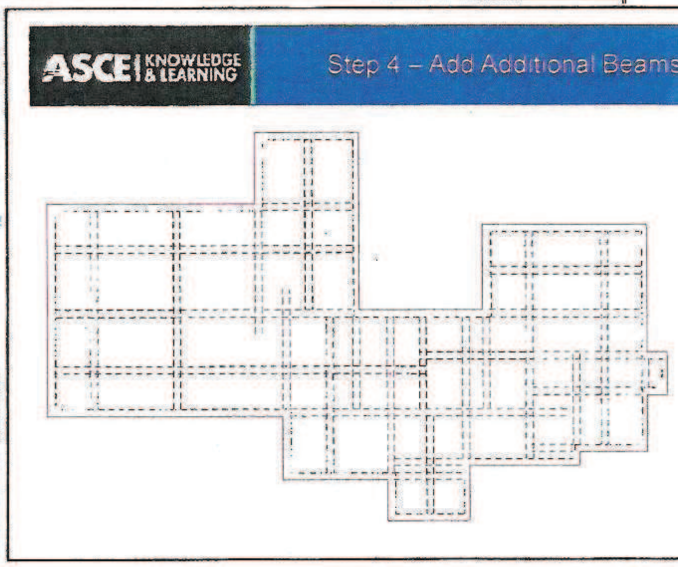
1.Deeper or more beams
2. Revise Floor Plan
3. Treat Soil to reduce movement Potential
4. Use Structurally Suspended Foundation

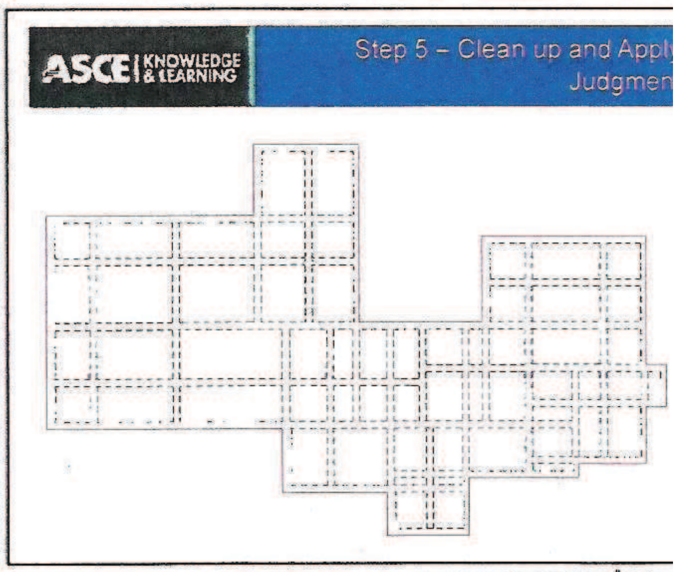
TABLE 1D – STIFFENED SLABS ON ACTIVE SOILS
(Continued)

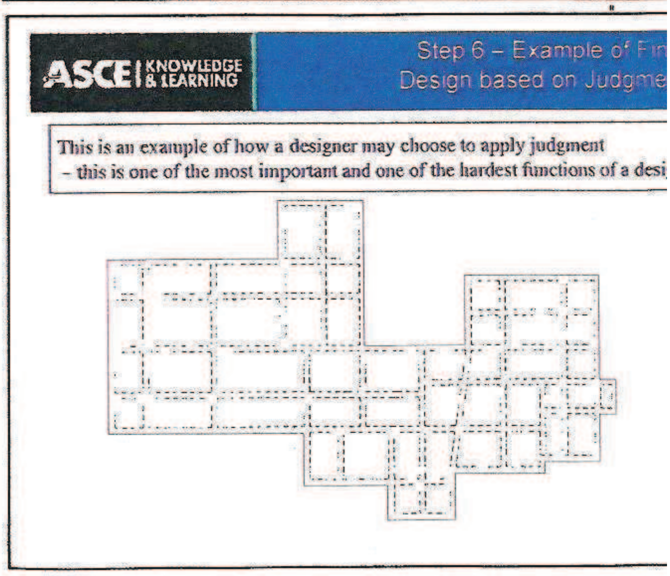












Houston's Flood Is a Design Problem

It's not because the water comes in. It's because it is forced to leave again.

IAN BOGOST | AUG 28, 2017 | TECHNOLOGY

Floods cause greater property damage and more deaths than tornadoes or hurricanes. And Houston's flood is truly a disaster of biblical proportions: The sky unloaded 9 trillion gallons of water on the city within two days, and much more might fall before Harvey dissipates, producing as much as 60 inches of rain.

Pictures of Harvey's runoff are harrowing, with interstates turned to sturdy and mature rivers. From Katrina to Sandy, Rita to Tōhoku, it's easier to imagine the flooding caused by storm surges wrought by hurricanes and tsunamis. In these cases, the flooding problem appears to be caused by water breaching shores, seawalls, or levees. Those examples reinforce the idea that flooding is a problem of keeping water *out*—either through fortunate avoidance or engineering foresight.

But the impact of flooding, particularly in densely developed areas like cities, is far more constant than a massive, natural disaster like Harvey exposes. The reason cities flood isn't because the water comes in, not exactly. It's because the pavement of civilization forces the water to get back out again.

* * *

There are different kinds of floods. There's the storm surge from hurricanes, the runoff from snowmelt, the inundation of riverbanks. But all these examples cast flooding as an occasional foe out to damage human civilization. In truth, flooding happens constantly, in small and large quantities, every time precipitation falls to earth. People just don't tend to notice it until it reaches the proportions of disaster.

Under normal circumstances, rain or snowfall soaks back into the earth after falling. It gets absorbed by grasslands, by parks, by residential lawns, by anywhere the soil is exposed. Two factors can impede that absorption. One is large quantities of rain in a short period of time. The ground becomes inundated, and the water spreads out in accordance with the topography. The second is covering over the ground so it cannot soak up water in the first place. And that's exactly what cities do—they transform the land into developed civilization.

Roads, parking lots, sidewalks, and other pavements, along with asphalt, concrete, brick, stone, and other building materials, combine to create impervious surfaces that resist the natural absorption of water. In most of the United States, about 75 percent of its land area, less than 1 percent of the land is hardscape. In cities, up to 40 percent is impervious.

The natural system is very good at accepting rainfall. But when water hits pavement, it creates runoff immediately. That water has to go somewhere. So it flows wherever the grade takes it. To account for that runoff, people engineer systems to move the water away from where it is originally deposited, or to house it in situ, or even to reuse it. This process—the policy, planning, engineering, implementation, and maintenance of urban water systems—is called stormwater management.

The combination of climate change and aggressive development made an event like this almost inevitable.

According to my Georgia Institute of Technology colleague Bruce Stiftel, who is chair of the school of city and regional planning and an expert in environmental and water policy governance, stormwater management usually entails channeling water away from impervious surfaces and the structures built atop them. In other words, cities are built on the assumption that the water that would have been absorbed back into the land they occupy can be transported away instead.

Like bridges or skyscrapers designed to bear certain loads, stormwater management systems are conceived within the limits of expected behavior—such as rainfall or riverbank overrun events that might happen every 10 or 25 years. When these intervals are exceeded, and the infrastructure can't handle the rate and volume of water, flooding is the result.

Houston poses both a typical and an unusual situation for stormwater management. The city is enormous, stretching out over 600 square miles. It's an epitome of the urban sprawl characterized by American exurbanism, where available land made development easy at the edges. Unlike New Orleans, Houston is well above sea level, so flooding risk from storm surge inundation is low. Instead, it's rainfall that poses the biggest threat.

A series of slow-moving rivers, called bayous, provide natural drainage for the area. To account for the certainty of flooding, Houston has built drainage channels, sewers, outfalls, on- and off-road ditches, and detention ponds to hold or move water away from local areas. When they fill, the roadways provide overrun. The dramatic images from Houston that show wide, interstate freeways transformed into rivers look like the cause of the disaster, but they are also its solution, if not an ideal one. This is also why evacuating Houston, a metropolitan area of 6.5 million people, would have been a terrible idea. This is a city run by cars, and sending its residents to sit in gridlock on the thoroughfares and freeways designed to become rivers during flooding would have doomed them to death by water.

* * *

Accounting for a 100-year, 500-year, or "million-year" flood, as some are calling Harvey's aftermath, is difficult and costly. Stiftel confirms that it's almost impossible to design for these "maximal probable flood events," as planners call them. Instead, the hope is to design communities such that when they flood, they can withstand the ill effects and support effective evacuations to keep people safe. "The Houston event seems like an illustration that we haven't figured it out," Stiftel says.

Many planners contend that impervious surface itself is the problem. The more of it there is, the less absorption takes place and the more runoff has to be managed. Reducing development, then, is one of the best ways to manage urban flooding. The problem is, urban development hasn't slowed in the last half-century. Cities have only become more desirable, spreading outward over the plentiful land available in the United States.

The National Flood Insurance Program, established in 1968, offered one attempt at a compromise. It was meant to protect and indemnify people without creating economic catastrophe. Instead of avoiding the floodplain, insurance allowed people to build within it, within management constraints recommended by FEMA. In theory, flood-hazard mitigation hoped to direct development away from flood-prone areas through the disincentives of risk insurance and regulatory complexity.

Sometimes "living with water" means sidestepping the consequences.

Since then, attitudes have changed. For one part, initial avoidance of floodplains created desirable targets for development, especially in the middle of cities. But for another, Stiftel tells me that attitudes about development in floodplains have changed, too. "It's more about living with water than it is about discouraging development in areas prone to risk."

Sometimes "living with water" means sidestepping the consequences. Developers working in flood zones might not care what happens after they sell a property. That's where governmental oversight is supposed to take over. Some are more strict than others. After the global financial crisis of 2008, for example, degraded local economies sometimes spurred relaxed land-use policy in exchange for new tax bases, particularly commercial ones.

In other cases, floodplains have been managed through redevelopment that reduces impervious surfaces. Natural ground cover, permeable or semi-permeable pavers, and vegetation that supports the movement of water offer examples. These efforts dovetail with urban redevelopment efforts that privilege mixed-use and green space, associated with both new urbanism and gentrification. Recreation lands, conservation lands and easements, dry washes, and other approaches attempt to counterbalance pavement when possible. Stiftel cites China's "sponge cities" as a dramatic example—a government-funded effort to engineer new, permeable materials to anticipate and mitigate the flooding common to that nation.

But Thomas Debo, an emeritus professor of city planning at Georgia Tech who also wrote a popular textbook on stormwater management, takes issue with pavement reduction as a viable cure for urban flooding. "We focus too much on impervious surface and not enough on the conveyance of water," he tells me. Even when reduced in quantity, the water still ends up in in pipes and concrete channels, speeding fast toward larger channels. "It's like taking an aspirin to cure an ailment," he scoffs. Houston's flooding demonstrates the impact.

Instead, Debo advocates that urban design mimic rural hydrology as much as possible. Reducing impervious surface and improving water conveyance has a role to play, but the most important step in sparing cities from flooding is to reduce the velocity of water when it is channelized, so that it doesn't deluge other sites. And then to stop moving water away from buildings and structures entirely, and to start finding new uses for it in place.

That can be done by collecting water into cisterns for processing and reuse—in some cases, Debo explains, the result can even save money by reducing the need to rely on utility-provided water. Adding vegetation, reclaiming stormwater, and building local conveyance systems for delivery of this water offer more promising solutions.

Though retired from Georgia Tech, Debo still consults on the campus's local stormwater management efforts. In one case, the institute took a soccer field and made it into an infiltration basin. Water permeates the field, where it is channeled into pipes and then into local cisterns.

A centralized approach to stormwater management is a pipe dream.

In Houston's case, catastrophic floods have been anticipated for some time. The combination of climate change, which produces more intense and unpredictable storms, and aggressive development made an event like this week's almost inevitable. The Association of State Floodplain Managers has called for a national flood risk-management strategy, and the *Houston Chronicle* has called flood control the city's "most pressing infrastructure need." A lack of funding is often blamed, and relaxed FEMA regulations under the Trump Administration won't help either.

But for Debo and others, waiting for a holistic, centralized approach to stormwater management is a pipe dream anyway. Just as limiting impervious surface is not the solution to urban stormwater management, so government-run, singular infrastructure might not be either. "It's much more difficult, and a much bigger picture," Debo insists to me. "There is no silver bullet for stormwater management."

* * *

One problem is that people care about flooding, because it's dramatic and catastrophic. They don't care about stormwater management, which is where the real issue lies. Even if it takes weeks or months, after Harvey subsides, public interest will decay too. Debo notes that traffic policy is an easier urban planning problem for ordinary folk, because it happens every day.

So does stormwater—it just isn't treated that way. Instead of looking for holistic answers, site-specific ones must be pursued instead. Rather than putting a straight channel through a subdivision, for example, Debo suggests designing one to meander through it, to decrease the velocity of the water as it exits.

The hardest part of managing urban flooding is reconciling it with Americans' insistence that they can and should be able to live, work, and play anywhere. Waterborne transit was a key driver of urban development, and it's inevitable that cities have grown where flooding is prevalent. But there are some regions that just shouldn't become cities. "Parts of Houston in the floodway, parts of New Orleans submerged during Katrina, parts of Florida—these places never should have been developed in the first place," Debo concludes. Add sea-level rise and climate-change superstorms, and something has to give.

Debo is not optimistic about resisting the urge toward development. "I don't think any of it's going to happen," he concedes. "Until we get people in Congress and in the White House who care about the environment, it's just going to get worse and worse."

Q: **What is a 100-year floodplain?**
A: The term "100-year flood" is misleading. It is not the flood that will occur once every 100 year. There are many levels of floods: 500-year, 100-year, 20-year, and 10-year, for example. These numbers indicate the likelihood that a particular area will flood in a year's time. For example, a home in a 100-year floodplain has a one in 100 (or 1 percent) chance each year of being flooded. That percentage holds true every year, regardless of how many floods have occurred in previous years, or their severity.

Q: **Who sets the boundaries of floodplain?**
A: The Federal Emergency Management Agency, working with local governments, sets the 100-year floodplain boundaries through flood insurance rate studies. Separate studies are done for communities because floodplain levels vary depending on an area's characteristics.

Q: **What are my odds of flooding within a 100-year floodplain?**
A: If your home is in the 100-year floodplain, it has a 26% chance of getting flooded over a 30-year mortgage period, which is about five times higher than the risk for a severe fire! Your risk of flooding will increase if your home is located in a lower-lying area of the 100-year floodplain.

People outside of the 100-year floodplain are not free of risk. Federally-backed flood insurance is available to people outside of the 100-year flood zone as well.

Q: **Can I build on property in a floodplain?**
A: Yes. However, floodplain development restrictions apply to grading, new construction and some renovations. Contact the Harris County Permit Office at (713) 956-3000 for more information on these requirements.

Q: **Do I need a permit to grade, build or renovate in a floodplain?**
A: Yes. A Permit is needed to make sure the changes comply with Harris County's Floodplain Management Regulations.

Q: **Does standard homeowner's insurance cover losses and damages due to flooding?**
A: No.

Q: **Am I required to purchase flood insurance?**
A: Yes, if your property is located in a high risk area or Special Flood Hazard Area and you have a federally backed mortgage such as FHA or VA loan. Remember, everyone has some risk of flooding. Although flood insurance is not required for low and moderate risk properties, Harris County recommends everyone know their risk and options for purchasing flood insurance.

Q: **How much does flood insurance cost?**
A: The average premium for a yearly flood insurance policy is approximately $500. People in low-to-moderate-risk areas may be eligible for the Preferred Risk Policy with flood insurance premiums as low as $112 a year. Contact your insurance agent for more details.

Q: **How can I find out if my property is located in a Special Flood Hazard Area?**
A: Visit Harris County Flood Control District's Interactive Map or contact Harris County Permit Office at (713) 956-3000.

Q: **What is a Flood Insurance Rate Map (FIRM)?**
A: Flood Insurance Rate Map (FIRM) is an insurance and floodplain management map issued by the Federal Emergency Management Agency (FEMA) that identifies special flood hazard areas in a community. In Harris County, the map shows 1% (Base Flood or 100-year) and 0.2% (500-year) floodplain boundaries and regulatory floodway boundaries.

Q: **How do I get a copy of the Flood Insurance Rate Map for my property?**
A: Computer plots are available for $5 in the Records section of our office. Requests for historical maps can be faxed to (713) 956-3050, Attention: Records. You can also go to the FEMA map store.

What does a '500-year flood' really mean?

By Aaron Barker - Senior Digital Editor

Posted: 6:11 PM, November 28, 2017
Updated: 6:11 PM, November 28, 2017

Shares: 0

HOUSTON - Living in southeast Texas means dealing with flooding. Most times the flooding is minor, but occasionally, the water can reach catastrophic levels.

Since 2015, the region has been through at least three significant floods – Memorial Day in 2015, Tax Day in 2016 and Hurricane Harvey in 2017.

RELATED HEADLINES

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Officials said the Memorial Day and Tax Day floods, when the region picked up more than 20 inches of rain, represented a 500-year flood event.

During Hurricane Harvey, an average of 35 to 45 inches of rain fell across Harris County during a four-day period. Nearly 50 inches of rain fell in some isolated locations. Officials said those rainfall amounts constitute a 10,000-year or 20,000-year flood event. In the extreme case, the amount marks a 40,000-year flood.

What is a recurrence interval?

According to the U.S. Geological Survey, the technical name for terms like "500-year flood" is "recurrence interval." They are calculated through a statistical process called frequency analysis, and are used to estimate the probability of the occurrence of a given rainfall event.

The process takes into account not only the amount of precipitation a given area could receive in a given period of time, but also the amount of flow in nearby waterways that handle the runoff, according to the USGS.

What does it mean?

Without getting too technical, a 100-year flood means that type of flood has a one in 100 chance of occurring in any given year. In other words, there is a 1 percent chance that type of flood can happen in any year.

A 500-year flood means that type of flood as a one in 500 chance of occurring in any given year. In other words, there is a 0.2 percent chance of that type of flood occurring in any given year.

In Harvey's case, that flood had a 1 in 10,000 chance of occurring in any given year, or a 0.01 percent chance.

What it doesn't mean

Contrary to popular belief, the intervals do not mean that type of flood, for example, only happens once every 100 years. So, a region can experience, for example, multiple 100-year floods in any year.

If a homeowner settles in a 500-year flood plain, for example, that means the property has a one in 500 chance of flooding in any given year. However, it also means that 500-year flood, for example, can happen more than every 500 years.

Can intervals change?

According to the USGS, water levels that constitutes a flood interval can fluctuate based on changing climate.

10-Year Flood: 10% Chance
100-Year Flood: 1% Chance
500-Year Flood: 0.2% Chance

What Does All This Really Mean?

DURING ANY SINGLE YEAR:

House A:
Has a **0.2%** chance of flooding.

House B:
Has a **1%** chance of flooding.

House C:
Has a **10%** chance of flooding.

DURING ANY 30-YEAR MORTGAGE:

House A:
Has a **6%** chance of flooding.

House B:
Has a **26%** chance of flooding.

House C:
Has a **95%** chance of flooding.

BUT...
The deeper these houses are in the floodplains, the WORSE the damages will be.

Drought in Texas

Texas is no stranger to drought. The seven-year drought of record in the 1950s was a turning point in Texas history that led to the formation of the Texas Water Development Board. Since then, Texas has faced several droughts, including its most recent and severe drought, which began in the fall of 2010 and lasted through winter 2014/2015. This website brings together relevant resources, links, data, and analyses to provide updated information on drought in Texas.

With summer 2018 underway, pockets of severe to exceptional drought have made an appearance in Texas, bringing with them memories of the state's historic and devastating drought from 2010 to 2015. As folks wait to see what will happen during this year's drought, now is a good time to revisit a Story Map developed by NOAA's National Integrated Drought Information System (NIDIS) and Modeling, Analysis, Predictions and Projections program (MAPP). This story map is an interactive presentation that traces the evolution of the 2010-2015 Texas drought while taking users through a visual history of the event, using images and graphs to provide an interactive and engaging experience.

Pedernales River at Hwy 71 crossing (taken on August 29, 2011 by Texas Parks and Wildlife)

TWDB and Drought

The Texas Water Development Board (TWDB) serves on the Texas Drought Preparedness Council and the Emergency Drinking Water Task Force. The Task Force is responsible for helping water suppliers find solutions to water supply shortages. The Council is charged with supporting drought management efforts in the state and with conducting drought monitoring, assessment, preparedness, mitigation, and assistance. To serve this purpose, the Council prepares monthly drought situation reports on the status of drought conditions in the state and delivers these reports to state leadership. The latest monthly report can be viewed at the Council's home page.

The TWDB also provides financial assistance to entities across Texas in the form of both grants and loans. Assistance can be used for planning, acquisition, design, and construction of water-related infrastructure as well as other water quality improvements. Financial Assistance Project Teams for each of six geographic regions are designed to assist entities with the application process.

TWDB staff prepare monthly Texas Water Conditions reports. These reports document storage in the state's reservoirs as well as groundwater levels in the state's aquifers. In addition, TWDB issues a weekly water report and maintains information on reservoir storage and groundwater well levels across the state.

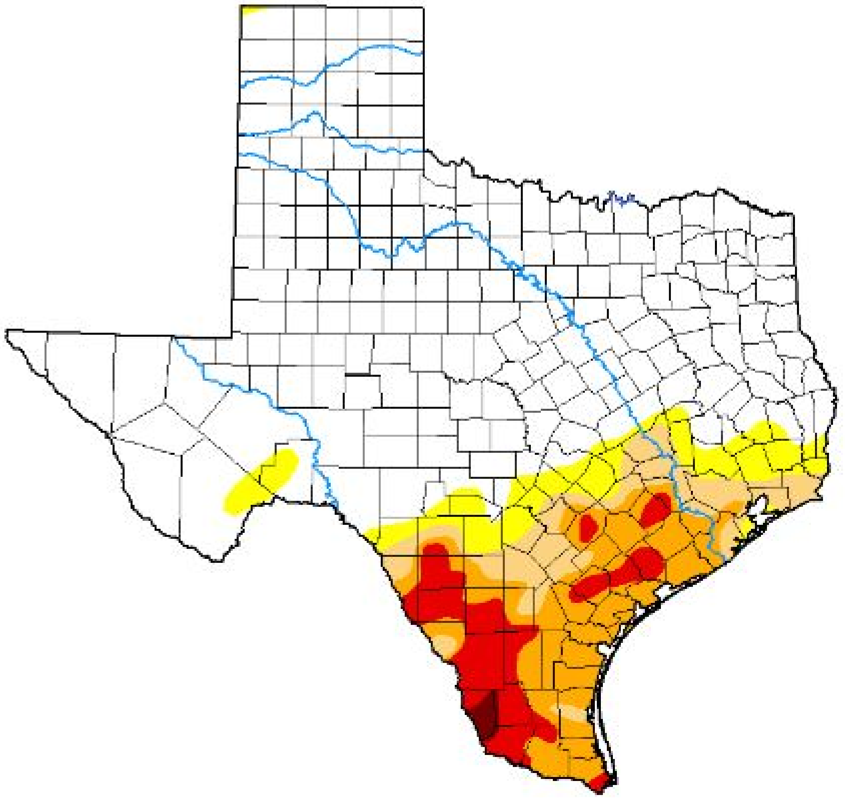
The TWDB is also a cooperator with the U.S. Geological Survey in monitoring real-time stream flows across the state.

The TWDB, in coordination with regional water planning groups across the state, develops a state water plan that plans for a repeat of the drought of record. The latest state water plan and planning efforts are available on the Water Resources Planning Information section of the TWDB website.

In addition to this website the TWDB publishes a PDF summary of TWDB's Drought Resources.

Online Drought Resources

Extensive drought-related resources are also available online. The following categories include commonly referenced drought-related websites.



Map released: Thurs. April 2, 2020

Data valid: March 31, 2020 at 8 a.m. EDT

Intensity:

- None
- **D0** (Abnormally Dry)
- **D1** (Moderate Drought)
- **D2** (Severe Drought)
- **D3** (Extreme Drought)
- **D4** (Exceptional Drought)
- **No Data**

Author(s):

David Simeral, Western Regional Climate Center

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying ***text summary*** *for forecast statements.*

Map Download

No text:

Legend:

Legend and statistics table:

Statistics

Statistics type: Traditional Percent Area Display: Statistics Export table:

Week	Date	None	D0-D4	D1-D4	D2-D4	D3-D4	D4	DSCI
Current	2020-03-31	73.40	26.60	20.26	14.60	5.47	0.35	67
Last Week	2020-03-24	73.64	26.36	19.78	14.89	4.44	0.35	66
3 Months Ago	2019-12-31	44.69	55.31	36.12	9.19	0.74	0.00	101
Start of Calendar Year	2019-12-31	44.69	55.31	36.12	9.19	0.74	0.00	101
Start of Water Year	2019-10-01	31.74	68.26	46.05	22.33	6.32	0.00	143
One Year Ago	2019-04-02	54.27	45.73	12.20	2.61	0.00	0.00	61

info@tceq.texas.gov

Drought in Texas

Weather patterns and demand on water supplies vary dramatically across the state. When dry conditions are prolonged, it can put a strain on all uses. Here is information to help you make better decisions about water use, including surface and groundwater regulations, and emergency procedures.

Email and Text Alerts Subscribe to receive an e-mail or text whenever new drought information is posted.

Drought and Public Water Systems

Water systems that are limiting amounts of water used, drought contingency plans and reporting, and educational materials and emergency management for public water systems.

- **PWS Drought Contingency Plan Online Reporting**
  Public water systems should use the current stage of their drought

Drought Alert Letters to Public Water Systems:

- **Aug. 22 2018**
- **July 13, 2018**
- **June 6, 2018**

Water Rights During Drought

How to make a water rights priority call or complaint, answers to common water rights and water use questions, and information on groundwater regulations and watermasters.

- **Water Rights Letters: Alerts and Activations**
  Drought alert letters to water rights holders, county judges, and county extension agents.

Priority Calls: Claiming Water Rights

How to make a priority call, and find active and historic calls.

Water Conservation

Water is essential for health, work, and the environment. Learn how you can conserve and what's happening around Texas.

Current Conditions

Map of **Drought Impact on Texas Surface Water**
Posted May 2, 2019

Map of Texas Vegetation Conditions (National Drought Mitigation Center)

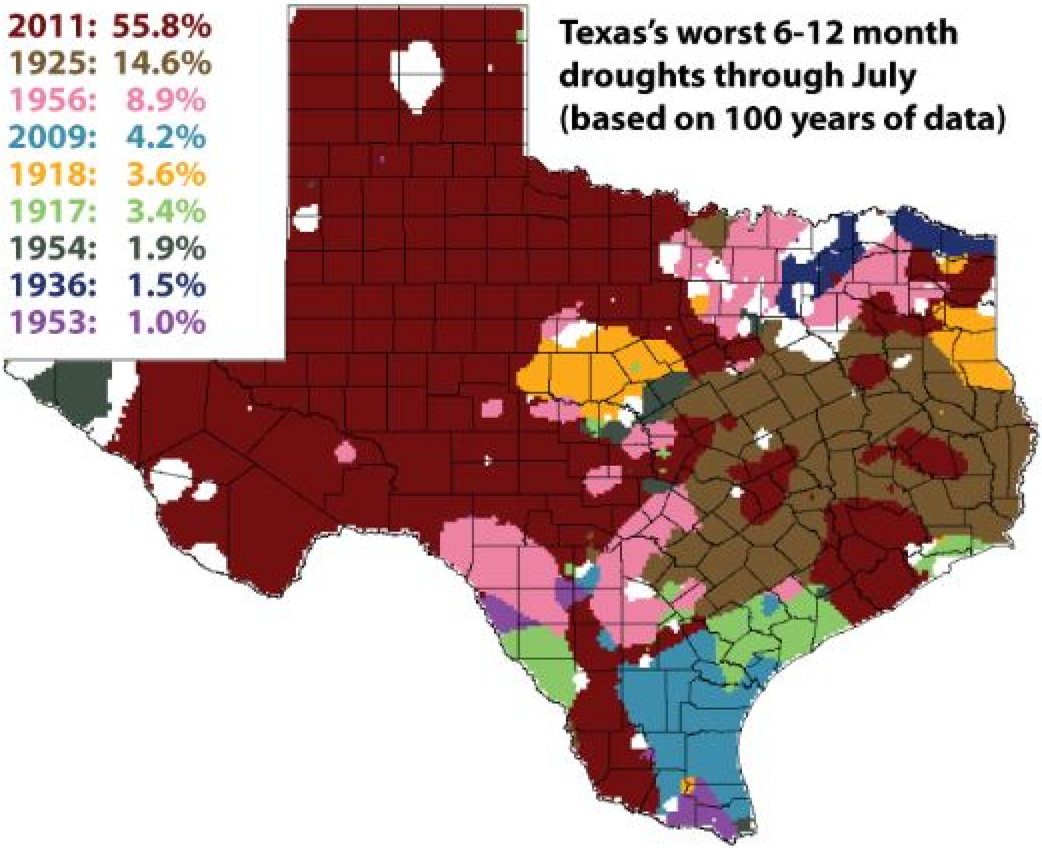
Map of Drought Conditions (U.S. Drought Monitor)

How the TCEQ Responds During Drought

- **Answers the public drought-information hot line during business hours: 800-447-2827**
- Consults public water systems regarding implementation of drought implementation plans and specific needs as they arise
- Tracks public drinking water systems under water use restrictions—both voluntary and mandatory
- Tracks and manages water-right draws of surface water
- Conducts training in TCEQ regional offices to equip inspectors in non-watermaster areas to measure and monitor surface water flows and to ensure the senior water-right priority calls are honored and respected by protecting the flow of water
- Enhances this web page to cover a wide range of drought-related topics
- Conducts weekly meetings across programs to provide updates, monitor status and forecasts, and address concerns
- Sends targeted news releases in areas where water rights have been curtailed to provide information and encourage conservation
- Actively participates with other state agencies on Joint Information Council and Drought Preparedness Taskforce

Other Resources

- **Texas Department of Agriculture's *Water Source***
- **Texas Water Development Board's *Drought in Texas***
- **Drought Resources from Texas A&M AgriLife Extension**
- **Weather Channel**
- **NOAA** Hydrological Prediction Service


2011: 55.8%
1925: 14.6%
1956: 8.9%
2009: 4.2%
1918: 3.6%
1917: 3.4%
1954: 1.9%
1936: 1.5%
1953: 1.0%
Texas's worst 6-12 month droughts through July (based on 100 years of data)