MTEC COMPANIES, LLC.

Report of Geotechnical Evaluation

Proposed Development
Addison Airport, FBO & Hanger
16051 Addison Road # 220
Addison, Texas 75001

MTEC Project MT 2012-009-023

March 29, 2019

MTEC Companies, LLC.
125 Weakley Way
Pinehurst, Texas 77362

March 29, 2019

MTEC Project Number: MT 2012-009-023

Subject: **GEOTECHNICAL EVALUATION**
Addison Airport, FBO & Hanger
16051 Addison Road # 220
Addison, Texas 75001

Submitted herein is our report of geotechnical evaluation for the proposed development at Addison Airport, 16051 Addison Road, # 220, Addison, Texas. The geotechnical evaluation was performed in accordance with Standard Practice and Care.

We trust that the study results will lead to economical design and construction of the proposed development. Please call us at your convenience if there are any questions, or when we may be of further service.

Respectively Submitted,
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1.0 INTRODUCTION

In accordance with your request, MTEC Companies Inc. (MTEC) has completed a very limited geotechnical evaluation for the construction of the development, Addison Airport, 16051 Addison Road, # 220, Addison, Texas. 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 facility.

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

1.1 PROJECT DESCRIPTION

MTEC understands that the proposed project will consist of the construction of a new Addison Airport, FBO & Hangers, vehicle parking area and airplane access.

As MTEC understands, the Project will consist of at least the following:

- 3 Hangers; I, II, and III
- FBO Building
- Airplane access
- Vehicle Access, Parking Areas

MTEC has not been advised of any additional future structures including retaining walls.

1.2 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
- Columns: About 10 to 15 kips
- Floors: About 100 to 125 lbs/ sq ft

1.3 PREVIOUS INVESTIGATIONS

MTEC has been advised of an Environmental Evaluation performed for this project. **It was found that the site has considerable distressed asphalt on the surface and some areas of concrete debris underground. Interestingly, these conditions were not present at the boring locations.**

2.0 SCOPE OF SERVICES

Based upon discussions with the Client, MTEC included the following services to provide our Report of Geotechnical Evaluation:

- Drilling, logging and sampling 20 small-diameter geotechnical soil test borings:

TABLE 1. MTEC EXPLORATORY TEST BORING PROGRAM

AREA / GENERAL LOCATION	TEST BORING NUMBER(	DEPTH TO ROCK (feet)	TEST BORING DEPTH (feet)
See Figure 2, hanger III	B-1	6	8
See Figure 2, hanger III	B-2	8	10
See Figure 2, hanger III	B-3	6	10
See Figure 2, hanger III	B-4	6	6
See Figure 2, hanger I	B-5	4	4
See Figure 2, hanger I	B-6	6	6
See Figure 2, hanger I	B-14	4	4
See Figure 2, hanger I	B-15	6	6
See Figure 2, FBO	B-7	7	8
See Figure 2, FBO	B-8	8	8
See Figure 2, FBO	B-9	8	10
See Figure 2, FBO	B-10	7	8
See Figure 2, hanger II	B-11	12	15
See Figure 2, hanger II	B-12	10	15
See Figure 2, hanger II	B-13	10	15
See Figure 2, Airplane Access	B-16	12	15
See Figure 2, Airplane Access	B-17	8	10
See Figure 2, Airplane Access	B-18	2	6
See Figure 2, Airplane Access	B-19	7	7
See Figure 2, Vehicle Parking	B-20	6	8

- Collection of soil samples and transport to in-house 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 deep foundations including allowable bearing capacity, and estimated settlement, as appropriate for the proposed building;
  - Recommendations for subgrade preparation for the floor slab and slab-on-grade support, including design recommendations;
  - Recommendations for design of vehicle pavement areas.

- 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 20 geotechnical soil test borings at the site. The borings were located in the field using tape measure accuracy and the existing structures. The field activities were performed on January 31, 2019 by West Drilling.

Equipment. Four-inch nominal diameter borings were advanced with a mobile track drilling rig using continuous solid-stem flight augers. The boring depths 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.

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.

Test boring logs attached to this report presents soil descriptions, boring depths, sampling intervals, consistency and relative density evaluations, groundwater conditions and the laboratory testing results, as appropriate. 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 the 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, overleaf.

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)).

TABLE 2. MTEC LABORATORY TEST PROCEDURES

LABORATORY TEST	APPLICABLE TEST STANDARD
Liquid and Plastic Limits 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

3.3 SAMPLE DISPOSAL

Soil samples were returned to the MTEC laboratory in Houston, Texas. Soil samples not tested in the laboratory will be stored for a period of about 60 days subsequent to submittal of this report.

These soil samples will be discarded without further notice after this period, unless we are notified otherwise in writing by the Client.

4.0 SURFACE AND SUBSURFACE CONDITIONS

4.1 FILL SOILS

There did not appear to be any fill soils at the development area of the site. West Drilling did not observe any “fill” soils, or piles of fill or debris, at the site on the day of the field activities; January 31, 2019.

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 test boring logs (B-1 through B-19), 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 soil strata:

Boring B-1 (8 feet):

- **About 4 feet of Sandy Lean Clay, overlying**
- **About 2 feet of Silty Sand, overlying**
- **About 4 feet of tan Limestone.**

Boring B-2 (10 feet):

- **About 2 feet of Sandy Lean Clay, overlying**
- **About 4 feet of Lean Clay with Sand, overlying**
- **About 2 feet of Sandy Lean Clay, overlying**
- **About 2 feet of gray clay with weathered Limestone.**
- **Tan Limestone.**

Boring B-3 (10 feet):

- **About 4 feet of Sandy Lean Clay, overlying**
- **About 2 feet of Silty Sand, overlying**
- **About 4 feet of gray and tan Limestone.**

Boring B-4 (6 feet):

- **About 2 feet of Sandy Fat Clay, overlying**
- **About 2 feet of Sandy Lean Clay, overlying**
- **About 2 feet of Silty Sand, overlying**
- **gray and tan Limestone.**

Borings B-5 (4 feet):

- **About 4 feet of Sandy Fat Clay, overlying**
- **gray and tan Limestone.**

Borings B-6 (6 feet):

- **About 6 feet of Sandy Fat Clay, overlying**
- **gray and tan Limestone.**

Borings B-7 (7 feet):

- **About 6 feet of Sandy Lean Clay, overlying**
- **About 1 foot of gray and tan Limestone.**

Boring B-8 (8 feet):

- **About 2 feet of Sandy Fat Clay, overlying**
- **About 6 feet of Sandy Lean Clay, overlying**
- **gray and tan Limestone.**

Boring B-9 (10 feet):

- **About 2 feet of Sandy Fat Clay, overlying**
- **About 2 feet of Sandy Lean Clay, overlying**
- **About 2 feet of Lean Clay with Sand, overlying**
- **About 2 feet of gray clay with weathered Limestone.**
- **About 2 feet of tan Limestone.**

Boring B-10 (8 feet):

- **About 4 feet of Sandy Lean Clay, overlying**
- **About 2 feet of gray clay with weathered Limestone.**
- **About 2 feet of tan Limestone.**

Boring B-11 (15 feet):

- **About 4 feet of Sandy Fat Clay, overlying**
- **About 8 feet of Sandy Lean Clay, overlying**
- **About 3 feet of brown Limestone.**

Boring B-12 (15 feet):

- **About 6 feet of Sandy Fat Clay, overlying**
- **About 6 feet of Sandy Lean Clay, overlying**
- **About 3 feet of brown Limestone.**

Boring B-13 (15 feet):

- **About 2 feet of Sandy Fat Clay, overlying**
- **About 5 feet of Sandy Lean Clay, overlying**
- **About 4 feet of brown Limestone.**

Boring B-14 (4 feet):

- **About 4 feet of Sandy Fat Clay, overlying**
- **gray and tan Limestone.**

Boring B-15 (6 feet):

- **About 6 feet of Sandy Lean Clay, overlying**
- **gray and tan Limestone.**

Boring B-16 (15 feet):

- **About 4 feet of Sandy Fat Clay, overlying**
- **About 8 feet of Sandy Lean Clay, overlying**
- **About 3 feet of brown Limestone.**

Boring B-17 (10 feet):

- **About 8 feet of Sandy Lean Clay, overlying**
- **About 2 feet of gray and tan Limestone, overlying**
- **gray Limestone.**

Boring B-18 (6 feet):

- **About 2 feet of Sandy Fat Clay, overlying**
- **About 2 feet of gray and tan Limestone, overlying**
- **About 2 feet of gray Limestone.**

Boring B-19 (7 feet):

- **About 2 feet of Sandy Lean Clay, overlying**
- **About 5 feet of Silty Sand, overlying**
- **gray and tan Limestone.**

Boring B-20 (8 feet):

- **About 4 feet of Sandy Lean Clay, overlying**
- **About 4 feet of gray and tan Limestone.**

Generally, the soil strata at the project site are very similar to each other.

The exploratory boring logs were reviewed in the laboratory to visualize the soil conditions intercepted at the site.

4.3 FREE WATER OR GROUNDWATER

Free water was not intercepted in any of the four borings at the time of the field activities, January 31, 2019.

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.

5.0 DESIGN RECOMMENDATIONS

Recommendations for the design and construction of the foundation for the proposed facility in Addison, Texas are presented in the following report sections.

5.1 GENERAL DESIGN CONSIDERATIONS

Potential Vertical Rise. Based upon the test results and field observations, the range of Potential Vertical Rise (PVR) values for the site, under present **predominately "dry" and "average" moisture conditions, are about 0.8 to about 1.3 inches** using the Texas Department of Transportation method (Test Procedure TEX-124-E). However, the TxDOT calculation is known to be somewhat conservative.

If the moisture conditions change to entirely dry, the PVR increases to about 0.8 to 1.5 inches

One (1) inch of PVR is generally accepted as the maximum allowable value for design and construction in the geographical area.

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)

Based on the observed soil data, the surficial soils encountered by the borings are considered to be expansive, but in a mostly "dry" moisture condition.

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

There are several approaches to the high PVR values:

One approach to mitigating this is to remove at least 1 1/2 feet of existing soils and replace with at least 1 ½ feet of properly compacted and moisture-controlled select fill to achieve a PVR of about 1 inch.

Another approach to mitigating this is to 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**

    a. **cover site with concrete,**

    b. **seal concrete joints with waterproof sealant,**

    c. **install French drains around the building to capture and redirect surface water,**

    d. **eliminate landscaping requiring watering,**

    e. **grade the site to avoid ponding at the building and in the parking and drive areas.**

    f. **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 and engineering decisions are left to the Design Team.

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 water control is provided**. Differential settlements for the slab/foundation are estimated to be on the order of ½ inch or less.

5.3 CAUTIONARY NOTES AND RECOMMENDATIONS

There are at least four significant cautionary notes relative to the development of this property:

1. **The underlying dry soils are very sensitive to moisture inundation;**

   Silty sands were intercepted in at least four borings (B-1, B-3, B-4 and B-19); the area around Hanger III.

2. **About 2 to 12 feet of surficial sandy fat clays, high plastic limit sandy lean clays and low plastic limit sandy lean clays**

   The surficial soils are especially sensitive to moisture content. If this area becomes inundated (i.e., because of precipitation and/or storm events), the surficial soils can have trafficability problems.

   The surficial soils can become a hindrance to construction traffic and general site access and site preparation (i.e., proof-rolling).

   If trees had been removed from the project site within the last 5 to 6 years, or will be removed for development of the site, the underlying soils are susceptible to changing moisture contents as the soils stabilize under the process of re-distributing the local groundwater.

3. **The on-site distressed asphalt should be removed and wasted from the site.**

4. **There should be at least a 2 foot soil "buffer" between any encountered concrete debris and the surficial structures (floor slab, roads, parking areas).**

5.4 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" and generally high plasticity clays with various amounts of sands and significant elevation differences of the limestone surface.**

Soils Considerations. MTEC has recommended:

conventional slab on grade or

"stiffened" post-tension slabs, and

straight-sided drilled piers socketed into the underlying limestone.

The final foundation selection should be based upon economics, experience of the client and/or the foundation installer, and/or other considerations.

5.4.1 CONVENTIONAL SLAB ON GRADE

The MTEC recommended design parameters for an alternate conventionally reinforced concrete slab with grade beams are itemized on TABLE 3.

TABLE 3. RECOMMENDED REINFORCED SLAB AND GRADE BEAMS

SLAB DETERMINATION		
Climatic Rating	Cw	19
Support Index	C	0.86
Slab Thickness	t	Minimum of 6 inches

GRADE AND PERIMETER BEAMS	
Allowable Bearing Pressure	2,700 psf with Factor of Safety = 3
Minimum Depth in Select Fill	12 inches
Minimum Width	12 inches

5.4.2 "STIFFENED" POST-TENSION SLAB

A "stiffened" post-tensioned slab-on-grade foundation system may be utilized to support the planned residence. The foundation slab should be designed to sustain the estimated soil movements expected at this site.

TABLES 1A through 1D, in the Appendix, has been included as a guideline for the design of "stiffened" slabs.

"Stiffened" Post-Tensioned Slab Design. A "stiffened" post-tensioned, slab-on-grade may use and designed in accordance with the publication *Design of Post-Tensioned Slabs-on-Ground 3rd Edition*, Post-Tensioning Institute (PTI). TABLE 4, provides post-tension slab parameters.

TABLE 4. "STIFFENED" POST- SLAB DESIGN PARAMETERS

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

Design Shear Strength (Sandy Fat Clays and Sandy Lean Clays)	1,500 psf	
Allowable Soil Bearing Pressure Total Load Dead Load + Sustained Live Load	Minimum bearing depth into surficial soils = 12 inches **Say 4,000 psf** FS ≥ 2.0 **Say 2,700 psf** FS ≥ 3.0	
Potential Vertical Rise (PVR) – "dry" Conditions Thornthwaite Index, I_M Weighted BRAB Plasticity Index	About 0.8 to 1.5 inches About 20 Generally greater than 31	
MTEC Recommended Values ("Stiffened Slab")		
	Center Lift	**Edge Lift**
e_m	**5.4 feet**	**6.3 feet**
y_m	**1.0 inch**	**1.1 inches**
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.	

The design and construction of the "stiffened" post-tensioned slab should be performed by structural engineers and contractors experienced in such work.

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.

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.

5.4.3 STRAIGHT SIDED DRILLED PIERS

The MTEC recommended design parameters for deep foundations, drilled piers are itemized on TABLE 5, overleaf.

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.

Temporary Casing. **Temporary casing may be necessary to be installed to about 2 to 5 feet.** Care must be taken that a sufficient head of plastic concrete is maintained within the casing during extraction.

TABLE 5. RECOMMENDED SOCKETED STRAIGHT SIDED DRILLED PIER DESIGN PARAMETERS

PARAMETER	RECOMMENDATION	COMMENTS
Foundation Type	Socketed Straight Sided Drilled Piers	--------------------------
Bearing Depth **(1.5 foot Socketed into underlying limestone)**	3.5 to 13.5 feet Hanger I - 5.5 to 7.5 ft Hanger II - 11.5 to 13.5 ft Hanger III - 5.5 to 9.5 ft FBO - 7.5to 9.5 feet	Below existing grade at time of on-site activities. **The depth of the socketed piers may be modified depending upon initial contact with the underlying unweathered limestone and FFE.**
Bearing Material	**unweathered limestone**	--------------------------
Design Shear Strength, psf	2,100	--------------------------
Net allowable bearing pressure*, qall		
Total Load, ksf	8.4	Includes safety factor of 2
Dead Load + Sustained Live Load, ksf	5.6	Includes safety factor of 3
Footing Spacing	Clear spacing of at least two shaft (as appropriate) diameters	Measured center-to-center
Minimum Shaft Diameter	**18 to 20 inches**	--------------------------
Foundation Reinforcement	Minimum of 0.8%	Extend the full depth of shaft and underream. Final recommendation by the structural engineer.

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

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.

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. Minimum concrete structural strength should be 3,000 psi at 28-days.

Concrete Placement into Piers. **Individual should be excavated and filled with concrete within an 8-hour period** to help prevent deterioration of bearing surfaces. Placement of the drilled shaft concrete immediately following underream operations may be necessary to reduce the potential for caving.

Inspection Services. 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 diameter,
- Excavation depth,
- Excavation cleanliness,
- Plumbness of the shaft, and the
- Type of bearing material.

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.

5.4.4 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 leveling sand at the project site.**

5.4.5 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.

5.4.6 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
- 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.

5.5 VAPOR RETARDER

ACI 302.1R-96, *Guide for Concrete Floor and Slab Constructi[on]* (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 6 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 a 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")

5.6 IBC SEISMIC COEFFICIENT

The International Building Code defines seismic coefficients relative to the underlying soil and/or rock properties. Based upon the soil field logs and laboratory tests, *we have designated the underlying soils as IBC Type "C" soils.* The following tables and paragraphs are taken from the IBC.

IBC Section 1615.1.1 Site class definitions. The site shall be classified as one of the site classes defined in Table 1615.1.1. Where the soil shear wave velocity, v_s, is not known, site class shall be determined, as permitted in Table 1615.1.1, from standard penetration resistance, N, or from undrained shear strength, s_u, calculated in accordance with Section 1615.1.5.

Where site-specific data are not available to a depth of 100 feet, appropriate soil properties are permitted to be estimated by the registered design professional preparing the soils report based on known geologic conditions. "When the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the building official determines that Class E or F soil is likely to be present at the site."

IBC TABLE 1615.1.1
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, AS PER SECTION 1615.1.5		
		Soil shear wave velocity, v_s, (ft/s)	Standard penetration resistance, *N*	Soil undrained shear strength, s_u, (psf)
A	Hard rock	$v_s > 5{,}000$	Not applicable	Not applicable
B	Rock	$2{,}500 < v_s \le 5{,}000$	Not applicable	Not applicable
C	Very dense soil and soft rock	$1{,}200 < v_s \le 2{,}500$	$N > 50$	$s_u \ge 2{,}000$
D	Stiff soil profile	$600 \le v_s \le 1{,}200$	$15 \le N \le 50$	$1{,}000 \le s_u \le 2{,}000$
E	Soft soil profile	$v_s < 600$	$N < 15$	$s_u < 1{,}000$
E	-	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index *PI* > 20, 2. Moisture content *w* ≥ 40%, and 3. Undrained shear strength s_u < 500 psf		

IBC TABLE 1615.1.2(1)
VALUES OF SITE COEFFICIENT F_β AS A FUNCTION OF SITE CLASS
AND MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS (S_S)[a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS				
	$S_s \le 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Note b	Note b	Note b	Note b	Note b

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period, S_s.
b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values, except that for structures with periods of vibration equal to or less than 0.5 second, values of F_a for liquefiable soils are permitted to be taken equal to the values for the site class determined without regard to liquefaction in Section 1615.1.5.1.

IBC TABLE 1615.1.2(2)
VALUES OF SITE COEFFICIENT F_V, AS A FUNCTION OF SITE CLASS AND MAPPED SPECTRAL RESPONSE ACCELERATION AT 1-SECOND PERIOD (S_1)[a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS				
	$S_s \leq 0.1$	$S_s = 0.2$	$S_s = 0.3$	$S_s = 0.4$	$S_s \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Note b	Note b	Note b	Note b	Note b

a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at 1-second period, S_1.

b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values, except that for structures with periods of vibration equal to or less than 0.5 second, values of F_v for liquefiable soils are permitted to be taken equal to the values for the site class determined without regard to liquefaction in Section 1615.1.5.1.

IBC Section 1615.1.5 Site Classification for Seismic Design. Site classification for Site Class C, D, or E shall be determined from Table 1615.1.5.

IBC TABLE 1615.1.5
SITE CLASSIFICATION

SITE CLASS	v_s	N or N_{ch}	s_u
E	< 600 ft/s	< 15	< 1,000 psf
D	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
C	1,200 to 2,500 ft/s	> 50	> 2,000 psf

5.7 PAVEMENT DESIGN

The pavement areas should be prepared as described in **Section 6.2 SITE PREPARATION** of this report. If the surface soils are loose, wet, or pumping as the time of construction, a stable subgrade must be provided by one of the options discussed in **Section 6.2** of this report.

Once the subgrade is properly prepared both flexible pavement systems (consisting of asphalt and crushed limestone base) and reinforced concrete pavement systems may be considered for this project.

Detailed traffic loads and frequencies were not available. However, it is anticipated that traffic will consist primarily of passenger vehicles in the parking and drive thru areas and passenger vehicles combined with the possibility of large multi-axle delivery trucks on a very limited basis from time to time in driveways.

- TABLE 6 provides the presumed traffic frequencies and loads used to design pavement sections for this project.

- Listed in TABLE 7 and TABLE 8 are pavement component thicknesses which may be used as a guide for pavement systems at the site for the traffic classifications stated herein.

TABLE 6. PRESUMED TRAFFIC FREQUENCIES AND LOADS

PAVEMENT AREA	TRAFFIC DESIGN INDEX	DESCRIPTION
Automobile Parking Areas	DI-1	Light traffic – (Few vehicles heavier than passenger cars, no regular use by heavily loaded two axle trucks or larger).
Entry and Main Driveways (Light Duty)	DI-2	Medium to light traffic (Similar to DI-1 including not over 50 loaded two axle trucks or lightly loaded larger vehicles per day. No regular use by heavily loaded trucks with three or more axles).
Truck Traffic Areas (Heavy Duty)	DI-3	Medium traffic (Including not over 100 heavily loaded two axle trucks and no more than 5 heavily loaded trucks with more than three axles per day).

TABLE 7. RECOMMENDED FLEXIBLE PAVEMENT SYSTEMS

FLEXIBLE PAVEMENT SYSTEMS			
COMPONENT	MATERIAL THICKNESS (inches)		
	DI-1	DI-2 (MTEC Recommendation)	DI-3
Asphaltic Concrete	2.0	2.5	3.0
Crushed Limestone Base or Re-Cycled Crushed Concrete	8.0	8.0	10.0
Lime Stabilized Subgrade	6.0	6.0	10.0
Structural Numbers	SN = 2 (0.44) + 8 0.14) + 6.0 (0.11) = 2.66	SN = 2.5 (0.44) + 8 (0.14) + 6.0 (0.11) = 2.88	SN = 3 (0.44) + 10 (0.14) + 10 (0.11) = 3.82

TABLE 8. RECOMMENDED RIGID PAVEMENT SYSTEMS

RIGID PAVEMENT SYSTEMS			
COMPONENT	MATERIAL THICKNESS (inches)		
	DI-1	DI-2 (MTEC Recommendations)	DI-3
Reinforced Concrete	5.0	6.0	7.0
Lime Stabilized Subgrade	6.0	6.0	10.0

Reinforcing Steel: At least #3 bars spaced at 18 inches, or #4 bars spaced at 24 inches on centers in both directions.

Control Joint Spacing: Maximum of 15 feet. If sawcut, control joints should be cut within 6 to 12 hours of concrete placement.

Expansion Joint Spacing: Maximum of 45 feet.

Dowels at Expansion Joints: 3/4 inch bars, 18 inches in length, with one end treated to slip, spaced at 12 inches on centers at each joint.

Presented herein are our recommended material requirements for the various pavement sections. These recommendations may be supplemented by the structural engineer.

Hot Mix Asphaltic Concrete Surface Course. The asphaltic concrete surface course should be plant mixed, hot laid Type D (Fine Graded Surface Course) meeting the specifications requirements in TxDOT Item 340 (Hot Mix Asphaltic Concrete Pavement).

Specific criteria for the job specifications should include compaction to within air void range of 3 to 8 percent calculated using the maximum theoretical gravity mix measured by TxDOT Tex-227-F. The asphalt cement content by percent of total mixture weight should fall within a tolerance of +/- 0.5 percent asphalt cement from the job mix design.

Reinforced Concrete Pavement. The Portland cement concrete mix should have a minimum 28 day compressive strength of 3,300 psi, and a minimum of 4 to 6 percent entrained air.

Crushed Limestone Base. Base material should be composed of crushed limestone meeting the requirements of TxDOT Item 247 (Flexible Base), Type A, Grade 1. The base should be compacted to a minimum of 95 percent of the maximum density as determined by the modified moisture/density relation (ASTM D 1557) within two percentage points of optimum moisture.

Soil Stabilization will improve the long-term performance of the pavement and reduce the potential for premature pavement deterioration especially under varying surficial soil conditions.

- The predominately clayey soils at the subgrade level will react well with lime or lime-fly ash.
- It is our preliminary recommendation, **for planning and bidding purpose only**, that the subgrade be stabilized with about 7% lime by dry unit weight.

Perimeter Drainage. Proper perimeter drainage must be provided so that infiltration of surface water from unpaved areas, if any, surrounding the pavement is reduced, or if this is not possible, curbs should extend through the base and into the subgrade for a depth of at least 4 inches. A crack sealant compatible to both asphalt and concrete should be provided at concrete-asphalt interfaces.

Related civil design factors such as subgrade drainage, shoulder support, cross-sectional configurations, surface elevations and environmental factors which will significantly affect the service life must be included in the preparation of the construction drawings and specifications. Normal periodic maintenance will be required.

Waste Dumpster. If the project will be designed with mostly asphaltic concrete pavement areas, we recommend that waste dumpster areas be constructed of reinforced concrete. The concrete pad areas should be designed so that the vehicle wheels of the collection truck are supported on the concrete while the dumpster is being lifted to support the large wheel loading imposed during waste collection.

MTEC recommends a minimum concrete pavement thickness of 7 inches in the dumpster area(s), if any.

6.0 GENERAL SITE GRADING RECOMMENDATIONS

6.1 SITE GRADING AND DRAINAGE

Site Preparation. Initial site preparation will include grubbing and removal of roots in excess of ¼ inch in diameter (if any);after clearing and grubbing activities, the exposed construction area should be proof-rolled and hand-probed to identify soft, loose or wet areas that require remediation.

If uncontrolled is placed atop the ground surface, there may be future problems related to the following:

- Uncontrolled fill placement tends to be relatively loose and susceptible to future adverse settlement and consolidation movement.
- Uncontrolled fill placement is typically not placed at optimum moisture content which can again tends to be relatively loose and susceptible to future adverse settlement and consolidation movement.

If uncontrolled fill is placed at the site, an earth contractor should come back and compact the fill material to acceptable limits, unless the fill passes both proof-rolling operations/testing and hand probing operations/testing.

Grading. *Grading should provide positive drainage away from the building*, 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 adverse 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 for the building.

- 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

The soils immediately underlying the site appear to be composed of expansive sandy soils. These soils could become wetter and soft during construction activities. Therefore, the *construction contractor may have difficulty in densifying and preparing these soils*.

Site preparation within the building footprint area should consist of clearing, stripping and grubbing operations will probably remove at least 2 to 5 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 of the surficial soils, the building area exposed soils plus at least 5 feet beyond the building area **should be proof-rolled and hand-probed** to identify loose, soft, or pumping areas. These loose, soft, or weak areas should be hand probed to delineate the extent of the loose, soft, or pumping areas 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; ***not*** a dozer or backhoe.

- **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;
    - Placed at 0 to +3 percentage points above the optimum moisture content (ASTM D 698);
    - Maximum particle size is less than 3 inches;
    - Liquid limit less than 38; and
    - Plasticity index between 8 and 20.

6.3 SELECT FILL PLACEMENT IN BUILDING AREA

If required to modify grade, the select fill materials should be spread in loose lifts, less than 8 inches thick, and uniformly compacted between -2 and + 3 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 soil layer should be thoroughly manipulated by plowing, discing, 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. Our experience is that many contractors encounter major difficulties in working with these soils as well as silty sand, 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.

6.5 FILL TESTING FREQUENCY

Each lift of compacted soil (select fill or engineered fill) should be tested and inspected by the soils engineer or his representative prior to placement of subsequent lifts.

As a guideline, MTEC recommends the testing frequency noted on TABLE 9, overleaf.

TABLE 9. FILL TESTING FREQUENCY

FILL LOCATION	TEST FREQUENCY RECOMMENDATIONS
Building Areas	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.
Pavement Areas	Not less than 1 test per 3,000 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 and therefore have negative impact on the structures.

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 4 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 soils in the upper 8 feet of the site may have been desiccated by the presence of previous current trees. Water control in this area is extremely 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 9.

TABLE 9. 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

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 DROUGHT CONDITIONS

Generally, the Greater Dallas area is within historically Moderate to Severe to Extreme Drought conditions. Typically, semi-active soils and active soils (as have been intercepted at the project site tend to shrink or settle under drought moisture conditions and expand significantly with increasing soil moisture contents.

***The control of surface water on and across the site is absolutely essential in maintaining present moisture conditions*.**

A Texas Drought Monitor Map has been provided in the Appendix for information purposes.

6.8 AREA DESICCATION, PAST SHRINKAGE AND REHYDRATION

In general, as trees grow 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.

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

Tree Removal. The accumulative subsidence is “locked in place” until the tree is removed or dies. The underlying soils will then recover (rehydrate or recharge) from its desiccated state and if swelling forces generate sufficient pressure, they will tend to lift a building or portion of a building constructed on that soil.

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 at least 50 % lower than 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 in clays. Therefore, it appears that **some of the soils identified and observed are in a state of desiccation and susceptible to rehydration** once trees in the area are removed.

However, it is important to realize that this desiccation occurs in clay soils. Most of the sandy soils at the site are intermixed with silts and some clays. The sands will ameliorate the tendency to heave.

Future Trees. If trees are added in the proximity of the proposed construction area, MTEC has provided the following recommendations.

- 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 5 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.

6.9 FREE WATER OR GROUNDWATER CONTROL

Based on our experience, attaining adequate compaction of the in situ 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 reasonable possibility of intercepting perched water at the time of construction.

MTEC recommends that contract documents address the need for maintaining controls to preclude water from draining into excavations.

- 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. “Bleeder ditches” (temporary excavated de-watering ditches maximum four (4) 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.

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 plan review is necessary to evaluate whether the recommendations contained in this report have been properly incorporated into the project plans and specifications.

Based on the work already performed, MTEC may be 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 revised report are based on information obtained from field activities on January 31, 2019.

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,
- 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 the (Client) by MTEC Companies LLC. (MTEC).

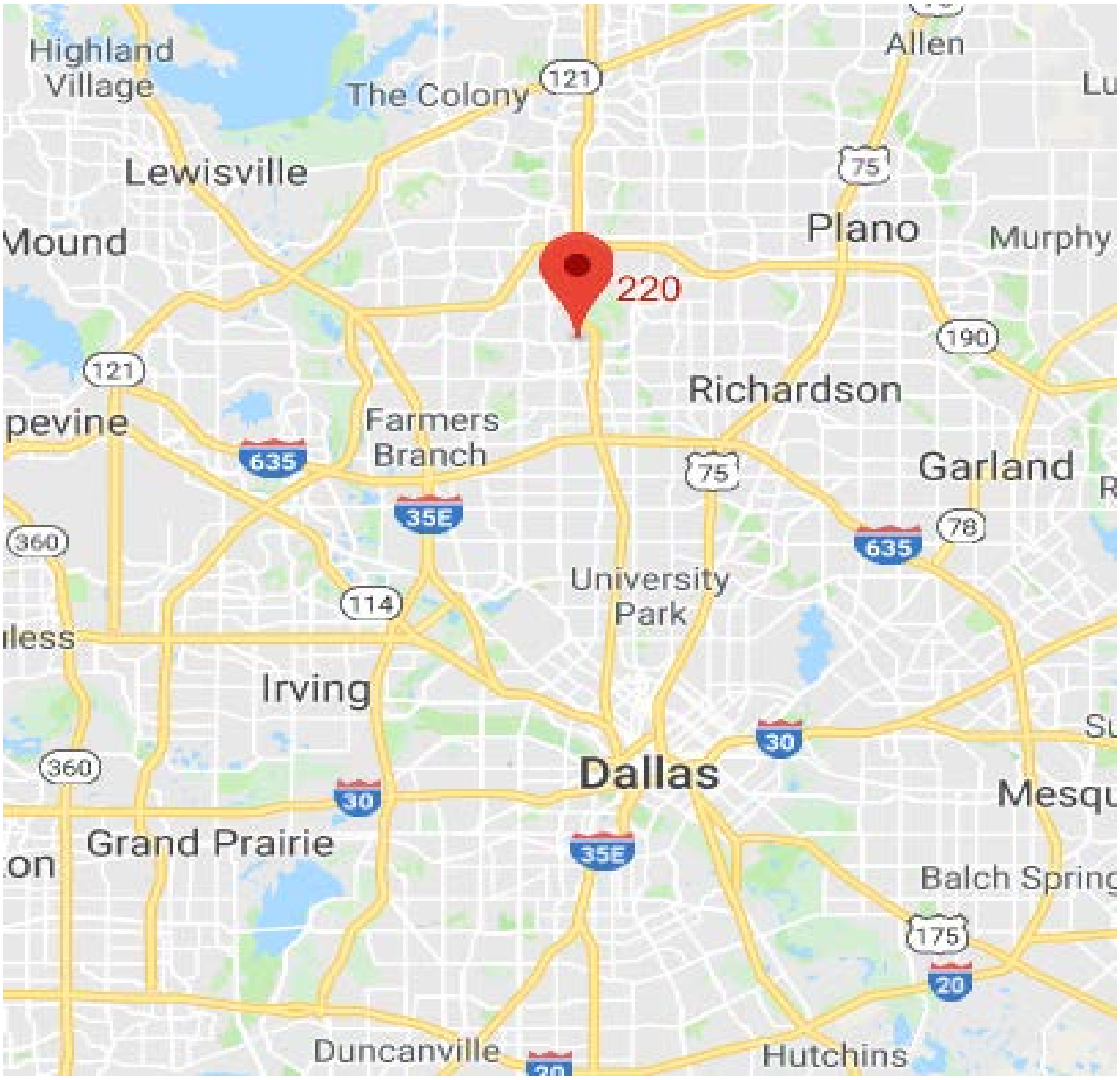
All contractors referring to this geotechnical report should draw their own conclusions regarding excavations, trafficability, etc., for bidding purposes.

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

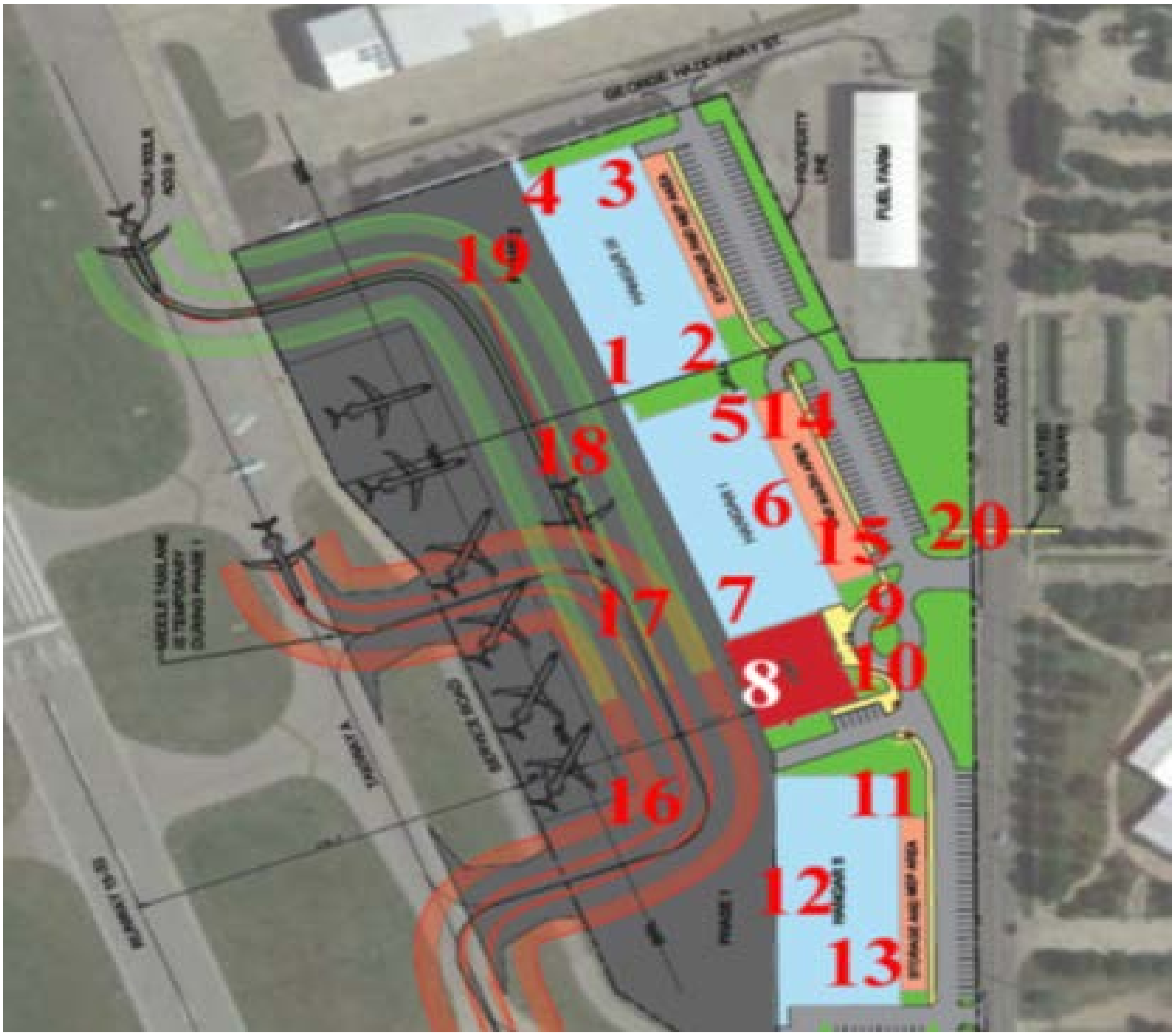
Warranty. MTEC has endeavored to perform our evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical professionals with experience in this area in similar soil conditions.

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

FIGURES



Proposed Addison Airport FBO and Three hangers 16051 Addison Road # 220 Addison, Texas 75001	MTEC Project Number: MT 2012-009-023	**FIGURE 1** **SITE VICINITY MAP**



Not To Scale

Proposed Addison Airport FBO and Three hangers 16051 Addison Road # 220 Addison, Texas 75001	MTEC Project Number: MT 2012-009-023	**FIGURE 2** **PLAN OF BORINGS**

APPENDIX

BORING LOGS (Borings B-1 through B-20)

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

TERMS USED ON BORING LOGS

TEXAS DROUGHT MONITOR MAP

TEXAS DROUGHT CONDITIONS

FLOOD INFORMATION

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-1

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** dark brown	22	46	18	28	63
		3.50		- light brown at 2 to 4 ft	20	49	19	30	66
5				**SILTY SANDY (SM),** light brown	16	Non-Plastic			44
				LIMESTONE, gray and tan					
10									
15									
20				**Boring Terminated at 8 feet.**					
25									

(Lab Tests: w %, LL, PL, PI, -200)

Drilling Company: West Drilling Company

Water: Initial Contact Depth: None feet.

Depth after ______ minutes: ______ feet.

Termination Depth of Boring: 8 feet.

Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-2

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff**,** dark brow	20	44	18	26	62
				- light brown at 2 to 4 ft	15	45	18	27	65
5		3.00		**LEAN CLAY with SAND (CL),** very stiff**,** light brown	19	43	19	24	71
		2.00		**SANDY LEAN CLAY (CL),** stiff**,** gray & weathered limestone	22	48	20	28	59
10				**LIMESTONE,** tan					
15									
20				**Boring Terminated at 10 feet.**					
25									

Drilling Company:
Water: Initial Contact Depth: None feet.
Depth after minutes: feet.
Termination Depth of Boring: 10 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-3

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff, dark brow	21	48	18	30	58
		3.50		**-** light brown at 2 to 4 ft	22	48	17	31	60
5		-----		**SILTY SAND (CL),** light brown	12	Non-Plastic			48
10				**LIMESTONE,** gray and tan					
15									
20				**Boring Terminated at 10 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 10 feet.

Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-4

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff, dark brown	20	50	21	29	63
		3.50		**SANDY LEAN CLAY (CL),** very stiff, light brow	22	47	18	29	60
5				**SILTY SANDY (SM),** light brown	11	Non-Plastic			50
				LIMESTONE, gray and tan					
10									
15									
20				**Boring Terminated at 6 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 8 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-5

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff, dark brown	20	50	21	29	63
5				**LIMESTONE, gray and tan**					
10									
15									
				Boring Terminated at 4 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 4 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-6

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY LEAN CLAY (CL),** very stiff, dark brow	21	48	18	30	60
5									
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 6 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ________ minutes: ________ feet.
Termination Depth of Boring: 6 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-7

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff, dark brow	23	48	18	30	60
				- light brown at 2 to 6 ft	20	47	18	29	53
5									
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 8 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 8 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-8

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY FAT CLAY (CH),** very stiff, dark brown	23	50	18	32	53
				SANDY LEAN CLAY (CL), light brown	20	48	17	31	55
5									
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 8 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 8 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-9

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY FAT CLAY (CH),** very stiff**,** dark brown	23	50	18	32	53
		3.50		**SANDY LEAN CLAY (CL),** very stiff**,** light brown	20	48	17	31	55
5		1.50		**LEAN CLAY with SAND (CL),** stiff**,** gray and tan & weathered limestone	16	27	16	11	72
10				**LIMESTONE,** tan					
15									
20				**Boring Terminated at 10 feet.**					
25									

Drilling Company: West Drilling Company

Water: Initial Contact Depth: None feet.

Depth after ______ minutes: ______ feet.

Termination Depth of Boring: 10 feet.

Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-10

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff**,** dark brown	21	46	18	28	50
		3.50		**SANDY LEAN CLAY (CL),** very stiff**,** light brown	18	45	18	27	51
5		1.50		**SANDY LEAN CLAY (CL),** stiff**,** gray and tan & weathered limestone	17	25	15	10	66
10				**LIMESTONE,** tan					
15									
20				**Boring Terminated at 10 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 10 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-11

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY FAT CLAY (CH),** very stiff**,** dark brown	22	52	20	32	60
		3.50			24	54	21	33	57
5		3.50		**SANDY LEAN CLAY (CL),** very stiff**,** gray	19	48	19	29	52
		3.50		- light brown at 6 to 8 ft	18	47	19	28	55
10		3.50		- brown at 8 to 12 ft	20	49	20	29	57
15				**LIMESTONE,** brown					
20				**Boring Terminated at 15 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 15 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-12

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY FAT CLAY (CH),** very stiff**,** dark brown	24	50	18	32	57
5		3.50		**SANDY LEAN CLAY (CL),** very stiff**,** dark gray	21	46	18	28	55
		3.00		- light brown at 6 to 11 ft	20	47	17	30	55
10		3.00			18	47	18	29	60
				LIMESTONE, brown					
15									
20				**Boring Terminated at 15 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 15 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-13

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		4.00		**SANDY FAT CLAY (CH),** very stiff**,** dark brown and gray	21	52	19	33	52
		3.50		**SANDY LEAN CLAY (CL),** very stiff**,** dark brown	20	49	20	29	57
5		3.50		- dark gray at 4 to 6 ft	21	48	20	28	55
		3.00		- light brown at 6 to 12 ft	19	47	20	27	61
10		3.00			17	46	20	26	62
				LIMESTONE, brown					
15									
20				**Boring Terminated at 15 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 15 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-14

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff, dark brown	20	50	21	29	63
5				**LIMESTONE, gray and tan**					
10									
15									
				Boring Terminated at 4 feet.					
20									
25									

Lab Tests

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ____ minutes: ____ feet.
Termination Depth of Boring: 4 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-15

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff, dark brown	20	49	20	29	59
					18	45	20	25	55
5									
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 6 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ____ minutes: ____ feet.
Termination Depth of Boring: 6 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-16

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff, dark brown	24	50	19	31	62
		3.00		- brown at 2 to 4 ft	22	53	19	34	56
5		3.50		**SANDY LEAN CLAY (CL),** very stiff, gray and brown	18	48	20	28	55
		3.00		- light brown at 6 to 8 ft	20	48	20	28	55
10		3.50		- brown at 8 to 12 ft	22	47	19	28	54
15				**LIMESTONE,** brown					
20				**Boring Terminated at 15 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ____ minutes: ____ feet.
Termination Depth of Boring: 15 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-17

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff**,** dark brow	20	48	16	32	62
				- light brown at 2 to 4 ft	19	45	18	27	58
5									
				LIMESTONE, gray and tan					
10				- gray at 9 to 10 ft					
15									
				Boring Terminated at 10 feet.					
20									
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after _____ minutes: _____ feet.
Termination Depth of Boring: 10 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-18

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.50		**SANDY FAT CLAY (CH),** very stiff, dark brown	22	52	22	30	60
5				**LIMESTONE, gray and tan**					
				LIMESTONE, gray					
10									
15									
20				**Boring Terminated at 7 feet.**					
25									

Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 7 feet.
Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-19

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY FAT CLAY (CH),** very stiff, dark brown	22	47	17	30	50
				SILTY SANDY (SM), light brown					
5					13	Non-Plastic			58
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 7 feet.					
20									
25									

Drilling Company: West Drilling Company

Water: Initial Contact Depth: None feet.

Depth after ______ minutes: ______ feet.

Termination Depth of Boring: 7 feet.

Additional Comments:

MTEC Companies, LLC
125 Weakley Way
Pinehurst, Texas 77362

MTEC LLC

Project No.: MTEC 2012-009-023 **Date:** January 31, 2019

Project Name: Addison Airport - Proposed FBO & Hanger, 16051 Addison Road # 220, Addison, Texas

Specifics:

BORING B-20

Depth	Samples	Penetron.		Soil Description(s)	w %	LL	PL	PI	-200
		3.00		**SANDY LEAN CLAY (CL),** very stiff, dark brown	20	49	20	29	59
		3.00			18	45	20	25	55
5									
				LIMESTONE, gray and tan					
10									
15									
				Boring Terminated at 8 feet.					
20									
25									

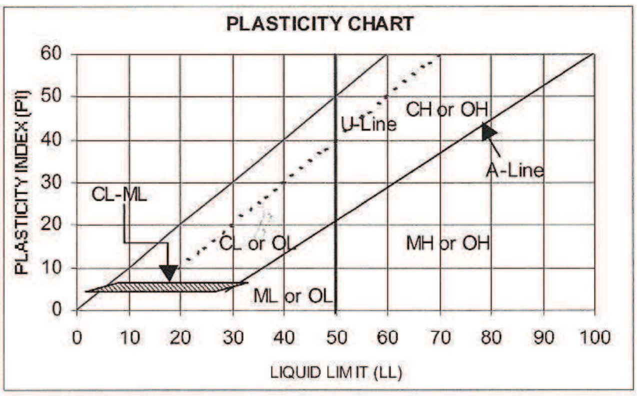
Drilling Company: West Drilling Company
Water: Initial Contact Depth: None feet.
Depth after ______ minutes: ______ feet.
Termination Depth of Boring: 8 feet.
Additional Comments:

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, poorly graded 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}).



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.

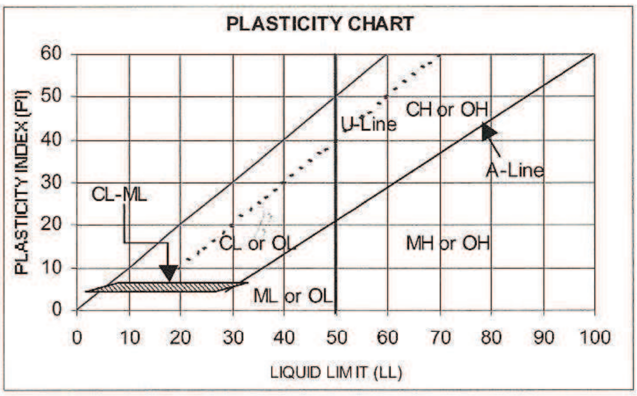
MTEC Companies, Inc.

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, poorly graded 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}).



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)	

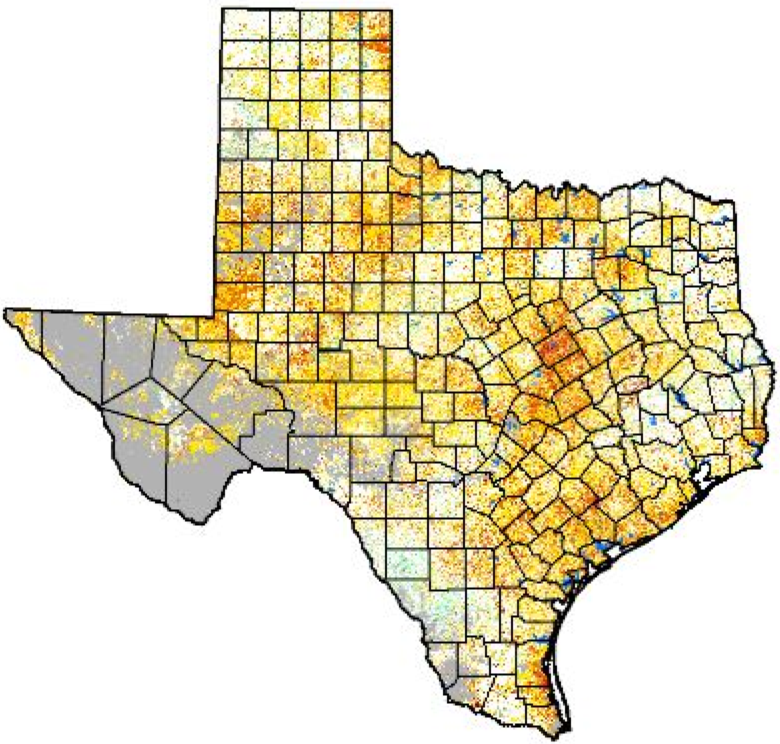
NOTES:
If soil (GW, GP, GM, GC) contains ≥ 15 % sand, add "**with sand**" to Group Name.
If soil fines (in GM, GC, SM, SC) classify as CL-ML, use **GC-GM** or **SC-SM** as Group Name.
If soil fines (in GM, GC, SM, SC) are organic, add "**with organic fines**" with Group Name.
If soil (SP, SM, SC) contains ≥ 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.

Vegetation Drought Response Index for Texas

Select map type: Complete

Download: PNG PDF JPG

Map for May. 27, 2018



Reference Map

(Click a region to zoom in further.)

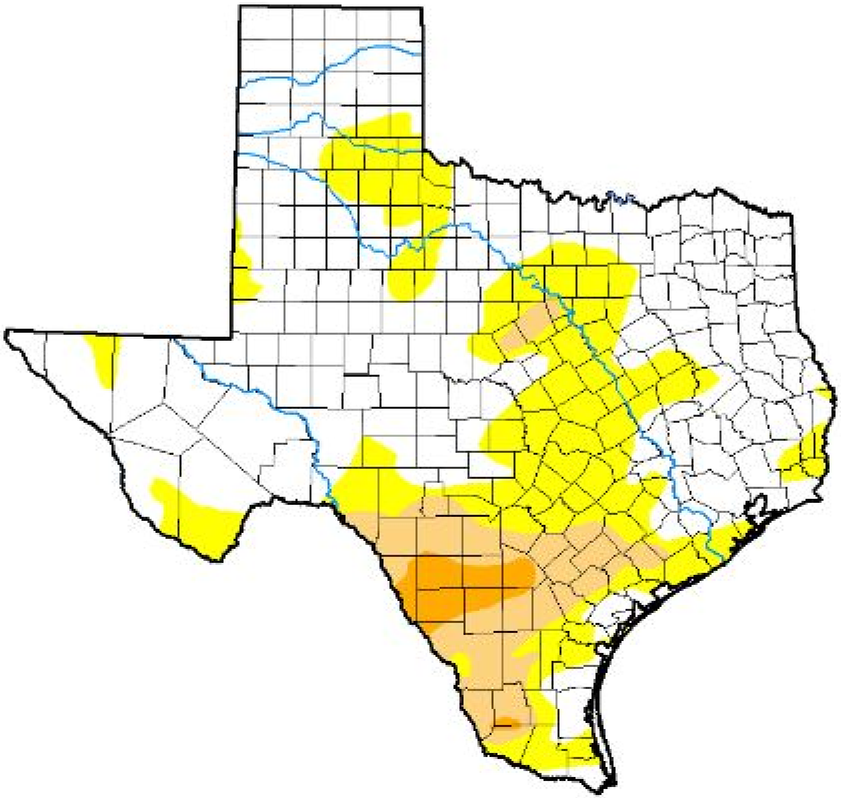
Return to the U.S. map

State Statistics

Vegetation Condition

- Extreme Drought
- Severe Drought
- Moderate Drought
- Pre-drought stress
- Near Normal
- Unusually Moist
- Very Moist
- Extremely Moist
- Out of Season
- Water
- Other Landcover

Texas



Map released: Thurs. March 28, 2019

Data valid: March 26, 2019 at 8 a.m. EDT

Intensity:

- **None**
- **D0** (Abnormally Dry)
- **D1** (Moderate Drought)
- **D2** (Severe Drought)
- **D3** (Extreme Drought)
- **D4** (Exceptional Drought)

Author(s):

Eric Luebehusen, U.S. Department of Agriculture

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

Map Download

No text:

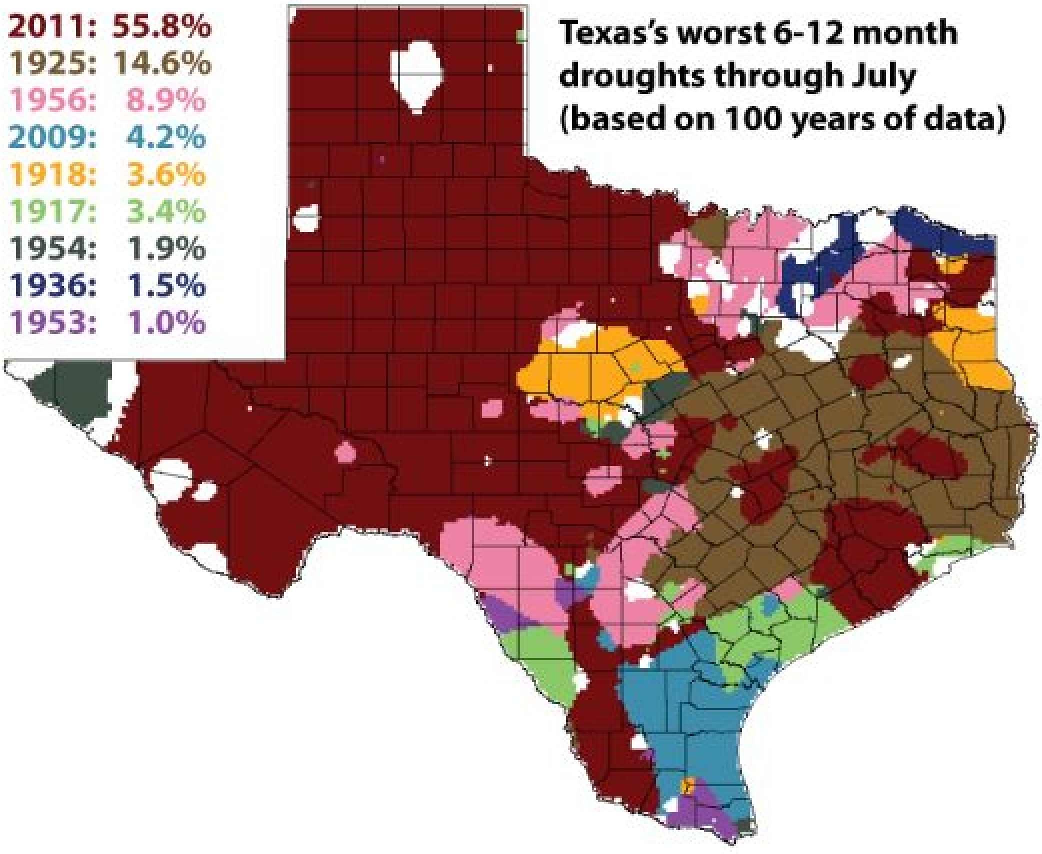
Legend:

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	2019-03-26	61.92	38.08	11.44	2.38	0.00	0.00	52
Last Week	2019-03-19	69.05	30.95	9.67	0.90	0.00	0.00	42
3 Months Ago	2018-12-25	90.02	9.98	0.80	0.00	0.00	0.00	11
Start of Calendar Year	2019-01-01	92.99	7.01	1.32	0.00	0.00	0.00	8
Start of Water Year	2018-09-25	57.46	42.54	20.19	7.03	0.96	0.00	71
One Year Ago	2018-03-27	26.19	73.81	64.23	28.30	15.08	1.21	183


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)

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.

PHOTO BY GERALD E. MCLEOD

The Best of Texas Daytripping

This encompasses a lot of ground. As usual, we've seen new destinations open and some old favorites improve. If I had to choose three things that thrilled me this year they would be:

• **Five-year drought finally over.** The late Texas author J. Frank Dobie said, "Texas is in a perpetual drought broken by an occasional flood." The map in the Texas Drought Monitor for May 21, 2015, showed no part of the state in extreme drought conditions for the first time since November 2010. That meant swimming holes were active again and the East Texas blueberry crop was one of the best in recent memory.

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."