Brakes Plus – Little Elm

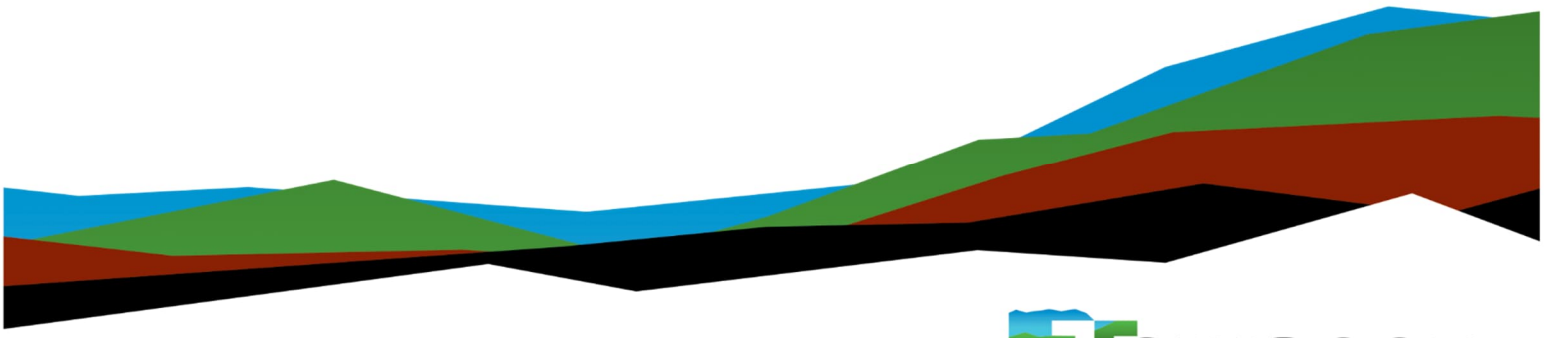
Geotechnical Engineering Report

Little Elm, Texas

May 7, 2026 | Terracon Project No. 94265131

Prepared for:

Express Oil Change, LLC
1880 Southpark Drive
Birmingham, AL 35244



Terracon
Explore with us

Nationwide
Terracon.com

- Facilities
- Environmental
- Geotechnical
- Materials

8901 John W. Carpenter Freeway
Dallas, Texas 75247
P (214) 630-1010
Terracon.com

May 7, 2026

Express Oil Change, LLC
1880 Southpark Drive
Birmingham, AL 35244

Attn: Tyler Hendon
P: (205) 703-7758
E: Tyler.Hendon@expressoil.com

Re: Geotechnical Engineering Report
Brakes Plus – Little Elm
FM 720
Little Elm, Texas
Terracon Project No. 94265131

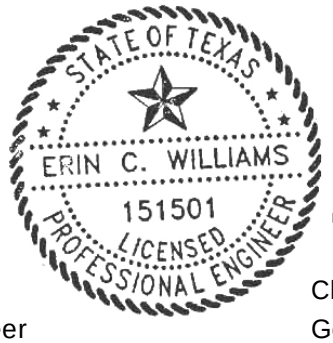
Dear Mr. Hendon:

We have completed the scope of Geotechnical Engineering services for the above referenced project in general accordance with Terracon Proposal No. P94265131 dated and authorized on March 13, 2026. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations, floor slabs, and pavements for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.
Registration No. F-3272

05/07/2026



Erin C. Williams, P.E., P.G.
Project Geotechnical Engineer

Christopher W. Eddy, P.E.
Geotechnical Department Manager

Table of Contents

Introduction 1
Project Description 1
Site Conditions 2
Geotechnical Characterization 3
Seismic Site Class 4
Geotechnical Overview 4
Earthwork 5
- Site Preparation 5
- Building Pad Preparation 6
- Fill Material Types 8
- Fill Placement and Compaction Requirements 8
- Utility Trenches Outside the Building Pad 9
- Earthwork Construction Considerations 10
- Construction Observation and Testing 11
- Site Grades and Drainage 12
- Landscape Considerations 13

Deep Foundations 14
- Straight Drilled Shafts - Axial Capacity 14
- Lateral Capacity 15
- Soil Induced Uplift Loads 16
- Drilled Shafts Construction Considerations 16
- Grade Beams, Pier Caps, and Wall Panels 18

Footing Foundations 18
- Design Parameters – Compressive Loads 18
- Design Parameters – Overturning and Uplift Loads 19
- Footing Foundation Construction Considerations 20

Floor Systems 20
- Structurally Suspended Floor System 21
- Floor Slab and Flatwork on Modified Subgrade 22
- Floor Slab Design Parameters 23
- Floor Slab Construction Considerations 23

Pavements 23
- Parking and Drive Lane Pavement Subgrades 23
- Pavement Sections 24
- Pavement Maintenance 25
- Pavement Design Considerations 25

General Comments 26

Figures

- GeoModel

Attachments

Exploration and Testing Procedures
Site Location and Exploration Plans
Exploration and Laboratory Results
Supporting Information

Note: Blue Bold text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the Terracon logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

Refer to each individual Attachment for a listing of contents.

Introduction

This report presents the results of our subsurface exploration and Geotechnical Engineering services performed for the proposed project. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface conditions
- Groundwater conditions
- Seismic site classification
- Site preparation and earthwork
- Foundation design and construction
- Floor slab design and construction
- Pavement design and construction

The geotechnical engineering Scope of Services for this project included the advancement of borings, laboratory testing, engineering analysis, and preparation of this report.

Drawings showing the site and boring locations are shown on the Site Location and Exploration Plan, respectively. The results of the laboratory testing performed on soil samples obtained from the site during our field exploration are included on the boring logs in the Exploration and Laboratory Results section.

Project Description

Our initial understanding of the project was provided in our proposal and was discussed during project planning and our final understanding of the project conditions is as follows:

Item	Description
Project Description	The project includes a single-story building with a footprint of about 5,580 square feet. The site will also have associated pavement areas and drive lanes.
Building Construction	Steel frame Grade-supported floor slab
Finished Floor Elevation	We have assumed that finished floor is ±2 feet of existing grade.

Item	Description
Maximum Loads	■ Columns: 75 kips ■ Walls: 5 kips per linear foot (klf) ■ Slabs: 150 pounds per square foot (psf)
Grading/Slopes	Finished grades will be within ±2 feet of existing grades, and final slopes are planned with an inclination of 4H:1V (Horizontal: Vertical) or flatter.
Below-Grade Structures	None planned
Free-Standing Retaining Walls	None planned
Pavements	Portland cement concrete driveway and parking areas will be constructed on the site. The anticipated ACI traffic categories (per ACI 330-21) and daily truck traffic will consist of: ■ Category A: Car parking areas and access lanes, 1 truck per day ■ Category B: Entrance and truck service lanes, 10 trucks per day ■ Category E: Garbage/dumpster pads or fire truck lanes The pavement design period is 20 years.

We should be notified if any of the stated information is inconsistent with the planned construction, especially the grading limits, as modifications to our recommendations may be necessary.

Site Conditions

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project site is located along the west side of FM 720, south of US Highway 380 in Little Elm, Texas. Latitude / Longitude (approximate): 33.2216° / -96.9772° See Site Location

Item	Description
Existing Improvements / Current Ground Cover	■ Undeveloped parcel ■ Grass and bare earth
Existing Topography	Based on the North Central Council of Governments (NCTCOG) topographic maps, the site generally slopes down from north to south with elevation changes from 594 to 590 feet.
Geology	The site is situated within the Woodbine geologic formation.

Geotechnical Characterization

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of the site. Conditions observed at each boring are indicated on the individual logs. The individual logs can be found in the Exploration and Laboratory Results and the GeoModel can be found in the Figures attachment.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	Native Sand Soils	Clayey Sand, brown to brown gray
2	Native Clay Soils	Sandy Lean Clay, Sandy Fat Clay, Fat Clay, brown to brown gray, gray
3	Bedrock	Shale, dark gray, with sandstone seams and layers

Groundwater was observed in borings B-1 and B-2 at 17 feet during drilling operations. Groundwater was not observed in the remaining borings while drilling, or for the short duration the borings could remain open. These groundwater observations provide an indication of the groundwater conditions present at the time the borings were drilled. Groundwater conditions may be different at the time of construction.

A relatively long period may be necessary for a groundwater level to develop and stabilize in a borehole. Long-term observations in piezometers or observation wells sealed from the

influence of surface water are often required to define groundwater levels. Long-term groundwater monitoring was outside the scope of services for this project.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Groundwater levels during construction or at other times in the life of the structure may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

Seismic Site Class

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7-16 and the International Building Code (IBC 2021). Based on the soil/bedrock properties observed at the site and as described on the exploration logs and results, our professional opinion is that a Seismic Site Classification of C be considered for the project. Subsurface explorations at this site were extended to a maximum depth of 35 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

Geotechnical Overview

Subsurface conditions encountered in the borings consist of clay and sand soils overlying shale bedrock. Groundwater was present in the deep borings.

Expansive soils are present on this site. The magnitude of the moisture induced potential vertical movement (PVM) is dependent on several factors including the thickness of active clay soils and moisture levels of the overburden soils at the time of construction. Based on the plasticity index (PI) of the soils and swell tests, the maximum PVM of the site soils is estimated to be on the order of 3 to 5 inches when the soils are in a dry moisture state.

The expansive soils present at this site can subject shallow foundations and floor slabs to significant differential movements due to moisture fluctuations in the soils. This report provides recommendations to help mitigate the effects of soil shrinkage and expansion; however, even if these procedures are followed, some movement and cracking in the

structure should be anticipated. The severity of cracking and other damage such as uneven floor slabs will increase if excessive wetting or drying of the expansive soils is allowed to occur during or after construction.

Straight drilled shafts bearing in dark gray shale are recommended to support the proposed structure. Grade beams and pier caps should be supported by the drilled shaft foundations with a void space between the grade beams and the subsurface clay soils. The floor slab should be structurally supported above the subgrade soils if floor slab movements cannot be tolerated. If movements on the order of 1 inch are acceptable, the floor slab can be placed on a modified subgrade. The Deep Foundations section addresses support of the building foundations. The Floor Systems section addresses structurally suspended and grade supported floor slabs.

As an alternative to deep foundations, footing foundations bearing on moisture conditioned soils could be used to support the proposed building if movements of the foundation and slab can be tolerated. The Footing Foundations section addresses support of the building on spread footings. The Building Pad Preparation section addresses the preparation of the subgrade.

Portland cement concrete (PCC) pavement sections can be used for the pavement area. The Pavements section addresses the design of pavement systems.

The recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, and our current understanding of the proposed project. The General Comments section provides an understanding of the report limitations.

Earthwork

Earthwork is anticipated to include clearing and grubbing, excavations, and engineered fill placement. The following sections provide recommendations for use in the preparation of specifications for the work.

Site Preparation

The site should be stripped and grubbed to remove all vegetation, root balls, deleterious material, and debris. Excavation required to remove the root balls should be backfilled with properly placed and compacted fill as discussed in Fill Placement and Compaction Requirements. The exposed subgrade should then be proofrolled prior to placing any fill. In cut areas, proofrolling should be performed after excavating to final grade. The proofrolling should be performed with a fully loaded, tandem-axle dump truck or other equipment providing an equivalent subgrade loading. A minimum gross weight of 20 tons is recommended for the proofrolling equipment. Where practical, the

proofrolling should consist of several overlapping passes in mutually perpendicular directions over a given area. Any soft or pumping areas should be modified using one of the methods discussed in this section.

Methods of remediating soft areas identified during the proofrolling include scarification and compaction at the proper moisture content, lime/cement treatment, or removal of unstable materials and replacement with flexible base (with or without a geogrid). The appropriate method of improvement, if required, would be dependent on factors such as schedule, weather, the size of the area to be stabilized, and the nature of the instability. More detailed recommendations can be provided during construction as the need for subgrade modification occurs. Performing site grading operations during warm seasons and dry periods would help to reduce the amount of subgrade stabilization required.

Building Pad Preparation

The following recommendations are for slab-on-grade construction. If the floor slab is structurally suspended above the clay soils as discussed in Structurally Suspended Floor System, the following recommendations do not apply.

Floor slabs, shallow foundations and flatwork placed on-grade will be subject to movement as a result of moisture induced volume changes in the active clay soils that can occur following construction. The soils expand (heave) with increases in moisture and contract (shrink) with decreases in moisture.

The magnitude of the moisture induced potential vertical movement (PVM) is variable and is influenced by the soil properties, overburden pressures, thickness of clay, and soil moisture levels at the time of construction. Based on the soil types and thickness encountered in the borings, the PVM for slabs placed on grade is estimated to be about 3 to 5 inches for dry soil moisture conditions that can exist prior to construction. The PVM is estimated based on Texas Department of Transportation's Test Procedure Tex-124-E, dry soil conditions, and the results of swell tests.

Reductions in anticipated movements to about 1 inch can be achieved by using methods developed in this area. Suitable methods for this site consist of moisture conditioning the clay soils and capping them with flexible base. The moisture conditioning can be achieved by excavation and replacement, as described in the following table.

Material	Thickness
Flexible Base Cap	12 inches
Moisture Conditioned Clays	9 feet

The moisture conditioned subgrade should extend at least 10 feet beyond the building perimeter and include entrances, abutting sidewalks and other flatwork areas sensitive to movement. The flexible base is not required beyond the building perimeter.

The flexible base cap must be placed above the moisture-conditioned soils in a short period of time (i.e. within 48 hours) following completion of the moisture conditioning process to prevent the loss of soil moisture. If the surface of the moisture conditioned soil is allowed to desiccate prior to placement of the subsequent lift or cap, the desiccated soils should be reworked and placed in a moisture conditioned state.

If a shallow foundation system is utilized as discussed in Footing Foundations, a minimum 10-mil polyethylene sheeting should be placed above the moisture conditioned soils that extend beyond the building perimeter, in areas where pavement or flatwork are not constructed adjacent to the building. The polyethylene sheeting should be covered with 12 to 18 inches of properly compacted, on-site clay soils. If the surface of the moisture conditioned soils is allowed to desiccate prior to placement of the polyethylene sheeting, the desiccated soils should be reworked and placed in a moisture conditioned state.

It should be noted that excessive water from any source, during or after construction, could result in movements greater than the slab was designed to accommodate. For example, should leaks develop in underground water or sewer lines or the grades around the structure allow ponding of water, unacceptable slab movements could develop. Design parameters stated in this report assume the area around the structure will be well drained, landscape beds are not over watered or allow ponding of water, and utility leaks are promptly repaired. Trees should be planted at least one-mature tree height from the building. Root barriers should be installed if trees are planted closer.

Excavation and Replacement

If movements on the order of 1 inch are acceptable, the subgrade should be moisture conditioned by performing the following steps:

1. Excavate on-site soils to a depth of 9½ feet below finished building pad elevation. The excavation should extend laterally at least 10 feet beyond the building perimeter and should extend below any flatwork and pavement that is sensitive to movement.
2. Scarify any clay soils at the bottom of the excavation to a depth of 6 inches, adjust the soil moisture content and compact soil to meet the requirements for moisture conditioned soil as described in Fill Placement and Compaction Requirements.
3. Backfill the excavated area with the moisture conditioned soils up to 12 inches below finished building pad elevation as recommended in Compaction Requirements. The excavated soils or imported fill, except for deleterious materials or rock greater than 4 inches, can be placed as moisture conditioned soils in accordance with Fill Placement and Compaction Requirements for moisture conditioned clays.
4. Place 12 inches of flexible base material over the moisture conditioned subgrade as recommended in the aforementioned table to establish finish building pad

elevation. The flexible base material should be compacted as recommended in Fill Placement and Compaction Requirements. The flexible base should not extend beyond the perimeter of the structure.

Care should be taken that a lift of moisture conditioned soils is not allowed to desiccate prior to placing a subsequent lift. If the surface of the moisture conditioned soil is allowed to desiccate prior to placement of the cap, the desiccated soils should be reworked and placed in a moisture conditioned state as recommended in this report. Positive drainage must be provided away from the structure to prevent the ponding of water in the fill, during and following construction.

Fill Material Types

Fill materials should meet the following requirements.

Material Type	Description	Appropriate Use
On-Site Soils	Free of vegetation, organic material, debris, and rocks greater than 4 inches in maximum dimension.	■ General site grading ■ Pavement subgrade ■ Utility trench backfill ■ Moisture conditioned soils
Imported Fill	Clay soil free of hazardous chemicals, vegetation, organic material, debris, and rocks greater than 4 inches in maximum dimension, with a liquid limit (LL) of 60 or less	■ General site grading ■ Pavement subgrade ■ Utility trench backfill ■ Moisture conditioned soils
Flexible Base	TxDOT[1] Item 247, Type A or D, Grade 1-2. Recycled concrete meeting this gradation is acceptable.	■ Cap above moisture conditioned soil ■ Pavement subgrade

1. Texas Department of Transportation

Fill Placement and Compaction Requirements

We recommend that all fill be observed and tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test must be reworked and retested as required until the specified moisture and compaction requirements are achieved.

Recommendations for compaction are presented in the following table. Fills should be placed at a maximum loose lift thickness of 6 and 9 inches for hand-operated and heavy compaction equipment, respectively.

Item	Compaction	Moisture Content
On-Site Soils or Imported Fills Placed Outside the Moisture Conditioned Zone	A minimum of 95% maximum standard Proctor dry density (ASTM D698)	In the range of 0 to +4 percentage points of optimum moisture content
Moisture Conditioned Soil and Backfill Against the Face of Grade Beams	In the range of 93% to 98% maximum standard Proctor dry density (ASTM D698)	In the range of +4 to +8 percentage points of optimum moisture content [2]
Flexible Base	A minimum of 95% maximum standard Proctor dry density (ASTM D698)	In the range of -2 to +2 percentage points of optimum moisture content
Pavement Subgrades (Upper 6 Inches of Natural or Lime Treated Soil Below Pavement) [1]	A minimum of 95% maximum standard Proctor dry density (ASTM D698)	In the range of 0 to +3 percentage points of optimum moisture content

1. The compaction criteria in the fire lanes and public roadways must meet the requirements of the local governing authority.
2. Swell tests must be performed on the moisture conditioned soils to evaluate the compaction moisture content that results in 1 percent or less swell. The testing program is described in Construction Observation and Testing.

Utility Trenches Outside the Building Pad

Utility trenches are a common source of water infiltration and migration. All utility trenches that penetrate beneath the structure should be backfilled to restrict water intrusion and flow through the trenches that could migrate below the structure. We recommend constructing a clay or flowable fill “trench plug” that extends at least 2 feet out from the exterior perimeter of the building. The clay fill/flowable fill should be placed to surround the entire utility line and it should fill the utility trench in width and height, with the exception of topsoil at the surface. If a clay plug is used, it should consist of a clay soil with a minimum plasticity index (PI) of 30 and should be compacted in accordance with the applicable recommendations as described in Fill Placement and Compaction Requirements. If flowable fill is used, it should meet the requirement of TxDOT Item 401, excavatable characteristics.

Utility lines will be placed in backfilled trenches surrounded by expansive clays capable of moving several inches cyclically throughout the year. This level of movement can lead to bending, cracking, or separation of utility lines and connections. Care should be taken that utility trenches are not left open for extended periods, and they are properly

backfilled. Flexible joints and connections should be designed by the MEP to accommodate differential movements along the utility lines, particularly in areas where ground supported utilities and structurally supported utilities converge. Where utilities penetrate grade beams, wall panels, and below-grade walls, an opening should be provided in the grade beams, wall panels, and below-grade walls and the utility line should be centered in the opening. A clear spacing equivalent to the potential vertical movement (PVM) of the on-site soil should be provided between the outside surface of the utility line and the grade beam, wall panel, and below-grade wall. If moisture conditioning is performed as discussed in Building Pad Preparation, the PVM will be about 1 inch.

Earthwork Construction Considerations

The on-site clay soils exposed during construction are anticipated to be relatively stiff and therefore should be able to support lightly loaded construction equipment when dry; however, stability of the subgrade will be affected by rainfall and repetitive construction traffic. If unstable conditions develop, workability of the soils may be improved by scarifying and drying. Effective drainage should be completed early in the construction sequence and maintained after construction to avoid potential issues. If possible, the grading should be performed during the warmer and drier time of the year. If grading is performed during the winter months, an increased risk for possible undercutting and replacement of unstable subgrade will persist.

The earthwork contractor selected for moisture conditioning (by mechanically mixing of soil and water) should have experience with the process. Disks, plows or other equipment capable of mixing and achieving a uniform moisture content throughout each lift should be used. Proper equipment capable of achieving a uniform moisture content within the moisture conditioned fill is essential. Dry or extremely wet zones within the moisture conditioned fill can result in excess swelling if the fill is dry or settlement if the fill is too wet. Either of these conditions can be detrimental to the long-term performance of the building subgrade.

Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of grade-supported improvements such as floor slabs and pavements. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to floor slab construction.

Groundwater could affect excavation efforts. A temporary dewatering system consisting of sumps with pumps may be necessary to achieve the recommended depth of overexcavation depending on groundwater conditions at the time of construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, “Excavations” and its appendices, and in accordance with any applicable local and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety or the contractor's activities; such responsibility shall neither be implied nor inferred.

Excavations or other activities resulting in ground disturbance have the potential to affect adjoining properties and structures. Our scope of services does not include review of available final grading information or consider potential temporary grading performed by the contractor for potential effects such as ground movement beyond the project limits. A preconstruction/precondition survey should be conducted to document nearby property/infrastructure prior to any site development activity. Excavation or ground disturbance activities adjacent or near property lines should be monitored or instrumented for potential ground movements that could negatively affect adjoining property and/or structures.

Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of any existing fill, vegetation, any debris/ deleterious materials, trees, tree roots, and topsoil, proofrolling and mitigation of areas delineated by the proofroll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked as necessary until approved by the Geotechnical Engineer prior to placement of additional lifts as outlined in Fill Placement and Compaction Requirements and as recommended in the following table.

Testing Location	Frequency of In-Place Moisture and Density Tests
Building Pad Areas	At least 1 test per 2,500 sf of area per compacted lift with a minimum of 3 tests per lift
Pavement Areas	At least 1 test per 5,000 sf of area per compacted lift with a minimum of 3 tests per lift
Trench Backfill	At least 1 test for every 100 linear feet per lift of compacted trench backfill

Daily reports documenting activities, test results and a list on non-conforming tests should be provided to the team. The imported fill and flexible base should be sampled

and tested on a regular basis to confirm that it does meet the properties recommended in this report.

The following requirements must be met where moisture conditioning is used:

- The soil samples used to determine the soil moisture-density relationship (i.e., Proctor testing) of moisture conditioned materials with a plasticity index (PI) of 30 or higher should be allowed to cure for a minimum period of 48 hours following the addition of water and prior to compaction.
- Prior to the start of the moisture conditioning operations, laboratory swell testing is required on laboratory compaction sample points (i.e., Proctor points) to evaluate the target field moisture contents that result in 1 percent swell or less. Swell tests should be performed on the laboratory compaction sample points (i.e., Proctor points) that are prepared at molding water contents greater than optimum moisture. The swell tests must be performed with a surcharge pressure of 250 psf. The water content that results in 1 percent or less swell should be considered the minimum field target moisture content to be used during moisture conditioning.
- Swell tests must be performed on the moisture conditioned soils during earthwork operations to verify that the target moisture content for the moisture conditioned soil results in 1 percent or less swell at the estimated overburden pressures at completion of grading. Samples of the moisture conditioned fill should be periodically obtained as the fill is being placed, and swell test performed with the applicable overburden pressure applied. Should the swell exceed 1 percent, the specified moisture content of the moisture conditioned soils should be adjusted to achieve 1 percent or less swell. In areas of foundation excavations, the bearing subgrade should be evaluated by the Geotechnical Engineer. If unanticipated conditions are observed, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

Site Grades and Drainage

All permanent slopes taller than 6 feet should be 4 Horizontal to 1 Vertical (4H:1V) or flatter. A slope stability analysis should be performed if steeper slopes are considered.

Positive drainage away from the building must be provided during the construction and maintained through the life of the building. Infiltration of water into excavations should be prevented during construction. It is important that subgrade soils are not allowed to

become excessively wet or dry. Exposed (unpaved) ground should be sloped away from the building for at least 10 feet beyond the perimeter of the building.

Roof runoff and surface drainage should be collected and discharged away from the building to prevent wetting of the subgrade soil. Roof gutters should be installed and connected to downspouts and pipes directing the roof runoff at least 10 feet away from the building or discharged on to positively sloped flatwork such as the aprons. Also, consideration can be given to having roof drains discharged directly into the storm drainage system.

Locally, flatter grades may be necessary to transition ADA access requirements for flatwork. After building construction and landscaping, final grades should be verified to document effective drainage has been achieved. Grades around the structures should also be periodically inspected and adjusted as necessary as part of the structure's maintenance program. Where paving or flatwork abuts the structures, a maintenance program should be established to effectively seal and maintain joints and prevent surface water infiltration. Water permitted to pond next to the structures can result in greater soil movements than those discussed in this report. Estimated movements described in this report are based on effective drainage for the life of the structures and cannot be relied upon if effective drainage is not maintained.

Landscape Considerations

Sprinkler mains and spray heads should be located at least 5 feet away from the building such that they cannot become a potential point source of water directly adjacent to the building. Watering of vegetation should be performed in a timely and controlled manner and prolonged watering, or prolonged non-watering periods should be avoided. Special care should be taken such that underground utilities do not develop leaks with time.

The owner and landscape designer should be made aware that placing large bushes and trees adjacent to the building may cause significant moisture variations in the soil underlying the building that could cause distress. A general guideline would be to locate trees no closer than a distance equal to the mature tree height for that tree species. Planters located adjacent to the building should preferably be self-contained, or at least designed to drain away from the building.

Deep Foundations

Straight Drilled Shafts - Axial Capacity

Straight drilled shaft foundations can be used to support the loads of the planned structures. They should be designed in accordance with the recommendations provided in the following table.

Design Parameter	Recommendations
Bearing Stratum	Dark Gray Shale
GeoModel Layer No.	3
Approximate Depth Below Existing Grades to Bearing Stratum	14 to 22 feet
Maximum Net Allowable End Bearing Capacity [1]	16,500 psf
Allowable Skin Friction – Compression [1]	2,500 psf
Allowable Skin Friction – Tension [1]	1,850 psf
Minimum Penetration to Develop End Bearing	3 feet or 1 shaft diameter, whichever is greater.
Minimum Penetration to Develop Skin Friction	Below the surface of the shale or below any temporary casing set in the shale, whichever is deeper.
Minimum Center-To-Center Spacing to Develop Full Skin Friction	3 times the diameter of the larger shaft. Closer spacing may require some reductions in skin friction and/or changes in installation sequences. Closely spaced shafts should be examined on a case-by-case basis. As a general guide, the design skin friction will vary linearly from the full value at a spacing of 3 diameters to 50 percent of the design value at 1 diameter.
Groups of 3 or More Shafts Spaced Closer Than 2.5 Shaft Diameters	Should be evaluated on a case-by-case basis by this office. Alternative installation sequences may be needed to allow for a minimum of 48 hours concrete curing time, before installation of adjacent shafts.

Design Parameter	Recommendations
Total Settlement [2]	Less than ½ inch
Differential Settlement [2]	50 to 75 percent of the total settlement

1. The allowable end bearing and skin friction (both compression and tension) values are based on a safety factor of 3.
2. The foundation settlement will depend upon the variations within the subsurface profile, the structural loading conditions, and the embedment depth.

Lateral Capacity

The following table lists input values for use in LPILE analyses. Modern versions of LPILE provide estimated default values of k_h and ε_{50} based on strength and are recommended for the project. Since deflection or a service limit criterion will most likely control lateral capacity design, no safety/resistance factor is included with the parameters.

Design Parameter	Moisture Conditioned Clay Soils	Undisturbed Clay and Clayey Sand Soils	Dark Gray Shale
LPILE Material Type	Soft Clay	Stiff clay w/o free water	Weak Rock (Reese)
Effective Unit Weight (pcf)	120	125 (above water table) 62 (below water table)	135
Undrained Cohesion, c (psf)	500	1,750	N/A
Initial Modulus of Rock Mass, Er (psi)	N/A	N/A	14,000
Uniaxial Compressive Strength (psi)	N/A	N/A	140
Rock Quality Designation, RQD (%)	N/A	N/A	70
K_{rm}	N/A	N/A	0.0005

Soil Induced Uplift Loads

Drilled shafts will be subject to uplift as a result of heave in the overlying clay soils. The magnitude of these loads varies with the shaft diameter, soil parameters, and the in-situ moisture levels at the time of construction. The shafts must contain sufficient continuous vertical reinforcing to resist the net tensile load (soil induced uplift minus structural dead load). The drilled shafts must have enough embedment depth into the bedrock to resist the net tensile load.

For the conditions encountered at this site, the uplift load can be approximated by assuming a uniform uplift of 1,800 psf over the shaft perimeter for a depth of 10 feet or to the top of rock. If the building pad is moisture conditioned as discussed in Building Pad Preparation, a uniform uplift of 500 psf can be used within the moisture conditioned zone.

Drilled Shafts Construction Considerations

The construction of all drilled shafts should be observed by experienced geotechnical personnel during construction to confirm: 1) the bearing stratum; 2) the minimum bearing depth; 3) that groundwater seepage, if encountered, is correctly handled; and 4) that the shafts are within acceptable vertical tolerance.

Recommendations for drilled shaft construction are presented in the following table.

Item	Recommendation
Drilled Shaft Installation Specification	Current version of American Concrete Institute's "Standard Specification for the Construction of Drilled Piers" ACI 336.
Top of Shaft Completion	Enlarged (mushroom-shaped) top in contact with the clays should not be allowed.
Time To Complete	Drilled shaft construction should be completed within 8 hours in a continuous manner to reduce side wall and base deterioration.
Installation Methods	Shaft excavations should be installed using dry methods within the bearing material. The concrete should be placed in a manner to avoid striking the reinforcing steel during placement. Care should be taken to not disturb the sides and bottom of the excavation during construction. The bottom of the shaft excavation should be free of loose material and less than 3 inches of water before concrete placement. Concrete should be placed as soon as possible after the foundation excavation is completed, to reduce potential disturbance of the bearing surface.

Item	Recommendation
Groundwater Control	Seepage was observed in the borings and will likely be encountered during installation of the straight shafts, particularly during or following wet periods of the year. Seepage rates will be sufficient to require the use of temporary casing for installation of the straight shafts. The casing should be seated in the shale with all water and most of the loose material removed prior to beginning the design penetration. While withdrawing casing, care should be exercised to maintain concrete inside the casing at a sufficient level to resist earth and hydrostatic pressures acting on the casing exterior. Arching of the concrete, loss of seal and other problems can occur during casing removal and result in contamination of the drilled shaft. These conditions should be considered during the design and construction phases. Placement of loose soil backfill should not be permitted around the casing prior to removal. Groundwater can also be encountered in the shale/sandstone bedrock. This water usually cannot be controlled with casing. Underwater placement using a tremie or pumped concrete is often required. Mineral solid or chemical polymer slurry may be required to stabilize the shaft excavation. The properties and mixing of slurry and the installation of the shaft should follow the requirements in ACI 336. Tremied or pumped-in concrete for shafts should take place as continuously as possible until the concrete placement is complete. The bottom of the discharge pipe should always be kept below the surface of the concrete. Before tremied or pumped-in concrete is used, care should be taken to ensure that the water is at a stabilized level and muck is removed to as low a level as possible, which will provide for a thin water solution to be displaced during concrete placement. The pipe or tremie is to be plugged when inserted into the shaft and lowered until it is resting on the bottom of the hole. It should be filled with concrete and then lifted off the bottom about 1 foot. The concrete should then be placed in a continuous operation until all water is forced out of the hole. The tremie or pipe must always have about 10 feet of pipe into the concrete. Once the water is forced from the shaft, the remaining concrete operation will be the same as for a cased hole.

The drilled shaft installation process should be performed under the observation of the Geotechnical Engineer. The Geotechnical Engineer should document the shaft installation

process including soil/rock and groundwater conditions observed, consistency with expected conditions, and details of the installed shaft.

Grade Beams, Pier Caps, and Wall Panels

All grade beams should be supported by drilled shafts. A minimum void space of 10 inches is recommended between the bottom of grade beams, pier cap extensions, and walls panels and the subgrade soil. The void space may be reduced to 4 inches where it is founded within the moisture conditioned fill. This void will serve to reduce distress resulting from swell pressures generated by the clay soils. Structural cardboard forms are one acceptable means of providing the void space beneath cast-in-place elements. Soil retainers should be used to prevent infilling of the void.

The grade beams should be formed rather than cast against earth trenches. Backfill against the exterior face of grade beams, wall panels and pier caps should be on site materials placed and compacted as described in Fill Placement and Compaction Requirements.

Footing Foundations

Footing foundations can be used to support the proposed structure if it can tolerate vertical movements. They should be designed in accordance with the recommendations provided in the following table.

Design Parameters – Compressive Loads

Item	Description
Bearing Stratum [1]	Modified subgrade placed in accordance with recommendations in Building Pad Preparation (moisture conditioned clays)
Maximum Net Allowable Bearing Pressure [2, 3]	1,500 psf
Minimum Foundation Dimensions	Per IBC
Minimum Embedment Below Finished Grade	24 inches
Ultimate Passive Resistance [4]	1,500 psf (uniform)
Ultimate Sliding Resistance	350 psf adhesion
Estimated Total Settlement from Structural Loads [3]	Less than about 1 inch

Item	Description
Estimated Differential Settlement from Structural Loads [3, 5]	About 50 to 75 percent of total settlement
Estimated Vertical Movement Due to Active Clay Soil	About 1 inch

1. Unsuitable or soft soils should be over excavated and replaced per the recommendations presented in Earthwork.
2. The maximum net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. Values assume that exterior grades are no steeper than 20% within 10 feet of structure.
3. Values provided are for maximum loads noted in Project Description. Additional geotechnical consultation will be necessary if higher loads are anticipated.
4. Use of passive earth pressures require the sides of the excavation for the spread footing foundation to be nearly vertical and the concrete placed neat against these vertical faces or that the footing forms be removed and compacted structural fill be placed against the vertical footing face. Assumes no hydrostatic pressure.
5. Differential settlements are noted for equivalent-loaded foundations and bearing elevation as measured over a span of 50 feet.

Design Parameters – Overturning and Uplift Loads

Shallow foundations subjected to overturning loads should be proportioned such that the resultant eccentricity is maintained in the center-third of the foundation (e.g., e < b/6, where b is the foundation width). This requirement is intended to keep the entire foundation area in compression during the extreme lateral/overturning load event. Foundation oversizing may be required to satisfy this condition.

Uplift resistance of spread footings can be developed from the effective weight of the footing and the overlying soils with consideration to the IBC basic load combinations.

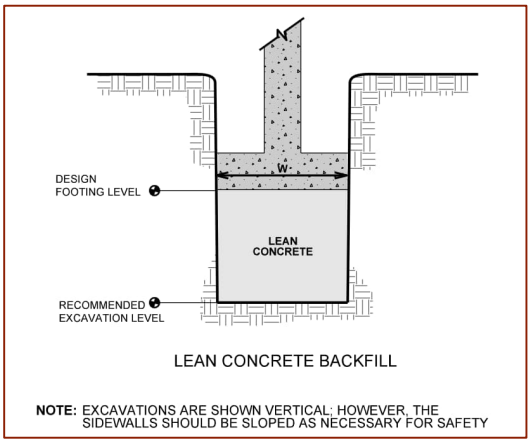
Item	Description
Soil Moist Unit Weight	125 pcf
Soil Effective Unit Weight[1]	63 pcf
Soil Weight Included in Uplift Resistance	Soil included within the prism extending up from the top perimeter of the footing at an angle of 20 degrees from vertical to ground surface

1. Effective (or buoyant) unit weight should be used for soil above the foundation level and below a water level. The high groundwater level should be used in uplift design as applicable.

Footing Foundation Construction Considerations

As noted in Earthwork, the footing excavations should be evaluated under the observation of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the footing excavations should be removed/reconditioned before foundation concrete is placed.

If unsuitable bearing soils are observed at the base of the planned footing excavation, the excavation should be extended deeper to suitable soils, and the footings could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. The lean concrete replacement zone is illustrated on the following sketch.



Floor Systems

The finished floor elevation is planned within ±2 feet from existing grade. Terracon should be contacted if the planned grading is changed so that we may review and/or modify the recommendations presented in this report.

Lightly loaded floor slabs and flatwork placed on-grade will be subject to movement as a result of moisture induced volume changes in the active soils that can occur following construction. The soils expand (heave) with increases in moisture and contract (shrink) with decreases in moisture. The movement typically occurs as post construction heave.

A structurally suspended system in conjunction with a drilled shaft foundation system is recommended if floor movements cannot be tolerated. If floor movements of about 1 inch are acceptable, the building floor slab can be supported on a modified subgrade that has been prepared to reduce soil movements according to the Building Pad Preparation section.

Movements of even ½ inch can result in uneven floors, sticking doors, and cracking of floor slabs and wall partitions. If the risk of these movements is unacceptable, the floor slab should be structurally supported above the active clays. Flatwork adjacent to the building should also be supported on modified subgrade if movements on the order of the site PVM cannot be tolerated.

The use of a vapor retarder should be considered beneath concrete slabs covered with wood, tile, carpet, or other moisture sensitive or impervious coverings, when the project includes humidity-controlled areas, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

Structurally Suspended Floor System

A minimum void space of 10 inches is recommended below a structurally suspended floor system. The minimum void space can be provided by use of cardboard carton forms, or a deeper crawl space. A ventilated and drained crawl space is preferred under the structures for several reasons, including the following:

- Ground movements will affect the project utilities, which can cause breaks in the lines and distress to interior fixtures.
- A crawl space permits utilities to be hung from the superstructure with a clear space provided between the utility and subgrade greater than or equal to the void space, which greatly reduces the possibility of distress due to ground movements. It also can provide ready access in the event repairs are necessary.
- Ground movements could be uneven. A crawl space can be positively drained preventing the ponding of water and reducing the possibility of distress due to unexpected ground movements.

The expansive soils at this site will undergo shrink and swell with changes in moisture content. This soil movement can damage plumbing below the structure, especially where it connects to or penetrates the structure. Damaged plumbing will leak, causing significantly more swelling of the soils, leading to possible failures of the plumbing or structural damage to the building. The project mechanical engineer should account for this concern in their designs.

Where slabs are isolated from expansive soils by an under-floor void space, such as with a crawl space or a space created by void forms, under-slab plumbing should be suspended so that plumbing, hangers, and supports are isolated from the expansive soil by a void space. The void space should be a minimum of 10 inches vertically clear above the subgrade and any plumbing, hangers, or supports. To protect and maintain the void space, soil below it should be sloped or benched on a minimum of 2 units horizontally for

every 1 unit vertically, or structurally retained in accordance with an approved design methodology that accounts for lateral expansion of expansive soil.

It should not be permitted for the plumbing, hangers, and supports below the slab or below the framing to be in contact with soil or any assemblage of materials that is in contact with soil within the active zone. As a clarifying exception to this recommendation, it is acceptable for plumbing to be suspended by a deep foundation system. These recommendations for isolation of plumbing can be met by installing anchors and plumbing within a crawlspace after an isolated slab is installed. It should not be permitted for a slab and plumbing to be lifted off the subgrade as an assembly to create the void space unless the under-floor space is a crawlspace with access to allow inspection of plumbing after lifting. At each location where a plumbing line transitions to a buried condition beyond the perimeter of the foundation, an adequately flexible expansion joint should be provided in the plumbing system to accommodate the effects of expansive soil swelling and shrinking. The flexible expansion joint should also be isolated from soil and accessible for maintenance. These recommendations for isolation of plumbing do not apply to the portions of a plumbing system that provide drainage of an under-floor space.

Several proprietary or patented systems are available on the market which are intended to isolate plumbing from expansive soil subgrades; however, many of these systems do not meet these recommendations. The project mechanical engineer should only use plumbing isolation systems on this project that are compliant with these recommendations.

Floor Slab and Flatwork on Modified Subgrade

Slab-on-grade construction should only be considered if slab movements on the order of 1 inch are considered acceptable. If floor movements of about 1 inch are acceptable, the building floor slab can be supported on a modified subgrade that has been prepared to reduce soil movements according to the Building Pad Preparation section.

Where floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or floor slab cracks beyond the length of the structural dowels. The Structural Engineer should account for potential differential settlement through use of sufficient control joints, appropriate reinforcing or other means.

Floor Slab Design Parameters

Item	Description
Floor Slab Support	For building pad prepared with moisture conditioned soils and a 1-foot cap of flexible base material as discussed in Building Pad Preparation.
Estimated Modulus of Subgrade Reaction [1]	100 pounds per square inch per inch (psi/in) for point loads

1. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in Earthwork, and the floor slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.

Floor Slab Construction Considerations

Finished subgrade, within and for at least 10 feet beyond the floor slab, should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or desiccated prior to construction of floor slabs, the affected material should be removed, and structural fill should be added to replace the resulting excavation. Final conditioning of the finished subgrade should be performed immediately prior to placement of the floor slab support course.

The Geotechnical Engineer should observe the condition of the floor slab subgrades immediately prior to placement of the floor slab support course, reinforcing steel, and concrete. Attention should be paid to high traffic areas that were rutted and disturbed earlier, and to areas where backfilled trenches are located.

Pavements

Parking and Drive Lane Pavement Subgrades

Subgrade materials at this site will most likely consist of clay and sand soils. Portland cement concrete pavements can be placed on unmodified, properly compacted subgrade. The pavement subgrades should be proofrolled as discussed in Site Preparation. The exposed pavement subgrade should be scarified to a depth of 6 inches and uniformly compacted to the criteria described in Fill Placement and Compaction Requirements.

If lime treatment of the pavement subgrade is required by the city in fire lanes, a minimum of 6 percent hydrated lime (TxDOT Item 260), by dry weight, is estimated for treating the subgrade soil. The lime application rate should be determined by laboratory testing once the pavement subgrade is rough graded. The lime should be thoroughly mixed and blended with the top 6 inches of the subgrade and uniformly compacted to the criteria described in Fill Placement and Compaction Requirements. Lime treatment should extend a minimum of 1 foot beyond the edge of the pavement.

Pavement subgrades should be protected and maintained in a moist condition until the pavement is placed. Pavement subgrades should be graded to prevent ponding and infiltration of excessive moisture on or adjacent to the pavement subgrade surface.

Site grading is generally accomplished early in the construction phase; however, as construction proceeds, the subgrade may be disturbed due to utility excavations, construction traffic, desiccation, or rainfall. As a result, the pavement subgrade may not be suitable for pavement construction and corrective action will be required. The subgrade should be carefully evaluated at the time of pavement construction for signs of disturbance or excessive rutting. If disturbance has occurred, pavement subgrade areas should be reworked, moisture conditioned, and properly compacted to the recommendations in this report immediately prior to paving.

Support characteristics of the subgrade for pavement design do not account for shrink/swell movements of an expansive clay subgrade, such as soils encountered on this project. Thus, the pavement may be adequate from a structural standpoint, yet still experience cracking and deformation due to shrink/swell related movement of the subgrade.

Pavement Sections

Design of portland cement concrete (PCC) pavements are based upon American Concrete Institute (ACI) 330-21 - Commercial Concrete Parking Lots and Site Paving Design and Construction - Guide.

Detailed traffic loads and frequencies were not available; however, we anticipate that traffic will consist primarily of passenger vehicles in the parking areas and passenger vehicles combined with emergency vehicles, occasional garbage trucks, service trucks, and delivery trucks in driveways. If heavier traffic loading is expected or other traffic information is available, Terracon should be provided with the information and allowed to review the pavement sections provided herein.

The anticipated ACI traffic categories (per ACI 330-21) and daily truck traffic will be assumed to consist of:

- Category A: Car parking areas and access lanes, 1 truck per day
- Category B: Entrance and truck service lanes, 10 trucks per day

- Category E: Garbage/dumpster pads or fire truck lanes

The pavement design period is 20 years.

The following table provides our estimated minimum thickness of PCC pavements.

Portland Cement Concrete Design

Layer	Thickness (inches)		
	Traffic Category A	Traffic Category B	Traffic Category E [2,3]
PCC [1]	5	6	7
Compacted Subgrade	6	6	6

1. The PCC should have a minimum 28-day compressive strength of 3,500 psi and should contain a minimum of 4.5±1.5 percent entrained air. As a minimum, the section should be reinforced with No. 3 bars on 18-inch centers in both directions. Refer to ACI PRC-330-21 “Commercial Concrete Parking Lots and Site Paving Design and Construction - Guide” for more information concerning joint spacing, joint depth, joint location, etc.
2. Traffic Category E will withstand the axle loading of an 85,000-pound fire truck weight.
3. If lime treatment is required by the city for fire lanes, the pavement thickness can be decreased by 1 inch. Alternatively, flexible base can be used in lieu of lime.

Pavement Maintenance

The pavement sections represent the minimum recommended thicknesses and, as such, periodic upkeep should be anticipated. Preventive maintenance should be planned and provided for through an on-going pavement management program. Maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment. Pavement care consists of both localized (e.g., crack and joint sealing and patching) and global maintenance (e.g., surface sealing). Additional engineering consultation is recommended to determine the type and extent of a cost-effective program. Even with periodic maintenance, some movements and related cracking may still occur, and repairs may be required.

Pavement Design Considerations

Proper joint spacing will be required to prevent excessive slab curling and shrinkage cracking. Joints should be sealed to prevent entry of foreign material and doweled where necessary for load transfer. PCC pavement details for joint spacing, joint reinforcement,

and joint sealing should be prepared in accordance with the most current ACI 325 and ACI 330 documents.

Where practical, we recommend early-entry cutting of crack-control joints in PCC pavements. Cutting of the concrete in its “green” state typically reduces the potential for micro-cracking of the pavements prior to the crack control joints being formed, compared to cutting the joints after the concrete has fully set. Micro-cracking of pavements may lead to crack formation in locations other than the sawed joints, and/or reduction of fatigue life of the pavement.

Openings in pavements, such as decorative landscaped areas, are sources for water infiltration into surrounding pavement systems. Water can collect in the islands and migrate into the surrounding subgrade soils thereby degrading support of the pavement. Islands with raised concrete curbs and irrigated foliage are particular areas of concern. The civil design for the pavements with these conditions should include features to restrict or collect and discharge excess water from the islands. Examples of features are edge drains connected to the stormwater collection system, longitudinal subdrains, or other suitable outlets and impermeable barriers preventing lateral migration of water such as a cutoff wall installed to a depth below the pavement structure.

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope to prevent ponding of water.
- Subgrade and pavement surfaces should be sloped to promote proper surface drainage.
- Install joint sealant and seal cracks immediately.
- Seal all landscaped areas in or adjacent to pavements to reduce moisture migration to subgrade soils.
- Compacted, on site clay soils should be used as backfill against the exterior side of curb and gutter.
- Place curb, gutter and/or sidewalk directly on clay subgrade soils rather than granular material.

General Comments

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the

Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client and is not intended for third parties. Any use or reliance of the information provided by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly affect excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety and cost estimating including excavation support and dewatering requirements/design are the responsibility of others. Construction and site development have the potential to affect adjacent properties. Such impacts can include damage due to vibration, modification of groundwater/surface water flow during construction, foundation movement due to undermining or subsidence from excavation, as well as noise or air quality concerns. Evaluation of these items on nearby properties are commonly associated with contractor means and methods and are not addressed in this report. The owner and contractor should consider a preconstruction/precondition survey of surrounding development. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

Figures

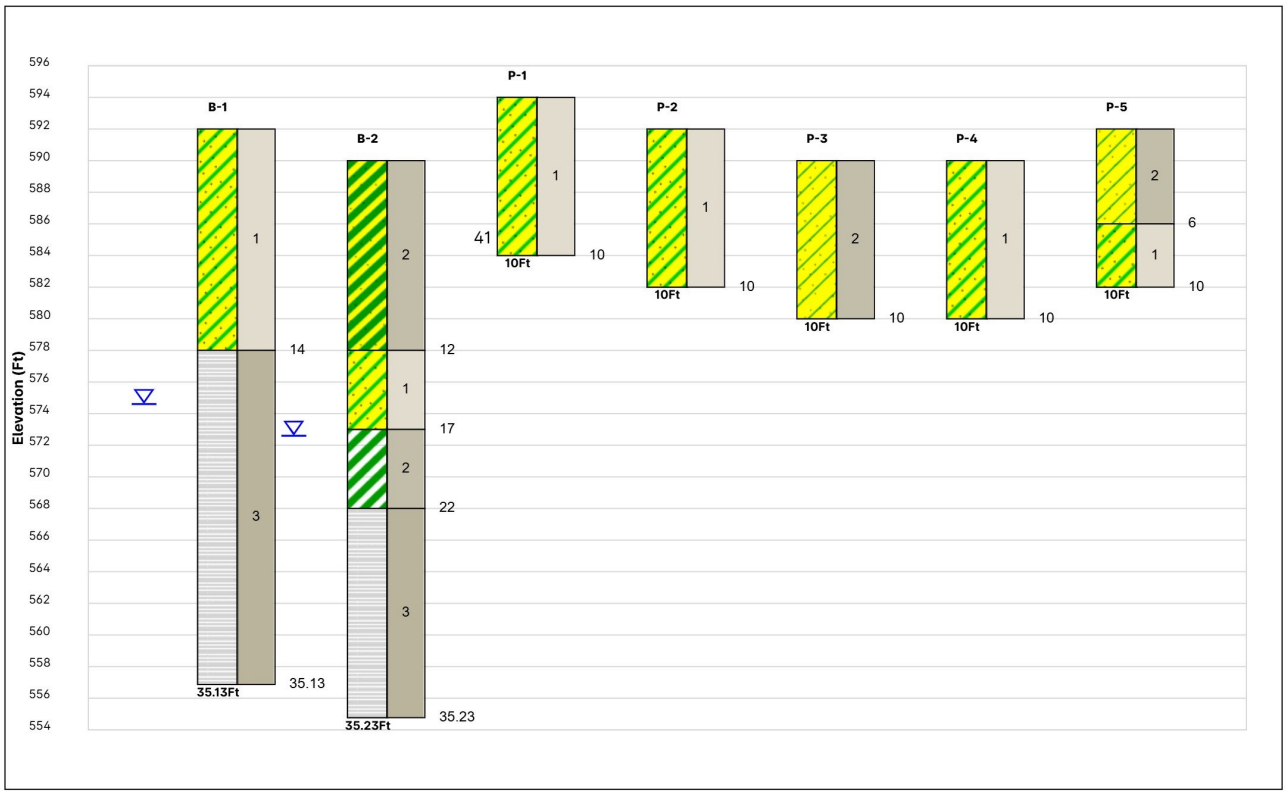
Contents:

GeoModel

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No: 94265131

Terracon
8901 John W Carpenter Fwy, Ste 100
Dallas, TX 75247-4547

GeoModel



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions

#	Layer Name	General Description
1	**Native Sand Soils**	Clayey Sand, brown to brown gray
2	**Native Clay Soils**	Sandy Lean Clay, Sandy Fat Clay, Fat Clay, brown to brown gray, gray
3	**Bedrock**	Shale, dark gray, with sandstone seams and layers

Legend

Clayey Sand	Shale	Sandy Fat Clay
Fat Clay	Sandy Lean Clay	

Notes:

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time.
Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

First Water Observation

Second Water Observation

Third Water Observation

Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.
Numbers adjacent to soil column indicate depth below ground surface.

Attachments

Exploration and Testing Procedures

Field Exploration

Borings	Approximate Boring Depth (feet)	Location
B-1 and B-2	35	Building area
P-1 through P-5	10	Parking and drive area

Boring Layout and Elevations: Terracon personnel provided the boring layout using handheld GPS equipment (estimated horizontal accuracy of about ±10 feet) and referencing existing site features. Approximate ground surface elevations were obtained by interpolation from topographical information available at www.dfwmaps.com.

Subsurface Exploration Procedures: We advanced the borings with a truck-mounted drill rig using continuous flight augers. Samples were obtained at 2 feet intervals in the upper 10 feet of each boring and at intervals of 5 feet thereafter using push tube sampling and split-spoon sampling procedures. In the push tube sampling procedure, a seamless steel tube with a sharp cutting edge was pushed hydraulically into the soil to obtain a relatively undisturbed sample. In the split-spoon sampling procedure, a standard 2-inch outer diameter split-spoon sampler was driven into the ground by an automatic hammer. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration is recorded as the Standard Penetration Test (SPT) resistance value. The load-carrying capacity of bedrock was evaluated in place by the Texas Department of Transportation (TxDOT) cone penetration test.

We observed and recorded groundwater levels during drilling and sampling. The groundwater levels are shown on the attached boring logs. For safety purposes, all borings were backfilled with auger cuttings after their completion.

The sampling depths, penetration distances, SPT resistance values (N-values), and other sampling information was recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a Geotechnical Engineer. Our exploration team prepared field boring logs as part of the drilling operations. These field logs included visual classifications of the materials observed during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field logs. The final boring logs represent the Geotechnical Engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests. The laboratory testing program included the following types of tests:

- Water (moisture) content
- Liquid limit, plastic limit, and plasticity index
- Unconfined compressive strength of soil
- Absorption swell tests
- Material finer than 75-µm (No. 200) sieve

The laboratory testing program often included examination of soil samples by an engineer. Based on the results of our field and laboratory programs, we described and classified the soil samples in accordance with the Unified Soil Classification System.

The results of the laboratory tests are presented on the individual boring logs, tables, or graphs in Exploration and Laboratory Results.

Site Location and Exploration Plans

Contents:

Site Location Plan
Exploration Plan

Note: All attachments are one page unless noted.

Site Location

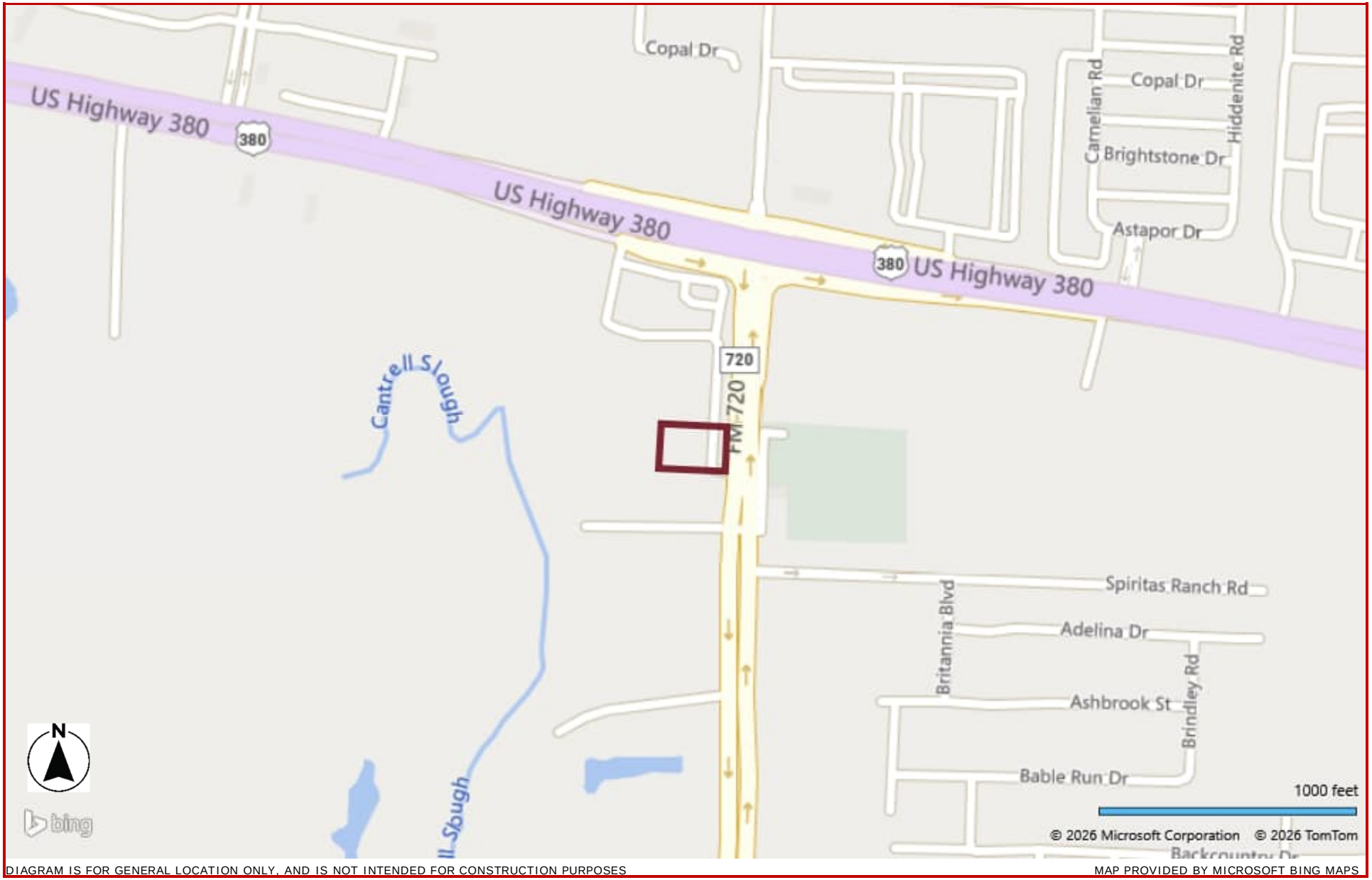


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

Exploration Plan

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS; OVERLAY PROVIDED BY EXPRESS OIL

Exploration and Laboratory Results

Contents:

Boring Logs (B-1 and B-2; P-1 through P-5)
Summary of Swell Tests

Note: All attachments are one page unless noted.

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22177864° Longitude: -96.97723387°

BORING LOG NO. B-1

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
592(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Water Level Observations	Field Test Results	Hand Penetrometer (tsf)	Strength Test: Compressive Strength (tsf)	Strength Test: Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Percent Fines	Swell/Collapse (%)	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI
1		14.0	**CLAYEY SAND (SC),** fine to medium grained sand, brown to brown gray, medium dense to dense, with ferrous nodules	0	592.0				4.5+			16						
									4.5+			17			1.4	46	12	34
				5					4.5+	2.76	1.4	14	113.7					
									4.5+			15		41.5		43	11	32
				10					4.5+	1.73	2.1	15	105.8					
3			**SHALE,** dark gray, with sandstone seams and layers	14	578.0			31-50/4"				21						
				15														
				20				40 - 50/5.5"										
				25				50/2.5" - 50/1.25"										
				30				50/2" - 50/3.25"										
				35				50/1" - 50/0.5"										
			Boring Terminated at 35.13 Ft															

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered upon completion
17 Ft. While drilling

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Hammer Type
Automatic

Driller
StrataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22154125° Longitude: -96.97718877°

BORING LOG NO. B-2

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
590(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Water Level Observations	Field Test Results	Hand Penetrometer (tsf)	Strength Test: Compressive Strength (tsf)	Strength Test: Strain (%)	Water Content (%)	Dry Unit Weight (pcf)	Percent Fines	Swell/Collapse (%)	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI
2			**SANDY FAT CLAY (CH),** brown gray, very stiff to hard, with ferrous nodules		590.0				4.5+			17						
									4.5+	3.25	6.5	17	113.6					
				5					4.5+			13		54.7		66	18	48
									4.5+			16						
									4.5+			20			3.0	50	17	33
				10														
		12.0			578.0													
1			**CLAYEY SAND (SC),** fine to medium grained sand, brown, dense					14-28-50/5"				20		28.4				
		17.0		15														
					573.0		▽											
2			**FAT CLAY (CH),** dark gray and light brown, hard, shaley, interbedded with sand						4.5+	4.66	5.8	17	112.3					
		22.0		20														
					568.0													
3			**SHALE,** dark gray, with sandstone seams and layers					50/3" - 50/1.25"										
				25														
								50/1.25" - 50/0.5"										
				30														
				35				50/1.75" - 50/1"										
			Boring Terminated at 35.23 Ft															

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered upon completion
▽ 17 Ft. While drilling

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Hammer Type
Automatic

Driller
StrataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.2218258° Longitude: -96.97746502°

BORING LOG NO. P-1

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
594(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Field Test Results	Hand Penetrometer (tsf)	Water Content (%)	Percent Fines	Atterberg Limits		
											LL	PL	PI
1			**CLAYEY SAND (SC),** fine to medium grained sand, brown to brown gray, medium dense to dense, with ferrous nodules	5	594.0			4.5+	13				
								4.5+	13	39.4	35	10	25
								2.0	5				
								4.5+	9				
							22-24-17 N = 41						
			Boring Terminated at 10 Ft										

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered while drilling
Groundwater not encountered upon completion

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Equipment
Subcontractor - JCB 50Z-1

Driller
StataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22154597° Longitude: -96.97750073°

BORING LOG NO. P-2

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
592(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Hand Penetrometer (tsf)	Water Content (%)
1			**CLAYEY SAND (SC),** fine to medium grained sand, brown to brown gray, medium dense to dense, with ferrous nodules	5	592.0		4.5+	
							4.5+	15
							4.0	13
							4.5+	17
							4.5+	
			Boring Terminated at 10 Ft					

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered while drilling
Groundwater not encountered upon completion

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Equipment
Subcontractor - JCB 50Z-1

Driller
StataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22151095° Longitude: -96.97731813°

BORING LOG NO. P-3

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
590(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Hand Penetrometer (tsf)	Water Content (%)	Atterberg Limits LL	PL	PI
2			**SANDY LEAN CLAY (CL),** brown to brown gray, hard, with ferrous nodules		590.0		4.25	16			
							4.5+	14			
				5			4.5+	15	48	13	35
							4.5+				
							4.5+				
			Boring Terminated at 10 Ft								

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered while drilling
Groundwater not encountered upon completion

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Equipment
Subcontractor - JCB 50Z-1

Driller
StataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22151845° Longitude: -96.9770111°

BORING LOG NO. P-4

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
590(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Hand Penetrometer (tsf)	Water Content (%)
1			**CLAYEY SAND (SC),** fine to medium grained sand, brown to brown gray, medium dense to dense, varying fines content, with ferrous nodules	5	590.0		4.25	19
							4.5+	16
							4.5+	
							4.5+	13
							4.5+	
			Boring Terminated at 10 Ft					

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered while drilling
Groundwater not encountered upon completion

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Equipment
Subcontractor - JCB 50Z-1

Driller
StataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

Brakes Plus - Little Elm
FM 720 E. University Drive, Little Elm, TX,USA
Terracon Project No. 94265131

Latitude: 33.22180811° Longitude: -96.97698981°

BORING LOG NO. P-5

8901 John W Carpenter
Fwy, Ste 100 Dallas, TX 75247-4547

Surface Elevation:
592(Ft) +/-

Model Layer	Graphic Log	Lithology Depth (Ft.)	Material Description	Depth (Ft.)	Elevation (Ft.)	Sample Type	Hand Penetrometer (tsf)	Water Content (%)	Percent Fines	Atterberg Limits LL	Atterberg Limits PL	Atterberg Limits PI
2			**SANDY LEAN CLAY (CL),** brown gray, very stiff to hard, with ferrous nodules		592.0		3.0	20				
							4.5+	14	54.2	46	15	31
				5			4.5+	13				
		6.0			586.0							
1			**CLAYEY SAND (SC),** fine to medium grained sand, brown, medium dense to dense, with ferrous nodules				4.5+					
							4.5+					
			Boring Terminated at 10 Ft									

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes
Elevation Reference: Elevations obtained from publicly available www.dfwmaps.com.

Water Level Observations
Groundwater not encountered while drilling
Groundwater not encountered upon completion

Abandonment Method
Boring backfilled with soil cuttings upon completion.

Equipment
Subcontractor - JCB 50Z-1

Driller
StataBore

Logged By
Costilla

Start Date
03/25/2026

Completion Date
03/25/2026

SUMMARY OF SWELL TESTS

Boring	Depth (ft)	Liquid Limit	Plasticity Index	Initial Moisture (%)	Final Moisture (%)	Surcharge (psf)	Swell (%)
B-1	2 to 4	46	34	16.3	18.6	375	1.4
B-2	8 to 10	50	33	21.8	29.0	1,125	3.0

Supporting Information

Contents:

General Notes
Unified Soil Classification System

Note: All attachments are one page unless noted.

General Notes

Sampling			Water Level	Field Tests	
Auger Cuttings	Modified California Ring Sampler	Rock Core	Water Initially Encountered	N	Standard Penetration Test Resistance (Blows/Ft.)
Dynamic Cone Penetrometer	Modified Dames & Moore Ring Sampler	Dual Sampler SPT	Water Level After a Specified Period of Time	(HP)	Hand Penetrometer
Grab Sample	GeoProbe Macro Core or Large Bore	No Recovery	Water Level After a Specified Period of Time	(T)	Torvane
Ring Sampler	Shelby Tube	Standard Penetration Test	Cave In Encountered	(DCP)	Dynamic Cone Penetrometer
Split Spoon	Texas Cone Penetrometer	Vane Shear	Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.	UC	Unconfined Compressive Strength
				(PID)	Photo-Ionization Detector
				(OVA)	Organic Vapor Analyzer

Descriptive Soil Classification

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

Location And Elevation Notes

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See Exploration and Testing Procedures in the report for the methods used to locate the exploration points for this project. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

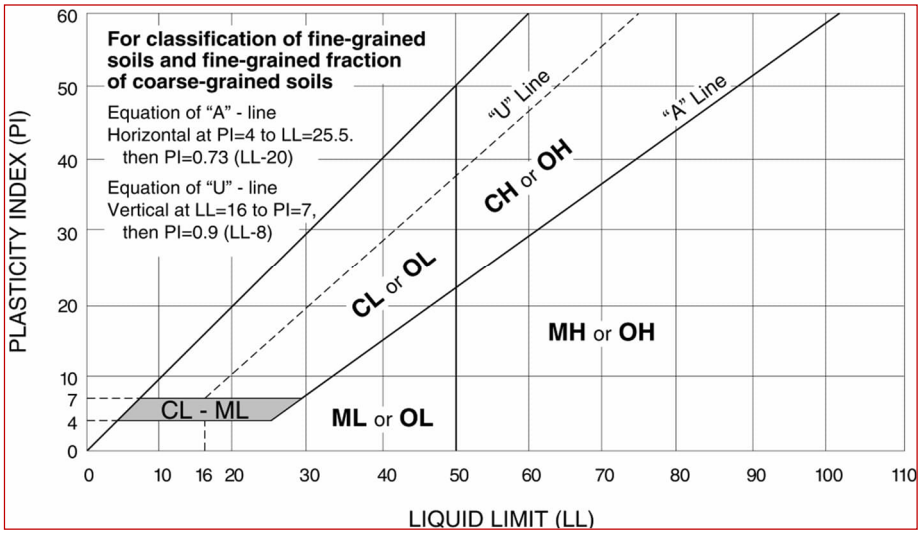
Strength Terms

Relative Density of Coarse-Grained Soils (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		Consistency of Fine-Grained Soils (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Relative Density	**Standard Penetration or N-Value (Blows/Ft.)**	**Consistency**	**Unconfined Compressive Strength Qu (tsf)**	**Standard Penetration or N-Value (Blows/Ft.)**
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	5 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	9 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	16 - 30
		Hard	> 4.00	> 30

Relevance of Exploration and Laboratory Test Results

Exploration/field results and/or laboratory test data contained within this document are intended for application to the project as described in this document. Use of such exploration/field results and/or laboratory test data should not be used independently of this document.

Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse-Grained Soils: More than 50% retained on No. 200 sieve	Gravels: More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels: Less than 5% fines [C]	Cu≥4 and 1≤Cc≤3 [E]	GW	Well-graded gravel [F]
			Cu<4 and/or [Cc<1 or Cc>3.0] [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands: Less than 5% fines [D]	Cu≥6 and 1≤Cc≤3 [E]	SW	Well-graded sand [I]
			Cu<6 and/or [Cc<1 or Cc>3.0] [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	Silts and Clays: Liquid limit less than 50	Inorganic:	PI > 7 and plots above "A" line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried}$ < 0.75	OL	Organic clay [K, L, M, N]
					Organic silt [K, L, M, O]
	Silts and Clays: Liquid limit 50 or more	Inorganic:	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic silt [K, L, M]
		Organic:	$\frac{LL\ oven\ dried}{LL\ not\ dried}$ < 0.75	OH	Organic clay [K, L, M, P]
					Organic silt [K, L, M, Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-inch (75-mm) sieve.
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay.
[E] $Cu = D_{60}/D_{10}$ $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[F] If soil contains ≥ 15% sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 4 and plots on or above "A" line.
[O] PI < 4 or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.