GEOTECHNICAL INVESTIGATION – REPORT NO. 1

Church Road and Cloice Creek Lift Stations
Waco, Texas

LFE Project No. W19-050
November 14, 2019

Report Prepared For:

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1.0 INTRODUCTION

Project Description: Work is planned at the Church Road and Cloice Creek Lift Stations, including new Lift Stations and Electrical Buildings at both locations. A Generator Pad is also planned at the Cloice Creek site.

The project vicinity is shown on Plate 1. The scope of services is described in Langerman Foster Engineering (LFE) proposal number GEO 18-146R1, dated April 23, 2019. Authorization was provided by the signature of CDM Smith Representative Allen D. Woelke, PE, Vice President dated June 28, 2019 on the project contract.

Sewer lines are also planned as part of this project, and were included in the Scope of Services to be addressed by LFE. A 2nd Report will be provided for the sewer lines.

Purpose: The purpose of this Geotechnical Investigation Report No. 1 has been to provide geotechnical design and construction recommendations for the proposed structures. These recommendations are based on field investigations, laboratory investigations, and engineering analysis of the investigation results.

2.0 SUBSURFACE EXPLORATION

Drilling Date: July 16, 2019.

Boring Layout: The approximate boring locations are shown on Plate 2. The locations shown are based on GPS coordinates collected with a handheld GPS device with a stated accuracy of +/- 16 feet.

Sampling and Drilling Operations: Boring 1 extended 35 feet, and Boring 11 extended 25 feet. Sampling and drilling details are shown on the boring logs in the Appendix. In general, push-tubes were used in cohesive soils, and Standard Penetration Tests
(SPT, ASTM D 1586) in harder soils. The borings were drilled without drilling fluid.

3.0 LABORATORY TESTS

Test Procedures: The following tests were conducted in general conformance with the standards noted in Table 3.1.

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atterberg Limits</td>
<td>ASTM D 4318</td>
</tr>
<tr>
<td>-#200 Mesh Sieve</td>
<td>ASTM D 1140</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>ASTM D 2216</td>
</tr>
<tr>
<td>Soil Classification</td>
<td>ASTM D 2487</td>
</tr>
<tr>
<td>Unconfined Compression (soil)</td>
<td>ASTM D 2166</td>
</tr>
</tbody>
</table>

Test Results: Laboratory test results are tabulated on Plate 3 in the Appendix, and on the boring logs.

4.0 SUBSURFACE MATERIALS

Geology: The Environmental Atlas of McLennan County\(^1\) maps the Church Road B1 site in alluvial soils, and near the Del Rio and Georgetown geologic formations. The Del Rio is described in the Baylor Geological Studies Environmental Atlas of McLennan County as a gray clay with a few thin limestone beds. The Atlas describes the Georgetown formation as consisting of limestone with a few thin layers of shale.

The Atlas maps the Cloice Creek B11 site in the Lake Waco Shale formation. This formation is described as primarily shale with limestone seams and layers.

Stratigraphy: Individual boring logs are contained in the Appendix. Material descriptions are general and range of depths approximate because boundaries between different strata are seldom clear and abrupt in the field. In general, the following was found at each Boring location.

- **Church Road** (Boring 1): Mostly fat clay (with a lean zone identified at about 9 to 12 feet, which also had water at about that depth) was encountered with varying sand content, and transitioned to a dark gray Shaly Clay at about 22 feet.

- **Cloice Creek** (Boring 11): Fill was encountered to about 4 feet, and consisted of sandy clay to clayey sand, with about 2-inch diameter pumice rock. A sulfur odor was also noted. Fat clay was then encountered to about 8 feet, followed by lean clay to about 12 feet, then clayey sand with gravel to about 16 feet. Sandy lean clay was then encountered to about 20 feet, followed by dark gray Shaly Clay to the 25-foot termination depth.

Groundwater: Groundwater was observed in the borings at each Lift Station as follows:

- **Church Road**. Groundwater was not encountered in Boring 1 during drilling. Water was measured at about 10 ½ feet below ground surface (BGS) at the end of the day, and the next day the water was measured about 10 feet BGS.

- **Cloice Creek**. In Boring 11, groundwater was initially measured about 15 feet BGS while drilling. Drilling was stopped when water was first encountered, and after about 10 minutes the water was measured about 7 feet BGS. At the end of the day, water was measured at about 6 feet BGS. The boring was backfilled the same day, so a next day reading was not obtained.

The water observations conducted for this investigation, except for the monitor wells, are short-term and should not be interpreted as a groundwater study. However, the presence of groundwater will affect construction and long-term performance of the proposed foundations.

Site Observations: Following are site pictures.
Subsurface Material Characteristics:

**Soil Movement Potential.** Clay soils in the Central Texas area tend to swell when allowed to increase in moisture content and shrink when allowed to decrease in moisture content. The moisture fluctuations occur due to seasonal wet and dry cycles, but are also influenced after construction by site grading, drainage, landscaping, and groundwater. Some clay soils swell when the overlying load is reduced, such as in the bottom of excavations. Soil movements can occur vertically, affecting foundations, and laterally, affecting retaining walls. Actual soil movement is difficult to predict due to the many variables involved.

Based on the TxDOT PVR method, and considering the results of the pressure swell tests and engineering judgement, LFE estimates about 3-inches of expansive soil potential vertical movement (PVM) at each site.

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### 5.0 GEOTECHNICAL FOUNDATION RECOMMENDATIONS

**Project Information:** The following is planned at the existing Church Road Lift Station, where Boring 1 was done:

- A new Lift Station, about 30 feet deep and about 13 ½ feet by 23 feet. The allowable soil bearing (net) at the base and lateral earth pressures for the wall are desired.
- A new Electrical building with a single level CMU wall and metal framed building measuring about 40 feet by 23 feet. Allowable soil bearing and recommendations for select fill below the building are desired.

The following is planned at the Cloice Creek Lift Station, where Boring 11 was done:
- A new Lift Station measuring about 18 feet deep and 14 ½ feet by 22 feet. The allowable soil bearing (net) at the base and lateral earth pressures for the wall are desired.

- A new Electrical building with a single level CMU wall and metal frame and roof building measuring about 25 ½ feet by 17 ½ feet. Allowable soil bearing and recommendations for select fill below the building are desired.

- A Generator Pad measuring about 13 feet by 20 ½ feet. Allowable soil bearing and recommendations for select fill below the building are desired.

Expansive Soil: Based on the TxDOT PVR method, and considering the results of the pressure swell tests and engineering judgement, LFE estimates about 3-inches of expansive soil potential vertical movement (PVM) at each site.

This movement can be up or down. Soil movement estimates are approximate. Actual soil movements will depend on the subsurface moisture fluctuations over the life of the structure. Soil movements may be less than those calculated if moisture variations are reduced after construction. However, significantly larger soil movements than estimated could occur due to inadequate site grading, poor drainage, ponding of rainfall, and/or leaking utilities. Good drainage is a critical factor in reducing the risk of foundation movements due to expansive soils, and good drainage should be obvious to the casual observer. Floor slabs must be adequately elevated above surrounding ground.

Groundwater: As was noted earlier in this report, groundwater was observed in the borings at each Lift Station as follows:

- **Church Road.** Groundwater was not encountered in Boring 1 during drilling. Water was measured at about 10 ½ feet below ground surface (BGS) at the end of the day, and they next day the water was measured about 10 feet BGS.

- **Cloice Creek.** In Boring 11, groundwater was initially measured about 15 feet BGS while drilling. Drilling was stopped when water was first encountered, and after about 10 minutes the water was measured about 7 feet BGS. At the end of the day, water was measured at about 6 feet BGS. The boring was backfilled the same day, so a next day reading was not obtained.
The Contractor must be prepared to handle subsurface water in excavations. Shallow groundwater is common in Central Texas, often as seasonal water associated with rainfall events or wet climate periods.

Non-Engineered Fill: **Cloice Creek.** Fill was not observed in Boring 11.

**Church Road.** Fill was encountered in Boring 1 to about 4 feet BGS, as shown on the boring logs. The actual fill depth may vary across the site. As noted on the log, LFE noted a sulfur odor and gravel that appeared to be pumice in the fill.

Non-engineered fill has unknown engineering properties such as strength and settlement potential, and should be removed and replaced with select fill that has known strength and settlement properties.

*Be aware that the borings drilled for this investigation were drilled exclusively for geotechnical purposes. Other environmental-related investigations may be warranted. For purposes of this report, we have assumed that the existing fill can be constructed upon. If environmental requirements demand that the existing fill be removed, remediated in place, or other special treatment is necessary, then we must be contacted to provide additional geotechnical recommendations.*

**New Electrical Building Foundations:**

The Project Structural Engineer plans to use a shallow foundation for the electrical buildings. We understand the option of a fully-suspended foundation on piers anchored below the soil movement zone with a void between the ground and floor slab is not being considered.

The foundation should be designed to account for the anticipated soil movement potential of about 3-inches. Recommendations for a Stiffened Slab on Grade to account for the soil movement potential are provided subsequently. LFE recommends that the Design Team consider the performance of the existing foundations when designing new foundation elements.

LFE recommends reducing the existing expansive soil PVM by removing and replacing (R&R) some depth of the existing clays to achieve the movement potential indicated by Table 5.1. Regardless of the depth of R&R, at least 1 foot of TxDOT Type A (or D) Grade 3 or better should be installed immediately beneath the slab to create generally consistent and
desirable support conditions for the slab. Recall that about 4 feet of non-engineered fill was observed in Boring 11, and is to be removed and/or replaced regardless of concerns about PVM reduction.

Spread footings near the ground surface on select fill meeting the requirements of this report or on natural firm soils such as were encountered in the borings may be sized for an allowable loading of 2000 psf. At the Cloice Creek site (Boring 11), non-engineered fill was encountered to about 4 feet, and may be deeper or shallower across the site. Non-engineered fill must be removed and/or replaced with select fill meeting requirements provided subsequently in this report.

Generator Pad at Cloice Creek:

Boring 11 was done at the Cloice Creek site. The concern for negative impacts from expansive soil movements on the generator pad may be less than for the electrical buildings. If so, less removal and replacement may be appropriate. Follow the design recommendations provided for the electrical building foundations, but reduce the depth of removal and replacement as deemed appropriate in light of acceptable potential vertical expansive soil movements. However, install at least 1-foot of TxDOT Type A or D, Grade 3 or better base immediately below the slab to create consistent conditions across the slab.

**STIFFENED SLAB ON GRADE**

![Schematic](image)

*Figure 5.1: Sketch of Stiffened Slab on Grade, for Illustration Only*
Risk: A properly designed and constructed stiffened slab on grade used in conjunction with replacement of expansive soils and non-engineered fill with select fill offers a low to moderate amount of risk of future foundation movements. The adverse movements occur as a result of shrinking and swelling of the expansive clay soils, which may result in cracking and differential movement of the slab.

Rigid architectural features such as masonry, stucco, CMU block walls and floor tiles do not perform well when the PVR exceeds approximately ½-inch. Allowances for differential movement including frequent movement joints will be required to reduce architectural cracking. A properly designed slab may perform satisfactorily from a structural standpoint but still experience architectural cracking.

From a practical standpoint, geometrically simple shapes (square or rectangular overall shape) can be expected to offer less risk of poor performance than more complex shapes with cut-outs or extensions that complicate the soil-structure interaction.

Stiffened Slab Design Parameters: The Building Research Advisory Board (BRAB) and Pre-stressed Concrete Institute (PCI) are two published design procedures for slabs on expansive soils. Both methods use an effective PI of the subsurface soils and a Regional Climatic Index of $C_w\approx 20$. Remove and replace existing soil with Select Structural Fill to a depth indicated in Table 5.1 as necessary to reach a soil movement potential acceptable to the Structural Engineer and Client. Select Structural Fill requirements are provided subsequently. Recall that about 4 feet of non-engineered fill was observed in Boring 11, and non-engineered fill of whatever depth is encountered in the field is to be removed and/or replaced regardless of PVM reduction concerns.
TABLE 5.1: REMOVAL AND REPLACEMENT TO REDUCE POTENTIAL VERTICAL MOVEMENT (PVM)

<table>
<thead>
<tr>
<th>Boring</th>
<th>Depth of Removal and Replacement (feet)</th>
<th>PVM, inches</th>
<th>Effective P.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>3</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1 ½</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1 ½</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1</td>
<td>22</td>
</tr>
</tbody>
</table>

Note: The PVR movements listed above are approximations. Actual movements will vary in part depending on site grading, drainage, and maintenance.

The removal must extend a minimum horizontal distance of 3 feet beyond the building perimeter. Select Structural Fill must then be placed and compacted as recommended in the following Section of this report.

A subgrade modulus of 150 kcf may be used for a slab resting on Select Structural Fill. At least 1 foot of TxDOT Type A or D, Grade 3 or better select fill is advised beneath the slab regardless of the final requirements for removal and replacement, in order to provide generally uniform conditions beneath the slab.

Bearing Pressure: An allowable bearing pressure of 2,000 psf can be used on Select Structural Fill or firm natural ground. Footings should bear at a depth of at least 24 inches below the final ground surface.
MISCELLANEOUS DESIGN ITEMS:

Subgrade Improvement:  The onsite soils may be unstable during construction, and subgrade pumping may occur. The following 3 options can be considered to create a firm working surface where needed. Other options may be available that should be evaluated by LFE and the Design Team prior to use.

- Layer of crushed stone;
- Lime treatment; and
- Natural drying;

For the **crushed stone option**, field conditions will dictate the needed thickness. The crushed stone must be clean and should generally range in size from 3 to 5 inches. Compaction specifications do not apply; however, the rock should be placed in such a manner that stabilizes the soils. This type of clean stone is normally used to stabilize construction entrances and should be readily available. However, this stone may interfere with utility installations and excavations in general. If more than about a foot of crushed stone is used, a filter fabric should be installed to prevent fines from migrating out of the overlying soils into the crushed stone.

**Lime** can also be used to create a working platform. Since this is a temporary measure to facilitate construction for the contractor’s convenience, the contractor shall determine the lime percentage and procedure as the contractor may deem appropriate. However, lime can affect vegetation, and the Design Team must be made aware of plans for using lime to assess the effect on vegetation or other project aspects.

A working platform may also be made by **allowing the soil to naturally dry** to increase strength. The contractor may wish to scarify and re-compact the pumping subgrade as required to accelerate drying and achieve a non-pumping subgrade.

Seismic:  For structural designs based upon the 2015 IBC, the following criteria apply. The Site Class is C. The Mapped Spectral Response Acceleration at short periods (SS) is about 0.10g, and the Mapped Spectral Response Acceleration at a 1 second period (S1) is about 0.04g. Site Coefficients are as follows: $F_a = 1.2$ and $F_v = 1.7$. 
Utility Connections: Depending on the foundation system selected, utilities resting on or within expansive soils are subject to soil movements. Utility connections should account for such movement potential, such as by using flexible connections. Rigid utilities should be suspended above the soils in suspended floor foundations.

Corrosion Protection: Based on our previous experience, clay soils are corrosive to buried metals. Corrosion protection should be provided for such metals. If granular backfill materials are used for the utility lines, then a clay plug must be placed at the exterior foundation penetrations to avoid water intrusion and collection within the utility trenches.

Review by MEP: We recommend that this report be provided to the project Mechanical, Electrical, and Plumbing engineers (MEP’s). Their designs should account for the estimated soil movement potential. We are available to help with questions they may have about soil movements.

Slab Elevation Survey: In areas of expansive soils or other more challenging foundation design situations, knowing the topography of the finished floor immediately after construction is important if foundation performance becomes an issue after construction. LFE recommends retaining a registered surveyor to conduct a topographic survey of the finished floor that can be used as a baseline if needed for future comparisons.

6.0 LIFT STATION RECOMMENDATIONS

Project Information: Figure 6.1 shows the planned Church Road Lift Station, which is to be about 30-feet deep and about 13 ½ by 23-feet. It will connect to the existing lift station.

LFE respectfully recommends that the structural engineer consider the structural condition of the existing lift station and confirm that the new design addresses perceived problems with the structural performance of the existing lift station. LFE is not aware of known structural issues, but should be informed of them so that they can be considered in light of the recommendations of this report.
Figure 6.1. CDM September 2019 Drawing of Planned Church Road Lift Station, Sheet SA-1

Figure 6.2 shows the planned Cloice Creek Lift Station, which is to be about about 18 feet deep and 14 ½ by 22-feet.
Figure 6.2. CDM Drawing of Planned Cloice Creek Lift Station

Buoyancy: The structure will be subject to hydrostatic uplift. The weight of the soil above the lip of the mat foundation extending beyond the lift station walls will help anchor against uplift, as will the submerged weight of the structure. LFE recommends using 43 pcf for the submerged weight of the soil directly above the lip to resist buoyancy. If additional resistance is needed, contact LFE for widening the geometry of the soil above the lip, which would increase the weight of the soil above the lip.

Net Bearing Capacity: The net pressure is the pressure above the existing overburden pressure. At the Church Road Lift Station, shaly clay was encountered below about 22 feet in Boring 1, and may have encountered limestone. LFE recommends using a conservative 3000 psf net allowable bearing capacity.
in the Shaly Clay. Please contact LFE to consider a greater design bearing capacity if a higher value would create a more desirable design.

At the Cloice Creek Lift Station, sandy lean clay was encountered at about 16 feet, and shaly clay at about 20. However, clayey sand was encountered from 12 to about 16 feet. LFE recommends using 2000 psf net allowable bearing capacity in the sandy lean clay or clayey sand. However, construction operations and hydrostatic pressures from natural groundwater in the more granular seams may compromise the bearing capacity of the excavation bottom during construction. Construction recommendations to assure the recommended bearing capacity are discussed in the following Bottom Heave subsection.

Settlement: Settlements and shrink/swell from expansive clays are expected to be on the order of 1 inch.

Bottom Heave: Excavations may be subject to bottom heave, although shaly clay is unlikely to exhibit bottom heave unless a sandy layer is present. In this situation, groundwater flowing upward through a sandy layer may cause the overlying clay soils to heave upward and create a bulge at the bottom of the excavation. Quick conditions are also possible.

The bottom of the excavation may be unstable, and it may be necessary to place clean rock and/or a mud mat to increase the firmness. Clean rock should consist of locally available 3 to 5-inch crushed stone. The amount of clean rock will need to be determined during construction, and LFE will be available to assist based on the actual field conditions encountered. A filter fabric is recommended above the rock if the thickness exceeds about 1-foot, to reduce migration of fines from the overlying select fill into the voids between the rock.

Below Grade Walls: Below grade walls will be constructed for the sidewalls. These types of walls are normally considered to be restrained at the top, and at-rest earth pressures apply. Table 7.1 contains lateral earth pressure criteria, and assumes submerged conditions for the backfill.
TABLE 6.1: EARTH PRESSURE PARAMETERS

<table>
<thead>
<tr>
<th>Earth Pressure</th>
<th>Coefficient</th>
<th>Equivalent Fluid Pressure (pcf)</th>
<th>Surcharge Pressure, $P_1$ (psf)</th>
<th>Earth Pressure, $P_2$ (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At-Rest ($K_0$)</td>
<td>0.50</td>
<td>96</td>
<td>(0.5)S</td>
<td>96X</td>
</tr>
</tbody>
</table>

- Values assume Select Structural Backfill, that the walls are NOT drained, and hydrostatic forces have been added in the table.
- Earth pressure parameters do not include a factor of safety
- Resultant Horizontal Forces per linear foot:
  - $R_{H1} = (P_1)(X)$, where $R_{H1}$ is acting at $\frac{1}{2}X$ from the top of the wall
  - $R_{H2} = (0.5)(P_2)(X)$, where $R_{H2}$ is acting at $\frac{2}{3}X$ from the top of the wall

Common Backfill: Select Structural Backfill must be used against the walls to use the lateral earth pressures shown in Table 6.1. Otherwise, higher earth pressures must be used. The wedge of Select Structural Backfill should extend from the bottom of the wall up and away from the wall at a 2 vertical to 1 horizontal slope. Common backfill outside of this zone outside of the walls may consist of on-site clay soils provided that these materials are placed with a high moisture content and loose compaction (92% to 95% of Standard Proctor at the optimum moisture content or higher). The intent is to avoid unanticipated pressure on the walls from expansive clay squeezing and/or from over-compaction.

Select Structural Backfill: Figures 6.1 and 6.2 also show Select Structural fill. The advantage of Select Structural Fill is that it is essentially non-expansive, and will not produce swelling pressure on the walls. Select Structural Fill may consist of TxDOT Type A or D, Grade 3 or better material.
Backfill immediately against the wall may also consist of free-draining aggregate such as is described in September 2019 CDM drawings as follows:


To reduce the risk of over-compaction generating higher lateral loads on the walls than shown in Table 6.1, Select Structural Fill behind walls should have a compaction of 92 to 95 percent of Standard Proctor at 0 to +4% of optimum moisture. However, this increases the risk of settlement at the ground surface. Where construction is planned on top of the backfill, construction on top of the backfill should be delayed as long as possible so that primary settlement can occur prior to above-ground construction. Settlement plates could be installed to periodically monitor settlement and to document that primary settlement has occurred. As shown in Figure 6.2, CDM plans to use columns supported on spread footings founded on firm natural subgrade to support concentrated loads at the ground surface, so as not to be concerned about general ground settlement.

Otherwise, where slabs or other structures will rest on wall backfill, we understand that CDM has specified 95% of Standard Proctor density on past projects, without negative impacts on the wall performance and without harmful settlement at the ground surface. In light of this successful performance, Select Structural Fill compacted to 95 to 97% of optimum density is acceptable when needed to limit surface settlement, with lesser compaction effort closer to the wall.

Excavations:

The following paragraphs contain general comments regarding below grade excavations. Excavation characteristics, design of temporary support systems, and dewatering methods are the sole responsibility of the contractor. Accordingly, the following statements should be regarded only as opinions.

Refer to the boring logs for a description of the subsurface materials encountered at the 2 lift stations. Excavations in the soil-like materials can be accomplished with conventional earth moving equipment. The shaly
clay and possible limestone seams and layers may require more robust excavation equipment.

The design of temporary excavation support systems, trench safety systems, and slope stability for temporary open cut excavations were excluded from our scope of services. The contractor is solely responsible for designing and constructing stable, temporary excavations and must shore, slope or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. All excavations must comply with applicable local, state, and federal safety regulations including current OSHA Excavation and Trench Safety Standards. Construction site safety is generally the sole responsibility of the contractor, who shall also be responsible for the means, methods, and sequencing of construction operations. We are providing information in this report solely as a service to our client. Under no circumstances should the provided information be interpreted to mean that LFE is assuming responsibility for construction site safety or the contractor’s activities; such responsibility is not being implied and must not be inferred.

In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations. Specifically, the current OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926 must be followed. The contractor’s “responsible person” as defined in 29 CFR Part 1926, must evaluate the materials exposed in the excavations as part of the contractor’s safety procedures. If an excavation, including a trench, is extended to a depth of more than twenty (20) feet, it will be necessary to have the side slopes designed by a professional engineer licensed in the State of Texas. The contractor’s “responsible person” must establish a minimum lateral distance from the crest of the slope for vehicles, spoil piles, or other surcharge loads. Likewise, the contractor’s “responsible person” shall establish protective measures for exposed slope faces.

The contractor must include the proximity to adjacent features when planning their method of excavation and support. These features include, but are not limited to, adjacent structures and utility lines. The contractor must also be prepared to manage varying amounts of subsurface water. Dewatering quantities will depend on drainage features, any groundwater, and rainfall prior to and during construction.
7.0 GEOTECHNICAL CONSTRUCTION RECOMMENDATIONS

Flatwork: This site has expansive soils with significant PVM. This report primarily addresses the foundation design. Be aware that concrete flatwork, such as sidewalks, drainage features, plazas, and utilities may be subject to adverse soil movements. Make sure flatwork is structurally isolated from the foundation, so that movement forces in the flatwork are not transferred to the foundation. The owner should be prepared to repair and even replace flatwork over time, depending on the magnitude of movement that actually occurs. Where the ground is intentionally sloped and graded to provide positive drainage, the ground may swell and shrink (or settle) sufficiently over time to reverse the intended drainage and must be remediated when necessary.

The magnitude of shrink/swell and/or settlement movements can be reduced by placing select fill below items such as sidewalks and approaches to entrances. From a practical standpoint, about 1 or 2 feet of select fill helps reduce the effects of the expansive clay soils, but significant movement is still possible in some areas of the site. Cracks in ground-supported flatwork should be anticipated.

Site Preparation: Any existing fill that has not been approved for use by the geotechnical engineer should be removed from the site. Additionally, remove at least the existing 6 inches plus any organics, debris, utilities, underground structures, non-engineered fill or other unsuitable material. Remove the existing clays to the depth required to achieve movement reduction goals. The stripping depth must consider field observations with attention given to old drainage areas, uneven topography, and wet soils. Extend the area of removal and replacement at least 3 feet beyond the foundation perimeter.

Proof-roll to detect soft spots or pumping subgrade areas for remediation. Use a heavy pneumatic tired roller, loaded dump truck, or similar piece of equipment weighing at least 25 tons for proof-rolling. Compact the subgrade soils as required by the following Subgrade Preparation subsection.

The above site-preparation requirements are not essential if a suspended floor slab is chosen. However, it is still desirable to have a consistent subgrade. Site preparation as discussed above should still be performed. The subgrade below crawl spaces should be sloped to prevent water ponding, and drains should be installed to facilitate drainage.
Subgrade Preparation: After proof rolling, scarify and compact the subgrade soils to at least 95 percent of ASTM D698 (or TEX-113-E) maximum dry density at 0 to +3% of the optimum moisture content. A maximum compacted lift thickness of six inches should be specified, with each lift tested for compliance prior to the addition of subsequent lifts. LFE or a similarly qualified testing laboratory should observe, monitor and test fill placement and compaction on a full-time basis.

Select Structural Fill: Select Structural Fill should meet the requirements of 2014 TxDOT Item 247, Type A or D, Grade 3 or better. If another local source of select fill is desired, the following specification may be used as a guide:

- Maximum Aggregate: 3 inches
- Percent Retained on #4 Sieve: 25 - 50
- Percent Retained on #40 Sieve: 50 - 75
- Plasticity Index: 5 - 15
- Non-Organic

Crusher fines are not recommended. Other locally available non-expansive fill may be acceptable but should be evaluated by LFE on a case-by-case basis. Except next to below-grade walls (which has special compaction requirements), compact the Select Structural Fill material in 6-inch compacted lifts to at least 95% of ASTM D698 (or TEX-113-E) maximum dry density (MDD) at 0 to +3% of the optimum moisture content if the fill will be less than 5 feet in depth, and to 98% of MDD if deeper. However, the same compaction requirement should apply to the full depth. The top 1-foot of material must consist of the TxDOT Type A or D, Grade 3 or better material. LFE or a similarly qualified testing laboratory must observe, monitor, and test the fill placement and compaction on a full-time basis. Existing clay soils can also be lime stabilized and used as fill, as specified in the following subsection.

Lime Stabilized Soil: Lime Stabilized Soil (LSS)- TxDOT Item 260, with a lime solids application rate of at least 6 percent by dry soil unit weight for budgeting. This application percentage will result in an application rate of about 27 pounds of lime per square yard for a 6-inch lift for a soil with a dry unit weight of 100 pcf. When construction begins, LFE or a similarly qualified testing laboratory must obtain additional samples of the subgrade soils to confirm the percentage of lime by conducting at least 2 pH or PI Lime Series tests.
Compact the LSS in 6-inch compacted lift thicknesses to at least 95% of ASTM D698 (or TEX-113-E) MDD to within 0% to +3% of optimum moisture content if the fill will be less than 5 feet in depth, and to 98% of MDD if deeper. Liquid lime is advised to avoid generating harmful dust.

A pre-construction meeting must be held to specifically discuss the lime application and compaction process. We highly recommend that a representative of the Lime Association attend the meeting to provide guidance (there is currently no cost for this service).

Grading: Grading, landscaping, and drainage pose a significant risk factor for future foundation performance. Preventing water from ponding around the foundation is critical, and good drainage should be obvious to the casual observer. We suggest the following general guidelines for perimeter drainage:

1. The building pad or the finished floor elevation must be elevated from the exterior finished grade to assist in draining the surface water away from the structure.
2. Where possible, extend paved surfaces up to the building line to serve as a barrier to soil moisture evaporation and infiltration. These surfaces must slope away from the building.
3. Outlets for gutter systems must rapidly discharge water away from the foundation.
4. Roots from trees and decorative vegetation remove moisture from soils, which causes soil shrinkage (settlement). Trees should have root blockers near the foundation or be located as far away from the foundation as practical.
5. Sprinkler systems must be properly maintained and over-watering of the soils should be avoided.

Impervious Seal: We recommend constructing an impervious seal on top of the backfill material around the building perimeter to reduce surface runoff water from infiltrating the backfill. The seal must be sloped away from the foundation. The seal may consist of paved surfaces, a geo-membrane, or of at least 12 inches of clay soil. In addition, place a “plug” of clay soil at the exit points of the utilities from the foundation to reduce water entry into utility trenches.
Vapor Barriers: The structural engineer or architect must determine the need for vapor barriers, and where to place them, based on various considerations including the proposed floor treatment, building function, concrete properties, placement techniques, the construction schedule, and code requirements. When moisture barriers are used, take precautions during the initial floor slab concrete curing period to reduce differential curing and possible slab curling.

Foundations: Grade beam and spread footing foundations must be clean, dry, meet the dimension and reinforcement placement requirements provided in the plans and specifications and bear on the recommended bearing material. LFE should be retained to confirm these requirements are met. Concrete should be placed the same day that LFE notes general compliance, and LFE should conduct additional observations if concrete is placed a different day or if the footing conditions materially change following the observations.

8.0 DESIGN REVIEW AND LIMITATIONS

Design Review: The recommendations contained in this report were based on preliminary site plans and design information provided by the Client. Our recommendations may not be applicable if changes have been made to the original information that formed the basis for this report, and we must be retained to make such a determination if such changes have been made. We also must be given the opportunity to review construction documents to affirm that our recommendations have been interpreted correctly. We cannot be responsible for misinterpretations if not given the opportunity to review aspects of the project that are based on the contents of this report. Such a review is considered an additional service.

Limitations: This report has been prepared for the exclusive use of our client and their designated project design team. Preparation of the report has been performed using that degree of care and skill ordinarily exercised under similar conditions by reputable geotechnical engineers in the same locality. No warranties, express or implied, are intended or made.
As stated in the attachment titled ‘Important Information About Your Geotechnical Engineering Report,” the subsurface conditions are interpreted from samples taken only at the boring locations. During construction, variations will be encountered, and will require interpretation by LFE to verify the adequacy of the geotechnical recommendations. Other limitations and considerations are discussed in the attachment and are a part of this report.

LFE does not provide environmental services, and this investigation did not include environmental testing or evaluation. LFE does not know whether environmental services may be appropriate or required for this project. An environmental professional should be retained to evaluate whether such services are appropriate and/or necessary, and to provide such services when so deemed.

9.0 APPENDIX

Site Location Map – Plate 1
Boring Location Sketch – Plate 2
Laboratory Test Results – Plate 3
Explanation of Boring Log Symbols and Terms
Boring Logs
Important Information About Your Geotechnical Engineering Report
<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample Depth (ft.)</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>Plasticity Index</th>
<th>Percent Passing No. 200 Sieve</th>
<th>Moisture Content (%)</th>
<th>Unit Dry Weight (pcf)</th>
<th>Unconfined Compressive Strength (tsf)</th>
<th>Strain at Failure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>0.0 - 2.0</td>
<td>55</td>
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<td>85</td>
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<td>103.0</td>
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<td>B-1</td>
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<td>14</td>
<td>110.3</td>
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<td>64</td>
<td>14</td>
<td>110.3</td>
<td>8.8</td>
<td>3.2</td>
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### LITHOLOGIC SYMBOLS (Unified Soil Classification System)

- **CH**: USCS High Plasticity Clay
- **CHS**: USCS Sandy Fat Clay
- **CL**: USCS Low Plasticity Clay
- **CLAYEY SAND AND GRAVEL**: USCS Clayey Sand
- **CLS**: USCS Low Plasticity Sandy Clay
- **FILL**: Fill (made ground)
- **SHALY CLAY**: Shale and Clay

### SAMPLER SYMBOLS

- **Bag Sample**
- **Split Spoon**
- **Shelby Tube**

### WELL CONSTRUCTION SYMBOLS

- **Water Level at Time**
- **Drilling, or as Shown**
- **Water Level at End of**
- **Drilling, or as Shown**
- **Water Level After 24**
- **Hours, or as Shown**

### ABBREVIATIONS

- **LL**: Liquid Limit (%)
- **PI**: Plastic Index (%)
- **W**: Moisture Content (%)
- **DD**: Dry Density (PCF)
- **NP**: Non Plastic
- **-200**: Percent Passing No. 200 Sieve
- **PP**: Pocket Penetrometer (TSF)
- **TV**: TORVANE
- **PID**: Photoionization Detector
- **UC**: Unconfined Compression
- **ppm**: Parts Per Million

**KEY TO SYMBOLS**

Langerman Foster Engineering Company
Waco and Harker Heights (Killeen), Texas
Ph: 254-235-1048       www.LFECTX.com
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>MATERIAL DESCRIPTION</th>
<th>SAMPLE TYPE</th>
<th>RECOVERY % (ROD)</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>POCKET PEN. (tsf)</th>
<th>ATTERBERG LIMITS</th>
<th>UNCONFINED COMPRESSIVE STRENGTH (tsf)</th>
<th>STRAIN AT FAILURE (%)</th>
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</tr>
<tr>
<td>5</td>
<td>FAT CLAY; tan and light gray, with varying granular content</td>
<td>ST</td>
<td>2.0</td>
<td>18</td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>LEAN CLAY; tan and light gray, with sand</td>
<td>ST</td>
<td>1.0</td>
<td>55 18 37 85 24 101 2.4 5.8</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>FAT CLAY; tan and light gray, with varying granular content</td>
<td>ST</td>
<td>1.0</td>
<td>55 19 36 82 24</td>
<td></td>
<td></td>
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<tr>
<td>20</td>
<td>FAT CLAY; gray to dark gray</td>
<td>ST</td>
<td>1.5</td>
<td>52 17 35 76 21 103 1.0 11.0</td>
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<td></td>
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</tr>
<tr>
<td>25</td>
<td>SHALY CLAY; dark gray</td>
<td>ST</td>
<td>1.5</td>
<td>43 15 28 81 26 99 3.0 7.5</td>
<td></td>
<td></td>
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<tr>
<td>30</td>
<td>--- Becoming harder, possibly shaly limestone</td>
<td>ST</td>
<td>0.5</td>
<td>43 15 28 81 26 99 3.0 7.5</td>
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<td>35</td>
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</table>

Remarks: Boring was drilled without drilling fluid to the total depth of 35 feet, groundwater was not observed during the drilling process. At the end of the day groundwater measured about 10.7 feet below ground surface (BGS). The next day, groundwater was measured about 10 feet BGS.
### BORING NO. B-11

**CLIENT**  CDM Smith  
**PROJECT NUMBER**  W19-050  
**PROJECT NAME**  Church Road and Cloice Creek Lift Stations  
**PROJECT LOCATION**  Waco, TX  

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Graphic Log</th>
<th>Material Description</th>
<th>Sample Type</th>
<th>Recovery % (RQD)</th>
<th>Blown Counts (N Value)</th>
<th>Pocket Pen.</th>
<th>Atterberg Limits</th>
<th>Unconfined Compressive Strength (tsf)</th>
<th>Strain at Failure (%)</th>
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<tr>
<td>0</td>
<td></td>
<td>Approximate Surface Elevation feet</td>
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<td></td>
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</tr>
<tr>
<td>5</td>
<td></td>
<td>Fill: Sandy Clay to Clayey Sand; tan to dark brown --- Some limestone fragments --- Sulfur odor and 2&quot; diameter pumice gravel</td>
<td>ST</td>
<td>4.5+</td>
<td>54 21 33 64 14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Sandy Fat Clay; brown, with gravel (possible fill)</td>
<td>ST</td>
<td>2.5</td>
<td>64 22 42 63 25 92 2.5 6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Fat Clay; brown to tan</td>
<td>ST</td>
<td>2.5</td>
<td>55 20 35 92 24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Lean Clay; brown to tan, with sand</td>
<td>ST</td>
<td>2.0</td>
<td>39 15 24 74 21 107 2.4 6.3</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>15</td>
<td></td>
<td>Lean Clayey Sand; tan, with gravel</td>
<td>ST</td>
<td>1.0</td>
<td>45 18 27 77 21</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>15</td>
<td></td>
<td>Sandy Lean Clay; brown to tan</td>
<td>A</td>
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<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>Shaly Clay; dark gray</td>
<td>SS</td>
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<td>26-13-23 (36)</td>
<td>43 19 24 67 27</td>
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**Remarks:** Boring was drilled without drilling fluid. Groundwater was initially measured about 14.9 feet below ground surface (BGS). After about 10 minutes, groundwater was measured about 7 feet BGS. At the end of the day, groundwater was measured about 6.1 feet BGS.
Important Information about This
Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for This Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared solely for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

Do not rely on this report if your geotechnical engineer prepared it:
- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it;
  e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. If you are the least bit uncertain about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. Read and refer to the report in full.

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:
- the site’s size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, always inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. The geotechnical engineer who prepared this report cannot accept
Most of the “Findings” Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site’s subsurface using various sampling and testing procedures. Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed. The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report’s Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are not final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations only after observing actual subsurface conditions exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.

This Report Could Be Misinterpreted

Other design professionals’ misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals’ plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, but be certain to note conspicuously that you’ve included the material for informational purposes only. To avoid misunderstanding, you may also want to note that “informational purposes” means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, only from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and be sure to allow enough time to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled “limitations,” many of these provisions indicate where geotechnical engineers’ responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a “phase-one” or “phase-two” environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated subsurface environmental problems have led to project failures. If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer’s services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, proper implementation of the geotechnical engineer’s recommendations will not of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration by including building-envelope or mold specialists on the design team. Geotechnical engineers are not building-envelope or mold specialists.