Geotechnical Evaluation

Proposed U-Haul Facility

SWC of Meridian Road & Rolling Thunder Way

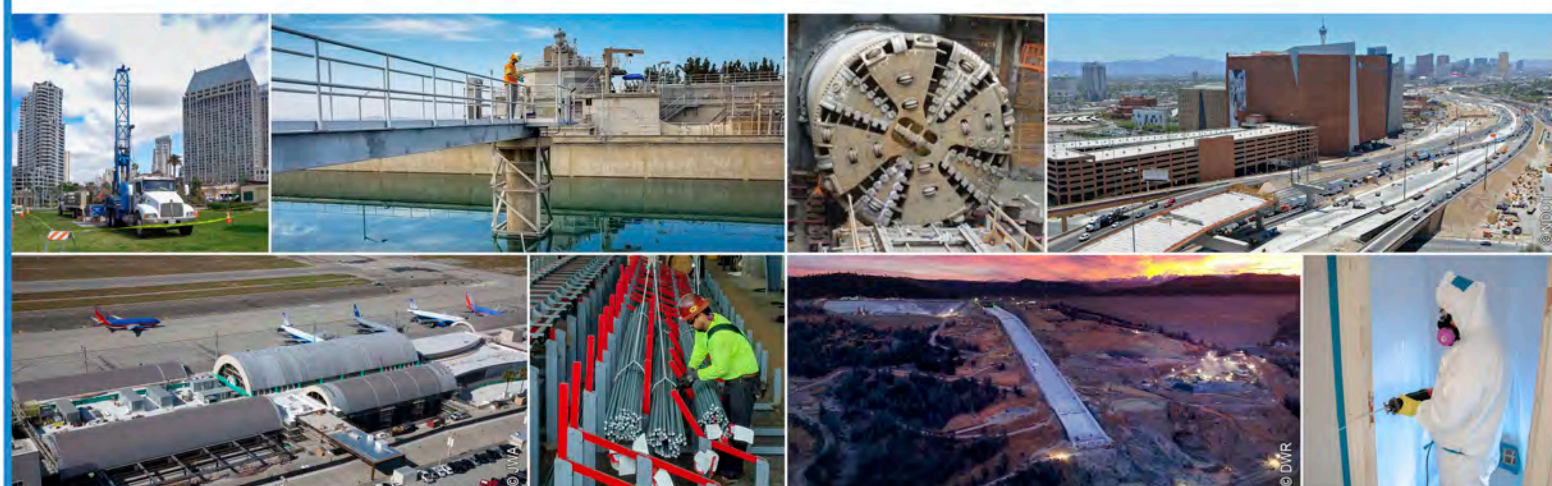
Falcon, Colorado

2727 North Central Avenue, Suite 5N | Phoenix, Arizona 85004

September 22, 2021 | Project No. 502209001

This report needs to include a map depicting the geologic hazards and constraints.

See comment below



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Ninyo & Moore

Geotechnical & Environmental Sciences Consultants

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Falcon, Colorado

Ms. Sabrina Perez
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September 22, 2021 | Project No. 502209001

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09/22/2021

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1 INTRODUCTION

In accordance with your authorization and our proposal dated July 15, 2021, we have performed a geotechnical evaluation for the proposed New U-Haul Facility located at the southwest corner of Meridian Road and Rolling Thunder Way in Falcon, Colorado. The approximate location of the site is depicted on Figure 1.

The purpose of our study was to evaluate the subsurface conditions and to provide design and construction recommendations regarding geotechnical aspects of the proposed project. This report presents the findings of our subsurface exploration program, results of our laboratory testing, conclusions regarding the subsurface conditions at the site, and geotechnical recommendations for design and construction of this project.

2 EXECUTIVE SUMMARY

A geotechnical evaluation has been performed for the proposed U-Haul Facility to be constructed at the southwest corner of Meridian Road and Rolling Thunder Way in Falcon, Colorado. Eight (8) borings were performed to depths ranging between approximately 14.3 and 24.3 feet below the ground surface (bgs). Based on the information obtained from our subsurface exploration, the following geotechnical considerations and recommendations are provided:

- Alluvium deposits were encountered at the surface in Borings B-3, and B-6 through B-8 and extended to depths generally ranging between approximately 1 and 2 feet bgs; however, the alluvium encountered in Boring B-8 extended to a depth of approximately 14 feet bgs. The alluvium was generally composed of dry to moist, clayey sand with varying amounts of gravel, and stiff to very stiff, sandy lean clay.

- Black Squirrel Formation bedrock was encountered beneath approximately 6 to 12 inches of topsoil in Borings B-1, B-2, B-4, and B-5, and below the alluvial deposits in Borings B-3, and B-6 through B-8, and extended to the borings' termination depths of up to approximately 24.3 feet bgs. The top approximately 3 to 9 feet of bedrock was observed to be weathered. The Black Squirrel Formation was generally composed of moist, soft to hard, claystone and weakly to strongly cemented, sandstone. Traces of lignite were observed within the formation.

- Groundwater was encountered in Boring B-8 at a depth of approximately 8 feet bgs during drilling. Groundwater levels will fluctuate due to seasonal variations in the amount of rainfall, runoff, water level of nearby streams, groundwater withdrawal from adjacent sites, and other factors. Based on our understanding of the project and the results of our subsurface exploration, groundwater is generally not anticipated to be encountered during foundation, floor slab, and pavement construction; however, construction on the south side of the site where alluvium extended deeper and groundwater was encountered during drilling, may encounter groundwater during excavations and dewatering techniques may be needed. The possibility of groundwater level fluctuations and perched water should be considered when developing the design and construction plans for the project.

- Based on our experience and the results of our laboratory testing, the soils expected to be encountered during project development would have a slab performance risk category of low to high. In general, the on-site soils consisted of shallow sandy claystone and clayey sandstone and sandy lean clay. As these materials are well below their optimum moisture content, the swell potential of the shallow overburden soils was high.

- As an alternative to deep foundation systems, overlot grading improvements should be designed carefully so that the swelling soils are removed, moisture-conditioned, and recompacted to create a zone of low-swelling material below the proposed structures and surface improvements.

- The proposed buildings can be supported with spread-footing foundations with slab-on-grade floors. Foundations and floor slabs should bear on 7 feet and 10 feet, respectively, of moisture-conditioned and re-compacted engineered fill. The top 12 inches of material beneath the floor slab should consist of select fill.

- Shallow foundation could be designed using a net allowable soil bearing pressure of 3,000 psf.

- There are risks associated with supporting pavements over expansive soils without soil modification. However, the costs associated with remediating pavement subgrades for expansive soils are generally considered cost-prohibitive. Therefore, the following recommendation for pavement subgrade preparation is provided assuming the owner is willing to accept some risk of poor pavement performance as a result of post-construction vertical movements associated with the high swell potential of the on-site soils. Asphalt and concrete pavements and flatwork may be placed on 24 or more inches of moisture conditioned and compacted engineered fill. As an alternative, the upper 12 or more inches of subgrade below the pavements sections could be chemically treated using fly ash or lime to reduce plasticity, reduce swell-potential, and increase strength of the treated subgrade soils.

- The on-site alluvium should generally be excavated with medium- to heavy-duty earthmoving or excavation equipment in good operating condition. Relatively dry soil will be encountered following removal of the surficial vegetation. It will be difficult to compact these soils at their in-place moisture contents. Significant moisture conditioning (e.g., wetting) should be anticipated prior to compaction. Excavations will slow down in the bedrock, especially in hard claystone zones. Rock breaking attachments may be needed to supplement heavy earth moving equipment. Increased wear and tear on excavation equipment should be anticipated at this site.

- Site soils generated from on-site excavation activities consisting of alluvial deposits that are free of deleterious materials, and do not contain particles larger than 3 inches in diameter, can generally be used as engineered fill during site grading.

- Based on our laboratory data and our experience with similar materials at adjacent sites, the sulfate content of the tested soils presents a high risk of sulfate attack to concrete. We recommend the use of Type V cement for construction of concrete structures at this site.

- No known or reported active faults are reported underlying, or adjacent to, the site. Based on the low ground motion hazard, the likelihood or potential for liquefaction is considered to be negligible and therefore not a design consideration.

- Based on the results of the seismic survey performed at the site, a designation of Seismic Site Class C is recommended for the site.

This summary is to be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein.

3 SCOPE OF SERVICES

The scope of our services for the project generally included:

- Review of readily available background information including aerial photographs, published geologic maps, and in-house geotechnical data pertaining to the project site and vicinity.
- Mark out of the boring locations at the project site and notification of Utility Notification Center of Colorado of the boring locations prior to drilling.
- Drilling, logging, and sampling 8 exploratory borings across the site to depths ranging from approximately 14.3 to 24.3 feet below ground surface (bgs). The approximate boring locations are presented on Figure 2. The boring logs are presented in Appendix A.
- Performance of laboratory tests on selected samples obtained from the borings to evaluate engineering properties including in-situ moisture content and dry density, Atterberg limits, percent fines passing the No. 200 sieve and gradation, swell/consolidation potential, and soil corrosivity characteristics (including pH, resistivity, water soluble sulfates and chlorides). The results of the in-situ moisture content and dry density laboratory testing are presented on the boring logs and the remainder of the laboratory testing results is presented in Appendix B.
- Performance of a microtremor array measurement (MAM) survey to evaluate the seismic site classification of the site. The results of the survey are presented on Figure 3.
- Compilation and analysis of the data obtained.
- Preparation of this report presenting our findings, conclusions, and geotechnical engineering recommendations regarding the design and construction of the project.

4 SITE DESCRIPTION AND BACKGROUND INFORMATION

The project consists of the development of a new U-Haul facility on an approximately 11.84-acre parcel located at the southwest corner of Meridian Road and Rolling Thunder Way in Falcon, Colorado. The site is bounded by Rolling Thunder Way to the north, by Meridian Road to the east, by Tamlin Road to the south, and by a drainage canal followed by single-family homes to the west. Project design documents were not available for review at the time of this report. We assume the project will involve the design and construction of multiple up to 4-story storage structures with associated pavements. The project site was undeveloped and vacant at the time of our subsurface exploration. Aerial photograph review indicates that the subject site has existed similar to its current condition since 1999 or earlier.

The site is gently sloped to the south with approximate difference in elevation of 20 feet between the south and north edges. Site grading plans were not available at the time of preparing this proposal. We assume the proposed ground floor level will be at or within 2 to 4 feet of existing site grade.

5 FIELD EXPLORATION AND LABORATORY TESTING

On August 10, 2021, Ninyo & Moore conducted subsurface exploration services at the project site to evaluate the existing subsurface conditions and to collect soil samples for visual observation and laboratory testing. The evaluation consisted of the drilling, logging, and sampling of 8 exploratory borings using a truck-mounted drill rig equipped with four-inch diameter continuous-flight solid-stem augers to depths of approximately 10 to 29.4 feet bgs. The approximate locations of the borings are presented on Figure 2. Relatively undisturbed and disturbed soil samples were collected at selected intervals.

The soil samples collected from our drilling activities were transported to the Ninyo & Moore laboratory for geotechnical laboratory analysis. Selected samples were analyzed to evaluate engineering properties including in-situ moisture content and dry density, Atterberg limits, percent fines passing the No. 200 sieve and gradation, swell/consolidation potential, and soil corrosivity characteristics (including pH, resistivity, water soluble sulfates and chlorides). The results of the in-situ moisture content and dry density tests are presented on the boring logs in Appendix A. A description of each laboratory test method and the remainder of the laboratory test results are presented in Appendix B.

6 GEOLOGY AND SUBSURFACE CONDITIONS

The geology and subsurface conditions at the site are described in the following sections.

6.1 Geologic Setting

The site is located in Falcon, Colorado, approximately 14 miles east of the Rocky Mountain Front Range, within the Colorado Piedmont section of the Great Plains Physiographic Province. The Laramide Orogeny uplifted the Rocky Mountains during the late Cretaceous and early Tertiary Periods. Subsequent erosion deposited sediments east of the Rocky Mountains, including the Black Squirrel Formation in the area. As a result of regional uplift approximately 5 to 10 million years ago, streams such as the South Platte River downcut and excavated into the Great Plains forming the Colorado Piedmont section (Trimble, 1980).

The surficial geology of the site vicinity is mapped by Morgan and White (2012) as Holocene- to Pleistocene-age alluvial deposits. The Black Squirrel Formation is mapped underlying the project area at depth.

6.2 Subsurface Conditions

Our understanding of the subsurface conditions at the project site is based on our field exploration, laboratory testing, and our experience with the general geology of the area. The following sections provide a generalized description of the subsurface materials encountered. More detailed descriptions are presented on the boring logs in Appendix A.

6.2.1 Alluvium

Alluvial deposits were encountered at the surface in Borings B-3, and B-6 through B-8 and extended to depths generally ranging between approximately 1 and 2 feet bgs; however, the alluvium encountered in Boring B-8extended to a depth of approximately 14 feet bgs. The alluvium was generally composed of dry to moist, clayey sand with varying amounts of gravel, and stiff to very stiff, sandy lean clay.

Based on the results of the laboratory testing, selected samples of the alluvium had in-place moisture contents between approximately 18.2 and 33.9 percent and dry densities ranging between approximately 87.0 and 111.0 pounds per cubic foot (pcf).

6.2.2 Black Squirrel Formation

Black Squirrel Formation bedrock was encountered beneath approximately 6 to 12 inches of topsoil in Borings B-1, B-2, B-4, and B-5, and below the alluvial deposits in Borings B-3, and B-6 through B-8, and extended to the borings' termination depths of up to approximately 24.3 feet bgs. The top approximately 3 to 9 feet of bedrock was observed to be weathered. The Black Squirrel Formation was composed of moist, soft to hard, claystone and weakly to strongly cemented, sandstone. Traces of lignite were observed within the formation.

Based on the results of the laboratory testing, select samples of the Black Squirrel Formation had in-place moisture contents of approximately 6.4 to 18.8 percent and dry densities of approximately 106.9 to 132.4 pcf.

6.3 Groundwater

An attempt to measure groundwater levels was performed during drilling operations. At that time, groundwater was encountered in Boring B-8 at a depth of approximately 8 feet bgs. Groundwater levels can fluctuate due to seasonal variations, irrigation, groundwater withdrawal or injection, and other factors. In addition, perched water can develop within higher permeability soils following periods of heavy or prolonged precipitation. The possibility of groundwater level fluctuations and perched water should be considered when developing the design and construction plans for the project.

Based on our understanding of the project and the results of our subsurface exploration, groundwater is generally not anticipated to be encountered during foundation, floor slab, and pavement construction; however, construction on the south side of the site where alluvium extended deeper and groundwater was encountered during drilling, may encounter groundwater during excavations and dewatering techniques may be needed.

7 GEOLOGIC HAZARDS

The following sections describe regional geologic hazards including seismicity, expansive soils, collapsible soils, and liquefaction.

7.1 Seismicity

In order to evaluate seismic site class, a seismic survey using passive surface wave techniques was performed at the site. The purpose of the study was to evaluate the subsurface shear-wave velocity at a representative location. The passive seismic method carried out included MAM and consisted of a single linear profile of seismic data collection. The method provided a shear wave velocity profile to a depth of approximately 100 feet bgs and V_s100 for seismic site classification (International Building Code [IBC], 2018).

Data was collected to a depth of approximately 100 feet bgs using a Geometrics Geode 24-channel seismograph and 4.5 Hertz vertical component geophones spaced approximately 20 feet apart for a total length of 460 feet (A-A’). Approximately 15 records were collected with a 2 millisecond sample interval for duration of 30 seconds each. The field data were digitally recorded in SEG2 format, reviewed in the field for data quality, saved to a hard disk, and documented.

The calculated average shear wave velocity to a depth of approximately 100 feet bgs at the locations of the geophone arrays were approximately 1,406 feet per second. Based on this information, the findings of our subsurface exploration program, and the 2018 IBC, a Seismic Site Class C is appropriate for the design of this project. The approximate locations of the MAM Survey Line is presented on Figure 2. The results of the MAM survey are presented on Figure 3.

Design of the proposed improvements should be performed in accordance with the requirements of the governing jurisdictions and applicable building codes. Table 2 presents the seismic design parameters for the site in accordance with the 2018 International Building Code guidelines and adjusted maximum considered earthquake spectral response acceleration parameters evaluated using the web-based OSHPD ground motion calculator (OSHPD, 2021).

Table 1 – 2018 International Building Code Seismic Design Criteria	
Site Coefficients and Spectral Response Acceleration Parameters	**Values**
Class	C
Coefficient, F_a	1.3
Coefficient, F_v	1.5
Mapped Spectral Response Acceleration at 0.2-second Period, S_s	0.186 g
Mapped Spectral Response Acceleration at 1.0-second Period, S_1	0.055 g
Spectral Response Acceleration at 0.2-second Period Adjusted for Site Class, S_{MS}	0.242 g
Spectral Response Acceleration at 1.0-second Period Adjusted for Site Class, S_{M1}	0.083 g
Design Spectral Response Acceleration at 0.2-second Period, S_{DS}	0.162 g
Design Spectral Response Acceleration at 1.0-second Period, S_{D1}	0.055 g

7.2 Expansive Soils

One of the more significant geologic hazards in the Front Range area is the presence of swelling clays in bedr … containing swelling clay … or damage to structures …

See Engineering Criteria Manual Appendix C Section C.2.2.E for list of geologic hazards and geologic constraints. Expansive soil is identified as constraints. Include a section for geologic constraints and revise the subcategories accordingly..

Based on the … erial tested exhibited swell potentials ranging from approximately 0.8 to 5.5 percent at a surcharge pressure of approximately 200 pounds per square foot (psf), approximately 0.8 to 7.0 percent at a surcharge pressure of approximately 500 psf, and approximately 0.4 to 5.1 percent at a surcharge pressure of approximately 1,000 psf.

Based on the results of our laboratory testing, the pavements and flatwork on the site would have a performance risk category of "LOW" to "HIGH" based on the criteria presented in Table 2 which is based on the CDOT Pavement Design Manual criteria.

Table 2 – Pavement Performance Risk Categories	
Pavement Performance Risk Category	**Representative Percent Swell (200 psf Surcharge)**
NONE	0
LOW	0 to <1
MODERATE	1 to <5
HIGH	5 to 20
VERY HIGH	> 20

NOTE: The information provided in this table is based on Colorado Department of Transportation (CDOT) Pavement Design Manual (2021), Chapter 4.

Based on the results of our subsurface exploration and laboratory testing, the on-site soils expected to be encountered during project development would have a slab performance risk category of “LOW” to “HIGH”, based on the criteria presented in Table 3.

Table 3 – Slab Performance Risk Categories		
Slab Performance Risk Category	**Representative Percent Swell (500 psf Surcharge)**	**Representative Percent Swell (1,000 psf Surcharge)**
LOW	0 to <3	0 to <2
MODERATE	3 to <5	2 to <4
HIGH	5 to <8	4 to <6
VERY HIGH	> 8	> 6

Note: Based on Colorado Association of Geotechnical Engineers, Guidelines for Slab Performance Risk Evaluation and Residential Basement Floor System Recommendations (Denver Metropolitan Area, 1996).

Based on these results, assuming no remedial grading is performed at the site, building foundations, floor slabs, pavements, and exterior flatwork type improvements would be subject to approximately 2 to 9 inches of vertical heave as the post-construction wetting of the site soils and bedrock takes place. Placement of the buildings on drilled pier foundations and providing them with structural floor systems that are constructed over a crawl space would isolate the buildings from the effects of such post-construction vertical movement. Although, such foundation and floor systems will isolate the buildings from the effects of the swelling soils, the isolation of the remainder of the site improvements from the swelling soils will not be possible, therefore, an increased differential movement risk between the buildings and the horizontal site improvements will occur.

Overexcavating (removing and replacing) of the site soils to create layers of engineered fill material with controlled moisture, density, and reduced swell potential is the most commonly used remedial grading technique in Colorado Front Range. Such process increases the moisture content of the site soils and bedrock to near optimum moisture contents and reduces the soil/bedrock affinity for additional water, which in turn reduces its swell potential. The remedial grading recommendations provided in this report are intendent to reduce the post-construction movement potential of the site soils under the proposed buildings to approximately 1 to 1.5 inches and reduce the angular distortions to approximately ½-inch vertical over 50 feet horizontal. Failure to follow the site drainage recommendations provided in Section 8.12 may also result in increased depth of wetting and additional vertical movement that is difficult to quantify. If the above mentioned post-construction movement tolerances are not acceptable, the buildings can be supported on drilled piers with structural floors and recommendations for such foundation and floor systems can be provided upon request.

There are risks associated with supporting pavements and exterior flatwork over expansive soils. Post-construction movement of pavements and flatwork (approximately 1 to 2 inches) will occur at this site even if the remedial grading recommendations provided in this report are followed and proper drainage measures are taken. This movement potential could increase to the free field heave values calculated above if the site drainage recommendations are not followed and wetting of the site soils below the pavements continue to depths of 10 or more feet.

7.3 Collapsible Soils

Compressible soils are generally comprised of soils that undergo consolidation when exposed to new loadings, such as fill or foundation loads. Soil collapse (or hydro-collapse) is a phenomenon where soils undergo a significant decrease in volume upon an increase in moisture content, with or without an increase in external loads. Buildings, structures, and other improvements may be subject to excessive settlement-related distress when compressible soils or collapsible soils are present.

Based on the subsurface exploration and information obtained from our background review, the project site is underlain by alluvial deposits and Black Squirrel Formation bedrock. Laboratory test results indicate the selected samples of the on-site material have low consolidation and collapse potential from applied loads.

7.4 Liquefaction Potential

Liquefaction is a phenomenon in which loose, saturated soils lose shear strength under short-term (dynamic) loading conditions. Ground shaking of sufficient duration can result in the loss of grain-to-grain contact in potentially liquefiable soils due to a rapid increase in pore water pressure, causing the soil to behave as a fluid for a short period of time.

To be potentially liquefiable, a soil is typically cohesionless with a grain-size distribution generally consisting of sand and silt. It is generally loose to medium dense and has relatively high moisture content, which is typical near or below groundwater level. The potential for liquefaction decreases with increasing clay and gravel content, but increases as the ground acceleration and duration of shaking increase. Potentially liquefiable soils need to be subjected to sufficient magnitude and duration of ground shaking for liquefaction to occur. Based on the depth to groundwater and low ground motion hazard, the potential for liquefaction at the project site is considered to be low and therefore not a design consideration for the project.

8 RECOMMENDATIONS

Based on our understanding of the project, the following sections present our geotechnical recommendations for design and construction of the proposed buildings and other site improvements.

Grading plans were not available for review at the time of this report. We have assumed the proposed ground floor levels will be at or within 5 feet of the existing site grades. It is important that Ninyo & Moore be notified and given an opportunity to reevaluate our recommendations once this information becomes available and prior to bidding the project for construction.

8.1 Earthwork

The following sections provide our earthwork recommendations for this project. We anticipate the site grading may consist of minimal material cuts and fills on the order of 5 feet. Deeper cuts and fills may be needed to install buried utilities.

8.1.1 Excavations

Our evaluation of the excavation characteristics of the on-site materials is based on the results of our subsurface exploration, our site observations, and our experience with similar materials. The alluvial deposits may generally be excavated with medium- to heavy-duty earthmoving or excavation equipment in good operating condition. Excavations will slow down in the bedrock, especially in hard claystone zones. Rock breaking attachments may be needed to supplement heavy earth moving equipment. Increased wear and tear on excavation equipment should be anticipated at this site.

Equipment and procedures that do not cause significant disturbance to the excavation bottoms should be used. Excavators and backhoes with buckets having large claws to loosen the soil should be avoided when excavating the bottom 6 to 12 inches of excavations as such equipment may disturb the excavation bases.

Depending on the time of year construction occurs, unstable subgrade conditions may be encountered during general construction operations. Subgrade conditions should be observed by Ninyo & Moore during construction. Where unstable subgrade conditions develop, stabilization measures will need to be employed.

Stabilization methods should be provided by the grading contractor, as needed, and may include the use of geogrids, geotextiles, pushing oversized rock into the subgrade, and chemical stabilization. The subgrade stabilization methods proposed should be discussed with the geotechnical engineer prior to implementation. The stabilization method selected should consider the effects of such stabilization on future utility installation and/or repair work.

Groundwater may be encountered within the remedial grading zone of the buildings on the south side of the site. Excavations within 5 feet of the groundwater table may encounter soft and/or wet conditions; therefore, implementation of various dewatering techniques and associated permitting may be needed

The contractor should provide safely sloped excavations or an adequately constructed and braced shoring system, in compliance with Occupational Safety and Health Administration (OSHA) (OSHA, 2005) guidelines, for employees working in an excavation that may expose employees to the danger of moving ground. If material is stored or equipment is operated near an excavation, stronger shoring should be used to resist the extra pressure due to superimposed loads.

8.1.2 Site Grading

Prior to grading, the ground surface in proposed structure and improvement areas should be cleared of any surface obstructions, debris, topsoil, organics (including vegetation) and other deleterious material. Materials generated from the clearing operations should be removed from the site and disposed of at a legal dumpsite.

Materials generated from clearing operations should be removed from the project site for disposal (e.g. at a legal landfill site). Obstructions that extend below finish grade, if present, should be removed and the resulting holes filled with compacted soil or cement slurry, or in accordance with the recommendations of the geotechnical engineer.

On-site topsoil, if encountered, should not be incorporated into engineered fill, but may be stockpiled for re-use as landscaping material or other non-structural material. Topsoil contaminated fill materials should not be used during site grading.

The proposed buildings may be supported on shallow foundation systems consisting of spread-footings bearing on a relatively uniform thickness of moisture conditioned and compacted engineered fill extending to 7 or more feet below the bottom of the footings. The limits of this fill layer should extend 10 or more feet out beyond the footings to reduce the swell potential within the structures as well as the surrounding building appurtenances, such as exterior flatwork adjacent to the building. If flatwork is attached to the building, it is recommended the lateral extent of the remedial grading be increased to encompass the flatwork.

The buildings may be provided with slab-on-grade floors bearing 10 or more feet of moisture conditioned and compacted engineered fill. The upper 12 or more inches below the floor slab should consist of select fill confined to within the foundation walls. The select fill should consist of clayey sand with less than 40 percent passing the No. 200 sieve. The purpose of the select fill is to limit moisture loss in the moisture-conditioned and recompacted clay soils from the site as well as further reduce the swell potential below floor slabs.

There are risks associated with supporting pavements over expansive soils without soil modification. However, the costs associated with remediating pavement subgrades for expansive soils are generally considered cost-prohibitive. Therefore, the following recommendation for pavement subgrade preparation is provided assuming the owner is willing to accept some risk of poor pavement performance as a result of post-construction vertical movements associated with the high swell potential of the overburden soils.

Asphalt and concrete pavements and flatwork may be placed on 24 or more inches of moisture conditioned and compacted engineered fill. As an alternative, the upper 12 or more inches of subgrade below the pavements sections could be chemically treated using fly ash or lime to reduce plasticity, reduce swell-potential, and increase strength of the treated subgrade soils. The chemically treated subgrade (CTS) should be performed in general accordance with Section 307 of the current Colorado Department of Transportation (CDOT) Standard Specifications for Road and Bridge Construction. CTS should extend 2 or more feet behind the curb (in areas where the sidewalks are detached or not present) and 1 foot or more behind the sidewalk (in areas where the sidewalks are attached or poured monolithically with the curb).

The CTS should be designed to exhibit a 7-day unconfined compressive strength of 150 psi or more and a swell potential of 1 percent or less at a surcharge pressure of 200 psf. CTS shall not be performed when the ambient air temperatures fall below freezing, the subgrade material is below 40 degrees Fahrenheit, or weather predictions suggest that the subgrade temperatures may fall below 40 degrees Fahrenheit. The CTS agent chosen shall be spread uniformly over the top of the subgrade by approved equipment for handling, weighing and spreading. Distribution of the chemical treatment agent shall be in such a manner that scattering by wind and fugitive dust will be minimal. CTS shall not be applied when wind conditions, in the opinion of the Engineer, are detrimental to a proper application.

Three options are suggested for CTS. They consist of lime, Class C fly ash, or Portland cement concrete. For bidding purposes, 5 or more percent of lime by dry weight of soil, 12 or more percent of Class C fly ash by dry weight of soil, or 3 or more percent of Portland cement concrete should be used. The actual CTS percentage should be evaluated by performing a mix design prior to placement.

The geotechnical consultant should be retained to observe the remedial excavations, and the elevations of the excavation bottoms should be surveyed by the project civil engineer.

The exposed subgrade materials should be firm and unyielding prior to fill placement. The extent of and depths of removal should be evaluated by our representative during the excavation work based on observation of the soils exposed. Additional recommendations specific to the site conditions encountered may be provided at the time of construction. The project budget should include additional cost associated with the removal and replacement of additional fill material. Subgrade materials that are disturbed during grading should be moisture conditioned and re-compacted according to the recommendations provided in this report.

Upon completion of grading operations, care should be taken to maintain the moisture content of the subgrade prior to construction of foundations, floor slabs, pavements, and exterior flatwork. Depending on the time of year construction occurs, loss of moisture content in exposed subgrades can occur. Therefore, prior to building or pavement construction, the subgrades should be moisture-conditioned and compacted, as necessary, as recommended in Section 8.1.4.

The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become desiccated, saturated, frozen, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior to slab and pavement construction.

8.1.3 Re-Use of Site Soils

The onsite soils encountered during our subsurface exploration consisted of alluvial deposits extending to depths of approximately 1to 14 feet bgs followed by Black Squirrel Formation bedrock consisting of claystone and sandstone. Laboratory testing indicates the on-site clay soils have moderate to high swell potentials. Soils generated from on-site excavation activities in the alluvial deposits that are free of deleterious materials and organic matter, do not contain particles larger than 3 inches in diameter, can generally be used as engineered fill as evaluated by the geotechnical consultant provided they are compacted and moisture conditioned as recommended in this report.

It should be noted that overburden deposits are relatively dry with respect to their optimum moisture content. The addition of significant amounts of water should be anticipated to achieve the recommended moisture content range provided in this report.

If excavated claystone bedrock is needed for site balance, it should be thoroughly processed and mixed with the overburden soils. The mixture should be placed such that it is not present within 2 feet of the foundation bearing elevations for the building or pavement subgrade. Lignite (undeveloped coal) was encountered within the Black Squirrel Formation. This material, where encountered, should not be incorporated into the engineered fill.

While zones of sandstone bedrock were encountered on the site, it may be difficult to segregate these materials for the recommended sand cap below the floor slab. The overburden clay soils would not meet the requirement of less than 40 percent passing the No. 200 sieve for and thus are not suitable for use as 12-inch select fill below the slab-on-grade floors. As a result, import of these materials should be anticipated.

Fragments of rock, cobbles, and inert construction debris (e.g., concrete or asphalt) larger than 3 inches in diameter may be incorporated into the project fills in non-structural areas and below the anticipated utility installation depths. A Geotechnical Engineer should be consulted regarding appropriate recommendations for usage of such materials on a case-by-case basis when such materials have been observed during earthwork. Care should be taken to avoid nesting of oversized materials during placement. Recommendations provided in Section 203 of the current Colorado Department of Transportation (CDOT) Standard

Specifications for Road and Bridge Construction should be followed during the placement of oversized material.

8.1.4 Fill Placement and Compaction

Fine-grained soils (on-site soils that classify as CL and CH) used as engineered fill should be moisture-conditioned to moisture contents between the material's optimum moisture content and 3 percent over optimum moisture content. Granular soils (on-site soils that classify as SC or import soils) used as engineered fill should be moisture-conditioned to moisture contents within 2 percent of optimum moisture content. Engineered fill should be compacted to a relative compaction of 95 percent or more as evaluated by American Society for Testing and Materials (ASTM) D698.

The fill material placed should be compacted by appropriate mechanical methods using vibratory compaction equipment. The optimal lift thickness for fill will be dependent upon the type of compaction equipment utilized, but generally should not exceed 8 inches in loose thickness. No fill materials should be placed, worked, or rolled while they are frozen, thawing, or during poor/inclement weather conditions. Compaction areas should be kept separate, and no lift should be covered by another until relative compaction and moisture content within the recommended ranges are obtained.

8.1.5 Imported Fill Material

Imported soil to be used as engineered fill should be free of organic material and other deleterious materials should consist of relatively impervious material with a very low to low expansion potential (less than 1 percent against a surcharge pressure of 500 psf when remolded at optimum moisture content). Imported fill should have less than 50 percent passing the No. 200 Sieve and should have a plasticity index that is between 10 and 20. Imported soil to be used as select fill should consist of clayey sand with less than 40 percent material passing the No. 200 sieve.

Import material in contact with ferrous metals should have low corrosion potential. Import material in contact with concrete should have soluble sulfate content less than 0.1 percent.

We further recommend that proposed import material be evaluated by the Ninyo & Moore at the borrow source for its suitability prior to importation to the project site. Import soils should be moisture-conditioned, placed, and compacted in accordance with Section 8.1.4.

8.1.6 Utility Installation

The contractor should take care to achieve and maintain adequate compaction of the backfill soils around manholes, valve risers and other vertical pipeline elements where settlements commonly are observed. Use of "flowable fill," (e.g. a controlled low strength mix, or a similar material) should be considered in lieu of compacted soil backfill for areas with low tolerances for surface settlements. This would also reduce the permeability of the utility trenches.

Pipe bedding materials, placement and compaction should meet the specifications of the pipe manufacturer and applicable municipal standards. Materials proposed for use as pipe bedding should be tested for suitability prior to use.

Special care should be exercised to avoid damaging the pipe or other structures during the compaction of the backfill. In addition, the underside (or haunches) of the buried pipe should be supported on bedding material that is compacted as described above. This may need to be performed with placement by hand or small-scale compaction equipment.

Surface drainage should direct water away from utility trench alignments. Where topography, site constraints or other factors limit or preclude adequate surface drainage, the granular bedding materials should be surrounded by non-woven filter fabric (e.g., Mirafi® 140N or the equivalent) to reduce migration of fines into the bedding which can result in severe, isolated settlements.

Development of site grading plans should consider the subsurface transfer of water in utility trenches and the pipe bedding. Sandy pipe bedding materials can function as efficient conduits for re-distribution of natural and applied waters in the subsurface. Cut-off walls in utility trenches or other water-stopping measures should be implemented to reduce the rates and volumes of water transmitted along utility alignments and toward buildings, pavements and other structures where excessive wetting of the underlying soils will be damaging. Incorporation of water cut-offs and/or outlet mechanisms for saturated bedding materials into development plans could be beneficial to the project. These measures also will reduce the risk of loss of fine-grained backfill soils into the bedding material with resultant surface settlement.

8.1.7 Temporary Cut Slopes

Temporary excavations will be needed for this project to construct utilities. Based on the subsurface information obtained from our exploratory excavations and our experience with similar projects, we anticipate that the soil conditions and stability of the excavation sidewalls may vary with depth. It is anticipated the clean sandy soils will not stand vertically for any period of time and may slough or cave during excavation. Soils with higher fines content may stand vertically for a short time (less than 12 hours) with little sloughing. However, as the soil dries after excavation or as the excavations are exposed to rainfall, sloughing may occur.

The contractor should provide safely sloped excavations or an adequately constructed and braced shoring system, in compliance with OSHA regulations as mentioned in Section 8.1.1.

In our opinion, the surficial site soils should generally be considered a Type C soil when applying the OSHA regulations. For these soil conditions, OSHA recommends a temporary slope inclination of 1.5H:1V or flatter for excavations 20 feet or less in depth. Appropriate slope inclinations should be evaluated in the field by an OSHA qualified "Competent Person" based on the conditions encountered.

8.2 Spread Footing Foundations

Perimeter footings should extend to 36 inches or more below the lowest exterior finished grade (for frost protection), and bear on a zone of adequately placed and compacted engineered fill as described in Section 8.1.2 of this report. Continuous wall footings should have a width of 18 inches or more and column footings should have a width of 24 inches or more. Footings should be reinforced in accordance with the recommendations of the structural engineer.

Footings may be designed using an allowable bearing pressure of 3,000 psf for static conditions. The bearing capacity may be increased by one-third when considering loads of short duration such as wind or seismic forces. The foundations should preferably be proportioned such that the resultant force from design loads, including lateral loads, falls within the kern (i.e., middle one-third of the footing base).

Uplift resistance can be developed from the weight of the footings, the effective weight of any overlying soil, and the weight of the supported structure itself. The effective unit weight of the soil can be assumed to be 125 pcf above the groundwater level. Soil uplift resistance may be calculated as the weight of the soil prism defined by a diagonal line extending from the perimeter of the foundation to the ground surface at an angle of 20 degrees from the vertical. Under large moment and/or shear loading, the effective size of the uplift soil prism may be reduced. An appropriate safety factor should be applied.

The base of foundation excavations should be free of water and loose soil prior to placing concrete. Concrete should be placed soon after subgrade compaction to reduce bearing soil disturbance. Should the soils at bearing level become excessively dry, disturbed, or saturated, the affected soil should be moisture conditioned and recompacted. It is recommended that Ninyo & Moore be retained to observe, test, and evaluate the soil foundation bearing materials.

Based on the limited information provided and the results of our subsurface exploration and laboratory testing, we estimate total and differential settlement of up to about 1 inch and ½-inch, respectively, may occur. It should be noted that settlement predictions do not take into account post-construction vertical movements. As previously mentioned, Ninyo & Moore should review the building layout and grading plans once available to determine if modifications to our recommendations are necessary.

8.3 Slab-On-Grade Floors

The design of the floor slabs (including jointing and reinforcement) is the responsibility of the structural engineer. Joints should be constructed at intervals designed by the Structural Engineer to help reduce the random cracking of the slab. Recommendations based on structural considerations for slab thickness, jointing, and steel reinforcement should be developed by the Structural Engineer in accordance with American Concrete Institute recommendations. Soils underlying the slabs should be moisture conditioned and compacted in accordance with the recommendations presented in Section 8.1.2 of this report.

For slab design, a design modulus of subgrade reaction (K) of 150 pounds per square inch per inch of deflection (pci) may be used for the subgrade soils in evaluating such deflections. This value is based on a unit square foot area and can be adjusted for large slabs. Adjusted values of the modulus of subgrade reaction, K_v, can be obtained from the following equation for slabs of various widths:

$$K_v = K[(B+1)/2B]^2 \qquad \text{(pci)}$$

B in the above equation represents the width of the slab in feet between line loads/point loads.

The slab should be constructed so that it “floats” independent of the foundations. Floor slabs should be separated from bearing walls and columns with expansion joints, which allow unrestrained vertical movement. Joints should be observed periodically, particularly during the first several years after construction. Slab movement can cause previously free-slipping joints to bind. Measures should be taken so that slab isolation is maintained in order to reduce the likelihood of damage to walls and other interior improvements.

Non load-bearing interior partitions resting on floor slabs should be provided with slip joints so that if the slabs move, the movement cannot be transmitted to the upper structure, including wallboards and door frames. A slip joint that allows 2 or more inches of vertical movement is recommended for placement at the bottoms of the interior partitions. If slip joints are placed at the tops of walls, in the event that the floor slabs move, it is expected that the wall will show signs of distress, especially where the floors meet the exterior wall. Interior plumbing lines that penetrate interior partition walls, where the slip joints are placed at the top of the walls, should be provided with flexible connections that can handle 2 or more inches of vertical movement.

The need for a moisture retarding and/or vapor retarding system should be considered by the Structural Engineer or Architect, based on the moisture sensitivity of the anticipated flooring. The placement of a vapor retarder is recommended in areas where moisture-sensitive floor coverings are anticipated.

8.4 Earth Pressures and Foundation Walls

Earth pressures are used to compute the lateral forces acting on below-grade walls. These pressures can be classified as at-rest, active, and passive. The direction and magnitude of the soil/wall movement just before failure affects the resulting pressure condition. At-rest conditions exist when there is no movement, such as for a restrained wall. Active stresses are exerted when the wall moves out and the soil moves toward the wall away from the soil mass, thereby mobilizing the shear strength of the soil. The active pressures are fully mobilized at horizontal movements of about 0.1 percent of the wall height for cohesionless soils, such as sands and gravels. Passive stresses exist when the wall moves toward the soil mass. Movement typically needed to mobilize passive pressures greatly exceeds that needed to mobilize active pressures. The passive pressures are, therefore, rarely fully mobilized and are often overestimated when used to compute resistance forces.

The recommended equivalent fluid pressures in Table 4 assume on-site soil with an angle of internal friction (ϕ) of 26 degrees and a unit weight of 125 pcf. The values listed below are for static conditions.

Table 4 – Lateral Earth (Equivalent Fluid) Pressures

Soil Condition	Active Pressure (pcf)	At-rest Pressure (pcf)	Passive Pressure (pcf)
On-Site Soils	49	70	300

The use of heavy compaction equipment adjacent to loading-dock walls could result in lateral earth pressures well in excess of those predicted in Table 4. We recommend that the upper 24 inches of soil that is not protected by pavement or a concrete slab, be neglected when calculating passive resistance. This zone, where applicable, should be backfilled with cohesive soils to minimize infiltration of surface water into the backfill. For frictional resistance to lateral loads, we recommend that an ultimate coefficient of friction of 0.35 be used between soil and concrete.

To limit long-term hydrostatic pressure behind the wall, we recommend measures be taken such that surface water is not allowed to penetrate between the base of retaining walls and exterior slabs.

8.5 Pavements

We understand that project site pavements will be privately maintained. Pavement section alternatives are included herein for the paved surfaces, which include light duty, medium duty, and heavy duty.

The following pavement designs are based upon the design methods described in the "AASHTO Guide for Design of Pavement Structures 1993" published by the American Association of State Highway and Transportation Officials and guidelines and procedures of the CDOT and El Paso County.

8.5.1 Pavement Subgrade Support

The current subgrade soils encountered in our borings typically consisted of lean and fat clay with varying amounts of sand to clayey sand that classify as A-4 to A-7-6 soils in accordance with the American Association of State Highway and Transportation Officials (AASHTO) classification system. It is anticipated that fill imported to the site will classify as A-4 or better.

We utilized a design R-Value of 10 for the pavement subgrade soils. If during construction, the subgrade is found to vary from the expected soil conditions, we should be contacted so we may re-evaluate our recommended resilient modulus value.

8.5.2 Design Traffic

Specific traffic loadings were provided by the client. We utilized an equivalent 18-kip single axle load value of 50,000 for the light duty, 110,000 for the medium duty, and 180,000 for the heavy duty pavements.

If design traffic loadings differ significantly from these provided, we should be notified to re-evaluate the pavement recommendations below.

8.5.3 Pavement Design

Pavement design for the site was based on the 1993 “Guidelines for Design of Pavement Structures” by AASHTO. The design of flexible pavements was based on the following input parameters:

Initial Serviceability:	4.5
Terminal Serviceability:	2.5
Reliability	80%
Overall Standard Deviation:	0.44
Resilient Modulus (M_R):	3,563 psi (R-Value of 10)
Stage Construction:	1.0

The design of rigid pavements was based on the following input parameters:

Initial Serviceability:	4.5
Terminal Serviceability:	2.5
28-Day Mean PCC Modulus Rupture:	650 psi
28-Day Mean Elastic Modulus of Slab:	3.5×10^6 psi
Mean Effective k value:	150 psi/in
Reliability:	80%
Overall Standard Deviation:	0.34
Load Transfer Coefficient:	4.2
Overall Drainage Coefficient:	1.1

8.5.4 Pavement Section Recommendations

Based on the above-mentioned design traffic and input parameters, and following the AASHTO method of pavement design, Table 5 provides our recommended pavement section thicknesses for pavements supported on 24 or more inches of moisture conditioned and compacted engineered fill.

Table 5 – Recommended Pavement Thickness			
Traffic Type	Recommended Pavement Section		
	Full Depth AC (inches)	Composite AC / ABC(inches)	PCCP(inches)
Light Duty	6.0	4.5 / 6.0	5.0
Medium Duty	7.0	5.0 / 6.0	5.0
Heavy Duty	7.5	5.5 / 6.0	6.0
NOTES: AC = Asphalt Concrete, ABC = Aggregate Base Course, PCCP = Portland Cement Concrete Pavement			

We recommend PCCP be utilized in entrance and exit sections, dumpster pads, loading areas, or other areas where extensive wheel maneuvering are expected. The dumpster pad should be large enough to support the wheels of the truck, which will bear the load of the dumpster. We understand dumpster pads will be located within the heavy-duty concrete section, and as such, no modifications to the pavement section are recommended in these areas.

Although the use of ABC is not integral for structural support in PCCP pavements, the placement of 4 or more inches of ABC below PCCP pavements will develop a more stable subgrade for concrete truck traffic associated with the pavement construction and help reduce potential slab curl, shrinkage cracking, and subgrade “pumping” through joints. Adequate joint spacing and reinforcement is recommended to prevent loss of load transfer across saw-cut crack control joints. Joints should be sealed to reduce water infiltration.

Where practical, we recommend “early-entry” cutting of crack-control joints in PCCP. Cutting of PCCP 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.

Ninyo & Moore has observed dishing in some AC parking lots. Dishing is observed in frequently-used parking stalls (such as near the front of buildings), and occurs under the wheel footprint in these stalls. The use of higher-grade AC, or surfacing these areas with PCCP, could be considered. The dishing is exacerbated by factors such as irrigated islands or planter areas, and sheet surface drainage to the front of structures.

8.5.5 Pavement Materials

The AC pavement shall consist of a bituminous plant mix composed of a mixture of high quality aggregate and bituminous material, which meets the requirements of a job-mix formula established by a qualified engineer. The asphalt material used should be based on a SuperPave Gyratory Design Revolution of 50. Lower lifts should be constructed using an asphalt mix Grading S and asphalt cement binder grade PG 64-22. The top lift should be constructed using an asphalt mix Grading SX and asphalt cement binder grade of PG 64-22. Pavement layer thickness should be between 2 and 4 inches for the lower lifts and 2 inches for the top lift. The geotechnical engineer should be retained to review the proposed pavement mix designs, grading, and lift thicknesses prior to construction.

PCCP should consist of a plant mix composed of a mixture of aggregate, Portland cement, and appropriate admixtures meeting the requirements of El Paso County. Concrete should have a modulus of rupture of third point loading of 650 psi or more. The concrete should be air-entrained with approximately 6 percent air and should have a cement content of six or more sacks per cubic yard. Allowable slump should be approximately 4 inches.

Thickened edges should be used along outside edges of PCCP. Edge thickness should be 2 inches or more than the recommended PCCP thickness and taper to the recommended PCCP thickness 36 inches inward from the edge. Integral curbs may be used in lieu of thickened edges.

PCCP should have longitudinal and transverse joints that meet the applicable requirements of El Paso County.

The ABC material placed beneath pavements should meet the criteria of CDOT Class 6 aggregate base. Requirements for CDOT Class 6 aggregate base can be found in Section 703 of the current CDOT Standards and Specifications for Road and Bridge Construction.

8.5.6 Pavement Subgrade Preparation

For both the PCCP and AC pavement sections recommended above, we recommend the underlying subgrade soils be prepared as described in Section 8.1.2 of this report.

The contractor should be prepared either to dry the subgrade materials or moisten them, as needed, prior to compaction. Some site soils may pump or deflect during compaction if moisture levels are not carefully monitored. In addition, relatively clean sandy soils may rut or roll if the surface is allowed to become desiccated. The contractor should be prepared to process and compact such soils to establish a stable platform for paving, including use of chemical stabilization or geotextiles, where needed.

The prepared subgrade should be protected from the elements prior to pavement placement. Subgrades that are exposed to the elements may need additional moisture conditioning and compaction, prior to pavement placements.

Immediately prior to paving, the subgrade should be proofrolled with a heavily loaded, pneumatic tired vehicle and checked for moisture. Areas that show excessive deflection during proof rolling should be excavated and replaced and/or stabilized. Areas allowed to pond prior to paving may need to be re-worked prior to proofrolling.

8.5.7 Pavement Maintenance

The collection and diversion of surface drainage away from paved areas is vital to satisfactory performance of the pavements. The subsurface and surface drainage systems should be carefully designed to facilitate removal of the water from paved areas and subgrade soils. Allowing surface waters to pond on pavements will cause premature pavement deterioration. Where topography, site constraints or other factors limit or preclude adequate surface drainage, pavements should be provided with edge drains to reduce loss of subgrade support. The long-term performance of the pavement also can be improved by backfilling and compacting behind curbs, gutters, and sidewalks so that ponding is not permitted and water infiltration is reduced.

Drip irrigation systems are recommended for "island" planters within paved areas to reduce over-spray and water infiltration beyond the planters. Enclosing the soil in the planters with plastic liners and providing them with positive drainage also will reduce differential moisture increases in the surrounding subgrade soils. 'Xeriscape'-type landscaping is highly recommended. If this is not possible, we recommend edge drains where the profile/slopes are less than 1 percent.

As noted above, the standard care of practice in pavement design describes the recommended pavement sections as "20-year" design pavements; however, many pavements will not remain in satisfactory condition without routine, preventive maintenance and rehabilitation procedures performed during the life of the pavement. Preventive pavement treatments are surface rehabilitation and operations applied to improve or extend the functional life of a pavement. These treatments preserve, rather than improve, the structural capacity of the pavement structure. In the event the existing pavement is not structurally sound, the preventive maintenance will have no long-lasting effect. Therefore, a routine maintenance program to seal cracks, repair distressed areas, and perform thin overlays during the life of the pavement is recommended.

8.6 Concrete Flatwork

Exterior walkways and flatwork should be 4 or more inches thick. The slab edges should be deepened by two or more inches where exterior slabs-on-grade are placed adjacent to landscaping areas and taper to the recommended thickness 36 inches inward from the edge.

Concrete flatwork placed on the site soils may experience post-construction movement related distress caused by vertical and lateral soil movements as the flatwork subgrade soil moisture content varies and related soil volume change occurs. Movement of flatwork will occur even with remedial grading measures performed below the flatwork. Thus, where these types of elements abut rigid building foundations or isolated/suspended structures, differential movements should be anticipated. We recommend that flexible joints be provided where such elements abut the main structure to allow for differential movement at these locations.

We recommend that exterior concrete flatwork be supported on improved subgrade as described in Section 8.1.2 of this report. As stated above, increasing the depth of moisture-density conditioning of the subgrade soils beyond the above recommended depth will improve concrete flatwork performance. Positive drainage should be established and maintained adjacent to flatwork.

To reduce the potential manifestation of distress to exterior concrete flatwork due to movement of the underlying soil, we recommend that such flatwork be installed with crack-control joints at appropriate spacing as designed by the structural engineer.

In no case should exterior flatwork extend under any portion of the building where there is less than 2 inches of clearance between the flatwork and any element of the building. Exterior flatwork in contact with brick, rock facades, or any other element of the building can cause damage to the structure if the flatwork experiences movements.

8.7 Corrosion Considerations

The corrosion potential of on-site soils to concrete and buried metal was evaluated in the laboratory using selected samples obtained from the exploratory borings. Laboratory testing was performed to assess the effects of sulfate on concrete and the effects of soil resistivity on buried metal. Results of these tests are presented in Appendix B. Recommendations regarding concrete to be utilized in construction of proposed improvements and for buried metal pipes are provided in the following sections.

8.7.1 Concrete

The test for water-soluble sulfate content of the soils was performed using CDOT Test Method CP-L 2104. The laboratory test results are presented in Appendix B. The percentage of water-soluble sulfates measured at 0.192 percent, corresponding to 1,920 parts per million. Based on Table 601-2 of the CDOT 2011 Standard Specifications for Road and Bridge Construction, the on-site soils represent a Class 2 severity of sulfate exposure to concrete on a scale that ranges between Class 0 and Class 3. Therefore, we recommend that the concrete used for this project should have a maximum water to cementitious material ratio of 0.45 and the cementitious materials should meet one of the below outlined requirements. Additional recommendations for scaling protection of exterior concrete are provided in Section 8.6.

- ASTM C 150 Type V with a minimum of a 20 percent substitution of Class F fly ash by weight.
- ASTM C 150 Type II or III with a minimum of a 20 percent substitution of Class F fly ash by weight. The Type II or III cement shall have no more than 0.040 percent expansion at 14 days when tested according ASTM C 452.
- ASTM C 1157 Type HS; Class C fly ash shall not be substituted for cement.
- ASTM C 1157 Type MS plus Class F fly ash where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012.
- A blend of Portland cement meeting ASTM C 150 Type II or III with a minimum of 20 percent Class F fly ash by weight, where the blend has less than 0.05 percent expansion at 6 months or 0.10 percent expansion at 12 months when tested according to ASTM C 1012.
- ASTM C 595 Type IP(HS); Class C fly ash shall not be substituted for cement.

The Structural Engineer should ultimately select the concrete design strength based on the project specific loading conditions. However, higher strength concrete may be selected for increased durability, resistance to slab curling and shrinkage cracking. We recommend the use of concrete with a design 28-day compressive strength of 4,000 psi or more, for concrete slabs at this site. Concrete exposed to the elements should be air-entrained.

8.7.2 Buried Metal Pipes

The corrosion potential of the on-site materials was analyzed to evaluate its potential effects on buried metals. Corrosion potential was evaluated using the results of laboratory testing of samples obtained during the subsurface evaluation that were considered representative of soils at the subject site.

The results of the laboratory testing indicate the on-site materials have low resistivity and could potentially be severely corrosive to ferrous metals. Therefore, special consideration should be given to the use of heavy gauge, corrosion protected, underground steel pipe or culverts, if any are planned. As an alternative, plastic pipe or reinforced concrete pipe could be considered. A corrosion specialist should be consulted for further recommendations.

8.8 Scaling

Climatic conditions in the project area including relatively low humidity, large temperature changes and repeated freeze-thaw cycles, may cause surficial scaling and spalling of exterior concrete. Occurrence of surficial scaling and spalling can be aggravated by poor workmanship during construction, such as "over-finishing" concrete surfaces and the use of de-icing salts on exterior concrete flatwork, particularly during the first winter after construction. The use of de-icing salts on nearby roadways, which can be transferred by vehicle traffic onto newly placed concrete, can be sufficient to induce scaling.

The measures below can be beneficial for reducing the concrete scaling. However, because of the other factors involved, including workmanship, surface damage to concrete can develop even though the measures provided below were followed. The mix design criteria should be coordinated with other project requirements including the criteria for soluble sulfate resistance presented in Section 8.7.1.

- Curing concrete in accordance with applicable codes and guidelines.
- Maintaining a water/cement ratio of 0.45 by weight for exterior concrete mixes.
- Including Type F fly ash in exterior concrete mixes as 20 percent of the cementitious material.
- Specifying a 28-day, compressive strength of 4,500 or more psi for exterior concrete that may be exposed to de-icing salts.
- Avoiding the use of de-icing salts through the first winter after construction.
- If colored concrete is being proposed for use at this site, Ninyo & Moore should be consulted for additional recommendations.

8.9 Frost Heave

Site soils are susceptible to frost heave if allowed to become saturated and exposed to freezing temperatures and repeated freeze/thaw cycling. The formation of ice in the underlying soils can result in two or more inches of heave of pavements, flatwork and other hardscaping in sustained cold weather. A portion of this movement may be recovered when the soils thaw, but due to loss of soil density some degree of displacement will remain. Frost heave of hardscaping could also result in areas where the subgrade soils were placed on engineered fill.

In areas where hardscape movements are a design concern (i.e. exterior flatwork located adjacent to the building within the doorway swing zone), replacement of the subgrade soils with 3 or more feet of clean, coarse sand or gravel, or supporting the element on foundations similar to the building, or spanning over a void should be considered.

8.10 Construction in Cold or Wet Weather

During construction, the site should be graded such that surface water can drain readily away from the building areas. Given the soil conditions, it is important to avoid ponding of water in or near excavations. Water that accumulates in excavations should be promptly pumped out or otherwise removed and these areas should be allowed to dry out before resuming construction. Berms, ditches, and similar means should be used to decrease stormwater entering the work area and to efficiently convey it off site.

Earthwork activities undertaken during the cold weather season may be difficult and should be done by an experienced contractor. Fill should not be placed on top of frozen soils. The frozen soils should be removed prior to the placement of fill or other construction material. Frozen soil should not be used as engineered fill or backfill. The frozen soil may be reused (provided it meets the selection criteria) once it has thawed completely. In addition, compaction of the soils may be more difficult due to the viscosity change in water at lower temperatures.

If construction proceeds during cold weather, foundations, slabs, or other concrete elements should not be placed on frozen subgrade soil. Frozen soil should either be removed from beneath concrete elements, or thawed and recompacted. To limit the potential for soil freezing, the time passing between excavation and construction should be minimized. Blankets, straw, soil cover, or heating may be used to discourage the soil from freezing.

8.11 Site Drainage

Infiltration of water into subsurface soils can lead to soil movement and associated distress, and chemically and physically related deterioration of concrete structures. To reduce the potential for infiltration of moisture into subsurface soils at the site, we recommend the following:

- Positive drainage should be established and maintained away from the proposed buildings. Positive drainage may be established by providing a surface gradient for paved areas of 2 to 5 percent or more for a distance of 10 feet or more away from structures. Where concrete flatwork is placed adjacent to structures and other considerations are required by law, such as ADA requirements, slopes of 1 percent or more are considered acceptable. For unpaved areas, positive drainage may be established by a slope of 5 to 10 percent for 10 feet or more away from structures, where possible.

- Adequate surface drainage should be provided to channel surface water away from on-site structures and off paved surfaces to a suitable outlet such as a storm drain. Adequate surface drainage may be enhanced by utilization of graded swales, area drains, and other drainage devices. Surface run-off should not be allowed to pond near structures.

- Building roof drains should have downspouts tightlined to an appropriate outlet, such as a storm drain or the street, away from structures, pavements, and flatwork. If tightlining of the downspouts is not practicable, they should discharge 5 feet or more away from structures and onto surfaces that slope away from the structure. Downspouts should not be allowed to discharge onto the ground surface adjacent to building foundations or on exterior walkways.

- The possibility of moisture infiltration beneath a structure, in the event of plumbing leaks, should be considered in the design and construction of underground water and sewer conduits. Permitting increases in moisture to the building supporting soils may result in a decrease in bearing capacity and an increase in settlement, heave, and/or differential movement. Incorporating a perimeter drainage system around the building foundations that will aid in reduction of the moisture infiltration of subsurface soils may be considered. Due to the proposed construction and anticipated utilities within the structures, not placing the perimeter drainage would be considered a low risk to the owner.

- Irrigated landscaping, consisting of sprinklers to water plants with high demands for water, should not be placed within 10 feet of the building. Drip irrigation is considered acceptable within this zone.

- Utility trenches should be backfilled with compacted, low permeability fill (i.e. permeability of 5-10 cm/s or less) within 5 feet of the building. Planters, if any, should be maintained 10 feet or more from the building and constructed with closed bottoms or with drainage systems to drain excess irrigation away from the building.

8.12 Construction Observation and Testing

A qualified geotechnical consultant should perform appropriate observation and testing services during grading and construction operations. These services should include observation of any soft, loose, or otherwise unsuitable soils, evaluation of subgrade conditions where soil removals are performed, evaluation of the suitability of proposed borrow materials for use as fill, evaluation of the stability of open temporary excavations, evaluation of the results of any subgrade stabilization or dewatering activities, and performance of observation and testing services during placement and compaction of engineered fill and backfill soils.

The geotechnical consultant should also perform observation and testing services during placement of concrete, mortar, grout, AC, and steel reinforcement. If another geotechnical consultant is selected to perform observation and testing services for the project, we request that the selected consultant provide a letter to the owner, with a copy to Ninyo & Moore, indicating that they fully understand our recommendations and that they are in full agreement with the recommendations contained in this report. Qualified subcontractors utilizing appropriate techniques and construction materials should perform construction of the proposed improvements.

8.13 Plan Review

The recommendations presented in this report are based on preliminary design information for the proposed project and on the findings of our geotechnical evaluation. When finished, project plans and specifications should be reviewed by the geotechnical consultant prior to submitting the plans and specifications for bid. Additional field exploration and laboratory testing may be needed upon review of the project design plans.

8.14 Pre-Construction Meeting

We recommend a pre-construction meeting be held. The owner or the owner's representative, the architect, the contractor, and the geotechnical consultant should be in attendance to discuss the plans and the project.

9 LIMITATIONS

The field evaluation, laboratory testing, and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request. Please also note that our evaluation was limited to assessment of the geotechnical aspects of the project, and did not include evaluation of structural issues, environmental concerns, or the presence of hazardous materials.

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

This report is intended for design purposes only. It does not provide sufficient data to prepare an accurate bid by contractors. It is suggested that the bidders and their geotechnical consultant perform an independent evaluation of the subsurface conditions in the project areas. The independent evaluations may include, but not be limited to, review of other geotechnical reports prepared for the adjacent areas, site reconnaissance, and additional exploration and laboratory testing.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site could change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

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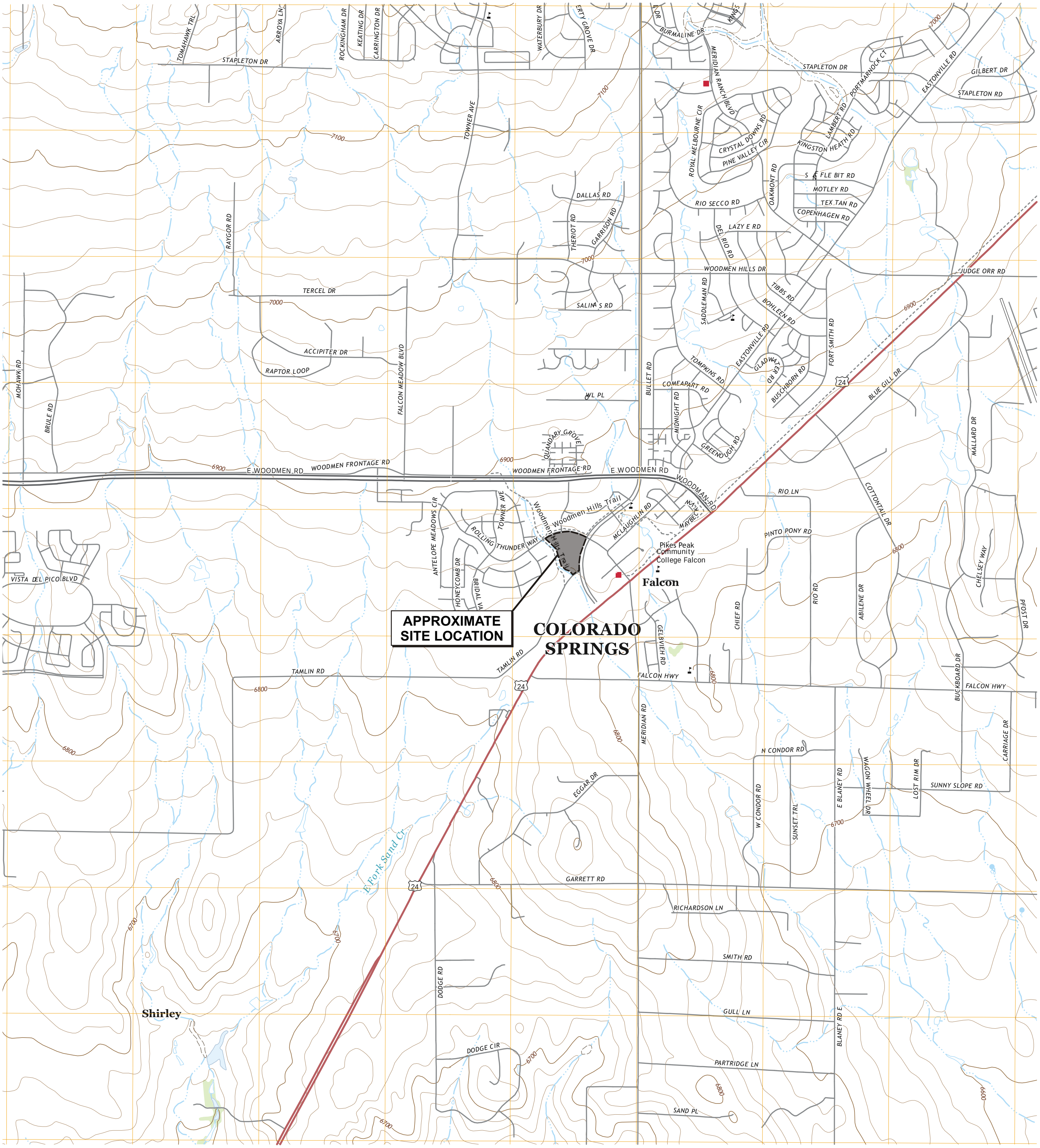
FIGURES



Source: US Geological Survey 7.5-minute topographic map, Falcon and Falcon NW, Colorado, 2019.

N

FEET

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NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

FIGURE 1

SITE LOCATION

PROPOSED NEW U-HAUL FACILITY
SOUTHWEST CORNER OF MERIDIAN ROAD AND ROLLING THUNDER WAY
FALCON, COLORADO

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elt file no: 2209vmap0921

Source: NAVTEQ, 10/06/19.

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

FIGURE 2

EXPLORATION LOCATIONS

PROPOSED NEW U-HAUL FACILITY
SOUTHWEST CORNER OF MERIDIAN ROAD AND ROLLING THUNDER WAY
FALCON, COLORADO

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elt file no: 2209exp0921

502209001: Vs Model, Line A-A'

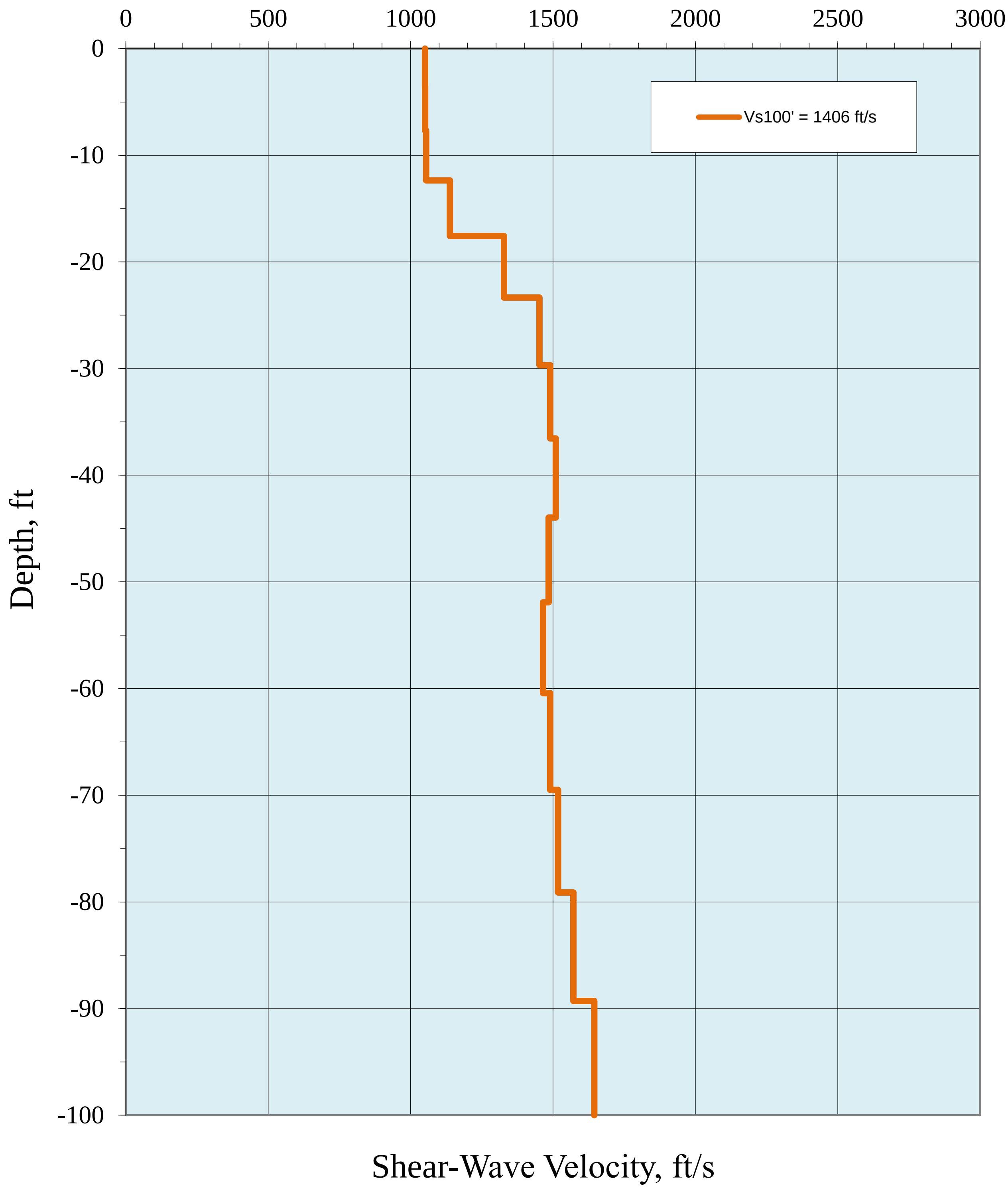

FIGURE 3

SEISMIC A - A'

PROPOSED NEW U-HAUL FACILITY
SOUTHWEST CORNER OF MERIDIAN ROAD AND ROLLING THUNDER WAY
FALCON, COLORADO

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elt file no: 2209cht0921

APPENDIX A

Boring Logs

APPENDIX A

BORING LOGS

Field Procedure for the Collection of Disturbed Samples
Disturbed soil samples were obtained in the field using the following methods.

Bulk Samples
Bulk samples of representative earth materials were obtained from the exploratory borings. The samples were bagged and transported to the laboratory for testing.

Field Procedure for the Collection of Relatively Undisturbed Samples
Relatively undisturbed soil samples were obtained in the field using the following methods.

The Modified California Split-Barrel Drive Sampler
The sampler, with an external diameter of 3.0 inches, was lined with 1-inch long, thin brass rings with inside diameters of approximately 2.4 inches. The sample barrel was driven into the ground with a 140-pound hammer free-falling from a height of 30 inches in general accordance with ASTM D3550. The approximate length of the fall, the weight of the hammer, and the number of blows per foot of driving are presented on the boring logs as an index to the relative resistance of the materials sampled. The samples were removed from the sample barrel in the brass rings, sealed, and transported to the laboratory for testing.

The California Drive Sampler
The sampler, with an external diameter of 2.4 inches, was lined with four, 4-inch long, thin brass rings with inside diameters of approximately 1.9 inches. The sample barrel was driven into the ground with the weight of a hammer in general accordance with ASTM D3550. The driving weight was permitted to fall freely. The approximate length of the fall, the weight of the hammer, and the number of blows per foot of driving are presented on the boring logs as an index to the relative resistance of the materials sampled. The samples were removed from the sample barrel in the brass liners, sealed, and transported to the laboratory for testing.

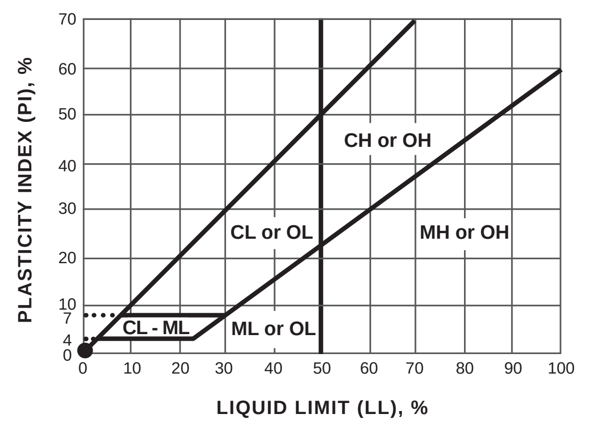
SOIL CLASSIFICATION CHART PER ASTM D 2488

PRIMARY DIVISIONS			SECONDARY DIVISIONS: GROUP SYMBOL	SECONDARY DIVISIONS: GROUP NAME
COARSE-GRAINED SOILS more than 50% retained on No. 200 sieve	**GRAVEL** more than 50% of coarse fraction retained on No. 4 sieve	CLEAN GRAVEL less than 5% fines	GW	well-graded GRAVEL
			GP	poorly graded GRAVEL
		GRAVEL with DUAL CLASSIFICATIONS 5% to 12% fines	GW-GM	well-graded GRAVEL with silt
			GP-GM	poorly graded GRAVEL with silt
			GW-GC	well-graded GRAVEL with clay
			GP-GC	poorly graded GRAVEL with clay
		GRAVEL with FINES more than 12% fines	GM	silty GRAVEL
			GC	clayey GRAVEL
			GC-GM	silty, clayey GRAVEL
	SAND 50% or more of coarse fraction passes No. 4 sieve	CLEAN SAND less than 5% fines	SW	well-graded SAND
			SP	poorly graded SAND
		SAND with DUAL CLASSIFICATIONS 5% to 12% fines	SW-SM	well-graded SAND with silt
			SP-SM	poorly graded SAND with silt
			SW-SC	well-graded SAND with clay
			SP-SC	poorly graded SAND with clay
		SAND with FINES more than 12% fines	SM	silty SAND
			SC	clayey SAND
			SC-SM	silty, clayey SAND
FINE-GRAINED SOILS 50% or more passes No. 200 sieve	**SILT and CLAY** liquid limit less than 50%	INORGANIC	CL	lean CLAY
			ML	SILT
			CL-ML	silty CLAY
		ORGANIC	OL (PI > 4)	organic CLAY
			OL (PI < 4)	organic SILT
	SILT and CLAY liquid limit 50% or more	INORGANIC	CH	fat CLAY
			MH	elastic SILT
		ORGANIC	OH (plots on or above "A"-line)	organic CLAY
			OH (plots below "A"-line)	organic SILT
	Highly Organic Soils		PT	Peat

GRAIN SIZE

DESCRIPTION		SIEVE SIZE	GRAIN SIZE	APPROXIMATE SIZE
Boulders		> 12"	> 12"	Larger than basketball-sized
Cobbles		3 - 12"	3 - 12"	Fist-sized to basketball-sized
Gravel	Coarse	3/4 - 3"	3/4 - 3"	Thumb-sized to fist-sized
	Fine	#4 - 3/4"	0.19 - 0.75"	Pea-sized to thumb-sized
Sand	Coarse	#10 - #4	0.079 - 0.19"	Rock-salt-sized to pea-sized
	Medium	#40 - #10	0.017 - 0.079"	Sugar-sized to rock-salt-sized
	Fine	#200 - #40	0.0029 - 0.017"	Flour-sized to sugar-sized
Fines		Passing #200	< 0.0029"	Flour-sized and smaller

PLASTICITY CHART



APPARENT DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPOOLING CABLE OR CATHEAD: SPT (blows/foot)	SPOOLING CABLE OR CATHEAD: MODIFIED SPLIT BARREL (blows/foot)	AUTOMATIC TRIP HAMMER: SPT (blows/foot)	AUTOMATIC TRIP HAMMER: MODIFIED SPLIT BARREL (blows/foot)
Very Loose	≤ 4	≤ 8	≤ 3	≤ 5
Loose	5 - 10	9 - 21	4 - 7	6 - 14
Medium Dense	11 - 30	22 - 63	8 - 20	15 - 42
Dense	31 - 50	64 - 105	21 - 33	43 - 70
Very Dense	> 50	> 105	> 33	> 70

CONSISTENCY - FINE-GRAINED SOIL

CONSIS-TENCY	SPOOLING CABLE OR CATHEAD: SPT (blows/foot)	SPOOLING CABLE OR CATHEAD: MODIFIED SPLIT BARREL (blows/foot)	AUTOMATIC TRIP HAMMER: SPT (blows/foot)	AUTOMATIC TRIP HAMMER: MODIFIED SPLIT BARREL (blows/foot)
Very Soft	< 2	< 3	< 1	< 2
Soft	2 - 4	3 - 5	1 - 3	2 - 3
Firm	5 - 8	6 - 10	4 - 5	4 - 6
Stiff	9 - 15	11 - 20	6 - 10	7 - 13
Very Stiff	16 - 30	21 - 39	11 - 20	14 - 26
Hard	> 30	> 39	> 20	> 26

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USCS METHOD OF SOIL CLASSIFICATION

Explanation of USCS Method of Soil Classification

PROJECT NO.	DATE	FIGURE

BORING LOG EXPLANATION SHEET

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	
0								Bulk sample.
								Modified split-barrel drive sampler.
								2-inch inner diameter split-barrel drive sampler.
								No recovery with modified split-barrel drive sampler, or 2-inch inner diameter split-barrel drive sampler.
								Sample retained by others.
5								Standard Penetration Test (SPT).
								No recovery with a SPT.
			XX/XX					Shelby tube sample. Distance pushed in inches/length of sample recovered in inches.
								No recovery with Shelby tube sampler.
								Continuous Push Sample.
10								Seepage.
								Groundwater encountered during drilling.
								Groundwater measured after drilling.
							SM	<u>MAJOR MATERIAL TYPE (SOIL)</u>: Solid line denotes unit change.
							CL	Dashed line denotes material change.
								Attitudes: Strike/Dip b: Bedding c: Contact j: Joint f: Fracture F: Fault cs: Clay Seam s: Shear bss: Basal Slide Surface sf: Shear Fracture sz: Shear Zone sbs: Shear Bedding Surface
15								
								The total depth line is a solid line that is drawn at the bottom of the boring.
20								

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BORING LOG

Explanation of Boring Log Symbols

PROJECT NO.	DATE	FIGURE

DATE DRILLED 8/4/2021 BORING NO. B-1

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME 75, 4" Solid Stem Auger (Dakota Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cathead) DROP 30"

SAMPLED BY JDA LOGGED BY JDA REVIEWED BY BFG

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0								TOPSOIL: Approximately 1 foot thick.
								BLACK SQUIRREL FORMATION: Gray, moist, moderately soft, sandy CLAYSTONE; weathered; calcium mineralization and iron staining.
			33	12.3	122.4			
			50/9"	12.6	122.8			Gray to yellow, hard, sandy CLAYSTONE; calcium mineralization and iron staining.
			50/7"	11.9	124.1			Gray.
10								
			50/8"					Dark brown to gray; trace lignite.
			50/3"					Gray to light gray; dry to moist; very hard.
20								
			50/2"					Light blue and gray.
								Total Depth: 24.2 feet. Groundwater was not encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021.
								Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
30								
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FALCON, COLORADO

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DATE DRILLED	8/4/2021	BORING NO.	B-2
GROUND ELEVATION	--	SHEET	1 OF 1
METHOD OF DRILLING	CME 75, 4" Solid Stem Auger (Dakota Drilling)		
DRIVE WEIGHT	140 lbs. (Spooling Cathead)	DROP	30"
SAMPLED BY	JDA	LOGGED BY	JDA
REVIEWED BY	BFG		

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	X							TOPSOIL: Approximately 1 foot thick.
	X	X	20	56.3	114.6			BLACK SQUIRREL FORMATION: Gray to light gray, moist, soft, sandy CLAYSTONE; weathered.
	X	X	30	9.0	130.3			Gray to light gray, moist, weakly cemented, clayey SANDSTONE; weathered; iron staining.
10		X	32	18.8	111.9			Dark gray, dark brown, and yellow, moist, moderately soft, CLAYSTONE; weathered; iron staining; lignite; calcium mineralization.
		X	50/5"	17.4	110.3			Gray, moist, very hard, CLAYSTONE; trace iron staining.
								Total Depth: 14.4 feet. Groundwater was not encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
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FIGURE A- 2

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PROPOSED U-HAUL FACILITY
FALCON, COLORADO

DATE DRILLED 8/4/2021 BORING NO. B-3

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME 75, 4" Solid Stem Auger (Dakota Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cathead) DROP 30"

SAMPLED BY JDA LOGGED BY JDA REVIEWED BY BFG

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	Bulk					SC	ALLUVIUM: Light brown, dry, clayey SAND with gravel.
	Bulk / Driven	50/7"	7.3	129.4			BLACK SQUIRREL FORMATION: Gray to light gray, dry, hard, sandy CLAYSTONE; trace iron staining.
	Bulk / Driven	50/5"	6.7	125.2			Gray to yellow, dry, strongly cemented, clayey SANDSTONE.
10	Driven	50/9"	12.3	124.2			Dark gray to dark brown, moist, hard, CLAYSTONE.
	Driven	50/5"					Trace lignite.
							Total Depth: 14.4 feet. Groundwater was not encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021.
							Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
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FIGURE A- 3

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PROPOSED U-HAUL FACILITY
FALCON, COLORADO

DATE DRILLED	8/4/2021	BORING NO.	B-4
GROUND ELEVATION	--	SHEET 1 OF 1	
METHOD OF DRILLING	CME 75, 4" Solid Stem Auger (Dakota Drilling)		
DRIVE WEIGHT	140 lbs. (Spooling Cathead)	DROP	30"
SAMPLED BY JDA	LOGGED BY JDA	REVIEWED BY	BFG

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0								TOPSOIL: Approximately 6 inches thick.
								BLACK SQUIRREL FORMATION: Gray to light gray, dry to moist, moderately soft, sandy CLAYSTONE; weathered.
	■	X	39	10.2	126.3			
	■	X	50	8.4	132.4			Moderately hard; trace iron staining.
		X	50/10"	10.3	127.7			Dark brown to dark gray, dry to moist, moderately hard, CLAYSTONE; trace iron staining.
10								
		X	50/7"					Dark gray; hard.
								Total Depth: 14.7 feet. Groundwater was not encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
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FIGURE A- 4

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DATE DRILLED	8/4/2021
BORING NO.	B-5
GROUND ELEVATION	--
SHEET	1 OF 1
METHOD OF DRILLING	CME 75, 4" Solid Stem Auger (Dakota Drilling)
DRIVE WEIGHT	140 lbs. (Spooling Cathead)
DROP	30"
SAMPLED BY	JDA
LOGGED BY	JDA
REVIEWED BY	BFG

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	Bulk							TOPSOIL: Approximately 6 inches thick.
	Bulk							BLACK SQUIRREL FORMATION: Gray, brown, and red, moist, soft, sandy CLAYSTONE; weathered; calcium mineralization.
	Bulk	Driven	16	16.3	112.4			
	Bulk	Driven	43	17.6	112.1			Dark gray to dark brown; moderately hard; trace iron staining.
		Driven	50/7"	18.0	113.7			Gray, moist, hard, CLAYSTONE; trace iron staining.
10								
		Driven	50/6"					
								Total Depth: 14.5 feet. Groundwater was encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
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DATE DRILLED 8/4/2021 BORING NO. B-6

GROUND ELEVATION -- SHEET 1 OF 1

METHOD OF DRILLING CME 75, 4" Solid Stem Auger (Dakota Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cathead) DROP 30"

SAMPLED BY JDA LOGGED BY JDA REVIEWED BY BFG

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	X						SC	ALLUVIUM: Light brown, dry, clayey SAND with gravel.
	X	X	44	11.7	125.9			BLACK SQUIRREL FORMATION: Gray, dry to moist, moderately hard, CLAYSTONE; weathered; iron staining.
	X	X	50	11.3	125.5			Dark gray to dark brown.
		X	50/6"	16.0	116.5			Gray, dry to moist, hard, CLAYSTONE; trace iron staining.
10								
		X	50/4"					Dark gray; very hard.
								Total Depth: 14.3 feet. Groundwater was not encountered during drilling. Backfilled with on-site soil after drilling on 8/4/2021.
								Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20								
30								
40								

DATE DRILLED	8/4/2021	BORING NO.	B-7
GROUND ELEVATION	--	SHEET	1 OF 1
METHOD OF DRILLING	CME 75, 4" Solid Stem Auger (Dakota Drilling)		
DRIVE WEIGHT	140 lbs. (Spooling Cathead)	DROP	30"
SAMPLED BY	JDA	LOGGED BY	JDA
REVIEWED BY	BFG		

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	Bulk						ALLUVIUM: Light brown, dry, clayey SAND.
	Bulk / Driven	27	8.5	122.2			BLACK SQUIRREL FORMATION: Light brown, gray, dry to moist, weakly cemented, clayey SANDSTONE; weathered.
	Bulk / Driven	50/11"	6.4	126.8			Gray to brown to yellow; moderately cemented; iron staining.
10	Driven	50	15.8	115.0			Gray, dry to moist, moderately hard, CLAYSTONE; trace iron staining.
	Driven	50/6"	12.0	121.0			Gray to light gray, dry to moist, hard, CLAYSTONE.
20	Driven	50/5"	14.4	118.0			Gray, moist, strongly cemented, SANDSTONE.
	Driven	50/4"	10.8	106.9			Light blue and gray.

Total Depth: 24.3 feet.
Groundwater was not encountered during drilling.
Backfilled with on-site soil after drilling on 8/4/2021.

Note:
Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.

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DATE DRILLED	8/4/2021
BORING NO.	B-8
GROUND ELEVATION	--
SHEET	1 OF 1
METHOD OF DRILLING	CME 75, 4" Solid Stem Auger (Dakota Drilling)
DRIVE WEIGHT	140 lbs. (Spooling Cathead)
DROP	30"
SAMPLED BY	JDA
LOGGED BY	JDA
REVIEWED BY	BFG

DEPTH (feet)	SAMPLES (Bulk / Driven)	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	Bulk					CL	ALLUVIUM: Dark brown to black, moist, stiff, sandy lean CLAY; trace rootlets.
	Driven	16	22.7	102.1			
	Driven	13	33.9	87.0			
			▽				@8': Groundwater was encountered during drilling.
10	Driven	26	18.2	111.0			Light gray; wet; very stiff.
	Driven	50/5"					BLACK SQUIRREL FORMATION: Light blue and gray, moist, very hard, CLAYSTONE.
							Total Depth: 14.4 feet. Groundwater was encountered during drilling at approximately 8 feet. Backfilled with on-site soil after drilling on 8/4/2021.
							Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
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FIGURE A- 8

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PROPOSED U-HAUL FACILITY
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APPENDIX B

Laboratory Testing

APPENDIX B

LABORATORY TESTING

Classification

Soils were visually and texturally classified in accordance with the Unified Soil Classification System (USCS) in general accordance with ASTM D2488. Soil classifications are indicated on the logs of the exploratory borings in Appendix A.

In-Place Moisture and Density Tests

The moisture content and dry density of relatively undisturbed samples obtained from the exploratory excavations were evaluated in general accordance with ASTM D2937 and ASTM D2216. The test results are presented on the logs of the exploratory excavations in Appendix A.

Atterberg Limits

Tests were performed on selected representative soil samples to evaluate the liquid limit, plastic limit, and plasticity index in general accordance with ASTM D4318. These test results were utilized to evaluate the soil classification in accordance with the USCS. The test results are incorporated in the logs in Appendix A, and are summarized on Figure B-1.

200 Wash

An evaluation of the percentage of particles finer than the No. 200 sieve in a selected soil sample was performed in general accordance with ASTM D1140. The results of the tests are presented on Figure B-2.

Consolidation/Swell Tests

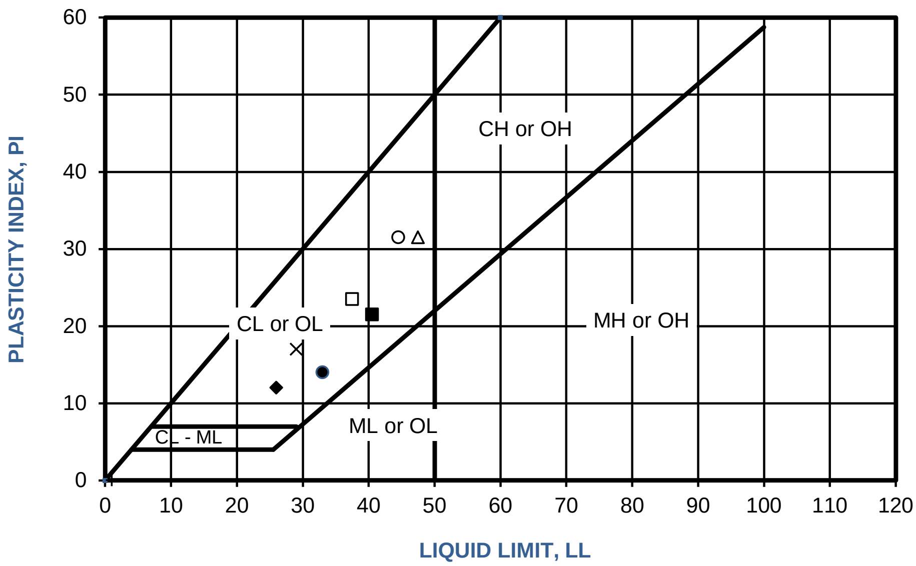
The swell potential of selected materials was evaluated in general accordance with ASTM D4546, Method B. Relatively undisturbed specimens were loaded with a specified surcharge before inundation with tap water. Readings of volumetric swell were recorded until completion of primary swell. The results of the tests are presented on Figures B-3 through B-11.

Soil Corrosivity Tests

Soil pH and resistivity tests were performed on representative samples in general accordance with ASTM D4972 and AASHTO T288, respectively. The soluble sulfate of a selected sample was evaluated in general accordance with CDOT Test Method CP-L 2103. The chloride content of a selected sample was evaluated in general accordance with CDOT Test Method CP-L 2104. The test results are presented on Figure B-12.

SYMBOL	LOCATION	DEPTH (ft)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	USCS CLASSIFICATION (Fraction Finer Than No. 40 Sieve)	EQUIVALENT USCS
●	B-1	2.0-3.0	33	19	14	CL	CL
■	B-1	4.0-4.8	41	19	22	CL	CL
◆	B-3	4.0-4.4	26	14	12	CL	SC
○	B-4	2.0-3.0	45	13	32	CL	CL
□	B-4	9.0-9.8	38	14	24	CL	CL
Δ	B-5	4.0-5.0	48	16	32	CL	CL
X	B-7	19.0-19.4	29	12	17	CL	SC

NP - INDICATES NON-PLASTIC



PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4318

SAMPLE LOCATION	SAMPLE DEPTH (ft)	DESCRIPTION	PERCENT PASSING NO. 4	PERCENT PASSING NO. 200	EQUIVALENT USCS
B-1	4.0-4.8	Gray, and Yellow, CLAYSTONE; BLACK SQUIRREL FORMATION	100	74	CL
B-3	4.0-4.4	Gray, and Yellow, Clayey SANDSTONE; BLACK SQUIRREL FORMATION	100	33	SC
B-4	2.0-3.0	Gray Sandy CLAYSTONE; BLACKSTONE FORMATION	100	64	CL
B-4	9.0-9.8	Dark Brown and Dark Gray, CLAYSTONE; BLACK SQUIRREL FORMATION	100	85	CL
B-5	4.0-5.0	Dark Gray and Dark Brown CLAYSTONE; BLACK SQUIRREL FORMATION	100	88	CL
B-7	19.0-19.4	Gray SANDSTONE; BLACK SQUIRREL FORMATION	100	23	SC
B-8	2.0-3.0	Dark Brown and Black, Sandy Lean CLAY	100	64	CL

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 1140

FIGURE B-2

NO. 200 SIEVE ANALYSIS TEST RESULTS

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PROPOSED U-HAUL FACILITY
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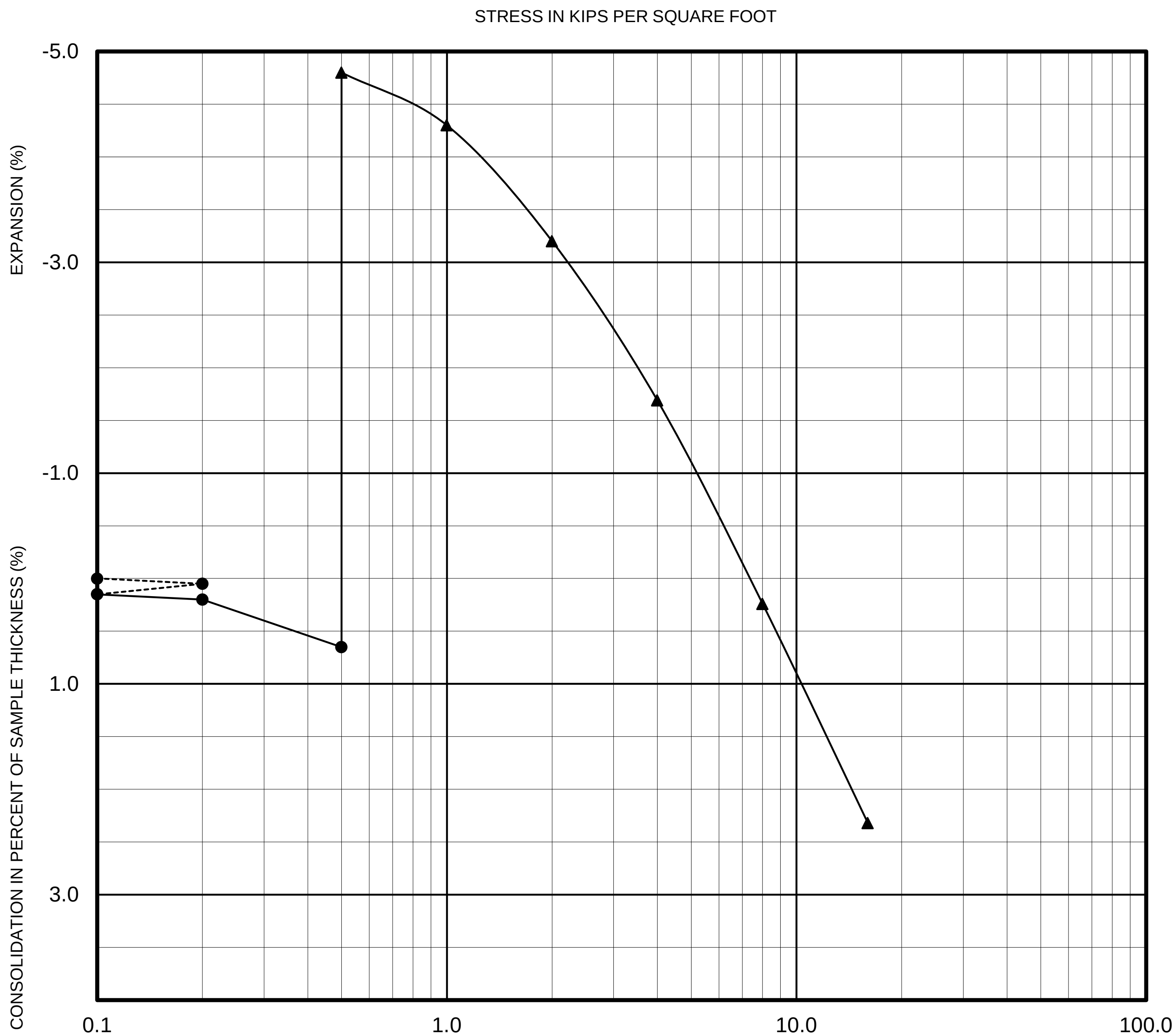

Seating Cycle
Loading Prior to Inundation
Loading After Inundation
Rebound Cycle

Moisture Increase (%): 3.7
Swell Percentage (%): 5.5
Swell Pressure (psf): 8,700

Sample Location: B-1
Depth (ft): 4.0-4.8
Soil Type: CLAYSTONE

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4546

FIGURE B-4

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CONSOLIDATION TEST RESULTS

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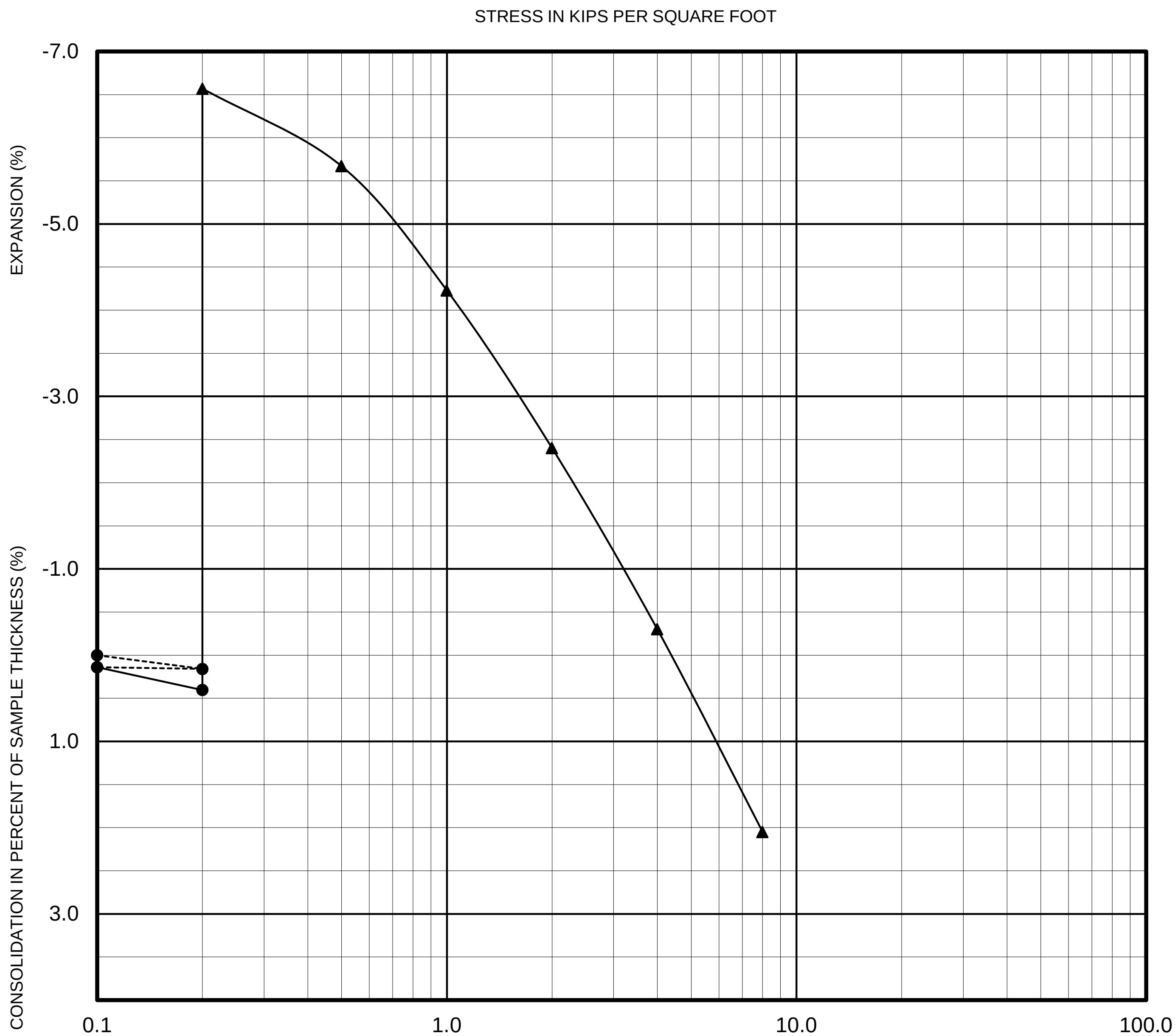

Seating Cycle
Loading Prior to Inundation
Loading After Inundation
Rebound Cycle

Moisture Increase (%): 5.0
Swell Percentage (%): 7.0
Swell Pressure (psf): 4,800

Sample Location: B-1
Depth (ft): 2.0-3.0
Soil Type: CLAYSTONE

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FIGURE B-3

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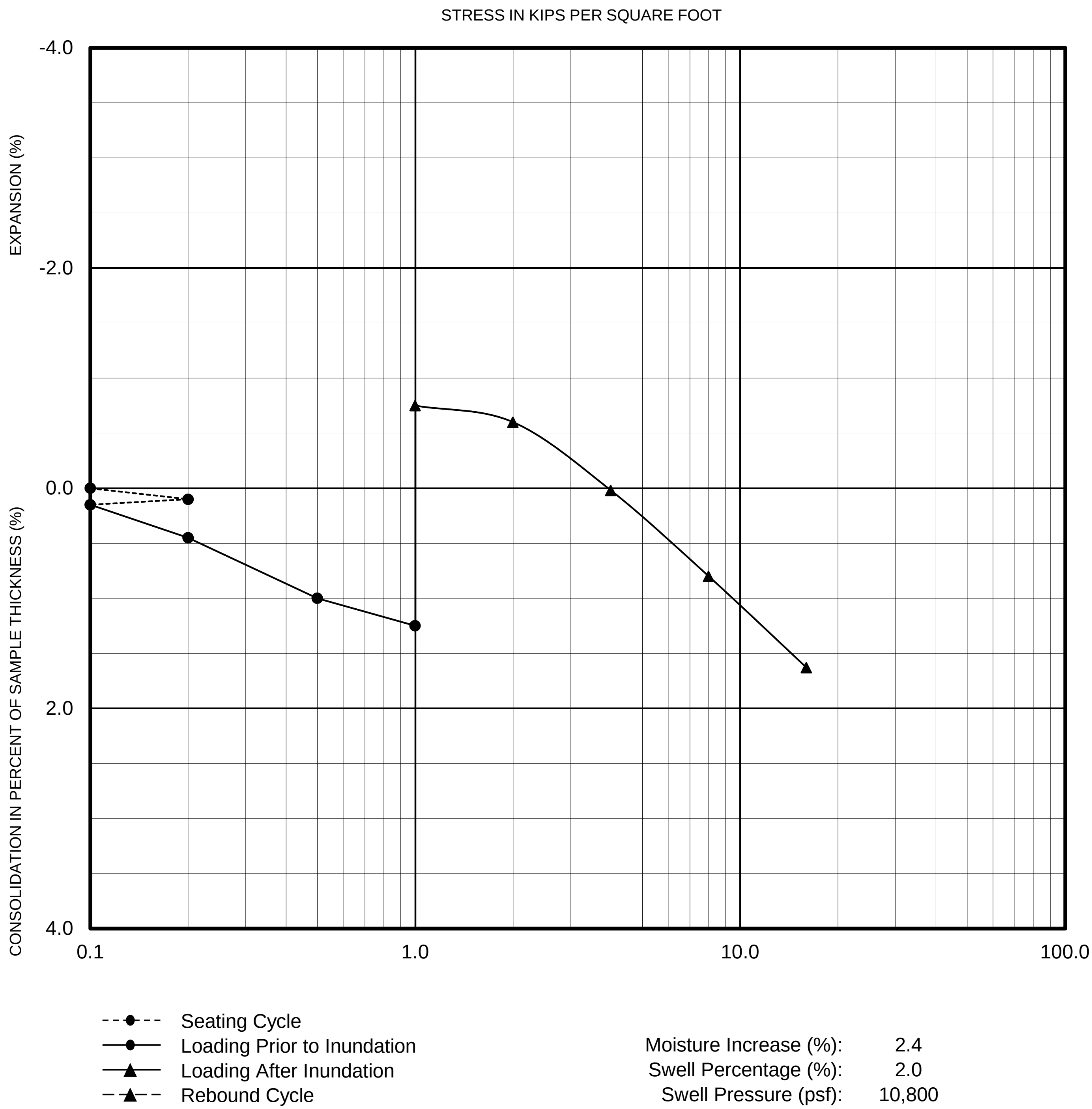

Moisture Increase (%):	2.4
Swell Percentage (%):	2.0
Swell Pressure (psf):	10,800

Sample Location: B-1
Depth (ft): 9.0-9.6
Soil Type: CLAYSTONE

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4546

FIGURE B-5

CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY
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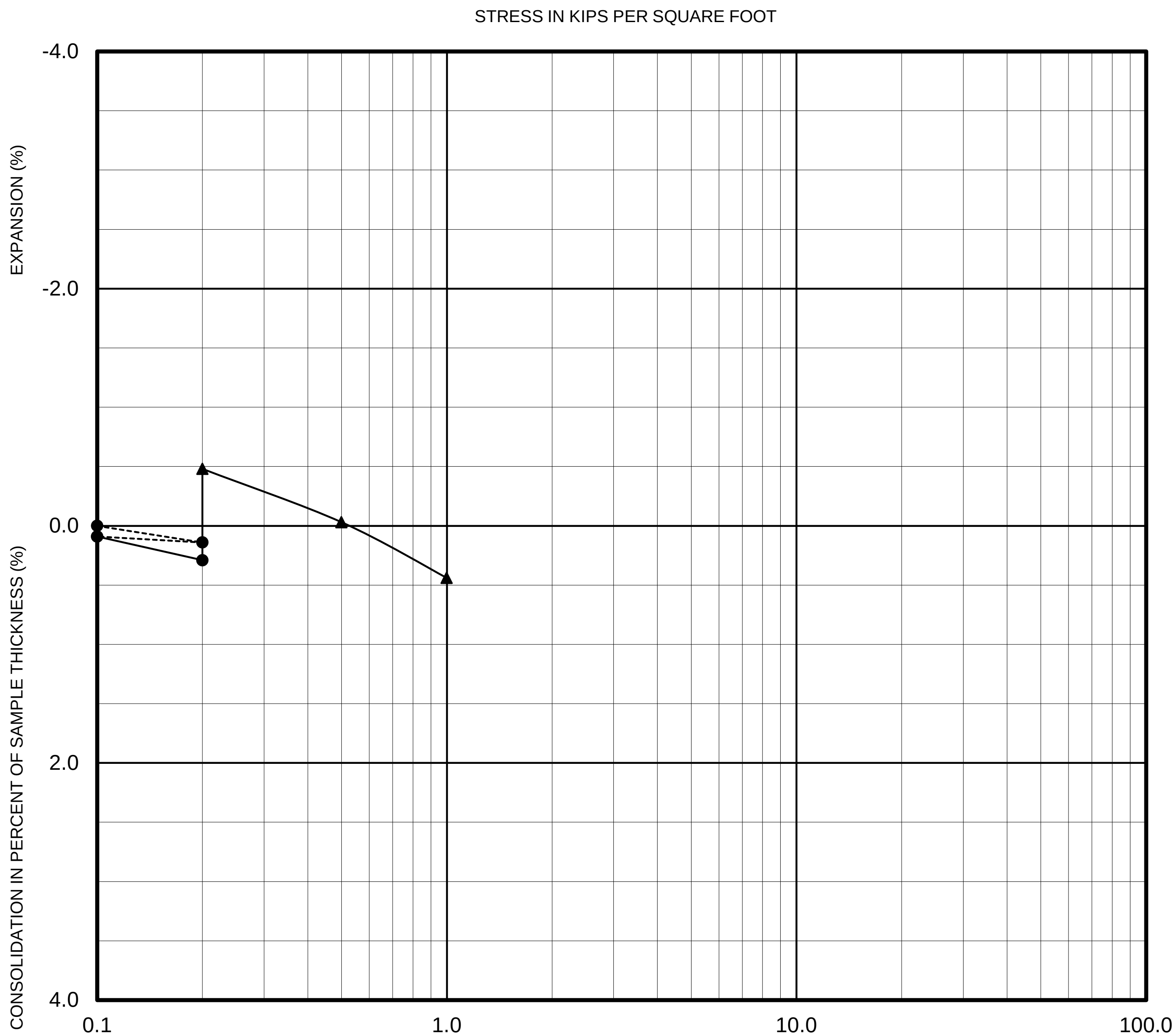

Seating Cycle
Loading Prior to Inundation
Loading After Inundation
Rebound Cycle

Moisture Increase (%):	2.5
Swell Percentage (%):	0.8
Swell Pressure (psf):	600

Sample Location: B-5
Depth (ft): 2.0-3.0
Soil Type: CLAYSTONE

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FIGURE B-6

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CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY
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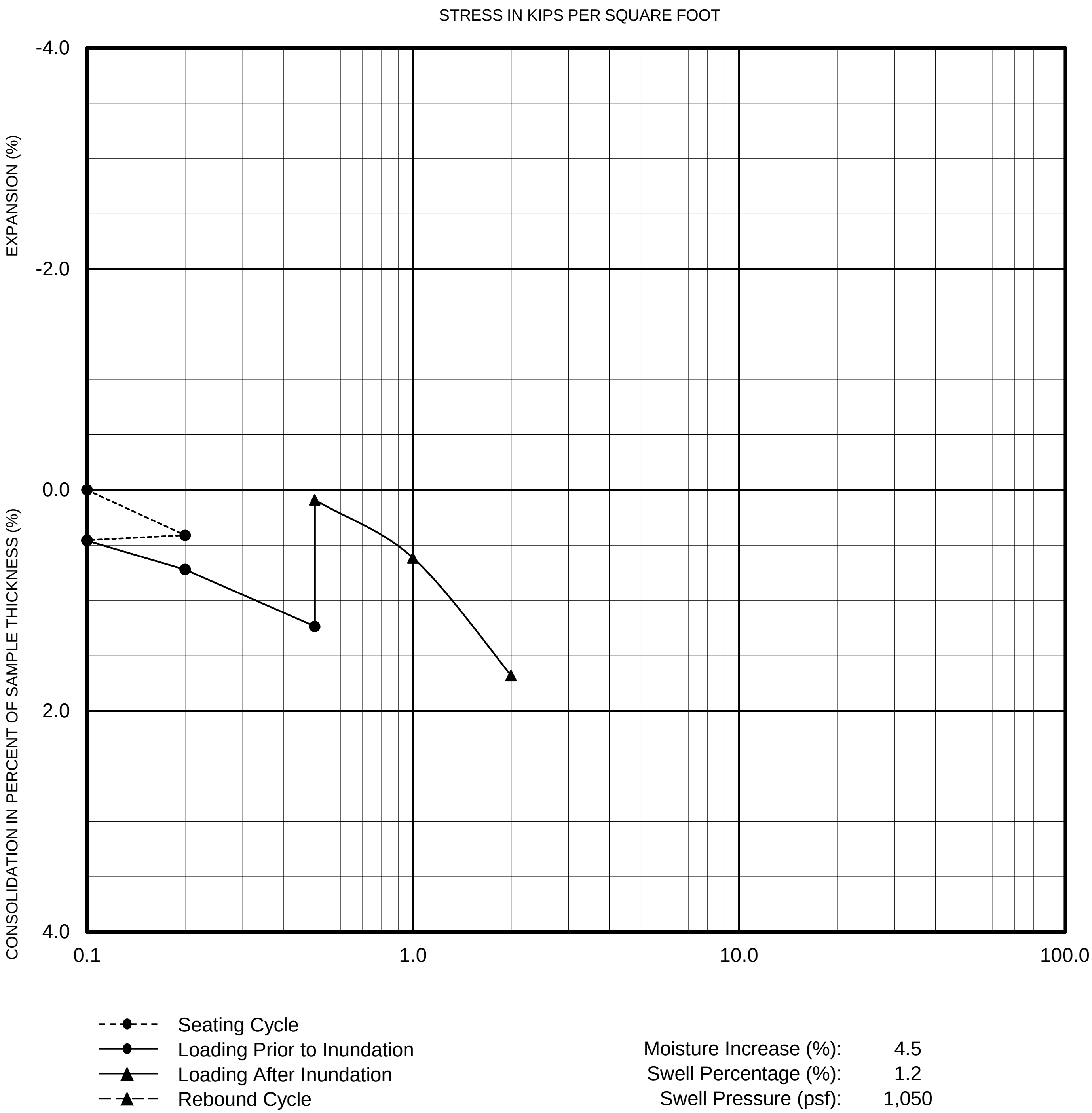

Moisture Increase (%): 4.5
Swell Percentage (%): 1.2
Swell Pressure (psf): 1,050

Sample Location: B-5
Depth (ft): 4.0-5.0
Soil Type: CLAYSTONE

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FIGURE B-7

CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY
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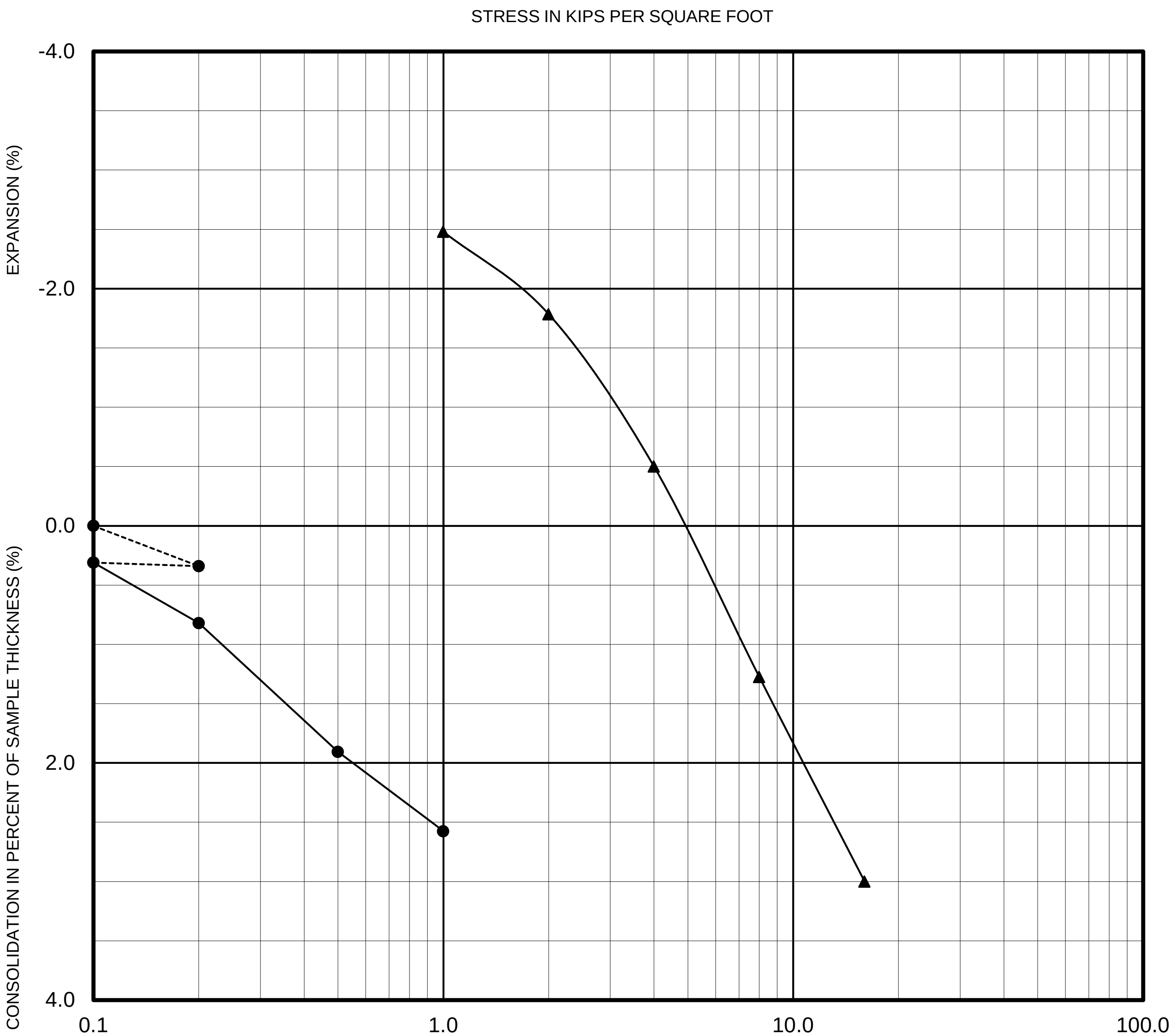

Seating Cycle
Loading Prior to Inundation
Loading After Inundation
Rebound Cycle

Moisture Increase (%): 3.6
Swell Percentage (%): 5.1
Swell Pressure (psf): 12,600

Sample Location: B-5
Depth (ft): 9.0-10.0
Soil Type: CLAYSTONE

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4546

FIGURE B-8

CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY
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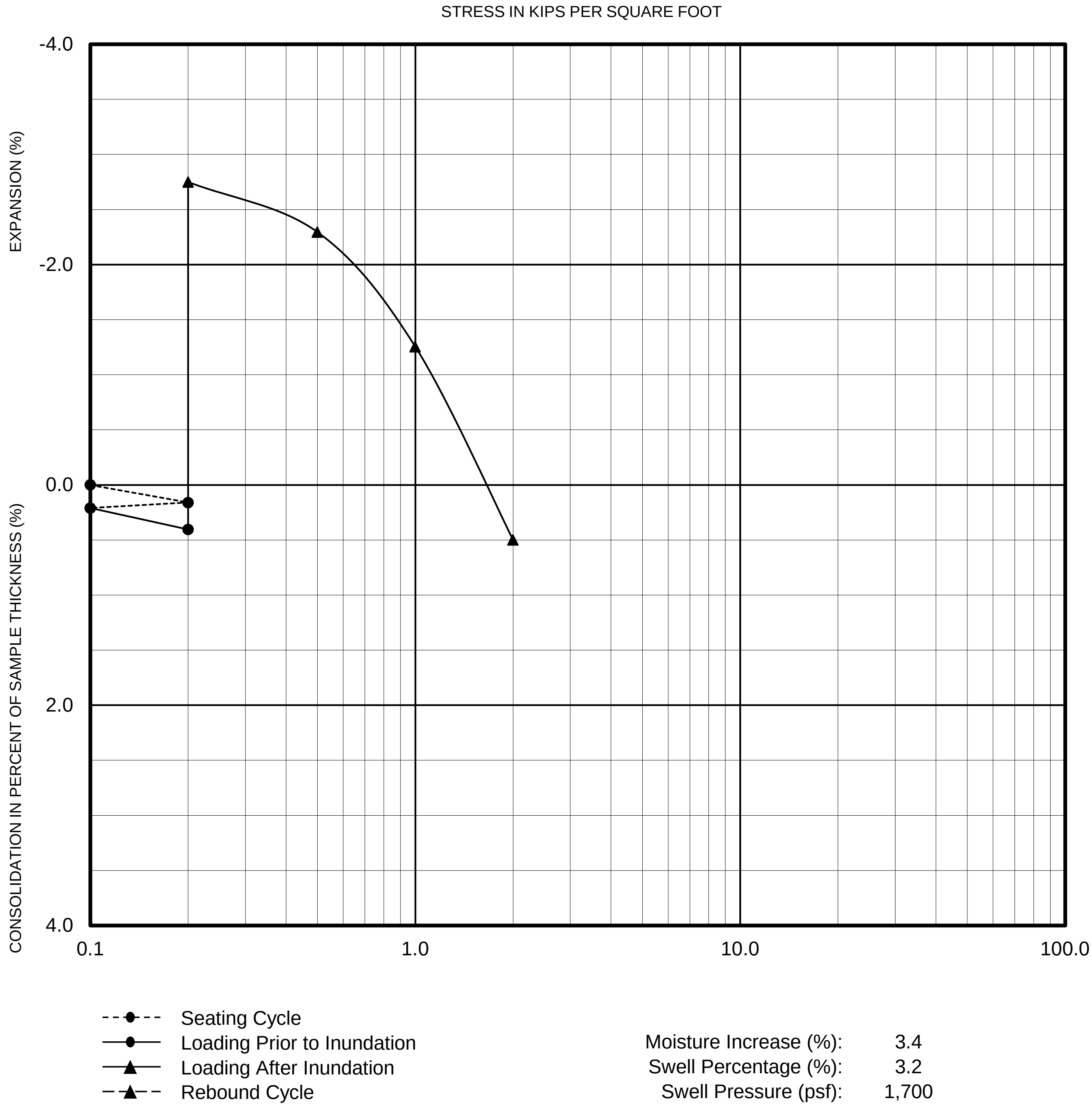

Moisture Increase (%):	3.4
Swell Percentage (%):	3.2
Swell Pressure (psf):	1,700

Sample Location: B-8
Depth (ft): 2.0-3.0
Soil Type: CL

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4546

FIGURE B-9

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CONSOLIDATION TEST RESULTS

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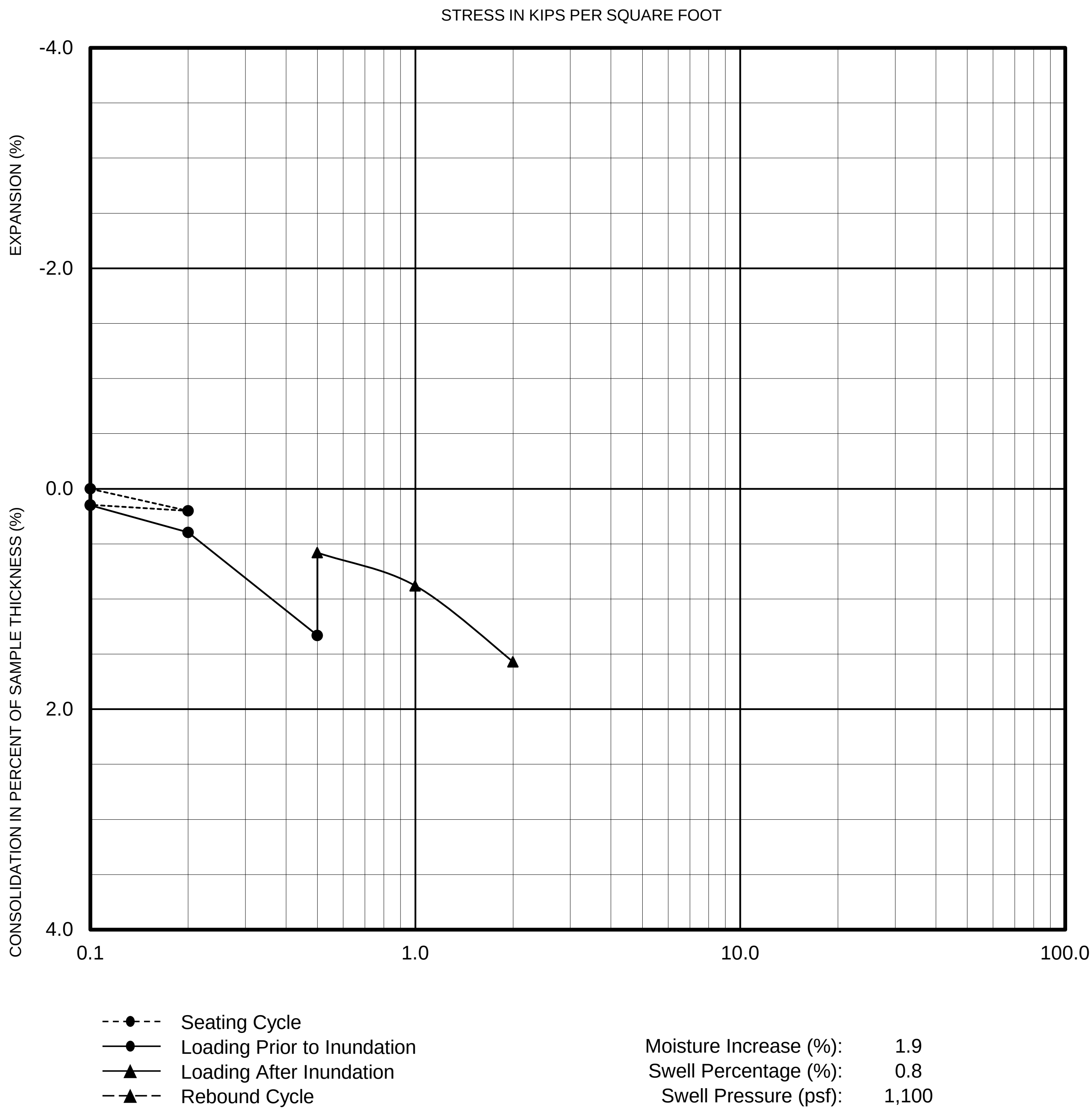

Moisture Increase (%): 1.9
Swell Percentage (%): 0.8
Swell Pressure (psf): 1,100

Sample Location: B-8
Depth (ft): 4.0-5.0
Soil Type: CL

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FIGURE B-10

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CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY

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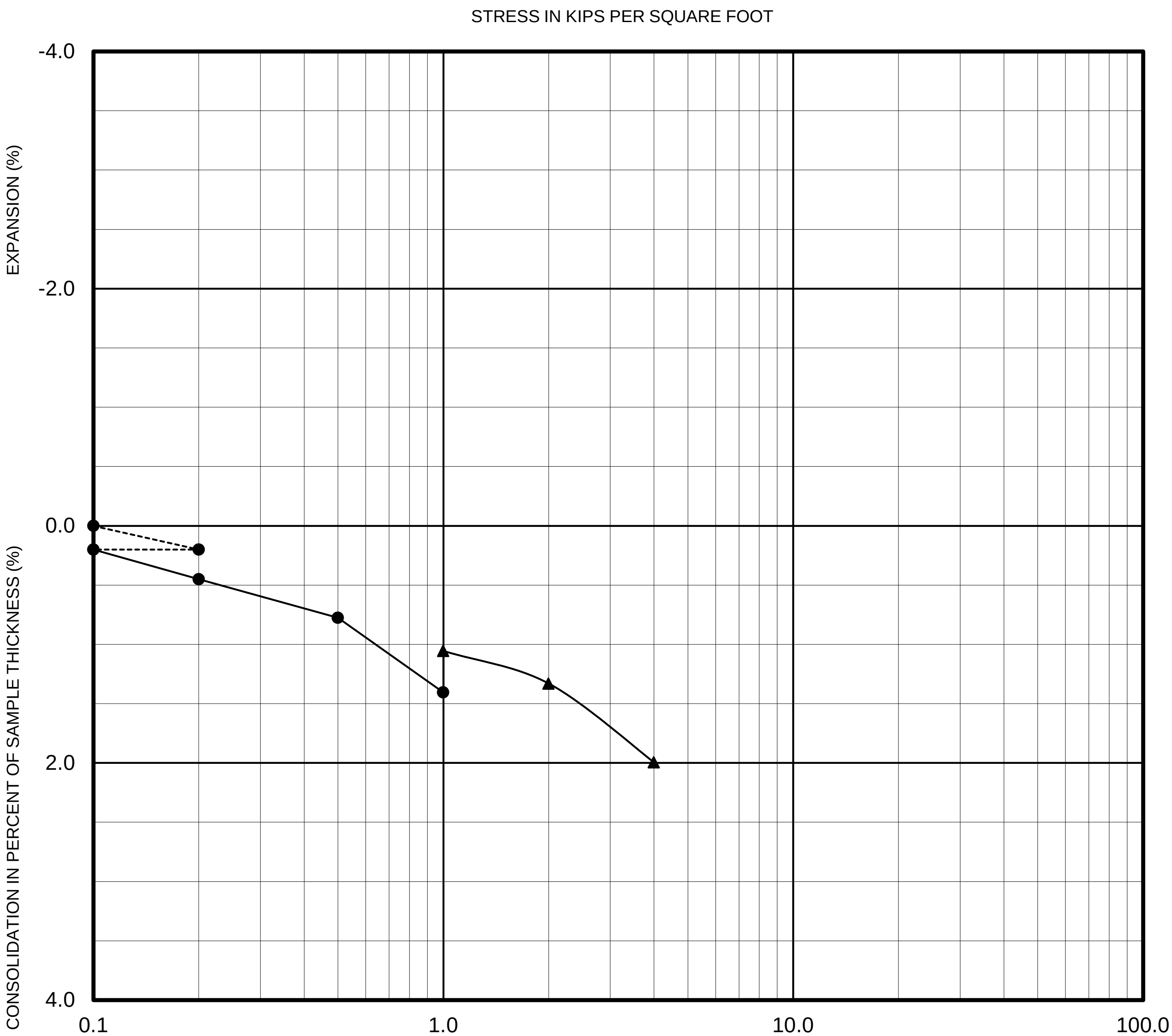

Seating Cycle
Loading Prior to Inundation
Loading After Inundation
Rebound Cycle

Moisture Increase (%):	0.5
Swell Percentage (%):	0.4
Swell Pressure (psf):	1,250

Sample Location:	B-8
Depth (ft):	9.0-10.0
Soil Type:	CL

PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4546

FIGURE B-11

CONSOLIDATION TEST RESULTS

PROPOSED U-HAUL FACILITY
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SAMPLE LOCATION	SAMPLE DEPTH (ft)	pH [1]	RESISTIVITY [2] (ohm-cm)	SULFATE CONTENT [3] (ppm)	SULFATE CONTENT [3] (%)	CHLORIDE CONTENT [4] (ppm)
B-1 through B-7	0.0-5.0	7.8	369	1920	0.192	40

[1] PERFORMED IN GENERAL ACCORDANCE WITH ASTM D 4972

[2] PERFORMED IN GENERAL ACCORDANCE WITH AASHTO T288

[3] PERFORMED IN GENERAL ACCORDANCE WITH CDOT TEST METHOD CP-L 2103

[4] PERFORMED IN GENERAL ACCORDANCE WITH CDOT TEST METHOD CP-L 2104

FIGURE B-12

CORROSIVITY TEST RESULTS

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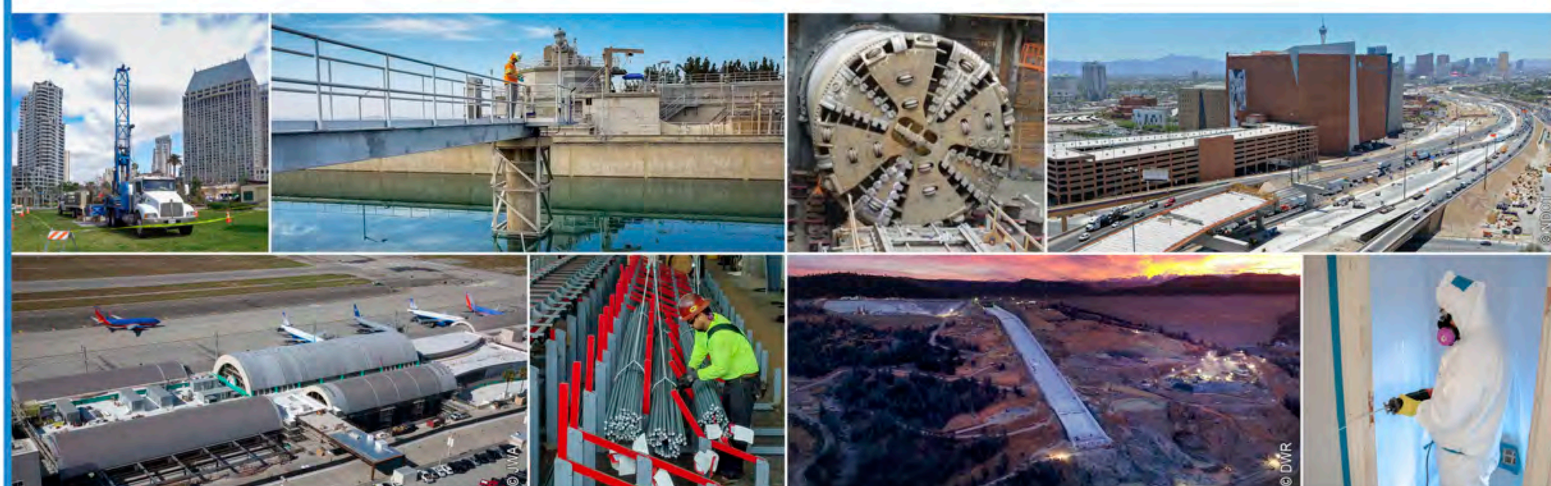

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