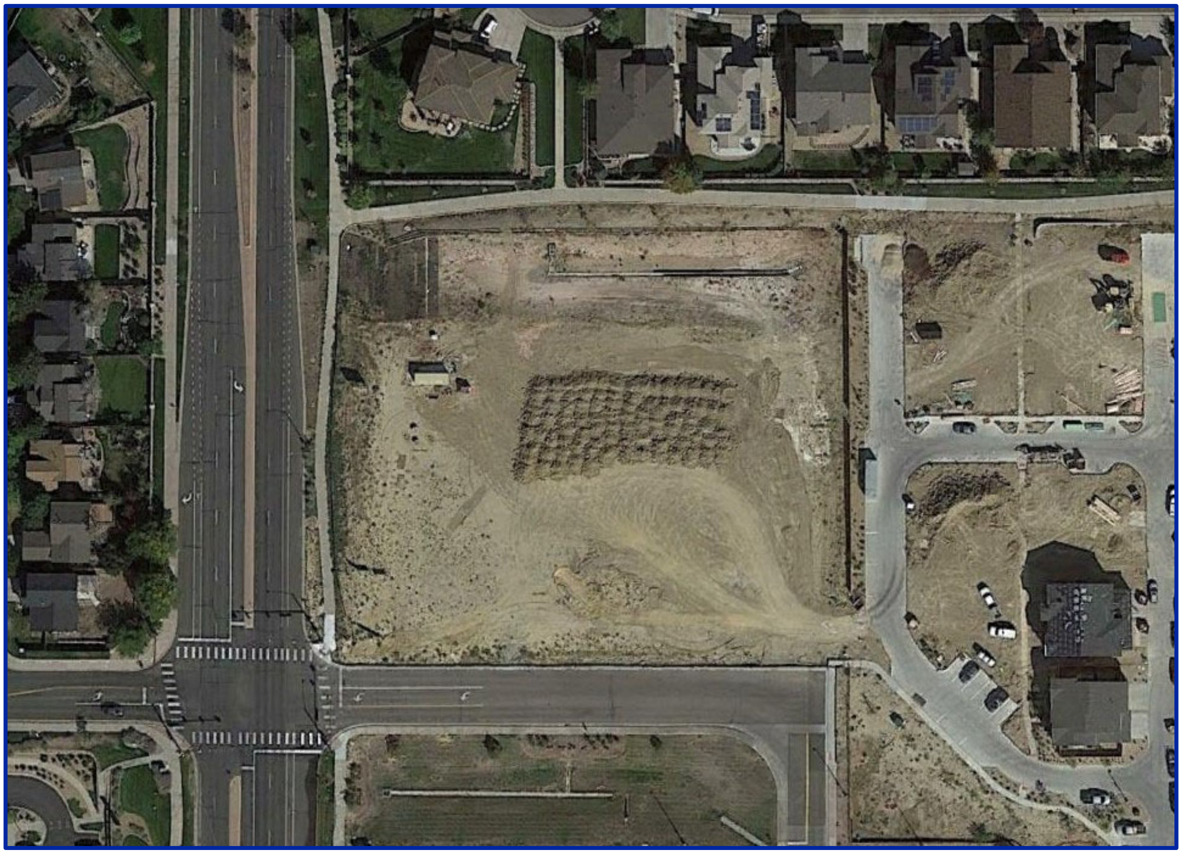
Geotechnical Engineers & Construction Materials Consultants

GEOTECHNICAL STUDY

New Horizon Academy Thornton
Thornton, Colorado



Report Prepared for:

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Project No. 21.3051
September 10, 2021

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CESARE, INC.

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COMMON ABBREVIATIONS

AASHTO.........**American Association of State Highway and Transportation Officials**
ABC................**aggregate base course**
ACI................**American Concrete Institute**
ADA...............**Americans with Disabilities Act**
ADSC.............**Association of Drilled Contractors**
AI..................**Asphalt Institute**
APM.............**asphalt paving material**
ASCE.............**American Society of Civil Engineers**
ASTM............**American Society for Testing and Materials**
AWWA...........**American Water Works Association**
bgs.................**below ground surface**
CDOT.............**Colorado Department of Transportation**
CBR................**California Bearing Ratio**
CFR................**Code of Federal Regulations**
CGS................**Colorado Geological Survey**
CKD...............**cement of kiln dust stabilized subgrade**
CMU...............**concrete masonry unit**
CTB................**cement treated base course**
deg................**degree**
EDLA.............**equivalent daily load application**
e_m.................**edge moisture variation distance**
EPS................**expanded polystyrene**
ESAL.............**equivalent single axle loads**
f'c..................**specified compressive strength of concrete at the age of 28 days**
F_a...................**seismic site coefficient**
FHWA............**Federal Highway Administration**
FS..................**factor of safety**
F_V...................**seismic site coefficient**
GSA................**global stability analysis**
GVW.............**gross vehicle weight**
HMA...............**hot mix asphalt**
IBC................**International Building Code**
ICC-ES...........**International Code Council Evaluation Services, Inc.**
IRC................**International Residential Code**
kip.................**1,000 pounds-force**
km.................**kilometer**
LTS................**lime treated subgrade**
MDD.............**maximum dry density**
mg/L............**milligrams per liter**
MGPEC...........**Metropolitan Government Pavement Engineers Council**
mm................**millimeter**
Mr..................**resilient modulus**
MSE...............**mechanically stabilized earth**
mV.................**millivolts**
NAPA.............**National Asphalt Pavement Association**
N_{DESIGN}...........**design gyrations**

OSHA .... **Occupational Safety and Health Administration**
OMC .... **optimum moisture content**
PCA .... **Portland Cement Association**
PCC .... **portland cement concrete**
pcf .... **pounds per cubic foot**
pci .... **pounds per cubic inch**
pH .... **power of hydrogen**
psf .... **pounds per square foot**
psi .... **pounds per square inch**
PT .... **post-tension**
S_s .... mapped spectral accelerations for short periods
UBC .... **Uniform Building Code**
USGS .... **United States Geological Survey**

Important Information about This

Geotechnical-Engineering Report

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

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

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

Understand the Geotechnical-Engineering Services Provided for this Report

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

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

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

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

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

Do <u>not</u> rely on this report if your geotechnical engineer prepared it:

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

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

Read this Report in Full

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

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept* *responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

Most of the "Findings" Related in This Report Are Professional Opinions

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

This Report's Recommendations Are Confirmation-Dependent

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

This Report Could Be Misinterpreted

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

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

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

Give Constructors a Complete Report and Guidance

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

Read Responsibility Provisions Closely

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

Geoenvironmental Concerns Are <u>Not</u> Covered

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

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

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

GEOPROFESSIONAL BUSINESS ASSOCIATION

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1. PURPOSE

1.1 GENERAL

Cesare, Inc. (Cesare) performed a geotechnical study of a proposed New Horizon Academy (NHA) site located at the northeastern quadrant of the Colorado Boulevard and 138th Avenue intersection in Thornton, Colorado (Thornton). The study was performed to characterize subsurface conditions at the site to provide design criteria for planning, site development, foundation systems, interior floor systems, exterior flatwork, surface and subsurface drainage adjacent to structures, and to address other pertinent geotechnical issues applicable to this project. Information gathered during the field exploration and laboratory testing is summarized in Figures 1 and 2 and Appendices A through D. Cesare's opinions and recommendations presented in this report are based on data generated during this field exploration, laboratory testing, and its experience.

1.2 SCOPE OF SERVICES

The scope of services performed is detailed in Cesare's Proposal Agreement No. F191209.B, executed on July 19, 2021.

2. SUMMARY OF FINDINGS AND CONCLUSIONS

This section is intended as a summary only and does not include design details. The report should be read in its entirety and utilized for design.

- Cesare's borings encountered manmade fill at the surface of three borings extending to depths of about 1 to 10 feet. Native soil was encountered at the surface extending to depths of about 7 to 13 feet in three of the remaining borings.
- Claystone and sandstone bedrock was encountered at the surface in one boring and below the fill and native soil in the remaining borings extending to the remaining depths explored of about 10 to 40 feet.
- Groundwater was encountered in three of the deeper borings at depths of 18 to 39 feet during drilling. Groundwater was measured at depths of 15-1/2 to 33 feet in the four deeper borings when checked 3 days after drilling.
- A cursory review of limited geologic mapping indicates the site is identified within an area of high expansive soil and bedrock and potentially collapsible soil. Based on ASCE 7-20, Cesare estimates the site has a Site Class C soil classification for seismic design.
- The swell test results indicate the soil and bedrock underlying the site exhibit low to high swell potential. Shallow bedrock in one of the borings will promote differential movement of shallow spread footings. Cesare recommends drilled piers to support the structure with structurally suspended floors to reduce the risk of future differential movement.
- An alternative to drilled piers is to excavate the fill, native clays, and shallow bedrock underlying the site to a depth of about 10 feet below existing grade, moisture conditioning them, and placing them as compacted structural fill in the excavation. With this approach, shallow pad footings and/or interrupted continuous footings can provide structural support with a concrete slab-on-grade floor or a structurally suspended floor.
- Good surface drainage should be established and positive drainage away from the structures, pavement, and other site improvements should be provided during construction and maintained throughout the life of the proposed structure. Below grade

areas, such as a crawlspace, should be provided with an exterior perimeter subsurface drainage system.

- Flexible pavement consisting of APM is recommended for the site. Cesare recommends layered pavement sections consisting of 4 inches of APM over 8 inches of ABC for parking and 4-1/2 inches of APM over 8-1/2 inches of ABC in drive lanes. These sections should be mechanically stabilized by placing geogrid between the ABC and the prepared subgrade surface according to manufacturer's requirements.

3. SITE CONDITIONS

The site is located in Thornton, Colorado as shown in a vicinity map in Figure 1. The project site is the approximate western half of a currently rough graded undeveloped 3 acre lot. The project site is bound by:

- a stormwater detention pond immediately north,
- a residential subdivision north of the detention pond,
- the remaining undeveloped portion of the property on the east,
- a residential subdivision east of the undeveloped portion,
- 138th Avenue on the south, and
- Colorado Boulevard on the west.

Topography of the overall property is relatively flat, having been graded most recently in 2019, generally sloping downwards to the northwest. The relief across its extent is unknown. The westernmost roadway of the residential development to the east is above the project property in elevation with an estimated 8 to 10 foot high slope, at an estimated 3:1 horizontal to vertical slope, along the boundary between the two.

The project site is relatively flat and slopes downwards to the north with unknown relief between boring locations. The ground surface was bare of cover at the time of Cesare's field exploration. No bodies of water or bedrock outcrops were observed onsite. Wadley Reservoir No. 1 is located about 1 mile northwest of the site. Several small, apparently private, reservoirs are located about 1 mile west of the site. Various small ephemeral drainages occur within 1/4 mile of the site to the south. No bedrock outcrops were noted at the site beyond what was exposed by grading.

Photo 1. View to the east of site (Google Earth Pro©).

4. PROPOSED CONSTRUCTION

The proposed structure will be almost 13,000 square feet in plan area. It will be single story with no basement and preferably concrete slab-on-grade floors. Construction will be wood frame with anticipated foundation loads of about 1,200 to 2,000 pounds per lineal foot on walls. Cesare's boring locations are shown on the boring location plan in Appendix A. The extent of planned grading is not known; however, Cesare estimates the building pad will be constructed in a cut to fill procedure of about 2 to 3 feet, based on the topographic fall across the building pad. Cesare should be notified when the grading plan is prepared so this report can be reviewed for possible revisions in recommendations.

The proposed paved area will consist of drive lanes and vehicle parking. The total pavement area is about 10,400 square feet. Cesare assumes some minor cuts and fills of less than 3 feet will be required, and onsite soil or similar quality offsite soil will be used for fill.

5. FIELD EXPLORATION

Subsurface conditions were explored on August 2, 2021 by drilling four borings to 30 to 40 feet in the building location and three borings to 10 feet in the pavement and playground areas. The locations are shown in the boring location plan presented in Appendix A. The soil and bedrock were sampled using a modified California sampler as described in Appendix A. Disturbed bulk samples were collected from the pavement borings. Graphical logs of the subsurface conditions observed, locations of sampling, and further explanation of the exploration performed are presented in the boring logs presented in Appendix A.

6. LABORATORY TESTING

Cesare personnel returned samples obtained during field exploration to its laboratory where professional staff visually classified them and assigned testing to selected samples to evaluate pertinent engineering properties. Laboratory tests performed are listed in Table 6.1. Further discussion of laboratory testing and the laboratory test results are presented in Appendix B.

TABLE 6.1. Laboratory Testing Performed

Laboratory Test	To Evaluate
Grain size analysis	Grain size distribution for classification purposes.
Atterberg limits	Soil plasticity for classification purposes.
Swell/consolidation	Effect of wetting and loading on the soil.
Water soluble sulfate content	Potential reactivity of sulfates in the soil with cementitious material.

7. SUBSURFACE CONDITIONS

Cesare's borings encountered:

- Existing sandy clay fill in three borings to depths of about 1 to 10 feet.
- Silty sand overburden soil in one boring below the fill to a depth of 16 feet.
- Sandy clay and silty sand overburden soil in three borings to depths of 12 and 13-1/2 feet.
- Claystone and/or sandstone and/or siltstone bedrock at the surface in one boring and below the fill and/or overburden soil in the remaining borings extending to the remaining depths explored in all borings.
- Groundwater at depths of 18, 39, and 39 feet in Borings B-1, B-3, and B-4, respectively, at the time of drilling.
- Three days after drilling, groundwater was measured at depths of about 15-1/2, 18, 17, and 33 feet in Borings B-1 through B-4, respectively.
- Borings B-1 through B-7 caved to depths of 22, 34, 23, 36, 9-1/2, 8-1/2, and 8 feet, respectively, when measured 3 days after drilling.

The subsurface conditions observed represent conditions at the time of field exploration and may not be indicative of other times or other locations. Groundwater can be expected to fluctuate and can be influenced by variations in seasons, weather, precipitation, drainage, vegetation, landscaping, irrigation, leakage of water and/or wastewater systems, etc., both onsite and offsite. Discontinuous zones of perched water may exist or develop within the overburden material and/or upper zones of the bedrock. Cesare's field explorations were performed during the summer when groundwater levels are usually higher than in the fall but lower than in the spring.

8. GEOLOGIC HAZARDS

The following subsections present a cursory review of geologic publications. A detailed geologic hazards assessment is not the focus of these scope of services, nor was it requested.

8.1 EXPANSIVE SOIL

A soil swelling map[1] indicates the site is located in an area of high swell potential soil and bedrock.

8.2 COLLAPSIBLE SOIL

A collapsible soil susceptibility map[2] indicates the site is located in an area of potentially collapsible soil.

8.3 SEISMIC CONSIDERATIONS

Based on penetration tests and Cesare's experience, the soil types present onsite classify as Type C for seismic design, according to the 2018 IBC (ASCE 7, Chapter 20). Additional geophysical studies are necessary to justify a different site classification.

9. GEOTECHNICAL CONSIDERATIONS

9.1 EXISTING FILL

Cesare found 1 to 10 feet of fill in three borings. This fill is undocumented and; therefore, considered unreliable to provide proper support for the planned structure. If shallow foundations are considered for structural support, Cesare opines the existing fill should be removed in its entirety and replaced, observed, and tested as properly compacted structural fill.

9.2 HEAVE POTENTIAL

The fill and some of the native clay soil and claystone bedrock encountered onsite are moisture sensitive and prone to swell upon wetting. This material is stable at its existing moisture contents, but upon becoming wetted, may swell and heave structures and/or pavement bearing on it. The amount of heave that can potentially occur depends on the thickness, depth, and swell potential of the moisture sensitive strata and the degree and depth of moisture increase. Some moisture increase is inevitable after site development as a result of covering the soil and reducing the evaporation from the soil. Additional moisture increase can occur from irrigation. Moisture increase can also result from poor or inadequate surface drainage, inoperable subsurface drainage, or utility ruptures or leaks.

In Cesare's experience, foundation and floor systems designed using a design depth of wetting of 15 to 20 feet, have typically performed well. Within the last several years, some designs have utilized a more conservative assumption of 25 feet for a design depth of wetting. In Cesare's opinion, a design depth of wetting of 20 feet below the existing ground surface is reasonable and appropriate for use at this site. Cesare computed potential free field heave, considering the ground in its present condition with no modification or structure loading, of about 6 to 9 inches for a depth of wetting of 20 feet based on the results of laboratory swell tests.

9.3 COLLAPSE POTENTIAL

The site is mapped within an area of soil susceptible to collapse upon wetting. Results of Cesare's field exploration and laboratory testing results did not indicate the soil encountered is prone to collapse; thus, no collapsible soil mitigation is necessary.

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[1] Hart, S.S., Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado, Greater Denver Area, Sheet 2 of 4, Colorado Geological Survey, Department of Natural Resources, 1974.

[2] White, J.L., Greenman, C., Collapsible Soils in Colorado, Collapsible Soil Susceptibility Map of Colorado, Plate 1, Colorado Geological Survey, Department of Natural Resources, 2008.

9.4 SHALLOW BEDROCK

Sandstone bedrock was encountered at the surface of Boring B-1. This condition will cause differential movement of shallow spread footings when deeper soil underlies the remainder of the building. Mitigation consists of either extending footings to bear on bedrock where soil underlies the building or excavating the bedrock to a nominal depth below footings and replacing it with structural fill. Both alternatives are meant to provide similar bearing conditions across the building.

9.5 FOUNDATION ALTERNATIVES

Drilled piers will provide the least risk of structural movement considering the potential heave and differing bearing conditions. Furthermore, constructing structurally suspended interior floors over a crawlspace will provide the lowest risk of floor distress from heave. Cesare, therefore, recommends the structure be supported on straight shaft drilled piers, with structurally suspended floors constructed over a crawlspace. Design recommendations for these foundations are presented in Section **11.1 DRILLED PIERS**.

A higher risk alternative is to use shallow spread footings, which requires reducing the soil swell potential and providing more uniform bearing conditions across the building. Reducing the soil swell potential is typically accomplished by excavating the soil and/or bedrock a prescribed minimum depth, moisture conditioning the excavated soil and bedrock to optimum moisture content or above, and replacing them in the excavation as compacted structural fill. Extending footings to bear in bedrock is not efficient on this site; however, providing a more uniform bearing condition requires similar excavation and backfill to mitigating expansive soil. Shallow spread footing design recommendations are presented in Section **11.2 SPREAD FOUNDATIONS**.

On this site, the existing fill at the building extends to depths of about 10 feet, exhibits high swell, and is recommended to be removed in its entirety. The native clay appeared somewhat lenticular; however, excavating to 10 feet appears to remove most of it. This zone of moisture conditioned soil will provide a buffer between the structure and deeper expansive soil that will distribute heave more uniformly across the building footprint. Moisture conditioning will not fully exhaust the swell potential of the moisture conditioned soil and bedrock, such that the treated soil remains susceptible to swell should it become wetter than its compaction moisture content. Cesare estimates moisture conditioning at least 10 feet of existing fill and clay below the building will reduce the potential free field heave to about 1-1/2 to 2 inches.

As described previously, excavating and moisture conditioning the clay soil will reduce its swell potential. Excavating the shallow bedrock to the same depth, moisture conditioning them, and replacing them as structural fill will provide more uniform bearing conditions for shallow spread type footings. In addition, mixing the excavated bedrock and clay soil to homogenize them can likely further reduce the swell potential of the clay soil.

Conventional shallow spread footings and concrete slab-on-grade floors are higher risk alternatives to the recommended drilled pier foundations and structurally suspended floors. The higher risk of distress to the structure, its floors, and interior finishes is due to potential differential movement, even with the site preparation recommended in following sections. Architectural details to mitigate interior distress are critical to aesthetics for this alternative.

Recommendations for soil treatment for both foundation alternatives are presented in Section **10. SITE PREPARATION**. Design and construction details for floors relative to this alternative are presented in Section **13.1 CONCRETE SLAB-ON-GRADE**.

10. SITE PREPARATION

10.1 DRILLED PIER FOUNDATIONS

The building pad should be excavated to the crawlspace surface. The exposed surface should be scarified to a depth of 8 inches, moisture conditioned, and compacted prior to drilled pier construction. Moisture conditioning and compaction should be performed according to the requirements presented in Section **16.1 STRUCTURAL FILL**.

10.2 SHALLOW FOUNDATIONS

Excavate the soil and bedrock from below the building pad to 10 feet below existing grade, which will remove the existing fill in its entirety. The excavation base should extend beyond the building perimeter a distance equal to at least the depth of excavation below the foundations, in this case, 10 feet. Moisture condition the excavated soil and bedrock to OMC or above, and replace it in the excavation as properly compacted structural fill. The estimated remaining potential slab-on-grade heave is 1-1/2 to 2 inches and potential footing heave is 1/2 to 1 inch.

11. FOUNDATION RECOMMENDATIONS

11.1 DRILLED PIERS

The proposed structure should bear on straight shaft drilled piers designed in accordance with the following recommendations:

a) Dead load plus full live load of the structure should be used for pier sizing.
b) Piers shall be designed so that dead loads are as high as reasonably practicable.
c) Depth of wetting zone below ground surface assumed for design is 20 feet.
d) Maximum allowable end bearing pressure of 25,000 psf.
e) No side shear shall be used to resist downward axial load (compression load) for any portion of the pier in natural soil or manmade fill. No side shear shall be used to resist upward forces (tensile load) within the top 20 feet of the pier shaft.
f) Allowable side shear of 2,500 psf for the portion of pier in competent bedrock, having blow counts of 50/12 or higher. Piers in the area of Boring B-1 will require deeper penetration to develop the appropriate side shear due to the claystone with blow counts of less than 50/12.
g) Minimum dead load pressure is assumed to be zero.
h) Piers should be reinforced their full length to resist tension forces and shall be capable of resisting uplift due to a uniform swelling pressure of 3,100 psf applied over a 10 foot length of each pier.
i) Piers should have a center-to-center spacing of at least 3 pier diameters when designing for vertical loading conditions or be designed as a group.
j) Piers aligned in the direction of lateral forces should have center-to-center spacing of at least 6 pier diameters.

k) Piers should have a maximum length to diameter ratio of about 30 for constructability and observation purposes.
l) Piers shall have a minimum diameter of 12 inches.
m) Piers shall have a minimum length of 33 feet below the foundation grade beam.
n) Piers shall have a minimum penetration of 13 feet into competent bedrock, having blow counts of 50/12 or greater. Piers in the area of Boring B-1 will require deeper penetration to develop the appropriate side shear due to the claystone, having blow counts of less than 50/12.
o) A 12 inch minimum void space shall be provided beneath grade beams between the piers and below all pier caps to achieve effective concentration of loads on the piers. Void forms should be protected before and during concrete placement.
p) It is anticipated that casing will not be needed for most of the drilled shafts. Concrete should be placed as soon as possible after drilling to reduce the potential for caving soil and/or water accumulation. Concrete should not be placed by freefall through more than 3 inches of water, unless proper tremie techniques are utilized to place concrete from the bottom of the shaft or the water is removed. Drilled shafts shall not be allowed to remain open overnight.
q) Difficult drilling may be encountered in the very hard bedrock, having blow counts of 50/6 or higher. Use of a large drill rig with high downward crowd or coring equipment may be required. Pier penetration may not be decreased, unless acceptable by the project geotechnical engineer.
r) Concrete for each pier should be formed at the top of the pier, if necessary, to achieve a uniform diameter at the top of the pier. Excess concrete or overpour resulting in enlargement of the pier shall be removed.
s) Soil retainers, such as Sure Retainer, are recommended to keep backfill soil from entering the void space beneath the foundation walls/grade beams.
t) Proper concrete mixture design for drilled shafts varies with the design stress intensity, anticipated concrete placement procedures, and spacing of the reinforcement. It is recommended that current design and construction procedures outlined by the ACI and the International ADSC be followed. Per these guidelines, current practice is to use a concrete mixture design slump in the range of 5 to 7 inches if casing is to be utilized or the shaft is heavily reinforced. A design slump in the range of 7 to 9 inches with 3/4 inch maximum size aggregate is recommended if concrete is to be placed by tremie or pumping methods. Additional recommendations as outlined by ACI and ADCS should also be followed.
u) A Cesare representative should observe pier drilling in an effort to confirm that actual subsurface conditions are consistent with those presented in this study. If conditions deviate significantly, recommendations may need to be modified.

11.1.1 Laterally Loaded Piers

The bending resistance of piers can provide lateral resistance to horizontal forces. Recommended material properties for lateral capacity analysis using the LPILE computer analysis program can be presented on request.

11.2 SPREAD FOOTINGS

The proposed structure can bear on conventional continuous spread footings or pad type footings bearing on controlled, structural fill below frost depth in accordance with the following design recommendations:

a) The building pad is prepared according to Section **10.2 SHALLOW FOUNDATIONS**.
b) The minimum design frost depth, per Thornton Building Code is 30 inches.
c) Footings should be designed for a maximum allowable soil bearing pressure of 3,000 psf based on dead load plus full live load.
d) Continuous footings should have a minimum width of 18 inches and isolated pad type footings a minimum dimension of 24 inches.
e) Footings should be designed to have a minimum dead load pressure of 1,000 psf. This may be accomplished by using interrupted continuous spread footings and grade beams with a void space beneath the grade beam to increase loading. Pad type footings should be structurally connected to grade beams as specified by a structural engineer.
f) A 12 inch minimum void space should be provided below the grade beams between pad type footings. Void forms should be protected from collapse before and during concrete placement.
g) Estimated maximum heave of spread type footings is 1/2 to 1 inch. From a design perspective, acceptable vertical movement of spread footings in the Front Range is typically about 1 inch. Potential differential heave should be considered equivalent to the maximum.
h) Using the soil pressure recommended above, Cesare estimates the maximum potential settlement for the structure will be about 1 inch, with differential settlement of about 1/2 inch. Footings should be proportioned as much as practicable to reduce differential settlement.
i) Steel reinforcement for continuous concrete foundation walls should be designed to span localized vertical movements over a distance of 10 feet.
j) All soft or loose soil beneath footing areas should be densified in place, or removed and replaced with properly compacted structural fill, suitable flow fill, or concrete prior to placement of footing concrete. All footing excavations should be observed by a Cesare representative prior to placement of concrete to determine if bearing conditions are consistent with those assumed for design.

12. LATERAL EARTH PRESSURES - FOUNDATION WALLS

Lateral pressures on walls depend on the type of wall, hydrostatic pressure behind the wall, type of backfill material, and allowable wall movements. Cesare recommends drain systems be constructed behind walls to reduce the potential for hydrostatic pressures to develop. Where anticipated/permissible wall movements are greater than 0.5% of the wall height, lateral earth pressures can be estimated for an "active" condition. Where anticipated/permissible wall movement is less than approximately 0.5% of the wall height or wall movement is constrained, lateral earth pressures should be estimated for an "at rest" condition. Recommended lateral earth pressures for onsite material are provided in Table 12.1.

The recommended values for lateral earth pressures provided in Table 12.1 are given in terms of an equivalent unit weight. The equivalent unit weight multiplied by the depth below the top of the ground surface is the horizontal pressure against the wall at that depth. The resulting pressure distribution is a triangular shape. These soil pressures are for horizontal backfill with no surcharge loading and no hydrostatic pressures. If these criteria cannot be met, Cesare should be contacted for additional criteria.

The coefficient of sliding resistance between concrete and bearing soil are provided in Table 12.1.

TABLE 12.1. Lateral Earth Pressures and Coefficients of Sliding Resistance

Backfill Material Type	Equivalent Unit Weight (pcf)			Coefficient of Sliding Resistance
	Active	At Rest	Passive	
Existing fill	45	70	335	.35
Native clay	50	75	310	.35
New fill	40	60	425	.35

13. INTERIOR FLOORS

13.1 CONCRETE SLAB-ON-GRADE

Expansive soil is present at depths that will likely influence the performance of interior floors at this site if they are constructed as slabs-on-grade. The clay encountered at the site exhibits low to high swell potential, when tested. As described previously, the expansive material is stable at existing moisture contents, but upon an increase in moisture content or wetting, will swell.

Swell related upward slab movement or heave cannot be economically controlled by concentrating slab loads. Heave, depending upon the amount, can cause slabs to crack, become unlevel, tilted, undulated, or otherwise distorted and can create vertical and horizontal separation/offsets at joints in and around the perimeter of the slab and adjacent to foundation elements. To reduce the potential for slab movement, Cesare recommends subgrade conditioning and pad preparation as presented in Section **10.2 SHALLOW FOUNDATIONS**.

13.1.1 Slab-on-Grade Construction Details

Slab-on-grade cracking can occur as a result of heaving or compressing of the supporting soil but also as a result of concrete curing stresses. Cesare recommends that design and construction of all interior slab-on-grade floors incorporate the following considerations and precautions. These details will not reduce the amount of slab movement but are intended to reduce potential damage should some settlement or heave of the supporting subgrade take place. The ACI Committee 302, "Guide for Concrete Floor and Slab Construction (ACI 302.R-96)" should be consulted regarding methods/techniques to reduce the occurrence of concrete shrinkage cracks and other potential issues associated with concrete finishing and curing.

a) A vapor barrier is recommended beneath concrete slabs-on-grade that will support equipment sensitive to moisture or will be covered with wood, tile, carpet, linoleum, or other moisture sensitive or impervious coverings. Location of the vapor barrier should be in accordance with recommendations provided by ACI 302.2R-06, "Guide for Concrete

Slabs that Receive Moisture-Sensitive Flooring Materials."

b) Plumbing beneath slabs should be eliminated, where practicable. Where such plumbing is unavoidable, it should be thoroughly pressure tested during construction for leaks prior to slab placement.
c) Conduits supported on the ground and extend under or through walls should have a minimum void space of 3 inches above or below the conduit where it passes through or under the wall to avoid pinching or collapsing of the conduit via ground heave.
d) Backfill in the utility trenches beneath slabs should be compacted as specified in Section **16.1 STRUCTURAL FILL**.
e) Plumbing and utilities that pass through the slab should be isolated from the slabs and provided with flexible couplings above the floor that can be observed and maintained, as necessary, to accommodate potential ground/slab movement.
f) Mechanical equipment or systems supported by slabs should be provided with flexible connections or void space that allows for a minimum of 3 inches of movement between the equipment on the slab and associated overhead ductwork, piping, or structural members.
g) Where slab bearing partitions or stairs are necessary, a slip joint (i.e., partition framing void or float) allowing at least 3 inches of vertical slab movement should be used. Partition framing voids constructed at the base of the wall are, in most cases, more effective than joints above the wall, particularly on long walls. The void space can be covered with a molding strip. If finished, all furring strips, drywall, and paneling should stop at least 3 inches from the top of the slab if the slip joint is constructed at the bottom of the wall. In the event of slab heave, the movement should not be transmitted directly though the partitions or stairwells to the remainder of the structure.
h) Interior slab-supported partition walls should be isolated from foundation-supported perimeter walls to accommodate slab movement.
i) Doorways should be constructed to allow vertical movement of slabs. Allowance for vertical movement is typically accomplished by providing a gap below doorjambs.
j) CMU partition walls should be constructed with a minimum clearance of 3 inches between the top of wall and the bottom of roof or ceiling elements.
k) Separate slabs from foundation walls, interior columns, and utilities with a joint which allows/provides free vertical movement of the slab (i.e., floating slab construction).
l) Provide frequent control joints in the slab. Refer to ACI 302.1R-15.
m) Use of load transfer devices at construction and contraction joints is recommended when positive load transfer is required (See ACI 302.1R).

Following the above recommendations will not prevent movement of the floor slab but should reduce damage caused by slab movement. The void spaces and flexible joints recommended may not accommodate total potential slab movement. Care must be taken to monitor and reestablish partition voids and flexible connections, when necessary.

Concrete slabs-on-grade bearing on low expansive structural fill can be designed using a modulus of subgrade reaction value of 150 pci.

13.2 STRUCTURALLY SUSPENDED FLOORS

A floor system having no contact with the underlying soil/bedrock material is considered a structurally supported or structurally suspended floor. To achieve this system, the floor is constructed with an air or void space below the floor, typically a crawlspace, and supported by the foundation system. If potential movement of slab-on-grade floors and associated cracking/distress are not considered tolerable to the owner, developer, architect, or structural engineer for any reason, a structurally supported floor should be provided.

Design and construction issues associated with structurally supported floors must be considered and include ventilation and lateral loads. Where structurally suspended floors are installed, the minimum required air space depends on the material used to construct the floor and the expansion potential of the underlying soil. Building codes require a clearance space of at least 18 inches above exposed soil if untreated wood floor components are used. Where other support material is used, a minimum clearance space of 8 inches is recommended. This minimum clearance space should be maintained between any point on the underside of the floor system, including beams and plumbing, and the surface of the exposed soil. The minimum clearance between the crawlspace ground surface and the structural floor members and suspended plumbing should be constructed to meet minimum code or recommended clearances, plus the recommended void space.

Where structurally supported floors are used, utility connections, including water, gas, air duct, and exhaust stack connections to floor supported appliances should be capable of absorbing some deflection of the floor. Plumbing that passes through the floor should ideally be hung from the underside of structural floor and not lay on the bottom of the excavation. This configuration may not be achievable for some parts of the installation. It is prudent to maintain the minimum clearance space below all plumbing lines. If trenching below the lines is necessary, Cesare recommends sloping these trenches so they discharge to the foundation drain. Penetrations through the foundation wall should allow for at least 2 inches of clearance and/or be provided with flexible connections. The ground surface below the structurally supported floor should be sloped to the perimeter drain.

Control of humidity in crawlspaces is important for indoor air quality and performance of wood floor systems. The Moisture Management Task Force of Metro Denver has compiled additional discussion and recommendations regarding best practices for control of humidity in below grade, underfloor spaces. An engineering professional with expertise in the design and construction of crawlspace humidity control should be contacted.

14. EXTERIOR FLATWORK

Exterior flatwork is susceptible to movement resulting from moisture sensitive soil onsite, as discussed for interior floor slabs in Section **13. INTERIOR FLOORS**. Flatwork supported on foundation wall backfill may settle and crack if the backfill is not properly moisture conditioned and compacted.

Treatment of the soil, as recommended to reduce potential movement of interior floors, is applicable to exterior flatwork. The soil within about 7 to 11 feet of building will be the moisture conditioned and properly compacted structural fill as described in Section **10.2 SHALLOW FOUNDATIONS** to reduce slab heave to 2 inches or less. Cesare recommends removing, moisture conditioning, and replacing the existing fill soil in its entirety and expansive soil within 4 feet of finished subgrade elevation over the remainder of the exterior flatwork, as presented in Section **10.2 SHALLOW FOUNDATIONS**.

Excavating and moisture conditioning will reduce swell/movement potential, create a relatively low permeable surface over the more expansive/moisture sensitive material, and retard wetting of the deeper unconditioned expansive/moisture sensitive material. This conditioning will reduce potential slab-on-grade movement but will not eliminate it.

Exterior flatwork should be isolated from the structures. Exterior flatwork should be expected to move, although measures can be incorporated into construction to limit the movement or effects of the movement. Cesare recommends flatwork not be doweled into structure foundations, but rather supported on a haunch to limit settlement. The haunch should extend the full length of the slab. To reduce potential movement, the soil below the planned flatwork can be moisture conditioned or chemically treated. A lower risk approach is to construct a slab over void forming material and/or support the slab with a foundation meeting the same criteria as the structure.

Exterior flatwork, such as driveways and sidewalks, are normally constructed as slabs-on-grade. Porches and patios are increasingly constructed as structurally supported slabs, which in Cesare's opinion, is the most positive means of keeping slabs from moving and adversely affecting the operation of doors or means of egress. Cesare recommends that landings and slabs at egress doors, as well as porches and patios, be constructed as structurally supported elements if potential movement cannot be tolerated.

Simple decks that are not integral to the structure and can tolerate foundation movement can be constructed with less substantial foundations. A short pier or footing bottomed below frost depth can be used if movement is acceptable and if acceptable by local building requirements. Use of deeper foundation elements can reduce potential movement. Footings or short piers should not be underlain by wall backfill, due to risk of settlement. Inner edges of decks may be constructed on haunches and detailed such that movement of the deck foundations will not cause distress to the structure.

Cesare recommends use of connections or other details between foundations and deck posts so the posts can be trimmed or adjusted if movement occurs.

15. EXCAVATIONS

Conventional earthmoving equipment should be adequate to excavate the onsite soil and bedrock. Some of the shallow bedrock may require more aggressive excavation such as ripping and hoeram[3]. All excavations should be properly sloped and/or braced, and local and federal safety codes should be observed. Slopes and other areas void of vegetation should be protected against erosion.

It is the contractor's responsibility to provide safe working conditions and comply with the regulations

[3] A jackhammer attachment for an excavator.

in OSHA Standards-Excavations, 29 CFR Part 1926. The following guidelines are provided for planning purposes. Sloping and shoring requirements must be evaluated at the time of construction by the contractor's competent person as defined by OSHA. OSHA classifications for various material types and the steepest allowable slope configuration corresponding to those classifications are shown in Table 15.1.

TABLE 15.1. Allowable Slope Configuration for Onsite Material

Material Type	OSHA Classification	Steepest Allowable Slope Configuration*
Existing fill, native soil	Type C	1-1/2:1
Claystone/sandstone bedrock	Type A	3/4:1

* Units horizontal to units vertical. The values shown apply to excavation less than 20 feet in height. Conditions can change and evaluation is the contractor's responsibility.

These classifications and slope configurations assume that excavations are above the groundwater table, there is no standing water in the excavations, and there is no seepage from the slope into the excavations, unless otherwise specified. The classifications and slope configurations assume that the material in the excavations is not fractured, adversely bedded, jointed, nor left open to desiccate, crack, or slough, and are protected from surface runoff. There are other considerations regarding allowable slope configurations that the contractor is responsible for, including proximity of equipment, stockpiles, and other surcharge loads to the excavation. The contractor's competent person is responsible for all decisions regarding slope configuration and safety conditions for excavations.

Excavations should not undermine existing foundation systems of structures or infrastructure unless they are adequately protected. At a minimum, new excavations should not intersect a line drawn on a 45 degree angle down and away from the bottom edge of the existing foundation systems or bottom edge of infrastructure. If this condition cannot be met, shoring or staged excavations may be required. If shoring is required, a condition survey of the adjacent structures is recommended before construction starts and upon completion of construction. In Cesare's experience, condition surveys include, but may not be limited to, photographs of any distress to adjacent structures.

Permanent slopes should be no steeper than 3:1 and should be revegetated or otherwise protected from erosion.

16. FILL

16.1 STRUCTURAL FILL

Where fill and/or backfill soil is necessary, the onsite inorganic soil may be used below and around the structure, provided they contain no unsuitable material. At this site, unsuitable material is defined as topsoil, organics, trash, ash, frozen material; and cobbles, hard lumps, clods, and claystone particles larger than 3 inches that cannot be further broken down. Existing onsite fill material can be reused for structural fill and/or backfill, provided it is free of unsuitable material. If unsuitable material is encountered in the existing fill and cannot be removed or segregated, it cannot be reused as fill and/or backfill. Recommendations for fill and/or backfill placement are:

a) Fill/backfill material should be placed in loose lifts and compacted in accordance with Table 16.1.

b) Maximum loose lift thickness shall be 6 inches, depending on the type of equipment used to apply compactive effort, and shall be reduced if the specified compaction cannot be obtained with the equipment used.
c) Fill and/or backfill should not be placed if material is frozen or if the surface upon which fill/backfill is to be placed is frozen.
d) Fill and/or backfill material should be placed and spread in horizontal lifts of uniform thickness in a manner that avoids segregation.
e) Placement surface should be kept free of standing water, debris, and unsuitable material during placement and compaction of fill/backfill material.
f) Moisture conditioned weathered claystone and claystone bedrock can be included in the bottom portions of deep excavation fill and in areas that are not beneath structures.
g) Overlot fill placement and compaction should be observed and tested on a full-time basis by a representative of Cesare. At a minimum, utility trench backfill should be tested in accordance with jurisdictional requirements.

TABLE 16.1. Compaction Specifications

Material Type (General)	AASHTO Classification	Moisture Content (%)	Relative Compaction (%)	Compaction Standard
Granular material that is clean to silty	A-1, A-2-4, A-2-5, A-3, A-4, A-5	+ 2% of OMC	>95%	Standard Proctor (ASTM D698)
Fine grained material and granular material with plastic fines	A-2-6, A-2-7 A-6 A-7	0% to +3% of OMC	>95%	Standard Proctor (ASTM D698)

16.2 IMPORT FILL

Material imported for structural fill should be tested and approved for use onsite by the project geotechnical engineer prior to hauling to the site. Proctor, remolded swell, and classification tests should be conducted to determine if the fill meets required specifications. Fill material should be well graded, low permeable material meeting the specifications in Table 16.2.

TABLE 16.2. Import Fill Specifications

Soil Parameter	Specification
Maximum particle size	1 inch
Percent finer than No. 40 sieve	60% to 100%
Percent finer than No. 200 sieve	15% to 40%
Liquid limit	20% to 40%
Plasticity index	8% to 15%
Swell potential under anticipated loads	less than 1%*

* Upon inundation, when remolded to 97% maximum dry density at 1% below the optimum moisture content per ASTM D698 at a surcharge pressure of 100 psf.

17. SUBSURFACE DRAINAGE

Groundwater was measured at 15-1/2 to 33 feet deep when measured 3 days after drilling, which is more than 12 feet below a potential crawlspace level. This indicates that subdrains will not be required to accomplish below grade excavation and construction; however, development of a site often adversely affects groundwater conditions, sometimes raising the level of the water table. In addition, groundwater or surface water tends to drain into areas where excavations are made, even after backfilling. Fine grained soil and bedrock generally have relatively low permeability and may trap water that drains into these areas, resulting in localized perched groundwater problems around the structure.

The 2018 IBC requires that basement and/or crawlspace areas be provided with an exterior perimeter subsurface drainage system. The system shall be sloped to drain to a suitable gravity outlet or a sump. A pump shall be installed if a sump is used. The drainage system shall consist of perforated, machine slotted, or equivalent rigid plastic pipe placed around the perimeter of the basement or crawlspace foundation. Pipes with a smooth interior are recommended. Corrugated pipes can become obstructed more easily than pipes with smooth interiors and may be more difficult to clean. A recommended drain schematic is shown in Figure 2.

18. SURFACE DRAINAGE

Good drainage and surface water management is important. Performance of site improvements, such as foundations, floors, hardscape, and pavement is often adversely affected by failing to establish and/or maintain good site drainage. Grades must be adjusted to provide positive drainage away from the structure, pavement, and other site improvements during construction and maintained throughout the life of the proposed facility. The following drainage precautions are recommended:

a) The ground surface around the perimeter foundation walls should be sloped to drain away from the structure in all directions. Current building codes require a minimum slope of 6 inches in the first 10 feet (5%) of the structure. At the completion of construction, Cesare recommends a continuous slope away from foundations of 12 inches in the first 10 feet (10%), where site constraints permit. Cesare recommends that concrete and pavement adjacent to structures slope at a rate of at least 2% away from the structure or as otherwise required by ADA criteria. Maximum grades practical should be used for paving and flatwork to prevent areas where water can pond.
b) Joints that occur at locations where paving or flatwork abuts the structure should be properly sealed with flexible sealants and maintained.
c) The ground surface should be sloped so that water will not pond between or adjacent to structures and other site improvements. Curbs, sidewalks, paths, plants, or other improvements should not block, impede, or otherwise disrupt surface runoff. Use of chases and weep holes to promote drainage is encouraged. Landscape edging should be perforated or otherwise constructed in a manner to prevent ponding of surface water, especially in the vicinity of the backfill soil.
d) Drainage swales should be located as far away from the foundation as practicable.
e) If site constraints do not allow for the recommended slopes, the project civil engineer shall provide a method for drainage that is equivalent to the recommendations herein. Water should not be allowed to pond adjacent to or near foundations, flatwork, or other improvements.
f) Roof downspouts and other water collection systems should discharge onto pavements or extend away from the structure well beyond the limits of the backfill zone using

downspout extensions, appropriately sized splash blocks, or other means. Buried downspout extensions are discouraged as they can be difficult to monitor and maintain.

g) Irrigation directly adjacent to the structure is discouraged and should be minimized. Sprinkler lines, zone control boxes, and sprinkler drains shall be located outside the limits of the foundation backfill. Sprinkler systems should be placed so that the spray from the heads, under full pressure, does not fall within 5 feet of the foundation walls.

h) Plants, vegetation, and trees that require moderate to high water usage are discouraged and should not be located within 5 feet of foundation walls.

i) Plantings within 10 feet of the foundation should be placed in watertight planters/containers.

j) The project civil engineer shall perform measurements to document that positive drainage, as described in this section or as otherwise designed by the project civil engineer, is achieved. Maintenance of surface drainage is imperative subsequent to construction and is the responsibility of the owner and/or tenant.

19. PAVEMENT RECOMMENDATIONS

19.1 DESIGN CRITERIA

The pavement recommendations contained in this report are based on the MGPEC 2019 Pavement Design Standards and the design parameters indicated in Table 19.1.

TABLE 19.1. Pavement Design Parameters

Design Parameter	Value
Design period (years)	20
Initial serviceability (ρ_s)	4.5
Terminal serviceability (ρ_t)	2.0
Serviceability loss, (ρ_s-ρ_t)	2.5
Reliability, Z_r (%)	85
Overall standard deviation, S_o – APM	0.44
Total 18 kip ESALs • Automobile parking • Drive lanes and entry drives	 36,500 73,000
Subgrade strength • R-value (estimated) • Resilient modulus, Mr (psi) (by correlation to R-value per CDOT)	 5 3,025
Strength coefficients for: a. APM b. ABC	 0.44 0.11

Deviation from these parameters will require a revision to the recommended pavement section thicknesses. If the subgrade becomes saturated, the pavement is not properly maintained, and/or the actual traffic is greater than the values used in the design, the design service life will be reduced.

19.2 PAVEMENT THICKNESSES

As the borings indicate, the shallow subgrade material in the pavement areas consists of about 1 foot of silty sand or sandy clay fill over sandstone or claystone bedrock. According to FHWA-RD-97-

083 "Design Pamphlet for the Determination of Design Subgrade in Support of the 1993 AASHTO Guide for the Design of Pavement Structures", dated September 1997, this material is considered poor to fair for pavement subgrade. The recommended pavement sections are shown on Table 19.2.

TABLE 19.2. Recommended Pavement Section Thicknesses

Traffic Area	Alternate	APM (in)	ABC (in)
Parking	APM	6	--
	APM+ABC	4	8
Drive lanes	APM	7	--
	APM+ABC	4-1/2	8-1/2

19.3 TRASH DUMPSTER APPROACHES

Approaches to trash dumpsters typically experience a greater frequency of distress due to higher loading conditions. To reduce the risk of increased maintenance, Cesare recommends paving these areas with 8 inches of CDOT Class P portland cement concrete. Cesare recommends control joints at a maximum spacing of 12 feet, and at least one control joint transverse and longitudinal to each approach. The approach to the trash dumpster should be long enough to include the collection truck's runup braking distance and its front wheels should fully bear on the slab when emptying the dumpster.

19.4 SPECIAL CONCERNS

19.4.1 Existing Fill Soil

Cesare encountered existing fill in all borings, ranging from 1 to 10 feet thick, with about 1 foot found in the pavement borings. Cesare recommends removing the fill in its entirety from below paved areas as it is considered undocumented and; therefore, unreliable for pavement support. If the fill contains no unsuitable material, it can be used for structural fill below pavements.

19.4.2 Swell Potential

The sandstone and claystone exhibit low to medium swell potential upon wetting. Test results in Appendix A show the swell/consolidation curves for these materials. MGPEC recommends mitigating these swell conditions by excavating the soil and/or bedrock to at least 3feet below finished subgrade elevation, moisture conditioning the excavated soil and/or bedrock, and replacing them as structural fill. Moisture conditioning includes bringing the soil moisture content to between 1% and 3% over OMC as determined by ASTM D698. Compaction should be to at least 95% of maximum density. MGPEC also recommends subgrade treated as described should have an intermediate stiff layer (ISL) consisting of either chemically or mechanically stabilized soil. The soil's water soluble sulfate content is 0.14%, precluding lime stabilization. Mechanical stabilization is efficient and effective and; therefore, recommended. The mechanical stabilization will require constructing the layered pavement section geogrid reinforcement placed on top of the treated soil and below the ABC.

19.4.3 Frost Heave

The clay soil encountered onsite has low to high susceptibility to frost heave. The presence of water is required for frost heave to occur. Groundwater was encountered during this study to depths of 15-1/2 to 33 feet below existing grade. In Cesare's opinion, infiltration of surface water is the most likely source for moisture in the pavement section. Maintaining surface drainage and regularly sealing cracks will keep the potential for distress due to frost heave low and will help increase longevity of pavement.

19.5 SUBGRADE PREPARATION AND PAVEMENT CONSTRUCTION

19.5.1 Pavement Subgrade

Remove 3 feet of subgrade soil and/or bedrock below finished subgrade elevation, moisture condition the excavated soil and/or bedrock, and replace it in the excavation as structural fill. The structural fill should be compacted to a minimum of 95% of standard Proctor density at a moisture content between 1% and 3% above optimum according to ASTM D698.

Geogrid reinforcement should be placed on the prepared subgrade as soon as possible after achieving compaction. ABC should be placed on the geogrid immediately after subgrade preparation, before the prepared subgrade dries. Place the geogrid according to the manufacturer's recommendations.

The base course surface of the entire parking and drive areas should be proof rolled a maximum of 24 hours prior to paving with a loaded 988 front end loader or similar heavy rubber tired vehicle (GVW of 50,000 pounds with 18 kip per axle at tire pressures of 90 psi) to detect any soft or loose areas. All areas exhibiting unstable subgrade conditions, such as rutting, pumping, or excessive movement should be excavated to a firm soil layer or to a maximum depth of 2 feet, whichever is shallowest, and replaced with suitable compacted fill. If unstable subgrade conditions persist, Cesare should be contacted for consultation. Soft spots should be stabilized prior to placement of pavement sections. Positive drainage off paved surfaces should be provided.

19.5.2 Aggregate Base Course

ABC should meet the following requirements:

- ABC material should be approved prior to construction and subsequently tested as the material is being placed.
- ABC should have a minimum R-value of 69.
- ABC material should be compacted to a minimum of 95% of the MDD as determined by the modified Proctor test, ASTM D1557.

19.5.3 Pavement

Pavement construction shall be in accordance with the following recommendations and criteria:

a) APM shall meet the requirements in the MGPEC *Construction Specifications*, dated 2018.
b) Asphalt binder grade shall be PG 64-22 or PG 58-28, N_{Design} of 50.
c) Approved APM material should be placed in the lifts indicated on Table 19.3.

TABLE 19.3. Pavement Section Lift Thickness Recommendations

Grade	Lift Thickness (in)
S	2-1/4 to 3
SX	1-1/2 to 2

Per MGPEC 2019.

d) APM shall be compacted to 92% to 96% of the maximum theoretical density within 0.3% of the optimum asphalt content, as determined by ASTM D2041.
e) APM placement specifications should follow MGPEC/municipality specifications and industry standards as recommended by the NAPA and the AI.
f) Positive drainage off paved surfaces should be provided.
g) Construction material should be approved prior to use and should subsequently be tested as this material is being placed.

20. WATER SOLUBLE SULFATES

Water soluble sulfate content of 0.14% was measured on a tube sample comprised of clay fill from Boring B-2. Results are summarized in Appendix B. The PCA publication, "*Design and Control of Concrete Mixtures 2002*" and the ACI publication, "*Building Code Requirements for Structural Concrete and Commentary*" consider this range moderate for water soluble sulfate exposure. Recommendations for all concrete which will be in contact with or within 6 inches of the clay are shown in Table 20.1.

TABLE 20.1. Information from ACI 318-08 - Table 4.3.1

Water Soluble Sulfates (%)	Exposure Class	Maximum (w/cm)*	Minimum $f'c$, (psi)	Cementitious materials† (types)			Calcium Chloride Admixture
				ASTM C150	ASTM C595	ASTM C1157	
<0.10	S0	N/A	2,500	No type restriction	No type restriction	No type restriction	No restriction
0.10≤ to <0.20	S1 Moderate	0.50	4,000	II[‡]	IP (MS) IS (<70) (MS)	MS	No restriction
≤0.20 to ≤2.00	S2 Severe	0.45	4,500	V[§]	IP (HS) IS (<70) (HS)	HS	Not permitted
>2.00	S3 Very Severe	0.45	4,500	V + pozzolan or slag[II]	IP (HS)+pozzolan or slag[II] or IS (<70) (HS)+pozzolan or slag[II]	HS+pozzolan or slag[II]	Not permitted

*For lightweight concrete, see ACI 318-08 4.1.2.

[†]Alternative combinations of cementitious materials of those listed in Table 4.3.1 shall be permitted when tested for sulfate resistance and meeting the criteria in ACI 318-08 4.5.1.

[‡]For seawater exposure, other types of Portland cements with tricalcium aluminate (C_3A) contents up to 10 percent are permitted if the w/cm does not exceed 0.40.

[§]Other available types of cement such as Type III or Type I are permitted in Exposure Classes S1 or S2 if the C_3A contents are less than 8 or 5 percent, respectively.

[II] The amount of the specific source of the pozzolan or slag to be used shall not be less than the amount that has been determined by service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag to be used shall not be less than the amount tested in accordance with ASTM C1012 and meeting the criteria in ACI 318-08 4.5.1.

Refer to ACI 318-08 R4.3.1 for further interpretation of this table.

21. GEOTECHNICAL RISK

The concept of risk is an important aspect of any geotechnical study. The primary reason for this is that the analytical methods used by geotechnical engineers are generally empirical and must be tempered by engineering judgment and experience, therefore, the solutions or recommendations presented in any geotechnical study should not be considered risk free, and more importantly, are not a guarantee that the interaction between the soil and the proposed construction will perform as predicted, desired, or intended. The engineering recommendations presented in the preceding sections constitute Cesare's best estimate of those measures that are necessary to help the structure and pavement perform in a satisfactory manner based on the information generated during this study, training, and experience in working with these conditions.

22. LIMITATIONS

This document has been prepared as an instrument of service for the exclusive use of SEH, Inc. for the specific application to the project as discussed herein and has been prepared in accordance with geotechnical engineering practices generally accepted in the state of Colorado at the date of its preparation. No warranties, either expressed or implied, are intended or made. This document should not be assumed to contain information for other parties or other purposes.

The findings of this study are valid as of the date its preparation. Changes in the conditions of a property can occur with the passage of time, whether due to natural processes or the works of people on this or adjacent properties. Standards of practice evolve in engineering and changes in applicable or appropriate standards may occur, whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this study may be invalidated wholly or partially by changes outside of Cesare's control, therefore, this study is subject to review and should not be relied upon without such review after a period of 3 years.

In the event that changes, including but not limited to, the nature, type, design, size, elevation, or location of the project or project elements as outlined in this report are made, the conclusions and recommendations contained in this report shall not be considered valid unless Cesare reviews the changes and either confirms or modifies the conclusions of this report in writing.

Cesare should be retained to review final plans and specifications that are developed for proposed construction to judge whether the recommendations presented in this report and any addenda have been appropriately interpreted and incorporated in the project plans and specifications as intended.

The exploration locations for this study were selected to obtain a reasonably accurate depiction of underground conditions for design purposes and these locations are often modified based on accessibility and the presence of underground or overhead utility conflicts. Variations from the soil conditions encountered are possible. These variations may necessitate modifications to Cesare's design recommendations, therefore, Cesare should be retained to observe subsurface conditions, once exposed, to evaluate whether they are consistent with the conditions encountered during Cesare's exploration and that the recommendations of this study remain valid. If parties other than Cesare perform these observations and judgements, they must accept responsibility to judge whether the recommendations in this report remain appropriate.

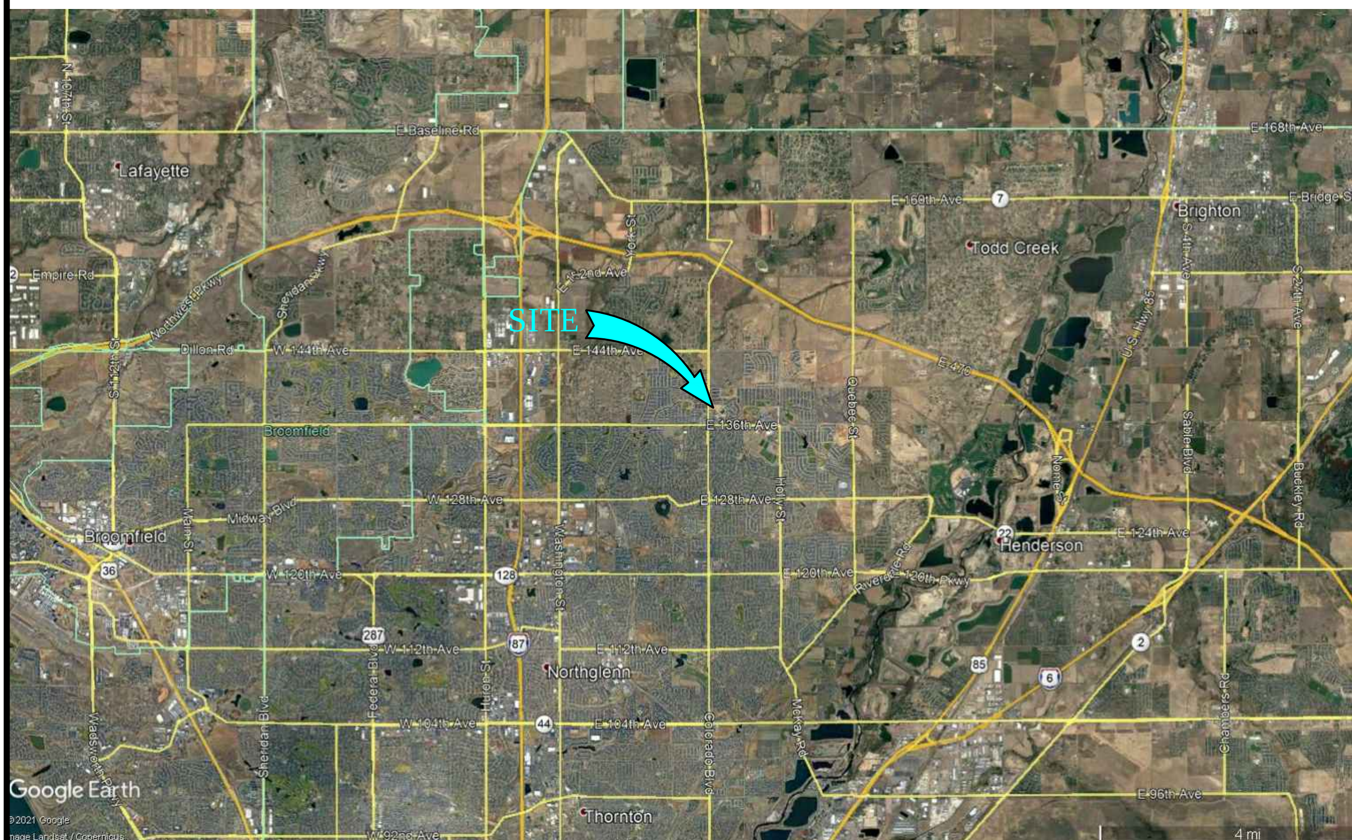
Cesare's scope of services for this report did not include either specifically, or by implication, any environmental assessment of the site or identification of contaminated or hazardous material or conditions. Additionally, none of the services performed in connection with this study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not, of itself, be enough to prevent mold from growing in or on the structures involved.

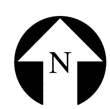
At a minimum, Cesare should be retained during construction to observe and/or test the following:

- completed excavations.
- fill placement and compaction.
- pier drilling operations.
- proposed import or onsite fill material.
- pavement subgrade, subbase, base course and asphalt placement and compaction.

Cesare offers many other construction observations, materials engineering, and testing services and can be contacted to discuss further.

W:\2021\Frederick\21.3051.A New Horizon - Thornton\ACAD\Boring Location Map.dwg 8/4/2021 11:56 AM





0 10,000' 20,000'

APPROXIMATE SCALE: 1 INCH = 10,000 FEET

BACKGROUND IMAGE FROM GOOGLE EARTH

FIGURE 1
Vicinity Map

PROJECT NO:	21.3051		
PROJECT NAME:	New Horizon Academy Thornton		
DRAWN BY:	JBE	CHECKED BY:	JAC2
DWG DATE:	08.04.21	REV. DATE:	--

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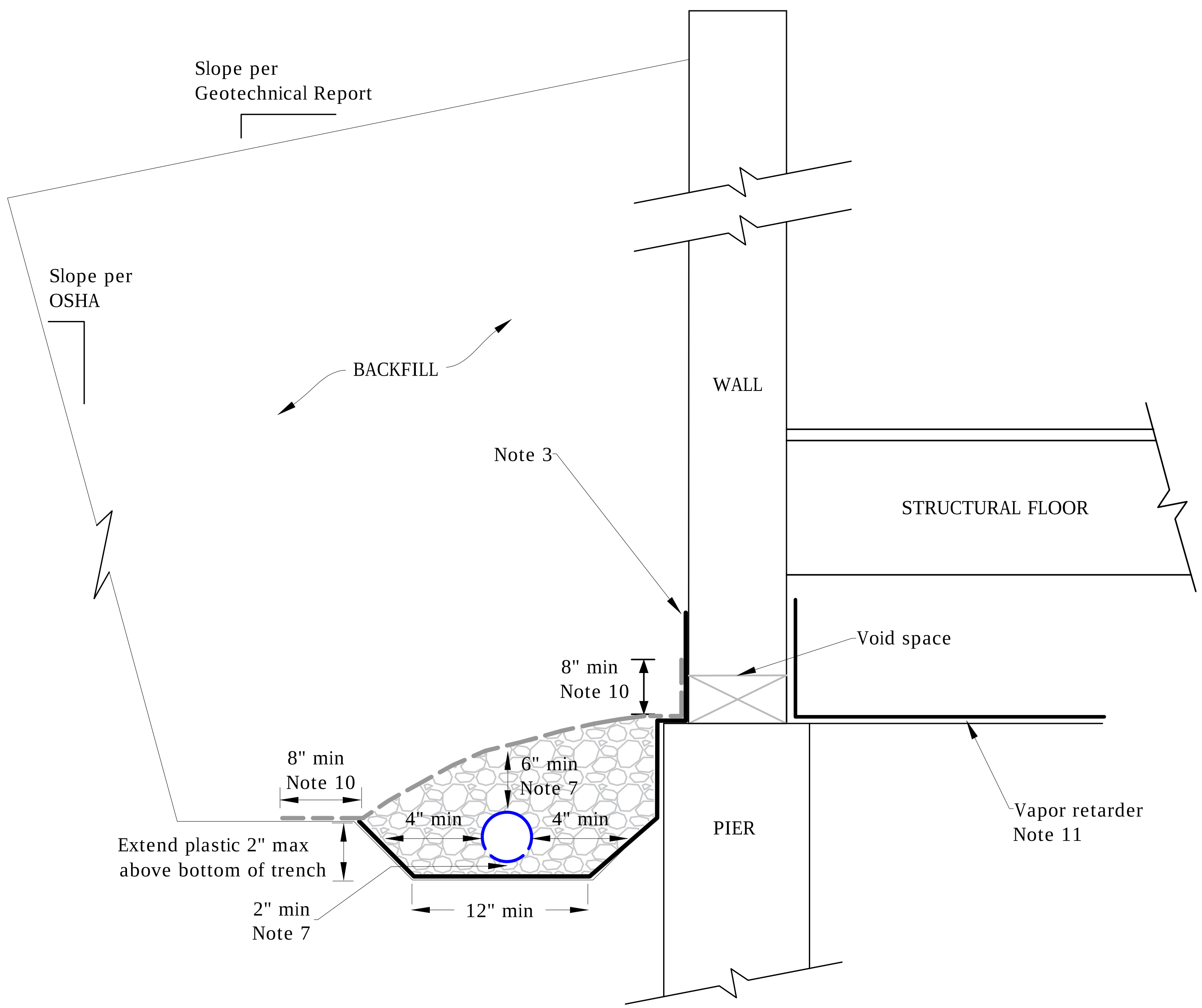

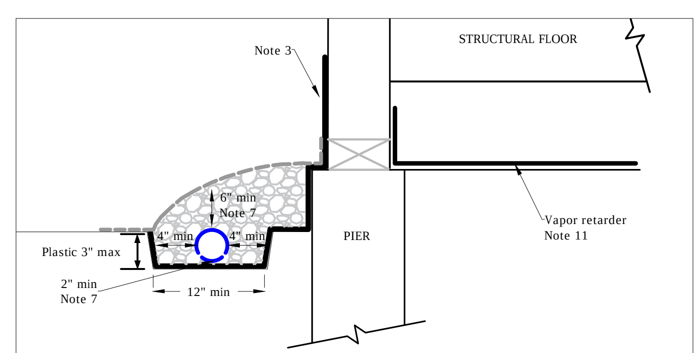

ALTERNATIVE CONFIGURATION

TYPICAL EXTERIOR PERIMETER DRAIN
DRILLED PIER / STRUCTURAL FLOOR

NOTES:

1. At the high point of the drain system the bottom of the pipe shall be a minimum of 2 inches below the bottom of the foundation void space.
2. Bottom of trench and drainpipe must slope a minimum of 1/8 inch per foot (i.e., 1%) to a positive gravity outlet (i.e. daylight) and/or to a sump where water can be removed by pumping.
3. Plastic sheeting shall have a minimum thickness of 10 mils, extend beneath the drain media across the bottom of the trench excavation and extend a maximum of 2 inches above the trench bottom. The plastic sheeting shall be continuous, attached to the foundation wall, and shall extend up above the bottom of the foundation wall a minimum of 12 inches. Where plastic sheeting must be lapped, upstream sections should be placed over downstream sections.
4. Drainpipe shall consist of perforated, machine slotted, or equivalent rigid plastic pipe (minimum Schedule 20), with a minimum inside diameter of 4 inches.
5. Perforated pipe should have a fabric sock around the pipe or alternatively, the pipe perforations or drainage media sized so that at least 85% of the drainage media is larger than the perforations in the pipe.
6. Perforated pipe shall be positioned so that perforations are facing down in about the 4 and 8 o'clock positions.
7. Drainpipe shall be surrounded by an envelope of drainage media. Drainage media shall be at least 2 inches thick under the pipe, 4 inches thick on both sides of the pipe, and shall extend at least 6 inches above the top of the pipe and at least 2 inches above the bottom of the foundation void space.
8. Drainage media shall consist of durable, washed, free draining, crushed natural stone aggregate. Recycled concrete or recycled asphalt materials are not acceptable.
9. Drainage media shall have a maximum particle size of 3/4 inches, 30% to 100% passing the 3/8 inch sieve, and a maximum of 35% passing the #4 sieve size. Alternatively, drainage media meeting CDOT 703.09 Class B Filter requirements may be used.
10. The drainage media shall be covered with a nonwoven geotextile filter fabric consisting of Mirafi 140N or 180N or equivalent. The fabric shall extend beyond the drainage media so that it is lapped against the foundation and the side or bottom of the trench at least 8 inches. Alternatively, the drainage media should be completely wrapped by nonwoven geotextile filter fabric with a minimum overlap of at least 8 inches on top of the drainage media.
11. A vapor retarder should be placed per the recommendation of the geotechnical report. Overlap joints at least 3 feet and seal.

LEGEND

- Free draining granular material (i.e., Drainage media)
- Perforated drainpipe
- Nonwoven geotextile filter fabric
- Plastic sheeting

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FIGURE 2
Typical Exterior Perimeter Drain
Drilled Pier/Structural Floor

PROJECT NO:	21.3051		
PROJECT NAME:	New Horizon Academy Thornton		
DRAWN BY:	JAC2	CHECKED BY:	KCV
DWG DATE:	09.05.21	REV. DATE:	--

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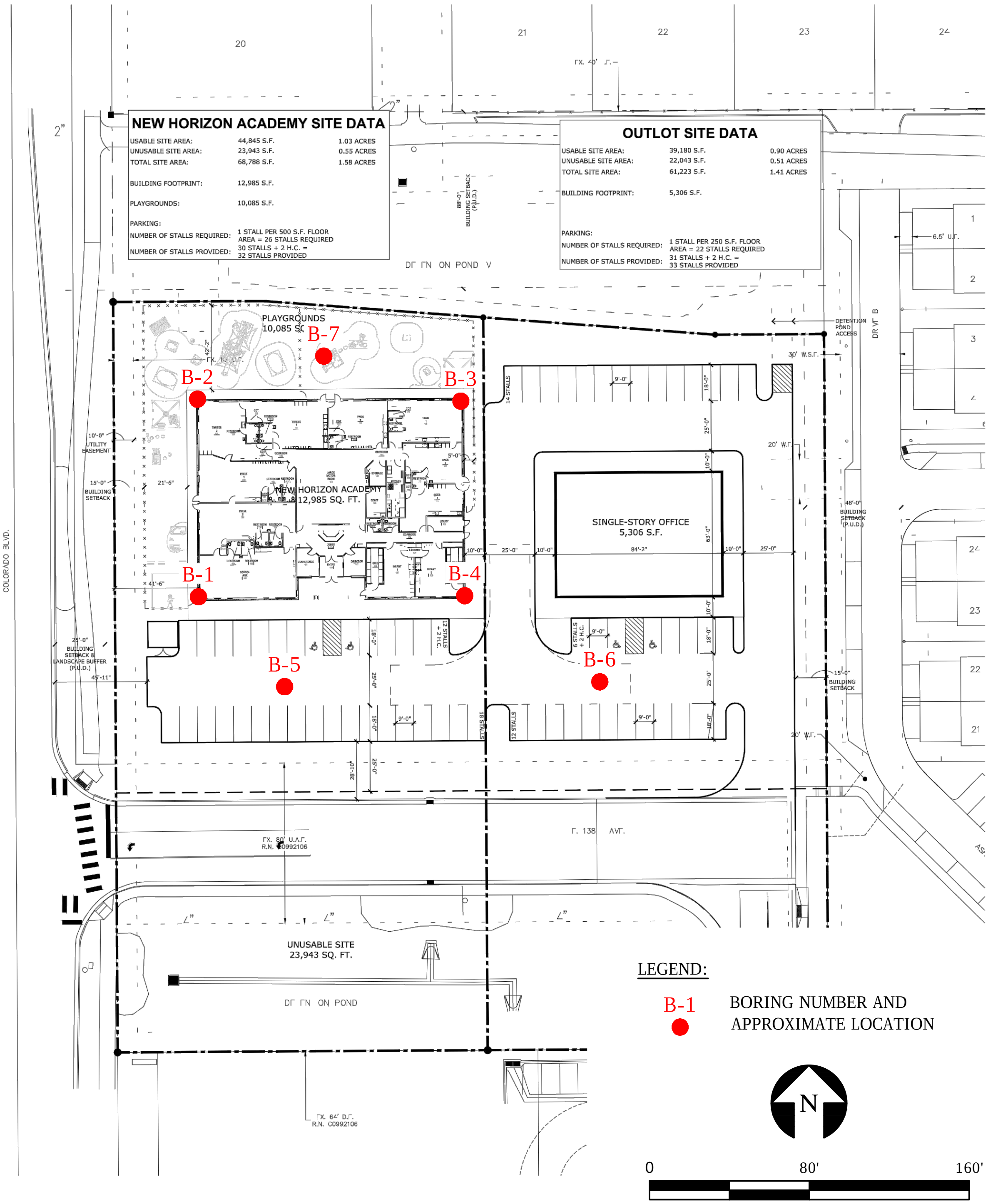
APPENDIX A

Field Exploration

FIELD EXPLORATION

Samples of the subsoil were obtained at this site using a modified California sampler which was driven into the soil by dropping a 140 pound hammer through a free fall of 30 inches. The modified California sampler is a 2-1/2 inch outside diameter by 2 inch inside diameter device lined with brass tubes. The procedure to drive the modified California sampler into the soil and to record the number of blows required to drive the sampler into the soil is known as a penetration test. The number of blows required for the sampler to penetrate 12 inches gives an indication of the relative stiffness of cohesive soil, relative density of non-cohesive soil, and relative hardness of sedimentary bedrock material encountered. Bulk samples were collected from cuttings generated during drilling. Locations of sampling and penetration test results are presented on the boring logs contained in this appendix.

W:\2021\Frederick\21.3051.A New Horizon - Thornton\ACAD\Boring Location Map.dwg 8/4/2021 11:55 AM



SITE PLAN PROVIDED BY CLIENT

SITE PLAN AND BORING LOCATIONS

PROJECT NO:	21.3051		
PROJECT NAME:	New Horizon Academy Thornton		
DRAWN BY:	JBE	CHECKED BY:	JAC2
DWG DATE:	08.04.21	REV. DATE:	--

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PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051	**B-1**
BORING LOCATION		BORING ELEVATION		
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore	
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021	
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021	Page 1 of 1

DEPTH (ft)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK
1.5	6.7	32	31-20-11	34/12	X	
4				50/6	X	
9				50/7	X	
14				50/10	X	
19				50/6	X	
24				44/12	X	
29				44/12	X	

ELEVATION (ft) | MATERIAL DESCRIPTION | DEPTH (ft) | Water Level and Depth of Cave (ft)

SANDSTONE, clayey, medium hard to very hard, slightly moist to wet, poorly to nonindurated, locally with claystone fragments, light brown to tan, orange to orange-brown.

Water level 3 days after drilling: ~15 ft; water level at time of drilling: ~18 ft

20

CLAYSTONE, medium hard, slightly moist, light gray to gray, locally mottled, locally with iron staining.

Depth of cave 3 days after drilling: ~22 ft

30

Boring terminated at 30 feet

LEGEND

- WATER LEVEL AT TIME OF DRILLING
- # WATER LEVEL # DAYS AFTER DRILLING
- # DEPTH OF CAVE # DAYS AFTER DRILLING
- DEPTH OF REFUSAL
- MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051
BORING LOCATION		BORING ELEVATION	
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021

B-2

DEPTH (ft)	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	SWELL-CONSOL VOL CHANGE/SURCHARGE PRESSURE (psf)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
											FILL; CLAY, sandy, very stiff, slightly moist, gray to brown to light brown.		
	124.2	10.6			13.8/100	27/12							
5.0	120.9	9.7	67	37-14-23	6.7/400	28/12							
						19/12							
10.0											INTERBEDDED CLAYSTONE & CLAYEY TO SILTY SANDSTONE, very hard, slightly moist, with iron staining, poorly to nonindurated sandstone, gray to brown.	10	
						50/6							
15.0											CLAYSTONE, hard to very hard, slightly moist to moist, brown to gray, with iron staining, mottled, locally weathered, locally with gypsum, occasional sandstone lenses.	16	▽3
20.0						50/11							
						50/7							
25.0											INTERBEDDED CLAYSTONE & SILTY SANDSTONE, very hard, slightly moist to wet, sandstone poorly to nonindurated, local iron staining, rusty brown to gray.	25	
						50/3							
30.0													
						50/3							→3

LEGEND

- ▼ WATER LEVEL AT TIME OF DRILLING
- ▽# WATER LEVEL # DAYS AFTER DRILLING
- →# DEPTH OF CAVE # DAYS AFTER DRILLING
- ↑ DEPTH OF REFUSAL
- MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051	**B-2**
BORING LOCATION		BORING ELEVATION		
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore	
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021	
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021	Page 2 of 2

DEPTH (ft)	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	SWELL-CONSOL VOL CHANGE/SURCHARGE PRESSURE (psf)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
						50/2					Boring terminated at 39.17 feet		39.17

LEGEND

WATER LEVEL AT TIME OF DRILLING

MODIFIED CALIFORNIA SAMPLER

\# WATER LEVEL # DAYS AFTER DRILLING

\# DEPTH OF CAVE # DAYS AFTER DRILLING

DEPTH OF REFUSAL

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051	B-3
BORING LOCATION		BORING ELEVATION		
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore	
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021	
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021	Page 1 of 1

DEPTH (ft)	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	SWELL-CONSOL VOL CHANGE/SURCHARGE PRESSURE (psf)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
											SAND, silty, clayey, medium dense to dense, moist, tan to brown.		
						36/12							
						21/12						5	
5.0											CLAY, sandy, very stiff, moist, brown.		
	108.2	17.3			0.6/900	25/12							
10.0												12	
											WEATHERED CLAYSTONE, sandy, stiff, moist to very moist, gray to brown.		
	111.4	17.8	58	28-14-14	-0.1/1400	14/12							
15.0												17.5	▽3
											CLAYSTONE, hard, slightly moist, occasional ironite veins, gray with local iron staining.		
	107.4	18.9			2.3/9200	50/11							
20.0													→3
						50/8							
25.0												28	
											SILTSTONE, very hard, slightly moist, brown with iron staining.		
						50/5						29.58	

Boring terminated at 29.42 feet

LEGEND

▼ WATER LEVEL AT TIME OF DRILLING

▽# WATER LEVEL # DAYS AFTER DRILLING

→# DEPTH OF CAVE # DAYS AFTER DRILLING

↑ DEPTH OF REFUSAL

MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051	**B-4**
BORING LOCATION		BORING ELEVATION		
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore	
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021	
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021	Page 1 of 2

DEPTH (ft)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
									CLAY, sandy, very stiff, moist, light brown.		
				19/12							
				15/12							
5.0											
										9	
	6.5	14	NV-NP-NP	50/7					SAND, silty, poorly graded, very dense, dry to slightly moist, slight to moderate calcareous, light brown to tan.		
10.0											
										13.5	
									CLAYSTONE, trace to with fine sand, hard to very hard, dry to slightly moist, gray, mottled, with iron staining, locally with gypsum crystals.		
				37/12							
15.0											
				50/10							
20.0											
				50/8							
25.0											
										29	
				50/5					INTERBEDDED CLAYSTONE, SILTSTONE, very hard, slightly moist to very moist, gray to brown, local iron staining.		
30.0											
											▽3
				50/5							

LEGEND

▼ WATER LEVEL AT TIME OF DRILLING

▽# WATER LEVEL # DAYS AFTER DRILLING

→# DEPTH OF CAVE # DAYS AFTER DRILLING

↑ DEPTH OF REFUSAL

MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051
BORING LOCATION		BORING ELEVATION	
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021

B-4

DEPTH (ft)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
											3
				50/5							39.42

Boring terminated at 39.42 feet

LEGEND

WATER LEVEL AT TIME OF DRILLING

WATER LEVEL # DAYS AFTER DRILLING

DEPTH OF CAVE # DAYS AFTER DRILLING

DEPTH OF REFUSAL

MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051
BORING LOCATION		BORING ELEVATION	
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021

B-5

DEPTH (ft)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
						FILL; SAND, silty, very dense, dry, light brown.	1	
	50/10	X				SANDSTONE, with siltstone partings, hard to very hard, slightly moist, brown to rusty brown, locally with iron staining.		
	50/8	X						
5.0								
	50/6	X					9.5	3

Boring terminated at 9.5 feet

LEGEND

WATER LEVEL AT TIME OF DRILLING

WATER LEVEL # DAYS AFTER DRILLING

DEPTH OF CAVE # DAYS AFTER DRILLING

DEPTH OF REFUSAL

MODIFIED CALIFORNIA SAMPLER

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051
BORING LOCATION		BORING ELEVATION	
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021

B-6

DEPTH (ft)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
						FILL: CLAY, silty, with sand to sandy, dry, light brown.	1	
	37/12					CLAYSTONE, medium hard to hard, slightly moist, olive-gray to gray, mottled, with iron staining, locally calcareous.		
5.0	47/12							
								→3
	50/10						9.82	

Boring terminated at 9.82 feet

LEGEND

WATER LEVEL AT TIME OF DRILLING

WATER LEVEL # DAYS AFTER DRILLING

→# DEPTH OF CAVE # DAYS AFTER DRILLING

DEPTH OF REFUSAL

MODIFIED CALIFORNIA SAMPLER

CESARE, INC.

Geotechnical Engineers & Construction Materials Consultants

PROJECT NAME	New Horizon Academy	PROJECT NUMBER	21.3051
BORING LOCATION		BORING ELEVATION	
DRILLING COMPANY/RIG	Dakota Drilling/CME 75	CESARE REP.	Z. Moore
DRILLING METHOD	4in. Diameter SSA	DATE STARTED	8/2/2021
HAMMER SYSTEM	Automatic Hammer	DATE COMPLETED	8/2/2021

B-7

DEPTH (ft)	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE CONTENT (%)	FINES (%)	LL-PL-PI	SWELL-CONSOL VOL CHANGE/SURCHARGE PRESSURE (psf)	BLOW COUNT	SAMPLE DRIVE	SAMPLE BULK	GRAPHIC LOG	ELEVATION (ft)	MATERIAL DESCRIPTION	DEPTH (ft)	Water Level and Depth of Cave (ft)
											CLAY, with sand, very stiff to medium stiff, dry to slightly moist, brown.		
	114.4	10.1			0.8/4000	26/12	X						
	109.2	12	80	35-15-20	0/4000	8/12	X				Small vugs at 4 feet.		
5.0													
												7	
											INTERBEDDED CLAYSTONE SANDSTONE & SILTSTONE, hard, slightly moist, rusty brown to gray.		→3
						50/9	X					9.75	

Boring terminated at 9.75 feet

LEGEND

- ▼ WATER LEVEL AT TIME OF DRILLING
- ▽# WATER LEVEL # DAYS AFTER DRILLING
- →# DEPTH OF CAVE # DAYS AFTER DRILLING
- ↑ DEPTH OF REFUSAL
- MODIFIED CALIFORNIA SAMPLER

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APPENDIX B

Laboratory Testing

LABORATORY TESTING

Swell/consolidation testing was performed on samples collected using a modified California sampler to evaluate the effect of wetting and loading on the soil. The samples were loaded incrementally to 4,000 psf or to approximate overburden pressure considering a unit weight of 100 psf, per foot of soil and then inundated with water.

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SUMMARY OF LABORATORY TEST RESULTS
New Horizon Academy Thornton
Project No. 21.3051

Sample Location		Natural Dry Density	Natural Moisture Content	Water Soluble Sulfates	Gradation			Atterberg Limits		Swell/Consolidation			Material Type
Boring	Depth (feet)	(pcf)	(%)	(%)	Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)	
B-1	1		6.7			68	32	31	11				SANDSTONE: SAND, clayey (SC, A-2-6)
B-2	1	124.2	10.6	0.14						100	13.8	20,500	FILL: CLAY, sandy, lean (CL, A-6)
B-2	4	120.9	9.7		1	32	67	37	23	400	6.7	10,600	FILL: CLAY, sandy, lean (CL, A-6(13))
B-3	9	108.2	17.3							900	0.6	2,050	CLAY, sandy, lean (CL, A-6)
B-3	14	111.4	17.8			42	58	28	14	1,400	-0.1	N/A	CLAYSTONE: CLAY, sandy, lean (CL, A-6(5))
B-3	19	107.1	18.9							1,900	2.3	9,200	CLAYSTONE: CLAY, sandy, lean (CL, A-6)
B-4	9		6.5			86	14	NV	NP				SAND, silty (SM, A-2-4)
B-5	1	119.1	5.7							150	0.9	N/A	SANDSTONE: SAND, silty (SM, A-6)
B-6	1	112.5	16.9							150	5.9	N/A	CLAYSTONE: CLAY, sandy (CL, A-6)
B-7	1	114.4	10.1							4,000	0.8	8,200	CLAY, lean, with sand (CL, A-6)
B-7	4	109.2	12.0			20	80	35	20	4,000	0.0	N/A	CLAY, lean, with sand (CL, A-6(14))

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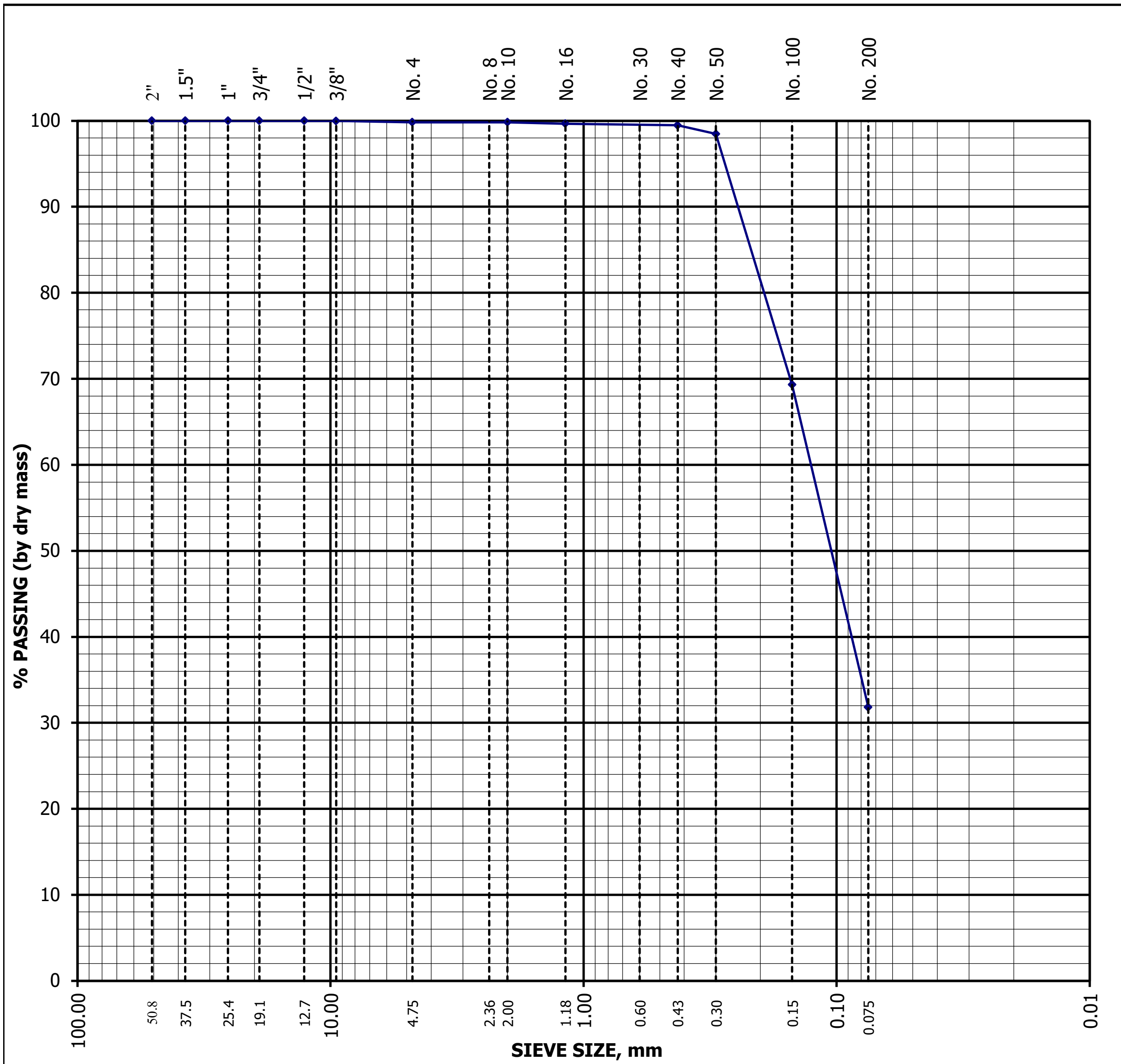
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	21.3051	Date:	18-Aug-21
Project Name:	New Horizon Academy Thornton	Technician:	G. Hoyos/D. Fuorry
Lab ID Number:	2121227	Reviewer:	G. Hoyos
Sample Location:	B-1 at 1'		
Visual Description:	SANDSTONE: SAND, clayey, brown		

AASHTO M 145 Classification: **A-2-6** **Group Index:** **(0)**
Unified Soil Classification System (ASTM D 2487): **(SC) Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	100
#16	100
#30	
#40	99
#50	98
#100	69
#200	31.8

Moisture (M) & Density (D)	
M, %:	6.7
D, pcf:	

LL	31
PL	20
PI	11

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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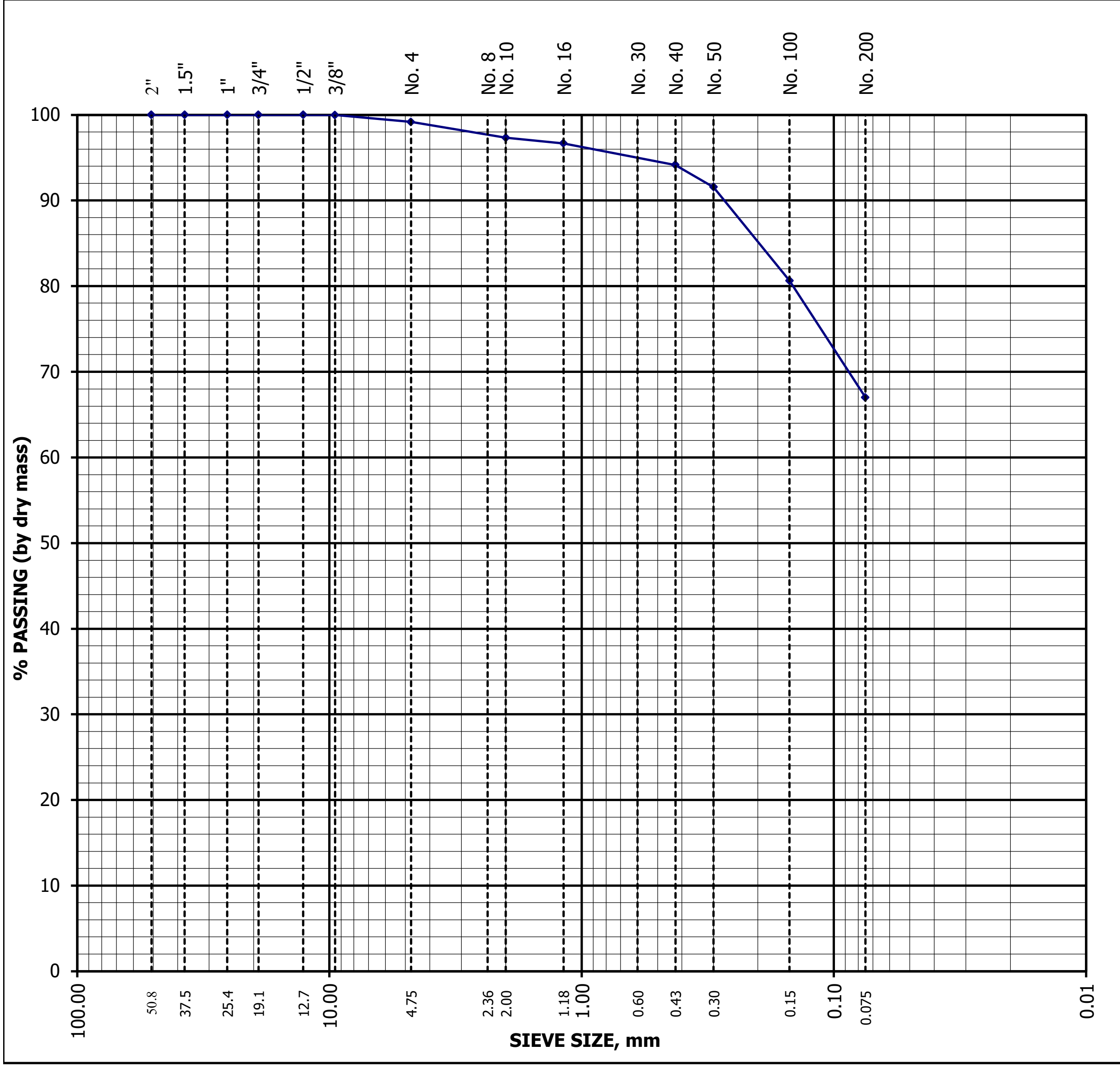
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	21.3051	Date:	17-Aug-21
Project Name:	New Horizon Academy Thornton	Technician:	G. Hoyos/D. Fuorry
Lab ID Number:	2121229	Reviewer:	G. Hoyos
Sample Location:	B-2 at 4'		
Visual Description:	FILL: CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **13**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	97
#16	97
#30	
#40	94
#50	92
#100	81
#200	67.0

Moisture (M) & Density (D)	
M, %:	9.7
D, pcf:	

LL	37
PL	14
PI	23

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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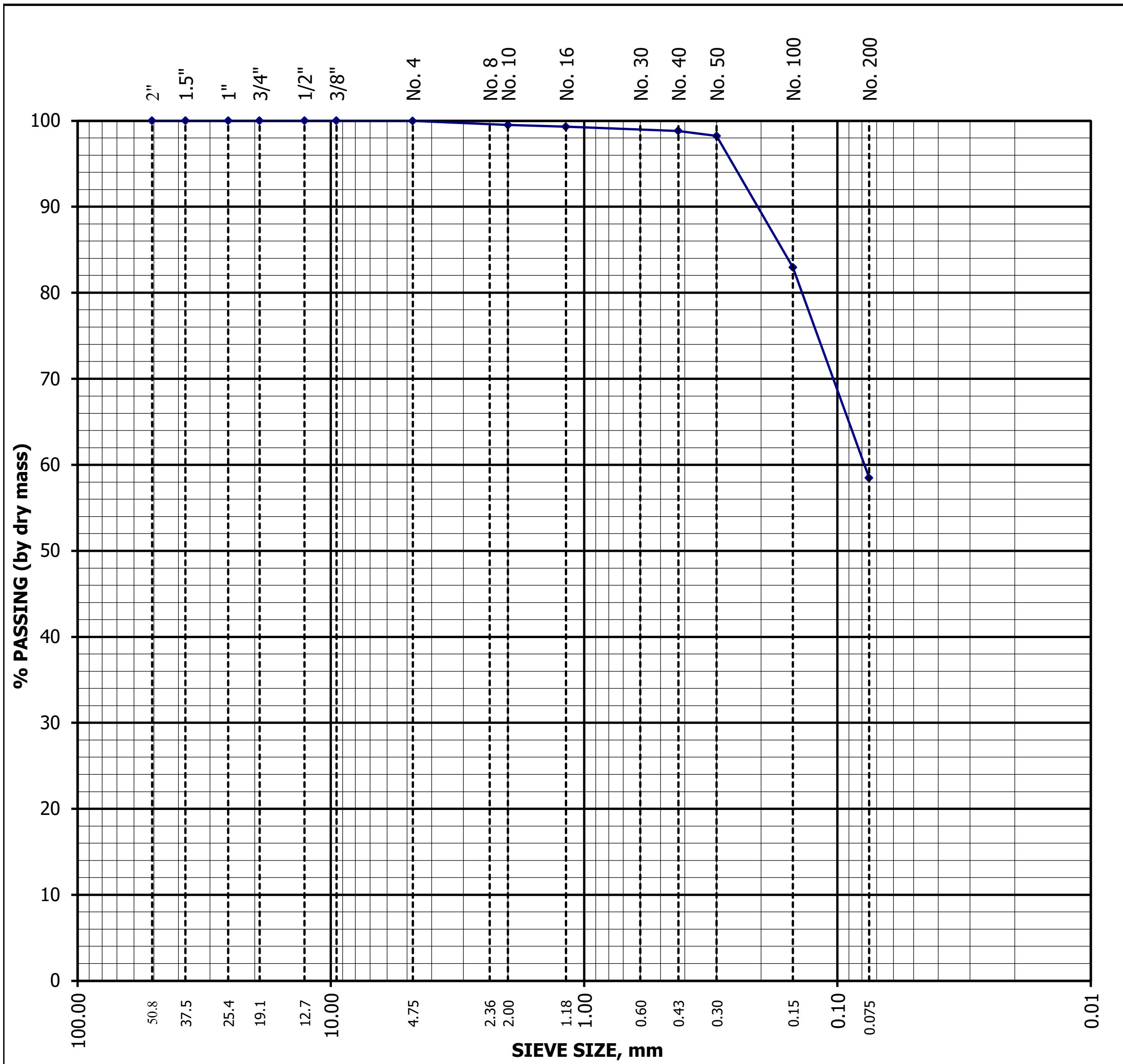
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	21.3051	Date:	18-Aug-21
Project Name:	New Horizon Academy Thornton	Technician:	G. Hoyos/D. Fuorry
Lab ID Number:	2121231	Reviewer:	G. Hoyos
Sample Location:	B-3 at 14'		
Visual Description:	CLAYSTONE: CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **5**

Unified Soil Classification System (ASTM D 2487): **(CL) Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	99
#30	
#40	99
#50	98
#100	83
#200	58.5

Moisture (M) & Density (D)	
M, %:	17.8
D, pcf:	

LL	28
PL	14
PI	14

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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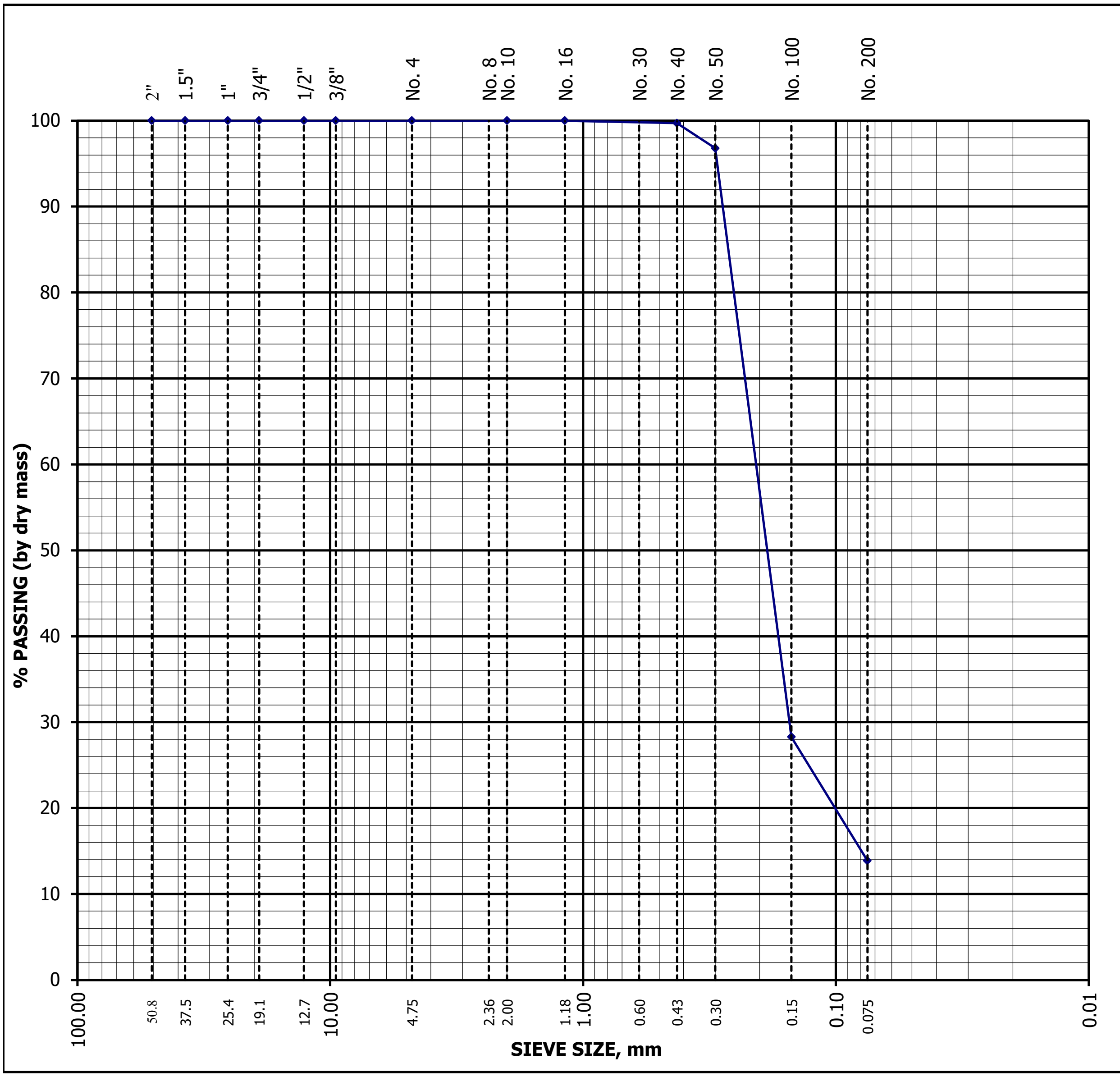
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	21.3051	Date:	18-Aug-21
Project Name:	New Horizon Academy Thornton	Technician:	G. Hoyos/D. Fuorry
Lab ID Number:	2121233	Reviewer:	G. Hoyos
Sample Location:	B-4 at 9'		
Visual Description:	SAND, silty, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SM) Silty sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	
#8	
#10	100
#16	100
#30	
#40	100
#50	97
#100	28
#200	13.9

Moisture (M) & Density (D)	
M, %:	6.5
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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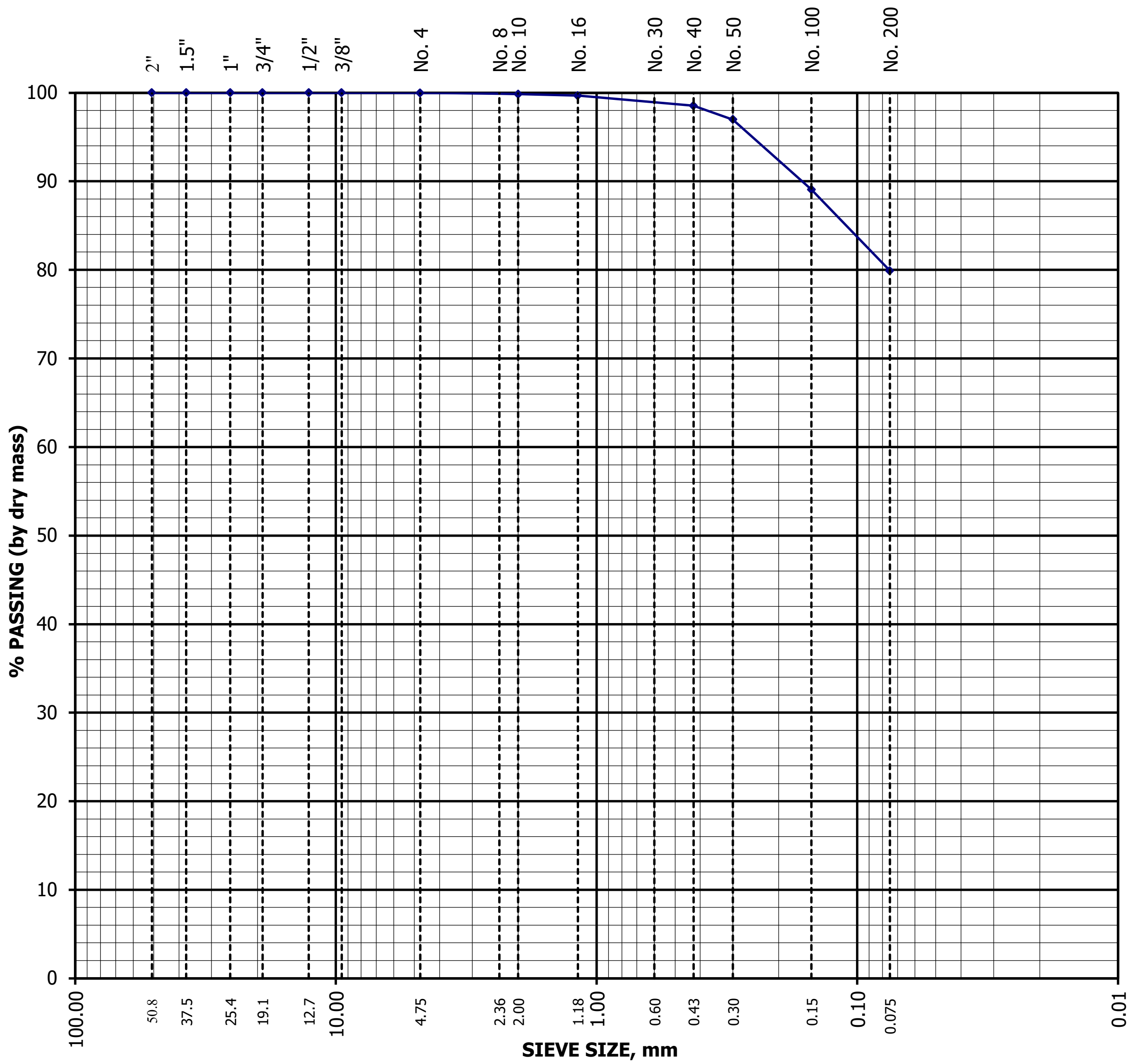
GRADATION PLOT - SOIL & AGGREGATE

Project Number:	21.3051	Date:	18-Aug-21
Project Name:	New Horizon Academy Thornton	Technician:	G. Hoyos/D. Fuorry
Lab ID Number:	2121235	Reviewer:	G. Hoyos
Sample Location:	B-7 at 4'		
Visual Description:	CLAY, with sand, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **14**
Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	100
#30	
#40	99
#50	97
#100	89
#200	79.9

Moisture (M) & Density (D)	
M, %:	11.9
D, pcf:	

LL	35
PL	15
PI	20

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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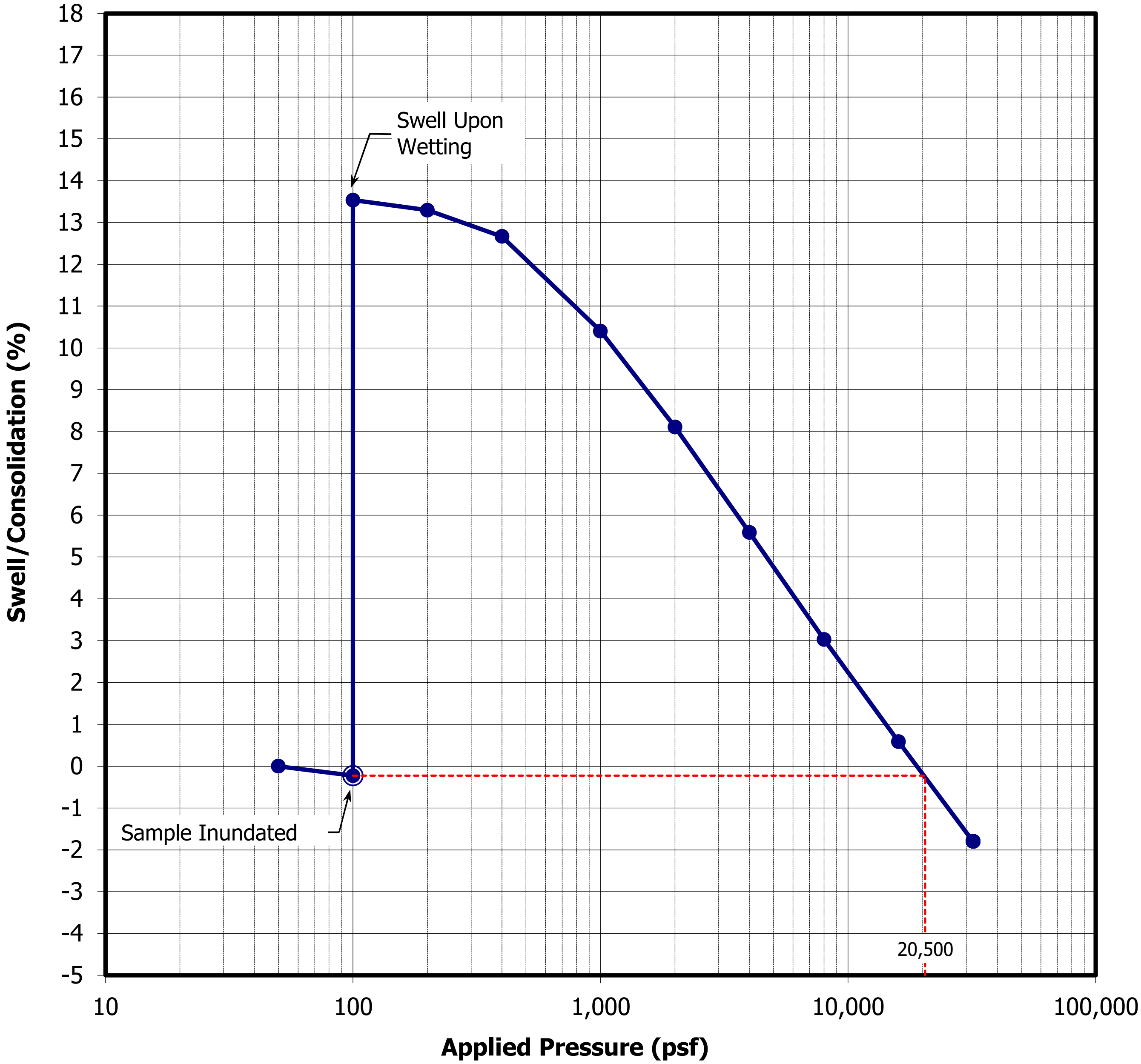
SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-2	1	Fill; CLAY, sandy, brown	124.2	10.6	100	13.8	20,500

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121228

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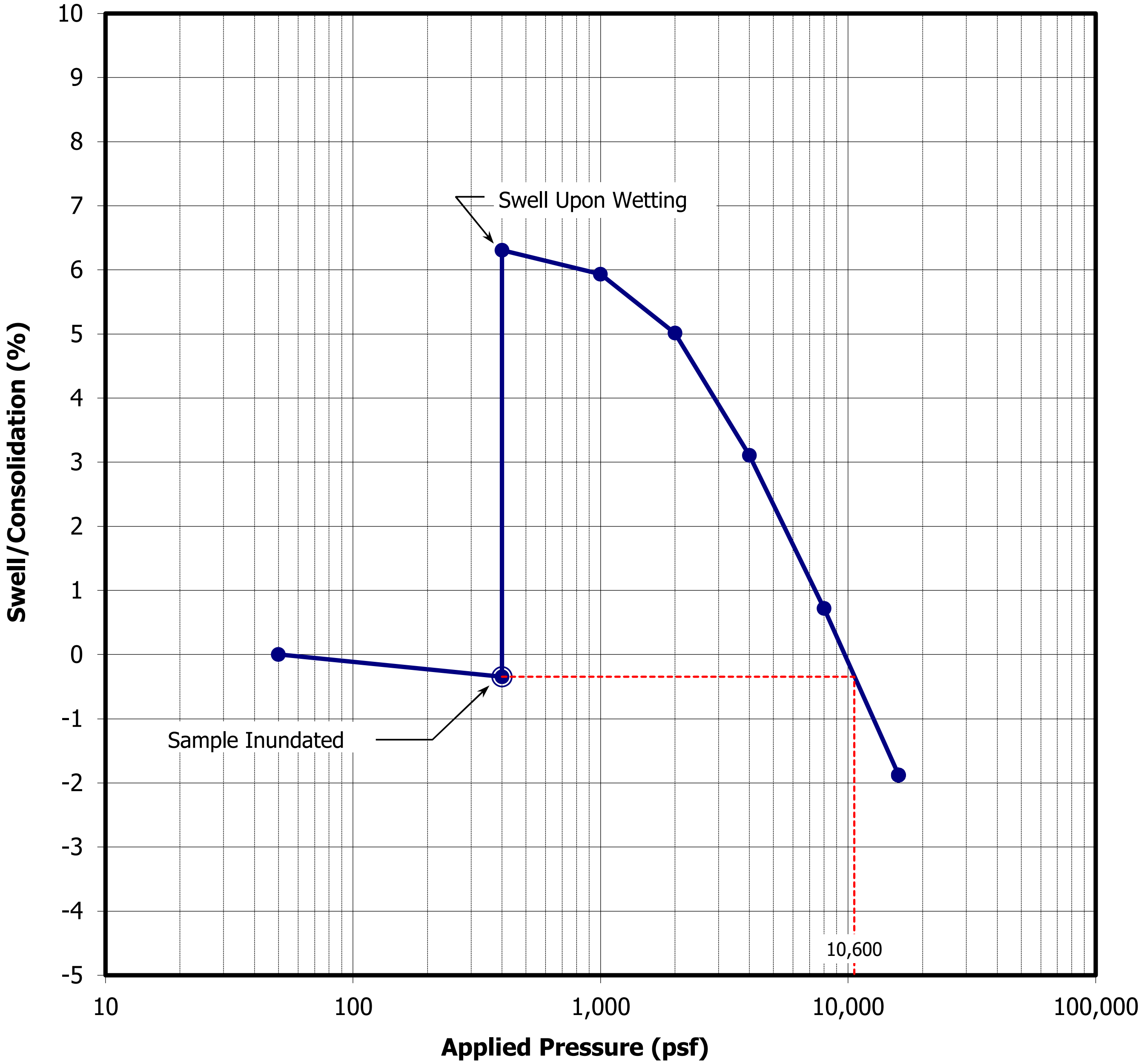
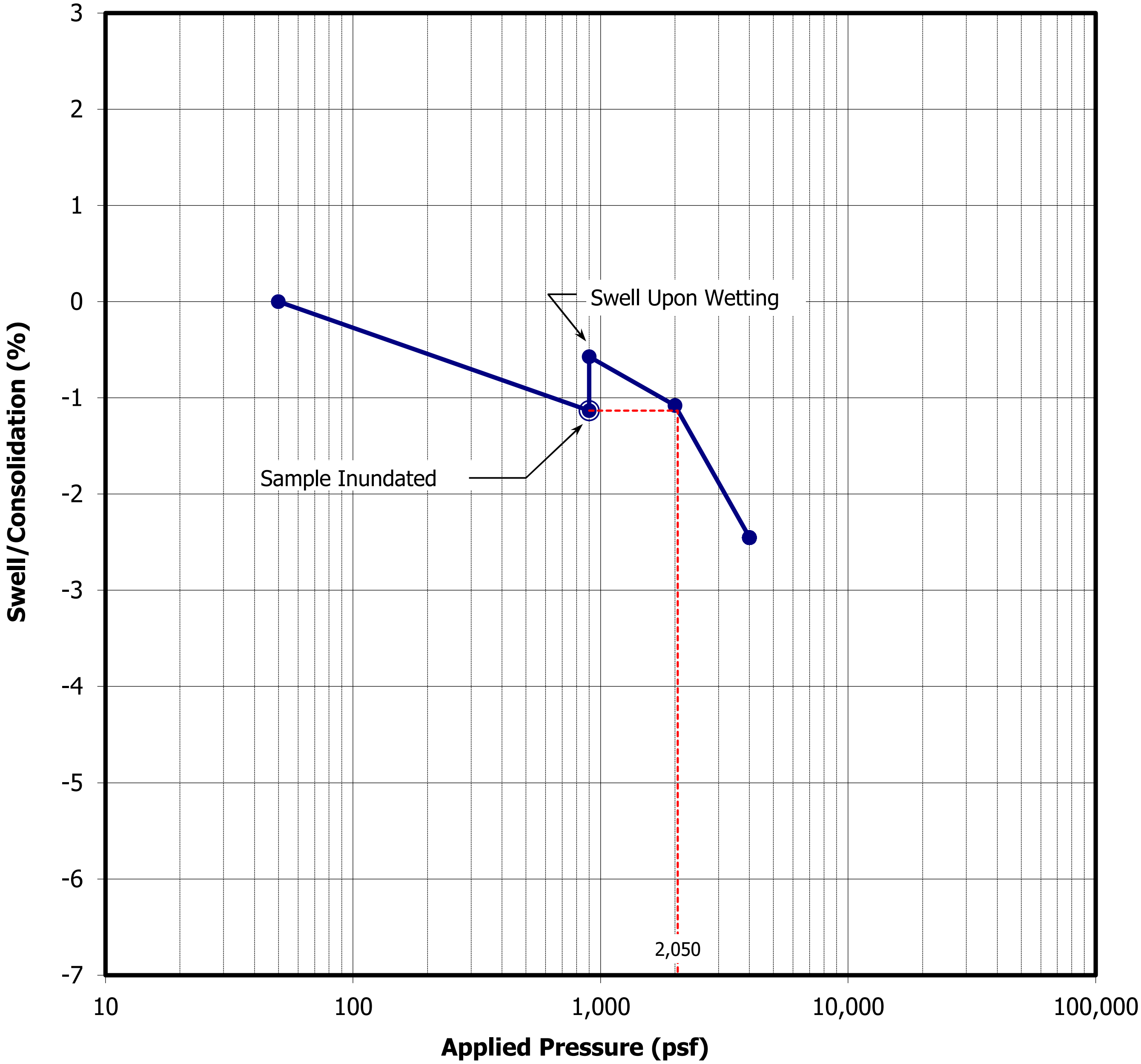
SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-2	4	Fill; CLAY, sandy, brown	120.9	9.7	400	6.7	10,600

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121229

SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-3	9	CLAY, sandy, brown	108.2	17.3	900	0.6	2,050

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121230

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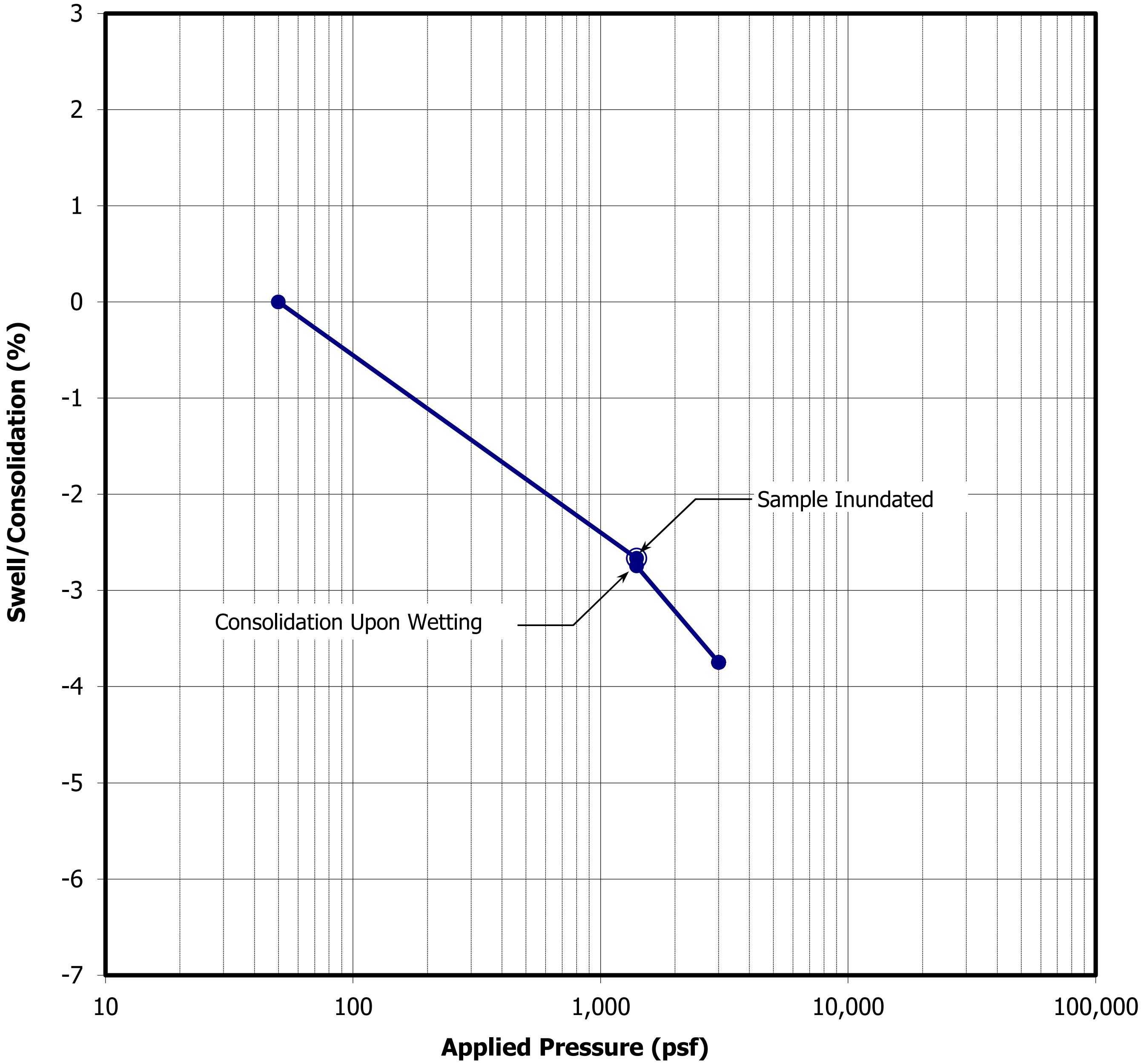
SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-3	14	Weathered CLAYSTONE, sandy, brown	111.4	17.8	1,400	-0.1	N/A

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121231

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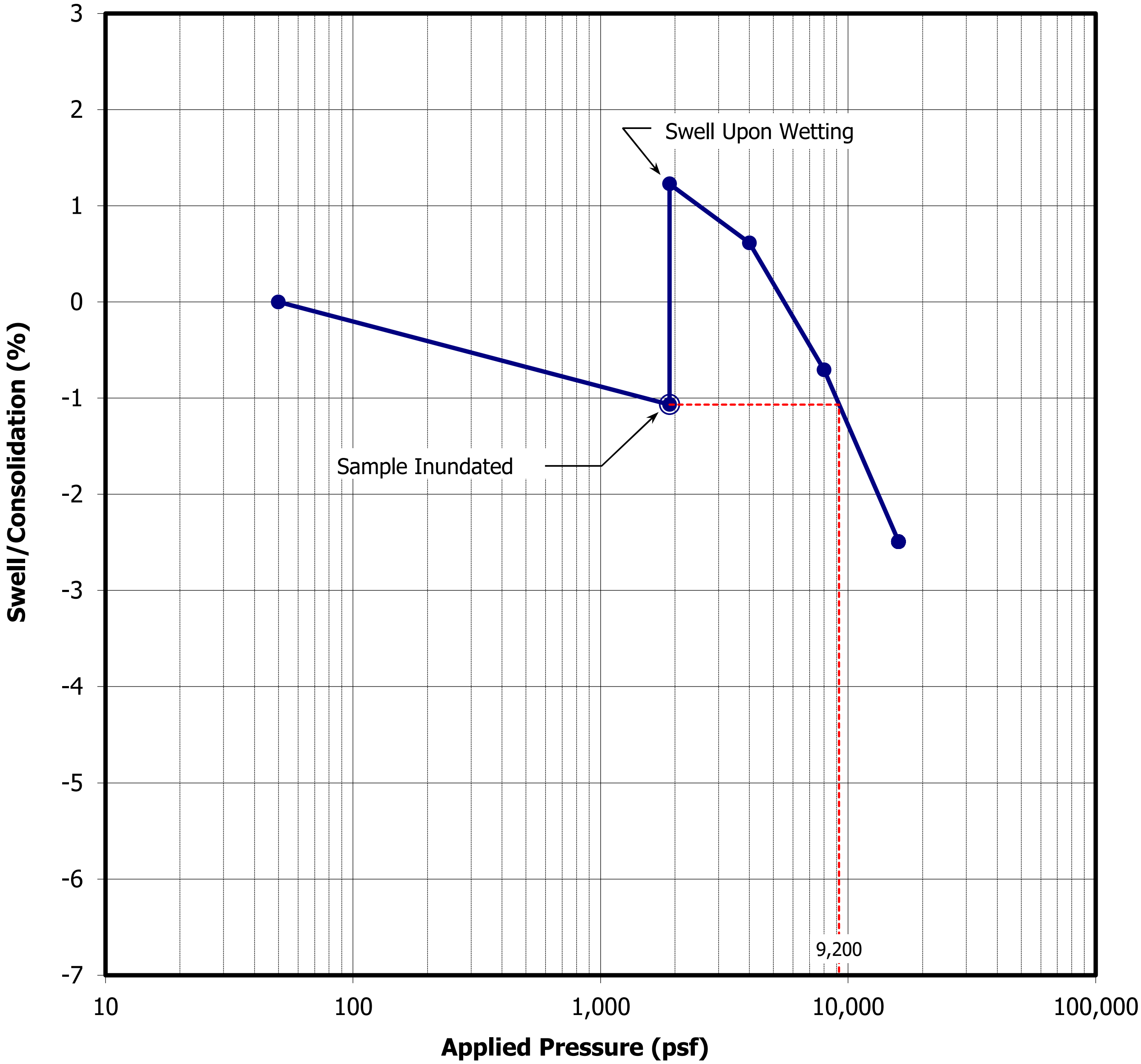

Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-3	19	CLAYSTONE, sandy, gray	107.1	18.9	1,900	2.3	9,200

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121232

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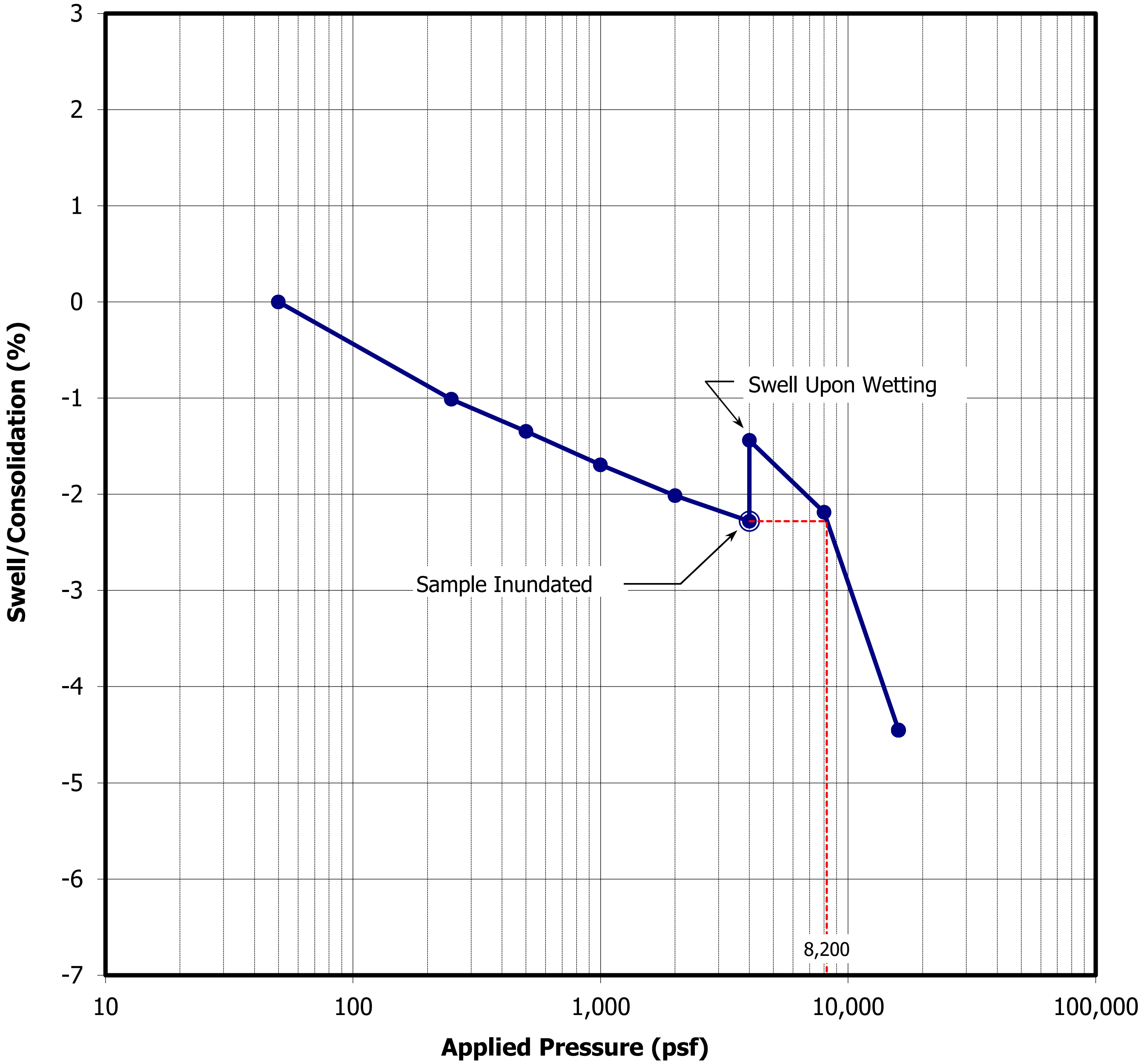

Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-7	1	CLAY, sandy, brown	114.4	10.1	4,000	0.8	8,200

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121234

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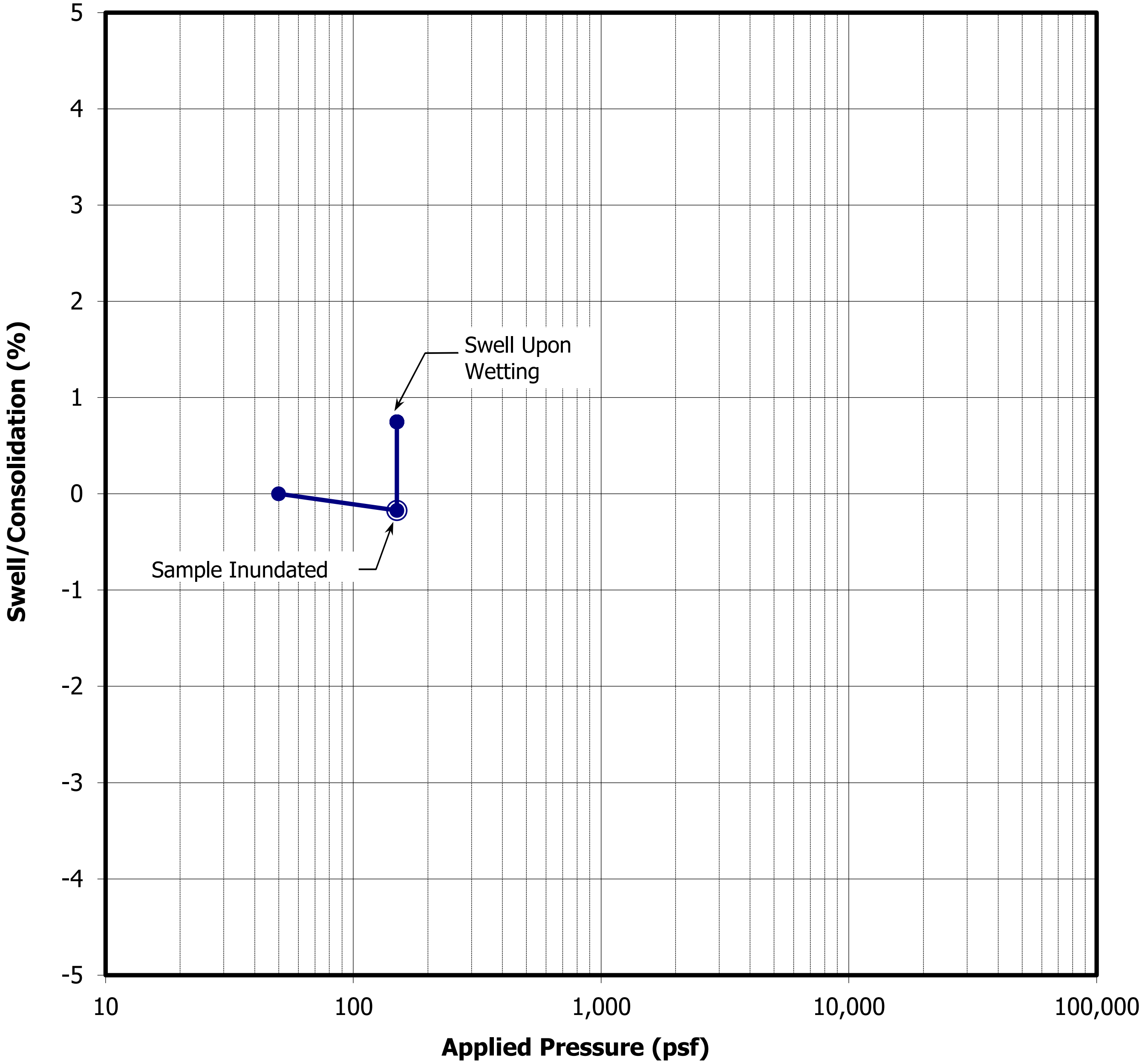

Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-5	1	SANDSTONE, brown	119.1	5.7	150	0.9	N/A

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121325

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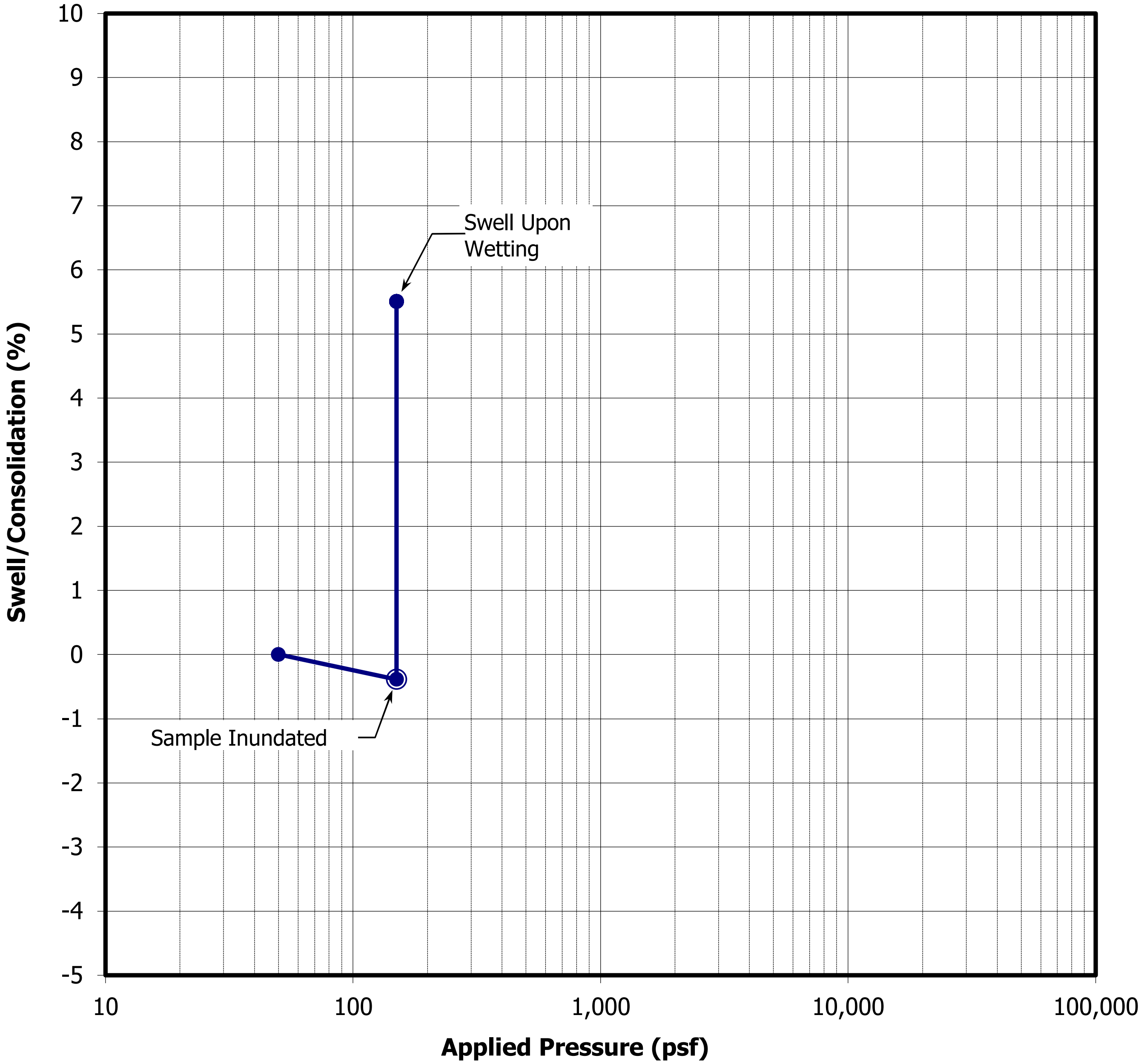

Sample Location	Sample Depth (ft)	Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
B-6	1	CLAYSTONE, sandy, brown	112.5	16.9	150	5.9	N/A

Project Number	Project Name	Lab ID Number
21.3051	New Horizon Academy Thornton	2121326

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APPENDIX C

Vapor Barriers

VAPOR BARRIERS

If it is determined that a vapor retarder/barrier is warranted below a concrete slab-on-grade, Cesare recommends the vapor barrier comply with ASTM E1745, and if moisture sensitive flooring will be utilized, have a permeance below 0.01 perms before and after mandatory conditioning testing. The vapor retarder/barrier should be installed per ASTM E1643 and the design professional should consider project specific requirements in specification verbiage. See the ACI Committee 302, "Guide for Concrete Floor and Slab Construction (ACI 302.R-96)" for additional discussion and guidance regarding the use of vapor retarders/barriers beneath floor slabs.

The 2018 IBC, Section 1805.2 Dampproofing states that where hydrostatic pressure will not occur, as determined by Section 18-03.5.4, floors shall be dampproofed in accordance with this section.

Section 1805.2 Floors, states,

> "*Dampproofing materials for floors shall be installed between the floor and the base course required by Section 1805.4.1, except where a separate floor is provided above a concrete slab. Where installed beneath the slab, dampproofing shall consist of not less than 6-mil (0.006 inch; 0.152 mm) polyethylene with joints lapped not less than 6 inches (152 mm), or other approved methods or materials. Where permitted to be installed on top of the slab, damp proofing shall consist of mopped-on bitumen, not less than 4-mil; (0.004 inch; 0.102 mm) polyethylene, or other approved methods or materials. Joints in the membrane shall be lapped and sealed in accordance with the manufacturer's installation instructions*".

Section 1805.4.1 Floor Base Course, states,

> *"Floors of basements, except as provided for in Section 1805.1.1 shall be placed over a floor base course not less than 4 inches (102 mm) in thickness that consists of gravel or crushed stone containing no more than 10 percent of material that passes through a No. 4 (4.75mm) sieve. Exception: Where a site is in well-drained gravel or sand/gravel mixture soils, a floor base course is not required."*

Historically, when considering slab-on-grade construction at sites with expansive soil, most of the geotechnical community local to the Front Range have recommended against placing a layer of base course material below slabs, except in shallow groundwater situations. A primary reason has been the concern that installation of a free draining granular material below the slab could allow or promote wetting of the underlying expansive soil from an isolated source of water.

Cesare recommends that slabs be constructed directly on the existing subgrade soil without the addition of a layer of base course material and that the architect be consulted regarding the need for a vapor retarder or vapor barrier. Decision to include a vapor retarder/barrier beneath the slab is dependent on the sensitivity of floor coverings and building use to moisture.

VAPOR BARRIERS

If it is determined that a vapor retarder/barrier is warranted below a concrete slab-on-grade, Cesare recommends the vapor barrier comply with ASTM E1745, and if moisture sensitive flooring will be utilized, have a permeance below 0.01 perms before and after mandatory conditioning testing. The vapor retarder/barrier should be installed per ASTM E1643 and the design professional should consider project specific requirements in specification verbiage. See the ACI Committee 302, "Guide for Concrete Floor and Slab Construction (ACI 302.R-96)" for additional discussion and guidance regarding the use of vapor retarders/barriers beneath floor slabs.

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APPENDIX D

DARWin Pavement Design Printouts

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

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Computer Software Product

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7108 S Alton Way
Centennial CO
usa

Flexible Structural Design Module

New Horizon Academy Pavement - Drive Lanes

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	73,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,025 psi
Stage Construction	1

Calculated Design Structural Number	2.91 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Hot Mix Asphalt	0.44	1	4.5	-	1.98
2	Aggregate Base Course	0.11	1	8.5	-	0.94
Total	-	-	-	13.00	-	2.92

Layered Thickness Design

Thickness precision	Nearest 0.5 in

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	Hot Mix Asphalt	0.44	1	-	-	-	-	7.00	3.08
Total	-	-	-	-	-	-	-	7.00	3.08

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

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usa

Flexible Structural Design Module

New Horizon Academy Pavement

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	36,500
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	85 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,025 psi
Stage Construction	1
Calculated Design Structural Number	2.62 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Hot Mix Asphalt	0.44	1	4	-	1.76
2	Aggregate Base Course	0.11	1	8	-	0.88
Total	-	-	-	12.00	-	2.64

Layered Thickness Design

Thickness precision — Nearest 0.5 in

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(in)	Min Thickness (Di)(in)	Elastic Modulus (psi)	Width (ft)	Calculated Thickness (in)	Calculated SN (in)
1	Hot Mix Asphalt	0.44	1	-	-	-	-	6.00	2.64
Total	-	-	-	-	-	-	-	6.00	2.64