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PRELIMINARY GEOTECHNICAL INVESTIGATION ALEXANDER WAY NORTHEAST OF ALEXANDER PLACE AND BREWER COURT CASTLE ROCK, COLORADO

Prepared For:

455 ALEXANDER, LLC
851 South High Street
Denver, Colorado 80209

Attention: Rick Rome

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SCOPE

This report presents the results of our Preliminary Geotechnical Investigation for Alexander Way in Castle Rock, Colorado (Figs. 1A and 1B). The purpose of our investigation was to evaluate the subsurface conditions to assist in due diligence assessment and planning of site development. The scope was described in our revised Proposal DN 22-0043R (revision dated February 22, 2022). Evaluation of the property for the possible presence of potentially hazardous materials (Environmental Site Assessment) was not included with this scope.

This report is based on our understanding of the planned construction, site reconnaissance, subsurface conditions disclosed by exploratory drilling and sampling, results of field and laboratory tests, engineering analysis of field and laboratory data, and our experience. The report contains descriptions of the subsurface conditions found in our exploratory borings, identification of geologic hazards and geotechnical concerns, preliminary recommendations for site development, and preliminary discussion of foundations, floor systems, pavements, and surface and subsurface drainage. The discussions of foundation, floor system and pavement alternatives are intended for planning purposes only. Additional investigation may be necessary to evaluate merits of sub-excavation. Site-specific investigations will be necessary to design structures, pavements, and other improvements. A summary of our conclusions and recommendations follows, with more detailed discussion in the report.

SUMMARY OF CONCLUSIONS

1. The site is judged suitable for development. The primary geotechnical concern is expansive soil and bedrock. The soils and bedrock were erratic and borings indicate portions of the site is underlain by expansive materials, a geologic hazard. Moderate to steep slopes are also present, along with regional issues of seismicity and potential radon. These concerns can be mitigated with proper planning,

engineering, design and construction. We believe there are no geotechnical constraints that would preclude development.

2. Strata encountered in our exploratory borings were erratic and consisted of 2 to more than 20 feet of sand and/or clay underlain by claystone and sandstone bedrock to the maximum depth explored of 35 feet. Roughly 5½ feet of existing fill was found at the ground surface in TH-8. Clay and claystone samples exhibited variable swelling characteristics.

3. Groundwater was not encountered during drilling. When the holes were checked after drilling, water was measured in one boring at a depth of about 29½ feet below existing and proposed grade. We do not expect groundwater will affect proposed construction. Groundwater may fluctuate seasonally and rise in response to development, precipitation, and landscape irrigation.

4. We estimate total potential heave at the proposed ground surface could range from 1 to 3 inches considering a wetting depth of 24 feet below proposed grades. Due to our widely spaced borings, variations from these estimates should be anticipated.

5. The site is judged to have variable risk of damage due to expansive soil and bedrock. Footing foundations may be used where low swelling soil and bedrock are present within depths likely to influence performance of foundations. Drilled piers or other deep foundation systems should be anticipated in areas where moderate to high swelling soil or claystone are present. Sub-excavation can be considered for a wider use of shallow foundations and slab-on-grade basement floors. The variability of soils and bedrock conditions imply depth of sub-excavation could be variable. You may elect to sub-excavate all lots to 10 feet below basements or 13 feet below structure foundations where no basements are planned. Our estimates are conservative for the eastern portion of the site that we were unable to access with a drill rig. <u>Further investigation, after the completion of site grading, can be performed to furth evaluate the merits of sub-excavation in areas where existing terrain restricted subsurface exploration.</u>

6. Slopes steeper than 20 percent will need to be benched prior to placement of fill. Sub-fill drains are recommended along the alignment of the existing drainages where about 15 or more feet of fill is planned.

7. The clayey soils are anticipated to possess poor pavement support qualities. For planning purposes, we believe the Town of Castle Rock's minimum pavement requirements are appropriate. Mitigation of expansive soils may be required. Minimum pavement sections are provided in the report. A subgrade investigation and pavement design should be performed after grading is complete.

8. Control of surface and subsurface drainage will be critical to the performance of foundations, slabs-on-grade, pavements and other improvements. Overall surface drainage should be designed to provide rapid run-off of surface water away from structures and off pavements and flatwork. Water should not be allowed to pond near structures or on pavements and flatwork, or on the crests of slopes. Conservative irrigation practices should be employed to reduce the risk of subsurface wetting.

SITE CONDITIONS

The Alexander Way site includes about 78.1 acres and is located northeast of Alexander Place and Brewer Court in Castle Rock, Colorado (Figs. 1A/1B and Photo 1). The site is vacant and bordered by Silver Heights subdivision and commercial shops to the west, vacant land to the north, Diamond Ridge subdivision to the north and east, and Alexander Place to the south. The site generally slopes west-northwest with a steep incline leading up to a ridge that runs along the site's eastern boundary. Several repeating ridge/gully features, running perpendicular to the eastern ridge, occupy the center of the site. Multiple overhead utilities are present on the site. A dirt road stemming from Alexander Place runs north through the site leading to an area (near TH-8) with existing fill and an electrical box. Review of historical aerial images indicates an existing structure was located here and was demolished sometime between 2011 and 2015. The ground surface of the lower, western portion is covered with grass, weeds, and trees and the eastern slope is covered with oak brush.

PROPOSED DEVELOPMENT

Preliminary plans indicate the site may be developed for about 55 single-family residences (Planning Area 1) and 24 mixed-use buildings (Planning Area 2). Roughly 29 acres of the steep eastern slope will be left as open space (Planning Area 3). Two detention ponds are planned at the southwest and northwest corners of the site. The single-family residences will include detached products and will likely range from one to three-story. It is not known if basements are planned. The development will be served by paved roadways and buried utilities. Significant cut and fill grading will be necessary to achieve proposed grades, with cuts up to about 29 feet and fills up to about 27 feet. The deepest cuts will be located around the ridges near the steep eastern slope. The deeper fills are planned within the gullies/drainages and in the north portion of the site. Many of the lots are planned over gullies.

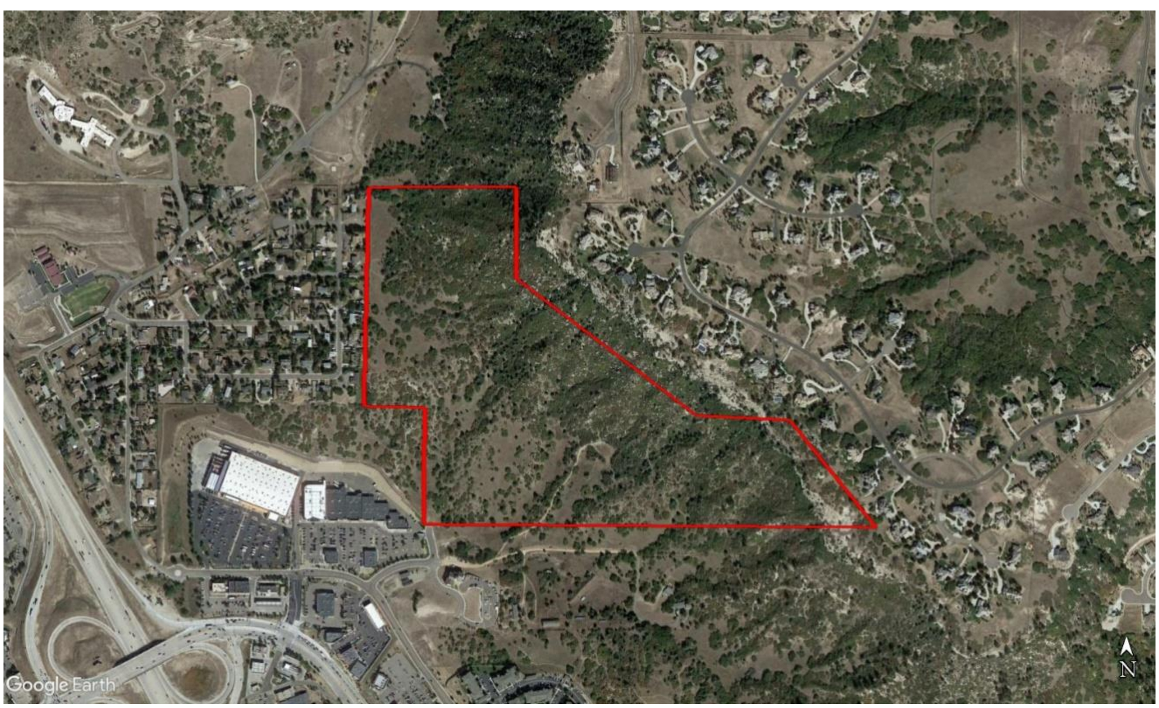


Photo 1 – Google Earth© Aerial Site Photo – October 2019

INVESTIGATION

Subsurface conditions were investigated by drilling and sampling 9 widely spaced exploratory borings at the approximate locations shown on Figs. 1A and 1B. Boring locations and elevations are approximate and were staked by the client. Prior to drilling, we contacted the Utility Notification Center of Colorado and local sewer and water districts to identify locations of buried utilities. The borings were drilled to depths of about 25 to 35 feet below existing grade using 4-inch diameter, continuous-flight solid-stem augers and truck-mounted drill rigs.

Samples of the soil and bedrock were obtained at approximate 5-feet intervals using a 2.5-inch diameter (O.D.) modified California barrel sampler driven by a 140-pound hammer falling 30 inches. Our field representatives were present to observe drilling, log the soil and bedrock, obtain samples and measure the depth to groundwater. Bulk samples were collected from auger cuttings at select borings. Summary logs of exploratory borings are presented in Appendix A.

Samples were returned to our laboratory where they were examined and assigned testing. Laboratory tests included dry density, moisture content, particle size analysis (gradation and percent silt and clay-sized particles), Atterberg limits, swell-consolidation, and water-soluble sulfate concentration. Swell-consolidation tests were performed by wetting the samples under approximate post-construction overburden pressures (the pressure exerted by overlying soils after proposed grading). Results of laboratory tests are presented in Appendix B.

SUBSURFACE CONDITIONS

Strata encountered in our exploratory borings were erratic and consisted of 2 to more than 20 feet of sand and/or clay underlain by claystone and sandstone bedrock to the maximum depth explored of 35 feet. Roughly 5½ feet of existing fill was found at the ground surface in one boring. Pertinent engineering characteristics of the soil and bedrock are described in the following paragraphs.

Existing Fill

About 5½ feet of existing, undocumented fill was encountered at the ground surface in TH-8 and consisted of slightly clayey sand. The fill was difficult to discern from the native soils as they are similar in composition, and more or less fill may be present than our borings imply. The fill was medium dense based on the result of a field penetration resistance test. One sample contained 10 percent silt and clay-sized particles (passing the No. 200 sieve). Review of historical aerial imagery indicates this fill is likely related to the construction/demolition of a pre-existing structure. A considerable amount of debris was observed around the perimeter of existing fill including concrete walls, bicycles, and car parts. Fill placement was not tested and is judged to be unsuitable to support proposed construction and should be removed and reworked to the criteria outlined in Site Grading.

Native Sand and Clay

Native strata encountered was highly variable and lithologic layer thickness was difficult to determine. The soils consisted of silty to clayey sand and sandy to very sandy. Clay was more predominant in the northern portion of the site and contained occasional sand lenses. These sand lenses were more frequent at depth in TH-1. Organics were identified in the upper 10 feet of samples taken from TH-6 and TH-8. Based on the results of field penetration resistance tests, the sand was medium dense to dense and the clay was very stiff. Three clay samples swelled 1.4 to 3.6 percent and one compressed when wetted under approximate post-construction overburden pressure. The average swell of clay samples tested was 2 percent. One clayey sand sample swelled 1.1 percent and contained 25 percent fines (passing the No. 200 sieve). One clay sample contained 61 percent fines and exhibited moderate plasticity with a liquid limit of 44 and plastic index of 28. Three interbedded clay/sand samples contained 23 to 51 percent fines, two of which also contained 1 to 4 percent gravel. Testing indicates the clay and clayey sand is predominantly expansive. We judge the silty sand to be non-expansive or low-swelling.

Bedrock

Bedrock was encountered in all 9 borings at depths of about 2 to 20½ feet (approx. elevations 6257.5 to 6347.5) and consisted of claystone and sandstone. The approximate depth to and elevation of bedrock are presented on Fig. 2. Bedrock was generally encountered at deeper depths near or within the gullies/drainages. The sandstone was very clayey at times and was hard to very hard. A 4-foot cemented zone was encountered in TH-7. The claystone was silty and medium hard to very hard. Seven claystone samples swelled 0.5 to 3.5 percent and one compressed when wetted under approximate post-construction overburden pressure. The average swell of claystone samples was 1.8 percent. Seven sandstone samples contained 6 to 35 percent fines. Testing indicates the claystone is expansive and we judge the sandstone to be non-expansive or low swelling.

Groundwater

Groundwater was not encountered during drilling. When the holes were checked after drilling on April 18, 2022, water was measured in TH-6 at a depth of about 29½ feet below existing grades (approx. elevation 6237½). We do not expect groundwater will affect proposed construction. Groundwater may fluctuate seasonally and rise in response to development, precipitation, and landscape irrigation.

SITE GEOLOGY AND GEOLOGIC HAZARDS

As part of our investigation, we reviewed a map by Thorson, J.P. (Open-File Report OF05-02, Geologic Map of the Castle Rock North Quadrangle, Douglas County, Colorado, 2005). The map indicates most of the site is covered by the Dawson Formation. Sheetwash deposits from the late Pleistocene to Holocene overlay the Dawson bedrock in the northwest corner of the site. Surficial soils are a mixture of clay and sand alluvium.

Geologic hazards and geotechnical concerns at this site include expansive soil and bedrock, some compressible soils, steep slopes, erosion, and the regional geologic hazards of seismicity and naturally occurring radioactive materials. These concerns can be mitigated with proper planning, engineering, design and construction. No geologic hazards or geotechnical concerns that would preclude development were noted. The following sections provide site development recommendations.

Expansive Soils and Bedrock and Compressible Soils

The presence of expansive/compressible soil and expansive bedrock implies risk that ground heave or settlement will damage foundations, slabs-on-grade floors, and pavements. Covering the ground with structures, streets, driveways, patios, etc., coupled with lawn irrigation and changing drainage patterns, leads to an increase in subsurface moisture conditions. Thus, some soil movement due to heave or settlement is inevitable. Expansive and compressible soils and bedrock are present at this site, which constitutes a geologic hazard. There is risk that foundations and slab-on-grade floors will experience heave and subsequent damage. It is critical that precautions are taken to increase the chances that proposed improvements will perform satisfactorily. Engineered planning, design and construction of grading, pavements, foundations, slabs-on-grade, and drainage can mitigate, but not eliminate, the effects of expansive and compressible soils. Sub-excavation is a ground improvement method that can be used to reduce the impacts of swelling soils.

Steep Slopes and Erosion

Existing slopes appear to be stable. Some steeper slopes approaching 1H:1V (horizontal:vertical) were observed along the eastern portion of the site. Slopes will require erosion control during and after construction. The granular soils are considered highly erodible. Soil cut and fill slopes no steeper than 3H:1V (horizontal:vertical) should be stable. Slopes of 4H:1V are preferable. Re-vegetation or other erosion control measures should be employed to control erosion. Slope stability analysis was not part of our scope and is being performed by others.

Water is expected to flow onto the site from the north and east, from the ridge above. During peak precipitation events, some accumulation of surface sheet flow in gullies and drainages is expected. Development will increase the amount of impervious surfaces, which can lead to drainage problems and erosion if surface water flow is not adequately designed. Surface drainage design and evaluation of flood potential should be performed by a Civil Engineer as part of the project design.

Seismicity

The soil and bedrock are not expected to respond unusually to seismic activity. According to the 2015 International Residential Code (IRC, Standard Penetration Resistance method of Section 1613.5.2) and based upon the results of our investigation, we judge the site classifies as Seismic Site Class C or D.

Radioactivity

It is normal in the Front Range of Colorado and nearby eastern plains area to measure radon gas in poorly ventilated spaces (e.g., crawl spaces, if any) in contact with soil or bedrock. Radon 222 gas is considered a health hazard and is just one of several radioactive products in the chain of the natural decay of uranium into lead. Radioactive nuclides are common in the soil and bedrock underlying the subject site. Because these sources exist or will exist on most sites in the area, there is a potential for radon gas accumulation in poorly ventilated spaces. The concentration of radon that can develop is a function of many factors, including the radionuclide activity of the soil and bedrock, construction methods and materials, soil gas pathways, and accumulation areas. The only reliable method to determine if a hazard exists is to perform radon testing of completed residential structures. Typical mitigation methods consist of sealing soil gas entry areas, ventilation of below-grade spaces, and venting from foundation drain systems. We recommend provision for ventilation of foundation drain systems to allow venting if a radon problem is discovered.

Other Considerations

Site grading will include filling of existing gullies and drainages. Subsurface drainage may follow these drainages. We recommend installation of drains below gullies and drainages where more than about 15 feet of fill is planned as discussed in Sub-Fill Drain.

ESTIMATED POTENTIAL HEAVE

Based on the subsurface profiles, swell-consolidation test results and our experience, we calculated the potential heave at the proposed ground surface for each boring, as shown in Table I. The analysis involves dividing the soil profile into layers and modeling the heave of each layer from representative swell tests. We assumed an average swell of 0.5 percent for fill placed during site grading. We estimated potential ground surface heave may range from about 1 to 3 inches. Wetting depths of 24 feet below proposed grades were considered for the analysis. Changes to grading plans will affect our estimates. Variations from our estimates should be anticipated. Our estimates are generally conservative; it is not certain whether the full estimated heave will occur. Sub-excavation can be used to mitigate the potential movements.

TABLE I
ESTIMATED POTENTIAL PROPOSED GROUND SURFACE HEAVE BASED ON 24-FEET DEPTHS OF WETTING

Boring	Estimated Potential Heave at Proposed Ground Surface (inches)
TH-1	1½
TH-2	3
TH-3	2
TH-4	1
TH-5	1
TH-6	2½
TH-7	1½
TH-8	1
TH-9	3

SITE DEVELOPMENT

The following sections provide site development recommendations based on our current understanding of the planned construction.

Existing, Undocumented Fill

During our investigation we encountered existing, undocumented fill in TH-8. The fill consisted of slightly clayey sand and a considerable amount of debris was observed in the vicinity of the fill. Based on review of historical aerial imagery we believe this fill is related to the construction and/or demolition of an existing structure that was torn down sometime between 2011 and 2015. Building debris may be encountered in this area and can potentially contain asbestos. We judge the fill to be unsuitable to support new improvements. It should be removed and replaced as moisture-conditioned, compacted fill as discussed in Site Grading. The fill can be reused, provided it is free of deleterious material.

Excavation

We believe the soils penetrated by the exploratory borings can generally be excavated with typical heavy-duty equipment. Very hard bedrock was encountered in our borings, and a layer of cemented sandstone was encountered at a shallow depth in TH-7. There may be areas with very hard or cemented bedrock that may require use of rock excavation techniques such as heavy ripping, rock saws, or possibly blasting.

Contractors should be familiar with applicable local, state and federal safety regulations, including the current Occupational Safety and Health Administration (OSHA) Excavation and Trench Safety Standards. Based on our investigation and OSHA standards, we anticipate the clay and bedrock will classify as Type B soil and the sand as Type C. Type B and C soils require maximum slope inclinations of 1:1 and 1½:1 (horizontal:vertical), respectively, for temporary excavations in dry conditions. Excavation side slopes specified by OSHA are dependent upon soil types and groundwater or seepage conditions encountered. The contractor’s “competent person” is required to identify the soils encountered in excavations and refer to OSHA standards to determine appropriate slopes. Stockpiles of soils and equipment should not be placed within a horizontal distance equal to one-half the excavation depth, from the edge of the excavation. A professional engineer should design excavations deeper than 20 feet. Excavations should not compromise stability of adjacent improvements.

Site Grading

Prior to fill placement, the ground surface in areas to be filled should be stripped of debris, vegetation/organics and other deleterious materials, scarified and moisture conditioned to between 1 and 4 percent above optimum moisture content for clay or within 2 percent of optimum for sand and gravel, and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698). Fill should be moisture conditioned and compacted in accordance with criteria shown in Table II. Based on the Town of Castle Rock specifications, utility trench backfill should be moistened between optimum and 4 percent wetter and compacted to at least 95 percent of standard Proctor maximum dry density for clay and moistened within 2 percent of optimum and compacted to 100 percent of standard Proctor for sand.

TABLE II
SUMMARY OF COMPACTION AND MOISTURE CONTENT SPECIFICATIONS

Soil Type	Depth of Site Grading Fill		Utility Trench Backfill
	≤20 Feet	>20 Feet	
Clay (CL, CH)	95% STD, 1 to 4 percent above optimum	98% STD, 2 percent below to 1 percent above optimum	95% STD, 0 to 4 percent above optimum
Granular Soils (Sand and Gravel)	95% STD, -2 to +2 percent from optimum	98% STD, 2 percent below to 1 percent above optimum	100% STD, within 2 percent of optimum

*Compaction and moisture content percentage specifications based on standard Proctor maximum dry density (STD, ASTM D 698) and optimum moisture content (optimum).

The properties of fill will affect the performance of foundations, slabs-on-grade, utilities, pavements, flatwork and other improvements. The on-site soils are suitable for use as new fill provided they are substantially free of debris, vegetation/organics and other deleterious materials. If import fill is necessary to achieve site grades, it should ideally consist of soil having a maximum particle size of 2 inches, between 25 and 50 percent passing the No. 200 sieve, a liquid limit less than 30, and a plasticity index less than 15. Potential fill should be submitted to our office for approval prior to importing to the site. Fill should be placed in thin loose lifts, moisture conditioned and compacted prior to placement of the next lift. The placement and compaction of fill should be observed and tested by a representative of our firm during construction. Guideline site grading specifications are presented in Appendix C.

Our experience indicates fill will settle under its own weight. We estimate potential settlement of about 1 to 2 percent of the fill thickness even if the fill is compacted to the specified criteria. Most of this settlement usually occurs during and soon after construction; for clayey fill, it may continue for longer. Heave or additional settlement may occur after development in response to wetting. If fill will be placed on slopes of 20 percent or steeper the slopes should be benched prior to placing fill (Fig. 4).

There are some areas where proposed grading will create non-uniform depths of fill below residence sites. Where the depth varies more than about 5 feet, sub-excavation or benching of existing slopes should be considered to create more uniform fill depth. <u>We recommend additional review of these conditions as grading and sub-excavation plans are formalized.</u>

<u>Sub-Excavation</u>

Our investigation indicates highly variable subsurface conditions are present across the site, and expansive soil and bedrock are present at depths likely to influence the performance of shallow foundations and slabs-on-grade for most of the site. Sub-excavation may be used to create more stable soil conditions and control risk of excessive movements. The variability of soil and bedrock materials implies that depth of sub-excavation could be variable, and that sub-excavation may not be merited for some of the site. You could elect to excavate all building areas to about 10 feet below lowest foundations for basements and 13 feet for no basements or use a variable depth approach as shown on Fig 3. Our estimates are conservative for the eastern portion of the site that we were unable to access with a drill rig. Further investigation, after the completion of site grading, can be performed to furth evaluate the merits of sub-excavation in areas where existing terrain restricted subsurface exploration.

The bottom of sub-excavation areas should extend laterally at least 5 feet outside the largest possible foundation footprint to ensure foundations are constructed over moisture-conditioned fill. The sub-excavation areas should be staked by a surveyor, and we recommend periodic surveying verification of the "as-built" bottom of the excavations. Conceptual sub-excavation profiles are shown on Figs. 5 and 6.

The excavation contractor(s) should be chosen carefully to assure they have experience with fill placement at over-optimum moisture and have the necessary compaction equipment. The contractors should provide a construction disc to break down fill materials and anticipate use of push-pull scraper operations and dozer assistance. The operation will be relatively slow. For the procedure to be performed properly, strict contractor control of fill placement to specifications is required. Sub-excavation fill should be moisture-conditioned between 1 and 4 percent above optimum moisture content with an average test moisture content each day of at least 1.5 percent above optimum.

Special precautions should be taken for compaction of fill at corners, access ramps and along the perimeters of sub-excavated areas due to equipment access constraints. The contractors should have appropriate equipment to reach and compact these areas. Our representative should observe placement procedures and test compaction of the fill. The fill should be tested after placement to evaluate swell. Guideline sub-excavation grading specifications are presented in Appendix D. We recommend a surveyor document the actual limits of treatment and create "as-built" plans to verify that the buildings are over the treated areas.

If the fill dries excessively prior to construction, it may be necessary to re-work the upper, drier materials just prior to constructing foundations. We judge the fill should retain adequate moisture for about two to three years.

Slopes

We recommend permanent cut and fill slopes be designed with a maximum slope of 3:1 (horizontal to vertical); use of 4:1 would be better to control erosion. If site constraints (property boundaries and streets) do not permit construction with recommended slopes, we should be contacted to evaluate the subsurface soils and steeper slopes. Slope stability analysis is not part of our scope. We understand it is being performed by others. Concentrated surface drainage should not be allowed to sheet flow across slopes or pond near the crest of slopes. All slopes should be re-vegetated soon after grading to reduce erosion.

Utilities

Water and sewer lines are usually constructed beneath paved roads. Compaction of trench backfill can have a significant effect on the life and serviceability of pavements. Trench backfill should be placed in thin (8 inches or less) loose lifts and moisture conditioned and compacted to the specifications provided in Site Grading.

For utility installation, we recommend use of a self-propelled compactor. Special attention should be paid to backfill placed adjacent to manholes as we have seen instances where settlement in excess of 2 percent has occurred. Any improvements placed over backfill should be designed to accommodate movement. The placement and compaction of utility trench backfill should be observed and tested by a qualified representative during construction.

Subsurface Drainage

With long term development and subsequent irrigation, groundwater may develop and rise. Our firm typically advocates an underdrain system below sanitary sewer mains and services to control groundwater that may accumulate in response to development and provide a gravity outlet for foundation drains. If a gravity outfall for the underdrain system is not possible, an alternative would be to outfall underdrains to a wet well where water can be removed with a pump; maintenance should be expected with this option. It may not be practical to install underdrains at this site if a gravity discharge is not available. If an underdrain system is not installed, individual house foundation drains would discharge into sumps with pumps. Sump discharge can result in ponding and recycling if slopes between lots are not adequately graded and well-drained. Problems with chronic ice or algae formation on sidewalks have also developed from sump discharge.

The underdrain should consist of ¾ to 1½-inch clean, free-draining gravel surrounding rigid PVC pipe (Fig. 8). The pipe should be sized for anticipated flow by the civil engineer and may consist of 4 or 6-inch lines. The PVC pipe should be placed at a grade of at least 0.5 percent. A concrete cutoff should be constructed around the sewer pipe and underdrain pipe immediately downstream of the point where the underdrain pipe exits the sewer trench and transitions to the outlet (Fig. 9). The underdrains should be designed to discharge to a gravity outfall and be provided with a permanent concrete headwall and trash rack. If the underdrain discharges into a detention pond, the risk of flood water backflow through the underdrain into basements should be evaluated. A check valve or backflow preventer can be considered. Where feasible, the underdrain services should be installed deep enough so that the lowest point of the basement foundation drain can be connected to the underdrain service as a gravity outlet (Fig. 10). Underdrain services can be 3-inch to avoid confusion with the 4 or 6-inch main line.

Sub-Fill Drain

A sub-fill drain is recommended along the bottom of the existing drainages where more than about 15 feet of site grading fill is planned. The drain should slope with the grade of the existing drainages and have a minimum slope of 0.5 percent. A typical sub-fill drain detail is provided as Fig. 7. A perforated pipe should be connected to the end of the drain and protected with a concrete headwall. The alignment and profile of the sub-fill drain should be shown in the development plans. We recommend re-routing the drainages to avoid installation of sub-fill drains below proposed building/structure footprints.

Pavements

Pavement subgrade soils are variable and may consist of clay, sand, bedrock, or fill of similar composition. The Town of Castle Rock's minimum pavement section alternatives are presented in Table III. Where expansive subgrade is encountered, Castle Rock only allows full depth pavement sections (rigid or flexible) over chemically treated subgrade and not over mechanically stabilized expansive subgrade. Certain very sandy subgrade conditions may require applying a non-structural covering of aggregate base course for constructability to support the paving equipment. The Town may increase the minimum pavement section at any location if conditions warrant. Additionally, sub-excavation (2 to 6 feet) may also be merited. Subgrade investigation and pavement designs should be performed after grading is complete.

TABLE III
CASTLE ROCK MINIMUM PAVEMENT SECTIONS

Traffic Classification	Hot Mix Asphalt (HMA) + Chemically Treated Subgrade (CTS)	Hot Mix Asphalt (HMA) + Aggregate Base (ABC)	Portland Cement Concrete (PCC)
Local Residential	4” HMA + 6” CTS	4” HMA + 6” ABC	6” PCC
Minor Collector	4” HMA + 6” CTS	4” HMA + 6” ABC	6” PCC
Commercial	4” HMA + 12” CTS	4” HMA + 8” ABC	6” PCC

BUILDING CONSTRUCTION CONSIDERATIONS

The following discussions are preliminary and are not intended for design or construction. After grading is completed, design-level investigations should be performed on a structure-specific basis.

Foundations

Footing foundations may be used for sites where low swelling soil and bedrock are present within depths likely to influence performance of foundations. Where moderate to high swelling clay and claystone are present, drilled piers or other deep foundation systems would be best to control risk of heave. Long (25 to 40 feet) drilled piers should be anticipated unless sub-excavation is performed. Sub-excavation should allow footing foundations and slab-on-grade basement floors on most or all treated sites.

Slab-On-Grade Construction

Slab-on-grade basement floors may be considered on low and some moderate risk sites where potential heave is acceptable to builders and home buyers. Structurally supported basement floors should be used on all sites with high or very high risk of poor basement slab performance. We judge risk is moderate or high for most of this site. Sub-excavation should result in low or possibly moderate risk conditions. A structurally supported basement floor should also be used where a buyer cannot tolerate potential movement. Structurally supported floor systems should be anticipated in all non-basement residences and finished living areas. Post-tensioned slab-on-grade foundations may also be considered where no basements are planned.

The risk of poor performance of garage floors, driveways, sidewalks and other surface flatwork will likely be moderate for a portion of this site, unless sub-excavation is performed. The following precautions will be required to reduce the potential for damage due to movement of slabs-on-grade placed at this site:

1. Isolation of the slabs from foundation walls, columns and other slab penetrations;
2. Voiding of interior partition walls to allow slab movement without transferring the movement to the structure;
3. Proper surface grading and foundation drain installation to reduce water availability to sub-slab and foundation soils; and

Below-Grade Areas

Surface water can penetrate relatively permeable loose backfill soils located adjacent to structures and collect at the bottom of relatively impermeable basement or crawl space excavations, causing wet or moist conditions. Foundation walls which retain earth should be designed for lateral earth pressures.

Foundation drains should be constructed around the lowest excavation levels and ideally should be connected to an underdrain system to provide a gravity outlet. The drains can be connected to a sump pit where water can be removed by pumping if an underdrain is not provided.

Surface Drainage

The performance of improvements will be influenced by surface drainage. When developing an overall drainage scheme, consideration should be given to drainage around each unit/residence and building. The ground surface around the residences and mixed-use buildings should be sloped to provide positive drainage away from the foundations. We recommend a slope of at least 10 percent for the first 10 feet surrounding each building with basements, where practical. For non-basement developments, we recommend a slope of at least 5 percent for the first 10 feet surrounding each building. If the distance between buildings is less than 20 feet, the recommended slope in this area should be installed to the swale between buildings. Where possible, drainage swales should slope at least 2 percent. Variations from these criteria are acceptable in some areas. For example, for lots graded to direct drainage from the rear yard to the front, it is difficult to achieve the recommended slope at the high point behind a house. We believe it is acceptable to use a slope of about 6 inches in the first 10 feet (5 percent) in this instance and others when achieving 10 percent is not practical. Roof downspouts and other water collection systems should discharge beyond the limits of all backfill around structures.

Proper control of surface runoff is also important to control the erosion of surface soils. Concentrated sheet flow should not be directed over unprotected slopes. Water should not be allowed to pond at the crest of slopes. Permanent slopes should be prepared to reduce erosion.

Attention should be paid to compaction of the soils behind curbs and gutters adjacent to streets and in utility trenches during the construction and development. If surface drainage between preliminary development and construction phases is neglected, performance of the roadways, flatwork and foundations may be poor.

Concrete

Concrete in contact with soil can be subject to sulfate attack. We measured water-soluble sulfate concentrations of 0.02 and 0.1 percent in two samples from this site. These tests indicate negligible sulfate concentrations (S0) and moderate sulfate concentrations (S1) are present at this site. Sulfate resistant concrete is not required in areas of negligible concentrations (S0). For moderate sulfate concentration (S1), ACI 332-20 *Code Requirements for Residential Concrete* indicates concrete shall be made with ASTM C150 Type II cement, or an ASTM C595 or C1157 hydraulic cement meeting moderate sulfate-resistant hydraulic cement (MS) designation. Additional testing should be performed during design-level investigations.

Superficial damage may occur to the above-grade exposed surfaces of concrete walls and grade beams in contact with soils. To control this risk and to resist freeze-thaw deterioration, the water-to-cementitious materials ratio should not exceed 0.50 for concrete in contact with soils that are likely to stay moist due to surface drainage or shallow groundwater. Concrete should have a total air content of 6 percent ± 1.5 percent. We recommend all foundation walls and grade beams in contact with the subsoils (including the inside and outside faces of garage and crawl space grade beams) be damp-proofed.

RECOMMENDED FUTURE INVESTIGATIONS

We recommend the following investigations and services:

1. Additional investigation to evaluate the extent and depth of variable sub-excavation (if selected).

2. Review of grading and sub-excavation plans to evaluate merits of benching under sites where variable fill depth will occur.

3. Construction testing and observation during site development, and building and pavement construction; including compaction testing of grading fill, utility trench backfill, and pavements;

4. Subgrade investigation and pavement design after grading;

5. Design-level Soils and Foundation Investigations after grading; and

6. Foundation installation observations.

CONSTRUCTION OBSERVATIONS

This report has been prepared for the exclusive use of 455 Alexander, LLC and your team to provide geotechnical information for development planning of the subject site. The information, conclusions, and recommendations presented herein are based upon consideration of many factors including, but not limited to, the type of structures proposed, the geologic setting, and the subsurface conditions encountered. The conclusions and recommendations contained in the report are not valid for use by others.

We recommend that CTL | Thompson, Inc. provide construction observation services to allow us the opportunity to verify whether soil conditions are consistent with those found during this investigation. If others perform these observations, they must accept responsibility to judge whether the recommendations in this report remain appropriate.

GEOTECHNICAL RISK

The concept of risk is an important aspect with any geotechnical evaluation, primarily because the methods used to develop geotechnical recommendations do not comprise an exact science. We never have complete knowledge of subsurface conditions. Our analysis must be tempered with engineering judgment and experience. Therefore, the recommendations presented in any geotechnical evaluation should not be considered risk-free. Our recommendations represent our judgment of those measures that are necessary to increase the chances that the development improvements will perform satisfactorily. It is critical that all recommendations in this and future reports are followed.

LIMITATIONS

Exploratory borings were widely spaced to provide a general picture of subsurface conditions for due diligence assessment and preliminary planning of development and construction. Variations from conditions indicated by the borings should be anticipated. Standards of practice evolve in the area of geotechnical engineering. The recommendations provided are appropriate for about three years. If the development is not constructed within about three years, we should be contacted to determine if we should update this report. We believe this investigation was conducted in a manner consistent with the level of care and skill ordinarily used by geotechnical engineers practicing under similar conditions. No warranty, express or implied, is made.

If we can be of further service in discussing either the contents of this report or the analysis of the influence of subsurface conditions on the project, please call.

CTL | THOMPSON, INC.

Robert J. Brown,
Staff Geologist

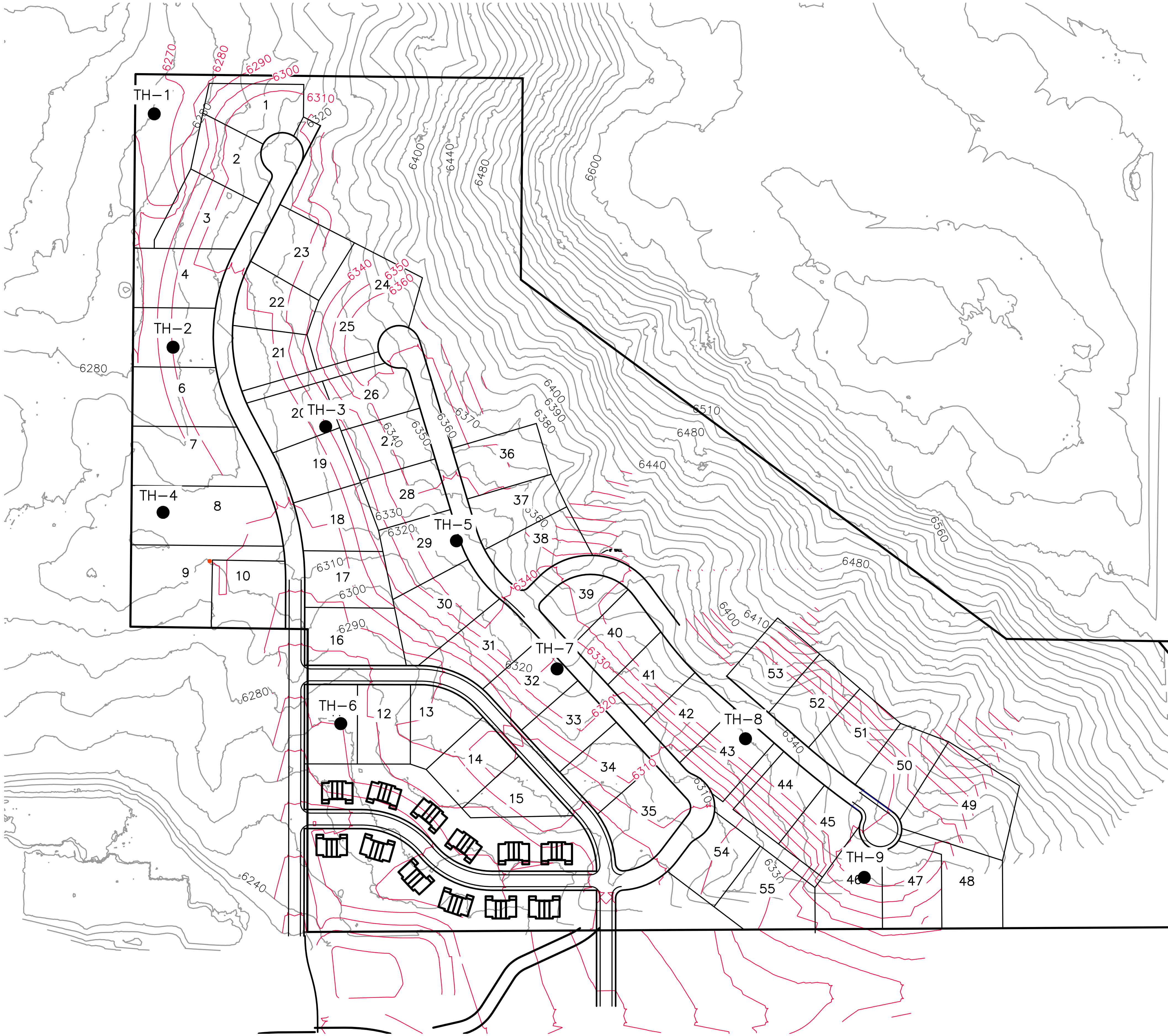
Reviewed by:

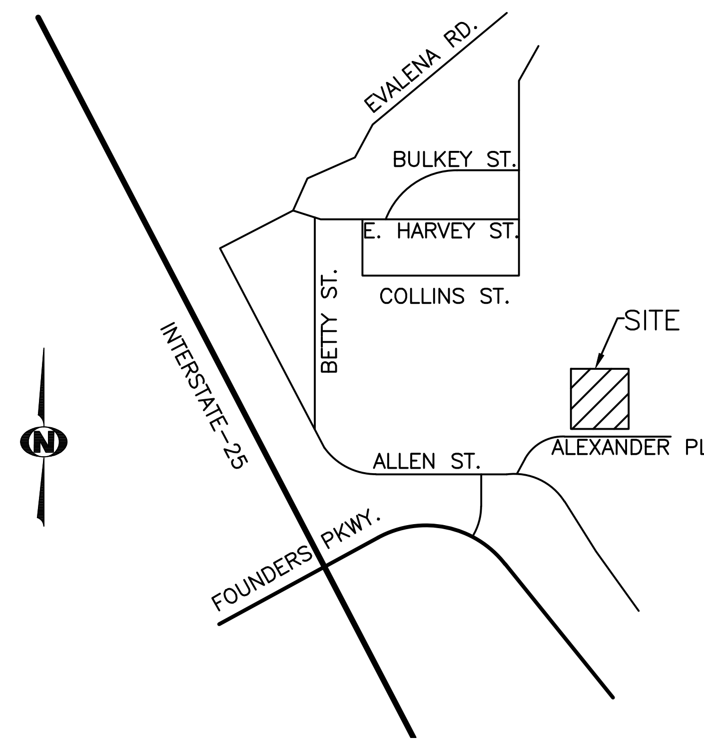
COLORADO LICENSED
ERIN CHRISTINE BEACH
54368
PROFESSIONAL ENGINEER

Erin C. Beach, P.E., P.G.
Project Geotechnical Manager

Erin Beach
May 23 2022 10:03 AM

Via e-mail: rick.a.rome@imegcorp.com
lmhaffeman@msn.com





VICINITY MAP
NOT TO SCALE

LEGEND:

TH–1 ●	APPROXIMATE LOCATION OF EXPLORATORY BORING
- - - - -	EXISTING GROUND SURFACE ELEVATION (FEET)
——	PROPOSED GROUND SURFACE ELEVATION (FEET)

0 125 250
SCALE: 1" = 250'

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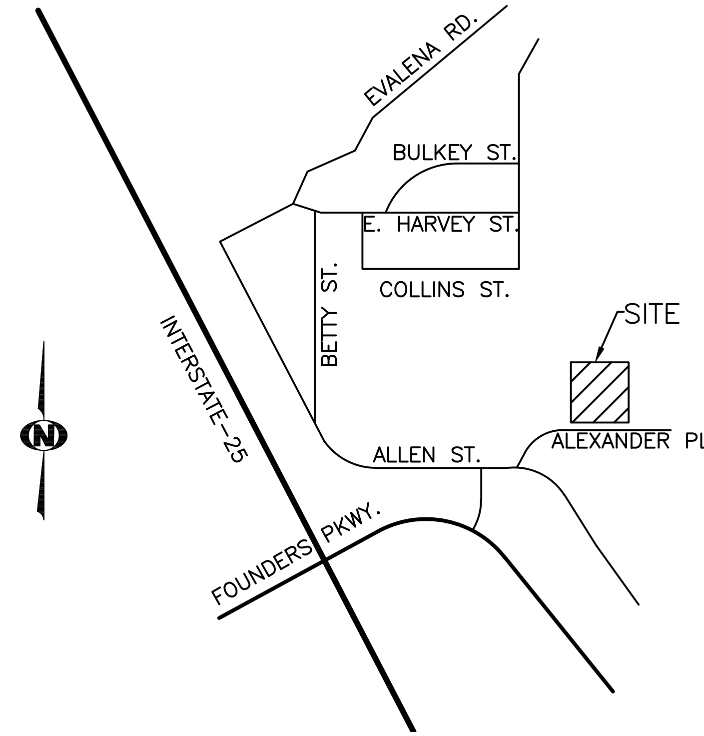
Locations of Exploratory Borings

Fig. 1A



VICINITY MAP
NOT TO SCALE

LEGEND:

TH–1 ● APPROXIMATE LOCATION OF EXPLORATORY BORING

EXISTING GROUND SURFACE ELEVATION (FEET)

PROPOSED GROUND SURFACE ELEVATION (FEET)

0 125 250
SCALE: 1" = 250'

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Locations of Exploratory Borings

Fig. 1B

LEGEND:

TH-1 ●	APPROXIMATE LOCATION OF EXPLORATORY BORING
(20.5)	INDICATES ESTIMATED DEPTH TO BEDROCK (FEET)
[6252.5]	INDICATES APPROXIMATE BEDROCK ELEVATION (FEET)
NOTE:	THIS ESTIMATE WAS BASED UPON A SUBJECTIVE ANALYSIS OF DRILL HOLE DATA AND MAY NOT REFLECT LOCAL VARIATIONS.

0 125 250
SCALE: 1" = 250'

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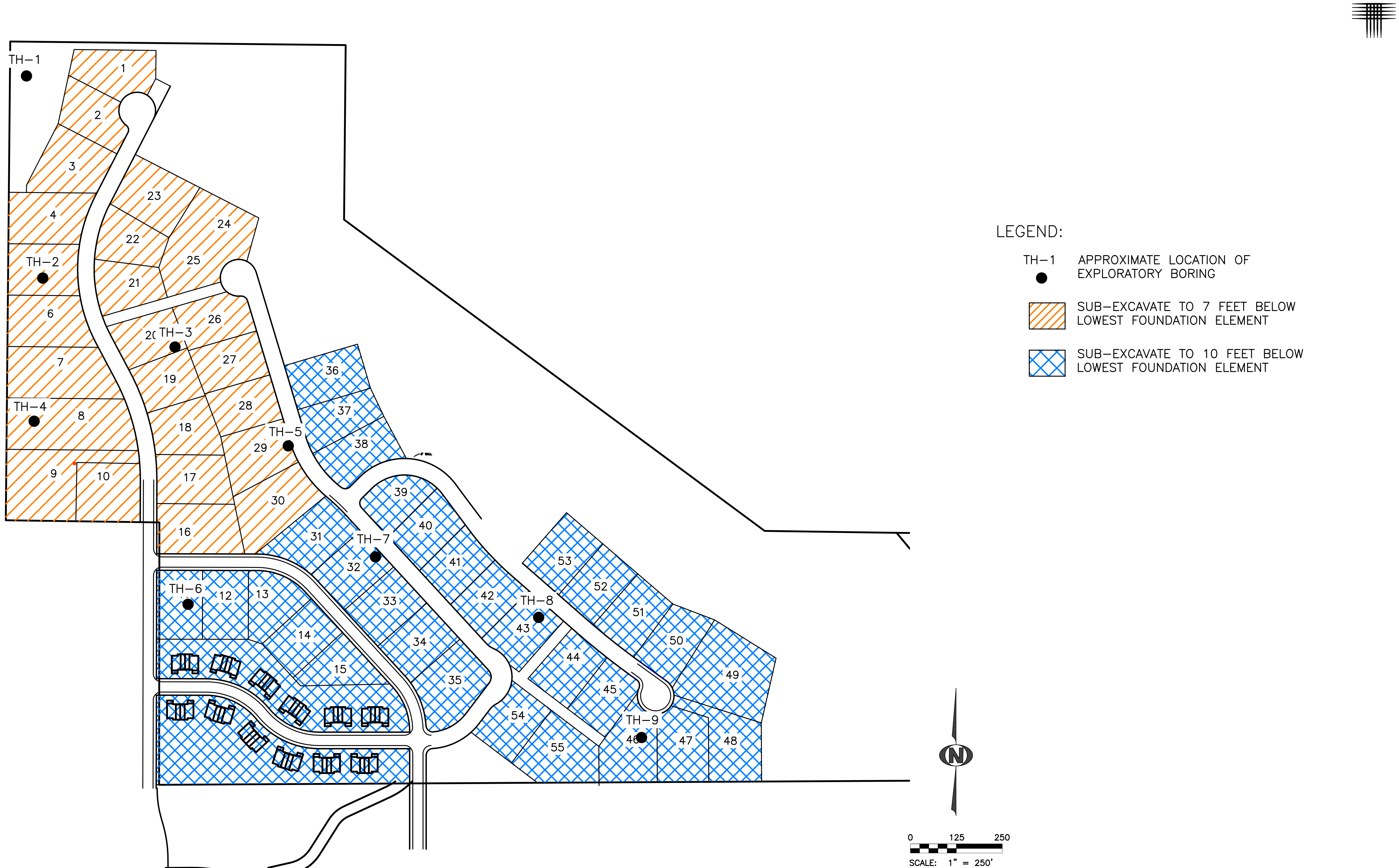
Depth and Elevation of Bedrock

Fig. 2



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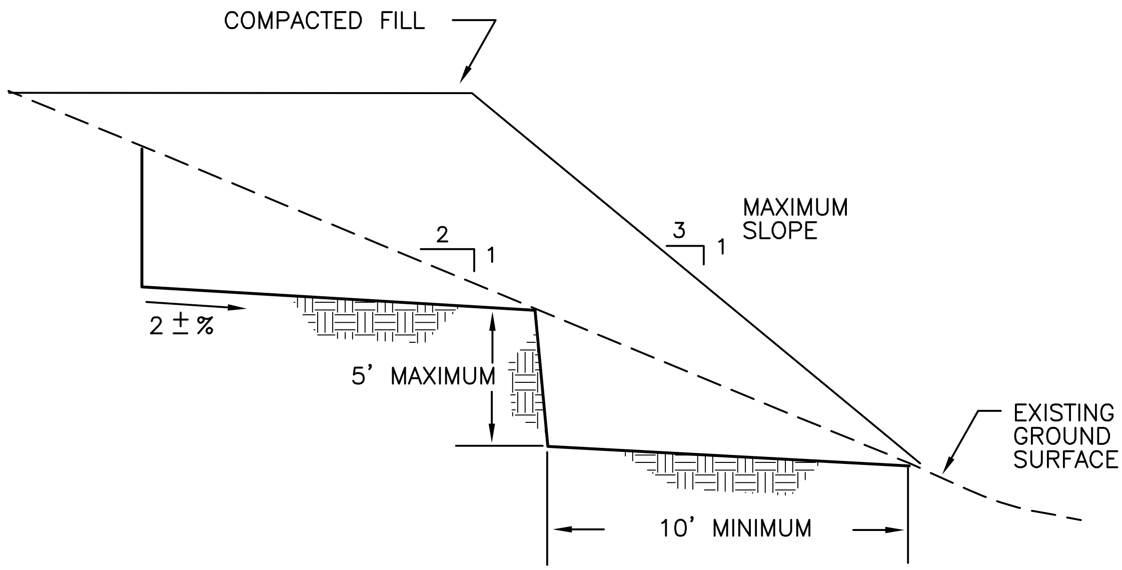
Sub-Excavation Consideration Fig. 3



NOTES:

1) NATURAL SLOPES OF 20 PERCENT OR STEEPER ARE TO BE BENCHED PRIOR TO FILL PLACEMENT.

2) SLOPE BENCHES TO OUTSLOPE AT 2± PERCENT.

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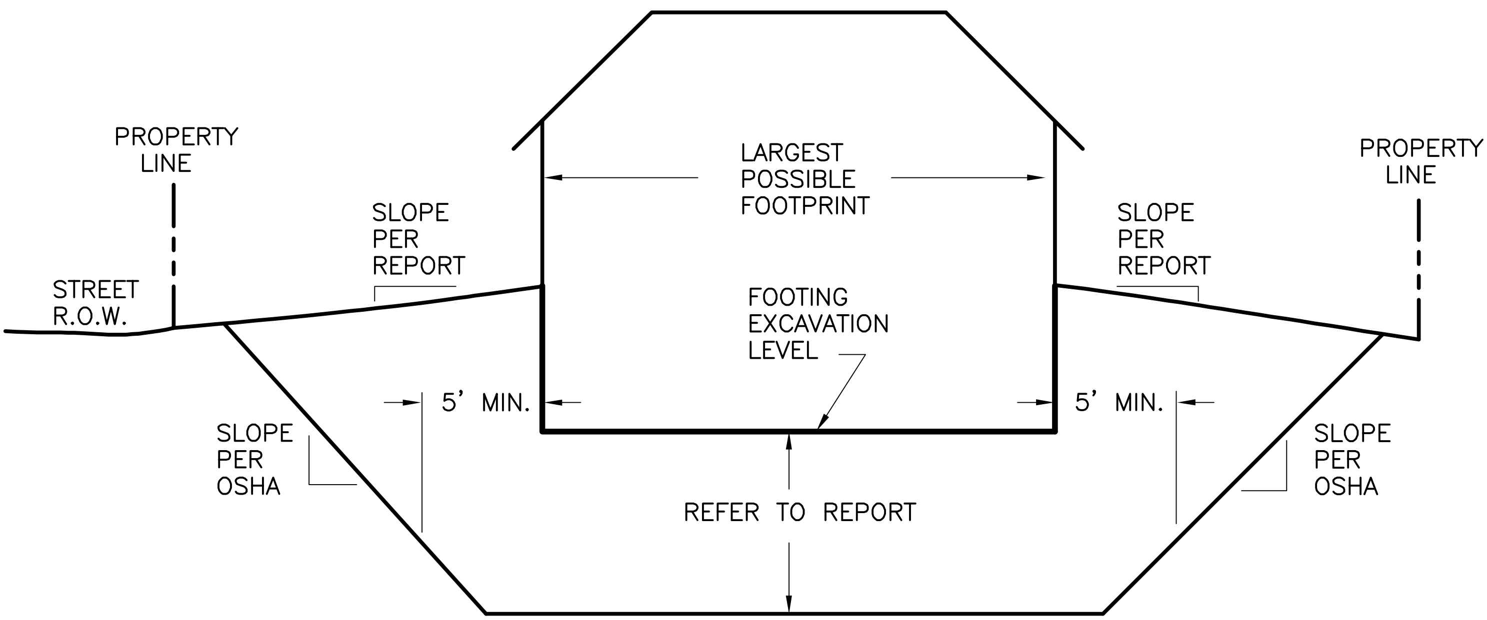
Benched Fill Detail

Fig. 4



NOT TO SCALE

95-SUB-EXC_01

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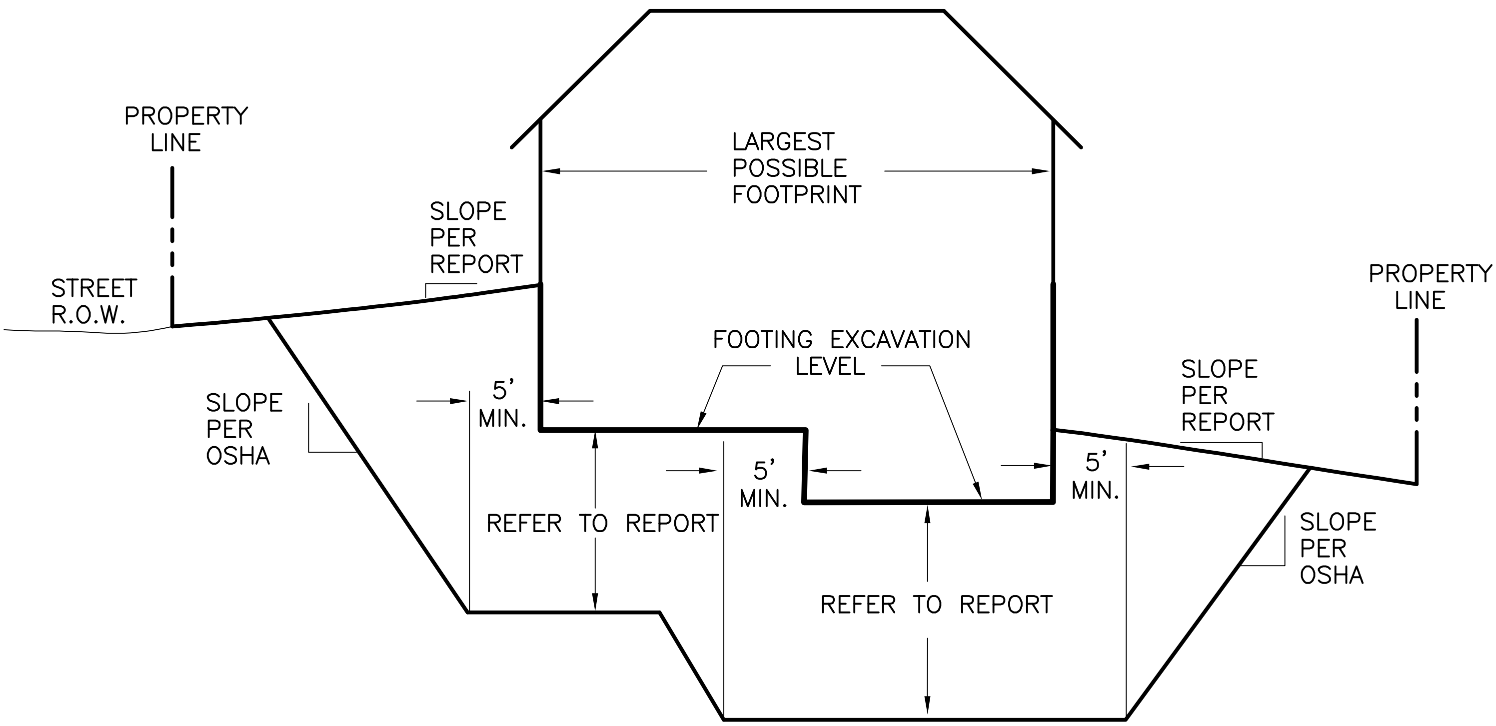
Conceptual Sub-excavation Profile

Fig. 5

95-SUB-EXCAVATION_03



NOT TO SCALE

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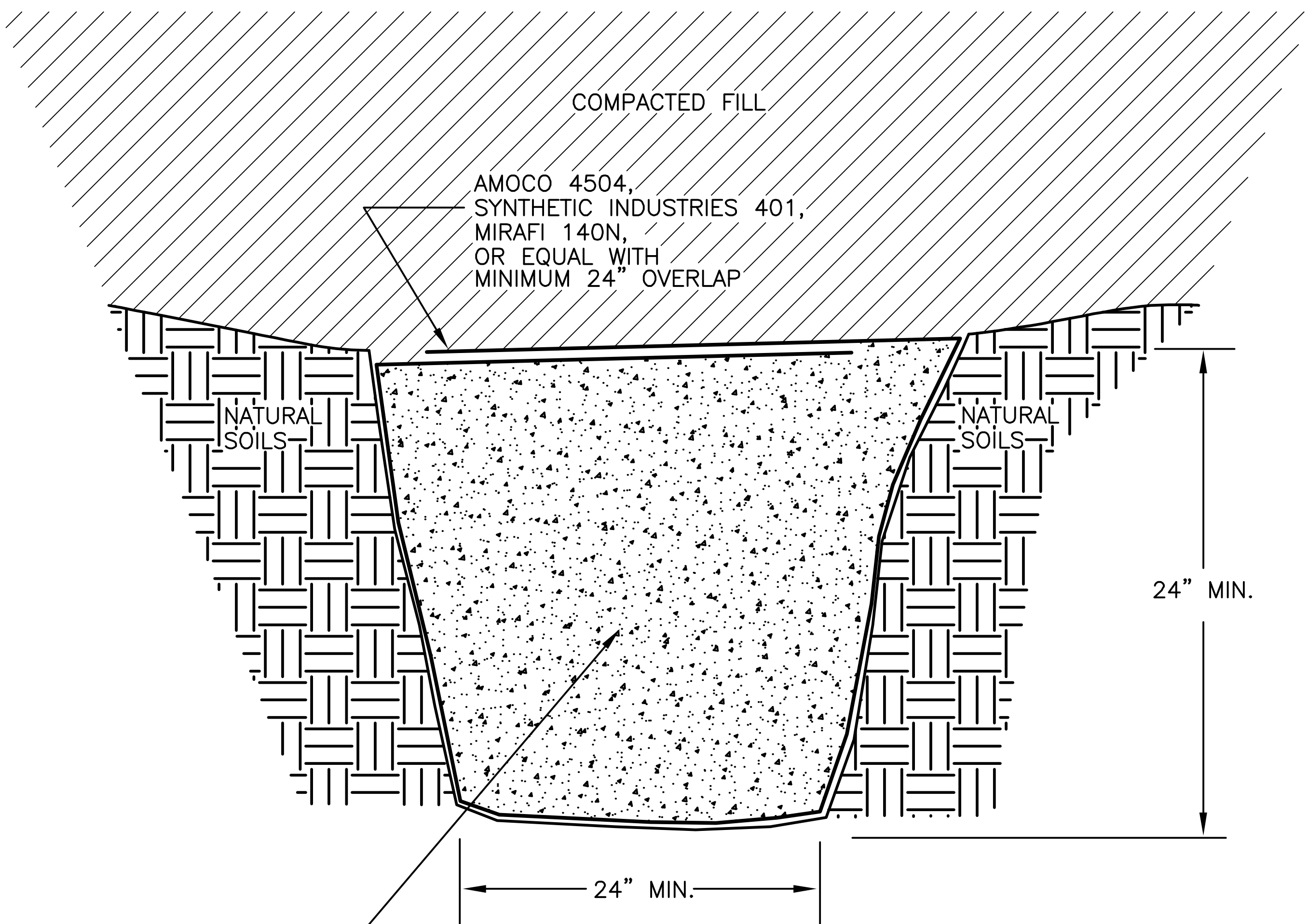
Conceptual Sub-excavation Profile

(Walk-out Basement) Fig. 6



GRAVEL AND SAND
GRADED AS FOLLOWS

SIEVE SIZE	% PASSING
1 1/2"	100
3/4"	82–100
3/8"	64–80
#4	46–64
#8	34–52
#16	25–42
#30	12–30
#50	5–15
#100	1–3
#200	0–1

NOTE:
THE SAND AND GRAVEL GRADATION CAN BE MET BY MIXING COURSE CONCRETE AGGREGATE NO. 57 AND FINE CONCRETE AGGREGATE NO. 67 IN EQUAL PARTS BY WEIGHT.

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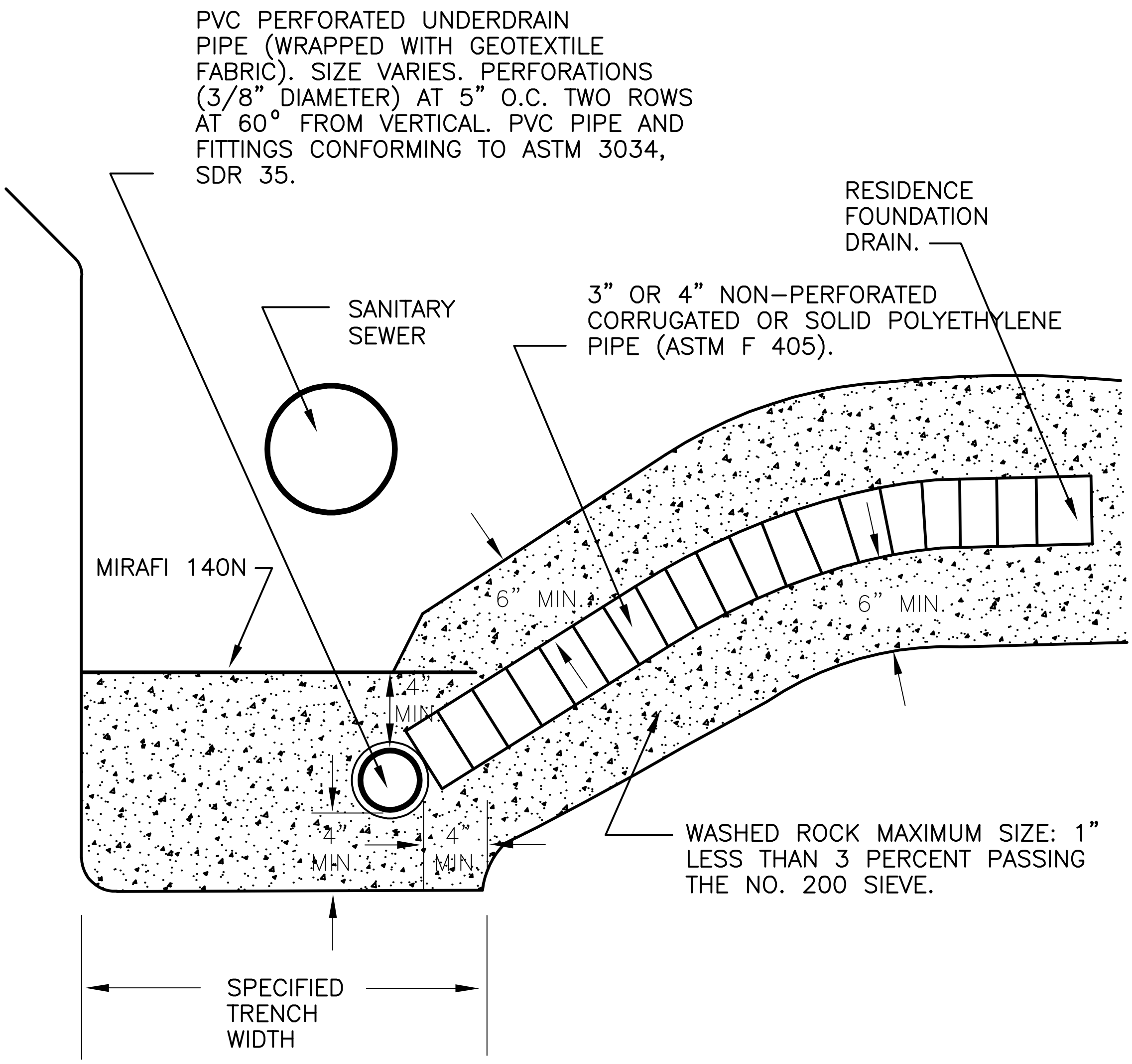
Drainage Sub-Drain

Fig. 7

50-UNDERDRAIN_02



NOTE: NOT TO SCALE.

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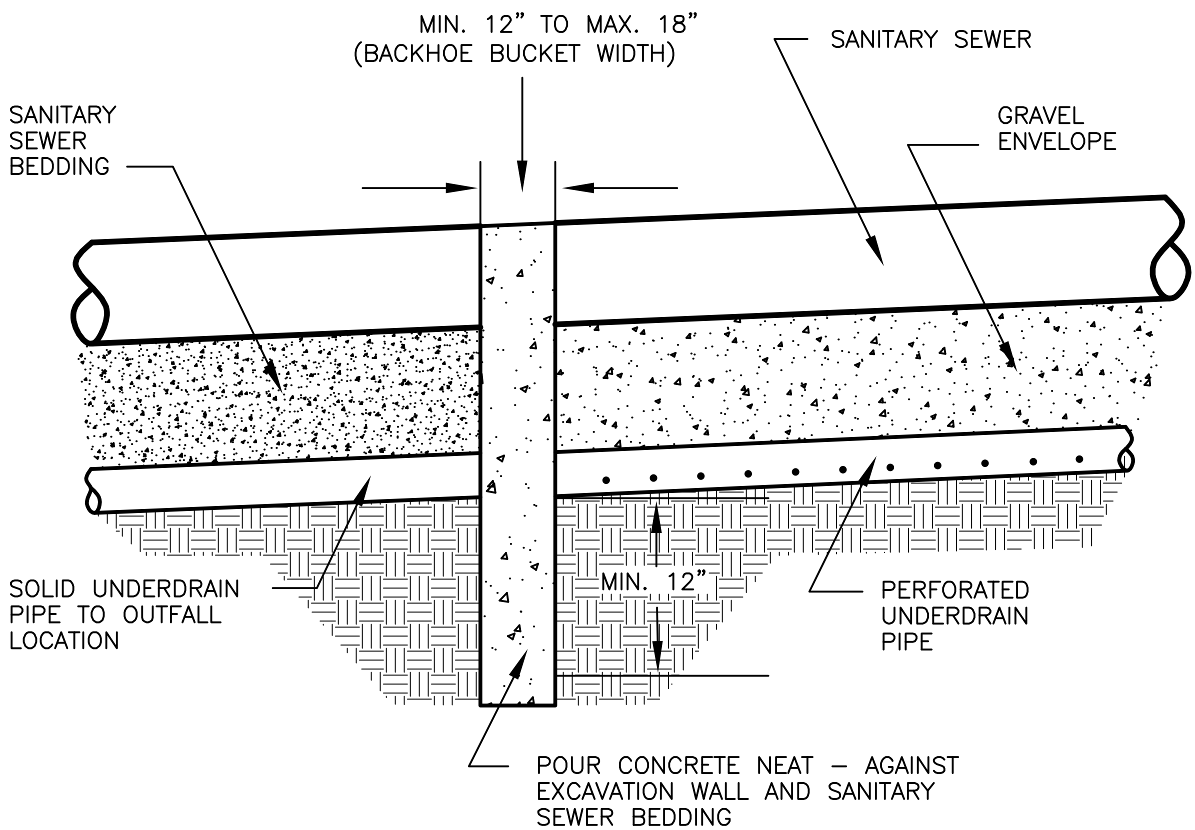
Sewer Underdrain Detail

Fig. 8

50-UNDERDRAIN_05



NOTE:
THE CONCRETE CUTOFF WALL SHOULD EXTEND INTO THE UNDISTURBED SOILS OUTSIDE THE UNDERDRAIN AND SANITARY SEWER TRENCH A MINIMUM DISTANCE OF 12 INCHES.

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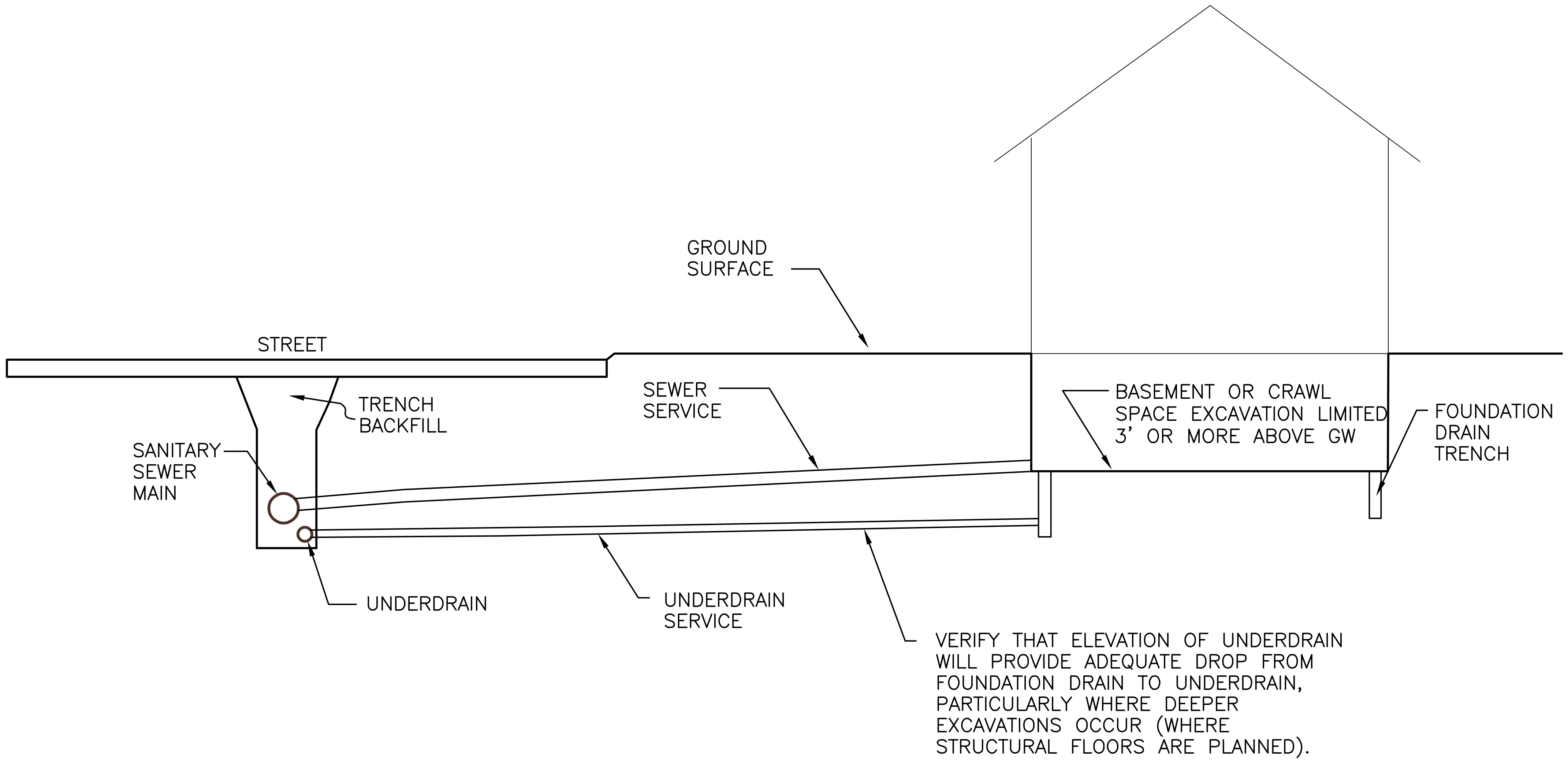
Underdrain Cutoff Wall Detail

Fig. 9



NOT TO SCALE

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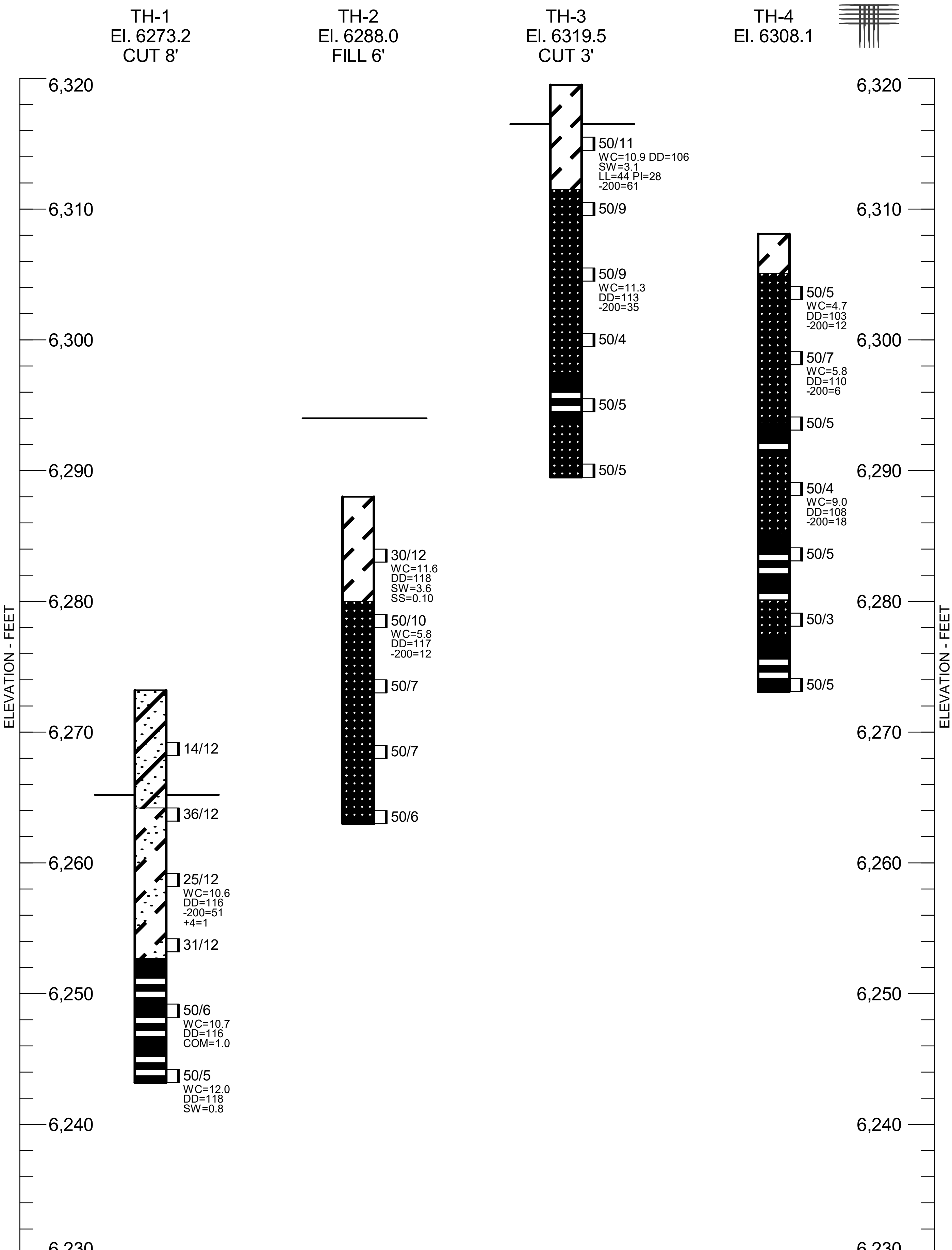
Conceptual Underdrain Profile Fig. 10

APPENDIX A

SUMMARY LOGS OF EXPLORATORY BORINGS



SUMMARY LOGS OF EXPLORATORY BORINGS

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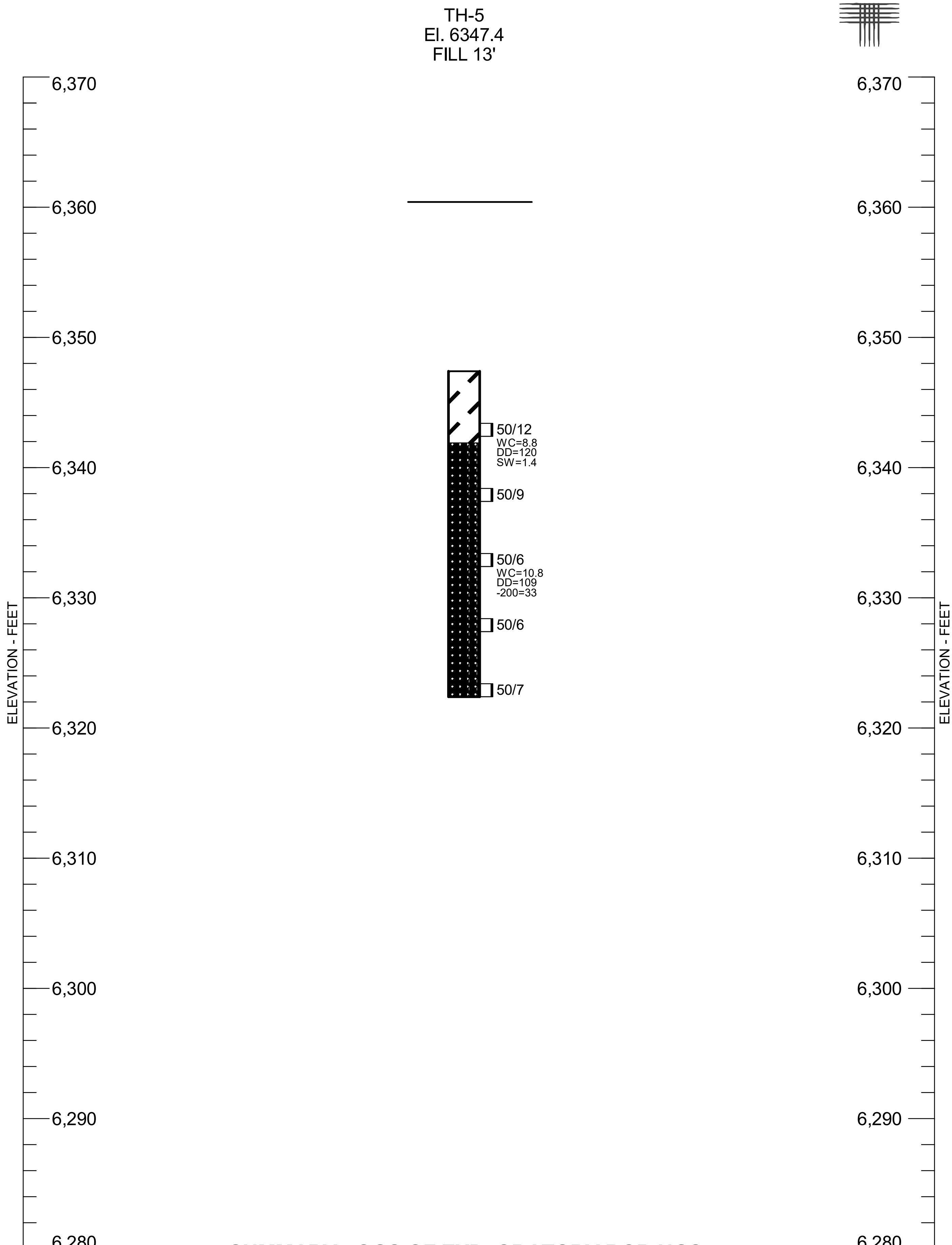
CTL|T PROJECT NO. DN51,491-115-R1

FIG. A- 1



SUMMARY LOGS OF EXPLORATORY BORINGS

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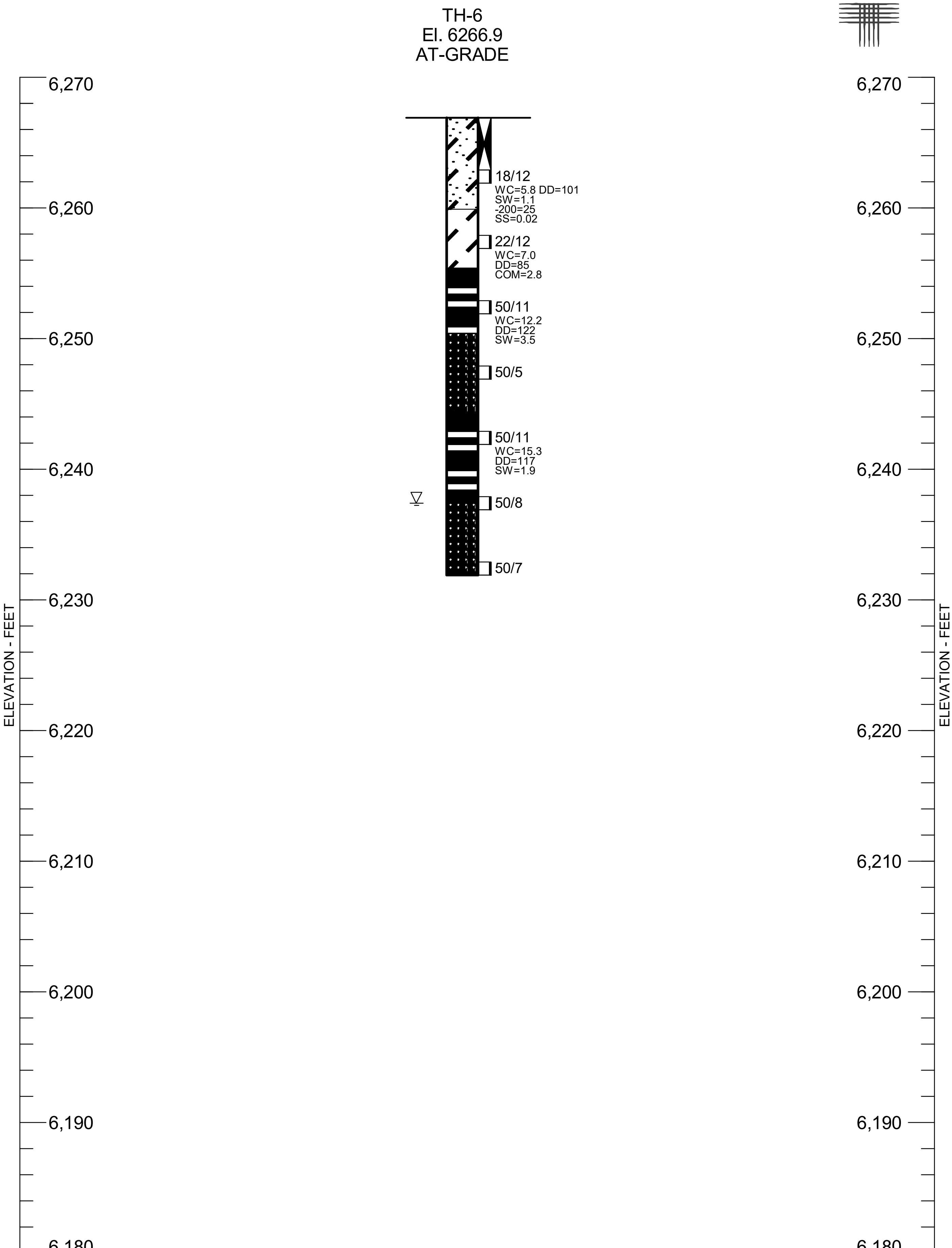
FIG. A- 2



SUMMARY LOGS OF EXPLORATORY BORINGS

455 ALEXANDER, LLC
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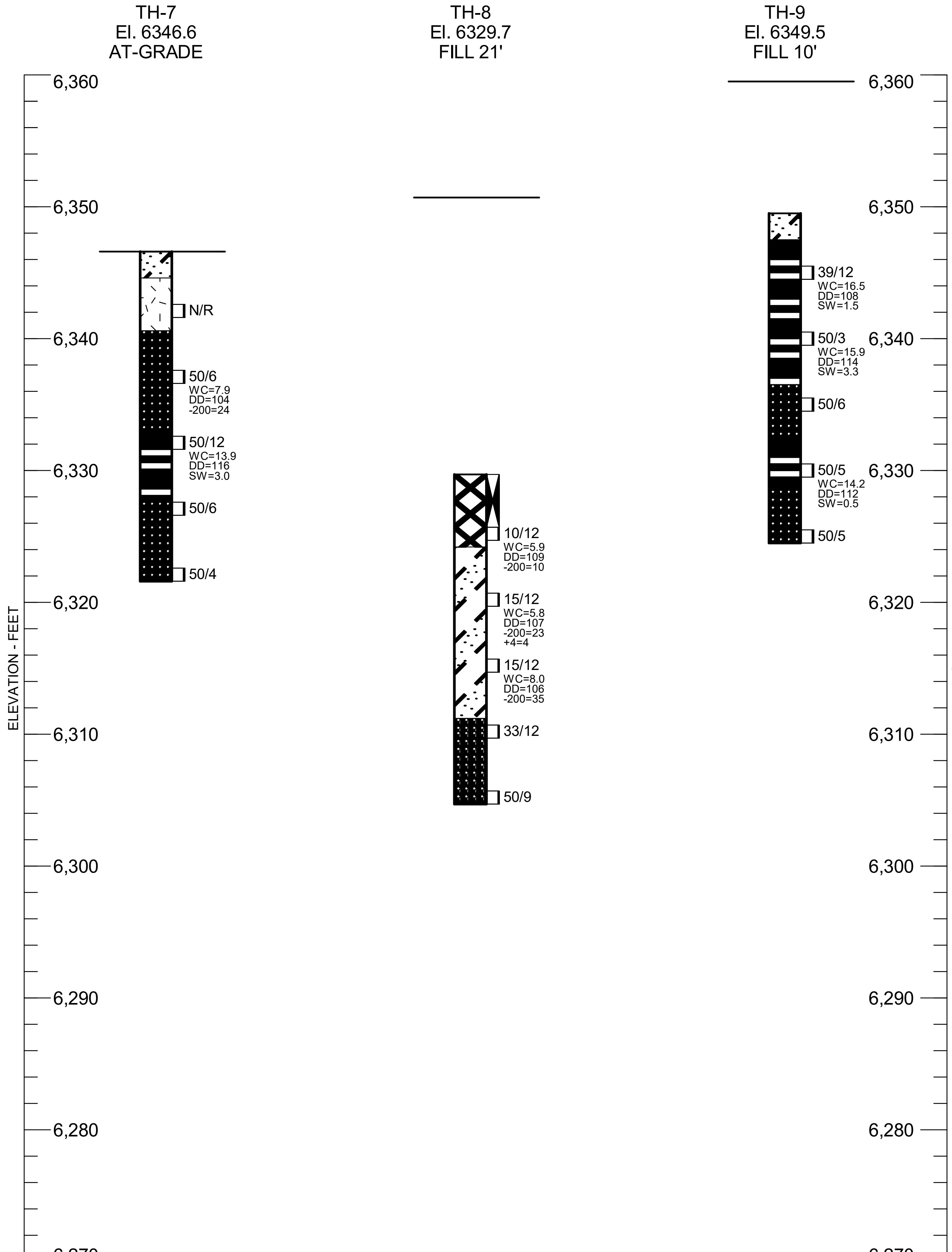
CTL|T PROJECT NO. DN51,491-115-R1

FIG. A- 3



SUMMARY LOGS OF EXPLORATORY BORINGS

LEGEND:

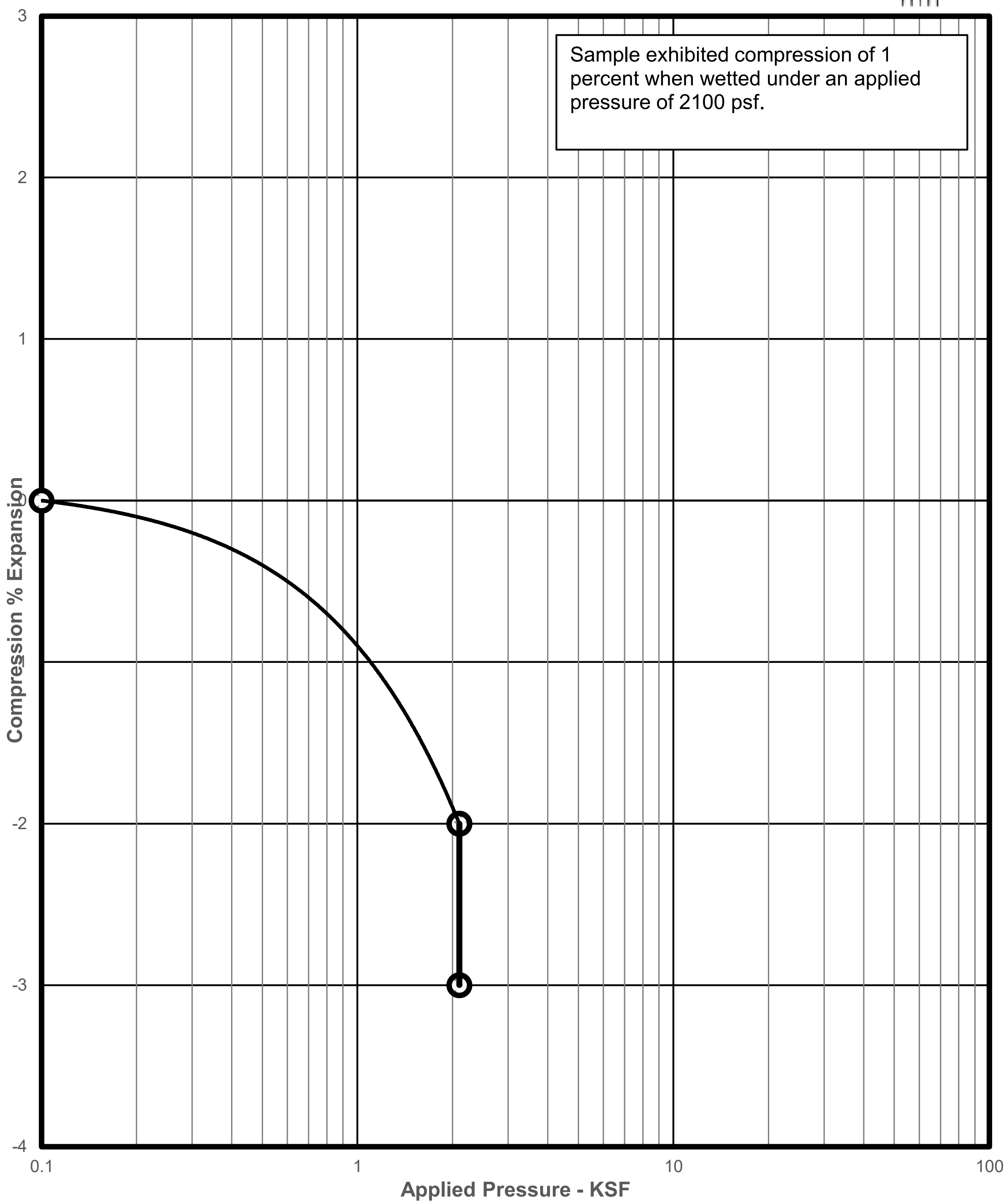
- FILL, SAND, SLIGHTLY CLAYEY, MEDIUM DENSE, MOIST, TAN, BROWN (SC).
- CLAY, SANDY TO VERY SANDY, OCCASIONAL ORGANICS, VERY STIFF, MOIST, BROWN, DARK BROWN, BLACK (CL).
- SAND, SILTY, MEDIUM DENSE, SLIGHTLY MOIST, WHITE, GRAY, TAN (SM).
- SAND, CLAYEY, OCCASIONAL ORGANICS, MEDIUM DENSE, SLIGHTLY MOIST TO MOIST, BROWN, TAN, BLACK (SC).
- INTERBEDDED CLAY/SAND, VERY STIFF OR MEDIUM DENSE TO DENSE, SLIGHTLY MOIST TO MOIST, BROWN, WHITE (CL/SC).
- BEDROCK, CLAYSTONE, SILTY, MEDIUM HARD TO VERY HARD, SLIGHTLY MOIST, BROWN, GRAY, WHITE.
- BEDROCK, SANDSTONE, VERY CLAYEY AT TIMES, MEDIUM HARD TO VERY HARD, SLIGHTLY MOIST, BROWN, RUST, WHITE, TAN, OLIVE.
- CEMENTED SANDSTONE, VERY HARD, SLIGHTLY MOIST, WHITE, TAN.
- DRIVE SAMPLE. THE SYMBOL 14/12 INDICATES 14 BLOWS OF AN AUTOMATIC 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.
- BULK SAMPLE COLLECTED FROM AUGER CUTTINGS.
- N/R NO RECOVERY.
- INDICATES PROPOSED GRADE.
- WATER LEVEL MEASURED AT TIME OF DRILLING.

NOTES:

1. THE BORINGS WERE DRILLED ON APRIL 4, 2022 USING 4-INCH DIAMETER, CONTINUOUS-FLIGHT SOLID-STEM AUGER AND TRUCK-MOUNTED CME-45 DRILL RIG.
2. BORING LOCATIONS AND ELEVATIONS ARE APPROXIMATE AND WERE STAKED AND SURVEYED BY THE CLIENT.
3. WC - INDICATES MOISTURE CONTENT (%).
   DD - INDICATES DRY DENSITY (PCF).
   SW - INDICATES SWELL WHEN WETTED UNDER APPROXIMATE POST-CONSTRUCTION (%).
   COM - INDICATES COMPRESSION WHEN WETTED UNDER APPROXIMATE POST-CONSTRUCTION (%).
   LL - INDICATES LIQUID LIMIT.
   PI - INDICATES PLASTICITY INDEX.
   -200 - INDICATES PASSING NO. 200 SIEVE (%).
   +4 - INCICATES RETAINED ON NO. 4 SIEVE (%).
   SS - INDICATES WATER-SOLUBLE SULFATE CONTENT (%).
   pF - INDICATES SOIL SUCTION VALUE (pF).
4. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS CONTAINED IN THIS REPORT.

APPENDIX B

LABORATORY TEST RESULTS
TABLE B-I – SUMMARY OF LABORATORY TEST RESULTS



SAMPLE OF CLAYSTONE
FROM: TH-1 AT 24 FEET

DRY UNIT WEIGHT: 116 pcf
MOISTURE CONTENT: 10.7 %

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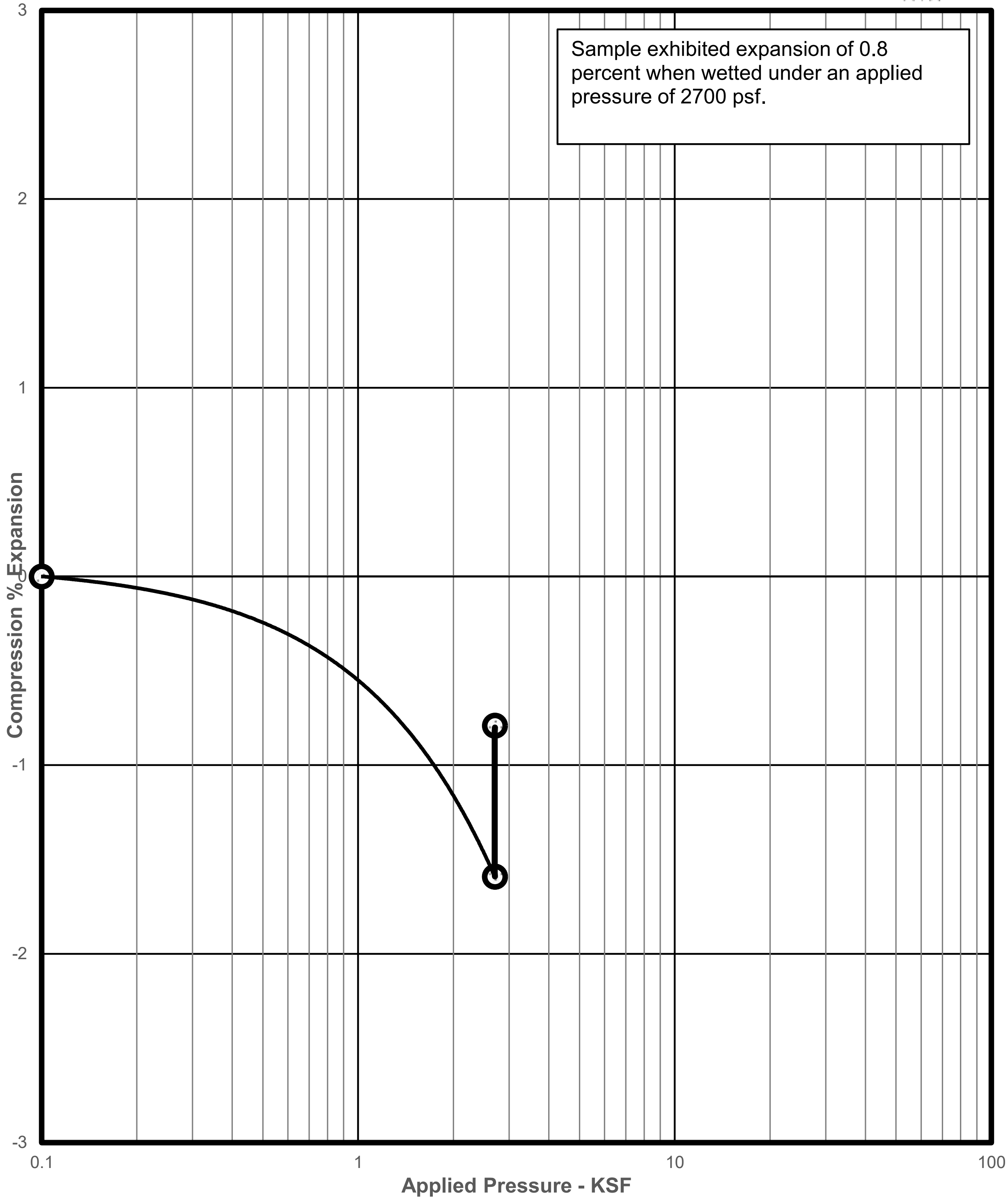
Swell Consolidation Test Results FIG. B- 1



SAMPLE OF CLAYSTONE
FROM: TH-1 AT 29 FEET

DRY UNIT WEIGHT: 118 pcf
MOISTURE CONTENT: 12.0 %

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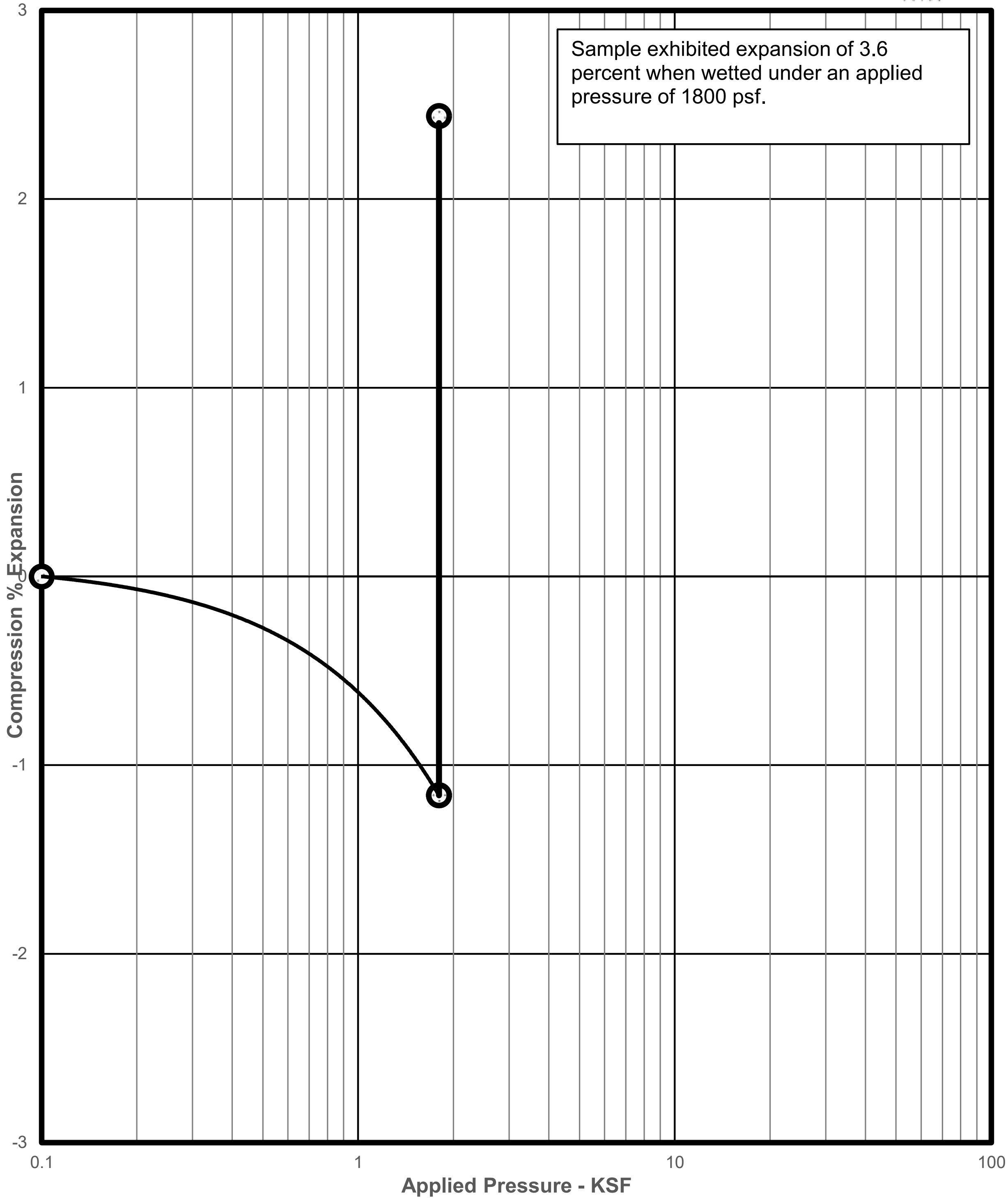
Swell Consolidation Test Results FIG. B- 2



SAMPLE OF CLAY, SANDY (CL) DRY UNIT WEIGHT: 118 pcf
FROM: TH-2 AT 4 FEET MOISTURE CONTENT: 11.6 %

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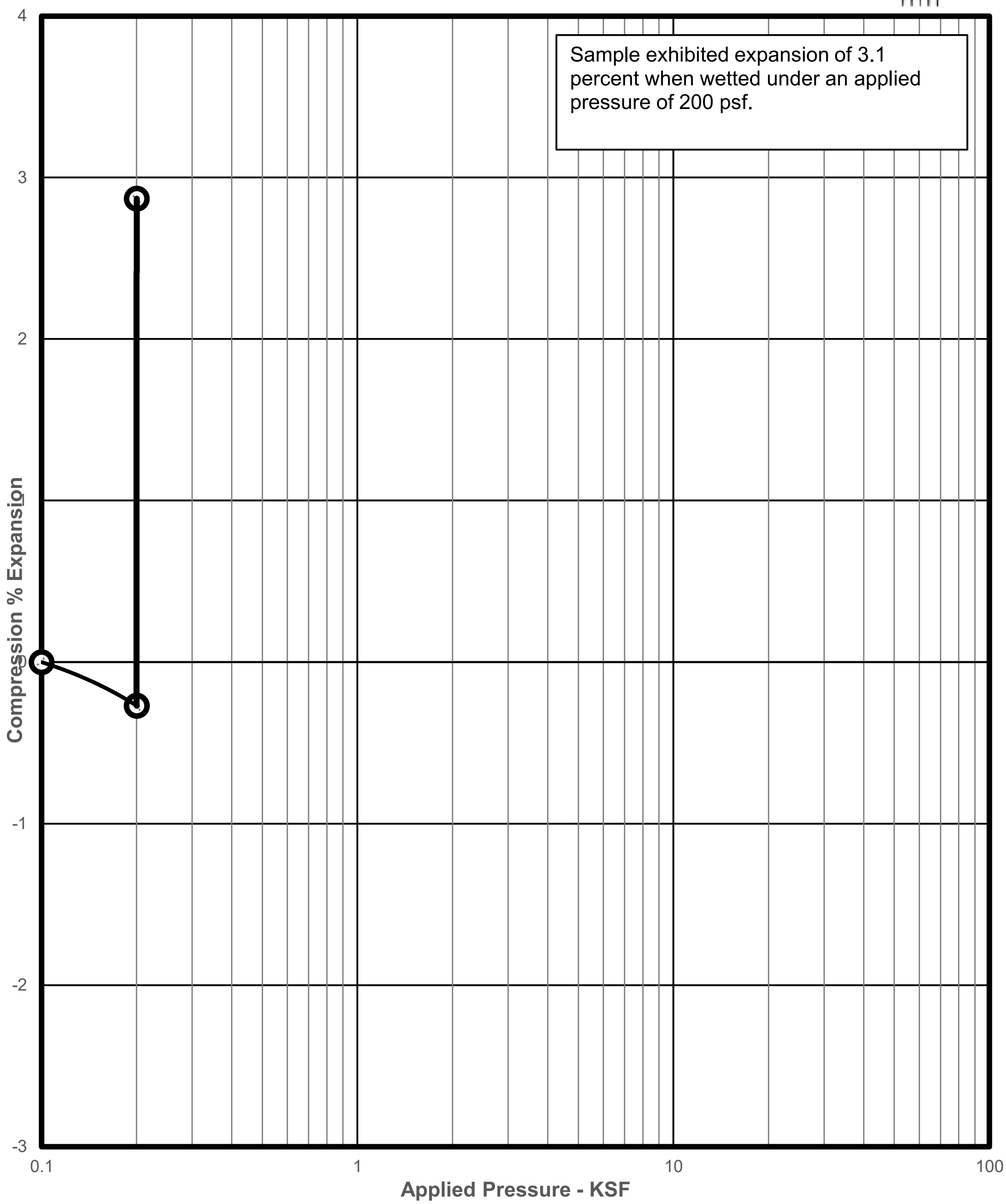
Swell Consolidation Test Results FIG. B- 3



SAMPLE OF	CLAY, SANDY (CL)	DRY UNIT WEIGHT:	106	pcf
FROM:	TH-3 AT 4 FEET	MOISTURE CONTENT:	10.9	%

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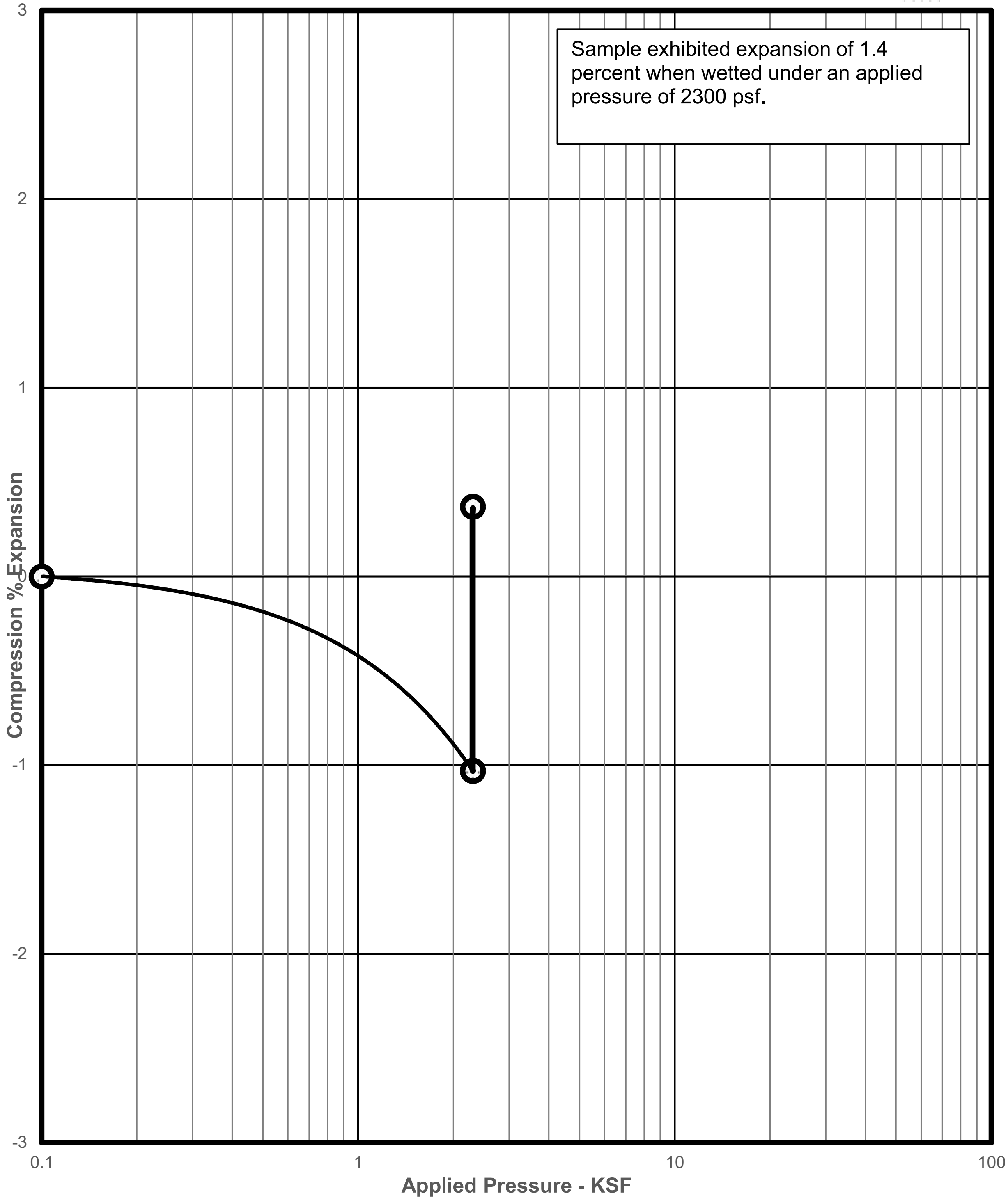
Swell Consolidation Test Results FIG. B- 4



SAMPLE OF CLAY, VERY SANDY (CL)
FROM: TH-5 AT 4 FEET

DRY UNIT WEIGHT: 120 pcf
MOISTURE CONTENT: 8.8 %

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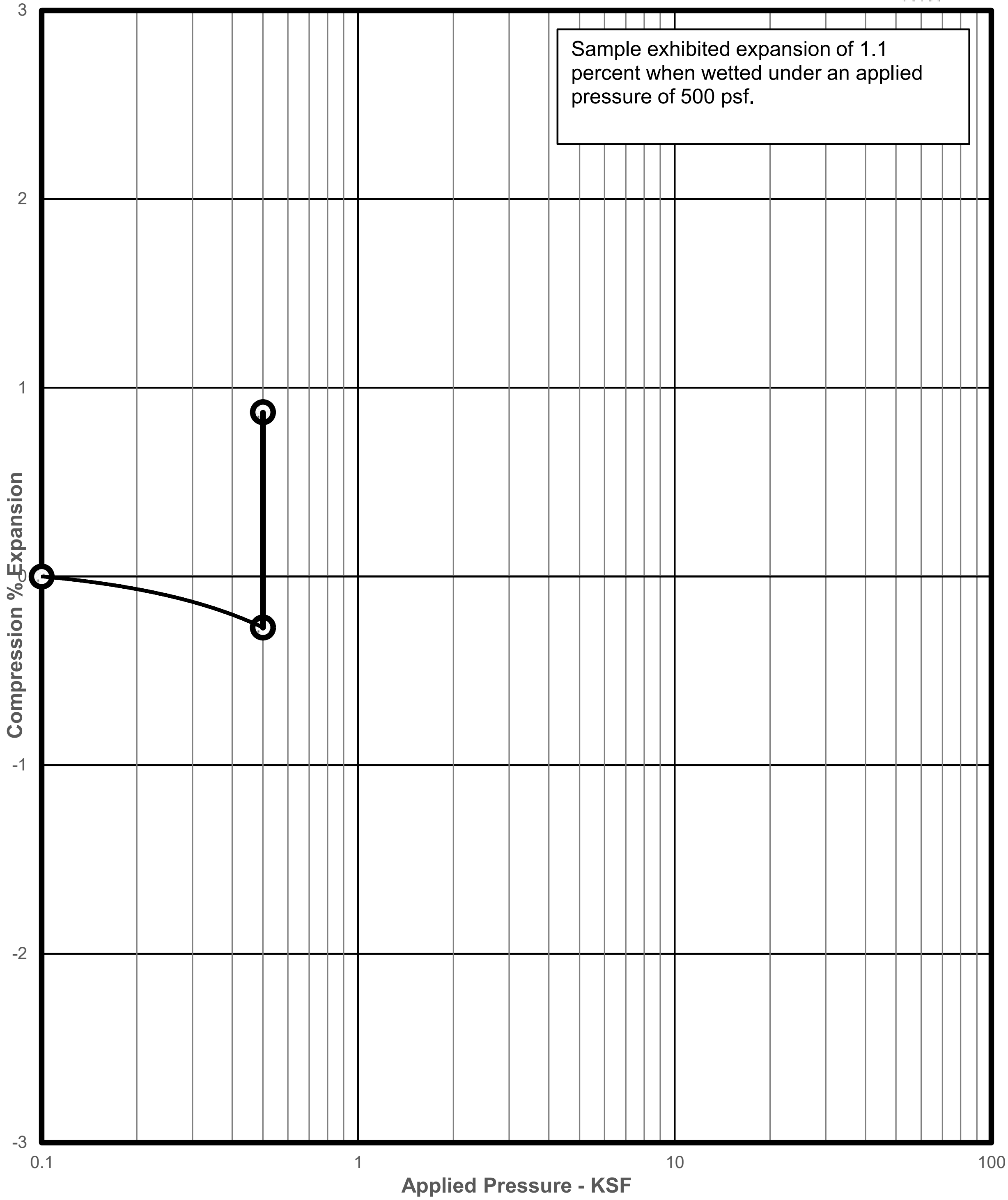
Swell Consolidation Test Results FIG. B- 5



SAMPLE OF SAND, CLAYEY (SC) DRY UNIT WEIGHT: 101 pcf

FROM: TH-6 AT 4 FEET MOISTURE CONTENT: 5.8 %

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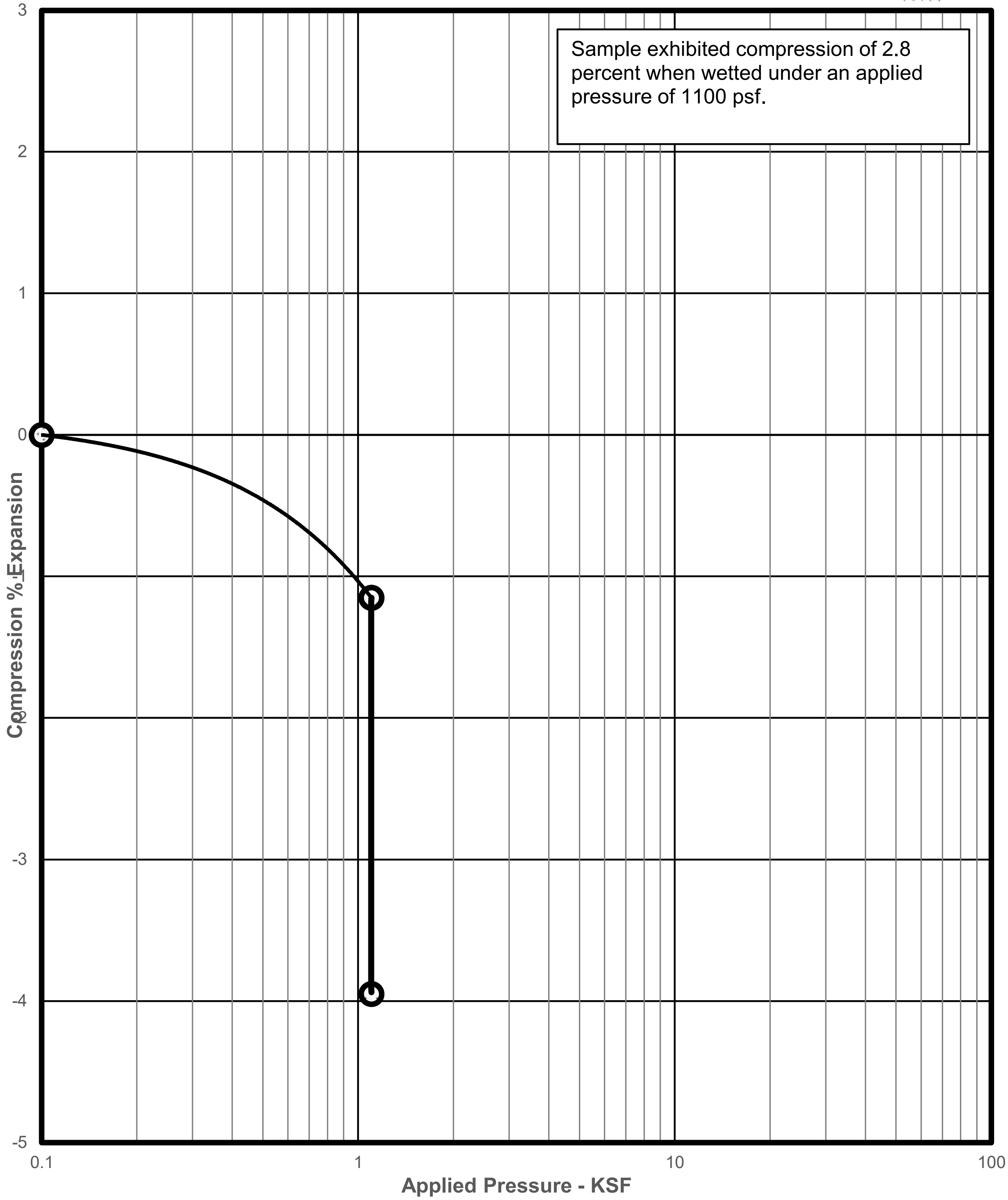
Swell Consolidation Test Results FIG. B- 6



SAMPLE OF	CLAY, VERY SANDY (CL)	DRY UNIT WEIGHT:	85	pcf
FROM:	TH-6 AT 9 FEET	MOISTURE CONTENT:	7.0	%

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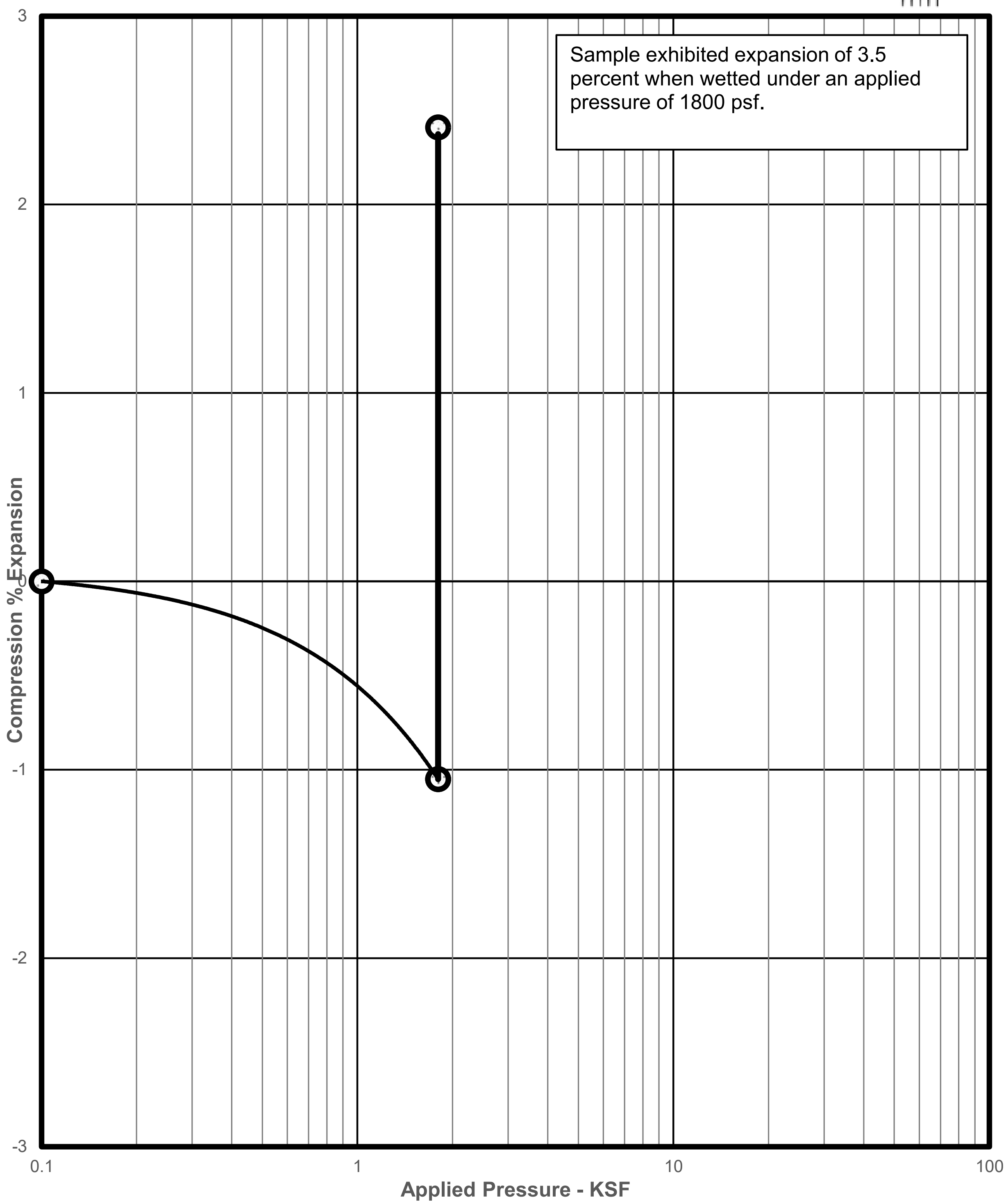
Swell Consolidation Test Results FIG. B- 7



SAMPLE OF	CLAYSTONE	DRY UNIT WEIGHT:	122	pcf
FROM:	TH-6 AT 14 FEET	MOISTURE CONTENT:	12.2	%

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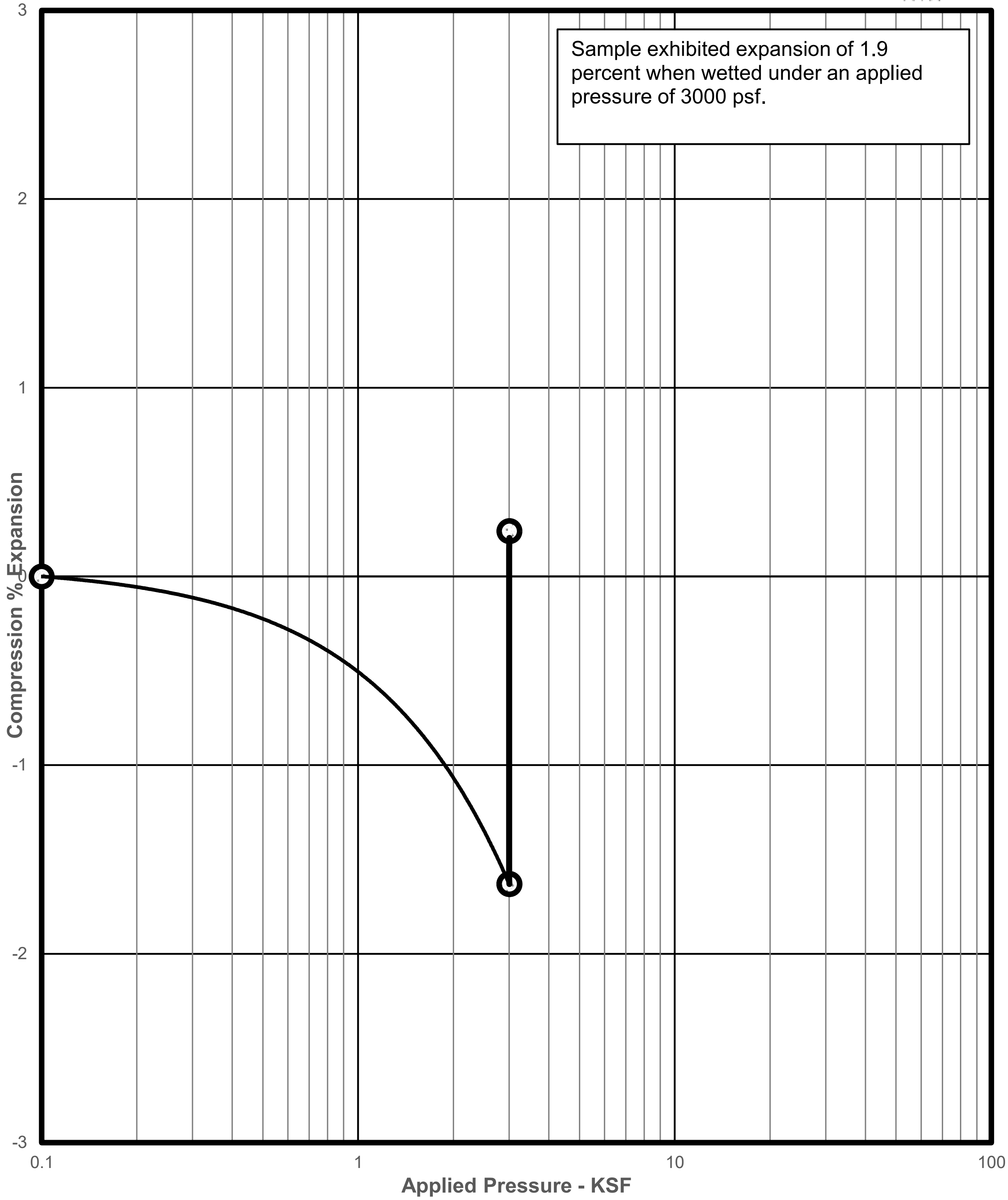
Swell Consolidation Test Results FIG. B- 8



SAMPLE OF CLAYSTONE

FROM: TH-6 AT 24 FEET

DRY UNIT WEIGHT: 117 pcf

MOISTURE CONTENT: 15.3 %

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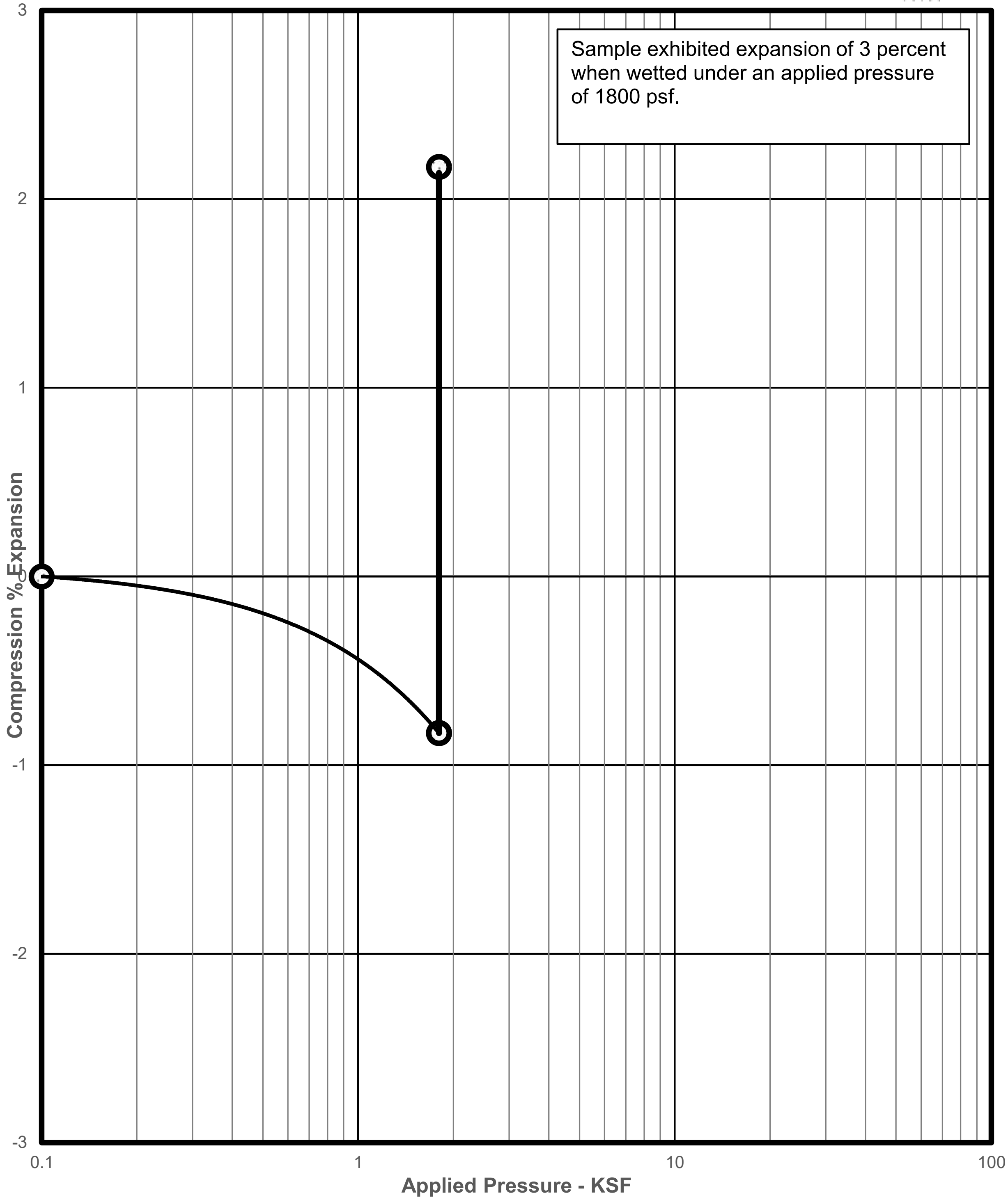
Swell Consolidation Test Results FIG. B- 9



SAMPLE OF	CLAYSTONE	DRY UNIT WEIGHT:	116	pcf
FROM:	TH-7 AT 14 FEET	MOISTURE CONTENT:	13.9	%

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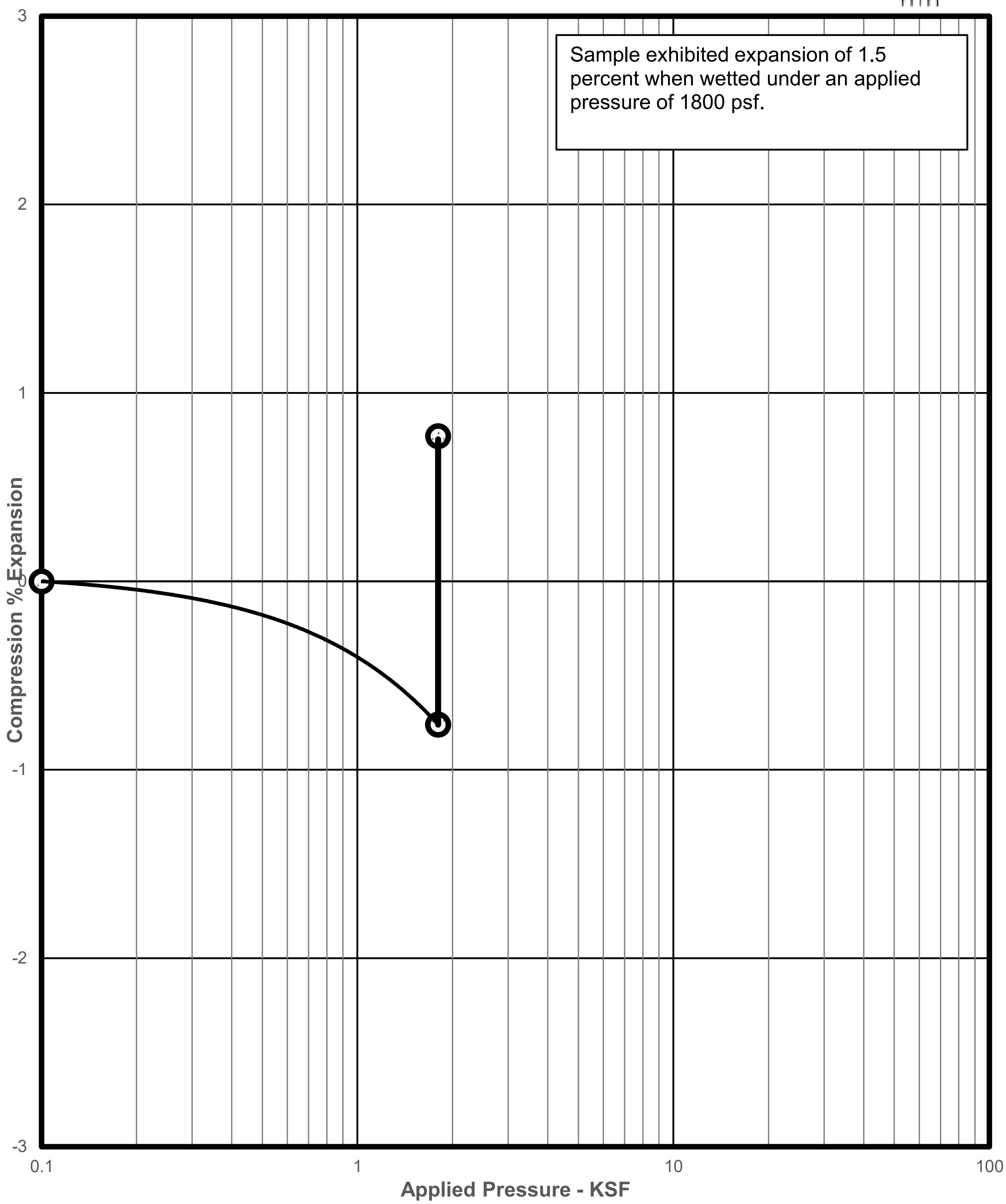
Swell Consolidation Test Results FIG. B- 10



SAMPLE OF	CLAYSTONE	DRY UNIT WEIGHT:	108	pcf
FROM:	TH-9 AT 4 FEET	MOISTURE CONTENT:	16.5	%

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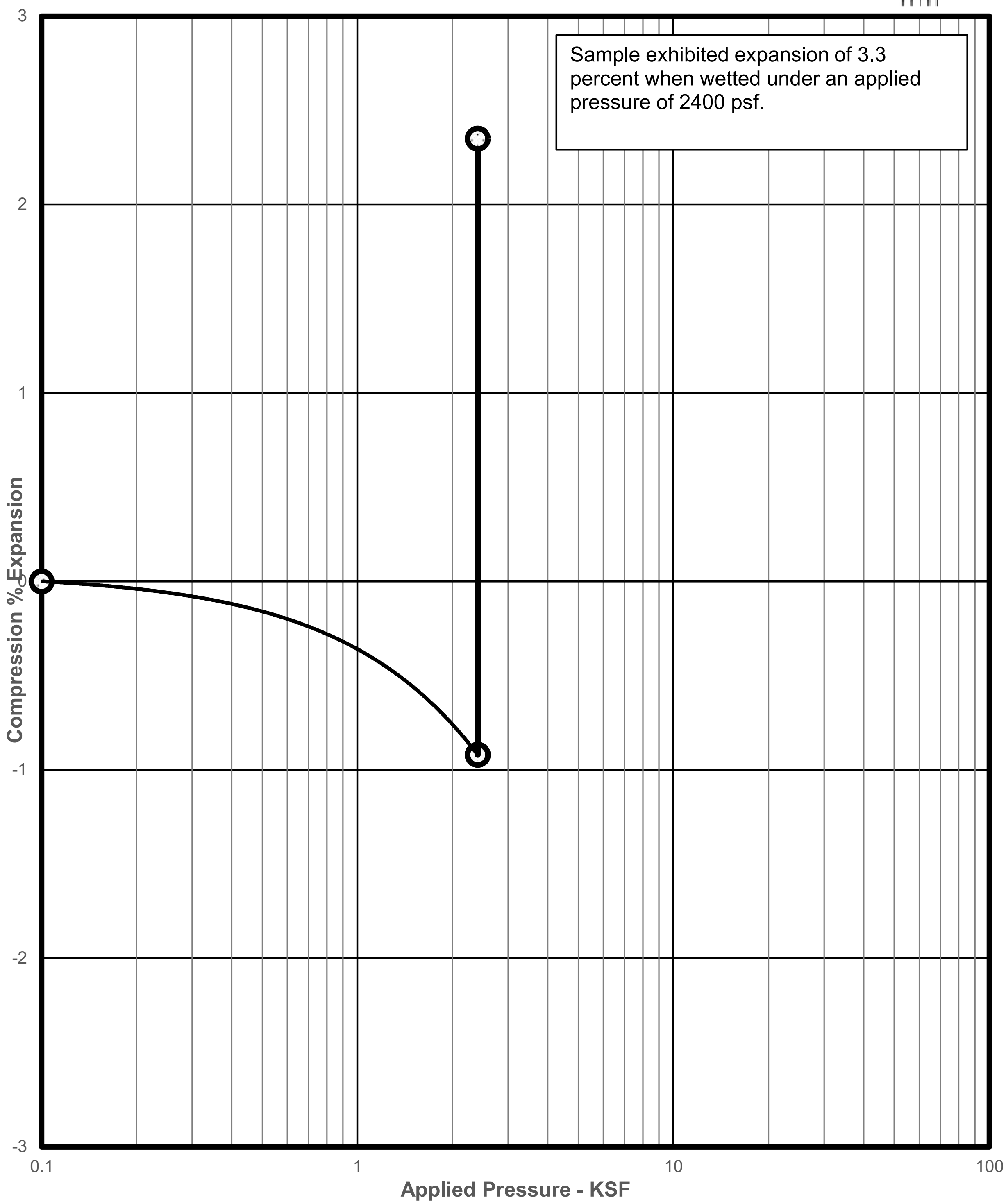
Swell Consolidation Test Results FIG. B- 11



SAMPLE OF CLAYSTONE
FROM: TH-9 AT 9 FEET

DRY UNIT WEIGHT: 114 pcf
MOISTURE CONTENT: 15.9 %

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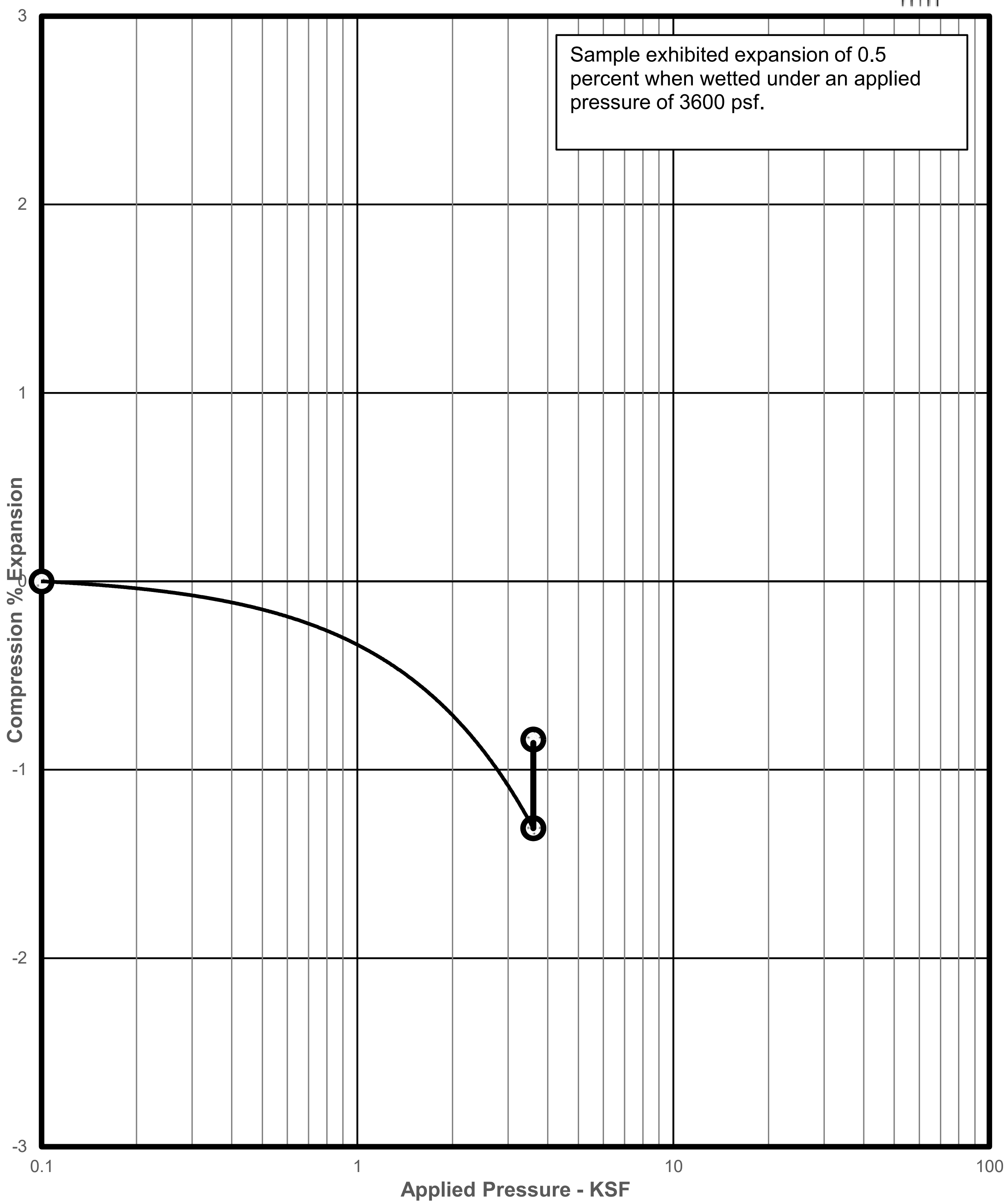
Swell Consolidation Test Results FIG. B- 12



SAMPLE OF CLAYSTONE

FROM: TH-9 AT 19 FEET

DRY UNIT WEIGHT: 112 pcf

MOISTURE CONTENT: 14.2 %

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Swell Consolidation Test Results FIG. B- 13

TABLE B - I

SUMMARY OF LABORATORY TEST RESULTS

BORING	DEPTH (ft)	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	SWELL TEST DATA: SWELL (%)	SWELL TEST DATA: COMPRESSION (%)	SWELL TEST DATA: APPLIED PRESSURE (psf)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	SOLUBLE SULFATE CONTENT (%)	RETAINED NO. 4 SIEVE (%)	PASSING NO. 200 SIEVE (%)	SOIL TYPE
TH-1	14	10.6	116							1	51	INTERLAYERED CLAY/SAND
TH-1	24	10.7	116		1.0	2,100						CLAYSTONE
TH-1	29	12.0	118	0.8		2,700						CLAYSTONE
TH-2	4	11.6	118	3.6		1,800			0.10			CLAY, SANDY (CL)
TH-2	9	5.8	117								12	SANDSTONE
TH-3	4	10.9	106	3.1		200	44	28			61	CLAY, SANDY (CL)
TH-3	14	11.3	113								35	SANDSTONE
TH-4	4	4.7	103								12	SANDSTONE
TH-4	9	5.8	110								6	SANDSTONE
TH-4	19	9.0	108								18	SANDSTONE
TH-5	4	8.8	120	1.4		2,300						CLAY, VERY SANDY (CL)
TH-5	14	10.8	109								33	SANDSTONE
TH-6	4	5.8	101	1.1		500			0.02		25	SAND, CLAYEY (SC)
TH-6	9	7.0	85		2.8	1,100						CLAY, VERY SANDY (CL)
TH-6	14	12.2	122	3.5		1,800						CLAYSTONE
TH-6	24	15.3	117	1.9		3,000						CLAYSTONE
TH-7	9	7.9	104								24	SANDSTONE
TH-7	14	13.9	116	3.0		1,800						CLAYSTONE
TH-8	4	5.9	109								10	FILL, SAND, CLAYEY
TH-8	9	5.8	107							4	23	SAND, CLAYEY (SC)
TH-8	14	8.0	106								35	SAND, CLAYEY (SC)
TH-9	4	16.5	108	1.5		1,800						CLAYSTONE
TH-9	9	15.9	114	3.3		2,400						CLAYSTONE
TH-9	19	14.2	112	0.5		3,600						CLAYSTONE

APPENDIX C

GUIDELINE SITE GRADING SPECIFICATIONS
Alexander Way
Castle Rock, Colorado

GUIDELINE SITE GRADING SPECIFICATIONS
Alexander Way
Castle Rock, Colorado

1. DESCRIPTION

This item shall consist of the excavation, transportation, placement and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve preliminary street and overlot elevations. These specifications shall also apply to compaction of excess cut materials that may be placed outside of the development boundaries.

2. GENERAL

The Soils Engineer shall be the Owner's representative. The Soils Engineer shall approve fill materials, method of placement, moisture contents and percent compaction, and shall give written approval of the completed fill.

3. CLEARING JOB SITE

The Contractor shall remove all vegetation and debris before excavation or fill placement is begun. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill or where the material will support structures of any kind.

4. SCARIFYING AREA TO BE FILLED

All topsoil and vegetable matter shall be removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified until the surface is free from ruts, hummocks or other uneven features, which would prevent uniform compaction.

5. COMPACTING AREA TO BE FILLED

After the foundation for the fill has been cleared and scarified, it shall be disked or bladed until it is free from large clods, brought to the proper moisture content (1 to 4 percent above optimum moisture content for clay and within 2 percent of optimum moisture content for sand) and compacted to not less than 95 percent of maximum dry density as determined in accordance with ASTM D698.

6. FILL MATERIALS

Fill soils shall be free from organics, debris or other deleterious substances, and shall not contain rocks or clods having a diameter greater than three (3) inches. Fill materials shall be obtained from cut areas shown on the plans or staked in the field by the Engineer.

On-site materials classifying as CL, CH, SC, SM, SW, SP, GP, GC and GM are acceptable. Concrete, asphalt, organic matter and other deleterious materials or debris shall not be used as fill.

7. MOISTURE CONTENT

Fill material shall be moisture-conditioned in accordance with specifications summarized below. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas.

SUMMARY OF MOISTURE CONTENT REQUIREMENTS

Soil Type	Depth of Site Grading Fill	
	≤20 Feet	>20 Feet
Clay (CL, CH)	1 to 4 percent above optimum	2 percent below to 1 percent above optimum
Granular Soils (SC, SM, SW, SP, GP, GC, GM	Within 2 percent of optimum	2 percent below to 1 percent above optimum

*Percentage specification based on optimum moisture content (optimum).

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor may be required to rake or disc the fill soils to provide uniform moisture content through the soils.

The application of water to embankment materials shall be made with any type of watering equipment approved by the Soils Engineer, which will give the desired results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling and all work on that section of the fill shall be delayed until the material has been allowed to dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

8. COMPACTION OF FILL AREAS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density. Fill materials shall be placed such that the thickness of loose materials does not exceed 10 inches and the compacted lift thickness does not exceed 6 inches.

SUMMARY OF MINIMUM COMPACTION SPECIFICATIONS

Soil Type	Depth of Site Grading Fill	
	≤20 Feet	>20 Feet
Clay (CL, CH)	95% STD	98% STD
Granular Soils (SC, SM, SW, SP, GP, GC, GM	95% STD	98% STD

*Compaction percentage specifications based on standard Proctor maximum dry density (STD).

Compaction shall be obtained by the use of sheepsfoot rollers, multiple-wheel pneumatic-tired rollers, or other equipment approved by the Engineer for soils classifying as CL, CH, or SC. Granular fill shall be compacted using vibratory equipment or other equipment approved by the Soils Engineer. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to ensure that the required density is obtained.

9. COMPACTION OF SLOPES

Fill slopes shall be compacted by means of sheepsfoot rollers or other suitable equipment. Compaction operations shall be continued until slopes are stable, but not too dense for planting, and there is not appreciable amount of loose soils on the slopes. Compaction of slopes may be done progressively in increments of three to five feet (3' to 5') in height or after the fill is brought to its total height. Permanent fill slopes shall not exceed 3:1 (horizontal to vertical).

10. PLACEMENT OF FILL ON NATURAL SLOPES

Where natural slopes are steeper than 20 percent in grade and the placement of fill is required, benches shall be cut at the rate of one bench for each 5 feet in height (minimum of two benches). Benches shall be at least 10 feet in width. Larger bench widths may be required by the Engineer. Fill shall be placed on completed benches as outlined within this specification.

11. DENSITY TESTS

Field density tests shall be made by the Soils Engineer at locations and depths of his choosing. Where sheepsfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate that the density or moisture content of any layer of fill or portion thereof is not within specification, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

12. SEASONAL LIMITS

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Engineer indicates that the moisture content and density of previously placed materials are as specified.

13. NOTICE REGARDING START OF GRADING

The Contractor shall submit notification to the Soils Engineer and Owner advising them of the start of grading operations at least three (3) days in advance of the starting date. Notification shall also be submitted at least 3 days in advance of any resumption dates when grading operations have been stopped for any reason other than adverse weather conditions

14. REPORTING OF FIELD DENSITY TESTS

Density tests made by the Soils Engineer, as specified under "Density Tests" above, shall be submitted progressively to the Owner. Dry density, moisture content, and percentage compaction shall be reported for each test taken.

15. DECLARATION REGARDING COMPLETED FILL

The Soils Engineer shall provide a written declaration stating that the site was filled with acceptable materials, and was placed in general accordance with the specifications.

APPENDIX D

GUIDELINE SUB-EXCAVATION SPECIFICATIONS
Alexander Way
Castle Rock, Colorado

Note: This guideline is intended for use with sub-excavation, If sub-excavation is not selected, the guidelines in Appendix C should be followed.

GUIDELINE SUB-EXCAVATION SPECIFICATIONS
Alexander Way
Castle Rock, Colorado

1. DESCRIPTION

This item shall consist of the excavation, transportation, placement and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve preliminary street and overlot elevations. These specifications shall also apply to compaction of materials that may be placed outside of the development boundaries.

2. GENERAL

The Soils Engineer shall be the Owners representative. The Soils Engineer shall approve fill materials, method of placement, moisture content and percent compaction, and shall give written approval of the completed fill.

3. CLEARING JOB SITE

The Contractor shall remove all vegetation and debris before excavation or fill placement is begun. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill where the material will support structures of any kind.

4. SCARIFYING AREA TO BE FILLED

All topsoil and vegetable matter shall be removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified until the surface is free from ruts, hummocks or other uneven features which would prevent uniform compaction.

5. COMPACTING AREA TO BE FILLED

After the foundation for the fill has been cleared and scarified, it shall be disked or bladed until it is free from large clods, brought to the proper moisture content, (1 to 4 percent above optimum) and compacted to not less than 95 percent of maximum density as determined in accordance with ASTM D 698.

6. FILL MATERIALS

Fill soils shall be free from vegetable matter or other deleterious substances, and shall not contain rocks having a diameter greater than three (3) inches. Fill materials shall be obtained from cut areas shown on the plans or staked in the field by the Engineer.

On-site materials classifying as CL, CH, SC, SM, SP, GP, GC and GM are acceptable. Concrete, asphalt, and other deleterious materials or debris shall not be used as fill.

7. MOISTURE CONTENT

Fill materials shall be moisture treated to within limits of optimum moisture content specified in “Moisture Content and Density Criteria”. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas or imported to the site.

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor will be required to rake or disc the fill to provide uniform moisture content throughout the fill.

The application of water to embankment materials shall be made with any type of watering equipment approved by the Soils Engineer, which will give the desire results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling and all work on that section of the fill shall be delayed until the material has been allowed to dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

8. COMPACTION OF FILL MATERIALS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density given in “Moisture Content and Density Criteria”. Fill materials shall be placed such that the thickness of loose material does not exceed 8 inches and the compacted lift thickness does not exceed 6 inches.

Compaction, as specified above, shall be obtained by the use of sheepsfoot rollers, multiple-wheel pneumatic-tired rollers, or other equipment approved by the Soils Engineer for soils classifying as CL, CH or SC. Granular fill shall be compacted using vibratory equipment or other equipment approved by the Soils Engineer. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to ensure that the required density is obtained.

9. MOISTURE CONTENT AND DENSITY CRITERIA

Fill material shall be substantially compacted to at least 95 percent of maximum ASTM D 698 (AASHTO T 99) dry density at 1 to 4 percent above optimum moisture content. Additional criteria for acceptance are presented in DENSITY TESTS.

10. DENSITY TESTS

Field density tests shall be made by the Soils Engineer at locations and depths of his choosing. Where sheepsfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate the density or moisture content of any layer of fill or portion thereof not within specifications, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

Allowable ranges of moisture content and density given in MOISTURE CONTENT AND DENSITY CRITERIA are based on design considerations. The moisture shall be controlled by the Contractor so that moisture content of the compacted earth fill, as determined by tests performed by the Soils Engineer, shall be within the limits given. The Soils Engineer will inform the Contractor when the placement moisture is less than or exceeds the limits specified and the Contractor shall immediately make adjustments in procedures as necessary to maintain placement moisture content within the specified limits, to satisfy the following requirements.

A. Moisture

1. The average moisture content of material tested each day shall not be less than 1.5 percent over optimum moisture content.

2. Material represented by samples tested having moisture lower than 1 percent over optimum will be rejected. Such rejected materials shall be reworked until moisture equal to or greater than 1 percent above optimum is achieved.

B. Density

1. The average dry density of material tested each day shall not be less than 95 percent of maximum ASTM D 698 dry density.

2. No more than 10 percent of the material represented by the samples tested shall be at dry densities less than 95 percent of maximum ASTM D 698 dry density.

3. Material represented by samples tested having dry density less than 94 percent of maximum ASTM D 698 dry density will be rejected. Such rejected materials shall be reworked until a dry

density equal to or greater than 95 percent of maximum ASTM D 698 dry density is obtained.

11. INSPECTION AND TESTING OF FILL

Inspection by the Soils Engineer shall be sufficient during the placement of fill and compaction operations so that they can declare the fill was placed in general conformance with specifications. All inspections necessary to test the placement of fill and observe compaction operations will be at the expense of the Owner.

12. SEASONAL LIMITS

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Engineer indicates the moisture content and density of previously placed materials are as specified.

13. REPORTING OF FIELD DENSITY TESTS

Density tests made by the Soils Engineer, as specified under “Density Tests” above, shall be submitted progressively to the Owner. Dry density, moisture content and percentage compaction shall be reported for each test taken