

GEOTECHNICAL SITE DEVELOPMENT STUDY

FAIRVIEW
NORTHEAST OF SOUTH GARRISON STREET AND WEST FAIRVIEW AVENUE
JEFFERSON COUNTY, COLORADO

Draft
PREPARED FOR

RICHMOND AMERICAN HOMES OF COLORADO, INC.
4350 SOUTH MONACO STREET
DENVER, COLORADO 80237

AUGUST 1, 2018
PROJECT NUMBER 184332

August 1, 2018

Richmond American Homes of Colorado, Inc.
4350 South Monaco Street
Denver, Colorado 80237

Attention: Mr. Eric Kubly

Subject: Geotechnical Site Development Study
Fairview
Northeast of South Garrison Street and West Fairview Avenue
Jefferson County, Colorado
Project Number 184332

Dear Mr. Kubly:

A. G. Wassenaar, Inc. (AGW) completed the geotechnical site development study for the proposed residential development at the subject site. The data collected during our field exploration and laboratory work and our analysis, opinions, and conclusions are presented in the attached report. The purpose of our study is to provide design recommendations for planning and site development and preliminary design concepts for foundation systems, interior floor support, and streets.

The subsurface materials encountered in our test borings consist of topsoil and clay overlying sedimentary bedrock. Claystone and/or sandstone bedrock was encountered at depths ranging from 2 to 7 feet below the ground surface. Ground water was measured at a depth of 25 feet during this study.

According to published information provided by the Colorado Geological Survey (CGS) and by Jefferson County (JeffCo), this site is located within the Dipping Bedrock Overlay District (DBOD). Regulations concerning the DBOD were considered when preparing the recommendations provided in this report.

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Site development considerations should include provisions for the presence of steeply dipping bedrock, highly to very highly expansive clays and claystone bedrock, and underground coal mines.

Based upon the results of this preliminary study, if the site is overexcavated and the excavated soils are placed as moisture treated fill using the recommendations presented in this report, it is likely that most of the structures could be founded on spread or pad-type footings bearing on the moisture treated fill bearing below frost depth. Preliminary foundation design concepts are presented in the report.

Slabs-on-grade will require a specific risk analysis by the Client because of the potential for movement of the soils and bedrock encountered. Foundation subsurface drainage systems will be necessary for all below grade areas. Water soluble sulfate test results and our experience working in the area indicate that site and foundation concrete should be designed for very severe sulfate exposure. Preliminary pavement and other geotechnical related recommendations are presented in the following report.

We encourage the Client to read this report in its entirety and not to solely rely on the cursory information contained in this summary. If you have any questions regarding the contents of this report or our analyses of the subsurface conditions, please call us. We have appreciated the opportunity to provide this service for you.

Sincerely,

A. G. WASSENAAR, INC.

Reviewed by:

Kathleen A. Noonan, P. E.
Senior Engineer

Keith D. Seaton, P. E.
Senior Engineer

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Draft

GEOTECHNICAL SITE DEVELOPMENT STUDY
Fairview
Northeast of South Garrison Street and West Fairview Avenue
Jefferson County, Colorado

PURPOSE

This report presents the results of a geotechnical site development study for the proposed residential development to be located northeast of South Garrison Street and West Fairview Avenue in Jefferson County, Colorado. The study was conducted to assist in determining geotechnical design criteria for planning, site evaluation, and development considerations. Preliminary geotechnical design concepts are also presented for foundations, interior floor support, foundation drainage, and street construction. Factual data gathered during the field and laboratory work are summarized on Figures 1 through 3 and in Appendix A. Our opinions and recommendations presented in this report are based on the data generated during our field exploration and laboratory testing, our understanding of the proposed project, and our experience with similar projects and geotechnical conditions. A Geologic Hazards study is being prepared by Lithos Engineering and will be forwarded when complete.

This study was performed in general conformance with our Proposal Number 184332, dated July 13, 2018. This report is not intended to provide all the development requirements of presented in the JeffCo LDR for this site. Additional geotechnical and geologic studies will be required to develop complete design criteria and construction recommendations for submittal to JeffCo.

PROPOSED CONSTRUCTION

We understand the proposed 6-acre residential development will include 36 or 37 Cityscape lots that are approximately 25 feet wide and the associated utility and roadway infrastructure. The structures will be three stories constructed over crawl spaces. No basements are planned. We also understand that the Client prefers to develop the site to avoid, if possible, the use of drilled piers and interior structural floors. Preliminary grading plans were not available at the time of this study. Once grading plans are completed, this report will need to be supplemented to include the proposed bottom of foundation elevations as required in the JeffCo LDR.

SITE CONDITIONS

The site is bounded by a South Garrison Street and a residential subdivision to the west, a car wash and a shopping center to the north, a residential subdivision to the east, and West Fairview Avenue and a residential subdivision to the south. Vegetation consists of native grasses, cacti, and yucca. The site slopes gently downwards to the southwest. No bedrock outcrops or bodies of water were observed on the site.

According to published information provided by the CGS and JeffCo, this site is in the DBOD. The DBOD defines an area of JeffCo where dipping, expansive bedrock possesses the potential for non-uniform heaving. Historically, a higher rate of damage has occurred where dipping beds of expansive claystone are found near the ground surface. Therefore, this site must be considered a high-risk site and special considerations are required during design and construction to reduce the risk of damage to structures and infrastructure. CGS and JeffCo can be contacted for additional published information related to the DBOD.

FIELD EXPLORATION

Subsurface conditions were explored by drilling 5 test borings at the approximate locations indicated on Figure 1. The test borings were advanced using a 4-inch diameter, continuous flight auger powered by a truck-mounted. At frequent intervals, samples of the subsurface materials were obtained 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 2.5-inch outside diameter by 2-inch inside diameter device. The number of blows required for the sampler to penetrate 12 inches and/or the number of inches that the sampler is driven by 50 blows gives an indication of the consistency or relative density of the soils and bedrock materials encountered. Results of the penetration tests and locations of sampling are presented on the "Test Boring Logs", Figures 2 and 3. Ground water measurements were made at the time of drilling and subsequent to drilling.

LABORATORY TESTING

The samples obtained during drilling were returned to the laboratory where they were visually classified by a geotechnical engineer. Laboratory testing was then assigned to specific samples to evaluate their engineering properties. The laboratory tests included swell-consolidation tests to evaluate the effect of wetting and loading on the selected samples. Gradation analysis and Atterberg limits tests were conducted to evaluate grain size distribution and plasticity. Hydrometer tests and specific gravity tests were conducted to evaluate the percentage of clay particles in selected samples. A standard Proctor test and remolded swell-consolidation tests were performed on a blended bulk sample of the soils anticipated to be used as fill. In addition, representative samples were tested for water soluble sulfates, pH, resistivity, and chlorides. The test results are summarized on Figures 2 and 3 and in Appendix A.

SUBSURFACE CONDITIONS

The subsurface materials encountered in our test borings consist of topsoil and clay overlying sedimentary bedrock. Claystone bedrock was encountered at depths ranging from 2 to 7 feet below the ground surface. Ground water was measured at a depth of 25 feet during this study. A more complete description of the subsurface conditions is shown on Figures 2 and 3.

NATURAL SOIL

Topsoil was encountered in all the test borings. The topsoil encountered consisted of sandy clay and was up to 1-foot thick. It was organic, moist, and dark brown.

Clay was encountered in all the test borings. The clay was stiff to very stiff, silty, sandy to very sandy, slightly moist to moist, and brown. The clay is considered to possess high to very high expansion potential.

BEDROCK

Claystone bedrock was encountered in all the test borings at depths ranging from 4½ to 7 feet. The claystone was steeply dipping, weathered to very hard, silty, sandy to very sandy, iron stained, moist, and gray to rust to olive. The claystone is considered to possess high to very high expansion potential.

Sandstone bedrock was encountered in three of the five test borings at depths ranging from 2 to 4½ feet. The sandstone was steeply dipping, very hard, silty, clayey to very clayey, moist, and brown to rust to gray to olive. The sandstone is considered to possess low to moderate expansion potential.

Interbedded claystone and sandstone bedrock was encountered in two of the five test borings at a depth of 11 feet. This bedrock was hard to very hard, silty, moist to wet, and brown to rust to gray to olive. This bedrock is considered to possess moderate to high expansion potential. Estimated elevation of bedrock is presented on Figure 4. It should be noted that the bedrock found in the DBOD can vary greatly in its expansion potential across relatively short distances.

GROUND WATER

Ground water was not encountered at the time of drilling. When we returned four days after drilling, ground water was encountered in Test Boring 3 at a depth of 25 feet. Ground water levels fluctuate with changing seasons and irrigation patterns and are expected to rise after construction is completed and landscape irrigation commences.

GEOTECHNICAL CONCERNS

STEEPLY DIPPING BEDROCK

The major concern for construction at the site is the presence of the steeply dipping bedrock beneath the site. Steeply dipping claystone bedrock was encountered in all test borings at depths ranging from 2 to 7 feet. Cut and fill depths to overlot grade were not known at the time of this study as grading plans were not completed. JeffCo regulations do not permit construction of foundations within 10 feet of undisturbed steeply dipping bedrock. Therefore, overexcavation will be required beneath all structures unless sufficient overlot grading fill is placed between the bottom of the foundations and the top of the bedrock. The inclination of the bedding plans of the dipping bedrock will impact excavations and may require shoring and/or cut slope stabilization. This is discussed in more detail in the "Construction Excavations" section of this report.

EXPANSIVE SOILS AND BEDROCK

Moderate to very high swelling clays and claystone bedrock were encountered across the site. Depending upon site grading and depth of foundation construction, foundations and any slabs constructed on grade may need to be designed for the potential of future movement of the soils. A separation of 14 feet between the lowest foundation element (crawl space footing) and the expansive clays and claystone is recommended.

UNDERGROUND COAL MINES

It is our understanding that this site is identified as being underlain by abandoned underground coal mines on the "Statewide Historic Underground Coal Mine Extents and Reported Coal Mine-Related Subsidence Events Map" available on the Colorado Geological Survey's website. In 2015 and 2016, Western Environment and Ecology, Inc. (Western) issued mine subsidence assessments for this site.

SITE DEVELOPMENT

OVERLOT GRADING

We understand the fill materials to be used on the site will be from on-site cut areas. In general, suitable inorganic on-site or off-site soils may be used for structural fill. Existing fill should be excavated prior to placement of new fill. Topsoil, soil containing significant vegetation, organic debris, or other deleterious material should be excavated and removed from structural areas. Off-site material considered for new fill should be evaluated by AGW prior to importing to the site.

Construction of the fill embankments throughout the site should consist of proper foundation preparation, constructing embankment benching where necessary, disposition of strippings, proper fill placement and compaction, and designing slopes in accordance with the recommendations provided in this report and the applicable governing regulations. The following are general site grading recommendations:

1. **The site grading plans should be reviewed by AGW prior to commencement of work at the site.**
2. It is recommended that AGW be retained on an essentially full-time basis to observe and test the fill placement. We should also be retained to provide observations and/or testing of the other items discussed below. The purpose of these observations and testing is to provide the Client with a greater degree of confidence that the work is being performed within the recommendations of this geotechnical study and the project specifications.
3. All topsoil and vegetation should be stripped and removed prior to fill placement. The vegetation, organic soils, or topsoil should be wasted from the site, placed in non-structural areas (e.g., parks, landscaping, tracts, etc.) and/or stockpiled for future use in revegetating the surface of exposed slopes. **In no case should these materials be used in the structural areas or where the stability of slopes will be affected. If placed in lots, topsoil must be placed outside of the structure setbacks and should not be placed where the fill depths exceed 5 feet.** If placed in depth across the back of lots, movements of fences and dry utilities should be expected.
4. Where the existing slopes are steeper than a 5:1 (horizontal:vertical), benching will be required for structural integrity of any fills (see Figure 5).

5. The stripped foundation areas should be observed by AGW prior to fill placement. Any soft soils found in these areas must be removed or stabilized as necessary prior to fill placement.
6. After the fill areas have been cleared, the exposed soils should be scarified to a minimum depth of 6 inches, brought to the proper moisture content, and then compacted according to Appendix B.
7. The compaction and moisture content of the soils will be dependent upon material types and the depth and location of placement. The specifications outlined in Appendix B are based upon providing a fill with sufficient shear strength to support structures and sufficient moisture to reduce the potential of swell of the expansive soil used in the fill.
8. The results of a Standard Proctor test performed on a bulk sample of the upper level soils likely to be used for moisture treated fill are shown on Figure A-13 in Appendix A. These results can be used as a guideline for contractors to estimate how much additional moisture may be required to bring the on-site soils to the required moisture content. **Additional processing of the excavated claystone bedrock may be required due to the hardness of the material and low moisture content. The earthwork contractor should be made aware of the extra processing required.**
9. Particular attention should be paid to compaction of the exterior faces of slopes.
10. Other specifications outlined in Appendix B should be followed.

OVEREXCAVATION AND PLACEMENT OF MOISTURE TREATED FILL

Based on the expansion potential of the clays and claystone bedrock, we recommend that the site be overexcavated if the use of shallow foundations is desired. Our experience indicates that overexcavation and placement of a moisture treated fill would be most effectively performed using mass grading techniques. The ideal time to do this would be during site development operations. As some overexcavation beneath the roadways will likely be required, it would be advantageous to perform this overexcavation during site grading. Additionally, Since the site is located in the DBOD, overexcavation should also be considered below the wet utilities that extend to within 5 feet of the steeply dipping bedrock. These recommendations may be modified during construction if soil conditions differing from those anticipated are encountered.

1. These recommendations are based upon our understanding that a crawl space depth product will be constructed. If a different product is considered, these recommendations must be reviewed by AGW.
2. The site should be excavated to a depth of at least 14 feet below the crawl space foundation elevation. The base of the excavation should extend, at a minimum, to a width of at least 5 feet beyond the foundation footprint (including any counterforts, covered porches, patios, decks, etc.). Excavations that do not extend to these minimums risk future foundation performance issues. It may be prudent to extend the base of the excavation to 5 feet outside of the front and rear setbacks to accommodate potential changes in structure dimension. Additionally, the street subgrade should be overexcavated to a depth of at least 10 feet which should extend to at least 1 foot beyond back of sidewalk (combination sidewalk) or back of curb (detached sidewalk). The local water and sanitation district will also require a minimum of 5 foot overexcavation

- beneath the wet utility trenches. The excavations should be sloped following current OSHA regulations. We will not be responsible for testing near excavations that do not meet OSHA regulations. A licensed surveyor must verify the extents of the excavation prior to any fill placement.
3. Once the excavation depth and width have been verified, fill placement may begin. The bottom of the excavation should be scarified and moistened prior to fill placement. The fill, consisting of the excavated materials, should be placed in maximum 8-inch loose lifts. Moisture should be added and the lift processed. The use of a construction disc to mix and process each lift is suggested. Mixing should be performed until the moisture content is relatively uniform throughout the lift and most of the particles are less than 3 inches in dimension. The results of a Standard Proctor test performed on a bulk sample of the upper level soils likely to be used for moisture treated fill are shown on Figure A-13 in Appendix A. These results can be used as a guideline for contractors to estimate how much additional moisture may be required to bring the on-site soils to the required moisture content. **Additional processing of the excavated claystone bedrock may be required due to the hardness of the material and low moisture content.** The earthwork contractor should be made aware of the extra processing required. The fill should then be compacted as described in Appendix B.
 4. Essentially full-time observation and testing of fill placement must be performed by AGW. Testing should include in-place moisture content and dry density. Swell-consolidation or other testing may also be performed at the discretion of the engineer.

5. Placement and compaction of fill should continue to final overlot grade. We recommend that the lots not be left low or “dished-out” and that placement of fill not stop at foundation elevation. **If the residences will not be constructed within two years of completion of the fill, additional effort may be necessary to help maintain the moisture within the fill.** This may include the addition of more soil to blanket the compacted fill, the placement of mechanical or chemical barriers, or applying water periodically to the fill surface.

It must be understood that while this method is used to reduce the likelihood of future heave, it is not free of risk of foundation movement. While future heave is less likely, the possibility of settlement induced by excess moisture is increased. **Therefore, the control and removal of surface water at the site will continue to be very important.**

Our experience indicates that clay materials of the type encountered at this site will likely exhibit an average swell of less than 2% under a surcharge load of 1,000 pounds per square foot (psf) when thoroughly mixed with water and processed with typical earthmoving equipment. It is anticipated that if this level of swell reduction is achieved, the foundations may be constructed by placing footings upon the fill. This level of swell should also provide for a low to moderate risk of basement slab movement. However, it must be understood that even with the procedures outlined above, there is a possibility that moderate to high measured swells may be found in the fill. This may require rework of portions of the fill or the use of pier foundations and structural support of interior floors. **Additional drilling after the soil modification has been**

completed will be required to provide final foundation recommendations and slab-on-grade movement assessments for each residence.

SLOPES AND RETAINING WALLS

Slope stability and retaining wall analyses were not conducted as part of this study. In areas where natural slopes exceed 5:1 (horizontal:vertical), benching prior to fill placement will be required (see Figure 5). Construction of conventional fill slopes should be limited to 3 to 1 or flatter. Cut slopes steeper than 2 to 1 should be evaluated for stability. Specific analysis will also be necessary if retaining walls are to be constructed.

CONSTRUCTION EXCAVATION

In our opinion, the majority of the site grading, utility, and foundation excavations may be constructed using conventional earth-moving equipment for the Front Range area. **Based on the amount of fracturing and the dip of the bedding planes, the claystone bedrock will present an additional caving hazard during the overexcavation process. Shoring and/or slope stabilization may be necessary along the southern and western property lines.** Excavations deeper than 3 feet should be properly sloped or braced to prevent collapse of potentially caving soils. For planning purposes, any soil influenced by ground water can be considered as a "Type C", the clay can be considered as "Type B", and the underlying bedrock can be considered as a "Type A" according to OSHA regulations. A final determination of the soil type must be made by the Contractor's "Competent Person" (as defined by OSHA Regulation). Local, city, county, state, and federal (OSHA) regulations should be followed.

UTILITY CONSTRUCTION

In our opinion, utility excavations may be constructed using conventional earth-moving equipment for the Front Range area. All excavations should be sloped or shored in the interest of safety, following local and federal (OSHA) regulations. For planning purposes, OSHA soil type designations are discussed under "Construction Excavations". Final determination of the soil types must be made by the contractor's "Competent Person" (as defined by OSHA) at the time of construction.

Trench backfill within all structural areas, as a minimum, should be compacted using the same methods and to the same specifications as required for overlot grading. This is especially important where utility lines and laterals are constructed beneath foundation, alley, and driveway areas during land development. Trenches in streets should be compacted to JeffCo specifications. Observation and testing of fill placement must be performed during trench backfilling. Since the site is located in the DBOD, overexcavation should also be considered below the wet utilities that extend to within 5 feet of the steeply dipping bedrock.

The choice of compaction equipment can have a significant effect on the performance of trench fills. It is our experience that utility trench backfills compacted with a compaction wheel attached to an excavator experience more settlement (both in area and magnitude) than those compacted with self-propelled equipment. While the contractor has control of the means and methods of construction, the Client should be aware of this issue.

SUBSURFACE DRAINAGE

Clay soils and claystone bedrock were encountered in the test borings drilled for this study.

These types of material have a relatively low permeability and can develop a perched water

condition. Perched water conditions generally occur after development and construction have taken place, when landscape irrigation and surface drainage conditions are changed.

For these reasons, an overall area drain (underdrain) can be considered for the site. In addition, the overall area drain could also provide for a discharge and collection point for individual foundation drains. If an area drain discharge is not available, the individual foundation drains will discharge collected water to the ground surface near each residence. Surface discharge can result in water recycling to the foundation drain and ponding of water where surface grading is not sufficient for water flow. Foundation drain discharge can also result in algae growth where water continually crosses sidewalks which become ice hazards on walkways and gutters in the winter months.

Typically, overall area drains can be designed and constructed with installation of the sanitary sewer system. Underdrain systems which connect to individual foundation drains are required in the JeffCo DBOD. The civil engineering company contracted to design the infrastructure should be able to provide this design. We are available to assist in drain design. For the system to work, the area drain must be graded to a positive discharge point. **If a permanent outfall for an area drain cannot be determined, the area drain should not be constructed.** AGW also recommends any basement or below grade area be provided with a perimeter subsurface drainage system sloped to drain to a positive gravity discharge such as a sump or connected directly to the overall area drain system.

SURFACE DRAINAGE

We recommend that provisions be made to divert surface runoff away from development areas.

This may reduce potential problems associated with excess water in structure bearing soils. The

site should be designed such that a 10% slope can be established near the structures after foundation construction. Slopes of at least 2% should be planned in landscaped areas once the water is away from the foundations.

SITE CONCRETE AND CORROSIVITY

Laboratory tests conducted on selected soil samples yielded water soluble sulfates ranging from less than 100 parts per million (ppm) to 670 ppm. Based upon these results and our experience in the area, the site soils and bedrock are assigned to possess very severe (S3 or RS3) sulfate exposure per ACI 318 or ACI 332. We recommend the "ACI Manual of Concrete Practice", of the most recent edition be used for proper concrete mix design properties as they relate to these conditions.

The pH test results ranged from 7.8 to 8.0, the resistivity test results at in-situ moisture ranged from 558 to 2,139 ohm•cm, and the chloride test results ranged from 0.0009% to 0.0193%. These results are summarized on Figures 2 and 3 and on Table A-1 in Appendix A. The results of this testing should be used as an aid in choosing the construction materials in contact with these soils which will be resistant to the various corrosive forces. Manufacturer's representatives should be contacted regarding the specific corrosivity resistance for their products. In addition, local specifications should be consulted when selecting pipe materials.

PRELIMINARY FOUNDATION DESIGN CONCEPTS

The foundation recommendations for each structure are dependent upon the subsurface profile and engineering properties of the materials encountered at and near the depth of the proposed foundation. These are dependent upon the final configuration of and construction methods used

during overlot grading at the site. The information in the following sections presents preliminary foundation concepts which must be finalized for each building site upon completion of the overlot grading operations. AGW should be retained to design level soil and foundation studies after completion of site grading.

FOOTINGS

If the expansive clays and claystone bedrock are overexcavated and the excavated materials are placed as moisture treated fill, it is likely most if not all of the structures could be founded on spread or pad-type footings bearing on the moisture treated fill. The footings must be founded below frost depth. The footings will likely be designed for maximum soil bearing pressures ranging from 2,000 to 3,000 psf. Minimum dead load pressures of 700 to 1,000 psf will likely be required.

LATERAL EARTH PRESSURES

Foundation walls with fill on only one side will need to be designed for lateral earth pressures. For this site, lateral earth pressures calculated based upon equivalent fluid densities on the order of 50 to 70 pcf should be anticipated. The preliminary estimates are for properly placed and compacted fill at foundation walls. They should not be used for site retaining walls.

FIRST FLOOR CONSTRUCTION

The structures will be three story houses constructed over crawl spaces. Structural floors will be constructed in the living areas of the residences. For the garage areas, it is likely that there will be a low to moderate risk of garage slab movement after the expansive clay is overexcavated (where necessary) and placed as a moisture treated fill.

DRAIN SYSTEMS

Drain systems will be required around the lowest excavation level for below grade spaces for each structure. Either interior or exterior drains may be used. Connection of foundation drains to the underdrain is required in the JeffCo DBOD.

BACKFILL AND SURFACE DRAINAGE

Foundation backfill should be moistened and compacted to reduce future settlement. The site grading should consider a slope of 10% away from the foundation at the completion of construction. All other drainage swales in landscaped areas should slope at a minimum of 2%.

PRELIMINARY STREET PAVEMENT DESIGN

Pavement design is based on the engineering properties of the subgrade and pavement materials, the assumed design traffic conditions, and JeffCo pavement regulations. Effective pavement structures are composed of various pavement materials bearing upon properly prepared subgrade soils. The following preliminary pavement recommendations are based upon the subsurface conditions encountered and our experience in the area.

Based upon our laboratory testing and our experience in the area, it is anticipated that the subgrade materials encountered on this site can be expected to exhibit enough swell to negatively impact the performance of the pavement and will likely exceed the amount allowed by JeffCo. Additionally, since this site is located in the JeffCO DBOD, there is a minimum recommended overexcavation of 5 feet below the pavement subgrade. It is our experience that a 5-foot overexcavation may not be adequate in zones of the dipping bedrock. We recommend that a 10-foot overexcavation be considered. The overexcavation should be performed during site grading prior to construction of utilities within the right-of-way. Overexcavation should cover

the area from one foot beyond back of sidewalk (for attached sidewalk areas) or back of curb (for detached sidewalks). The excavated material may be placed as moisture treated fill (see Appendix B) within the right-of-way. Chemical stabilization will also be required per JeffCO.

It appears the proposed subgrade materials will likely be clay, claystone, sandstone, or fill constructed from these materials. According to AASHTO, these materials classify as A-2-4, A-6, and A-7-6 soils. Based upon the subgrade soil classifications, we have estimated the relative strengths of the subgrade soils presented above to determine the preliminary pavement thicknesses. Based on this information and utilizing the design methodology determined from the pavement design regulations for JeffCo, the alternatives presented below were calculated. These preliminary thickness recommendations are based on a design life of 20 years. It should be emphasized that the design alternatives provided above are preliminary for the materials anticipated. The final design thicknesses could be more or less than indicated depending upon the materials sampled during the final pavement design.

Pavement Thickness Recommendations

Street Type	HBP / CTS (in)	Concrete / CTS (in)
Alley	5.0 - 6.5 / 12.0	6.0 - 8.0 / 12.0
Local Street	5.5 - 7.0 / 12.0	-
Collector	6.0 - 7.5 / 12.0	-

HBP = Hot Bituminous Pavement, CTS = Chemically Treated Subgrade

Proper surface and subsurface drainage is essential for adequate performance of pavements. It has been our experience that water from landscaped areas can infiltrate pavement subgrade soils and result in softening of the subgrade followed by pavement damage. Therefore, provisions should be made to maintain adequate drainage and/or contain runoff from such areas.

In addition, water and irrigation lines should be thoroughly pressure tested for leaks prior to placement of pavement materials.

It must be reiterated that the information contained in this section is preliminary in nature. More detailed information will be required by JeffCo prior to issuance of a paving permit. Therefore, when overlot grading is complete at the site, a final pavement evaluation must be performed.

FINAL DESIGN CONSULTATION AND CONSTRUCTION OBSERVATION

This report has been prepared for the exclusive use of Richmond American Homes of Colorado, Inc. for the purpose of providing geotechnical criteria for the proposed project. The data gathered and the conclusions and recommendations presented herein are based upon the consideration of many factors including, but not limited to, the type of structures proposed, the configuration of the structures, the proposed usage of the site, the configuration of surrounding structures, the geologic setting, the materials encountered, and our understanding of the level of risk acceptable to the Client. Therefore, the conclusions and recommendations contained in this report should not be considered valid for use by others unless accompanied by written authorization from AGW.

AGW should be contacted if the Client desires an explanation of the contents of this report. AGW should be retained to provide future geotechnical services for the site including, but not limited to, design level geotechnical studies, consultation during design, observation and testing during construction, and other geotechnically related services. Failure to contract with AGW for these

services or selection of a firm other than AGW to provide these services will eliminate liability for AGW. We are available to discuss this with you.

GEOTECHNICAL RISK

The concept of risk is an important aspect of any geotechnical evaluation. The primary reason for this is that the analytical methods used to develop geotechnical recommendations do not comprise an exact science. The analytical tools which geotechnical engineers use are generally empirical and must be tempered by engineering judgment and experience. Therefore, the solutions or recommendations presented in any geotechnical evaluation should not be considered risk-free and, more importantly, are not a guarantee that the interaction between the soils and the proposed structures will perform as desired or intended. What the engineering recommendations presented in the preceding sections do constitute is our judgement of those measures that increase the chances for the structures and improvements performing satisfactorily. The Developer, Builder, and Owner must understand this concept of risk, as it is they who must ultimately decide what is an acceptable level of risk for the proposed development of the site.

LIMITATIONS

We believe the professional judgments expressed in this report are consistent with that degree of skill and care ordinarily exercised by practicing design professionals performing similar design services in the same locality, at the same time, at the same site and under the same or similar circumstances and conditions. No other warranty, express or implied, is made. In the event that any changes in the nature, design or location of the facility are made, the conclusions and recommendations contained in this report should not be considered valid unless the changes are

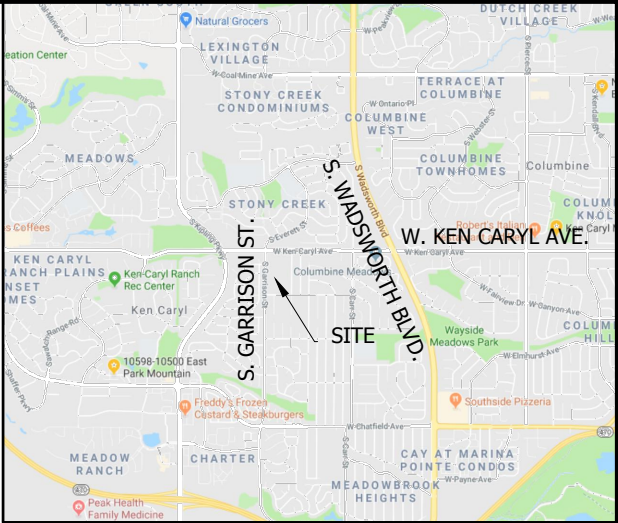
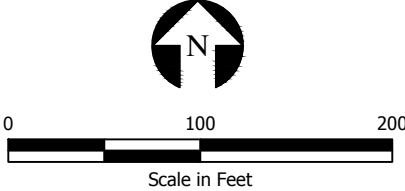
reviewed and the conclusions of this report are modified or verified in writing. Because of the constantly changing state of the practice in geotechnical engineering, and the potential for site changes after our field exploration, this report must not be relied upon after a period of three years without our firm being given the opportunity to review and, if necessary, revise our findings.

The test borings drilled for this study were spaced to obtain an understanding of subsurface conditions for design purposes. Variations frequently occur from these conditions which are not indicated by the test boring. These variations are sometimes sufficient to necessitate modifications in the designs. If unexpected subsurface conditions are observed by any party during site development, we must be notified to review our recommendations.

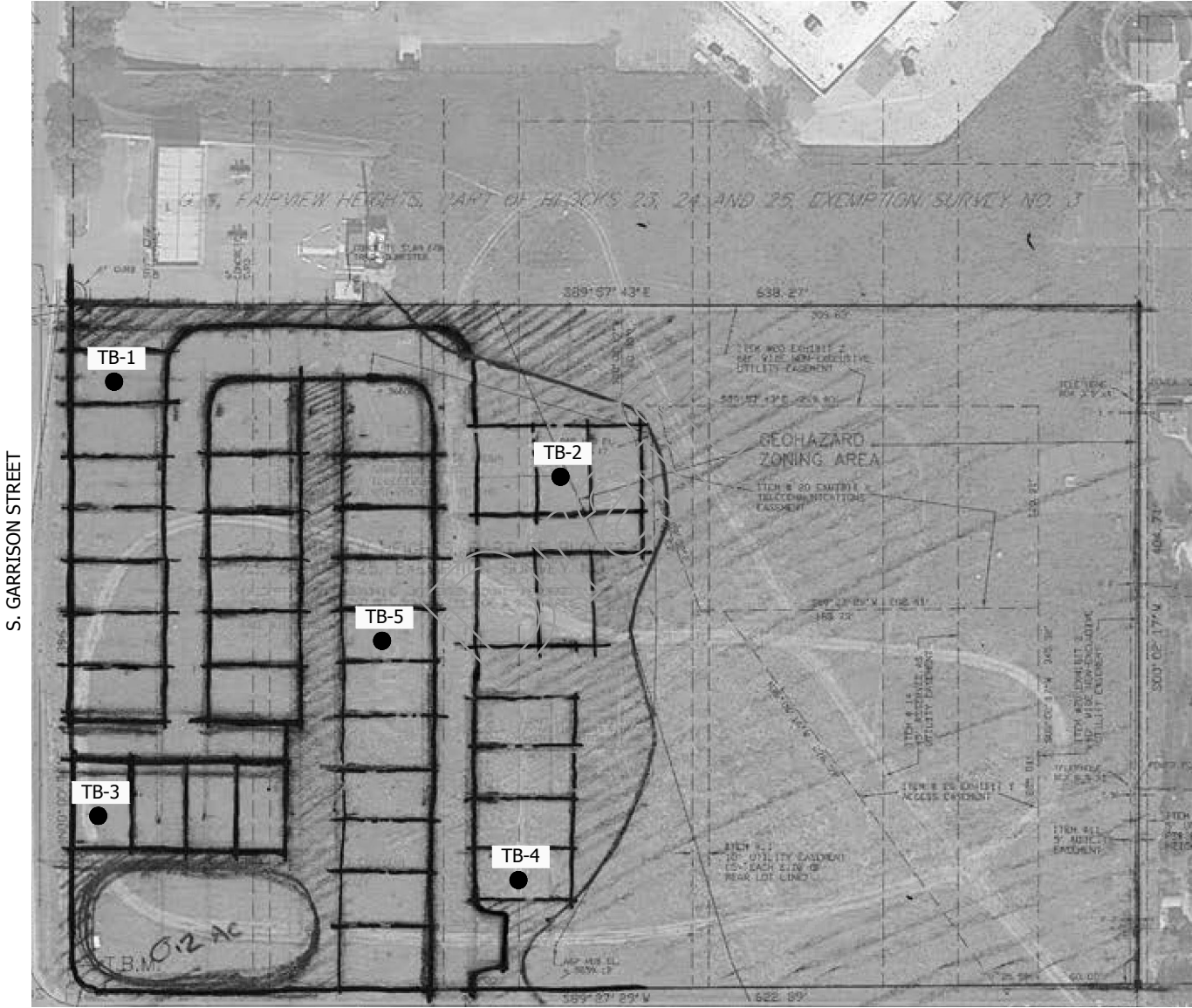
Our scope of services for this project did not include, either specifically or by implication, any research, identification, testing, or assessment relative to past or present contamination of the site by any source, including biological (i.e., mold, fungi, bacteria, etc.). If such contamination were present, it is likely that the exploration and testing conducted for this report would not reveal its existence. If the Client is concerned about the potential for such contamination or pollution, additional studies should be undertaken. We are available to discuss the scope of such studies with you.

Our scope of services for this project did not include a local or global geological risk assessment. Therefore, issues such as mine subsidence, slope stability, faults, etc. were not researched or addressed as part of this study. If the Client is concerned about these issues, we are available to discuss the scope of such studies upon your request.

FAIRVIEW
JEFFERSON COUNTY, COLORADO



VICINITY MAP
NOT TO SCALE

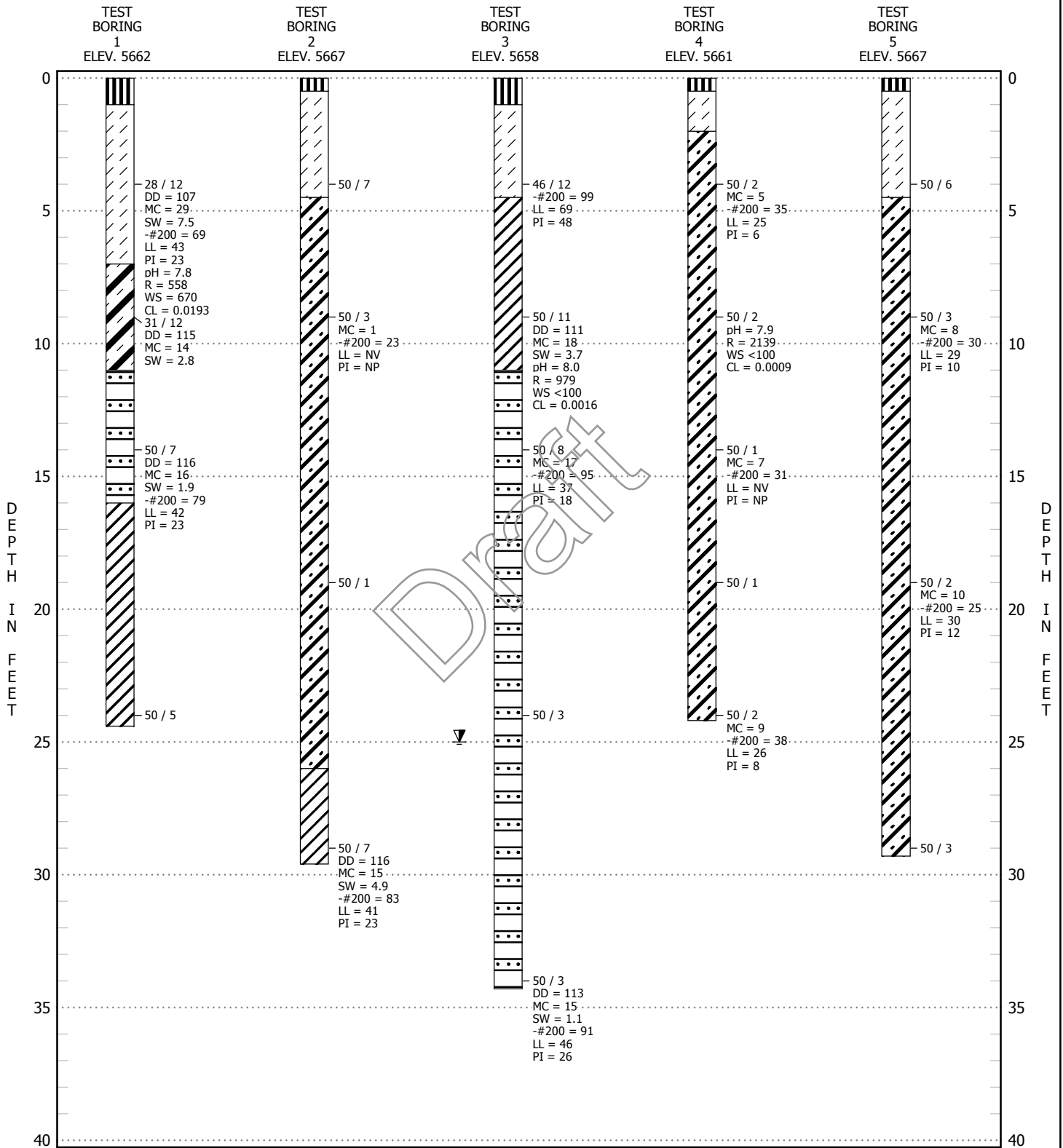


S. GARRISON STREET

W. FAIRVIEW AVENUE

- NOTES:
1. TEST BORINGS ARE OVERLAID ON THE "FAIRVIEW CONCEPT B", PLAN, PREPARED BY NORRIS DESIGN, DATED MAY 2018.
 2. ALL LOCATIONS ARE APPROXIMATE.

SITE PLAN AND VICINITY MAP	PROJECT NO. 184332 FIGURE 1



SEE FIGURE 3 FOR LEGEND AND NOTES TO TEST BORINGS

TEST BORING LOGS

FIGURE 2







CLIENT Richmond American Homes of Colorado, Inc.

PROJECT NAME Fairview







PROJECT NUMBER 184332

PROJECT LOCATION Jefferson County, Colorado

SOIL DESCRIPTIONS

-  Topsoil, clay, sandy, organic
-  Clay, stiff to very stiff
-  Clay (weathered claystone), medium stiff to stiff
-  Claystone (Bedrock), hard to very hard
-  Sandstone (Bedrock), hard to very hard
-  Claystone/Sandstone (Bedrock), interbedded, hard to very hard

ABBREVIATIONS

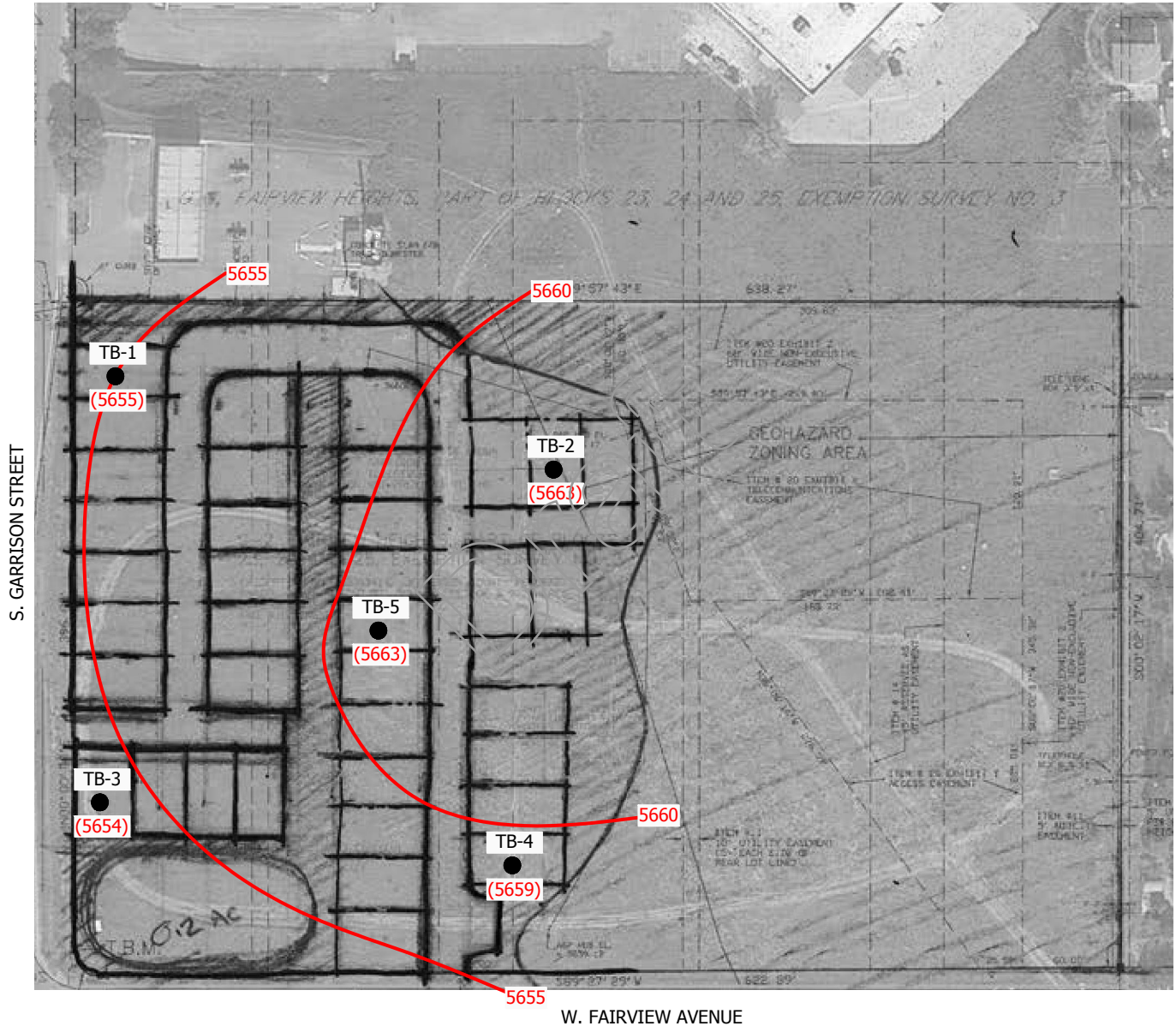
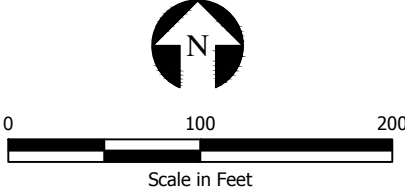
- DD Dry density of sample in pounds per cubic foot (pcf)
- MC Moisture content as a percentage of dry weight of soil (%)
- SW Percent swell under a surcharge of 1000 pounds per square foot (psf) upon wetting (%)
- COM Percent compression under a surcharge of 1000 pounds per square foot (psf) upon wetting (%)
- #200 Percent passing the Number 200 sieve (%)
- LL Liquid Limit
- PI Plasticity Index
- NP Non-Plastic
- NV No Value
- pH Acidity or alkalinity of sample in pH units
- R Resistivity in ohms.cm
- WS Water soluble sulfates in parts per million (ppm)
- CL Chlorides in percent (%)
- x/y X blows of a 140-pound hammer falling 30 inches were required to drive a 2.5-inch outside diameter sampler Y inches
- x/y SS X blows of a 140-pound hammer falling 30 inches were required to drive a 2.0-inch outside diameter sampler Y inches
- C-x Depth of cut to bottom of foundation or retaining wall (rounded to the nearest foot)
- F-x Depth of fill to bottom of foundation or retaining wall (rounded to the nearest foot)
- FG Finished grade (rounded to the nearest foot)
- NR No sample recovered
- Bounce Sampler bounced during driving
- B Bulk sample
- AS Auger sample
-  Moderately to well cemented layer
- Approximate bottom of foundation
-  Depth at which practical drilling refusal was encountered
-  Water level at time of drilling
-  Caved depth at time of drilling
-  Water level 4 day(s) after drilling
-  Caved depth 4 day(s) after drilling

Notes:

1. Test borings were drilled July 13, 2018 .
2. Location of the test borings were staked by others at locations chosen by this firm.
3. The horizontal lines shown on the logs are to differentiate materials and represent the approximate boundaries between materials. The transitions between materials may be gradual.
4. Elevations were obtained from staking provided by others and have been rounded to the nearest foot.
5. Boring logs shown in this report are subject to the limitations, explanations, and conclusions of this report.

LEGEND AND NOTES
FIGURE 3

FAIRVIEW
JEFFERSON COUNTY, COLORADO

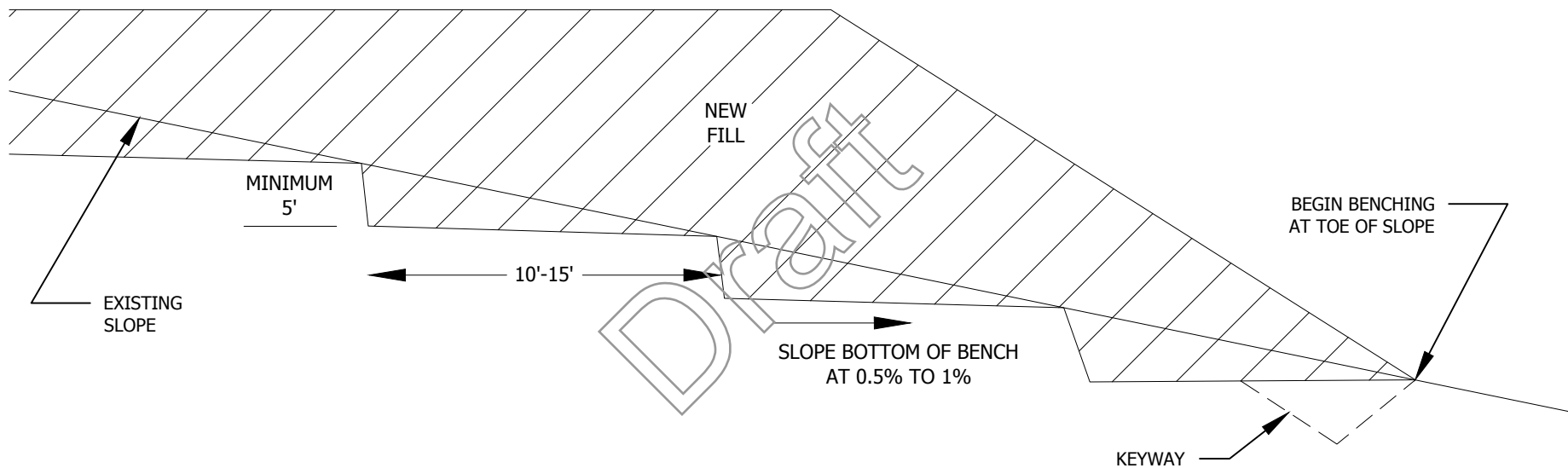


TB-1
● INDICATES BEDROCK WAS ENCOUNTERED AT AN ELEVATION OF 5,655 FEET IN TEST BORING 1

NOTES:

1. TEST BORINGS ARE OVERLAID ON THE "FAIRVIEW CONCEPT B", PLAN, PREPARED BY NORRIS DESIGN, DATED MAY 2018.
2. ALL LOCATIONS ARE APPROXIMATE.
3. ELEVATIONS ARE BASED UPON THE TEST BORING ELEVATIONS PROVIDED ON THE TEST BORING STAKES AND THE RECORDED DEPTHS TO BEDROCK.
4. ELEVATION CONTOURS ARE BASED UPON THE EXTRAPOLATION OF DATA FROM WIDELY SPACED TEST BORINGS. LOCAL AND SIGNIFICANT VARIATIONS MAY OCCUR BETWEEN THE BORINGS. THIS MAP REPRESENTS AN OPINION WHICH IS ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHODS USED.

A.G. WASSENAAR INC.	
ESTIMATED ELEVATION OF BEDROCK	PROJECT NO. 184332 FIGURE 4



NOTES:

1. BENCHING REQUIRED WHEN EXISTING SLOPE IS 5:1 (HORIZONTAL:VERTICAL) OR STEEPER
2. CONTINUE BENCHING UNTIL NATURAL SLOPE FLATTENS OR SLOPE DAYLIGHTS
3. DRAINS MAY BE REQUIRED IF GROUND WATER IS ENCOUNTERED.
4. ADDITIONAL CUTTING BACK OF SOME SLOPES MAY BE REQUIRED BY GEOTECHNICAL ENGINEER IF SLOPE INSTABILITY IS NOTED.
5. A KEYWAY MAY BE REQUIRED BY GEOTECHNICAL ENGINEER DEPENDING UPON SLOPE CONFIGURATION.

NOT TO SCALE

A. G. WASSENAAR | INC.

GENERALIZED
BENCHING
DETAIL

PROJECT NO. 184332
FIGURE 5

APPENDIX A
LABORATORY TEST RESULTS

SUMMARY OF LABORATORY TEST RESULTS TABLE A-1

SWELL-CONSOLIDATION TEST RESULTS FIGURES A-1 THROUGH A-5

GRADATION/ATTERBERG TEST RESULTS FIGURES A-6 THROUGH A-11

GRADATION/ATTERBERG WITH HYDROMETER TEST RESULTS FIGURE A-12

STANDARD PROCTOR TEST RESULTS FIGURE A-13

Draft

TABLE A-1
SUMMARY OF LABORATORY TEST RESULTS
 August 1, 2018

Test Boring Number	Depth (feet)	Soil Type	Natural Dry Density (pcf)	Natural Moisture (%)	Swell / Consolidation (-) (%) ¹	Swell Pressure (psf)	Specific Gravity	% Passing #200 Sieve	% Clay	Atterberg		pH	Resistivity (ohm•cm)	Water Soluble Sulfates (ppm)	Chlorides (%)
										Liquid Limit LL	Plasticity Index PI				
1	4	Clay, very sandy, silty	107	29	7.5	18,900	2.614	69	40.6	43	23	7.8	558	670	0.0193
1	9	Clay (Weathered Claystone), sandy	115	14	2.8	8,700									
1	14	Claystone/Sandstone, silty	116	16	1.9	6,800		79		42	23				
2	9	Sandstone, silty		1				23		NV	NP				
2	29	Claystone, sandy	116	15	4.9	13,200		83		41	23				
3	4	Claystone, very silty, trace sand					2.608	99	64.3	69	48				
3	9	Claystone, sandy	111	18	3.7	8,000						8.0	979	<100	0.0016
3	14	Claystone/Sandstone, silty		17				95		37	18				
3	34	Claystone/Sandstone, silty	113	15	1.1	3,000		91		46	26				
4	4	Sandstone, very silty, very clayey		5				35		25	6				
4	9	Sandstone, very silty, very clayey										7.9	2,139	<100	0.0009
4	14	Sandstone, very silty, very clayey		7				31		NV	NP				
4	24	Sandstone, very clayey		9				38		26	8				
5	9	Sandstone, very clayey		8				30		29	10				
5	19	Sandstone, clayey		10				25		30	12				

TABLE A-1
SUMMARY OF LABORATORY TEST RESULTS
 August 1, 2018

Test Boring Number	Depth (feet)	Soil Type	Natural Dry Density (pcf)	Natural Moisture (%)	Swell / Consolidation (-) (%) ¹	Swell Pressure (psf)	Specific Gravity	% Passing #200 Sieve	% Clay	Atterberg		pH	Resistivity (ohm•cm)	Water Soluble Sulfates (ppm)	Chlorides (%)
										Liquid Limit LL	Plasticity Index PI				
Bulk ²	NA	Blended Bulk Sample (Clay, very sandy)	112.0 ³	15.5 ³				51		22	12				
Bulk	-2	Blended Bulk Sample (-2% OMC remold)	106	14	0.3	-									
Bulk	0	Blended Bulk Sample (OMC remold)	107	16	0.0	-									
Bulk	2	Blended Bulk Sample (+2% OMC remold)	106	18	-0.1	-									
Bulk	4	Blended Bulk Sample (+4% OMC remold)	107	20	-0.3	-									

Notes:

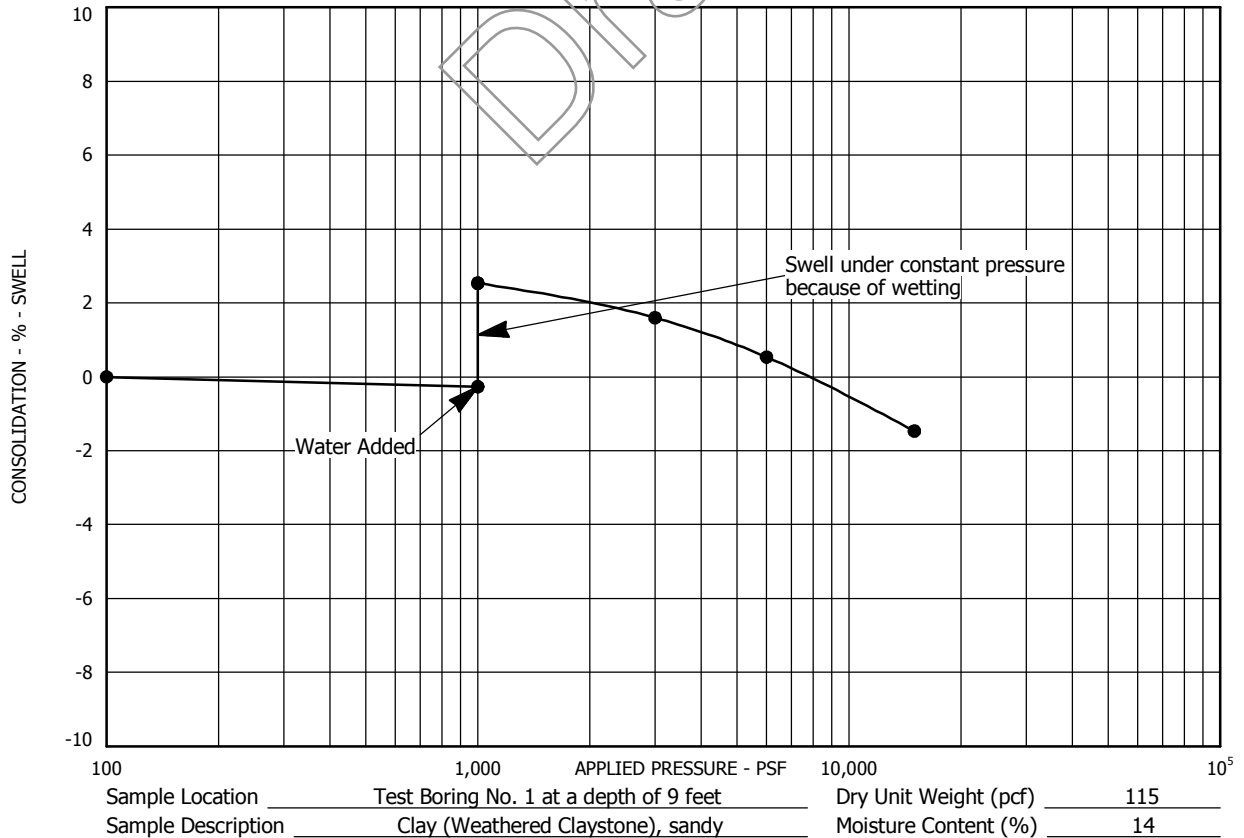
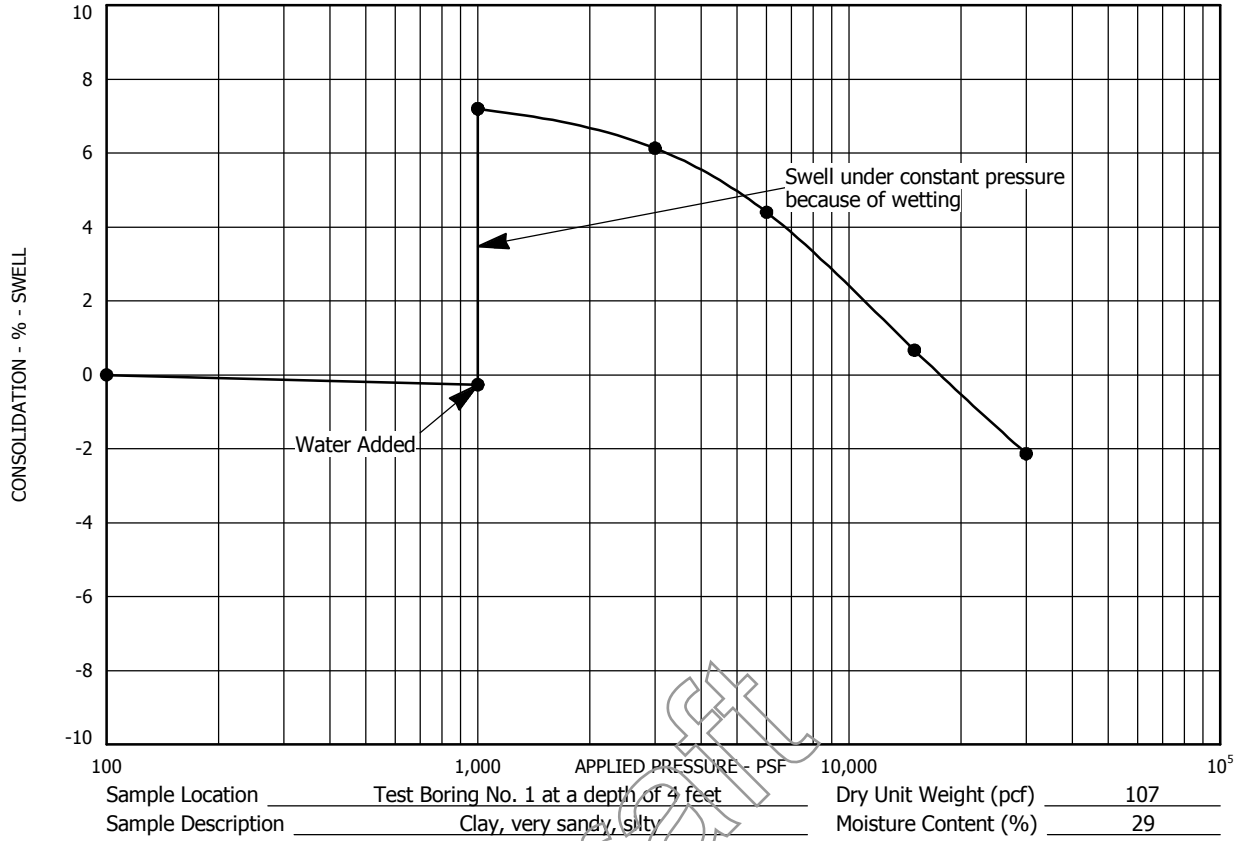
¹ Indicates percent swell or consolidation when wetted under a 1,000 psf load

² Bulk is a blended bulk sample obtained from the auger cuttings of various test borings

³ Maximum dry density (MDD) and optimum moisture content (OMC)

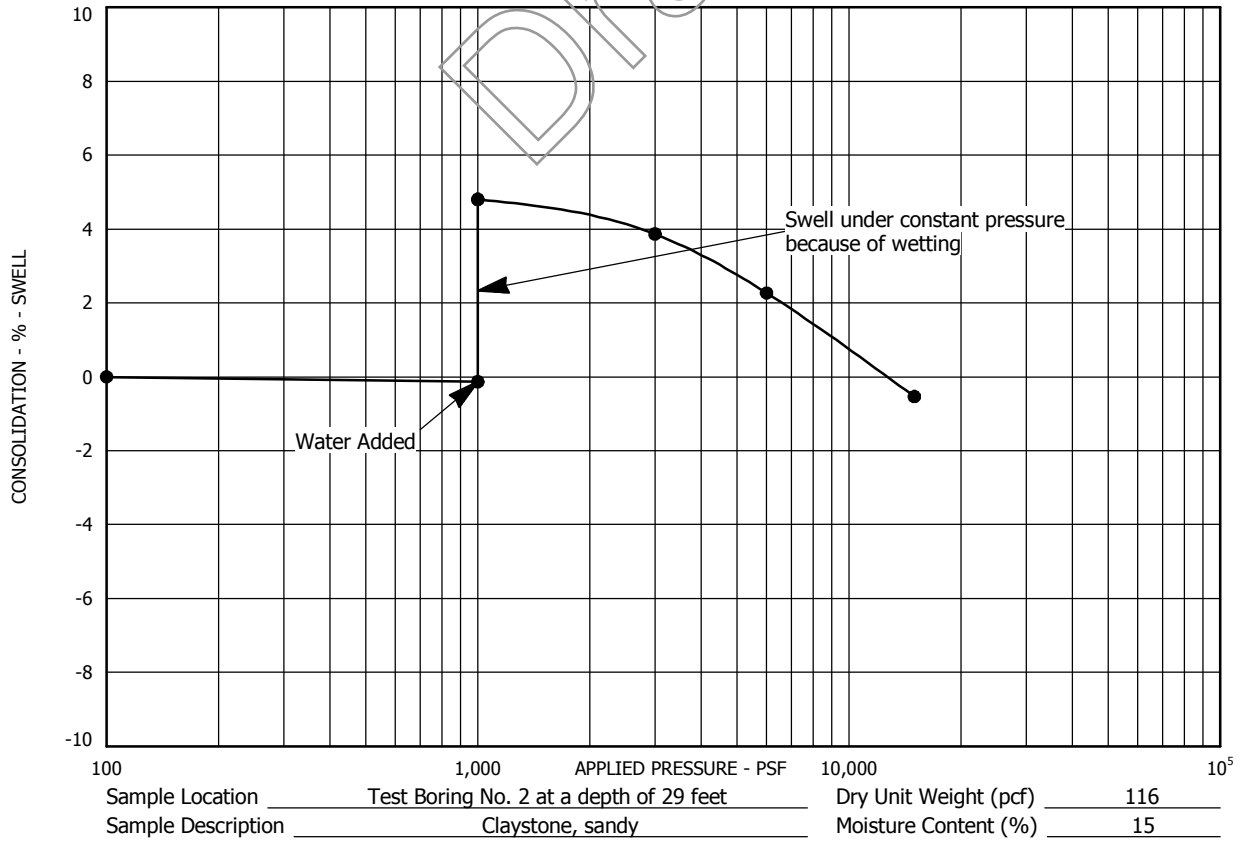
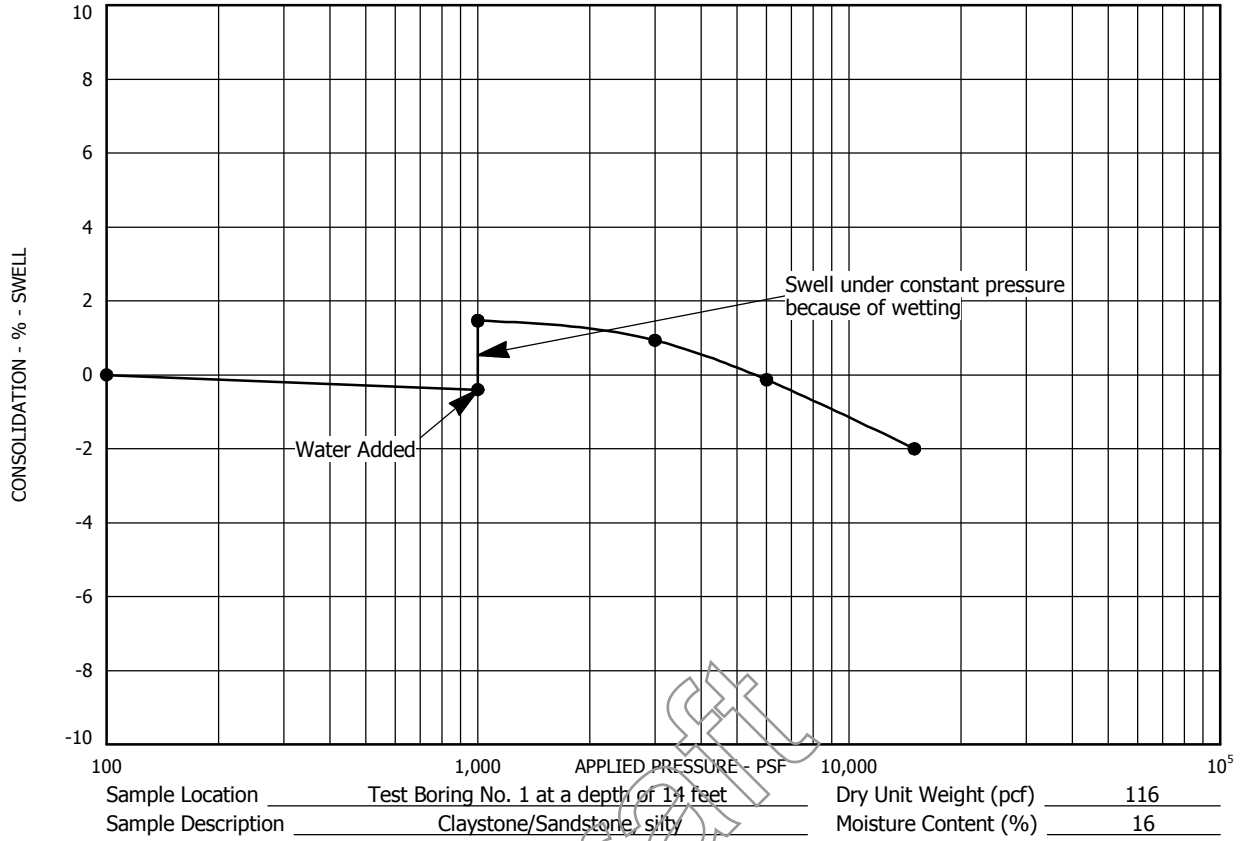
NV - No Value, NP - Nonplastic

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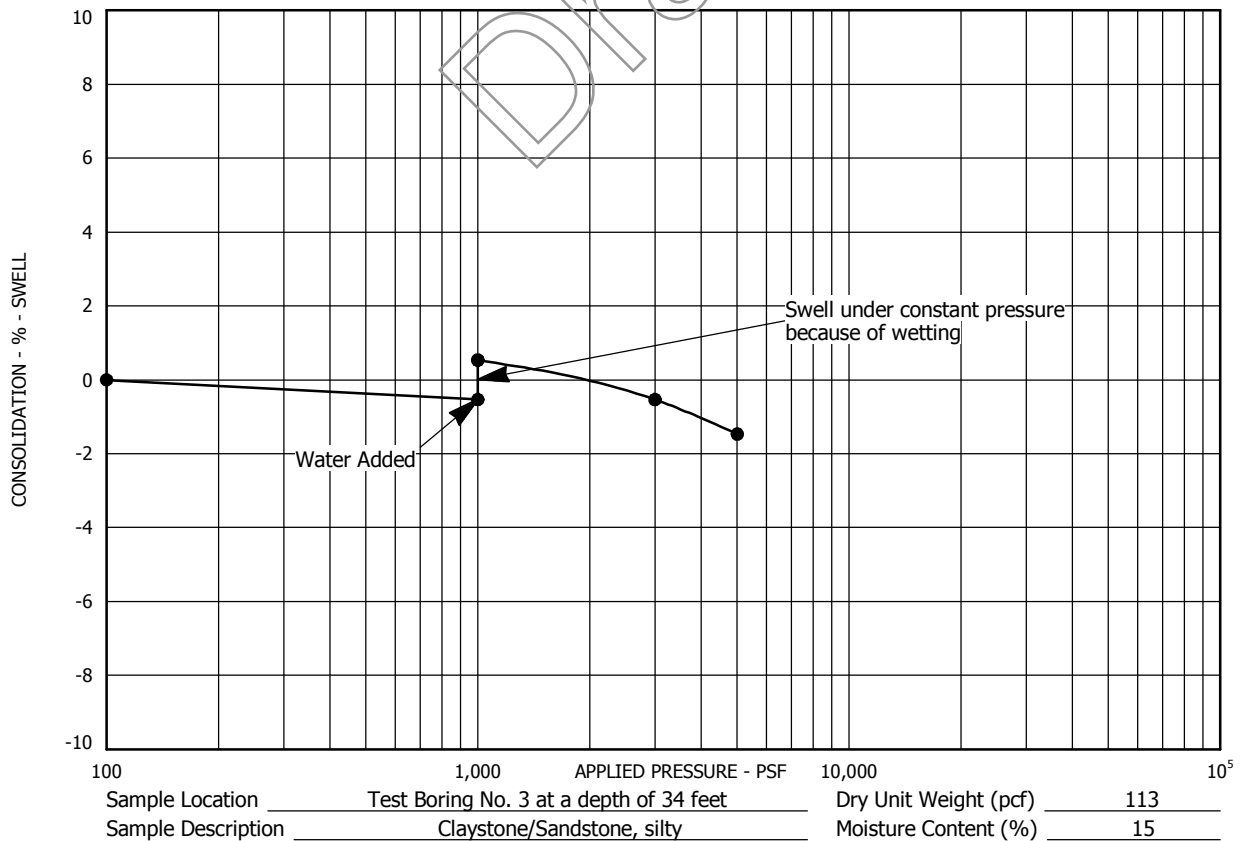
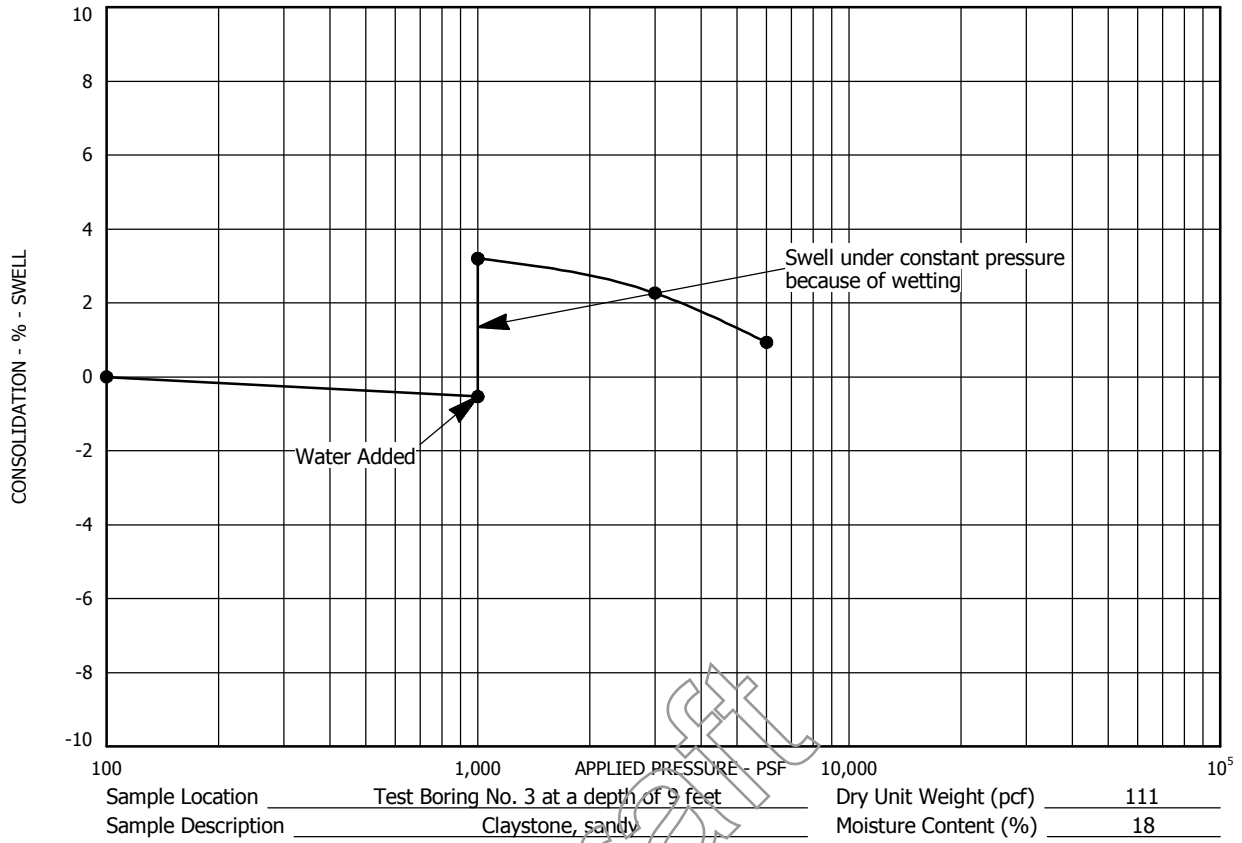
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-1



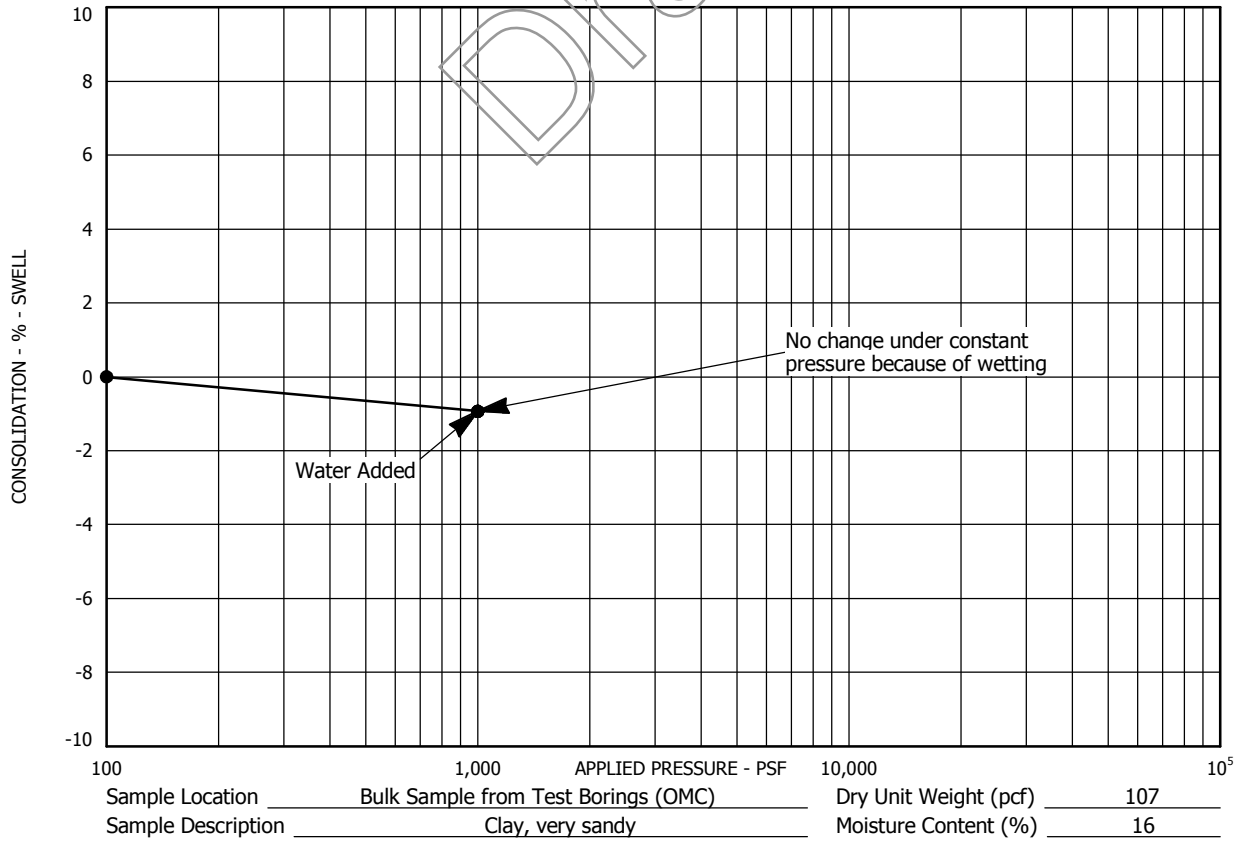
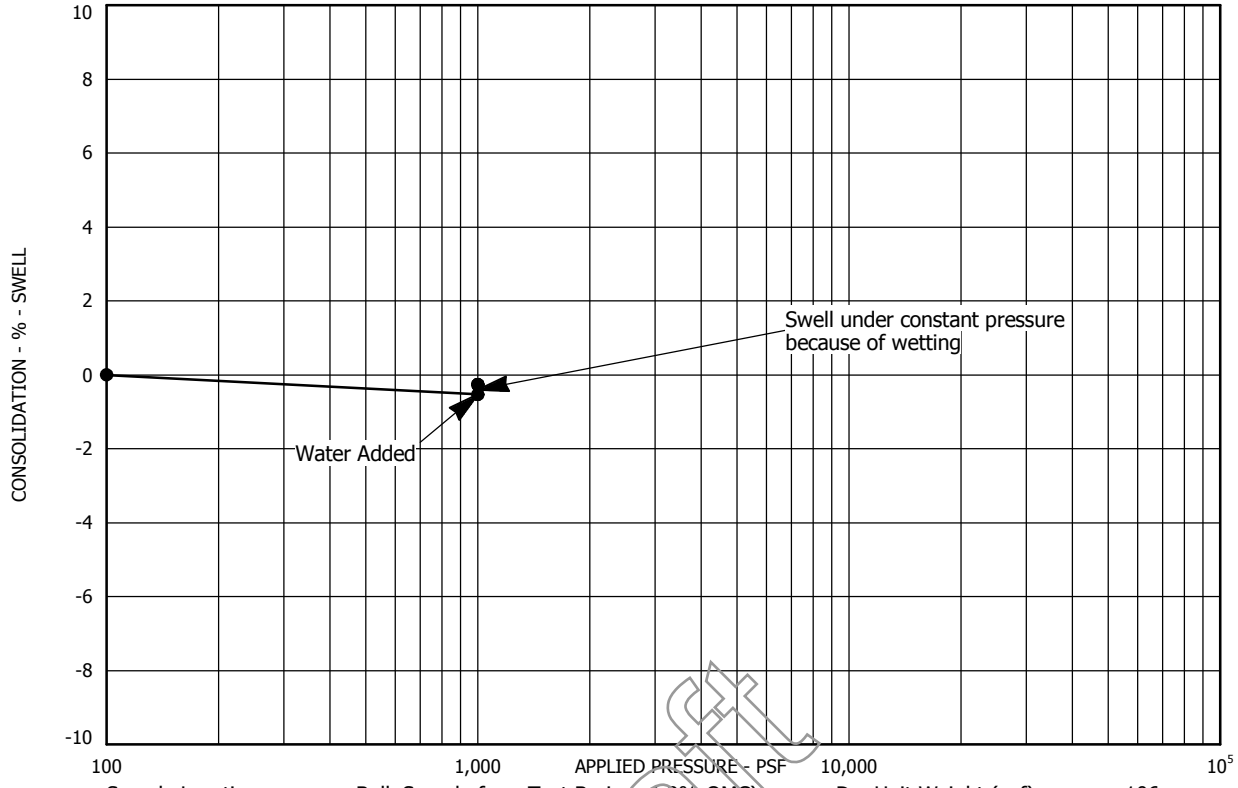
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-2



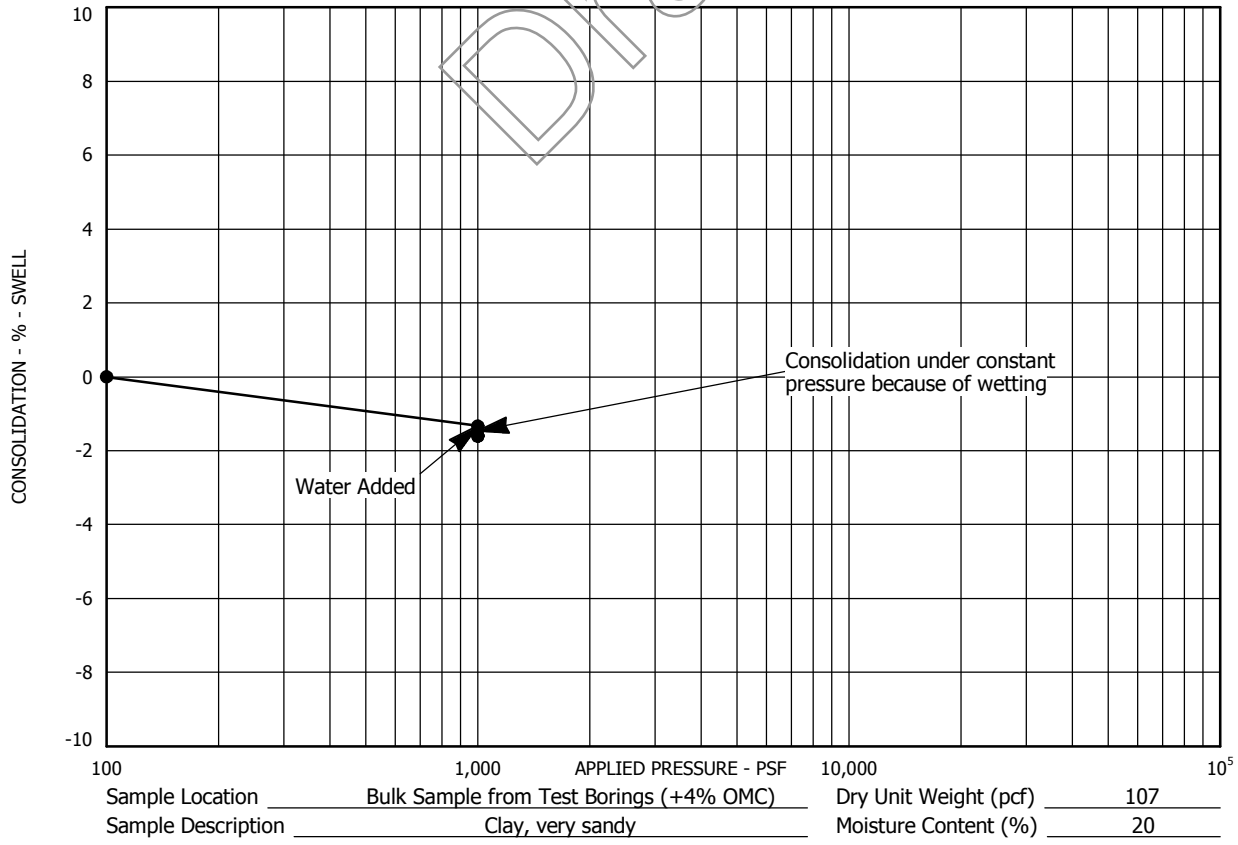
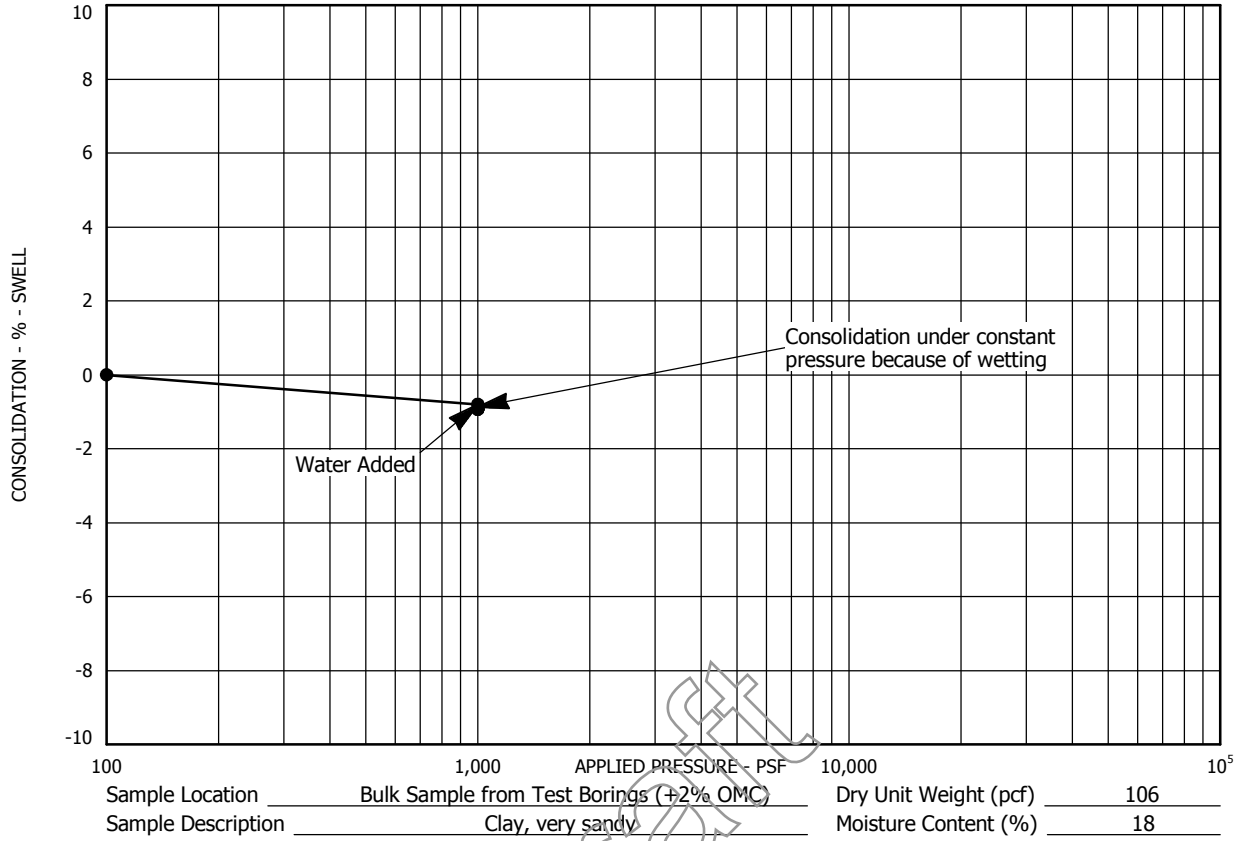
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-3



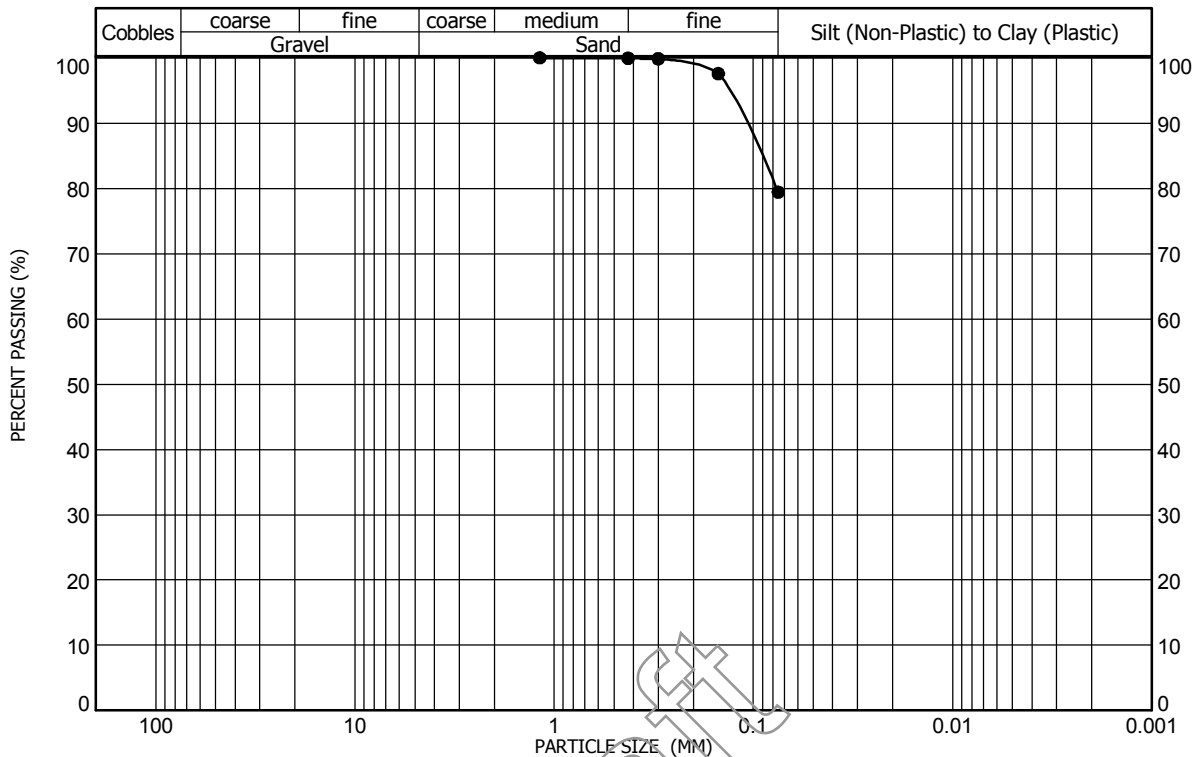
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-4

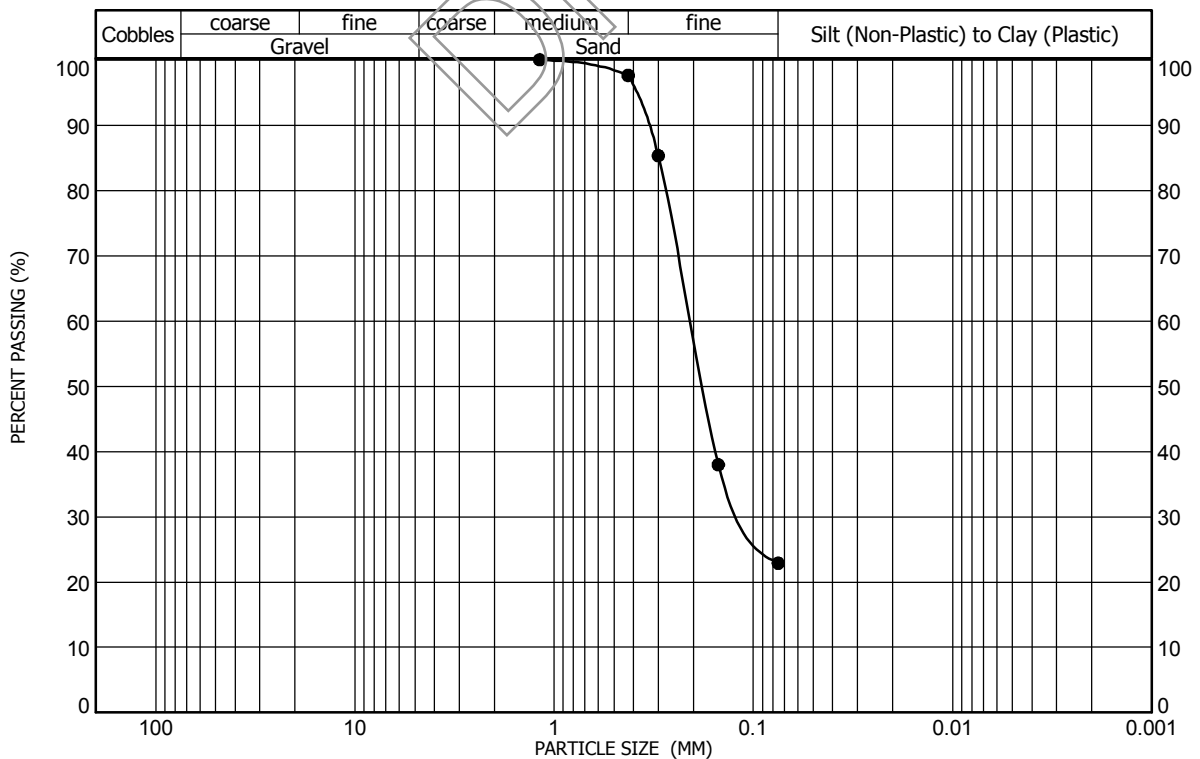


SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-5



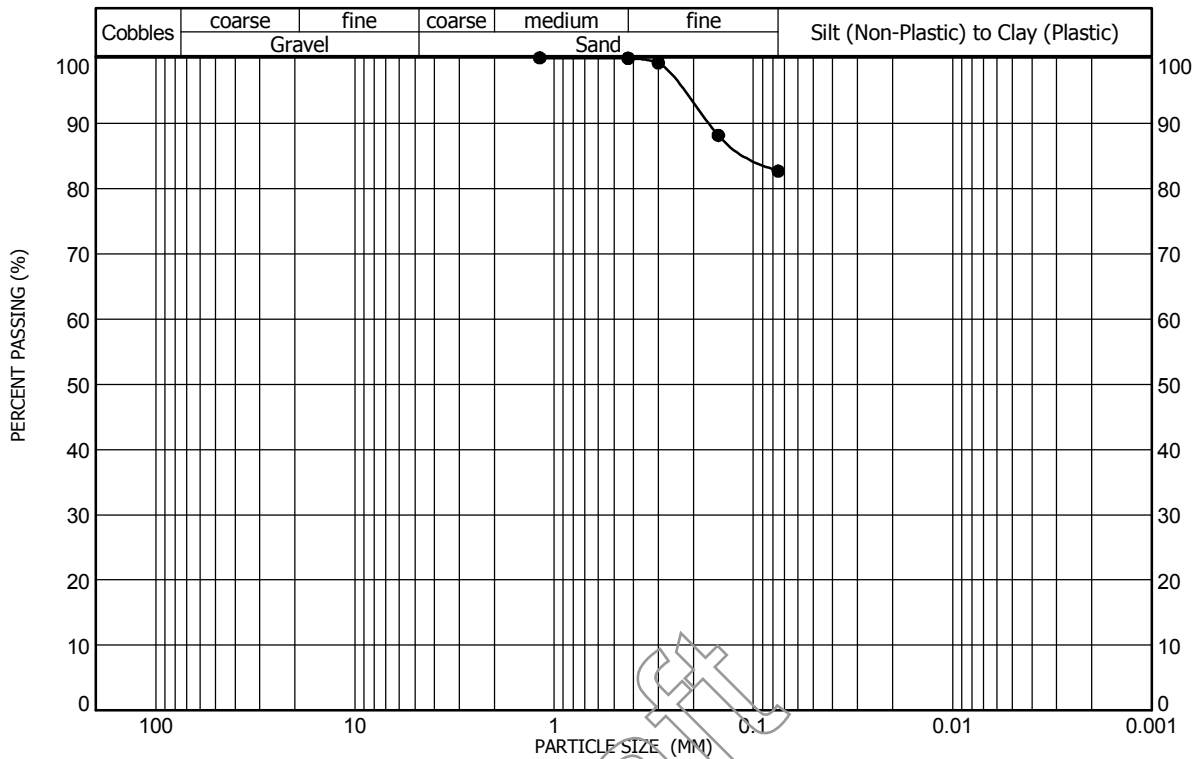
Sample Location Test Boring No. 1 at a depth of 14 feet Gravel (%) 0 Liquid Limit 42
 Sample Description Claystone/Sandstone, silty Sand (%) 21 Plasticity Index 23
 Classification A-7-6(18), LEAN CLAY with SAND(CL) Clay/Silt (%) 79



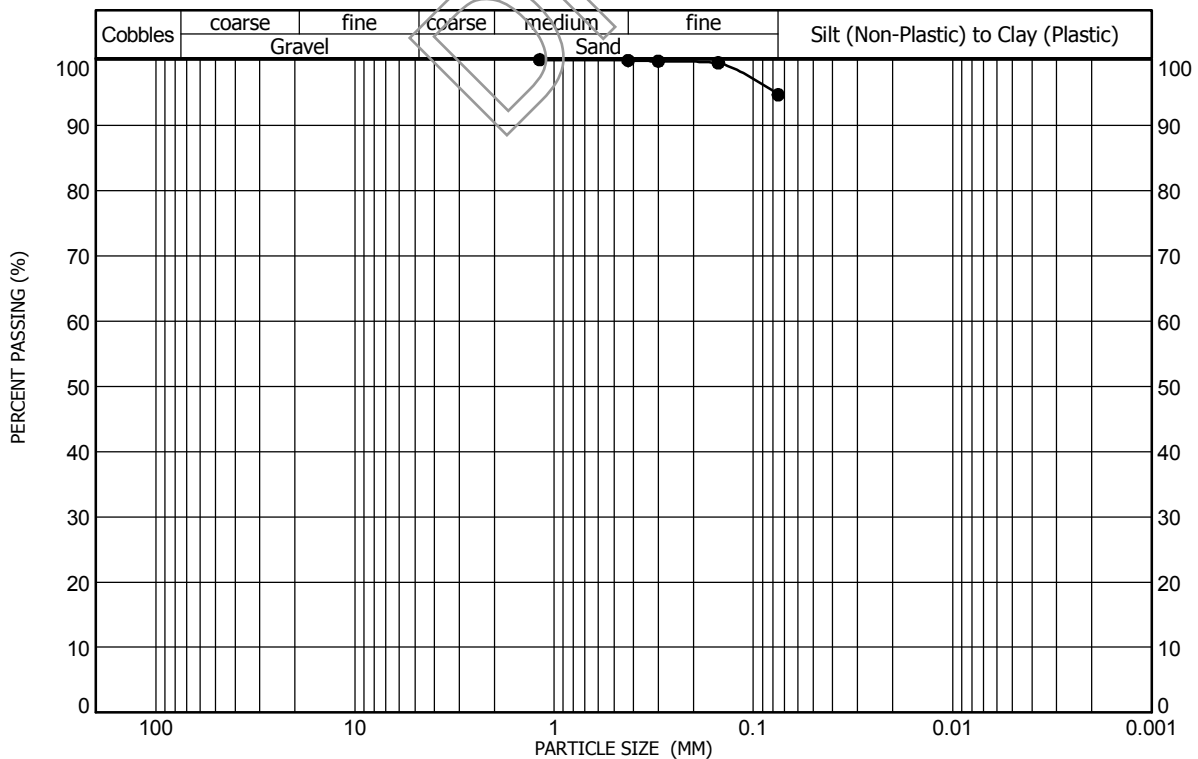
Sample Location Test Boring No. 2 at a depth of 9 feet Gravel (%) 0 Liquid Limit NV
 Sample Description Sandstone, silty Sand (%) 77 Plasticity Index NP
 Classification A-2-4(0), SILTY SAND(SM) Clay/Silt (%) 23

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-6



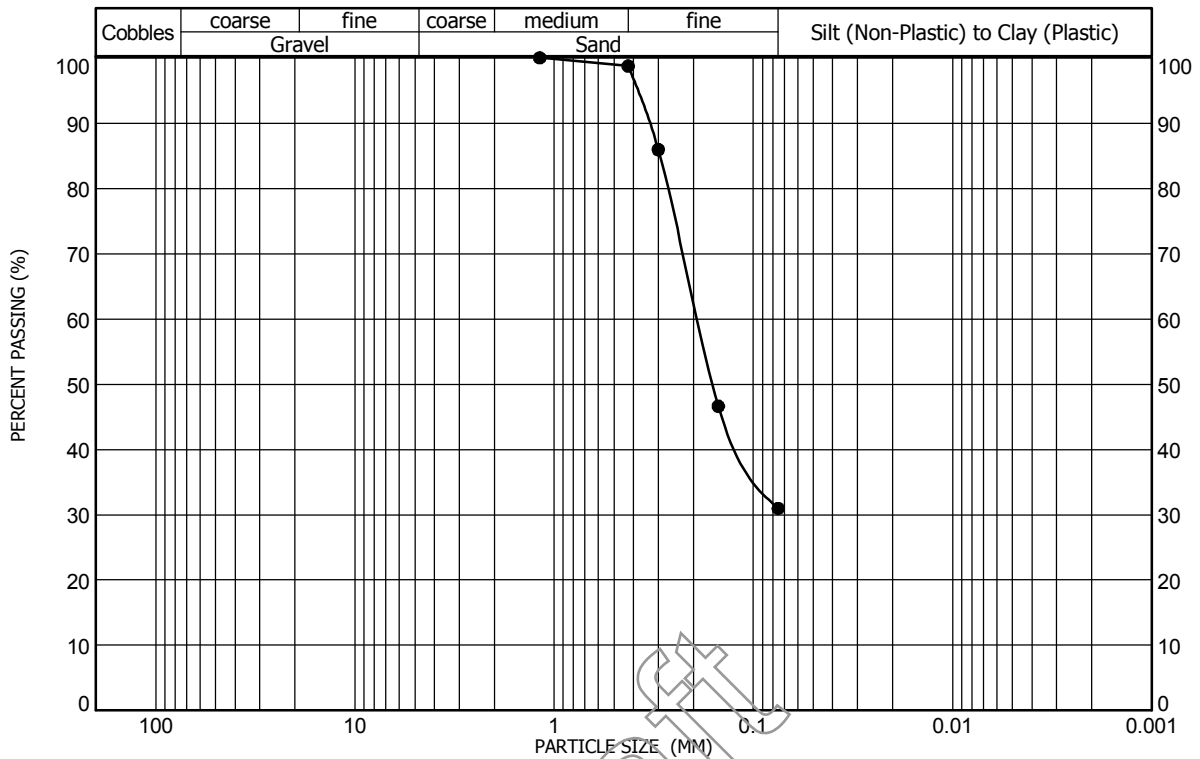
Sample Location Test Boring No. 2 at a depth of 29 feet Gravel (%) 0 Liquid Limit 41
 Sample Description Claystone, sandy Sand (%) 17 Plasticity Index 23
 Classification A-7-6(19), LEAN CLAY with SAND(CL) Clay/Silt (%) 83



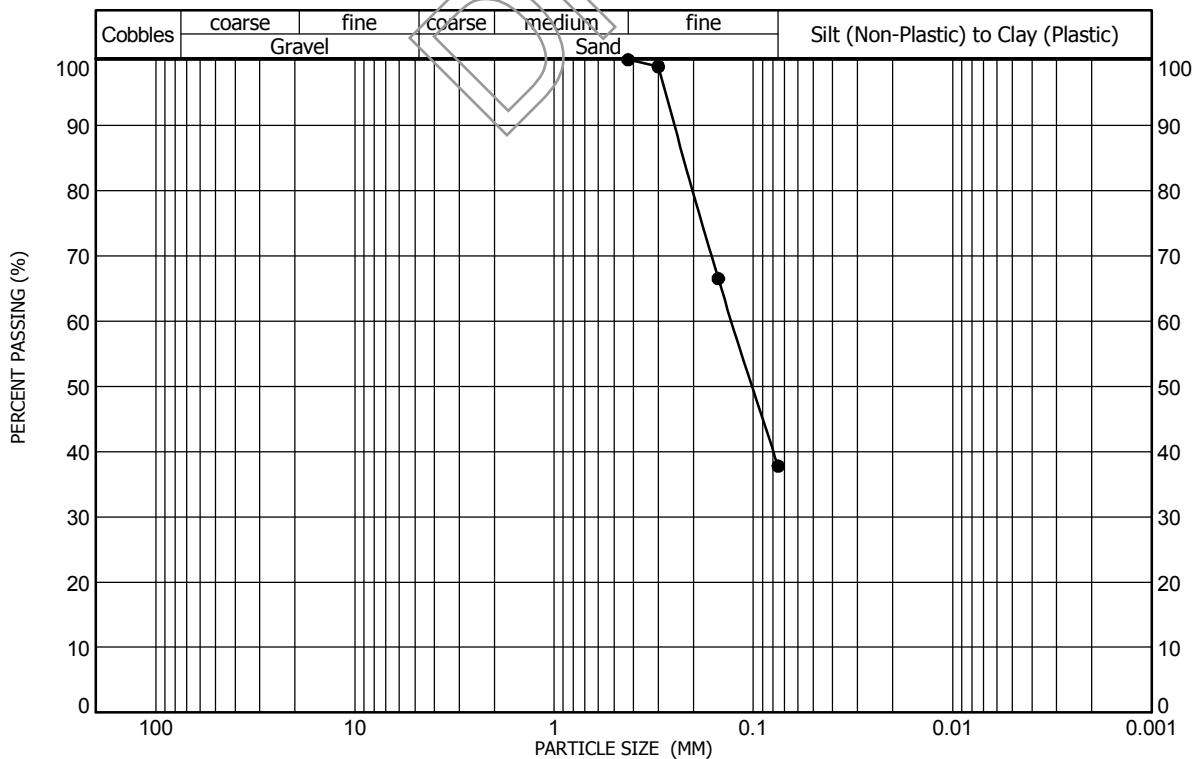
Sample Location Test Boring No. 3 at a depth of 14 feet Gravel (%) 0 Liquid Limit 37
 Sample Description Claystone/Sandstone, silty Sand (%) 5 Plasticity Index 18
 Classification A-6(18), LEAN CLAY(CL) Clay/Silt (%) 95

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-7



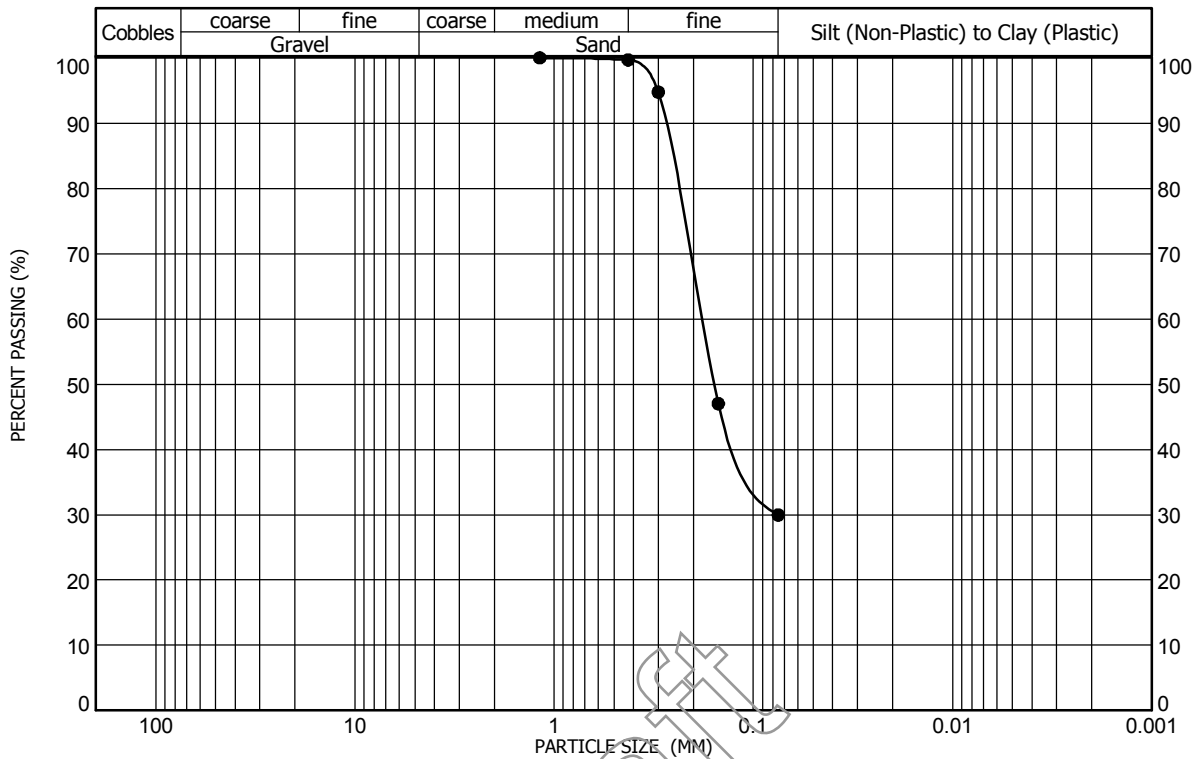
Sample Location Test Boring No. 4 at a depth of 14 feet Gravel (%) 0 Liquid Limit NV
 Sample Description Sandstone, very silty, very clayey Sand (%) 69 Plasticity Index NP
 Classification A-2-4(0), SILTY SAND(SM) Clay/Silt (%) 31



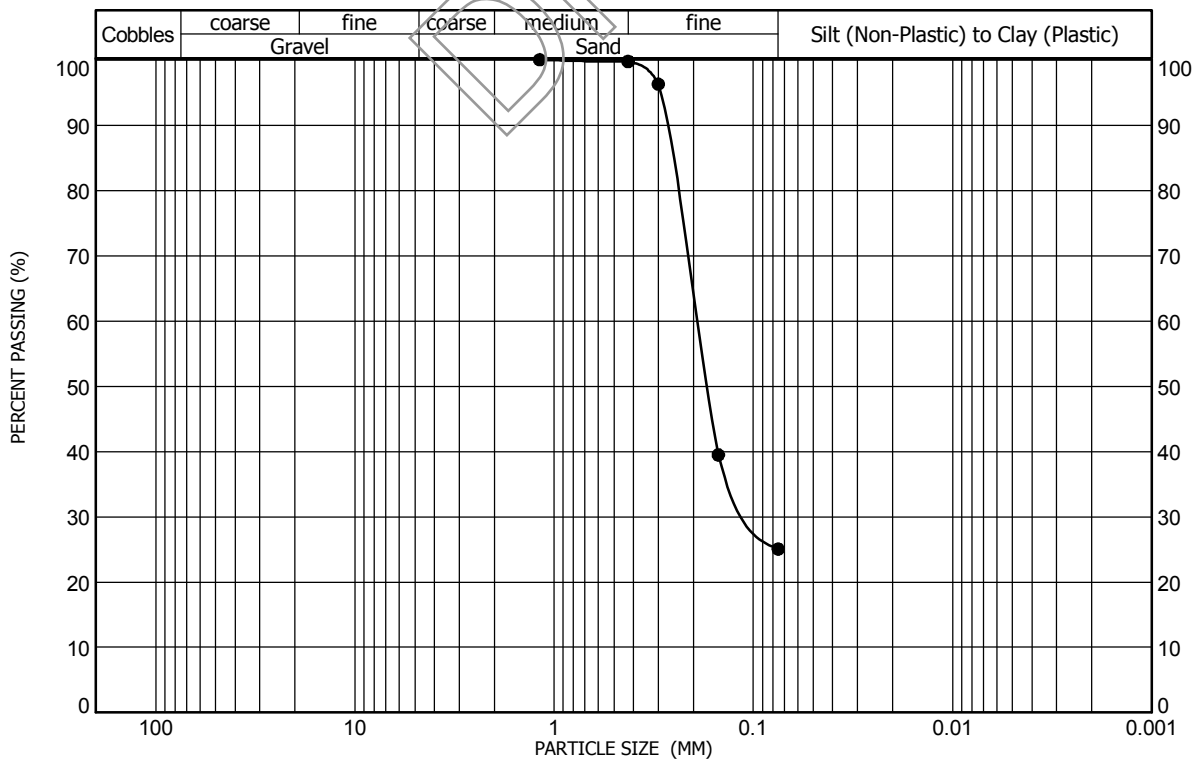
Sample Location Test Boring No. 4 at a depth of 24 feet Gravel (%) 0 Liquid Limit 26
 Sample Description Sandstone, very clayey Sand (%) 62 Plasticity Index 8
 Classification A-4(0), CLAYEY SAND(SC) Clay/Silt (%) 38

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-9



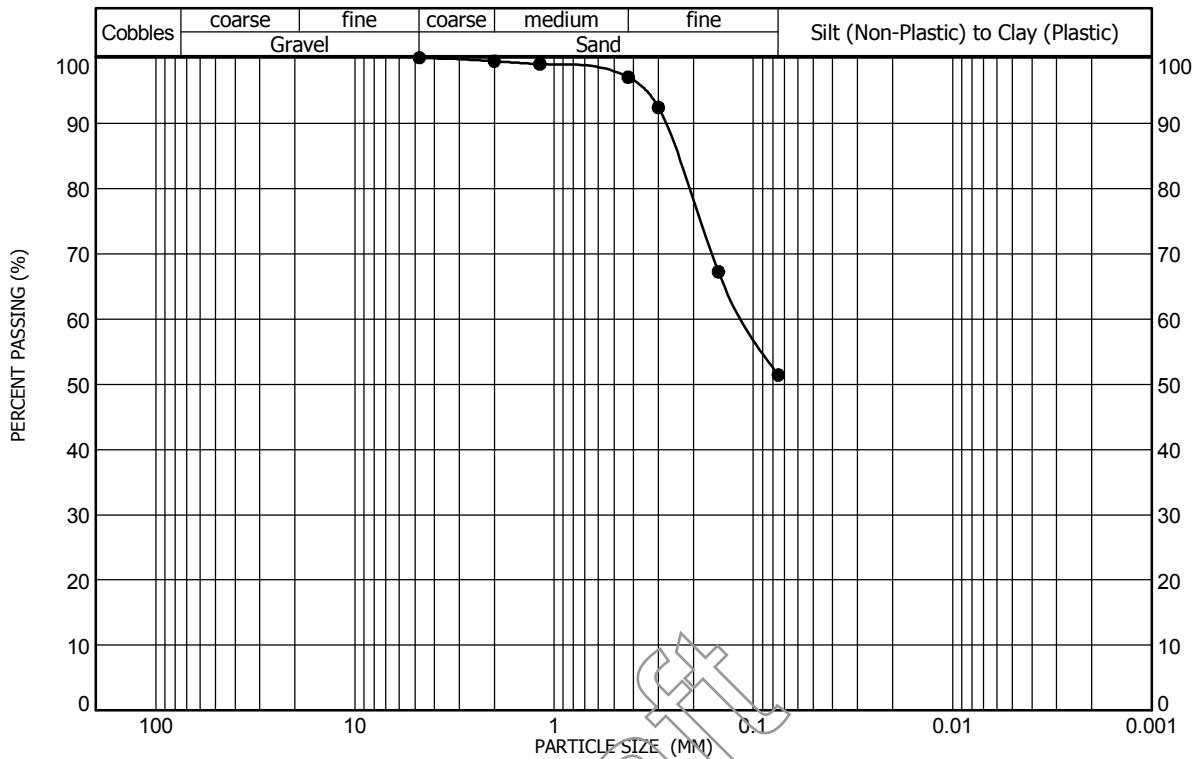
Sample Location Test Boring No. 5 at a depth of 9 feet Gravel (%) 0 Liquid Limit 29
 Sample Description Sandstone, very clayey Sand (%) 70 Plasticity Index 10
 Classification A-2-4(0), CLAYEY SAND(SC) Clay/Silt (%) 30



Sample Location Test Boring No. 5 at a depth of 19 feet Gravel (%) 0 Liquid Limit 30
 Sample Description Sandstone, clayey Sand (%) 75 Plasticity Index 12
 Classification A-2-6(0), CLAYEY SAND(SC) Clay/Silt (%) 25

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-10



Sample Location	Bulk Sample from Test Borings	Gravel (%)	0	Liquid Limit	22
Sample Description	Clay, very sandy	Sand (%)	49	Plasticity Index	12
Classification	A-6(2), SANDY LEAN CLAY (CL)	Clay/Silt (%)	51		

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-11

CLIENT Richmond American Homes of Colorado, Inc.

PROJECT NAME Fairview

PROJECT NUMBER 184332

PROJECT LOCATION Jefferson County, Colorado

TEST RESULTS

Maximum Dry Density 112.0 PCF
 Optimum Water Content 15.5 %

Sample Location Bulk Sample from Test Borings
 Sample Source _____
 AGW Description Clay, very sandy
 USCS Classification SANDY LEAN CLAY(CL)
 AASHTO Classification A-6(2)
 Test Method D698A

Gravel (%) 0
 Sand (%) 49
 Silt/Clay (%) 51
 Liquid Limit 22
 Plasticity Index 12

Curves of 100%
 Saturation for
 Specific Gravity Equal to:
 2.80
 2.70
 2.60

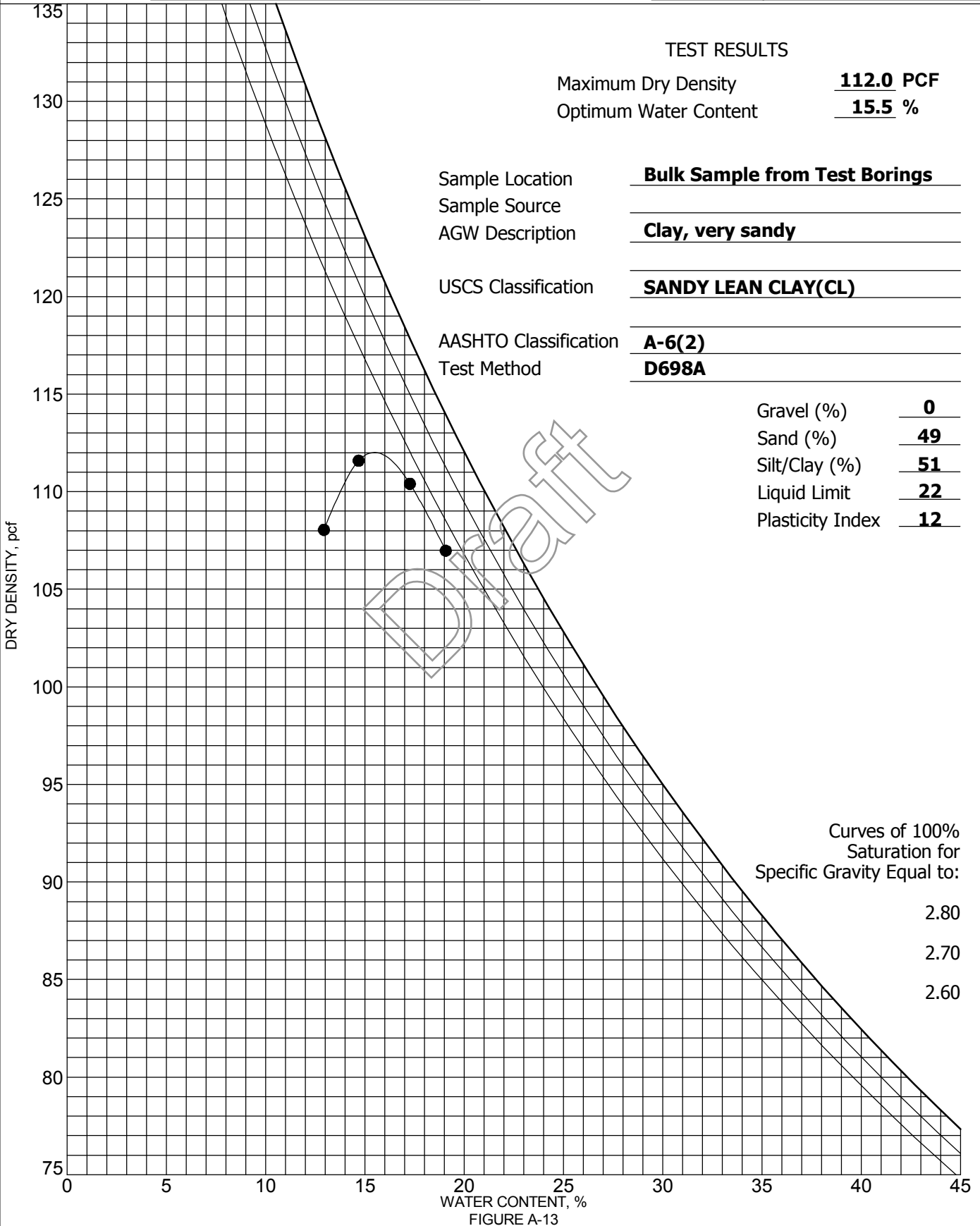


FIGURE A-13

APPENDIX B

SPECIFICATION FOR PLACEMENT OF FILL

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APPENDIX B

SPECIFICATION FOR PLACEMENT OF FILL

GENERAL

A. G. Wassenaar, Inc, (AGW), as the Client's representative, should observe fill placement and conduct tests to determine if the materials placed, methods of placement, and compaction are in reasonable conformance with these specifications. Specifications presented in this Appendix are general in nature. They should be used for construction except where specifically superseded by those presented in the attendant geotechnical study.

For the purpose of this specification, structural areas include those areas that will support constructed appurtenances (e.g., foundations, slabs, flatwork, pavements, etc.) and fill embankments or slopes that support significant fills or constructed appurtenances. Structural areas will be as defined by the AGW.

FILL MATERIAL

Fill material should consist of on or off-site soils which are relatively free of vegetable matter and rubble. Off-site materials should be evaluated by AGW prior to importation. No organic, frozen, perishable, rock greater than 6 inches, or other unsuitable material should be placed in the fill. For the purpose of this specification, cohesive soil is defined as a mixture of clay, sand, and silt with more than 35% passing a U. S. Standard #200 sieve and a Plasticity Index of at least 11. These materials will classify as an A-6 or A-7 by the AASHTO Classification system. Granular soils are all materials which do not classify as cohesive.

PREPARATION OF FILL SUBGRADE

Vegetation, organic topsoil, any existing fill, and any other deleterious materials should be removed from the fill area. The area to be filled should then be scarified, moistened or dried as necessary, and compacted to the moisture content and compaction level specified below prior to placement of subsequent layers of fill.

PLACEMENT OF FILL MATERIAL

The materials should be delivered to the fill in a manner which will permit a well and uniformly compacted fill. Before compacting, the fill material should be properly broken down, mixed, and spread in approximately horizontal layers not greater than 8 inches in loose thickness.

MOISTURE CONTROL

The material must contain uniformly distributed moisture for proper compaction. The Contractor will be required to add moisture to the materials if, in the opinion of AGW, sufficient and uniform moisture is not present in the fill. If the fill materials are too wet for proper compaction, aerating and/or mixing with drier materials will be required.

APPENDIX B

SPECIFICATIONS FOR PLACEMENT OF FILL

Page 2

Moisture content should be controlled as a percentage deviation from optimum. Optimum moisture content is defined as the moisture content corresponding to the maximum density of a laboratory compacted sample performed according to ASTM D698 for cohesive soils or ASTM D1557 for granular soils. The moisture content specifications for the various areas are as follows:

	<u>Cohesive Soils</u>	<u>Granular Soils</u>
1. Beneath Structural Areas:	0 to +4%	-2 to +2%
2. Beneath Non-Structural Areas:	-3 to +3%	-3 to +3%
3. Moisture Treated Fill:	0 to +4%	-2 to +2%

COMPACTION

When the moisture content and conditions of each layer spread are satisfactory, the fill should be compacted. Laboratory moisture-density tests should be performed on typical fill materials to determine the maximum density. Field density tests must then be made to determine fill compaction. The compaction standard to be utilized in determining the maximum density is ASTM D698 for cohesive soils or ASTM D1557 for granular soils. The following compaction specifications should be followed for each area:

1. Beneath Structural Areas: 95% of Maximum Dry Density
2. Beneath Non-Structural Areas: 90% of Maximum Dry Density
3. Moisture Treated Fill: 95% of Maximum Dry Density

If the fill contains less than 10% passing the No. 200 sieve, it may be necessary to control compaction based on relative density (ASTM D2049). If this is the case, then compaction around the structures and beneath walkway or other slabs should be to at least 70% relative density, and compaction beneath foundations and vehicle supporting should be to at least 80% relative density.

DEEP FILLS

In areas where fill depths exceed 20 feet beneath structural areas, additional compaction considerations will be required to reduce fill settlement. Fill placed within 20 feet of final overlot grade should be compacted as required above. Deeper fills should be compacted to 100% of maximum dry density at a moisture content of $\pm 2\%$ of optimum moisture content. Relative density of at least 85% will be required when necessary.

RESPONSIBILITY

Any mention of essentially full-time testing and observation does not mean AGW will accept responsibility for future fill performance. AGW shall not be responsible for constant or exhaustive inspection of the work, the means and methods of construction or the safety procedures employed by Client's contractor. Performance of construction observation services does not constitute a warranty or guarantee of any type, since even with diligent observation, some construction defects, deficiencies or omissions in the Contractor's work may occur undetected. Client shall hold its contractor solely responsible for the quality and completion of the project, including construction in accordance with the construction documents. Any duty hereunder is for the sole benefit of the Client and not for any third party, including the contractor or any subcontractor.