Pavement Study
Urban Collection at Palmer Village
El Paso County, Colorado

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Project Number 210970-P1
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ATTACHMENTS

1.0 EXECUTIVE SUMMARY

As requested, A. G. Wassenaar, Inc. (AGW) has completed the pavement study for the proposed roadways to be located at the subject site. This study was conducted in general conformance with El Paso County pavement design procedures. The following pavement study summarizes the field exploration, subsurface conditions encountered, laboratory tests performed, and pavement recommendations for the proposed roadways.

In general, the subgrade materials encountered consisted of very sandy clay fill and very clayey sand fill overlying clayey sand. No ground water was encountered at the time of drilling.

The pavement recommendations for the local roadways and parking consist of 4.5 inches of asphalt concrete overlying 8.0 inches of aggregate base course or 4.0 inches of asphalt concrete overlying 12.0 inches of chemically treated subgrade.

We encourage reading this report in its entirety and not solely relying on the cursory information contained in this summary.

2.0 PURPOSE

The purpose of this study was to provide pavement thickness recommendations for the subject site in general conformance with Appendix D of El Paso County's "Engineering Criteria Manual (Revised 2016)" ("Manual"). This study presents the analysis of approximately 2,800 feet of local residential roadways as part of the Palmer Village subdivision. Factual data gathered during the field and laboratory work and our analyses are summarized on Figures 1 through 5 and in Appendices A and B. Our opinions and recommendations presented in this report are based on the data generated during this field exploration, laboratory testing, and our experience with similar projects.

3.0 FIELD EXPLORATION

The subgrade soils were sampled by drilling 13 test borings within the proposed roadway alignments approximately 250 lineal feet apart (see Figure 1). The test borings were drilled using a 4-inch diameter continuous flight auger powered by a truck-mounted drill rig. The test borings were drilled to depths of approximately 5 or 10 feet with disturbed bulk samples collected in the upper 5 feet of rough subgrade elevation. Samples of the subsurface materials were also obtained using a Modified California sampler 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 subsurface materials encountered. Results of the penetration tests are presented on the "Test Boring Logs", Figures 2 through 5. Ground water was not encountered at the time of drilling.

4.0 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 gradation analysis and Atterberg limits to evaluate grain size distribution and plasticity. Swell-consolidation tests were conducted to evaluate the effect of wetting under load on selected samples. Representative samples were tested for water-soluble sulfate concentration. Selected subgrade materials were tested for R-value to estimate the subgrade support strength. The test results are summarized on Figures 2 through 5 and presented in Appendix A.

5.0 SUBSURFACE CONDITIONS

The subgrade soils encountered consisted of very sandy clay fill and very clayey sand fill overlying clayey sand. According to the AASHTO Soil Classification system, the soils from the bulk samples collected classified as A-6 (1 to 11). Based upon field observations, fill was encountered in each test boring to depths of approximately 6 to 10 feet below rough subgrade elevation. We understand this fill was tested for moisture and density by another firm. Compaction testing records should be thoroughly reviewed for compliance with El Paso County specifications. We cannot and will not be held liable for work conducted by others. Clayey sand was encountered in two of the test borings at depths of approximately 6 and 8 feet. No bedrock was encountered to the depths explored. Ground water was not encountered at the time of drilling.

6.0 WATER-SOLUBLE SULFATES

The Colorado Department of Transportation (CDOT) stipulates requirements for the risk of sulfate exposure on concrete structures based on Table 601-2 of the "Standard Specifications for Road and Bridge Construction". The water-soluble sulfate concentration of the samples tested indicated less than 100 and 500 parts per million (ppm). Based on these results, the sulfate concentration of the samples tested represents a Class 1 risk of sulfate exposure. We recommend concrete structures bearing upon onsite materials meet the requirements stipulated in Section 601.04 of the CDOT "Standard Specifications for Road and Bridge Construction". Based on the sulfate concentration found in this study, a sulfate resistant cement is not considered necessary.

7.0 EXPANSIVE SUBGRADE CONDITIONS

The "Manual" stipulates subgrade soils requiring expansive subgrade mitigation be discussed in the pavement design. Swell-consolidation testing was performed using a 200 psf surcharge load. The swell-consolidation testing exhibited an expansion potential ranging from 0.7 to 5.1% with an average of 2.2% (see Appendix A). Based on our laboratory testing, we recommend moisture treatment of the soils encountered in the area of Test Boring No. 6 (see Figure 1) to a depth of at least 2 feet. The area of treatment may extend at least 100 feet on both sides of the test boring location. The moisture treated fill should be placed in 8-inch maximum loose lifts and compacted to a minimum of 95% Standard Proctor (ASTM D 698) maximum dry density at optimum to +3% of optimum moisture content. The moisture treatment should extend at least 1 foot beyond the proposed back of curb/walk. We should be notified to document removal of expansive soil materials.

Existing utilities may limit the lateral and vertical extents of moisture treatment. The moisture treatment of expansive soils is intended to mitigate the risk of potential subgrade heave and should be understood that this risk cannot be eliminated. If desired, we are available to discuss other alternatives that can further reduce this risk. Alternatively, it is our opinion moisture treatment is not needed if the chemical treatment alternate is selected. The pavement recommendations are provided in Section 10.0.

8.0 SUBGRADE SUPPORT

The pavement subgrade support strength of soils is based on the resilient modulus (M_R). The resilient modulus is a measure of the elastic property of soil, which is dependent upon moisture content, density, and the applied stress level. Based on our laboratory testing, the soils encountered at the site are considered to possess poor subgrade support characteristics. The A-6 (11) soils from Test Boring No. 7 (0–5′) were tested for R-value and exhibited an R-value of 22 (see Appendix A). The CDOT "Pavement Design Manual" utilizes two equations to approximate the resilient modulus based upon the R-value. The following equations were used to approximate the resilient modulus:

$$M_R = 10 \wedge \left[\frac{S_1 + 18.72}{6.24}\right]$$

$$\text{where } S_1 = \left[\frac{\text{R-value} - 5}{11.29}\right] + 3$$

$$M_R = 5{,}273 \text{ psi}$$

9.0 TRAFFIC CONSIDERATIONS

Based on the "Manual" and the plans, the roadways at the site classify as local residential roadways with parking. The subject site contains 100 residential units. The residential units at the site are separated by existing Hannah Ridge Drive with 54 units on the west side and 46 units on the east side. The "Manual" stipulates a default traffic value of 292,000 Equivalent Single Axle Loads (ESALs (18-kip)) for local urban roadways based on a 20-year design period. We find this ESAL value to be substantially greater than typical traffic load values for local residential roadways. Nevertheless, this value was used in the pavement design. The following table summarizes the traffic design criteria.

Roadway Classification	ESALs	Reliability (%)	Serviceability Index
Local and Parking	292,000	80	2.0

10.0 PAVEMENT THICKNESS RECOMMENDATIONS

The pavement thickness recommendations were calculated using the 1993 AASHTO Pavement Design, DARWin Pavement Design and Analysis System computer program. Based on the design criteria referenced above and the calculations from Figures B-1 and B-2 (Appendix B), the recommended pavement thicknesses are provided in the table below and on Figure 1A. These pavement sections are the minimum standards as given in Table D-2 of the "Manual".

Roadway Classification	Alternate	ACS (in.)	ABC (in.)	CTS (in.)	Total (in.)
Local and Parking (ESAL = 292,000; M_R = 5,273 psi)	A	4.5	8.0	–	12.5
	B	4.0	–	12.0	16.0

ACS – Asphalt Concrete Surface
ABC – Aggregate Base Course
CTS – Chemically Treated Subgrade
Note: Moisture treatment is recommended in the area of Test Boring No. 6 (see Figure 1). The area of treatment may extend at least 100 feet on both sides of the test boring location. The moisture treated fill should be placed per Section 7.0. Alternatively, it is our opinion moisture treatment is not needed if the chemical treatment alternate is selected.

Chemical stabilization is the process of adding lime, fly ash, Portland cement, or another chemical agent to produce a stable paving platform. This is generally performed to the top 12 inches of subgrade. We typically recommend a mix design be conducted (using on-site soils and a sample of the chemical agent) to determine the percentage of chemical agent necessary to achieve an unconfined compressive strength of at least 200 pounds per square inch (psi) when cured at 100-degree Fahrenheit. A mix design may not be required if the stabilization is only to provide a firm surface for paving and no structural credit is desired.

Proper and timely maintenance will be required during the lifetime of the pavement in order to reach the designed service life. Pavement maintenance recommendations are provided in the Section 15.0.

11.0 GENERAL DISCUSSION

We understand several municipalities in the region allow "vertical" residential construction prior to the completion of the designed pavement structure (i.e., after placement of the bottom lift of asphalt). Our experience indicates construction traffic during the buildout phase often exceeds the anticipated daily traffic volume on residential streets. Pavement distress may occur on incomplete pavement structures as a result of construction traffic. It is our recommendation to consider full placement of the designed pavement structure prior to vertical residential construction. In addition, bottom lift only paving allows accumulation of water since the drainage structures cannot be effectively utilized. This could result in wetting of the subgrade soils and may result in weakening of the pavement structure.

12.0 DRAINAGE CONSIDERATIONS

Long-term pavement performance is aided by proper drainage. Surface drainage is necessary for water to drain into the proper collection system instead of fully infiltrating into the subgrade soils below the pavement structure. If the pavement is not properly drained, the soils below the pavement structure may become saturated, and the subgrade will lose strength, ultimately affecting the performance of the pavement layers above (generally from imposed traffic loads). A drain system may aid pavement performance near irrigated areas. Excessive irrigation could negatively impact the pavement structure. In addition, xeriscaping the landscaped areas is recommended.

13.0 CONSTRUCTION RECOMMENDATIONS

The following recommendations are intended as a guideline and not as replacement to the jurisdictional standards and specifications. Ultimately, it shall be the responsibility of the Contractor to abide by the standards and specifications stipulated in the "Manual".

13.1 Chemically Treated Subgrade

Chemically treated subgrade operations generally consist of blending chemicals (lime, fly-ash, cement kiln-dust, or Portland cement) with subgrade soils to a specified depth in order to improve the subgrade support properties. A mix design stating the amount of chemical agent necessary to modify the subgrade support properties should be performed using on-site soils. In addition, the chemical agent used in the mix design should be from the same source as to be used during construction.

13.1.1 Weather Limitation

The subgrade should not be chemically treated when the ambient air temperature at ground level is below 40°F in the shade or may fall below 40°F within 24 hours, when it is rainy, or in adverse conditions. The jurisdictional representative has authority to alter these requirements. In no case should the subgrade be treated when the material to be treated is frozen. If the subgrade is chemically treated and is expected to be exposed to freezing temperatures, the treated subgrade should be protected by either covering the subgrade or by placement of the subsequent course.

13.1.2 Equipment

The equipment required should include all equipment necessary but not limited to complete such items as: grading, scarifying, spreading (slaker for slurry mixtures), pulverizing, mixing, hauling, compacting, sprinkling of water, finishing, protecting, curing, and maintaining the completed course.

13.1.3 Subgrade Preparation

Prior to chemical treatment, the subgrade should be cut or bladed to the required surface according to the approximate line, grade, and/or cross sections specified in the plans. The subgrade should be moisture conditioned to within 0 to +3% of optimum moisture content prior to chemical treatment to permit proper processing of the subgrade. The subgrade should be proof rolled to detect any loose or soft areas. These areas should be overexcavated and replaced with suitable compacted fill. The stabilized subgrade should be free of roots, sod, weeds, wood, construction debris, other deleterious materials, or stones larger than 3 inches.

13.1.4 Construction Methods

The necessary construction requirement of chemical subgrade modification is to achieve a completed subgrade containing a mixture (free of loose or segregated areas) of uniform density and moisture content, well bound for its full depth, with a smooth surface suitable for placing subsequent courses, and it must meet the established design parameters. It is the responsibility of the Contractor to regulate the sequence of this work, to use the proper amount of chemical agent, to maintain the work, and to rework the courses as necessary to meet the above requirements.

13.1.5 Application

The chemical agent should be spread only on the area where the mixing operations can be completed during the same working day. Chemically treated subgrade with a cementitious stabilization agent should be completed (mixing, compacting, and finish grading, etc.) within 90 minutes of the time cementitious stabilizing agent and water is applied. The application rate should be established by the Contractor to ensure the required amount of chemical agent stipulated in the job mix formula is applied to achieve a uniform mixture for the specified depth. The chemical agent should be applied using the "Dry Placement" method or the "Slurry Placement" method.

<u>Dry Placement</u>
The design amount of chemical agent should be spread uniformly over the top of the subgrade by an approved screw-type spreader box or other approved spreading equipment. The chemical agent should be distributed in such manner that scattering by wind will be minimal. The chemical agent should not be applied when wind conditions, in the opinion of the jurisdictional representative, are detrimental to achieving proper application and sequentially an overall successful operation.

<u>Slurry Placement</u>
The design amount of chemical agent applied by slurry should be mixed with water in approved slaking equipment and applied on the subgrade as a thin water suspension or slurry. The slurry mixture should be applied with a percentage not less than that applicable for the grade used. The distribution equipment should be capable of continuous agitation to keep the slurry mixture uniform until applied on the subgrade. The distribution of the slurry mixture should be achieved by successive applications over a measured section of subgrade until the proper amount of slurry mixture has been applied. The slurry should not be exposed to allow the slurry mixture to runoff or dry out. If the slurry has dried to a point it has become "brittle", the effectiveness has been reduced and additional slurry will be required.

13.1.6 Mixing and Mellowing

<u>Mixing</u>
The treated subgrade material should be mixed continuously with an approved mixing machine to the specified depth below the bottom of the proposed pavement structure. The mixing machine should make enough passes to adequately achieve 100% of the mixture material passing the 1-inch sieve and 60% passing the ¼-inch sieve. Streaks or pockets of chemical agent is considered evidence of inadequate mixing. There should be a minimum 6-inch overlap between passes to establish proper mixing and breakdown. Water should be added to the subgrade mixture during mixing to maintain a moisture content at least 3% above optimum moisture. Sufficient water in the mixture is necessary to allow for the reaction of the chemical agent and the subgrade soils. After mixing is completed, lime treated soils should be lightly rolled to reduce evaporation during the mellowing period. Portland cement treated soils should be compacted immediately (no more than 90 minutes) after mixing.

<u>Mellowing (Lime Only)</u>
During the mellowing period, the water content of the mixture should be maintained at moisture contents above 3% above of optimum moisture by sprinkling water as necessary. A mellowing period

of at least two days (48 hours) is required or until the subgrade modification design criteria are met (i.e., pH and plasticity reduction). Remixing may be necessary to assist the reaction, as determined by the design Engineer.

Final Mixing (Lime Only)

Prior to final mixing, pH and plasticity reduction requirements should be confirmed. Final mixing cannot proceed until these parameters are confirmed. A cement application may be added during this phase, if necessary, to meet strength requirements.

13.1.7 Compaction

Compaction of the material mixture should begin immediately after mixing for Portland cement or final mixing for lime applications. The material should be aerated or sprinkled as necessary to maintain the material within the specified moisture content limits during and following compaction. Laboratory samples should be taken from the treated material prior to compaction or after the curing period. The laboratory samples should be tested in accordance with ASTM D558 to determine the maximum dry density and optimum moisture content. The field density of the compacted mixture should be at least 95% of maximum dry density at moisture contents between 0% to +3% of optimum moisture content. The thickness of the treated layer should be determined by depth tests at least every 1,000 square yards or less. Compaction should be accompanied by sufficient blading to eliminate irregularities. The Contractor should remedy any deficiencies observed in the treated subgrade. Otherwise, redesign of the pavement may be necessary.

13.1.8 Finishing and Curing

After the final layer of the specified depth of treated subgrade has been compacted, it should be brought to the required lines and grades in accordance with typical roadway sections. Rolling with a pneumatic or other suitable roller that is sufficiently light to prevent hairline cracking should be conducted on the completed section. Traffic on the chemically treated subgrade should be limited.

During the curing period, the subgrade should be lightly sprinkled with water as necessary to prevent the surface from possible shrinkage or cracking. Chemical treatment of the subgrade does not create a "weatherproof" surface. Therefore, proper curing and protections are necessary. If subsequent courses are not placed after the curing period, a liquid asphalt may be applied over the chemically modified subgrade with an emulsified asphalt CSS 1-H diluted 1 to 1 with water to provide a protective film for the treated subgrade.

13.1.9 Strength Testing

According to the "Manual", the chemical modification process should be observed and tested on a full-time basis. Chemically treated subgrade courses that are part of the pavement section should be tested for unconfined compressive strength. The chemically treated subgrade should develop compressive strengths of at least 200 psi in five days at 100°F in accordance with ASTM D5102 or ASTM D1633. If earlier strength tests show a minimum of 200 psi has been attained, subsequent construction may proceed (e.g., paving operations). If the strength parameters are not achieved, remixing with additional cement may be necessary or redesign. Micro-fracturing for Portland cement treated subgrade should be considered.

13.2 Subgrade

Prior to paving operations, the subgrade must be prepared in a manner that allows for adequate pavement support. The entire subgrade should be proof-rolled with a loaded 988 front-end loader or similar heavy rubber-tired vehicle (GVW of 50,000 pounds with 18-kip per axle at tire pressures of 90 pounds per square inch (psi)) to detect any soft or loose areas. All areas exhibiting unstable subgrade conditions such as loose soils, pumping, or excessive movement, should be overexcavated to a firm soil layer or to a maximum depth of 2 feet, whichever is shallowest, and replaced with suitable compacted fill. If unstable subgrade conditions persist, AGW should be contacted for our opinion. The subgrade should only be prepared when ambient conditions are such that they will not impede the Contractor from achieving the required density and moisture content. Frozen soil should never be used as subgrade fill.

If no unstable areas are observed during the proof-roll or after removal and replacement of unsuitable soils, the entire subgrade may be prepared by windrowing, tilling or by removing at least 12 inches of subgrade from proposed pavement subgrade elevation. If necessary, add or reduce moisture to the required moisture content. The subgrade fill should be placed in maximum 8-inch loose lifts and compacted to at least 95% of Standard Proctor (ASTM D698) maximum dry density at optimum to +3.0% of optimum moisture content for compaction of A-6 to A-7-6 soils. The fill should be compacted to at least 95% of Modified Proctor (ASTM D1557) maximum dry density at −2.0% to +2.0% of optimum moisture content for compaction of other soils. Chemically treated subgrade should be compacted to at least 95% maximum dry density (ASTM D558) at optimum to +3.0% of optimum moisture content. If additional fill is required to reach the pavement subgrade elevation, the fill should have a soil classification similar to or better than the poorest soils encountered during this study. The subgrade should be free of organics, vegetation, large rocks, or any other deleterious materials. The pavement subgrade should be crowned to the appropriate grade lines. Additional compactive effort should be applied along edged concrete structures such as curbs and crosspans.

13.3 Aggregate Base Course

The aggregate base course (ABC) should consist of aggregate which meets particular specifications for gradation, plasticity, abrasion wear, and strength. We recommend the use of a material meeting CDOT "Class 6" specifications and having an R-value equal to or exceeding 78. The ABC should be tested to determine compliance with these specifications prior to use. If the material used does not meet the required specifications, then the thickness calculations and recommendations should be revised. The ABC should be placed in loose lifts not exceeding 8 inches and should be compacted to a minimum of 95% of Modified Proctor maximum dry density (ASTM D1557). Aggregate thicknesses exceeding 8 inches should be placed and compacted in two separate lifts. The ABC should not be placed when weather conditions impede achievement of the required compaction.

13.4 Asphalt Concrete Surface

Asphalt material should conform to an agency approved mix design that states the SHRP Gyratory design properties (i.e., maximum density, optimum asphalt content, job mix formula, recommended mixing and placing temperatures, etc.). We recommend that the aggregate used in the asphalt meet Colorado Department of Transportation "Grading S", "Grading SX", "Grading SG", or equivalent regulatory aggregate specifications. If the material does not meet or exceed these specifications, the asphalt thickness should be revised. The asphalt material should be placed in lifts a minimum of three times the aggregate size and should be compacted to 92 to 96% of Theoretical Maximum Specific Gravity for Super Pave Mixes. Longitudinal joints should be compacted to 88 to 96% of Theoretical Maximum Specific Gravity. Materials standards and specifications per the "Manual" are required. Asphalt binder selection should be appropriate for each roadway classification. The paving contractor is responsible for mix submittal to the agency.

Asphalt concrete should not be placed when weather conditions are such that the materials cannot be properly placed or compacted. The asphalt concrete should be placed on a prepared surface, graded to the appropriate elevation. In no case should the asphalt concrete be placed on frozen subgrade or base. When applicable, a tack coat should be applied at joints, adjacent to curbs, gutters or crosspans. The Contractor is responsible for establishing rolling patterns to determine the amount of effort required to meet the compaction requirements. Field testing conducted by AGW will not relieve the Contractor from proper compaction and construction of the pavement.

14.0 PAVEMENT MAINTENANCE

Flexible pavement structures are typically designed for a service period of 20 years. However, timely and proper maintenance during the life of the pavement is essential to reach the designed service period and to possibly extend the serviceability of the pavement. We recommend implementing a maintenance program aimed at preserving the structural integrity of the pavement. The implementation of available maintenance operations varies depending upon pavement type and on-site conditions.

14.1 Flexible Pavements

Flexible pavements will exhibit some type of pavement distress during their service life. Periodic maintenance and rehabilitation should be anticipated in order to reach the anticipated design life. Typically, minor cracks may develop within the first three years. Crack sealant should be utilized immediately upon recognition of these cracks to reduce further deterioration and/or potential moisture induced damage. The use of crack sealants may extend the life of the pavement by two to five years before any other treatment is applied.

A variety of seal coats are available and can delay the need for a major surface structural treatment. However, careful engineering judgment should be utilized to determine the type of seal application that is most appropriate. Seal coats should not be applied on pavements with severe cracks, raveling or potholes. Fog seals typically have an estimated service life of approximately one to two years, but should only be utilized on structurally sound pavements. Slurry seals generally have a service life of four to seven years and are commonly utilized on pavements exhibiting no to low pavement distress. Chip seals aid in slowing surface oxidation, minor raveling, and sealing small cracks. Chip seals are considered to have a service life of approximately four to seven years.

Structural mill and overlay are a rehabilitation technique that generally occurs within eight to 12 years after initial construction. This technique should only be utilized on stable pavements with minor surface distress and a strong base. Conventional structural mill and overlay operations are known to have a service life of eight to 14 years.

15.0 LIMITATIONS

This pavement study was based upon laboratory testing of samples obtained at widely spaced locations. Variations in subsoil conditions could occur between sample locations. We should evaluate and test the subgrade and pavement materials during construction to determine that our recommendations have been properly interpreted. However, A. G. Wassenaar, Inc. 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. 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. The Owner should be aware that this report was prepared utilizing the "Manual" standards. Highly plastic and expansive soils pose a significant risk to pavement structures. This risk includes heave and cracking upon wetting. In addition, utility backfill settlement is a risk of development that can affect pavement performance. The Client is aware that isolated to more wide-spaced damage may occur. Longitudinal cracking parallel to the curb line may be indicative of an expansive subgrade becoming wetted. The only positive solution is removal of the subgrade materials to the depth of wetting and replacement or treatment. The "Manual" specifications do not require that the Client take these measures, but the Client should be aware that these measures are the only solution to dealing with highly plastic and expansive soils. As this is generally economically unfeasible, this design may be used as an attempt to provide a reasonable cost-effective pavement structure. The Owner assumes all liability for the performance of this pavement structure. We are available to discuss the risks associated with this design.

Sincerely,

A. G. Wassenaar, Inc.

COLORADO LICENSED PEDRO DAMIAN MANRIQUEZ 51793 PROFESSIONAL ENGINEER

Pedro D. Manriquez, P.E.
Project Engineer
Digitally signed by: Pedro D. Manriquez
Date: 2022.02.23 12:51:43 -07'00'

Reviewed by:

Thomas A. Hastings, S.E.T.
Vice President

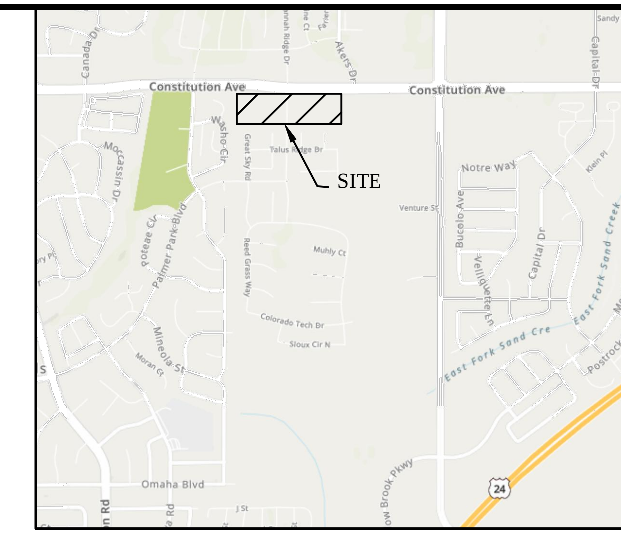
PDM/TAH/pdm

URBAN COLLECTION - PALMER VILLAGE
COUNTY OF EL PASO, COLORADO

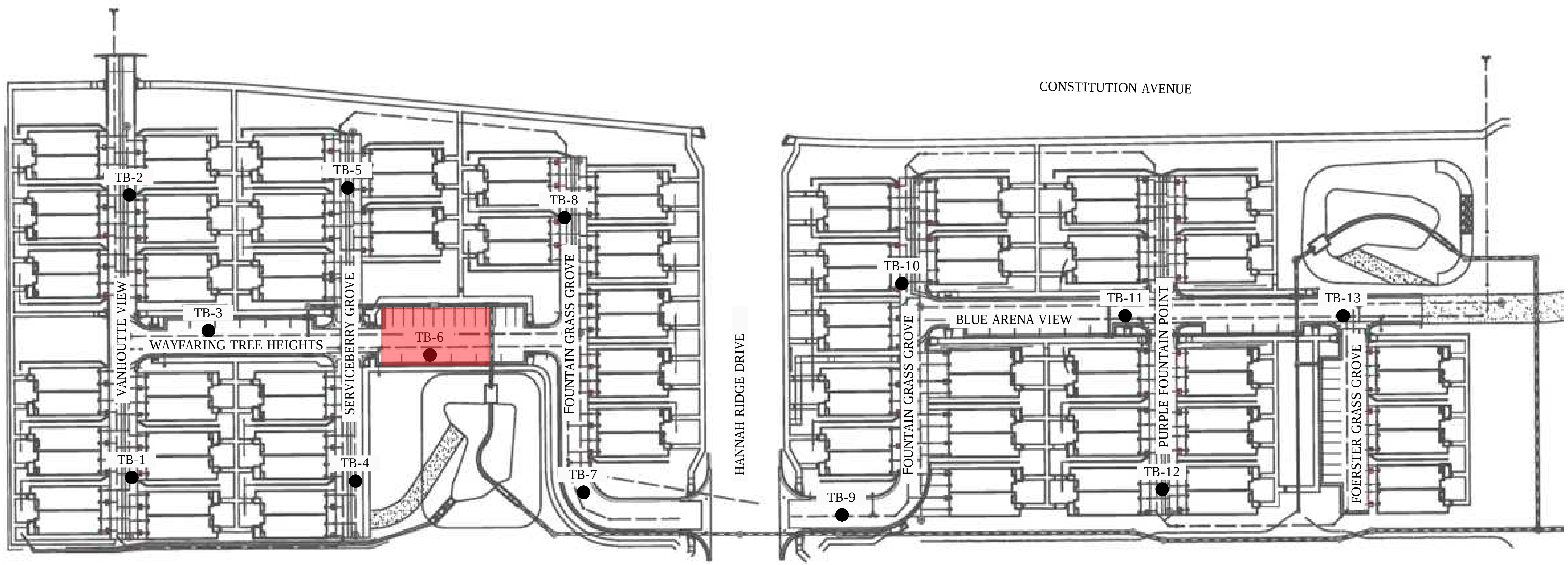
N

0 100 200

Scale in Feet



VICINITY MAP
NOT TO SCALE



MOISTURE TREATMENT IS RECOMMENDED IN THIS AREA TO A DEPTH OF AT LEAST 2 FEET BELOW THE DESIGNED PAVEMENT SECTION. THE FILL SHOULD BE PLACED IN 8-INCH MAXIMUM LOOSE LIFTS AND COMPACTED TO AT LEAST 95% OF STANDARD PROCTOR (ASTM D698) AT OPTIMUM TO +3% OF OPTIMUM MOISTURE CONTENT. WE SHOULD BE CONTACTED TO DOCUMENT REMOVAL OF EXPANSIVE MATERIALS. THE AREAS OF REMOVAL MAY BE LESS OR MORE THAN INDICATED. THE MOISTURE TREATMENT SHOULD EXTEND AT LEAST 1 FOOT BEYOND THE PROPOSED BACK OF CURB/ WALK.

NOTES:

1. TEST BORINGS WERE OVERLAID ON THE "URBAN COLLECTION AT PLAMER VILLAGE GRADING PLAN", PREPARED BY JR ENGINEERING, PROJECT NO. 25149.01, DATED JANUARY 26, 2021.
2. ALL LOCATIONS ARE APPROXIMATE.

AGW
A.G. WASSENAAR, INC.

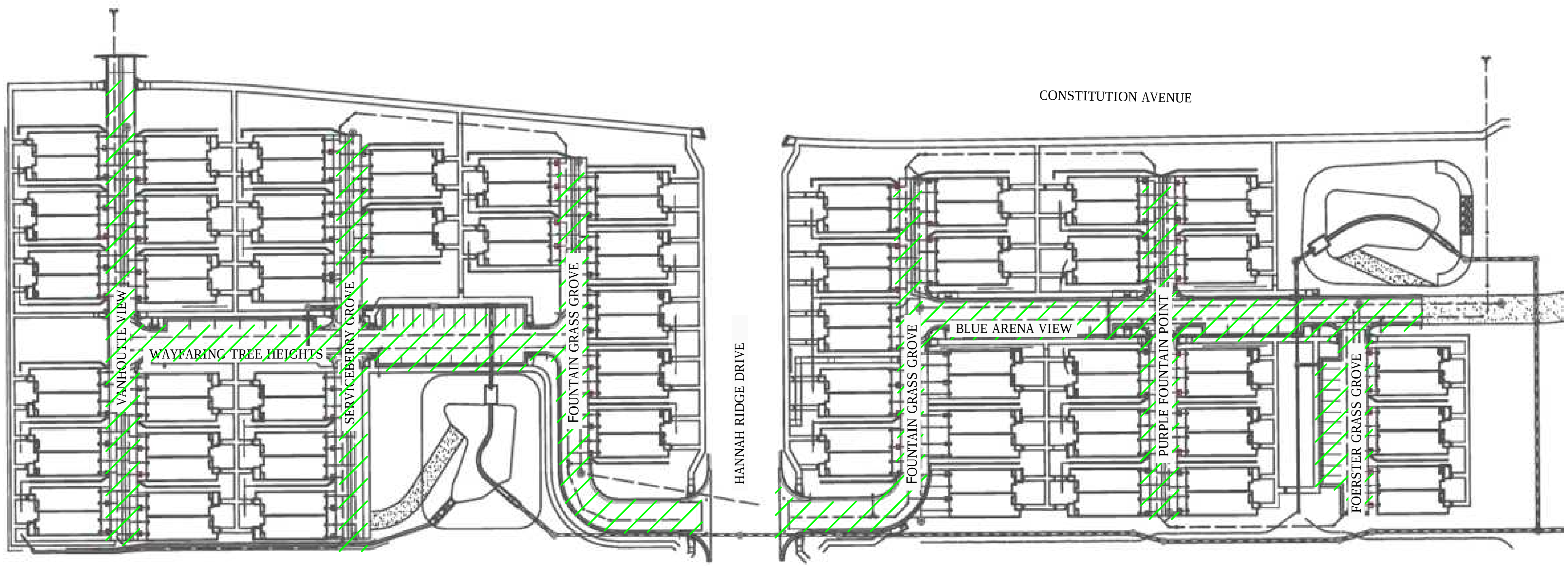
SITE PLAN AND VICINITY MAP	PROJECT NO. 210970 P1 FIGURE 1

URBAN COLLECTION - PALMER VILLAGE
COUNTY OF EL PASO, COLORADO

N

0 100 200

Scale in Feet



LOCAL AND PARKING
(ESAL = 292,000; M_R = 5,273 psi)

ALT	ACS (IN)	ABC (IN)	CTS (IN)	TOTAL (IN)
A	4.5	8.0	-	12.5
B	4.0	-	12.0	16.0

ACS - ASPHALT CONCRETE SURFACE
ABC - AGGREGATE BASE COURSE
CTS - CHEMICALLY TREATED SUBGRADE

NOTES:

1. TEST BORINGS WERE OVERLAID ON THE "URBAN COLLECTION AT PLAMER VILLAGE GRADING PLAN", PREPARED BY JR ENGINEERING, PROJECT NO. 25149.01, DATED JANUARY 26, 2021.
2. ALL LOCATIONS ARE APPROXIMATE.

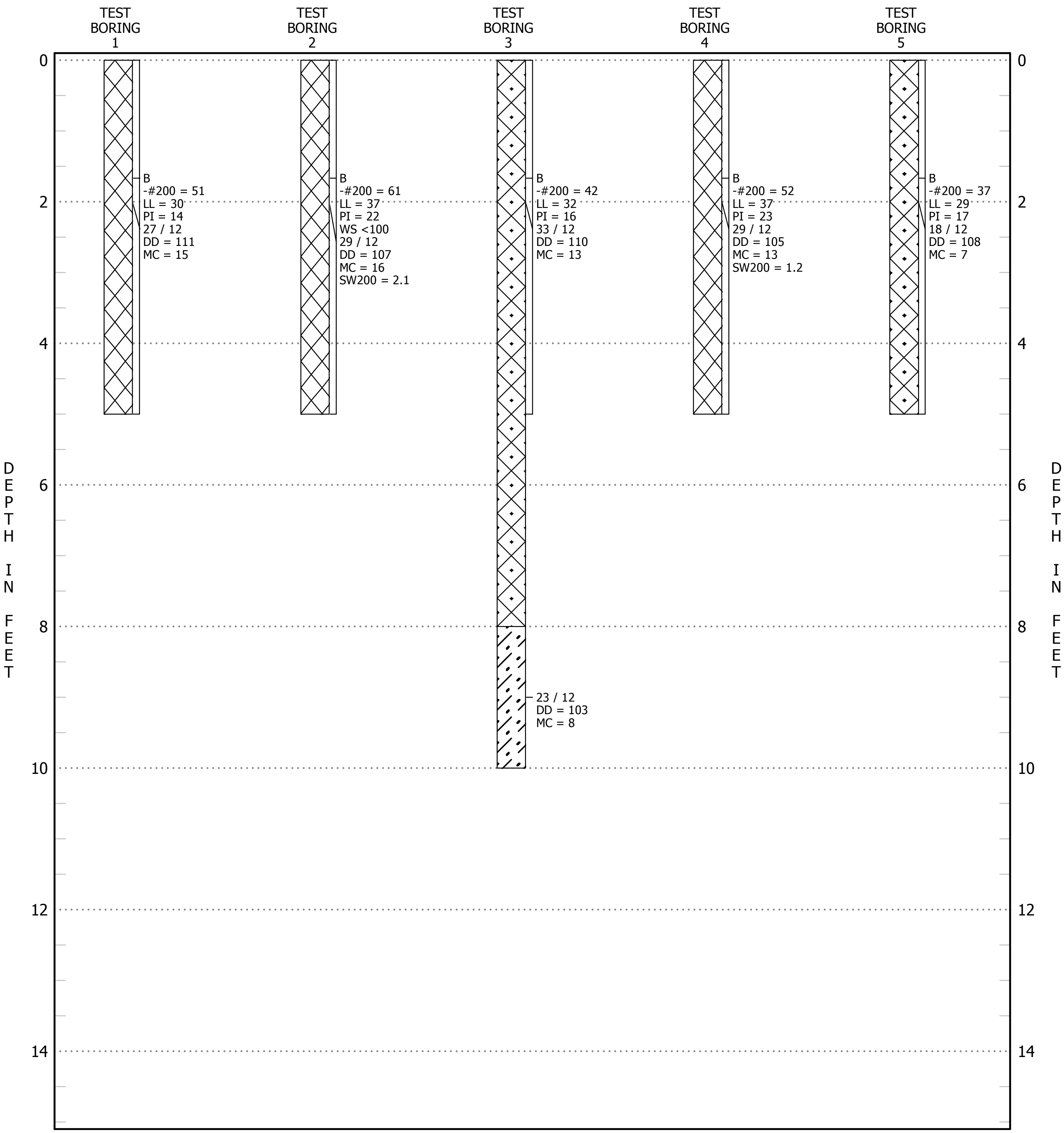
AGW
A.G. WASSENAAR, INC.

PAVEMENT THICKNESS RECOMMENDATIONS	PROJECT NO. 210970 P1 FIGURE 1A

A.G. WASSENAAR, INC.

CLIENT Richmond American Homes of Colorado, Inc. **PROJECT NAME** Urban Collection at Palmer Village

PROJECT NUMBER 210970 P1 **PROJECT LOCATION** County of El Paso, Colorado



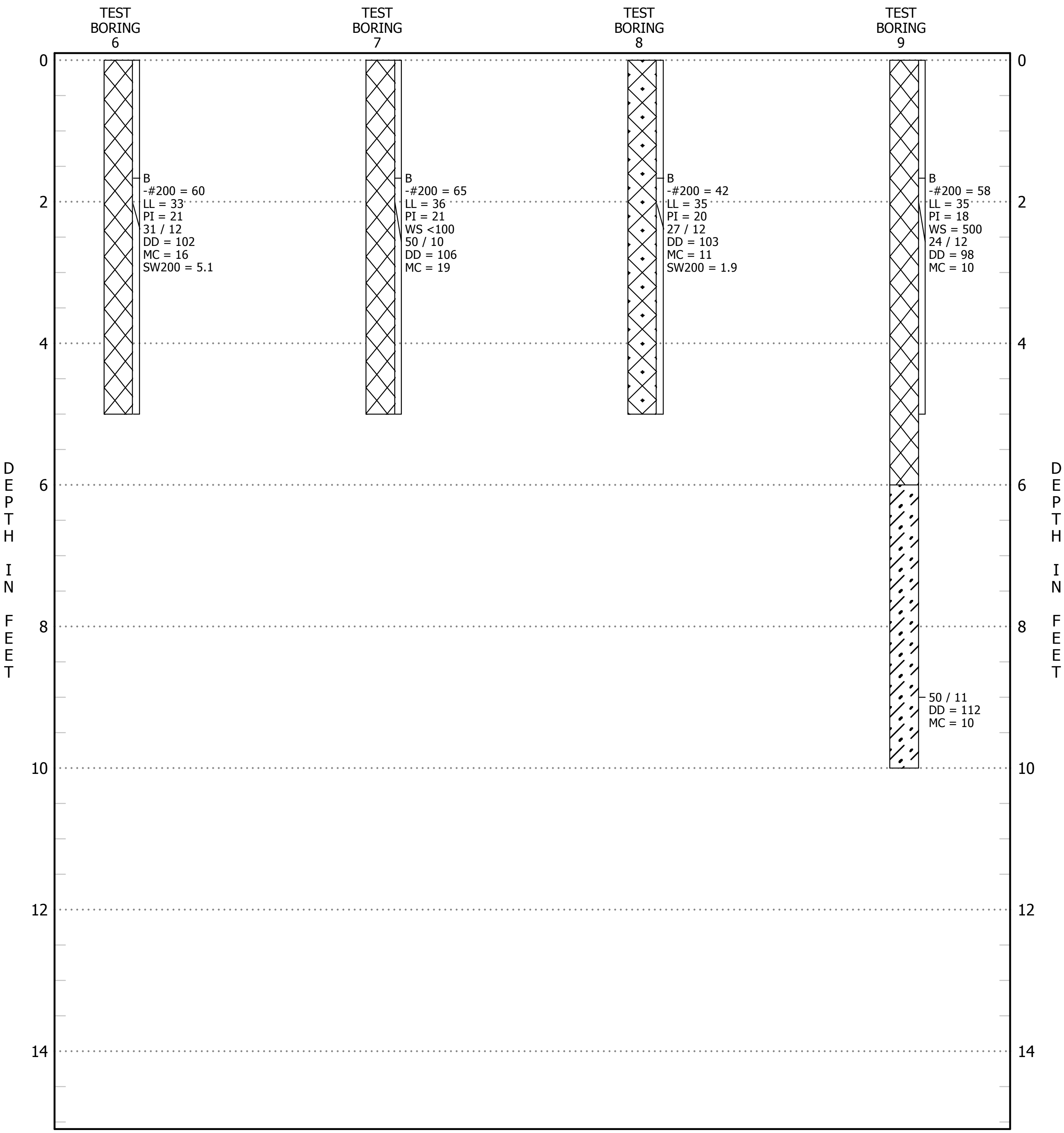
SEE FIGURE 5 FOR LEGEND AND NOTES

TEST BORING LOGS

FIGURE 2

A.G. WASSENAAR, INC.

CLIENT Richmond American Homes of Colorado, Inc.
PROJECT NAME Urban Collection at Palmer Village
PROJECT NUMBER 210970 P1
PROJECT LOCATION County of El Paso, Colorado



SEE FIGURE 5 FOR LEGEND AND NOTES

TEST BORING LOGS

FIGURE 3

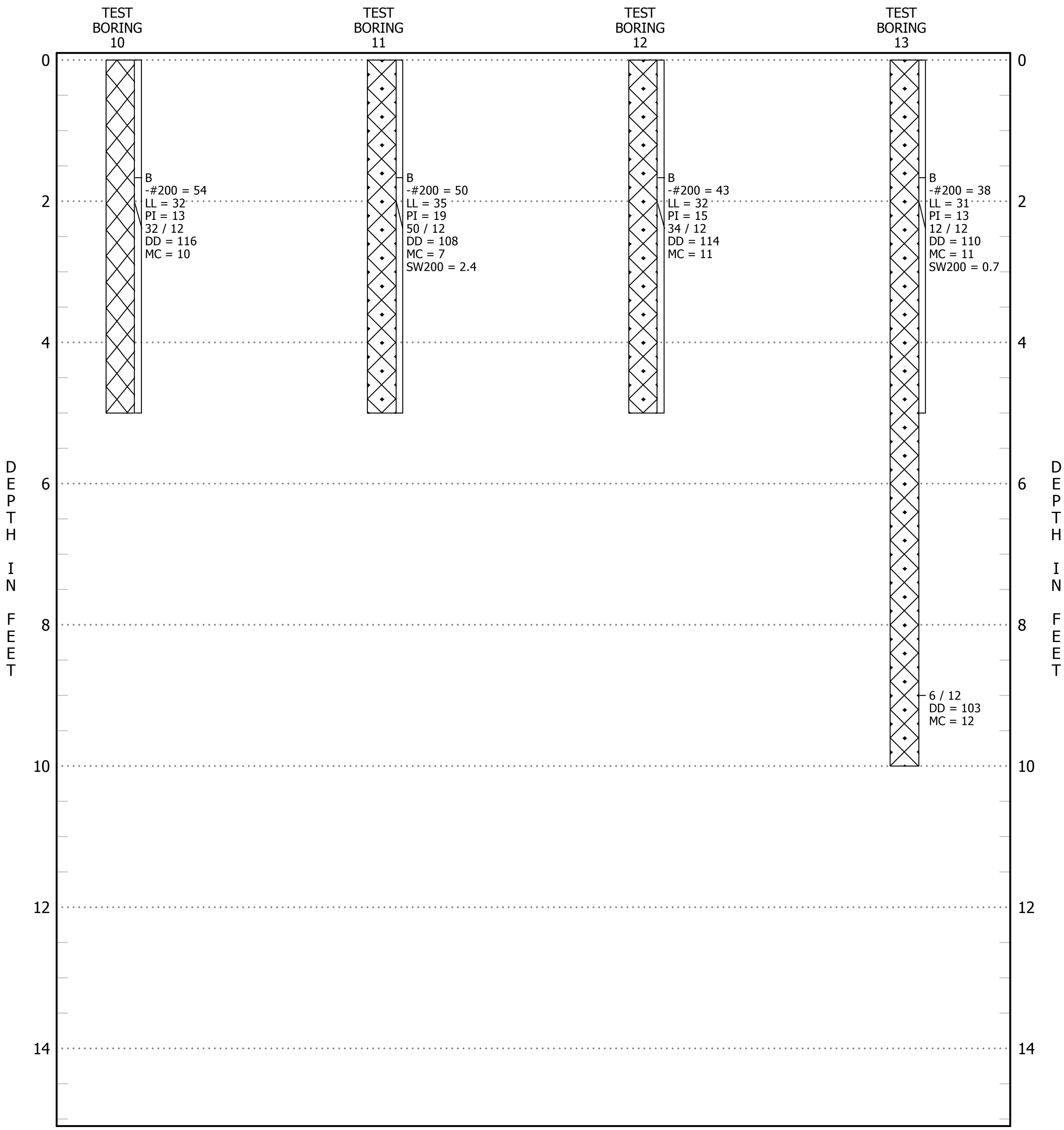
A.G. WASSENAAR, INC.

CLIENT Richmond American Homes of Colorado, Inc.

PROJECT NAME Urban Collection at Palmer Village

PROJECT NUMBER 210970 P1

PROJECT LOCATION County of El Paso, Colorado



SEE FIGURE 5 FOR LEGEND AND NOTES

TEST BORING LOGS

FIGURE 4

AGW
A.G. WASSENAAR, INC.

CLIENT Richmond American Homes of Colorado, Inc.
PROJECT NAME Urban Collection at Palmer Village
PROJECT NUMBER 210970 P1
PROJECT LOCATION County of El Paso, Colorado

SOIL DESCRIPTIONS

Fill, clay, stiff to very stiff, silty, sandy

Fill, sand, medium dense, silty, clayey

Sand, medium dense, silty, clayey

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 (%)
UC	Unconfined compressive strength in pounds per square foot (psf)
-#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 sufates 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 grade (rounded to the nearest foot)
F-x	Depth of fill to grade (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 depth of cut
	Depth at which practical drilling refusal was encountered
	Water level at time of drilling
	Caved depth at time of drilling
	Water level day(s) after drilling
	Caved depth day(s) after drilling

Notes:

1. Test borings were drilled January 10, 2022 to January 27, 2022.
2. Location of the test borings were measured by pacing from features shown on the site plan.
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 not provided.
5. Boring logs shown in this report are subject to the limitations, explanations, and conclusions of this report.

LEGEND AND NOTES
FIGURE 5

APPENDIX A
LABORATORY TEST RESULTS

A.G. WASSENAAR, INC.

TABLE A-1
SUMMARY OF LABORATORY TEST RESULTS
February 8, 2022

Project Number 210970-P1
Urban Collection at Palmer Village
Colorado Springs, Colorado

Test Boring Number	Depth (feet)	Soil Type	AASHTO Soil Classification	Dry Density (pcf)	Moisture (%)	Swell / Consolidation (-) (%) [1]	% Passing #200 Sieve	Atterberg Limits			Water Soluble Sulfates (ppm)
								Liquid Limit	Plastic Limit	Plasticity Index	
1	0-5	Fill, clay, very sandy	A-6(4)				51	30	16	14	
1	2	Fill, clay, very sandy		111	15						
2	0-5	Fill, clay, very sandy	A-6(10)				61	37	15	22	<100
2	2	Fill, clay, very sandy		107	16	2.1					
3	0-5	Fill, sand, very clayey	A-6(3)				42	32	16	16	
3	2	Fill, sand, very clayey		110	13						
3	9	Sand, clayey		103	8						
4	0-5	Fill, clay, very sandy	A-6(8)				52	37	14	23	
4	2	Fill, clay, very sandy		105	13	1.2					
5	0-5	Fill, sand, very clayey	A-6(2)				37	29	12	17	
5	2	Fill, sand, very clayey		108	7						
6	0-5	Fill, clay, very sandy	A-6(9)				60	33	12	21	
6	2	Fill, clay, very sandy		102	16	5.1					
7	0-5	Fill, clay, very sandy	A-6(11)				65	36	15	21	<100
7	2	Fill, clay, very sandy		106	19						
8	0-5	Fill, sand, very clayey	A-6(4)				42	35	15	20	
8	2	Fill, sand, very clayey		103	11	1.9					
9	0-5	Fill, clay, very sandy	A-6(7)				58	35	17	18	500
9	2	Fill, clay, very sandy		98	10						
9	9	Sand, clayey		112	10						
10	0-5	Fill, clay, very sandy	A-6(4)				54	32	19	13	
10	2	Fill, clay, very sandy		116	10						

Notes:
[1] Indicates Percent Swell or Consolidation (–) when wetted under a 200 psf load, unless otherwise noted.

NV - indicates No Value
NP - indicates Non-Plastic

A.G. WASSENAAR, INC.

TABLE A-1
SUMMARY OF LABORATORY TEST RESULTS
February 8, 2022

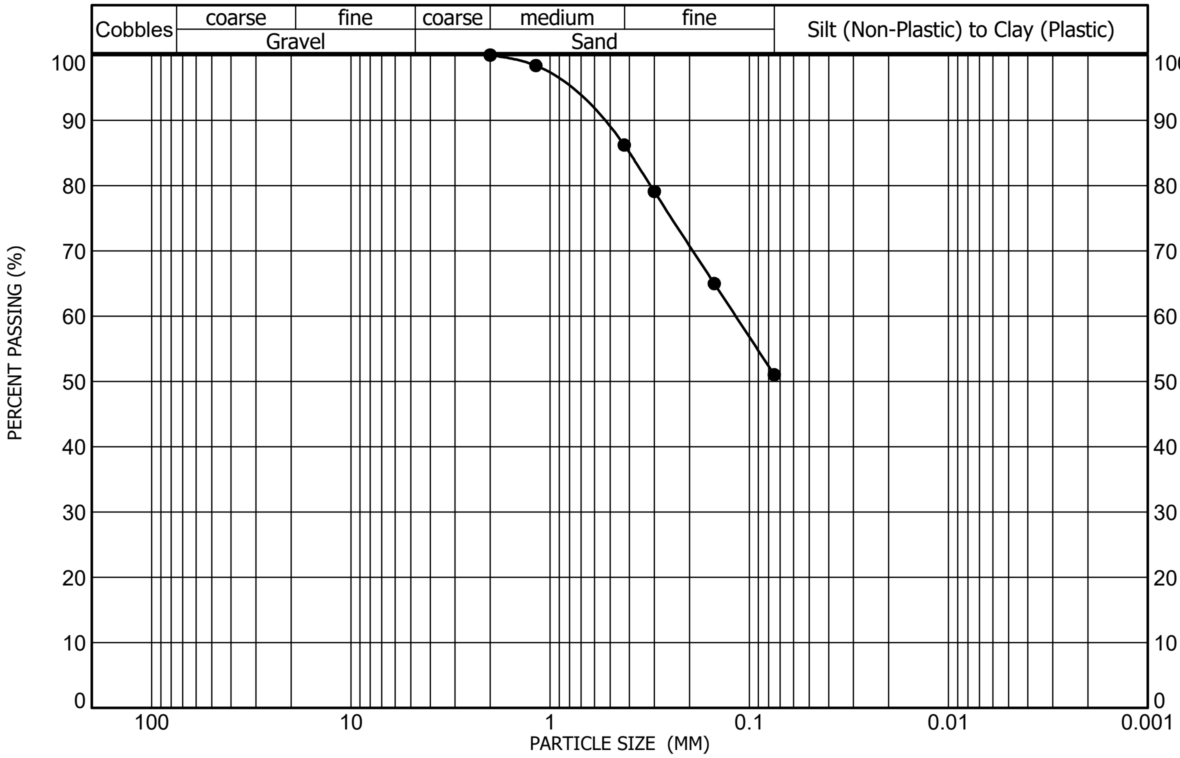
Project Number 210970-P1
Urban Collection at Palmer Village
Colorado Springs, Colorado

Test Boring Number	Depth (feet)	Soil Type	AASHTO Soil Classification	Dry Density (pcf)	Moisture (%)	Swell / Consolidation (-) (%) [1]	% Passing #200 Sieve	Atterberg Limits			Water Soluble Sulfates (ppm)
								Liquid Limit	Plastic Limit	Plasticity Index	
11	0-5	Fill, sand, very clayey	A-6(6)				50	35	16	19	
11	2	Fill, sand, very clayey		108	7	2.4					
12	0-5	Fill, sand, very clayey	A-6(3)				43	32	17	15	
12	2	Fill, sand, very clayey		114	11						
13	0-5	Fill, sand, very clayey	A-6(1)				38	31	18	13	
13	2	Fill, sand, very clayey		110	11	0.7					
13	9	Fill, sand, very clayey		103	12						

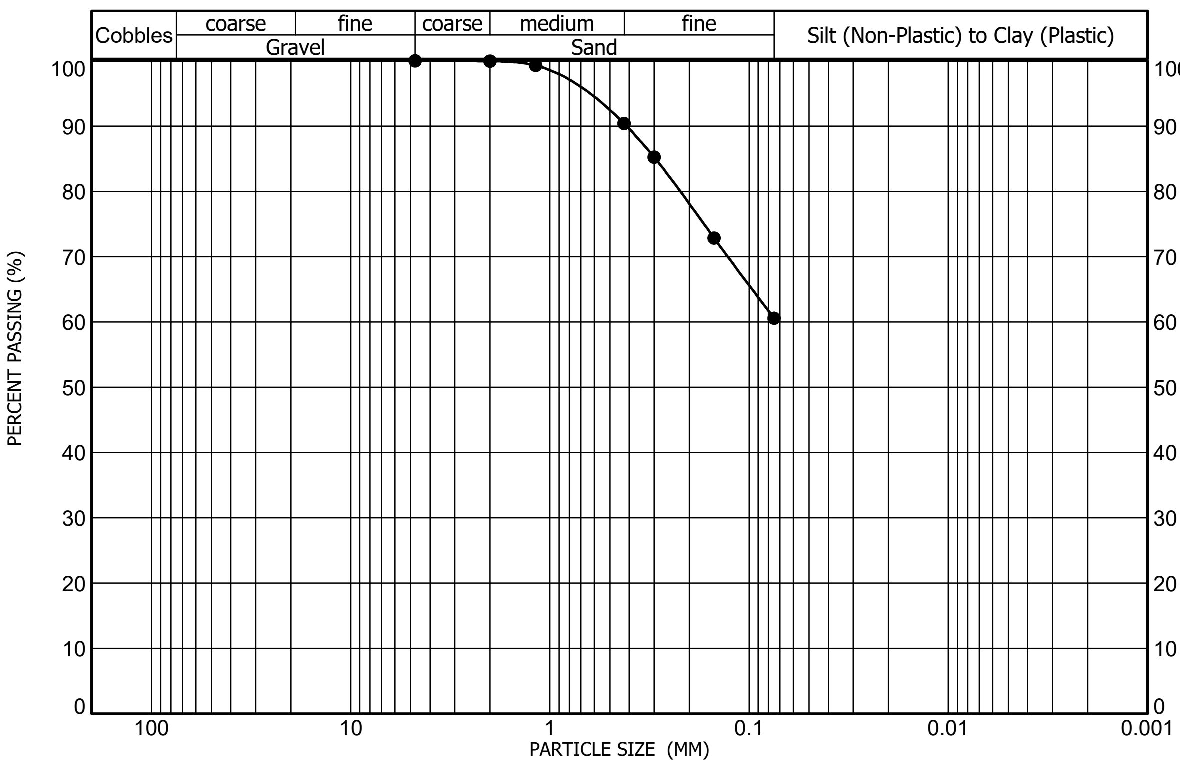
Notes:
[1] Indicates Percent Swell or Consolidation (–) when wetted under a 200 psf load, unless otherwise noted.

NV - indicates No Value
NP - indicates Non-Plastic

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 1 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(4), SANDY LEAN CLAY(CL)
Gravel (%): 0
Sand (%): 49
Clay/Silt (%): 51
Liquid Limit: 30
Plasticity Index: 14



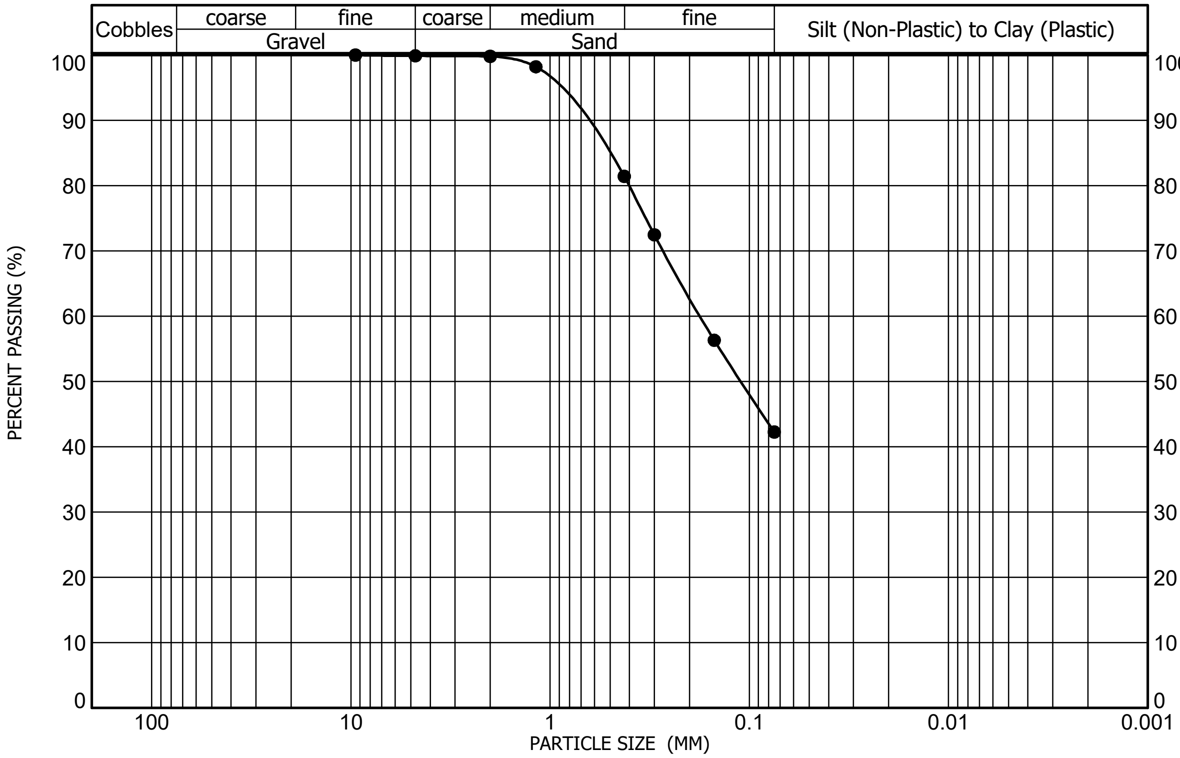
Sample Location: Test Boring No. 2 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(10), SANDY LEAN CLAY(CL)
Gravel (%): 0
Sand (%): 39
Clay/Silt (%): 61
Liquid Limit: 37
Plasticity Index: 22

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-1

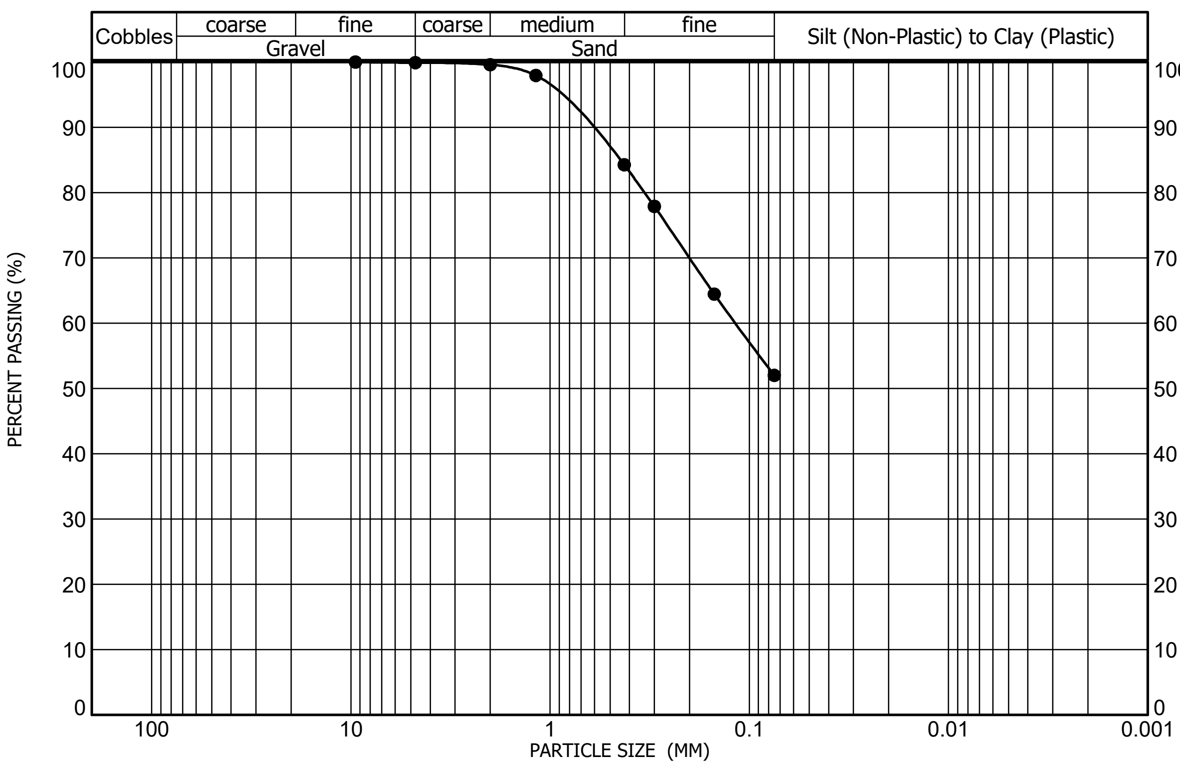
PROJECT NO. 210970 P1

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 3 at a depth of 0 feet to 5 feet
Sample Description: Fill, sand, very clayey
Classification: A-6(3), CLAYEY SAND(SC)

Gravel (%): 0
Sand (%): 58
Clay/Silt (%): 42
Liquid Limit: 32
Plasticity Index: 16



Sample Location: Test Boring No. 4 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(8), SANDY LEAN CLAY(CL)

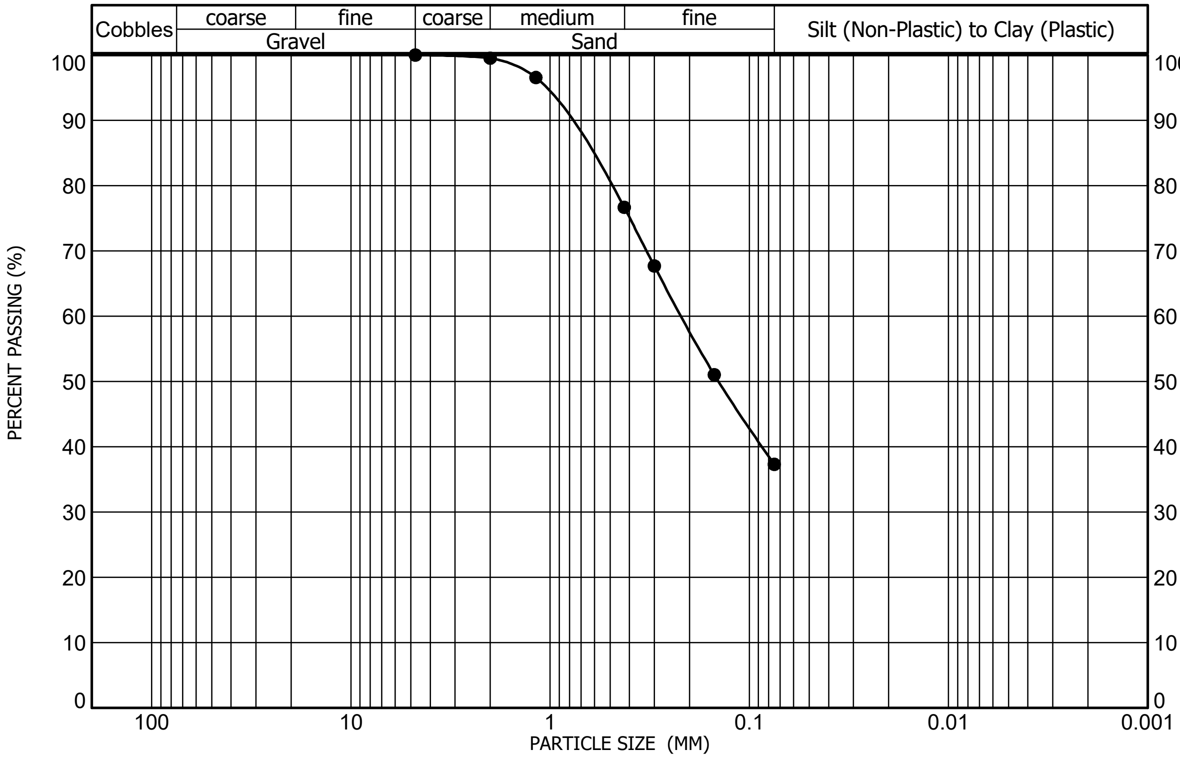
Gravel (%): 0
Sand (%): 48
Clay/Silt (%): 52
Liquid Limit: 37
Plasticity Index: 23

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-2

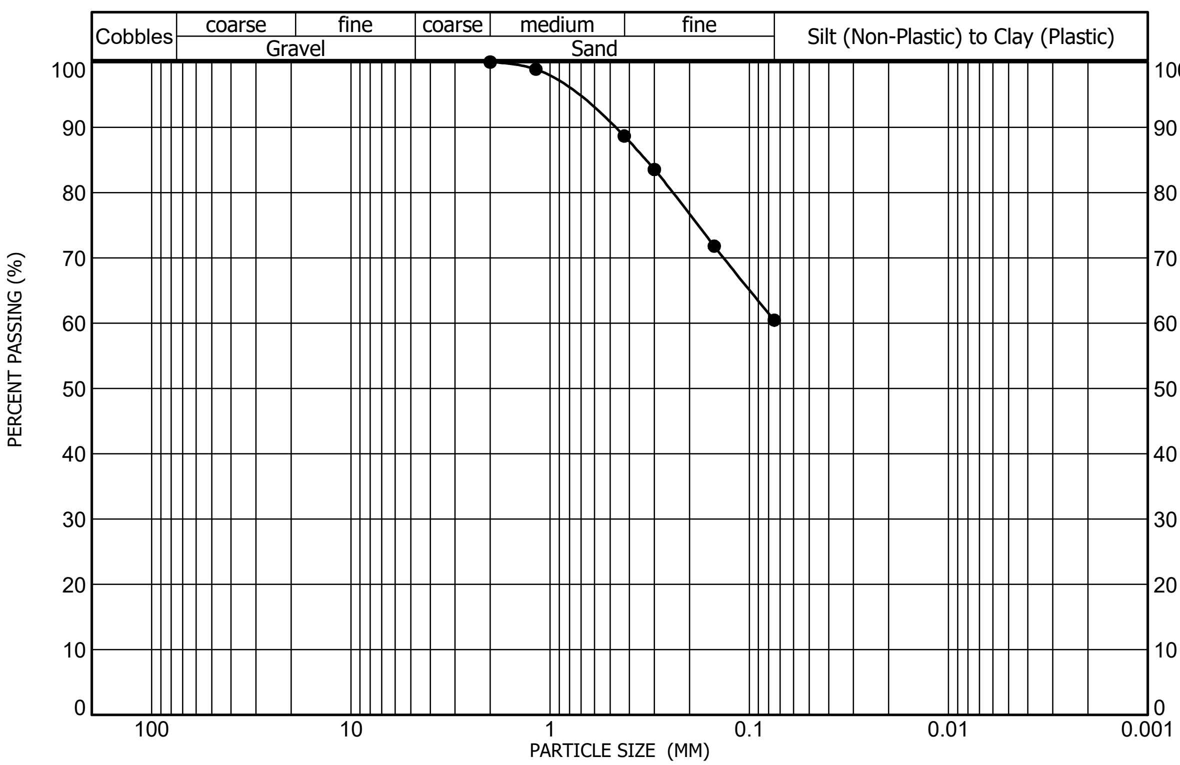
PROJECT NO. 210970 P1

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 5 at a depth of 0 feet to 5 feet
Sample Description: Fill, sand, very clayey
Classification: A-6(2), CLAYEY SAND(SC)

Gravel (%): 0
Sand (%): 63
Clay/Silt (%): 37
Liquid Limit: 29
Plasticity Index: 17



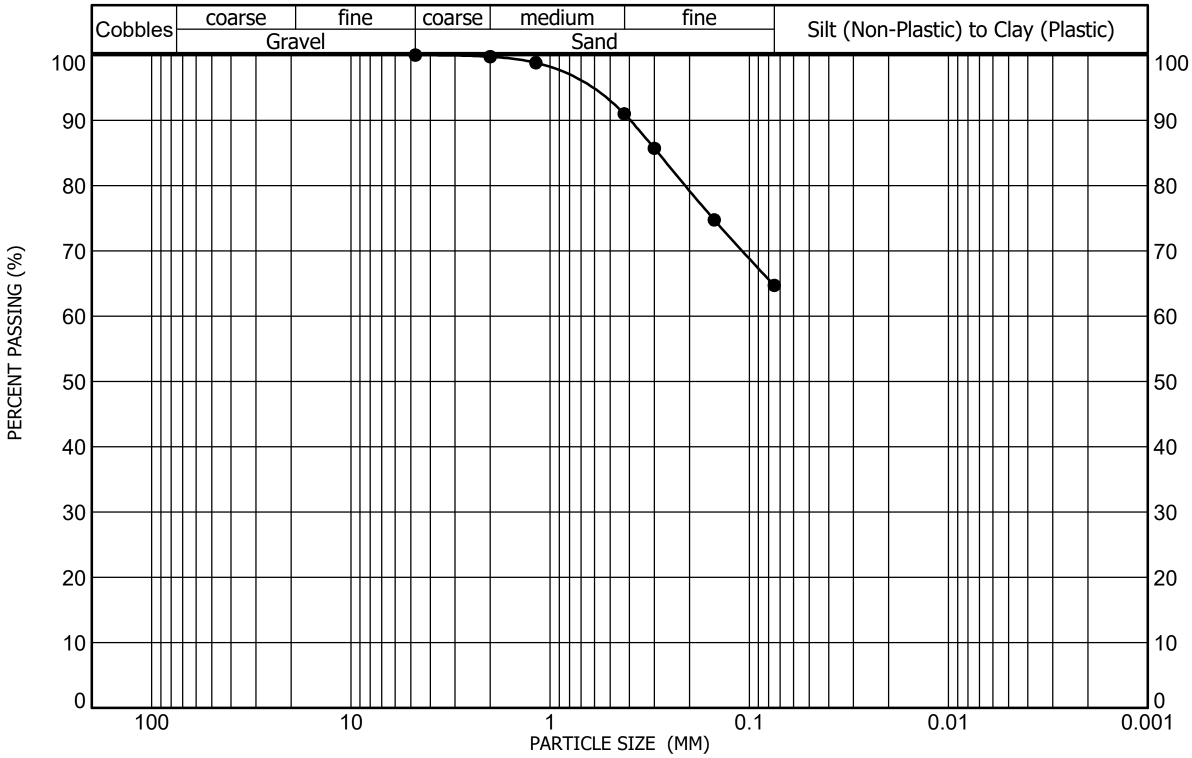
Sample Location: Test Boring No. 6 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(9), SANDY LEAN CLAY(CL)

Gravel (%): 0
Sand (%): 40
Clay/Silt (%): 60
Liquid Limit: 33
Plasticity Index: 21

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-3

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 7 at a depth of 0 feet to 5 feet

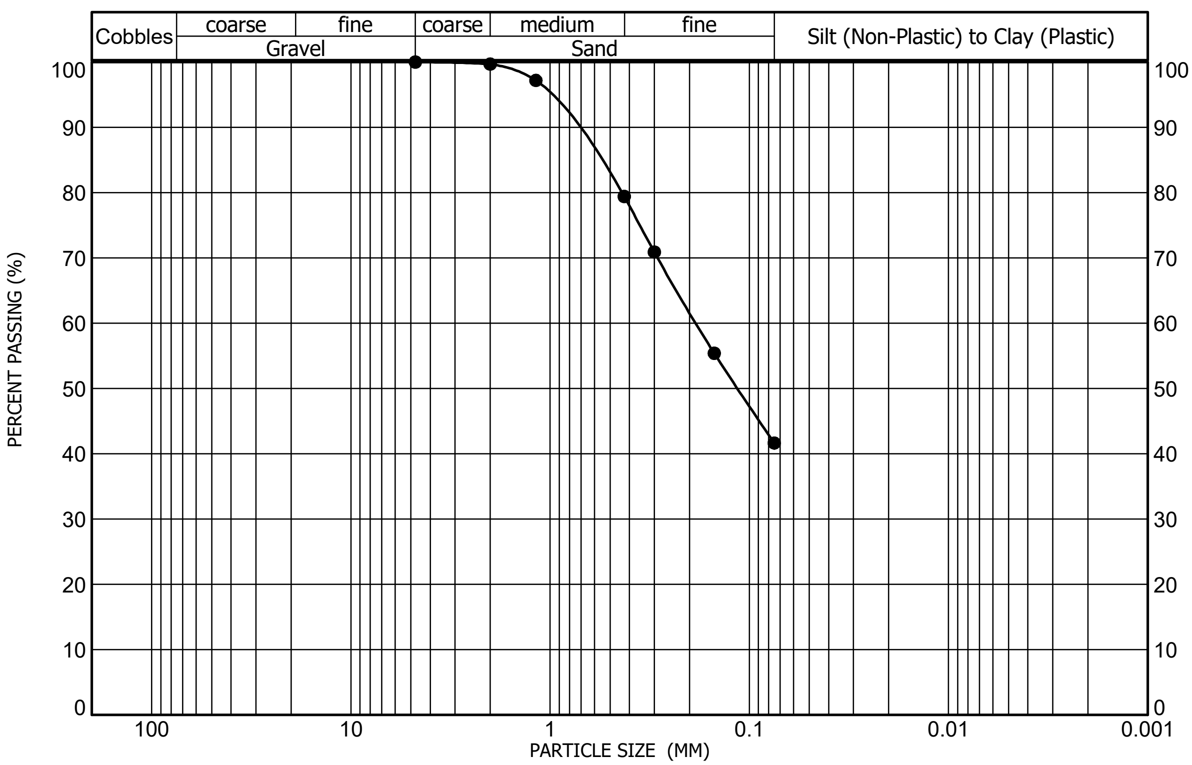
Sample Description: Fill, clay, very sandy

Classification: A-6(11), SANDY LEAN CLAY(CL)

Gravel (%): 0 | Liquid Limit: 36

Sand (%): 35 | Plasticity Index: 21

Clay/Silt (%): 65



Sample Location: Test Boring No. 8 at a depth of 0 feet to 5 feet

Sample Description: Fill, sand, very clayey

Classification: A-6(4), CLAYEY SAND(SC)

Gravel (%): 0 | Liquid Limit: 35

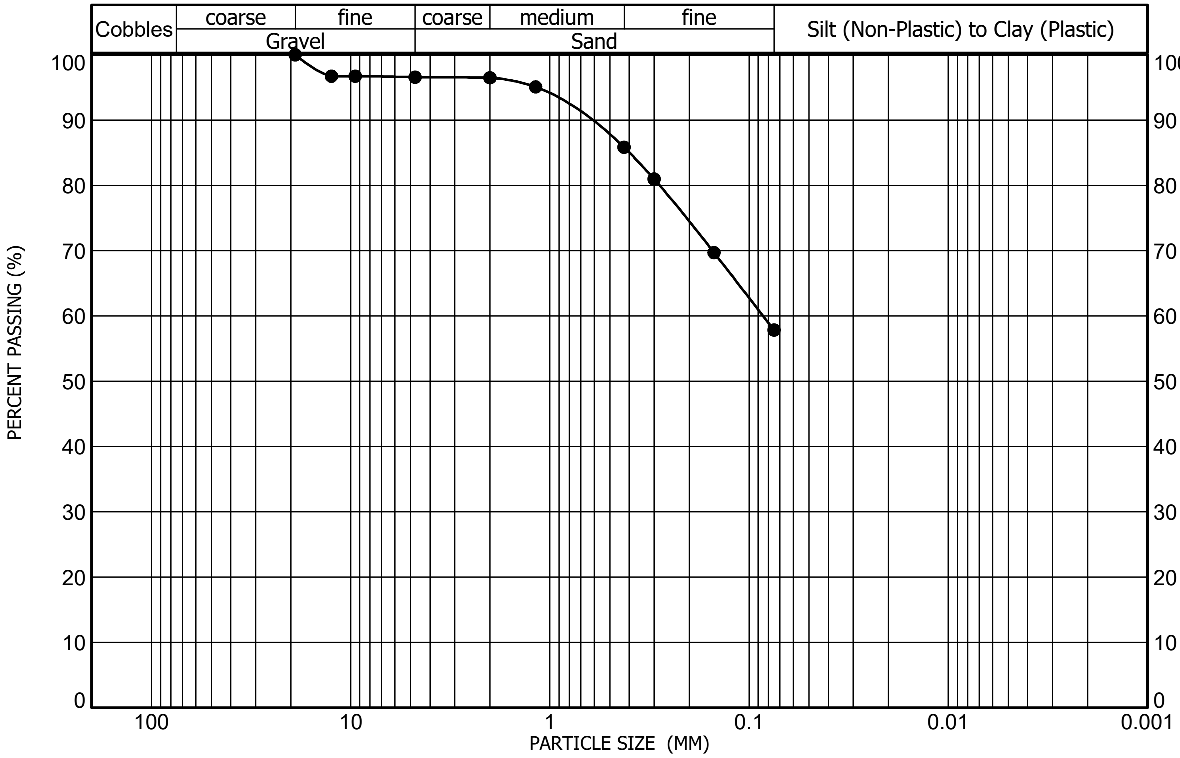
Sand (%): 58 | Plasticity Index: 20

Clay/Silt (%): 42

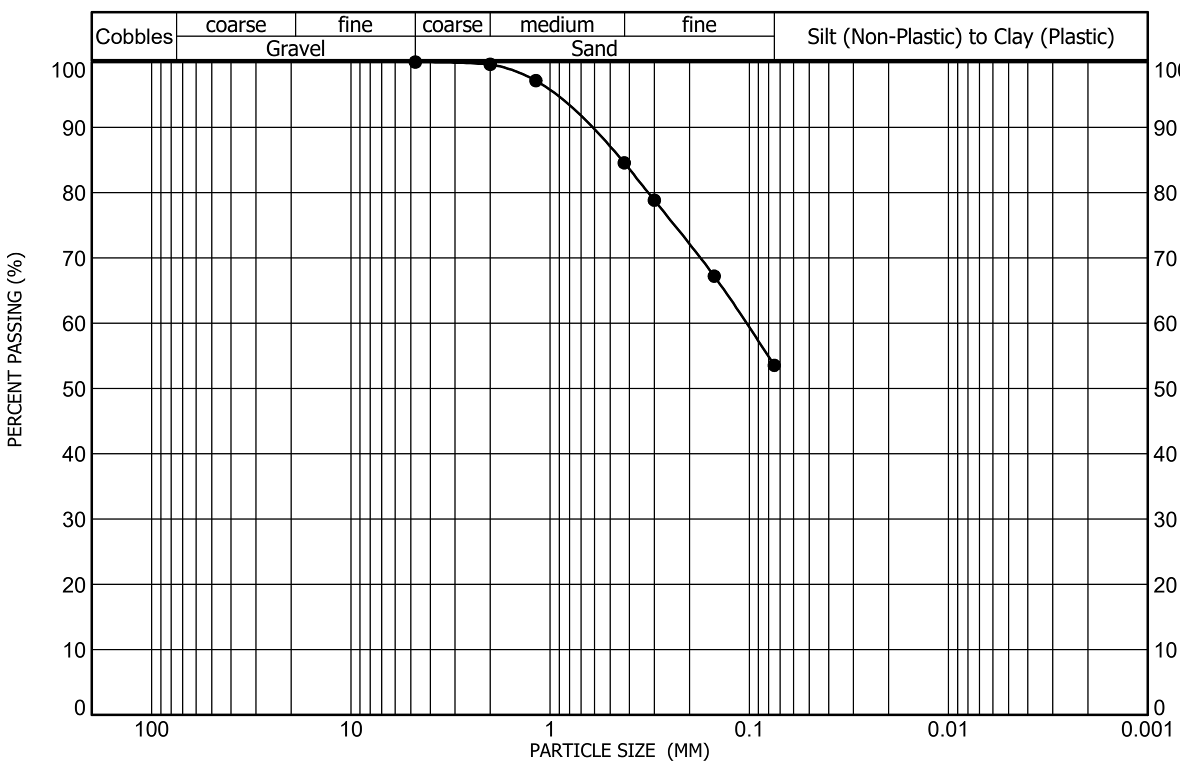
GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-4

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 9 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(7), SANDY LEAN CLAY(CL)
Gravel (%): 3
Sand (%): 39
Clay/Silt (%): 58
Liquid Limit: 35
Plasticity Index: 18

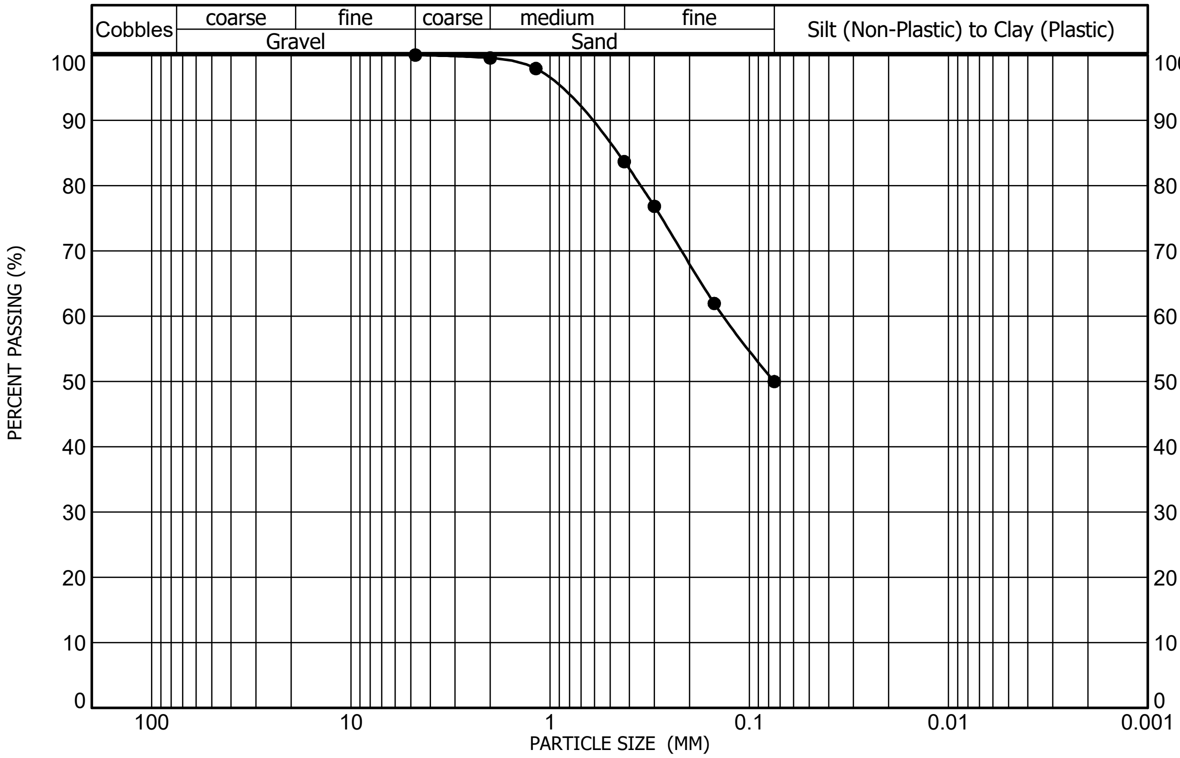


Sample Location: Test Boring No. 10 at a depth of 0 feet to 5 feet
Sample Description: Fill, clay, very sandy
Classification: A-6(4), SANDY LEAN CLAY(CL)
Gravel (%): 0
Sand (%): 46
Clay/Silt (%): 54
Liquid Limit: 32
Plasticity Index: 13

GRADATION AND ATTERBERG TEST RESULTS

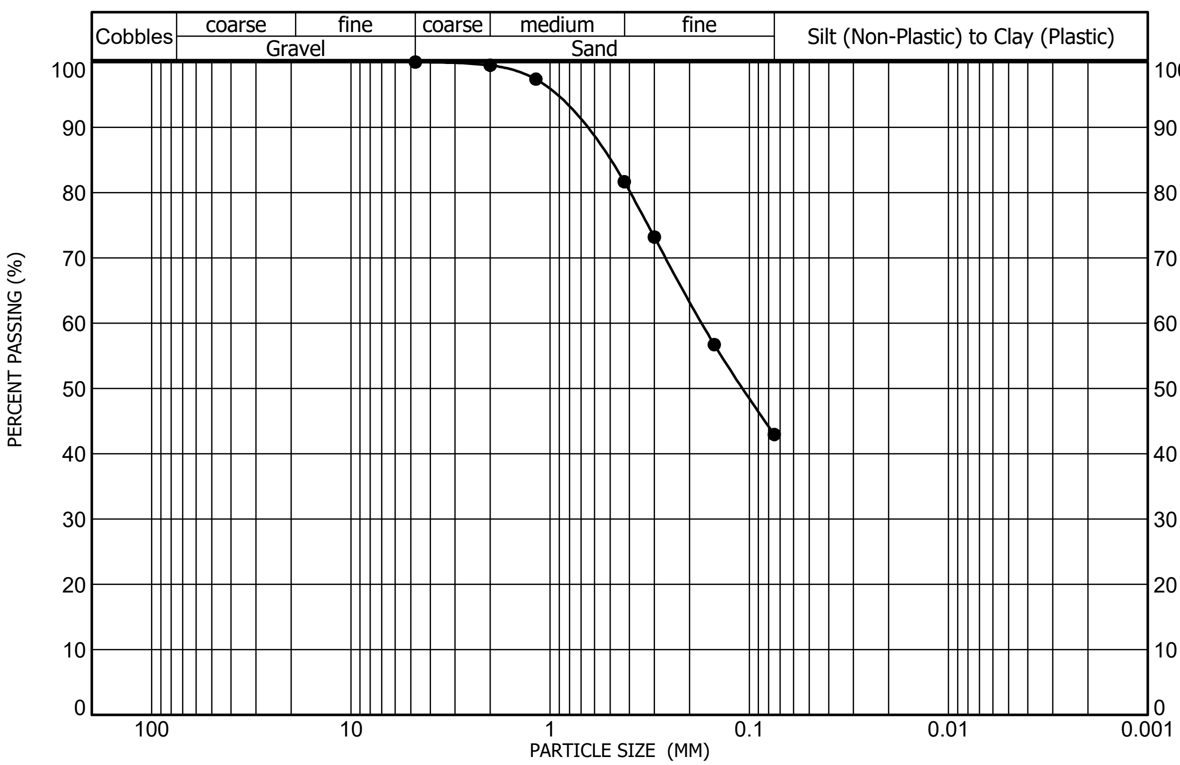
FIGURE A-5

A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 11 at a depth of 0 feet to 5 feet
Sample Description: Fill, sand, very clayey
Classification: A-6(6), CLAYEY SAND(SC)

Gravel (%): 0
Sand (%): 50
Clay/Silt (%): 50
Liquid Limit: 35
Plasticity Index: 19

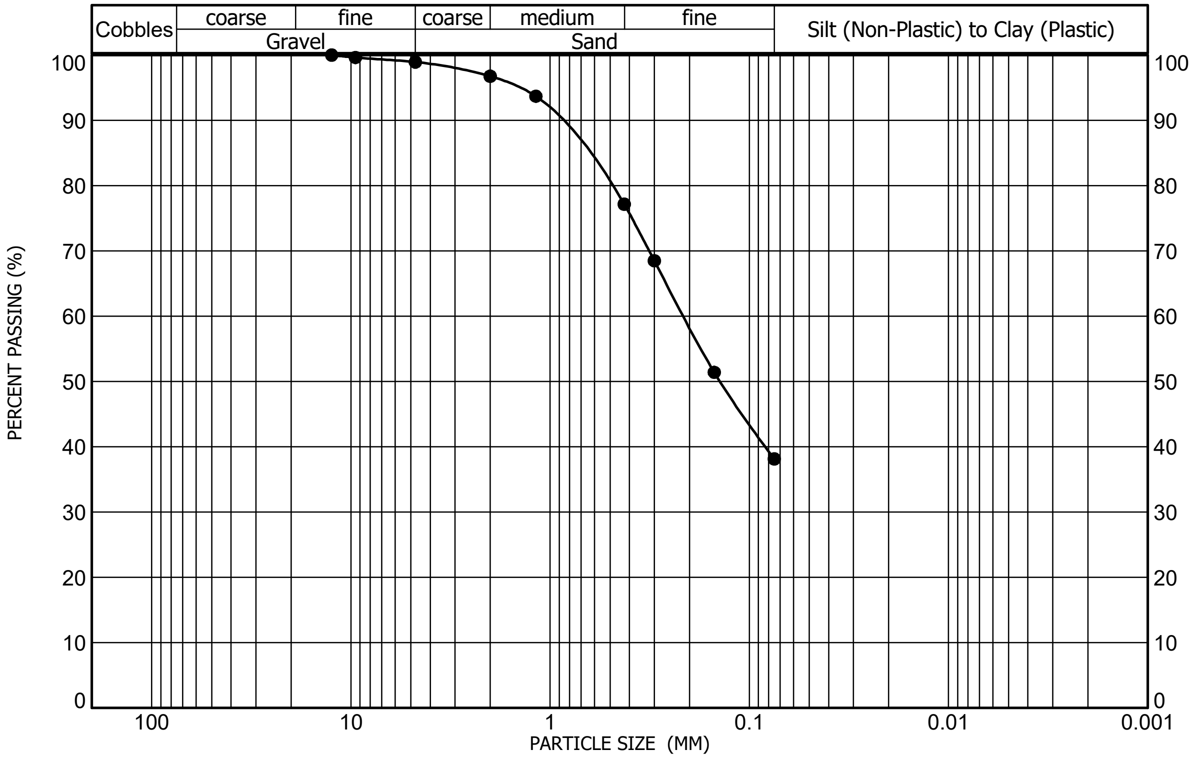


Sample Location: Test Boring No. 12 at a depth of 0 feet to 5 feet
Sample Description: Fill, sand, very clayey
Classification: A-6(3), CLAYEY SAND(SC)

Gravel (%): 0
Sand (%): 57
Clay/Silt (%): 43
Liquid Limit: 32
Plasticity Index: 15

GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-6



Sample Location: Test Boring No. 13 at a depth of 0 feet to 5 feet

Sample Description: Fill, sand, very clayey

Classification: A-6(1), CLAYEY SAND(SC)

Gravel (%): 1

Sand (%): 61

Clay/Silt (%): 38

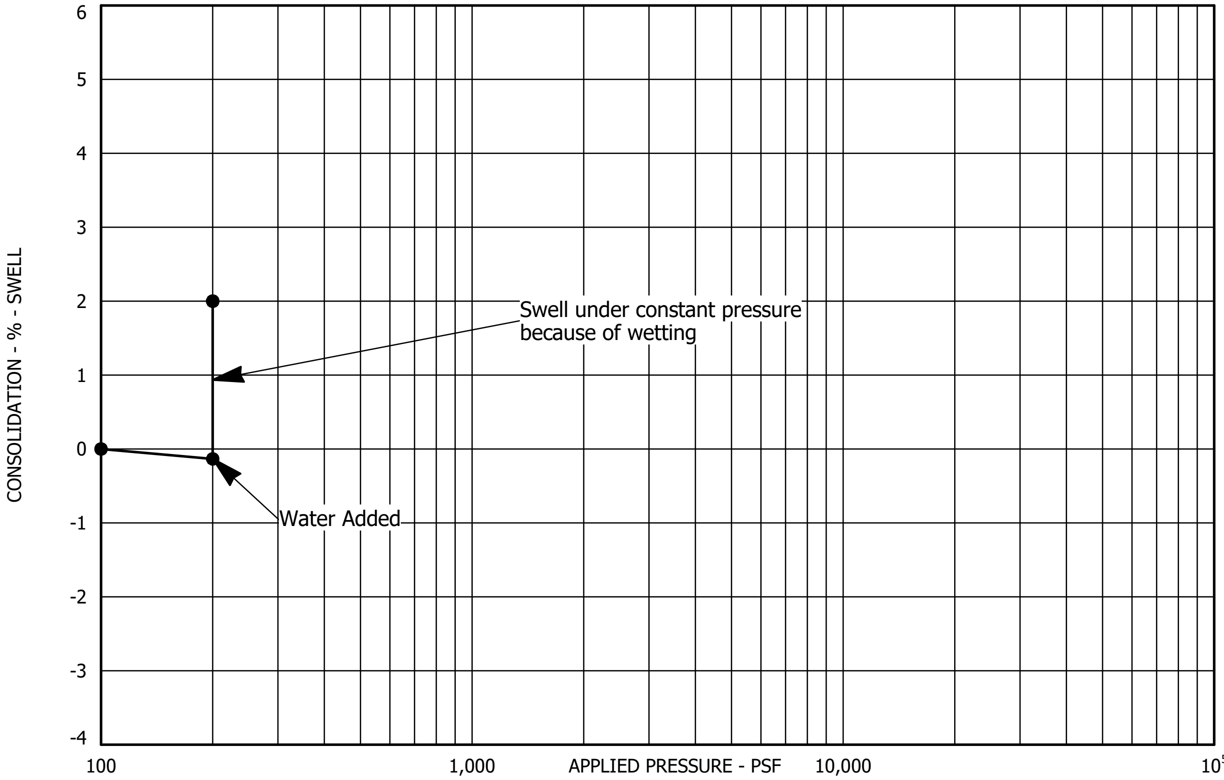
Liquid Limit: 31

Plasticity Index: 13

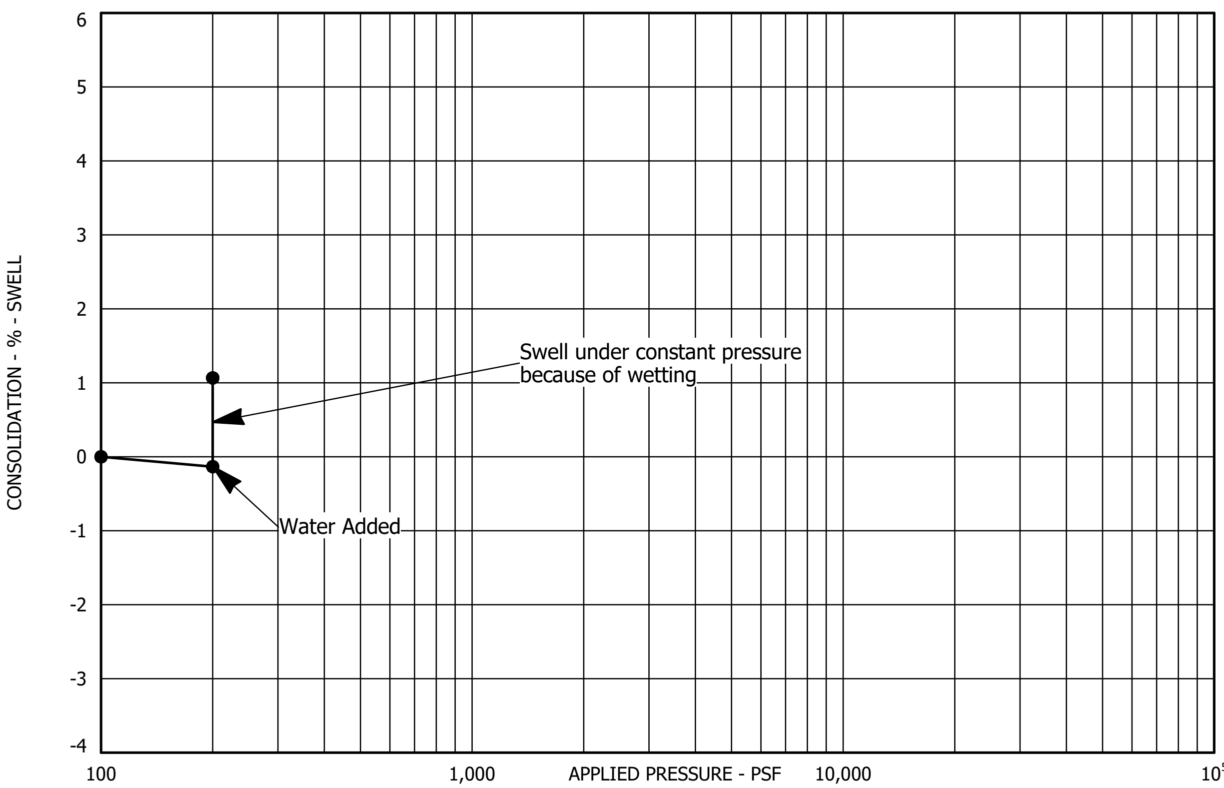
GRADATION AND ATTERBERG TEST RESULTS

FIGURE A-7

AGW
A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 2 at a depth of 2 feet
Dry Unit Weight (pcf): 107
Sample Description: Fill, clay, very sandy
Moisture Content (%): 16

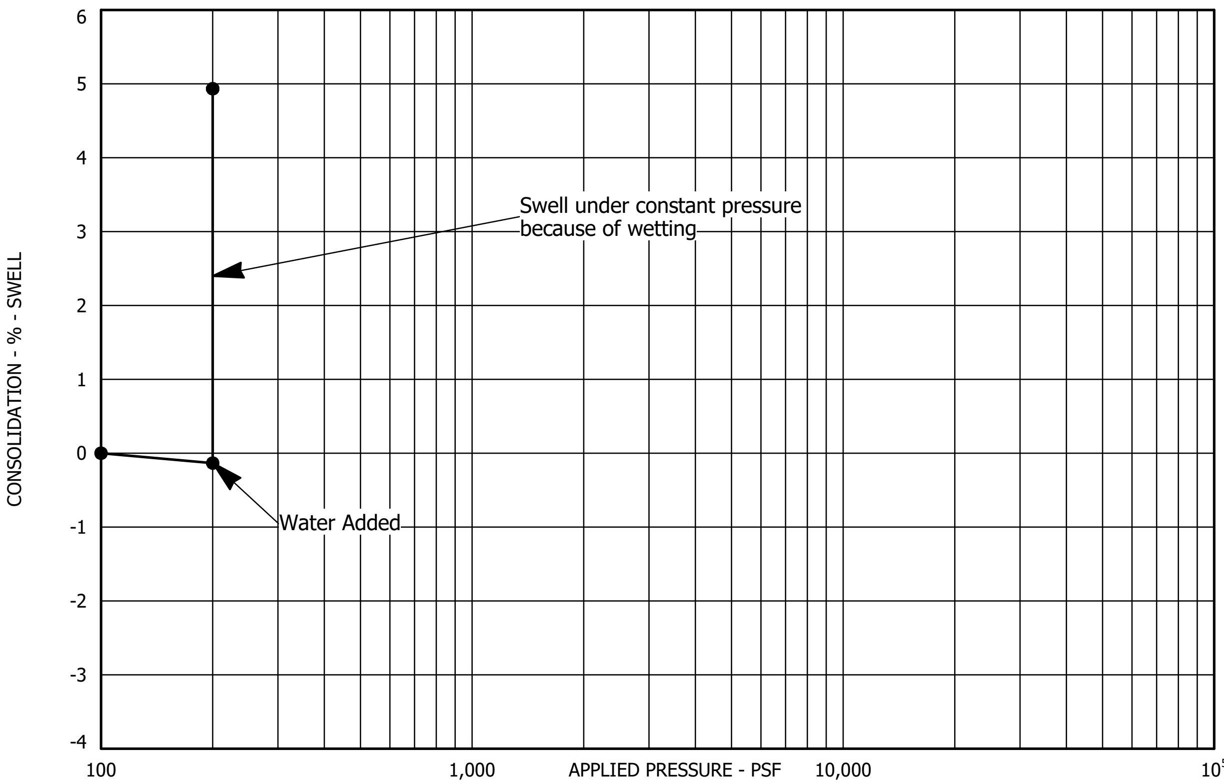


Sample Location: Test Boring No. 4 at a depth of 2 feet
Dry Unit Weight (pcf): 105
Sample Description: Fill, clay, very sandy
Moisture Content (%): 13

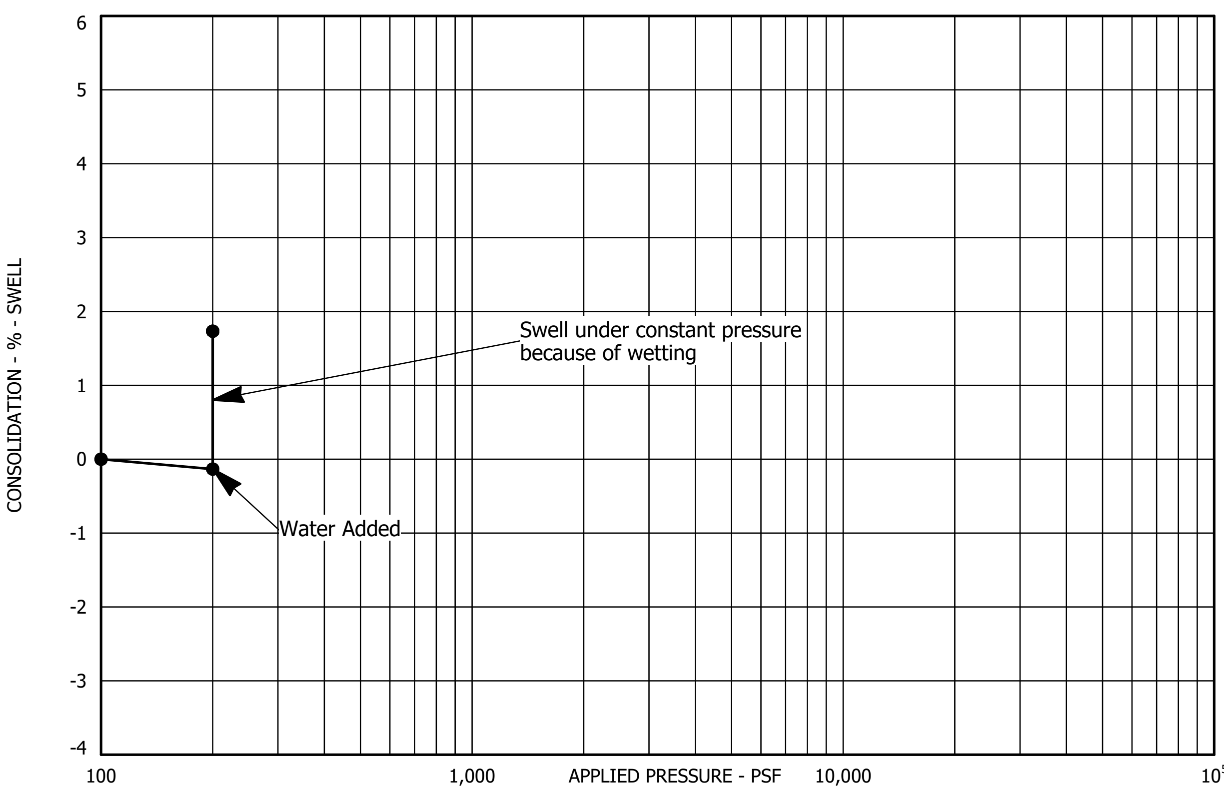
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-8

PROJECT NO. 210970 P1



Sample Location: Test Boring No. 6 at a depth of 2 feet
Dry Unit Weight (pcf): 102
Sample Description: Fill, clay, very sandy
Moisture Content (%): 16

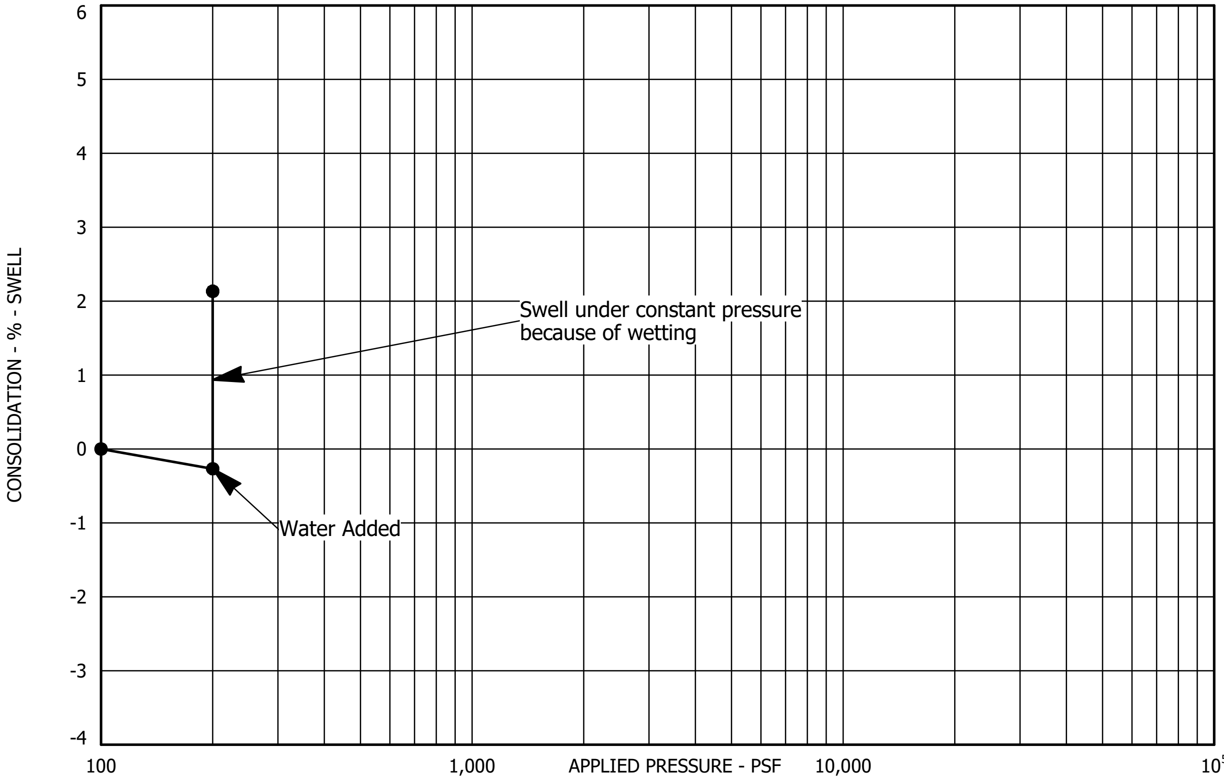


Sample Location: Test Boring No. 8 at a depth of 2 feet
Dry Unit Weight (pcf): 103
Sample Description: Fill, sand, very clayey
Moisture Content (%): 11

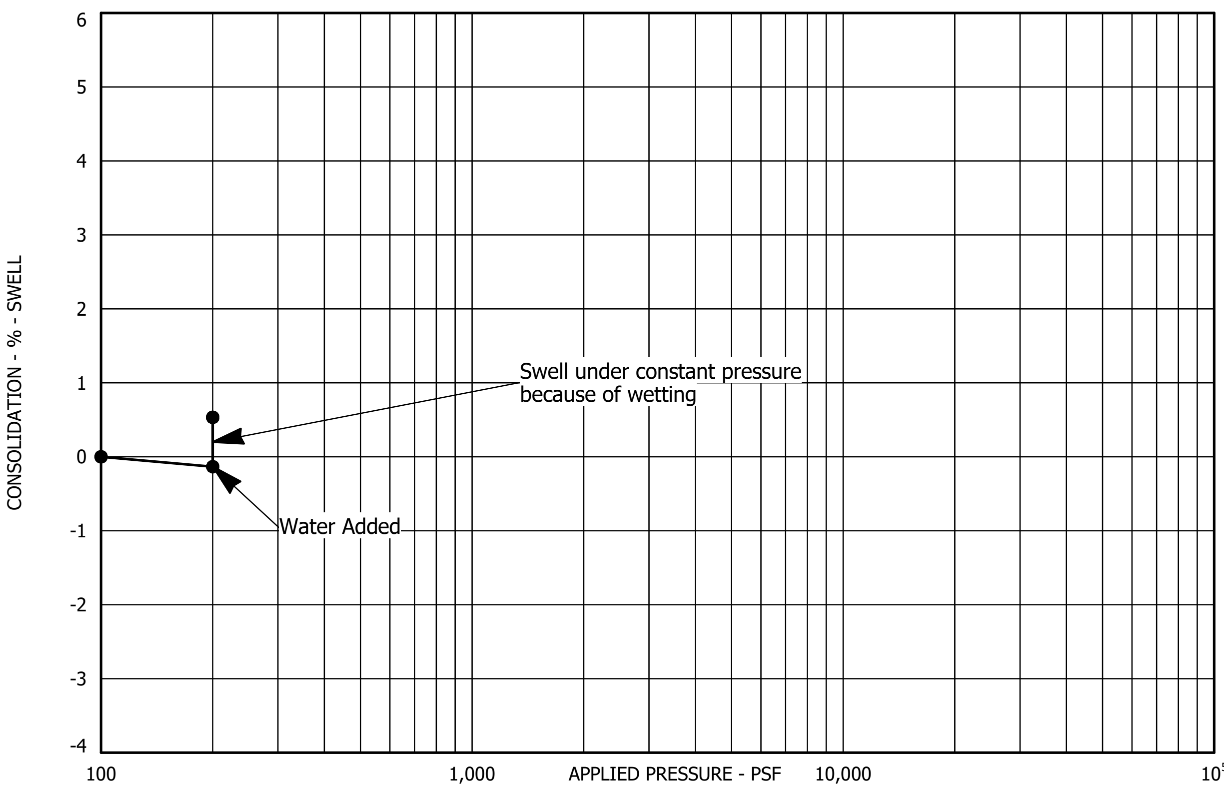
SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-9

AGW
A.G. WASSENAAR, INC.



Sample Location: Test Boring No. 11 at a depth of 2 feet
Sample Description: Fill, sand, very clayey
Dry Unit Weight (pcf): 108
Moisture Content (%): 7



Sample Location: Test Boring No. 13 at a depth of 2 feet
Sample Description: Fill, sand, very clayey
Dry Unit Weight (pcf): 110
Moisture Content (%): 11

SWELL - CONSOLIDATION TEST RESULTS

FIGURE A-10

PROJECT NO. 210970 P1

A.G. WASSENAAR, INC.

PROJECT: URBAN COLLECTION AT PALMER VILLAGE

DATE: FEBRUARY 8, 2022

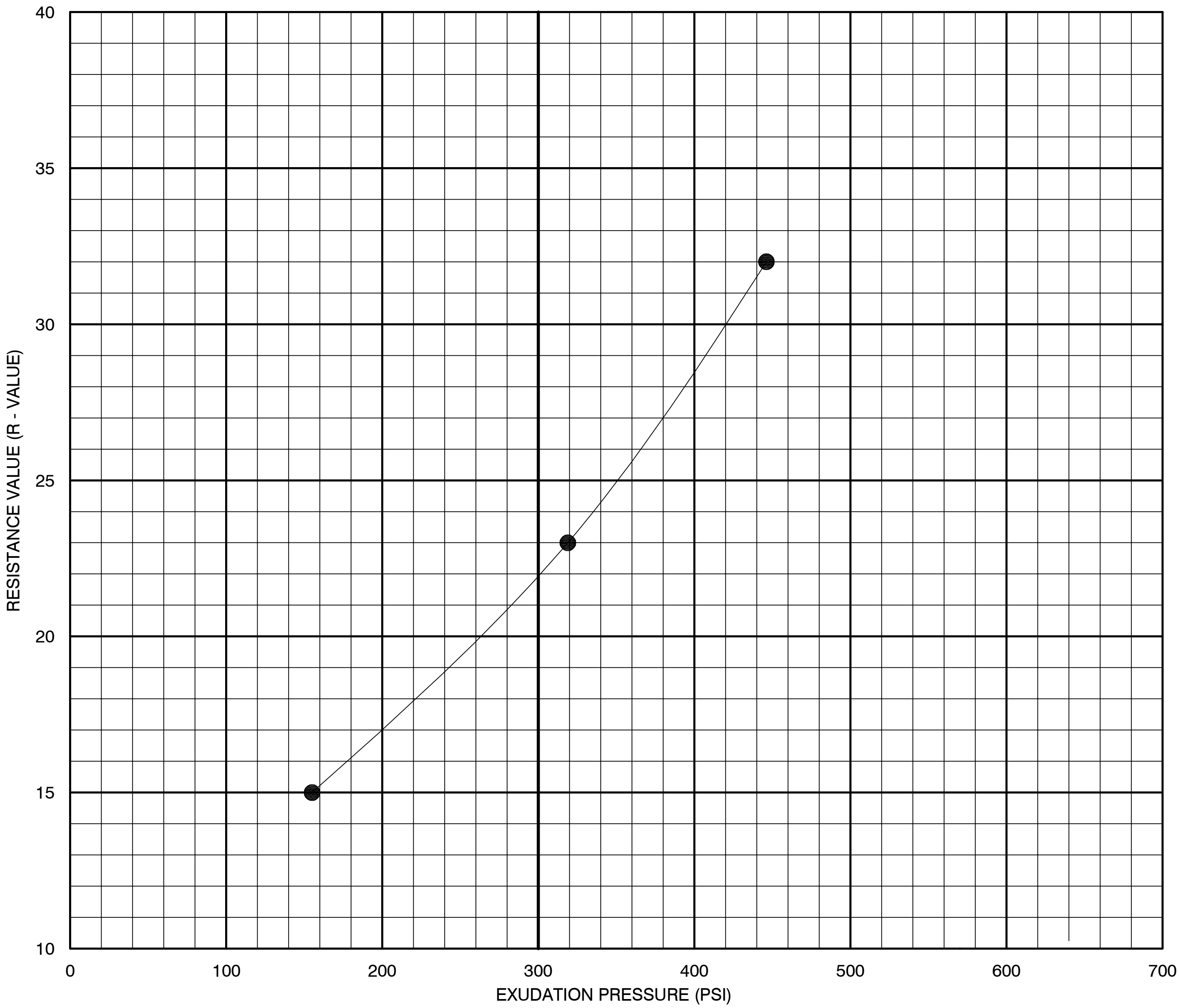
LOCATION: TEST BORING 7 (0-5')

PROJECT NO.: 210970 P1

SOIL DESCRIPTION: FILL, CLAY, VERY SANDY

TEST METHOD: ASTM D2844

AASHTO CLASSIFICATION: A-6 (11)



POINT	1	2	3	4
DRY DENSITY (PCF)	105.1	109.5	110.8	
MOISTURE CONTENT (%)	24.2	19.8	17.9	
EXUDATION PRESSURE (PSI)	155	318	447	
R-VALUE	15	23	32	

R - VALUE AT 300 PSI EXUDATION 22

RESISTANCE R-VALUE GRAPH

FIGURE A-11

APPENDIX B
PAVEMENT THICKNESS CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

A. G. Wassenaar, Inc.

Flexible Structural Design Module

Local and Parking
Urban Collection at Palmer Village
El Paso County, Colorado
Project Number 210970-P1

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	292,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	80 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	5,273 psi
Stage Construction	1
Calculated Design Structural Number	2.86 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Hot Bituminous Pavement	0.44	1	4.5	-	1.98
2	Aggregate Base Course	0.11	1	8	-	0.88
Total	-	-	-	12.50	-	2.86

FIGURE B-1

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

A. G. Wassenaar, Inc.

Flexible Structural Design Module

Local and Parking
Urban Collection at Palmer Village
El Paso County, Colorado
Project Number 210970-P1

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	292,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	80 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	5,273 psi
Stage Construction	1
Calculated Design Structural Number	2.86 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	Hot Bituminous Pavement	0.44	1	4	-	1.76
2	Chemically Treated Subgrade	0.12	1	12	-	1.44
Total	-	-	-	16.00	-	3.20

FIGURE B-2