

SUBMITTED TO:
HDR Engineering, Inc.
5555 Tech Center Dr, Ste 310
Colorado Springs, CO 80919

BY:
Shannon & Wilson
1321 Bannock St, Ste 200
Denver, CO 80204

(303) 825-3800
www.shannonwilson.com

GEOTECHNICAL & PAVEMENT DESIGN REPORT
Highway 105 School Access Lane
EL PASO COUNTY, COLORADO

Submitted To: HDR Engineering, Inc.
5555 Tech Center Dr, Ste 310
Colorado Springs, CO 80919
Attn: Contact Name

Subject: GEOTECHNICAL & PAVEMENT DESIGN REPORT, HIGHWAY 105
SCHOOL ACCESS LANE, EL PASO COUNTY, COLORADO

This report presents the results of our subsurface explorations at the site and provides recommendations for design of pavements, retaining walls, and earthwork for this portion of the larger Highway 105 Corridor Improvements project, and was prepared by the undersigned. Shannon & Wilson prepared this report and participated in this project as a subconsultant to HDR Engineering, Inc. (HDR). Our scope of services was specified in our amendment to subconsultant agreement with HDR, dated October 25, 2021.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON



Joseph C. Goode, PE
Senior Geotechnical Engineer

RAL:LOS:JCG:DAV/jma

CONTENTS

1	Introduction	1
2	Site and Project Description.....	1
3	Field Explorations and Laboratory Testing.....	3
4	Regional Geology and Subsurface Conditions	3
4.1	Regional Geology	3
4.2	Subsurface Conditions.....	4
4.3	Groundwater.....	4
4.4	Subsurface Variations	5
5	Geologic Hazard Evaluation	5
5.1	Seismic Hazards and Ground Motion Design Parameters	5
5.2	Expansive Soils	6
5.3	Corrosion Potential	6
6	Pavement Recommendations.....	7
6.1	Subgrade Conditions	7
6.2	Subgrade Mitigation	7
6.3	Traffic Loading	8
6.4	Recommended Pavement Section.....	8
7	Retaining Wall Recommendations	8
7.1	General.....	8
7.2	Global Slope Stability.....	9
7.3	Lateral Earth Pressures.....	10
7.4	Wall Backfill and Drainage	11
7.5	Lateral Resistance Parameters.....	11
7.6	Bearing Resistance.....	12
8	Construction Considerations.....	12
8.1	Site Preparation	12
8.2	Earthwork.....	13
8.2.1	Excavation Potential.....	13
8.2.2	Retaining Wall and Pavement Subgrade Preparation	13
8.2.3	Placement and Moisture Conditioning	13

8.3	Temporary Slopes	13
8.4	Paving Materials.....	14
9	Document Review and Construction Observation	14
10	Limitations	15
11	References	16

Exhibits

Exhibit 2-1:	Overview of proposed improvements.....	2
Exhibit 2-2:	Typical cross-section of proposed cut and fill walls.	2
Exhibit 4-1:	Surficial Geology of Project Site (Thorson and Madole, 2004)	4
Exhibit 5-1:	Seismic Design Parameters.....	6
Exhibit 6-1:	Recommended Pavement Sections.....	8
Exhibit 7-1:	MBRW Lateral Earth Pressures.....	10
Exhibit 7-2:	MBRW Sliding Resistance Design Parameters	12

Figures

Figure 1:	Vicinity Map
Figure 2:	Site and Exploration Plan
Figure 3:	Recommended Surcharge Loading for Temporary and Permanent Walls

Appendices

Appendix A:	Subsurface Explorations
Appendix B:	Laboratory Test Results
Appendix C:	Pavement Design Calculations
Important Information	

1 INTRODUCTION

This report summarizes the results of our subsurface exploration and laboratory testing program and presents design recommendations and construction considerations for pavements, retaining walls, and earthwork as part of the proposed School Access Lane project at Monument Academy in Monument, Colorado. The School Access Lane project is being led by El Paso County for the Monument Academy as part of the larger State Highway 105 Corridor Improvements project in El Paso County, Colorado. Our services were conducted in general accordance with the amendment to our subconsultant agreement with HDR Engineering, Inc. (HDR), dated October 25, 2021. Our conclusions and recommendations in this report are based on:

- The limitations of our approved scope, schedule, and budget described in our contract;
- Our understanding of the Project and information provided by HDR;
- Subsurface conditions encountered in the borings at the time our explorations were completed; and
- The results of testing performed on samples collected from the explorations.

The objective of our geotechnical study was to provide recommendations and construction considerations, as presented herein, for the proposed access lane. The authorized scope of services was based on this objective and this report should not be used for other purposes without Shannon & Wilson's review. If a service is not specifically indicated in this report, do not assume that it was performed.

2 SITE AND PROJECT DESCRIPTION

The project site is located north of Highway 105, approximately 0.9 miles east of its intersection with Interstate 25 in Monument (Figure 1). The proposed improvements consist of adding a paved access lane running from the school parking lot and drop-off lanes to the paved area on the north side of the school building, with the access lane alignment passing around an existing athletic field. The proposed layout is shown on Figure 2 and Exhibit 2-1.

We understand that the proposed improvements at the project site will include earthwork, new cut and fill modular block retaining walls, and new pavements for the access lane. We understand the pavements will be flexible Hot Mix Asphalt (HMA) and will follow the El Paso County Engineering Criteria Manual (El Paso County, 2016). Grading for the Project is anticipated to consist of 3H:1V (horizontal:vertical) sliver fills with a maximum height of about 15 feet, fill walls with a maximum height of about 11 feet, and cut walls with a

maximum height of about 6 feet. A typical section showing the proposed cut and fill wall is included as Exhibit 2-2.

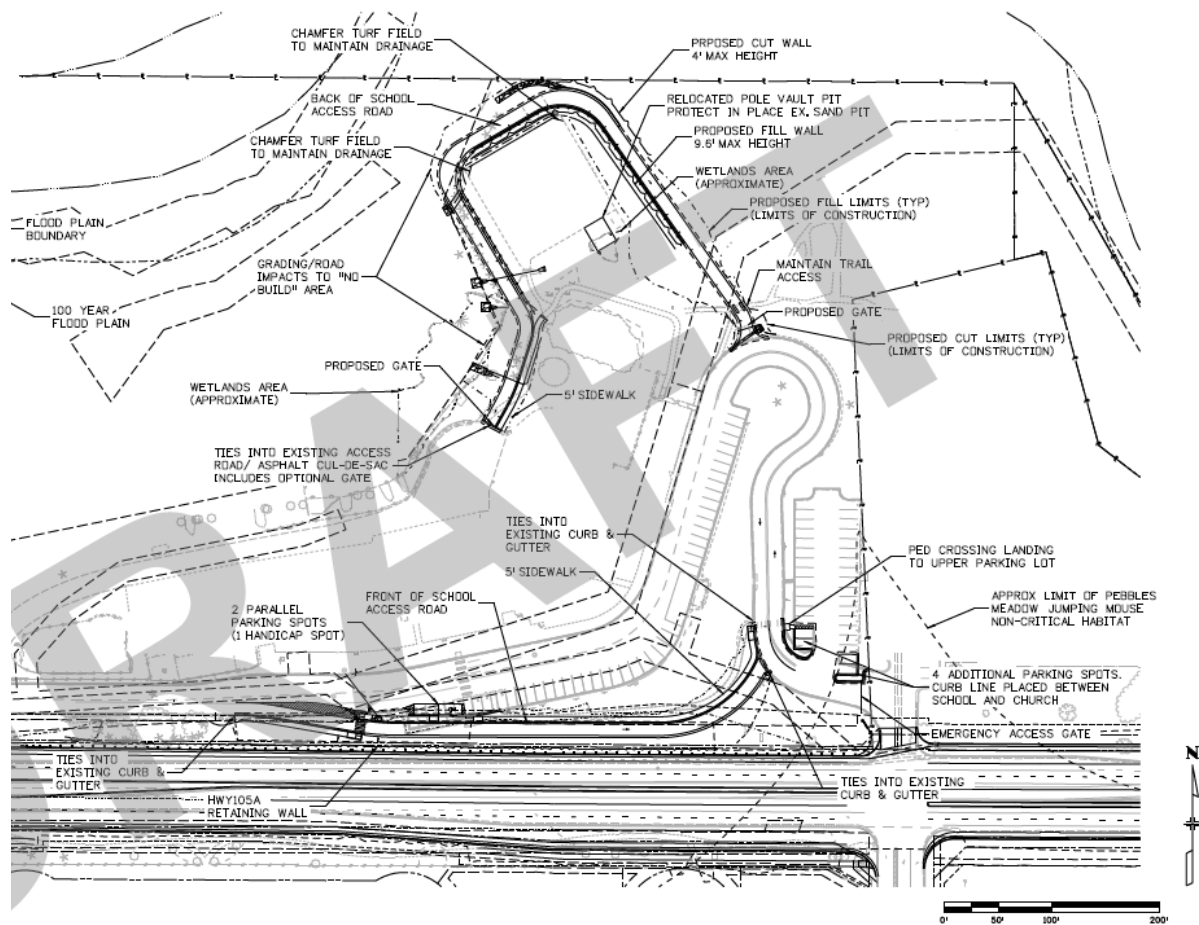


Exhibit 2-1: Overview of proposed improvements.

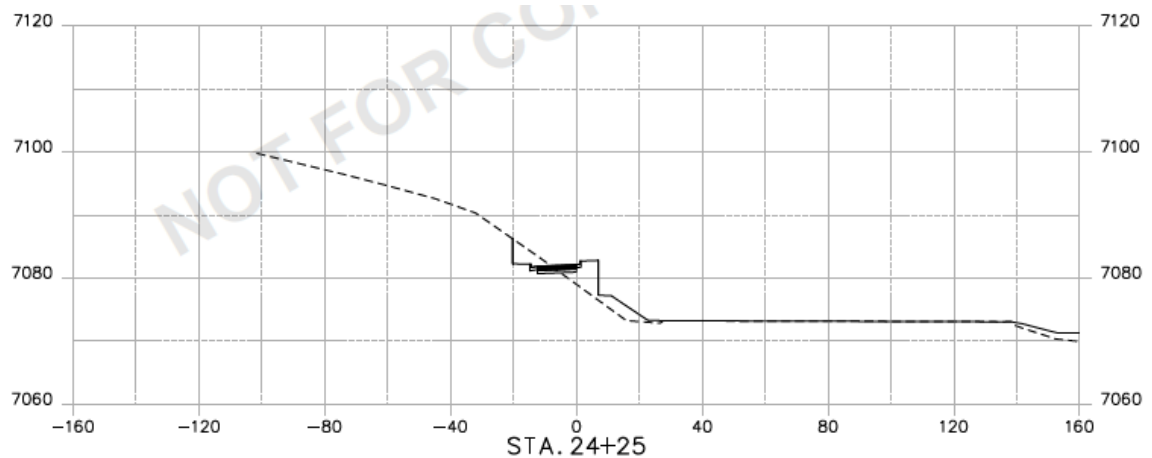


Exhibit 2-2: Typical cross-section of proposed cut and fill walls.

3 FIELD EXPLORATIONS AND LABORATORY TESTING

Shannon & Wilson conducted a geotechnical exploration program on August 5, 2021 to explore subsurface conditions at the site. The geotechnical exploration program consisted of drilling and sampling five borings, designated SW-101 through SW-105. Refer to Figure 2 for exploration locations. The borings were advanced to depths ranging from 5.5 to 19.8 feet below ground surface (bgs). Appendix A presents a discussion of the drilling, sampling, and testing procedures used in completing the borings. Appendix A also presents the individual exploration logs and an explanation of the symbols and terminology used.

Geotechnical laboratory tests were completed on selected samples retrieved from the borings to estimate soil index and engineering properties. Tests included natural water content, grain size distribution, Atterberg limits, Hveem Stabilometer (R-value), and corrosion (resistivity, pH, sulfate ion content in soil, and chloride content in soil). Laboratory test methods and results are provided in Appendix B. The natural water content, fines content, and Atterberg limits are also shown on the individual boring logs included in Appendix A.

4 REGIONAL GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Prior to completing our subsurface exploration program, Shannon & Wilson reviewed a regional geologic map (Thorson and Madole, 2004). The map indicates that subsurface conditions at the project site generally consist of Holocene- and Pleistocene-age alluvium of various named units describing soils comprised of fine sand with silt, clay, and gravel, underlain by sandstone of the Dawson Formation. The geologic mapping by Thorson and Madole (2004, excerpt in Exhibit 4-1) is generally consistent with the materials observed in our borings at the site, as described below.

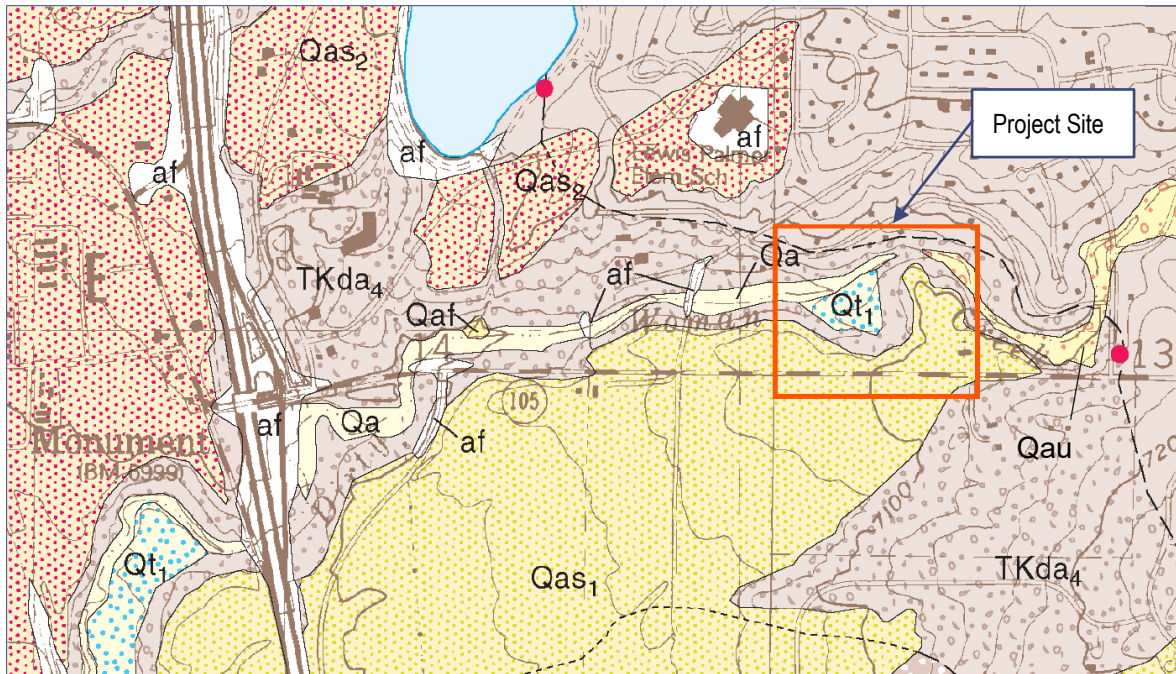


Exhibit 4-1: Surficial Geology of Project Site (Thorson and Madole, 2004)

Qa = channel and flood-plain alluvium; Qt₁ = Terrace alluvium one; Qau = Alluvium, undivided; Qas1 = Younger alluvial-slope deposits; TKda₄ = Dawson Formation, facies unit four

4.2 Subsurface Conditions

Overburden soils encountered in the borings consisted primarily of loose to medium dense sand with varying amounts of clay and silt overlying Dawson Formation bedrock. Layers of medium dense gravel and stiff clay, as well as a clayey sand layer containing organics, were encountered in boring SW-101. Overburden soils were generally classified as A-1-b, A-2-4, A-2-6, and A-2-7 in accordance with the American Association of State Highway and Transportation Officials (AASHTO) classification system. Thickness of the overburden layers ranged from 0 feet (at boring SW-105) to 17.3 feet (at boring SW-101). Bedrock was encountered in all five borings and consisted of extremely weak, moderately to slightly weathered Dawson Formation sandstone. Existing fill consisting of 3 feet of medium dense, silty sand was encountered in boring SW-101.

Boring SW-105 was drilled through existing pavement. We measured an asphalt pavement thicknesses of 6-inches at this location; we did not observe aggregate base course (ABC) underlying the HMA.

4.3 Groundwater

Groundwater was encountered within the overburden in boring SW-101 and within the bedrock in boring SW-103, at depths of 8.9 and 4.6 feet bgs, respectively. Groundwater was

not encountered in any of the other explorations during drilling. Fluctuations of groundwater levels at the site are possible and will depend on many factors, including seasonal variations, irrigation of landscaped areas, and local precipitation.

4.4 Subsurface Variations

The explorations were performed to evaluate subsurface conditions at the project site. Our observations are specific to the locations, depths, and times noted on the logs and may not be applicable to all areas of the site. No amount of explorations or testing can precisely predict the characteristics, quality, or distribution of subsurface and site conditions.

Potential variation includes, but is not limited to:

- The conditions between explorations may be different.
- The passage of time or intervening causes (natural and manmade) may result in changes to site and subsurface conditions.

If conditions different from those described herein are encountered during construction, we should review our description of the subsurface conditions and reconsider our conclusions and recommendations.

5 GEOLOGIC HAZARD EVALUATION

5.1 Seismic Hazards and Ground Motion Design Parameters

The Front Range of Colorado is an area of low potential for damaging earthquakes. Unfortunately, it is not possible to accurately estimate the timing or location of future earthquakes, because the occurrence of earthquakes is relatively infrequent and the historical earthquake record in Colorado is short (about 130 years). Based on a recent geologic map by the U.S. Geological Survey (Rogers and others, 1998), the nearest fault to the proposed project is the Rampart Range Fault, approximately 4 miles to the west. Based on geomorphic features along the fault trace, this fault is suspected to have been active less than 750,000 years ago. In our opinion, based on the location of the fault and lack of recent movement, the potential for ground surface fault rupture from this fault is low.

We understand that design ground motion parameters will be based on the requirements of the 2021 International Building Code (International Code Council, 2020), which has adopted the ASCE 7-16 design code for minimum design loads on buildings (ASCE, 2017). These design loads are in turn based on the USGS National Seismic Hazard Maps that were updated in 2008 (Petersen and others, 2008). Based soil and rock conditions encountered

along the wall alignments, we recommend assuming Site Class D. The following exhibit 5-1 provides seismic design parameters for the Project.

Exhibit 5-1: Seismic Design Parameters

Design Parameter	Value
Peak Ground Acceleration (PGA_B) ¹	0.119 g
Short-period Spectral Acceleration, S_S	0.214 g
Long-period Spectral Acceleration, S_1	0.059 g
Site Class	D
Site Factor, F_{PGA}	1.561
Site Factor, F_a	1.6
Site Factor, F_v	2.4
Site Modified Peak Ground Acceleration, PGA_m	0.186 g
Site Modified Spectral Acceleration (0.2 s), S_{MS}	0.343 g
Site Modified Spectral Acceleration (1.0 s), S_{M1}	0.141 g
Seismic Design Value (0.2 s), S_{DS}	0.229 g
Seismic Design Value (1.0 s), S_{D1}	0.094 g

NOTES:

1 PGA_B refers to peak ground acceleration for a site underlain by Site Class B soil (rock).

g = gravity; sec. = seconds

5.2 Expansive Soils

Swell susceptible soil and rock are common along the Front Range of Colorado. This geologic phenomenon has the potential to cause substantial damage to lightly loaded structures (in particular pavements) when such soil/rock undergoes a change in the moisture regime. As part of our evaluation of the swell potential through the project area, we reviewed a published geologic map of potentially swelling soil and rock of the Front Range urban corridor, developed by Hart (1974). The site is mapped as having low swell potential. Additionally, subsurface conditions at the site typically consisted of granular soils and sandstone bedrock. As such, it is our opinion that there is a relatively low risk of swell impacting the proposed construction.

5.3 Corrosion Potential

The clay soil and bedrock materials in the Colorado Front Range area can be corrosive to substructure elements. To assist in estimating the corrosion potential at the site, a select sample was tested for resistivity, pH, water-soluble sulfates, and water-soluble chlorides. The results are presented in Table B-1 in Appendix B.

The resistivity in the sample measured 5,500 ohm-centimeters. Based on correlations developed by Roberge (2012), the measured value suggests moderately corrosive subsurface conditions for metal in contact with subsurface materials at the site.

The concentration of water-soluble sulfates in the sample measured 0.02% by weight. Based on standard construction specifications prepared by the Colorado Department of Transportation (CDOT, 2021b), the measured value corresponds to Class 0 requirements for sulfate resistance. CDOT (2021b) recommends a minimum sulfate protection of Class 2 unless otherwise specified in the contract documents.

The test results and above discussion are provided to assist the designer in the selection of project materials, concrete type, or other features with respect to corrosion. As appropriate, the designer should consider protective measures, such as coatings, upsizing for section loss, or using alternative materials to reduce corrosion potential.

6 PAVEMENT RECOMMENDATIONS

Our pavement design was completed in general accordance with the 2016 El Paso County Engineering Criteria Manual. Pavement design calculations are provided in Appendix C.

6.1 Subgrade Conditions

Based on our subsurface explorations (see Section 4.0), subgrade soils for the proposed pavement were assumed to primarily consist of granular soils with silt and clay (AASHTO Classification A-2-6). Subgrade strengths for the pavement design are based on R-value testing of the subgrade in our geotechnical exploration program. In accordance with 2016 El Paso County Engineering Criteria Manual, subgrade strength was evaluated using a Hveem stabilometer (R-value) test completed on a bulk sample collected from boring SW-102 resulting in an R-Value of 21. For our pavement analysis, we used an El Paso County correlation between R-value and resilient modulus, which calculates a resilient modulus value of approximately 5,200 pounds per square inch (psi).

6.2 Subgrade Mitigation

Based on the requirements outlined in Section D.2.4 of the El Paso County Engineering Criteria Manual swell mitigation considerations are required for subgrades soils with a Plastic Index (PI) greater than 10. Although the materials throughout the school access lane alignment indicated PIs greater than 10, they had fines contents ranging from 15 to 33% (predominantly granular soils). Based on the subgrade conditions encountered in our

borings and discussion provided in Section 5.2, we recommend completing 8 inches of moisture treatment below all proposed pavements (refer to Section 8.2.2).

6.3 Traffic Loading

To estimate an 18-kip Equivalent Single-Axle Loading (ESAL) for the school access lane, we made assumptions regarding traffic distributions. We assumed an average daily traffic (ADT) of 1,000 vehicles for the paving year and no growth rate for the project design life (20 years). Traffic loadings were determined based on discussion with HDR. Specifically, HDR directed us to assume two delivery trucks per week, two trash trucks per week, and two fire trucks per year. Bus loading was not included (busses are not planned to use the access lane). Based on these assumptions, we estimated an 18-kip equivalent single axle loading (ESAL) of 21,000.

The projected traffic loading is below the County minimum required ESAL of 36,500 for local roadway classifications (El Paso County, 2016). To provide the County options for consideration, we provided pavement designs for both the projected traffic loading and County minimum.

6.4 Recommended Pavement Section

Using the procedures and the parameters outlined above and in Appendix C, we recommend the following pavement section alternatives in Exhibit 6-1 below.

Exhibit 6-1: Recommended Pavement Sections

Location	18-kip ESAL	Recommended Pavement Section
School Access Lane	21,000	3.5 in. HMA over 4 in. ABC
	36,500 ¹	4.0 in. HMA over 4 in. ABC

NOTE:

ABC = Aggregate Base Course; HMA = Hot mix asphalt; in.= inches

² El Paso County minimum design ESAL.

7 RETAINING WALL RECOMMENDATIONS

7.1 General

We understand that a Modular Block Retaining Wall (MBRW) is proposed to retain both fill and cuts supporting an access road located behind the school. Based on the Monument Academy Draft Wall Plan Set received from HDR on January 21, 2022, the proposed fill wall is 267 feet in length and up to approximately 11 feet in retained height, and the cut wall is

approximately 119 feet in length with max heights of 6 feet (see Exhibit 2-2). The walls will be located adjacent to each other to accommodate construction of the access lane along the existing 3H:1V slope. Based on borings SW-102 and SW-103, subgrade conditions are anticipated to vary from very loose to loose, clayey sand to sandstone bedrock. Toe slopes in front of the fill wall vary from approximately flat to a slope of 3 horizontal to 1 vertical (3H:1V). The existing backslope above the cut wall has a slope of approximately to 3H:1V. If conditions change, we should be notified so we can re-evaluate our recommendations and update as necessary.

We understand the Contractor will be responsible for final design of the wall (including geometry, internal stability, materials selection, and final sliding, overturning, and bearing design checks); we have provided recommendations for global slope stability, lateral earth pressures, sliding resistance, and bearing resistance only. We understand wall design and construction should be performed in general accordance with International Building Code (IBC) 2021 and AASHTO LRFD Bridge Design Specifications (2020). We recommend that backfill, and other fill materials, meet CDOT (2021b) material gradation requirements, unless otherwise stated in this section or as specified by the wall designer.

7.2 Global Slope Stability

We evaluated global slope stability for the proposed wall using GeoStudio SLOPE/W R19 limit equilibrium software (GeoStudio, 2019). For our analysis, we used the Spencer method of slices and the following assumptions:

- The modular blocks will be supported on a gravel leveling pad.
- A minimum embedment of 3 feet below the final grade in front of the wall, measured from the bottom of the first row of blocks.
- A live load vehicle surcharge of 250 pounds per square foot (psf) acting on top of the retained fill.
- Based on data from our subsurface explorations, depth to groundwater was set to 4.5 feet bgs.
- The seismic load horizontal coefficient was taken as two-thirds the site factored PGA (PGA_M).

We performed slope stability analyses at two critical sections along the proposed wall alignment, as presented in Monument Academy Draft Wall Plan Set (HDR, 2022).

Results of our global slope stability analysis indicate that the proposed wall and slope profiles satisfy minimum Factor of Safety (FS) requirements of 1.5 for static conditions and 1.1 for extreme (i.e., seismic loading) conditions.

7.3 Lateral Earth Pressures

The lateral earth pressures against retaining walls depend on many factors, including surcharge loads, type of backfill and adjacent native soils, drainage features, and the degree to which the wall can yield or deflect laterally or rotate at the top. We recommend that Class 1 Structure Backfill or free-draining granular material be used for wall backfill. We assume the proposed wall is free to displace at the top a minimum of 1/1,000th the structure's height (0.001H) in a horizontal direction. Our recommended active earth pressure parameters are presented below in Exhibit 7-1. Active earth pressures for the recommended backfill material, see Section 7.4, may be determined by multiplying the recommended active equivalent fluid unit weight by height of retained backfill. Wall backfill should be placed and properly compacted, see Section 8.2.3, within a 1:H:1V zone extending upward from a point 1.5 feet behind the heel of the wall.

Surcharge loads, such as motor vehicles and construction equipment, will induce lateral loads on retaining walls and buried structures. Consistent with AASHTO (2020) criteria, we recommend using a live load traffic surcharge of 250 psf for areas subject to motor vehicle loading. Lateral loads due to various types of surcharges may be calculated using the active earth pressure coefficient provided in Exhibit 7-1 and the diagrams provided in Figure 3, along with appropriate load factor(s).

If these assumptions are not met, we should be notified so that we may revise our lateral earth pressure recommendations.

Exhibit 7-1: MBRW Lateral Earth Pressures

	Design Parameters	Recommended Value
CDOT Class 1 Structure Backfill or Granular Backfill	Total Unit Weight (pcf) ¹	135
	Effective Friction Angle (degrees)	34
	Cohesion (psf)	0
	Wall Backfill Interface Friction Angle (degrees)	23
	Active Earth Pressure Coefficient, flat backslope, K_a	0.25
	Active Equivalent Fluid Unit Weight, flat backslope (pcf) ²	34
	Active Earth Pressure Coefficient, 3H:1V backslope, K_a	0.33
	Active Equivalent Fluid Unit Weight, 3H:1V backslope (pcf) ²	44

NOTES:

1 Total unit weight is moist unit weight of soil above the groundwater table.

2 Equivalent fluid active pressure calculated by multiplying K_a by the appropriate unit weight.

K_a = active earth pressure coefficient; pcf = pounds per cubic foot; psf = pounds per square foot

7.4 Wall Backfill and Drainage

Lateral earth pressure parameters provided in Section 7.3 assume the wall backfill is dry and hydrostatic pressure does not develop. As such, it is important that positive drainage measures are in place to reduce the potential for water to accumulate behind the walls.

In general, materials with greater than 3% fines content are not considered free draining. Specification for CDOT Class 1 Structure Backfill allows for a maximum fines content of 15% and may not be free draining. Accumulation of hydrostatic pressures behind the wall may be addressed by the final wall design accounting for unbalanced water pressures, or by including internal drainage features to reduce the potential for water to accumulate in the backfill. Appropriate internal drainage features would include limiting the fines content of the backfill to 3% or including a drain at the back of the wall. Internal drainage features should be selected and designed by the wall designer.

Surface water behind the wall should not be allowed to discharge directly into the wall backfill materials. At locations requiring excavation into existing slopes, additional drainage measures may be required if seepage is observed. We encountered groundwater at a depth of 4.6 feet in boring SW-103, and localized or perched groundwater may be encountered in the sandstone during wall construction. We recommend installing geocomposite strip drains along the back slope if seepage is observed during construction. These drains should be installed on the surface of the final cut slope every 10 feet (center to center) and should connect to the wall drainage system. Additionally, water should not be allowed to discharge or pond around retaining structures, including from landscape irrigation sources. We recommend sloping the ground surface in front of the walls a minimum grade of 5% away from the wall face for a minimum horizontal distance of 10 feet measured from the face of the wall (or until a paved surface is encountered, whichever distance is shortest).

7.5 Lateral Resistance Parameters

Lateral loads may be resisted by frictional resistance along the base of the retaining wall. Exhibit 7-2 provides our recommended sliding resistance design parameters. Anticipated embedment depth is 3 feet. Passive resistance should be ignored above the frost depth (3 feet) and on sloping ground, therefore passive parameters are not included.

Exhibit 7-2: MBRW Sliding Resistance Design Parameters

Design Parameters	Recommended Value
Coefficient of Friction for Sliding ($\tan\delta$), imported gravel leveling pad ¹	0.50
Strength Limit State Resistance Factor for Sliding	0.9

NOTES:

1 Provide a minimum of 12 inches of gravel below bottom of footing.

7.6 Bearing Resistance

As material properties vary along the length of the proposed wall alignments, bearing resistance for the wall footing also varies. Additionally, presence of downhill slopes in front of the wall footing will also affect the bearing resistance. We recommend that the bottom of the lowest wall block be embedded below the frost depth (36 inches). Our recommended bearing resistance assumes that this condition is met, that the lowest wall block is supported by a 12-inch-thick gravel leveling pad, and a maximum toe slope of 3H:1V. If these assumptions are not met during final design, we should be notified so that we may revise our bearing resistance recommendations.

We recommend a nominal bearing resistance of 5.5 kips per square foot (ksf), assuming a minimum width of 3 feet for the lowest block. AASHTO (2020) recommends a resistance factor of 0.45 be applied to the bearing resistance for MRBWs at the strength limit state. For the extreme event, bearing resistance can be calculated with a nominal resistance factor of 1.0.

8 CONSTRUCTION CONSIDERATIONS

The applicability of the design parameters provided is contingent on good construction practice. Poor construction techniques may alter conditions from those upon which our recommendations are based, and therefore result in poor performance. The following sections present additional construction and material considerations for this Project.

8.1 Site Preparation

Prior to site grading, ponded water should be drained from low-lying areas. In addition, construction areas should be cleared to a depth necessary to remove all surface and subsurface structures associated with current development of the site, including all pavements, utility poles, fence poles, underground utilities, and other deleterious material. Trees or shrubs to be removed should include the entire root ball and all roots larger than ½-inch-diameter. This may require laborers handpicking the roots from the subsurface soils prior to compaction.

Surface vegetation within construction areas should be removed by stripping. The depth of stripping should be determined at the time of construction based on existing conditions. Debris from the stripping should not be used in general fill construction in either pavement or wall foundation areas, but may be used in landscape areas.

8.2 Earthwork

8.2.1 Excavation Potential

We anticipate that excavation of overburden soil and shallow bedrock (where encountered) can be accomplished with conventional excavating equipment, such as dozers, front-end loaders or scrapers. We do not anticipate blasting will be required for rock excavation. However, excavation in fresh rock could be slow at times and require the use of hydraulic excavators with rock breakers and dozers with ripper attachments.

8.2.2 Retaining Wall and Pavement Subgrade Preparation

Wall and pavement subgrades should be stripped, scarified to a depth of 8 inches, moisture conditioned, and compacted in place to 95% of the Modified Proctor (AASHTO T180) maximum dry density and to a dense and unyielding condition. The compacted surface should then be proof-rolled with a fully loaded, tandem-axle, 10-yard dump truck or equivalent. Any areas that are identified as being loose, soft, or yielding during proof-rolling should be removed, replaced, and recompacted. Care should be taken during proof-rolling and subgrade preparation to avoid disturbing subgrade soils and supporting soils that will remain in place, as they can rut and pump under repeated construction traffic. All subgrade should be compacted to a firm, dense, and unyielding condition.

8.2.3 Placement and Moisture Conditioning

Fill materials should be placed in horizontal lifts and compacted to a dense and unyielding condition. The thickness of loose lifts should not exceed 8 inches for heavy equipment compactors and 4 inches for hand-operated compactors, but may be less depending on that required to obtain the required relative compaction. Granular soils (material with less than 35% fines) should be moisture treated to within 2% of optimum moisture content and compacted to at least 95% of the maximum dry density per AASHTO T180 (modified compaction effort). We do not recommend the use of cohesive soils as fill for the Project. If encountered, cohesive fill material can be placed in landscaping areas.

8.3 Temporary Slopes

We anticipate temporary excavations will be required to construct the Project. The type of excavation support system selected for construction will depend on proposed depth of the

excavation, proximity to existing structures, anticipated surcharge loads, and materials exposed during construction,

Temporary, unbraced excavations should be sloped, as needed, to provide a safe, stable slope. Consistent with conventional construction practice, the Contractor should be responsible for temporary excavation slopes. The Contractor is continually at the site, is able to observe the nature and conditions of the subsurface materials encountered, and is responsible for the methods, sequence, and schedule of construction.

For planning purposes only, we anticipate Type B soils will be encountered during excavation into Dawson formation bedrock and 1H:1V slopes may be used. Flatter slopes may be necessary in overburden material. We recommend using the excavation criteria in OSHA 29 CFR, Part 1926, Subpart P, Excavations (1989).

8.4 Paving Materials

Per Section D.5 of the El Paso County Engineering Criteria Manual, the ABC material shall consist of either CDOT Class 5 or Class 6 aggregated base course (CDOT, 2021b) and have a minimum R-value of 72.

HMA mix designs should be in accordance with the Pikes Peak Region Asphalt Paving Specification (2015). We recommend that the surface HMA lift be a Grade SX mix with a PG 64-22 binder. Below 2 inches, we recommend either a Grade S or SX mix with a PG 64-22 binder. CDOT (2021a) recommends lift thickness between 1-1/2 and 3 inches for Grade SX and 2-1/4 and 3-1/2 inches for Grade S. We recommend a Superpave design gyratory number (N) of 75. In addition, a tack coat should be placed between subsequent lifts.

9 DOCUMENT REVIEW AND CONSTRUCTION OBSERVATION

We recommend that we be retained to review the geotechnical aspects of the plans and specifications prior to bidding the work to determine that they are in accordance with our recommendations. While this step is often skipped in design document preparation, our experience is that the review can find discrepancies or misinterpretations and correct them before bidding, thus avoiding potential change orders during construction.

Geotechnical design recommendations are developed from a limited number of explorations and tests. Therefore, recommendations may need to be adjusted in the field. To this end, we recommend that a construction observation and monitoring program be implemented for the Project and that Shannon & Wilson be retained to monitor the geotechnical aspects of

construction. This monitoring would allow us to confirm that conditions encountered are consistent with those indicated by the explorations and provide expedient recommendations should conditions be revealed during construction that are different from those anticipated.

10 LIMITATIONS

This report has been prepared for the exclusive use of HDR and El Paso County for the purpose of providing pavement design and geotechnical engineering recommendations for the Project. This report should not be used without our approval if any of the following occurs:

- Assumptions stated in this report have changed,
- Project details change or new information becomes available such that our analyses and recommendations may be affected, or
- A substantial period of time has passed since the date of this report.

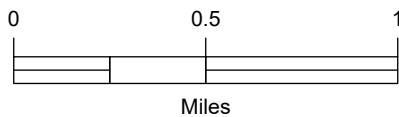
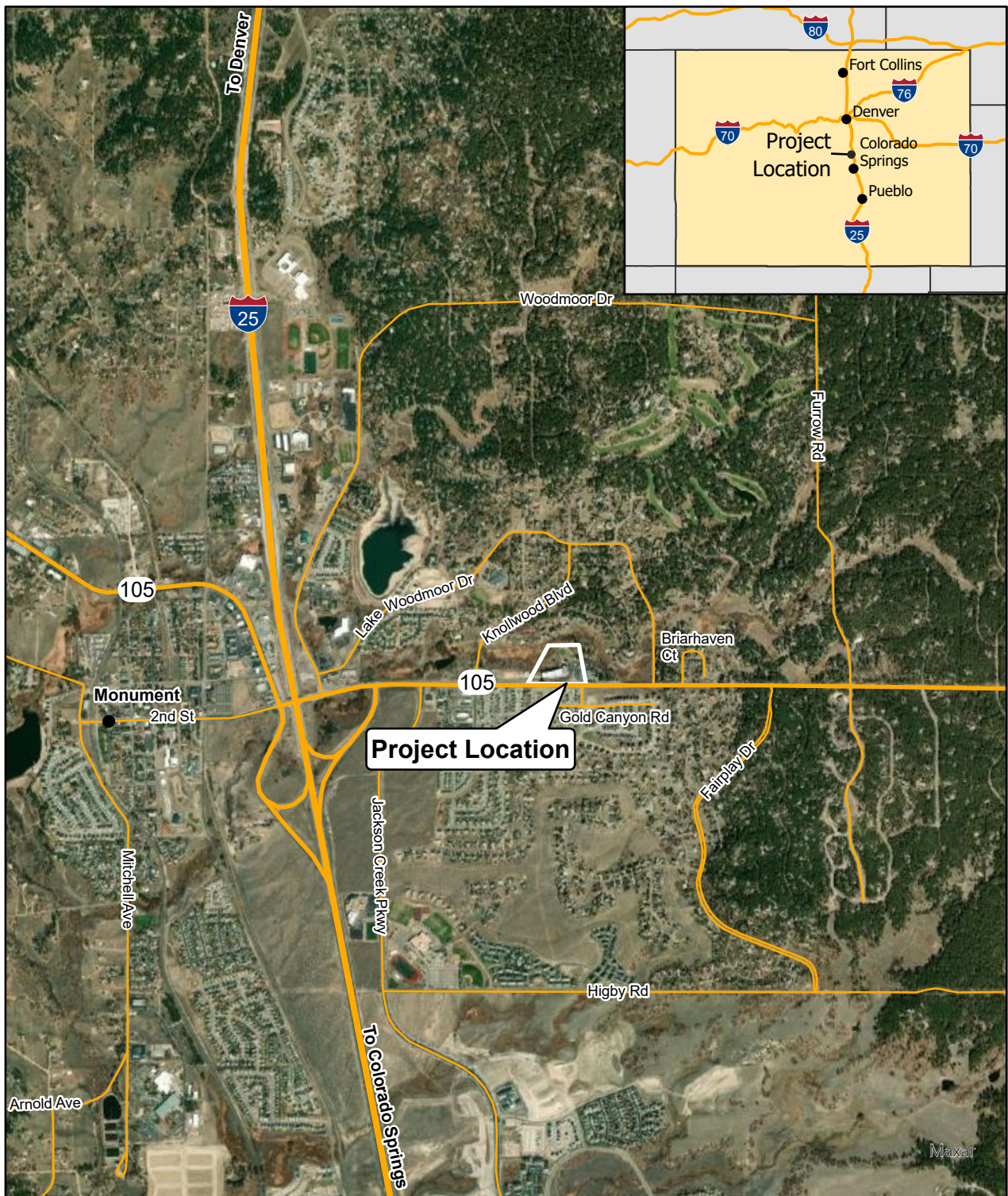
If any of these occur, we should be retained to review the applicability of our analyses and recommendations.

Within the limitations of scope, schedule and budget, the analyses, conclusions and recommendations presented in this report were prepared in general accordance with generally accepted professional geotechnical and geological principles and practice in this area at the time this report was prepared. We make no other warranty, either expressed or implied. Shannon & Wilson has prepared the attached document, "Important Information about Your Geotechnical Report," to assist you and others in understanding the use and limitations of our reports.

11 REFERENCES

- American Association of State Highway and Transportation Officials (AASHTO), 2020, AASHTO LRFD bridge design specifications, customary U.S. units, 9th edition: Washington, D.C., American Association of State Highway and Transportation Officials.
- American Society of Civil Engineers, 2017, Minimum design loads and associated criteria for buildings and other structures: Reston, Va. American Society of Civil Engineers, ASCE Standard ASCE/SEI 7- 16, 2 v.
- Colorado Department of Transportation (CDOT), 2021a, 2021 M-E Pavement Design Manual; available: <https://www.codot.gov/business/designsupport/materials-and-geotechnical/manuals/2021-m-e-pave-design-manual>
- CDOT, 2021b, Standard Specifications for Road and Bridge Construction, available at: <https://www.codot.gov/business/designsupport/cdot-construction-specifications/2021-construction-specifications/2021-specs-book/2021-standard-specifications-book>
- El Paso County, 2016, Engineering Criteria Manual, available from: <https://assets-publicworks.elpasoco.com/wp-content/uploads/Documents/EngineeringCriteriaManual.pdf>
- GeoStudio, 2019, SLOPE/W 2019, Version 10.1, Geoslope International.
- Hart, S.S., 1974, Potentially swelling soil and rock in the Front Range urban corridor, Colorado: Colorado Geological Survey, Greater Denver Area, Colorado, 4 sheets.
- HDR, Inc., 2021, Monument Academy Draft Wall Plan Set, dated January 28, 2022.
- International Building Code Council, Inc. (IBC), 2020, International building code 2021: Country Club Hills, Ill., International Code Council, Inc., 1 v.
- OSHA 29 CFR, Part 1926, Subpart P, Excavations (1989).
- Petersen, M.D., Frankel, A.D., Harmsen, S.C., and others, 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008-1128, 61p., <https://pubs.er.usgs.gov/publication/ofr20081128>

- Pikes Peak Region, 2015, Asphalt paving specifications, Version 3, Effective: February, 2015, available at:
<http://adm.elpasoco.com/publicservices/transportation/Documents/Pikes%20Peak%20Region%20Asphalt%20Paving%20Specs%20-%20February%202015%20-%20Version%203.pdf>
- Roberge, P.R., 2012, Handbook of corrosion engineering, 2nd edition: New York, McGraw-Hill, 1,078 p.
- Rogers, W.P., Kirkham, R.M., and Widmann, B.L., compilers, 1998, Fault number 2328, Rampart Range fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, <http://earthquakes.usgs.gov/hazards/qfaults>, accessed May, 2017
- Thorson, J.P. and Madole, R.F., 2004, Geologic map of the Monument quadrangle, El Paso County, Colorado: Colorado Geological Survey, Open-File Report OF02-04, scale 1:24,000, avail



Highway 105
School Access Lane
El Paso County, Colorado

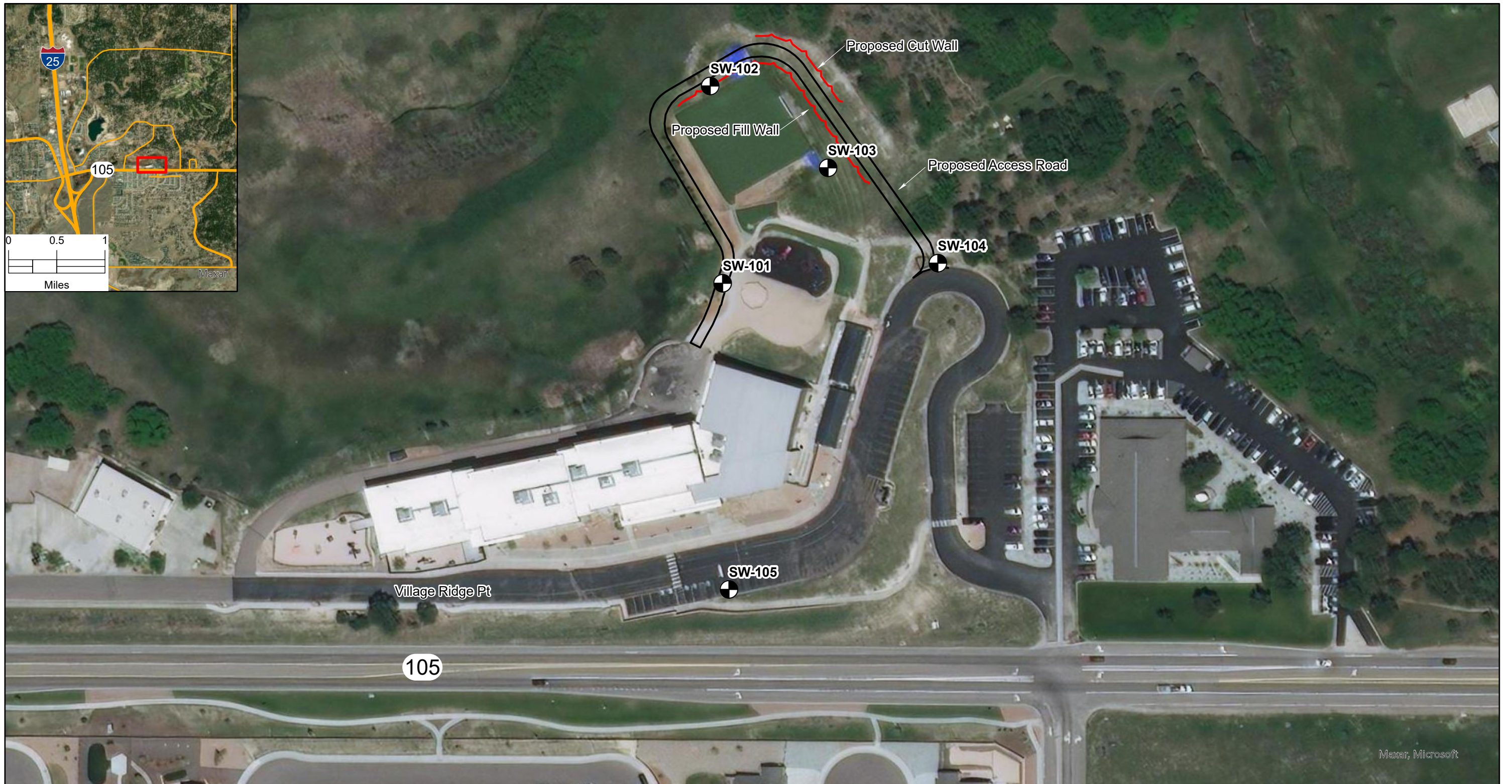
VICINITY MAP

February 2022





23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 1

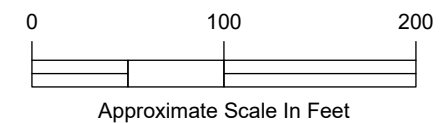


LEGEND

- SW-03**  Map Sheet
-  S&W Boring Designation and Approximate Location
-  Proposed Walls
-  Proposed Access Road

NOTES

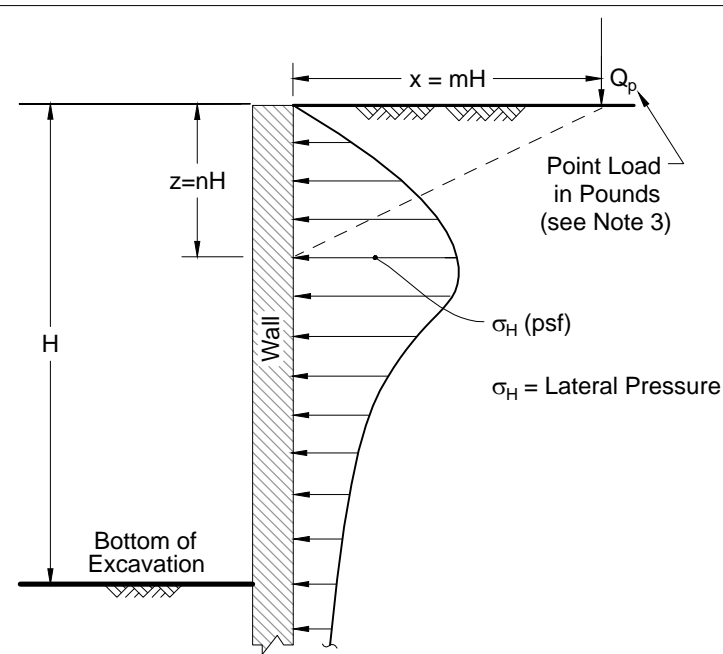
1. Boring locations were measured using recreational grade GPS and should be considered approximate.



Highway 105
School Access Lane
El Paso County, Colorado

SITE AND EXPLORATION PLAN

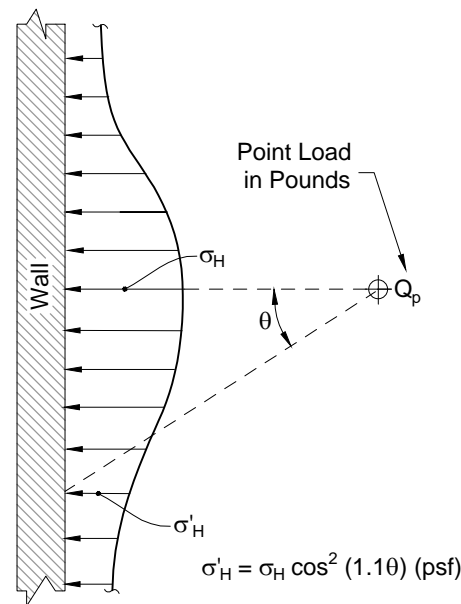
February 2022 23-01311-101
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants **FIG. 2**



ELEVATION VIEW

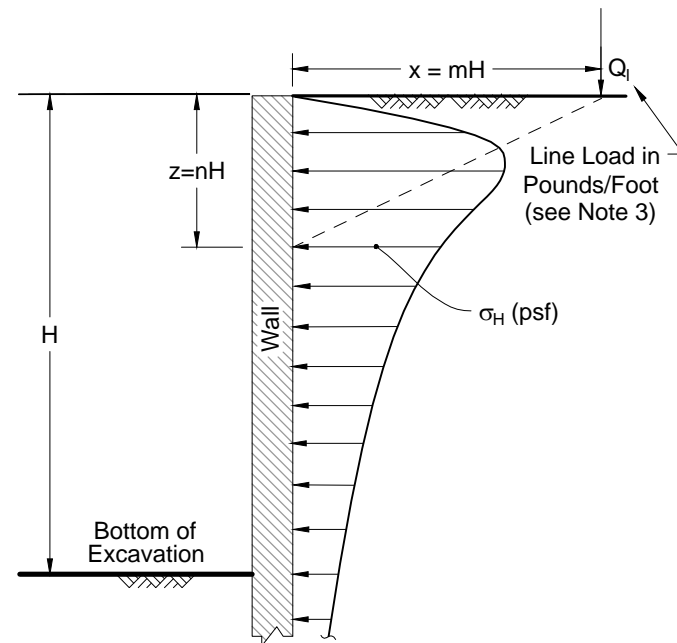
$$\text{For } m \leq 0.4: \sigma_H = 0.28 \frac{Q_p}{H^2} \frac{n^2}{(0.16 + n^2)^3} \text{ (psf) (see Note 3)}$$

$$\text{For } m > 0.4: \sigma_H = 1.77 \frac{Q_p}{H^2} \frac{m^2 n^2}{(m^2 + n^2)^3} \text{ (psf)}$$



PLAN VIEW

A) LATERAL PRESSURE DUE TO POINT LOAD
i.e. SMALL ISOLATED FOOTING OR WHEEL LOAD
(NAVFAC DM 7.2, 1986)



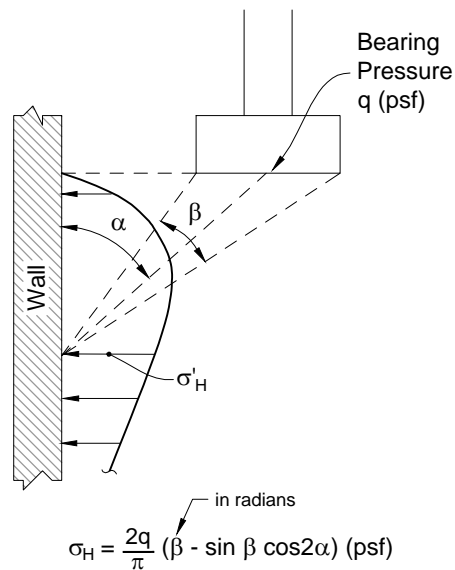
ELEVATION VIEW

$$\text{For } m \leq 0.4: \sigma_H = 0.20 \frac{Q_l}{H} \frac{n}{(0.16 + n^2)^2} \text{ (psf) (see Note 3)}$$

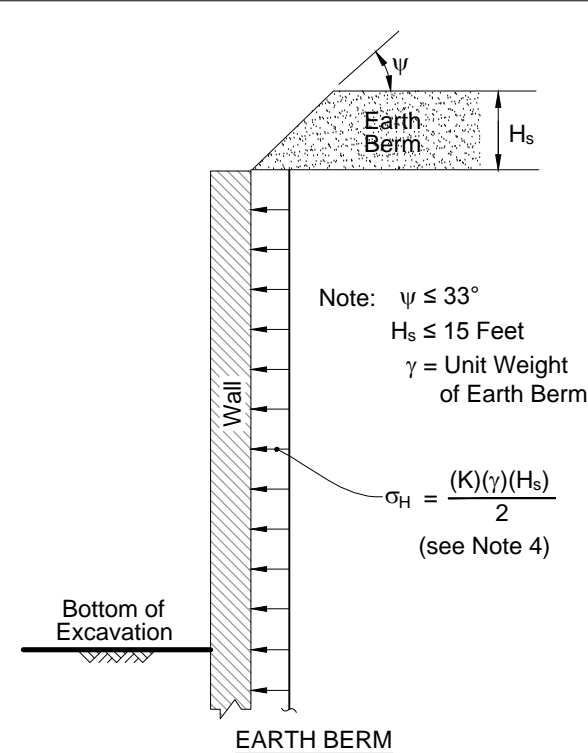
$$\text{For } m > 0.4: \sigma_H = 1.28 \frac{Q_l}{H} \frac{m^2 n}{(m^2 + n^2)^2} \text{ (psf)}$$

B) LATERAL PRESSURE DUE TO LINE LOAD
i.e. NARROW CONTINUOUS FOOTING
PARALLEL TO WALL

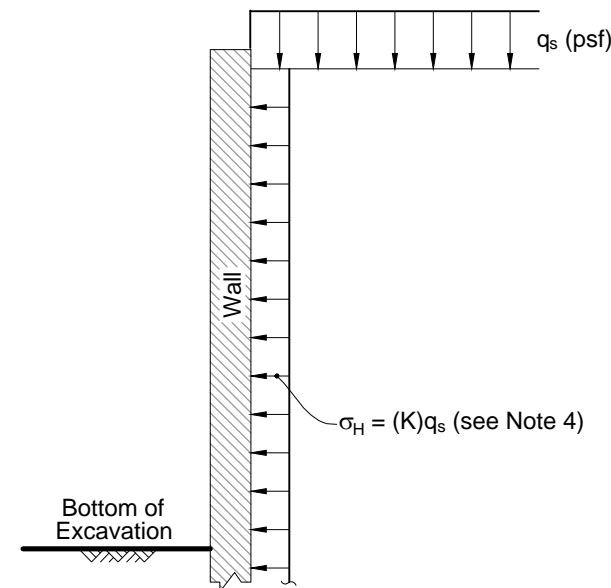
(NAVFAC DM 7.02, 1986)



C) LATERAL PRESSURE DUE TO STRIP LOAD
(derived from Fang, *Foundation Engineering Handbook*, 1991)



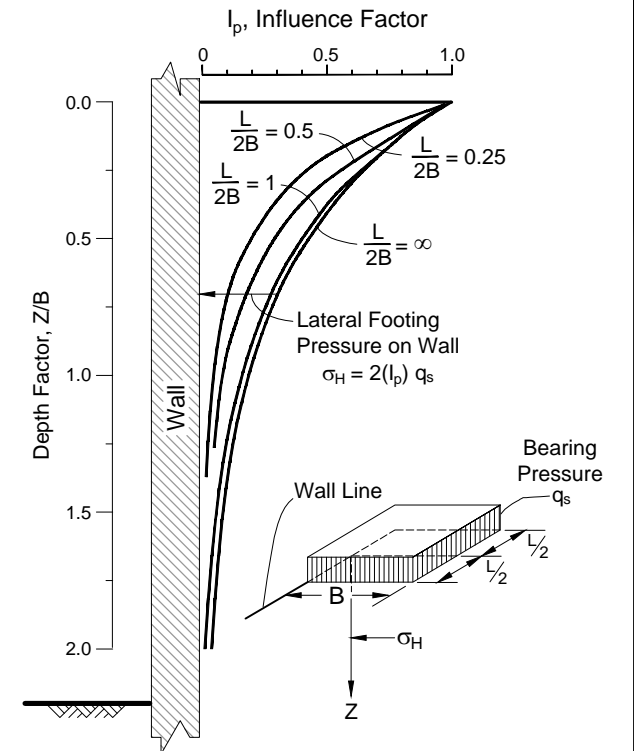
EARTH BERM



UNIFORM SURCHARGE

D) LATERAL PRESSURE DUE TO EARTH BERM
OR UNIFORM SURCHARGE

(derived from Poulos and Davis, *Elastic Solutions for Soil and Rock Mechanics*, 1974; and Terzaghi and Peck, *Soil Mechanics in Engineering Practice*, 1967)



E) LATERAL PRESSURE DUE TO ADJACENT FOOTING
(see Notes 5 and 6)

(derived from NAVFAC DM 7.02, 1986; and Sandhu, *Earth Pressure on Walls Due to Surcharge*, 1974)

NOTES

- Figures are not drawn to scale.
- Applicable surcharge pressures should be added to appropriate permanent wall lateral earth and water pressure.
- If point or line loads are close to the back of the wall such that $m \leq 0.4$, it may be more appropriate to model the actual load distribution (i.e., Detail E) or use more rigorous analysis methods.
- See text for recommended K values.
- The stress is estimated on the back of the wall at the center of the length, L, of loading.
- The estimated stress is based on a Poisson's ratio of 0.5.

Highway 105
School Access Lane
El Paso County, Colorado

RECOMMENDED SURCHARGE
LOADING FOR TEMPORARY AND
PERMANENT WALLS

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 3

Appendix A

Subsurface Explorations

CONTENTS

A.1	Introduction	A-1
A.2	Borings	A-1
A.3	Soil and Rock Classification System	A-1
A.3.1	Standard Penetration Test	A-2
A.3.2	Modified California Test and Sampling	A-2
A.3.3	Non-Standard Blow Counts	A-2
A.3.4	Pocket Penetrometer	A-3
A.3.5	Bulk Sampling	A-3

Figures

Figure A-1:	Soil Description and Log Key (3 Sheets)
Figure A-2:	Rock Description and Log Key (2 Sheets)
Figure A-3 through A-7:	Log of Borings SW-101 through SW-105

A.1 INTRODUCTION

Shannon & Wilson's field exploration program was conducted on August 5, 2021. The program consisted of drilling and sampling 5 borings, designated SW-101 through SW-105, at the locations shown on Figure 2. Boring locations were measured by Shannon & Wilson with a hand-held recreational grade global positioning system (GPS) unit. The GPS coordinates are indicated on the individual boring log and should be considered accurate to the degree implied by the method used. The methods used to conduct the field exploration program are described below.

A.2 BORINGS

The borings were coordinated (including subcontractor coordination and utility locates) and observed by a representative from Shannon & Wilson. Individual boring logs are presented in Figures A-3 through A-7. These exploration logs represent our interpretation of the contents of the field logs and select results of laboratory testing. The borings were drilled by Entech Engineering, Inc. of Colorado Springs, Colorado (under subcontract to Shannon & Wilson) using a Simco 2800 truck-mounted drill rig (one boring was drilled using a Diedrich D-50 truck-mounted drill rig). The borings were advanced with 4-inch diameter solid-stem augers and sampled to depths ranging from approximately 5.5 to 19.8 feet. Groundwater was encountered in two of the five borings; where encountered, the measured depth to groundwater ranged from 4.6 to 8.9 feet below ground surface. On completion of drilling, the borings were backfilled with drill cuttings. The parking lot pavement depth in boring SW-105 was matched with hot-mix asphalt.

A.3 SOIL AND ROCK CLASSIFICATION SYSTEM

During drilling, our representative collected samples and prepared field logs of the explorations. Soil classification for this project was based on ASTM International (ASTM) Designation: D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), and ASTM Designation: D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Soils were also classified using the AASHTO Soil Classification System based on AASHTO Standard M 145. The Unified Soil Classification System is summarized in Figure A-1.

The bedrock encountered in the borings was generally found to be very dense and hard when considered as a lithified soil material. However, when compared with other types of bedrock using the International Society for Rock Mechanics (ISRM) classification of rock

strength, the rock resembles a very low strength rock. Therefore, for completeness, the boring logs contain dual descriptions of the bedrock using the Unified Soil Classification System (USCS) and rock classification shown in Figure A-2, where appropriate.

A.3.1 Standard Penetration Test

Disturbed samples were obtained in the borings in general accordance with the Standard Penetration Test (SPT) (ASTM Designation: D1586). The SPT consists of driving a 2-inch outside diameter (O.D.), 1.375-inch inside diameter split-spoon sampler 18 inches. An automatic, free-falling 140-pound hammer was used to advance the split spoon sampler. During sampling, the Shannon & Wilson field representative recorded the number of blows for each 6-inch increment of penetration and summed the blow counts for the last two 6-inch increments. This sum is recorded as the penetration resistance number, or N-value. If high penetration resistance prevented driving the total length of the sampler, the Shannon & Wilson field representative recorded the partial penetration depth and blow count. The N-values provide a means for evaluating the relative density or compactness of cohesionless (granular) soils and consistency or stiffness of cohesive (fine-grained) soils (see Figure A-1). The raw N-values are shown on the individual boring logs. Representative portions of the split-spoon sample obtained in conjunction with the SPT were placed in a screw-top plastic jar and transported to our laboratory.

A.3.2 Modified California Test and Sampling

Samples were also obtained using a Modified California (MC) barrel sampler. The MC test procedure is similar to the Standard Penetration Test (SPT), except the sample barrel is larger (2½-inch O.D.) and lined with 2-inch-diameter brass tubing. The MC sampler is only driven 12 inches. During sampling, the Shannon & Wilson field representative recorded the number of blows for each 6-inch increment of penetration. As a result of the larger diameter, the MC sampler yields slightly higher raw blow count numbers when compared to SPT N-values for similar soils. Because the difference in blow counts does not significantly impact our evaluation, we used the field MC blow counts over the 12-inch increment to define the relative density and consistency/stiffness of the subsurface materials following SPT terminology. Representative samples were sealed in the brass liner tubes with plastic caps and transported to our laboratory for further testing.

A.3.3 Non-Standard Blow Counts

During drilling in the Dawson Formation bedrock, the drill crew and Shannon & Wilson field representative noted difficulties removing the sampler from the ground following penetration testing. To address the issue, samplers were generally driven a maximum of 50 total hammer blows and the penetration recorded in inches, rather than driving the sampler

the full 18 inches (SPT) or 12 inches (MC) and recording the number of hammer blows. Samples taken using the non-standard blow counts are indicated on the boring logs with a ‡ symbol.

A.3.4 Pocket Penetrometer

Select cohesive soil samples were also tested in the field using a pocket penetrometer. The penetrometer estimates the unconfined compressive strength of clay soil samples by penetrating the clay with a one-quarter-inch-diameter penetrometer and measuring the resistance (in units of tons per square foot [tsf]) with a calibrated spring. Measurements can be taken to the nearest 0.25 tsf increment. The field measurements from the pocket penetrometer are listed on the boring logs.

A.3.5 Bulk Sampling

A bulk grab sample was obtained by collecting the drill cuttings or material obtained from boring SW-102. Approximately 20 to 30 pounds of material were placed in a sealed plastic bag and transported to our laboratory for further analysis and testing.

Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

S&W INORGANIC SOIL CONSTITUENT DEFINITIONS

CONSTITUENT ²	FINE-GRAINED SOILS (50% or more fines) ¹	COARSE-GRAINED SOILS (less than 50% fines) ¹
Major	Silt, Lean Clay, Elastic Silt, or Fat Clay³	Sand or Gravel⁴
Modifying (Secondary) Precedes major constituent	30% or more coarse-grained: Sandy or Gravelly⁴	More than 12% fine-grained: Silty or Clayey³
Minor Follows major constituent	15% to 30% coarse-grained: with Sand or with Gravel⁴ 30% or more total coarse-grained and lesser coarse-grained constituent is 15% or more: with Sand or with Gravel⁵	5% to 12% fine-grained: with Silt or with Clay³ 15% or more of a second coarse-grained constituent: with Sand or with Gravel⁵

¹All percentages are by weight of total specimen passing a 3-inch sieve.

²The order of terms is: *Modifying Major with Minor*.

³Determined based on behavior.

⁴Determined based on which constituent comprises a larger percentage.

⁵Whichever is the lesser constituent.

MOISTURE CONTENT TERMS

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, from below water table

STANDARD PENETRATION TEST (SPT) SPECIFICATIONS

Hammer:	140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/4 rope turns, > 100 rpm
	NOTE: If automatic hammers are used, blow counts shown on boring logs should be adjusted to account for efficiency of hammer.
Sampler:	10 to 30 inches long Shoe I.D. = 1.375 inches Barrel I.D. = 1.5 inches Barrel O.D. = 2 inches
N-Value:	Sum blow counts for second and third 6-inch increments. Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches.
	NOTE: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.












PARTICLE SIZE DEFINITIONS

DESCRIPTION	SIEVE NUMBER AND/OR APPROXIMATE SIZE
FINES	< #200 (0.075 mm = 0.003 in.)
SAND Fine Medium Coarse	#200 to #40 (0.075 to 0.4 mm; 0.003 to 0.02 in.) #40 to #10 (0.4 to 2 mm; 0.02 to 0.08 in.) #10 to #4 (2 to 4.75 mm; 0.08 to 0.187 in.)
GRAVEL Fine Coarse	#4 to 3/4 in. (4.75 to 19 mm; 0.187 to 0.75 in.) 3/4 to 3 in. (19 to 76 mm)
COBBLES	3 to 12 in. (76 to 305 mm)
BOULDERS	> 12 in. (305 mm)

RELATIVE DENSITY / CONSISTENCY

COHESIONLESS SOILS		COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
< 4	Very loose	< 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
> 50	Very dense	15 - 30	Very stiff
		> 30	Hard

WELL AND BACKFILL SYMBOLS

	Bentonite		Surface Cement Seal
	Cement Grout		Asphalt or Cap
	Bentonite Grout		Slough
	Bentonite Chips		Inclinometer or Non-perforated Casing
	Silica Sand		Vibrating Wire Piezometer
	Perforated or Screened Casing		

PERCENTAGES TERMS^{1,2}

Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

¹Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.

²Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

Highway 105
School Access Lane
El Paso County, Colorado

SOIL CLASSIFICATION AND LOG KEY

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 1 of 3

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(Modified From USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL	TYPICAL IDENTIFICATIONS
COARSE-GRAINED SOILS (more than 50% retained on No. 200 sieve)	Gravels (more than 50% of coarse fraction retained on No. 4 sieve)	Gravel (less than 5% fines)	GW	Well-Graded Gravel; Well-Graded Gravel with Sand
			GP	Poorly Graded Gravel; Poorly Graded Gravel with Sand
		Silty or Clayey Gravel (more than 12% fines)	GM	Silty Gravel; Silty Gravel with Sand
			GC	Clayey Gravel; Clayey Gravel with Sand
	Sands (50% or more of coarse fraction passes the No. 4 sieve)	Sand (less than 5% fines)	SW	Well-Graded Sand; Well-Graded Sand with Gravel
			SP	Poorly Graded Sand; Poorly Graded Sand with Gravel
		Silty or Clayey Sand (more than 12% fines)	SM	Silty Sand; Silty Sand with Gravel
			SC	Clayey Sand; Clayey Sand with Gravel
FINE-GRAINED SOILS (50% or more passes the No. 200 sieve)	Silts and Clays (liquid limit less than 50)	Inorganic	ML	Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt
			CL	Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay
		Organic	OL	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
	Silts and Clays (liquid limit 50 or more)	Inorganic	MH	Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt
			CH	Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay
		Organic	OH	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat or other highly organic soils (see ASTM D4427)

NOTE: No. 4 size = 4.75 mm = 0.187 in.; No. 200 size = 0.075 mm = 0.003 in.

NOTES

- Dual symbols (symbols separated by a hyphen, i.e., SP-SM, Sand with Silt) are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart. Graphics shown on the logs for these soil types are a combination of the two graphic symbols (e.g., SP and SM).
- Borderline symbols (symbols separated by a slash, i.e., CL/ML, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand) indicate that the soil properties are close to the defining boundary between two groups.

Highway 105
School Access Lane
El Paso County, Colorado

**SOIL CLASSIFICATION
AND LOG KEY**

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 2 of 3

GRADATION TERMS

Poorly Graded	Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2487, if tested.
Well-Graded	Full range and even distribution of grain sizes present. Meets criteria in ASTM D2487, if tested.

CEMENTATION TERMS¹

Weak	Crumbles or breaks with handling or slight finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

PLASTICITY²

DESCRIPTION	VISUAL-MANUAL CRITERIA	APPROX. PLASTICITY INDEX RANGE
Nonplastic	A 1/8-in. thread cannot be rolled at any water content.	< 4
Low	A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.	4 to 10
Medium	A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit.	10 to 20
High	It takes considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit.	> 20

ADDITIONAL TERMS

Mottled	Irregular patches of different colors.
Bioturbated	Soil disturbance or mixing by plants or animals.
Diamict	Nonsorted sediment; sand and gravel in silt and/or clay matrix.
Cuttings	Material brought to surface by drilling.
Slough	Material that caved from sides of borehole.
Sheared	Disturbed texture, mix of strengths.

PARTICLE ANGULARITY AND SHAPE TERMS¹

Angular	Sharp edges and unpolished planar surfaces.
Subangular	Similar to angular, but with rounded edges.
Subrounded	Nearly planar sides with well-rounded edges.
Rounded	Smoothly curved sides with no edges.
Flat	Width/thickness ratio > 3.
Elongated	Length/width ratio > 3.

ACRONYMS AND ABBREVIATIONS

ATD	At Time of Drilling
Diam.	Diameter
Elev.	Elevation
ft.	Feet
FeO	Iron Oxide
gal.	Gallons
Horiz.	Horizontal
HSA	Hollow Stem Auger
I.D.	Inside Diameter
in.	Inches
lbs.	Pounds
MgO	Magnesium Oxide
mm	Millimeter
MnO	Manganese Oxide
NA	Not Applicable or Not Available
NP	Nonplastic
O.D.	Outside Diameter
OW	Observation Well
pcf	Pounds per Cubic Foot
PID	Photo-Ionization Detector
PMT	Pressuremeter Test
ppm	Parts per Million
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
rpm	Rotations per Minute
SPT	Standard Penetration Test
USCS	Unified Soil Classification System
q _u	Unconfined Compressive Strength
VWP	Vibrating Wire Piezometer
Vert.	Vertical
WOH	Weight of Hammer
WOR	Weight of Rods
Wt.	Weight

STRUCTURE TERMS¹

Interbedded	Alternating layers of varying material or color with layers at least 1/4-inch thick; singular: bed.
Laminated	Alternating layers of varying material or color with layers less than 1/4-inch thick; singular: lamination.
Fissured	Breaks along definite planes or fractures with little resistance.
Slickensided	Fracture planes appear polished or glossy; sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps that resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

Highway 105
School Access Lane
El Paso County, Colorado

SOIL CLASSIFICATION AND LOG KEY

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-1
Sheet 3 of 3

¹Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

²Adapted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

WEATHERING

TERM	DESCRIPTION
Fresh	No visible sign of rock material weathering
Slightly Weathered	Slight discoloration on surface
Moderately Weathered	Discoloring evident; Less than half of the rock material is decomposed
Highly Weathered	Entire rock mass discolored; More than half of the rock material is decomposed
Completely Weathered	Rock reduced to a soil with relict rock texture
Residual Soil	All rock material is converted to soil

STRENGTH

GRADE	DESCRIPTION	APPROX. UCS (psi)
R0	Extremely Weak Rock	36 to 145
R1	Very Weak Rock	145 to 700
R2	Weak Rock	700 to 3,600
R3	Medium Strong Rock	3,600 to 7,200
R4	Strong Rock	7,200 to 14,500
R5	Very Strong Rock	14,500 to 36,250
R6	Extremely Strong Rock	>36,250

JOINT ROUGHNESS COEFFICIENT (JRC)

COEFFICIENT	DESCRIPTION
14 to 20	VERY ROUGH: Near vertical edges evident
10 to 14	ROUGH: Smooth ridges, surface abrasion
6 to 10	SLIGHTLY ROUGH: Asperities on surface can be felt
2 to 6	SMOOTH: Appears and feels smooth
0 to 2	SLICKENSIDED: Visible polishing, striated surface

DISCONTINUITY DATA

SPACING	
DESCRIPTION	SPACING
Extremely Close	< 1 in
Very Close	1 to 2.5 in
Close	2.5 to 8 in
Moderate	8 to 24 in
Wide	24 in to 6 ft
Very Wide	6 to 20 ft
Extremely Wide	> 20 ft

DISCONTINUITY TERMS

FRACTURE - Collective term for any natural break excluding shears, shear zones, and faults

JOINT (JT) - Planar break with little or no displacement

FOLIATION JOINT (FJ) or BEDDING JOINT (BJ) - Joint along foliation or bedding

INCIPIENT JOINT (IJ) or INCIPIENT FRACTURE (IF) - Joint or fracture not evident until wetted and dried; breaks along existing surface

RANDOM FRACTURE (RF) - Natural, very irregular fracture that does not belong to a set

BEDDING PLANE SEPARATION or PARTING - A separation along bedding after extraction from stress relief or slaking

FRACTURE ZONE (FZ) - Planar zone of broken rock without gouge

MECHANICAL BREAK (MB) - Breaks due to drilling or handling; drilling break (DB), hammer break (HB)

SHEAR (SH) - Surface of differential movement evident by presence of slickensides, striations, or polishing

SHEAR ZONE (SZ) - Zone of gouge and rock fragments bounded by planar shear surfaces

FAULT (FT) - Shear zone of significant extent; differentiation from shear zone may be site-specific

APERTURE WIDTH

TERM	SPACING
Very Tight	<0.1mm
Tight	0.1 to 0.25mm
Partly Open	0.25 to 0.5mm
Open	0.5 to 2.5mm
Moderately Wide	2.5 to 10mm
Wide	10mm to 1cm
Very Wide	1 to 10cm
Extremely Wide	10 to 100cm
Cavernous	>1m

Highway 105
School Access Lane
El Paso County, Colorado

ROCK CLASSIFICATION AND LOG KEY

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 1 of 2

ROCK CLASSIFICATION SYMBOLS		
BEDROCK TYPE	GRAPHIC SYMBOL	ROCK NAME
Clastic Sedimentary Rocks		Breccia
		Conglomerate
		Sandstone
		Siltstone
		Claystone
		Shale
		Coal
Carbonate Sedimentary Rocks		Limestone
		Dolomite
		Coral
Evaporite Rocks		Gypsum
		Halite
		Calcite
Extrusive Igneous Rocks		Tuff
		Rhyolite
		Dacite
		Andesite
		Basalt
Intrusive Igneous Rocks		Granite
		Grano-diorite
		Diorite
		Gabbro
Metamorphic Rocks		Marble
		Quartzite
		Slate
		Phyllite
		Schist
		Gneiss

Highway 105
School Access Lane
El Paso County, Colorado

ROCK CLASSIFICATION AND LOG KEY

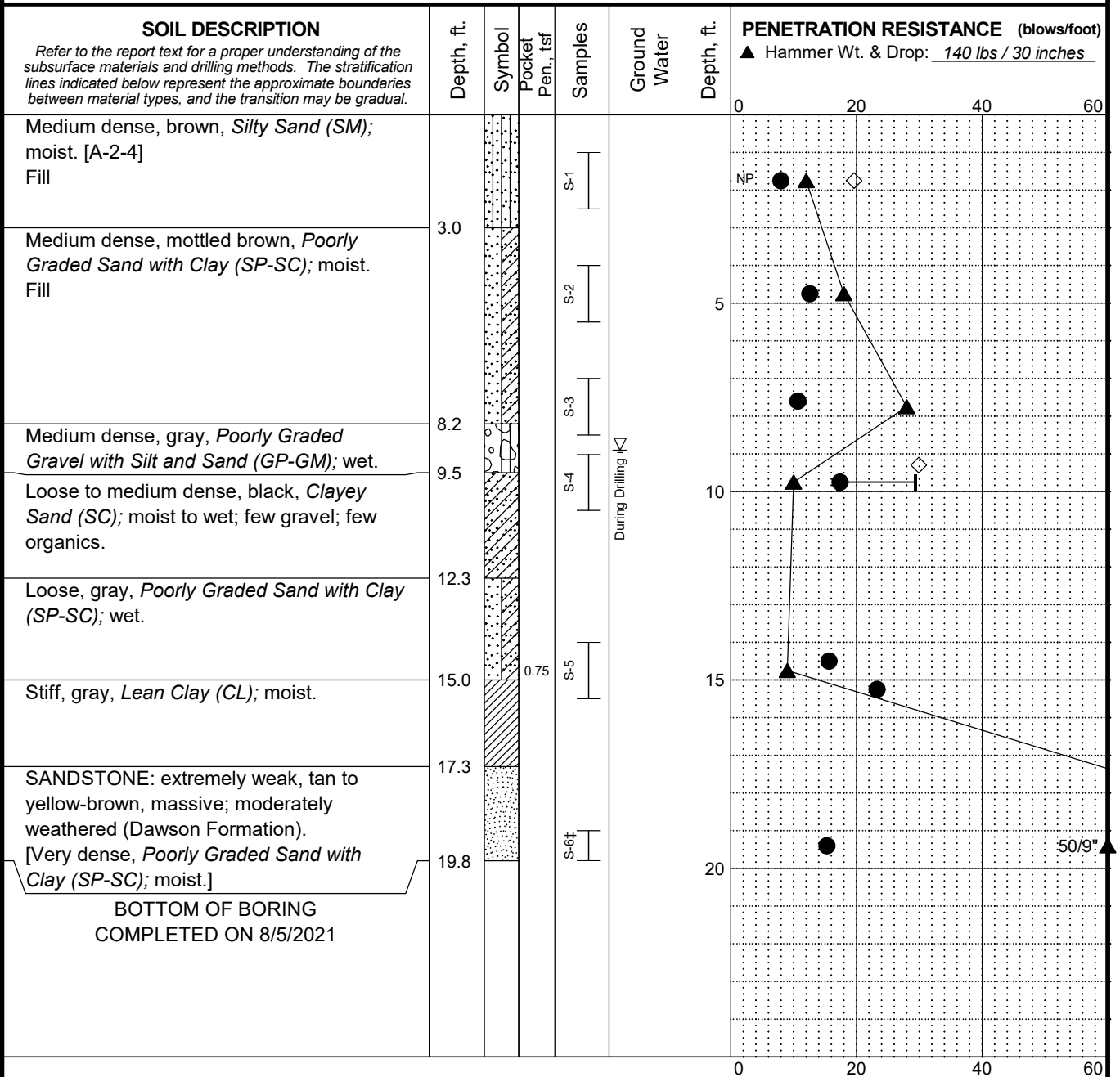
February 2022

23-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. A-2
Sheet 2 of 2

Total Depth: 19.8 ft. Latitude: ~ 39.09416° Drilling Method: Solid-Stem Auger Hole Diam.: 4 in.
 Top Elevation: ~ Longitude: ~ -104.84637° Drilling Company: Entech Engineering, Inc. Rod Type: AWJ
 Vert. Datum: _____ Station: ~ Drill Rig Equipment: Simco 2800 Truck Hammer Type: Automatic
 Horiz. Datum: _____ Offset: ~ Other Comments: _____



LEGEND

* Sample Not Recovered ▽ Ground Water Level ATD

┌ Standard Penetration Test

◇ % Fines (<0.075mm)

● % Water Content

Plastic Limit —●— Liquid Limit

Natural Water Content

NOTES

1. Non-standard soil sample indicated with "†". Sample was generally driven a maximum of 50 total hammer blows due to drill rig limitations in retracting sample from bedrock.
2. Refer to Figures A-1 and A-2 for explanation of symbols, codes, abbreviations and definitions.
3. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. USCS designation is based on visual-manual classification and selected lab testing.

Highway 105
 School Access Lane
 El Paso County, Colorado

LOG OF BORING SW-101

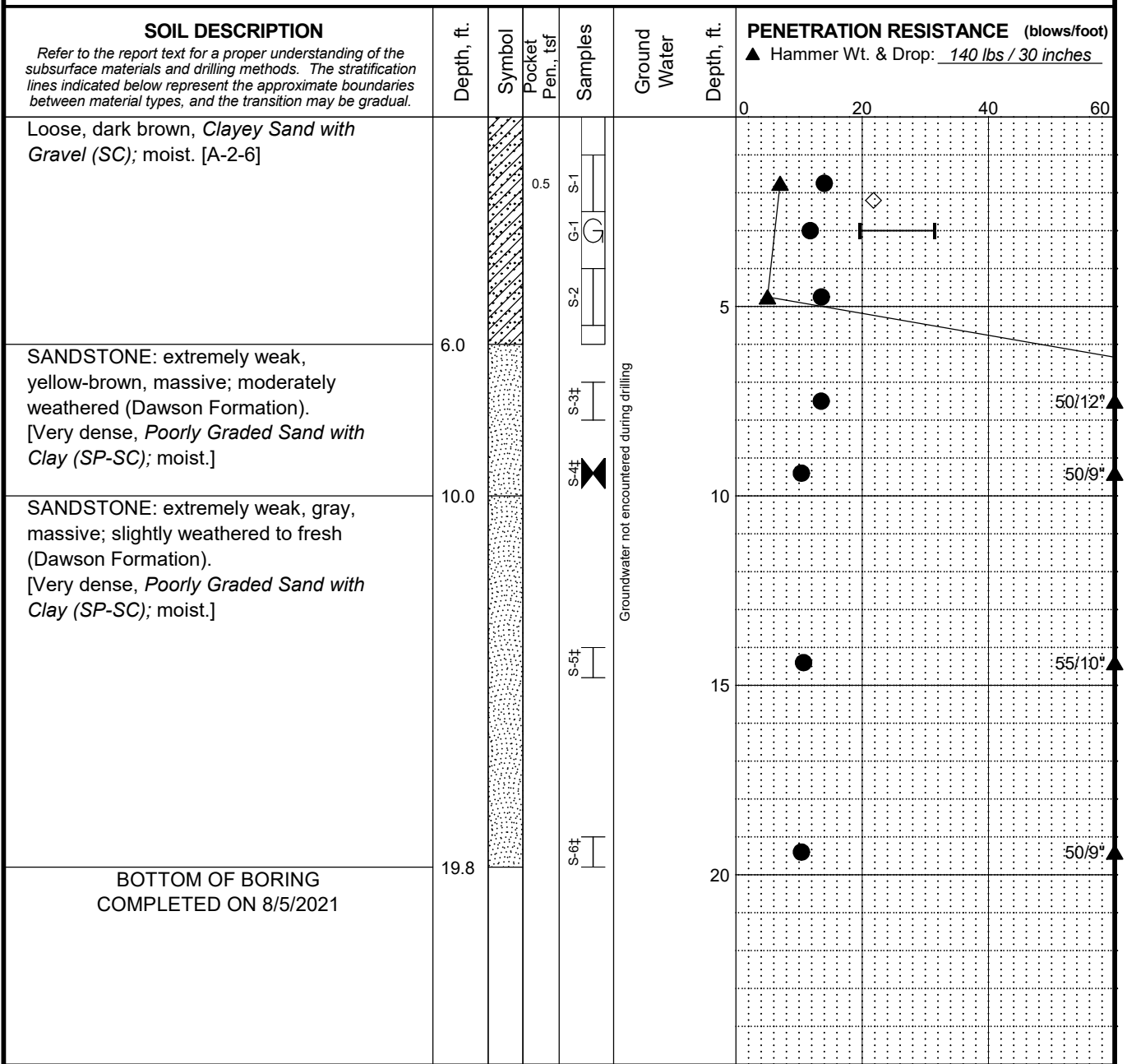
February 2022

23-1-01311-101

SHANNON & WILSON, INC.
 Geotechnical and Environmental Consultants

FIG. A-3

Total Depth: 19.8 ft. Latitude: ~ 39.09472° Drilling Method: Solid-Stem Auger Hole Diam.: 4 in.
 Top Elevation: ~ Longitude: ~ -104.84641° Drilling Company: Entech Engineering, Inc. Rod Type: AWJ
 Vert. Datum: ~ Station: ~ Drill Rig Equipment: Simco 2800 Truck Hammer Type: Automatic
 Horiz. Datum: ~ Offset: ~ Other Comments: ~



LEGEND

* Sample Not Recovered
 □ Grab Sample
 ⊥ Standard Penetration Test
 ✕ Modified California Sampler

◇ % Fines (<0.075mm)
 ● % Water Content
 Plastic Limit —●— Liquid Limit
 Natural Water Content

NOTES

1. Non-standard soil sample indicated with "†". Sample was generally driven a maximum of 50 total hammer blows due to drill rig limitations in retracting sample from bedrock.
2. Refer to Figures A-1 and A-2 for explanation of symbols, codes, abbreviations and definitions.
3. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
4. Groundwater level, if indicated above, is for the date specified and may vary.
5. USCS designation is based on visual-manual classification and selected lab testing.

Highway 105
 School Access Lane
 El Paso County, Colorado

LOG OF BORING SW-102

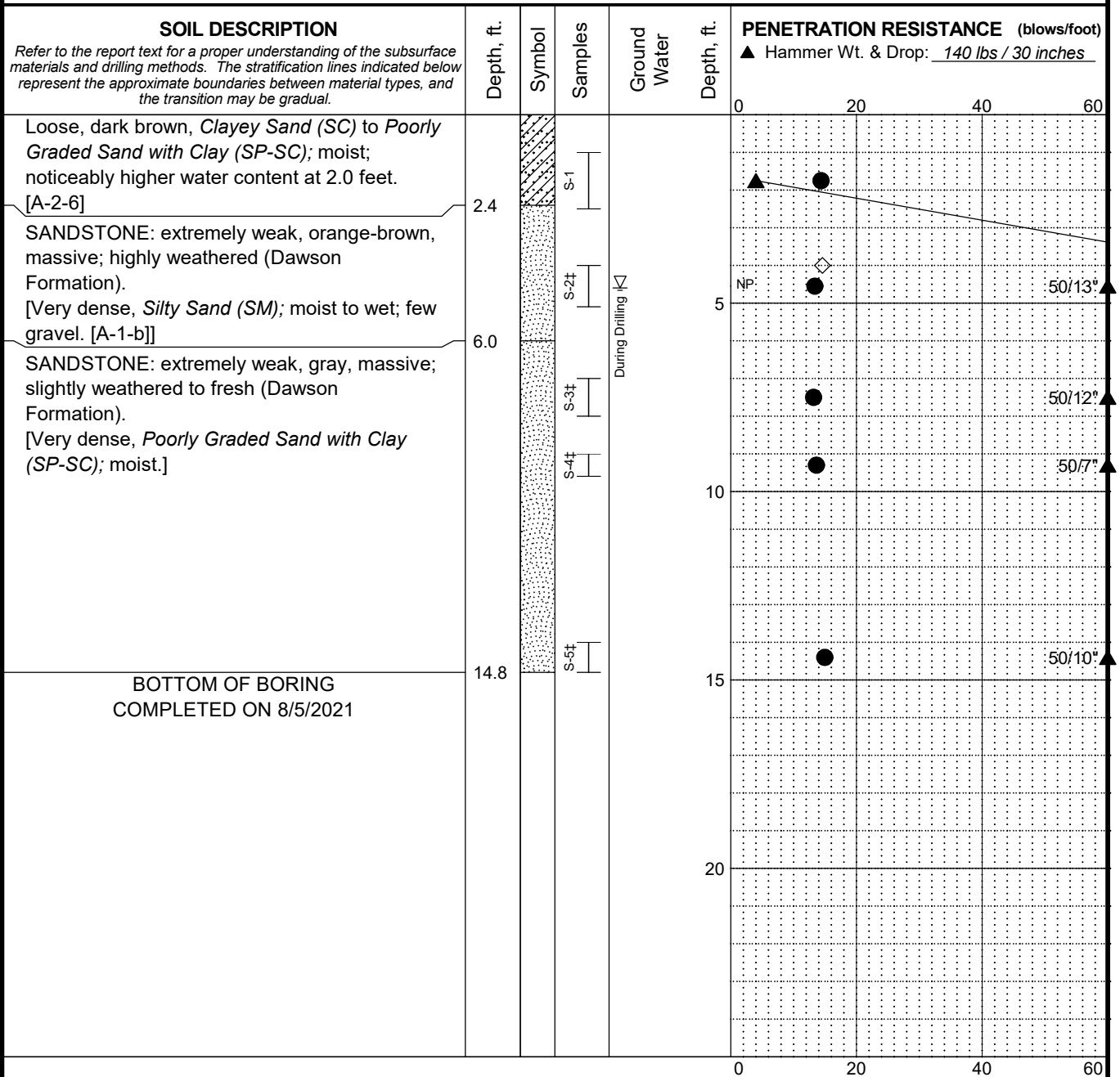
February 2022

23-1-01311-101

SHANNON & WILSON, INC.
 Geotechnical and Environmental Consultants

FIG. A-4

Total Depth: 14.8 ft. Latitude: ~ 39.09449° Drilling Method: Solid-Stem Auger Hole Diam.: 4 in.
 Top Elevation: ~ Longitude: ~ -104.84598° Drilling Company: Entech Engineering, Inc. Rod Type.: AWJ
 Vert. Datum: ~ Station: ~ Drill Rig Equipment: Simco 2800 Truck Hammer Type: Automatic
 Horiz. Datum: ~ Offset: ~ Other Comments: ~



LEGEND

* Sample Not Recovered ▽ Ground Water Level ATD
 I Standard Penetration Test ◇ % Fines (<0.075mm)
 ● % Water Content
 Plastic Limit —●— Liquid Limit
 Natural Water Content

- NOTES**
1. Non-standard soil sample indicated with "†". Sample was generally driven a maximum of 50 total hammer blows due to drill rig limitations in retracting sample from bedrock.
 2. Refer to Figures A-1 and A-2 for explanation of symbols, codes, abbreviations and definitions.
 3. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
 4. Groundwater level, if indicated above, is for the date specified and may vary.
 5. USCS designation is based on visual-manual classification and selected lab testing.

Highway 105
 School Access Lane
 El Paso County, Colorado

LOG OF BORING SW-103

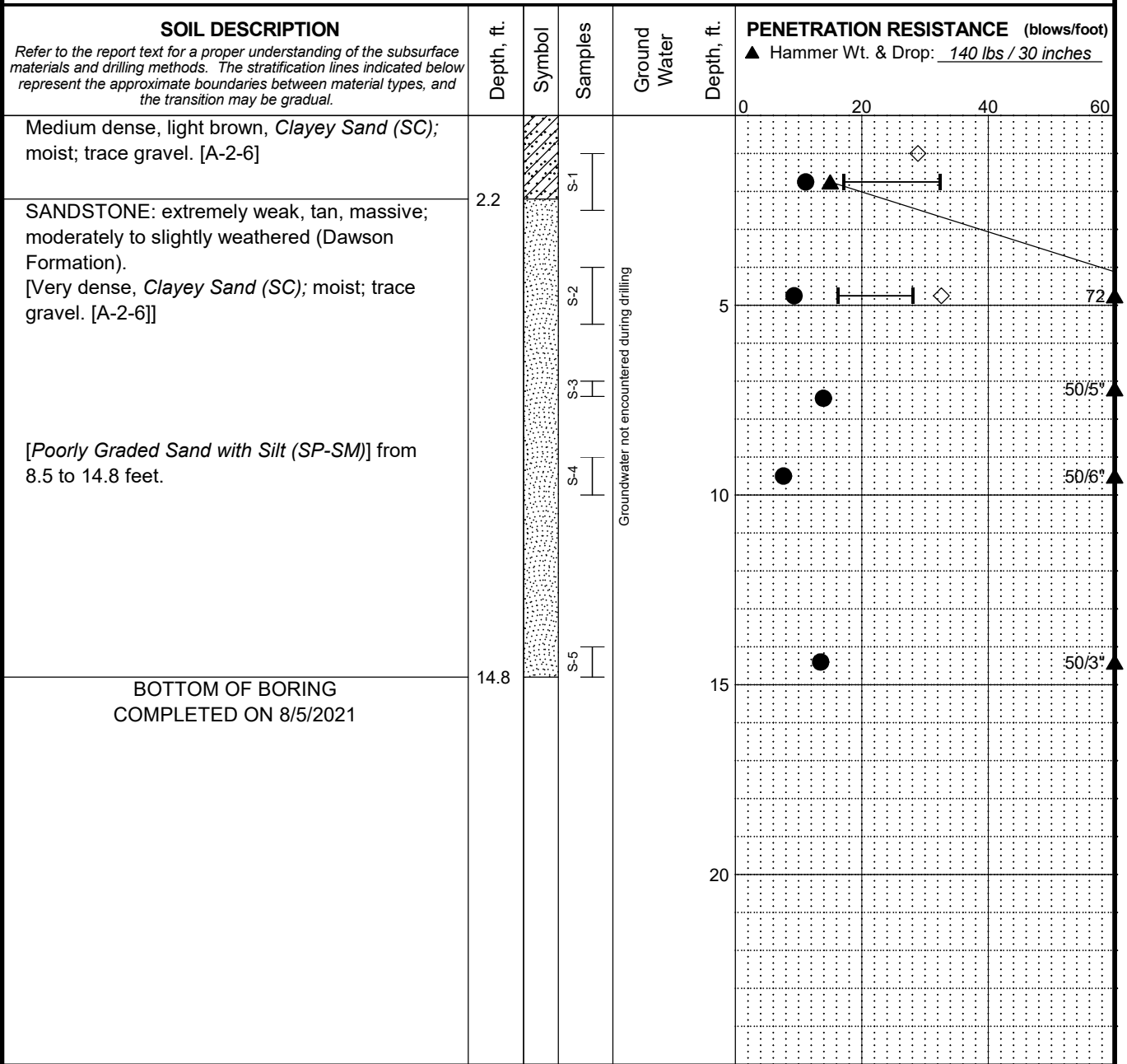
February 2022

23-1-01311-101

SHANNON & WILSON, INC.
 Geotechnical and Environmental Consultants

FIG. A-5

Total Depth: 14.8 ft. Latitude: ~ 39.09421° Drilling Method: Solid-Stem Auger Hole Diam.: 4 in.
 Top Elevation: ~ Longitude: ~ -104.84558° Drilling Company: Entech Engineering, Inc. Rod Type.: AWJ
 Vert. Datum: ~ Station: ~ Drill Rig Equipment: Simco 2800 Truck Hammer Type: Automatic
 Horiz. Datum: ~ Offset: ~ Other Comments: ~



LEGEND

* Sample Not Recovered
 I Standard Penetration Test

◇ % Fines (<0.075mm)
 ● % Water Content
 Plastic Limit —●— Liquid Limit
 Natural Water Content

NOTES

- Refer to Figures A-1 and A-2 for explanation of symbols, codes, abbreviations and definitions.
- The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
- Groundwater level, if indicated above, is for the date specified and may vary.
- USCS designation is based on visual-manual classification and selected lab testing.

Highway 105
 School Access Lane
 El Paso County, Colorado

LOG OF BORING SW-104

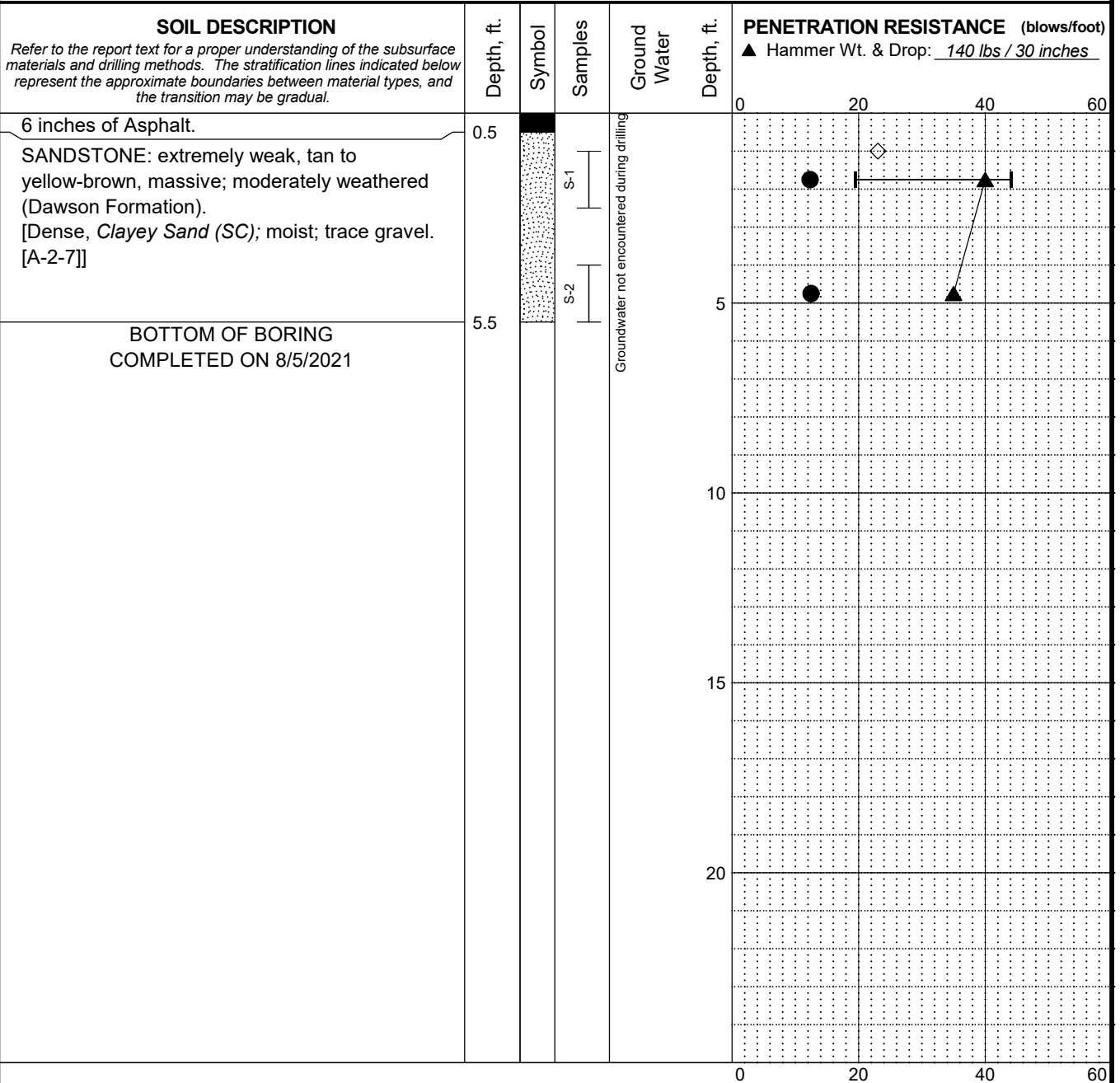
February 2022

23-1-01311-101

SHANNON & WILSON, INC.
 Geotechnical and Environmental Consultants

FIG. A-6

Total Depth: 5.5 ft. Latitude: ~ 39.09329° Drilling Method: Solid-Stem Auger Hole Diam.: 4 in.
 Top Elevation: ~ Longitude: ~ -104.84635° Drilling Company: Entech Engineering, Inc. Rod Type: AWJ
 Vert. Datum: ~ Station: ~ Drill Rig Equipment: Diedrich D-50 Truck Hammer Type: Automatic
 Horiz. Datum: ~ Offset: ~ Other Comments: ~



LEGEND
 * Sample Not Recovered
 I Standard Penetration Test

◇ % Fines (<0.075mm)
 ● % Water Content
 Plastic Limit —●— Liquid Limit
 Natural Water Content

NOTES

- Refer to Figures A-1 and A-2 for explanation of symbols, codes, abbreviations and definitions.
- The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
- Groundwater level, if indicated above, is for the date specified and may vary.
- USCS designation is based on visual-manual classification and selected lab testing.

Highway 105
 School Access Lane
 El Paso County, Colorado

LOG OF BORING SW-105

February 2022

23-1-01311-101

SHANNON & WILSON, INC.
 Geotechnical and Environmental Consultants

FIG. A-7

Appendix B

Laboratory Test Results

CONTENTS

B.1	Introduction	B-1
B.2	Geotechnical Index Tests.....	B-1
B.2.1	Water Content.....	B-1
B.2.2	Grain Size Analysis.....	B-1
B.2.3	Atterberg Limits	B-1
B.3	Geotechnical Engineering Property Tests.....	B-2
B.3.1	Corrosion.....	B-2
B.3.2	R-Value	B-2

Tables

Table B-1:	Summary of Laboratory Test Results by Boring
------------	--

Figures

Figure B-1:	Grain Size Distribution
Figure B-2:	Plasticity Chart
Figure B-3:	R-Value Test Results: Boring SW-102, Sample G-1

B.1 INTRODUCTION

Laboratory tests were completed on soil samples retrieved from the borings in general accordance with American Association of State Highway and Transportation Officials (AASHTO) and ASTM International (ASTM) test methods. The laboratory testing program was performed to classify the materials into similar geologic groups and provide data that can be used for design of the project. The geotechnical laboratory testing was performed at our laboratory in Denver, Colorado and at Vine Laboratories, Inc. in Commerce City, Colorado. A summary of the laboratory test results is presented in Table B-1. The following sections describe the laboratory testing procedures.

B.2 GEOTECHNICAL INDEX TESTS

B.2.1 Water Content

Water content was determined for selected samples in general accordance with AASHTO T265, Laboratory Determination of Moisture Content of Soils. To perform this test, a sample was weighed before and after oven-drying, and the water content was calculated. Water content determinations are shown graphically on the boring logs and are also summarized in Table B-1.

B.2.2 Grain Size Analysis

The grain size distribution of selected samples was determined in general accordance with AASHTO T311, Standard Method of Test for Grain-Size Analysis of Granular Soil Materials. Results of these analyses are presented as grain size distribution curves in Figure B-1 and summarized in Table B-1. Where applicable, the percent fines (silt- and clay-sized particles passing the No. 200 sieve) are shown graphically on the boring logs in Appendix A and are summarized in Table B-1.

Selected samples were tested for the percentage of material passing the No. 200 sieve in general accordance with ASTM D1140, Standard Test Method for Amount of Material in Soils Finer than the No. 200 (75- μ m) Sieve. The percent fines are shown graphically on the boring logs in Appendix A and are summarized in Table B-1.

B.2.3 Atterberg Limits

Soil plasticity was determined by performing Atterberg limits tests on selected fine-grained samples. The tests were completed in general accordance with AASHTO T89, Standard Test

Method for Determining the Liquid Limit of Soils and AASHTO T90, Standard Test Method for Determining the Plastic Limit and Plasticity Index of Soils. The Atterberg limits include liquid limit (LL), plastic limit (PL), and plasticity index (PI equals LL minus PL) and are generally used to assist in classification of soils, to indicate soil consistency (when compared to natural water content), and to provide correlation to soil properties. The results of the Atterberg limits tests are plotted on a plasticity chart on Figure B-2, shown graphically on the boring logs in Appendix A, and summarized in Table B-1.

B.3 GEOTECHNICAL ENGINEERING PROPERTY TESTS

B.3.1 Corrosion

We completed corrosion testing on one sample for resistivity, pH, sulfate content, and chloride content. Testing for resistivity was completed in general accordance with ASTM G57-06, Standard Test Method for Measurement of Soil Resistivity Using the Wenner Four-Electrode Method. Testing for pH was completed in general accordance with AASHTO T289, Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing. Testing for sulfate content was completed in general accordance with CDOT laboratory procedure CP-L 2103, Determining the Water-Soluble Sulfate Ion Content in Soil. Testing for chloride content was completed in general accordance with CDOT laboratory procedure CP-L 2104-12, Determining the Water-Soluble Chloride Ion Content in Soil. The test results are summarized in Table B-1.

B.3.2 R-Value

A Hveem stabilometer (R-Value) test was completed by Vine Laboratories. The test was completed in general accordance with AASHTO T190, Standard Method of Test for Resistance R-value and Expansion Pressure of Compacted Soils. The results of the test are included in Figure B-3 and summarized in Table B-1.

Table B-1 - Summary of Laboratory Test Results by Boring

SAMPLE DATA							GRAIN-SIZE ANALYSES ²			ATTERBERG LIMITS ³			CORROSION				R-VALUE	
Boring	Sample	Depth (feet)		USCS Symbol ¹	AASHTO Designation	Natural Moisture Content (%)	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Resistivity (ohm-cm)	pH	Sulfate Content (%)	Chloride Content (%)	R-Value	Exudation Pressure (psi)
SW-101	S-1	1.0	2.5	SM	A-2-4	8.0			20	NV	NP	NP						
	S-2	4.0	5.5			12.6												
	S-3A	7.0	8.2			10.7												
	S-4	9.0	10.5	SC	A-2-6 (0)	17.4	7	63	30	29	17	12						
	S-5A	14.0	15.0			15.6												
	S-5B	15.0	15.5			23.3												
	S-6‡	19.0	19.8			15.3												
SW-102	G-1	0.0	6.0	SC	A-2-6 (0)	11.8	20	58	22	31	20	11					21	300
	S-1	1.0	2.5			14.0												
	S-2	4.0	5.5			13.5												
	S-3‡	7.0	8.0			13.5												
	S-4‡	9.0	9.8			10.4												
	S-5‡	14.0	14.8			10.7												
	S-6‡	19.0	19.8			10.4												
SW-103	S-1	1.0	2.5			14.4												
	S-2‡	4.0	5.1	SM	A-1-b	13.4	6	79	15	NV	NP	NP	5,500	7.1	0.02	0.006		
	S-3‡	7.0	8.0			13.2												
	S-4‡	9.0	9.6			13.6												
	S-5‡	14.0	14.8			15.0												
SW-104	S-1	1.0	2.5	SC	A-2-6 (1)	11.1	2	69	29	32	17	15						
	S-2	4.0	5.5	SC	A-2-6 (0)	9.3	1	66	33	28	16	12						
	S-3	7.0	7.9			13.9												
	S-4	9.0	10.0			7.6												
	S-5	14.0	14.8			13.5												
SW-105	S-1	1.0	2.5	SC	A-2-7 (1)	12.3	2	75	23	44	19	25						
	S-2	4.0	5.5			12.5												

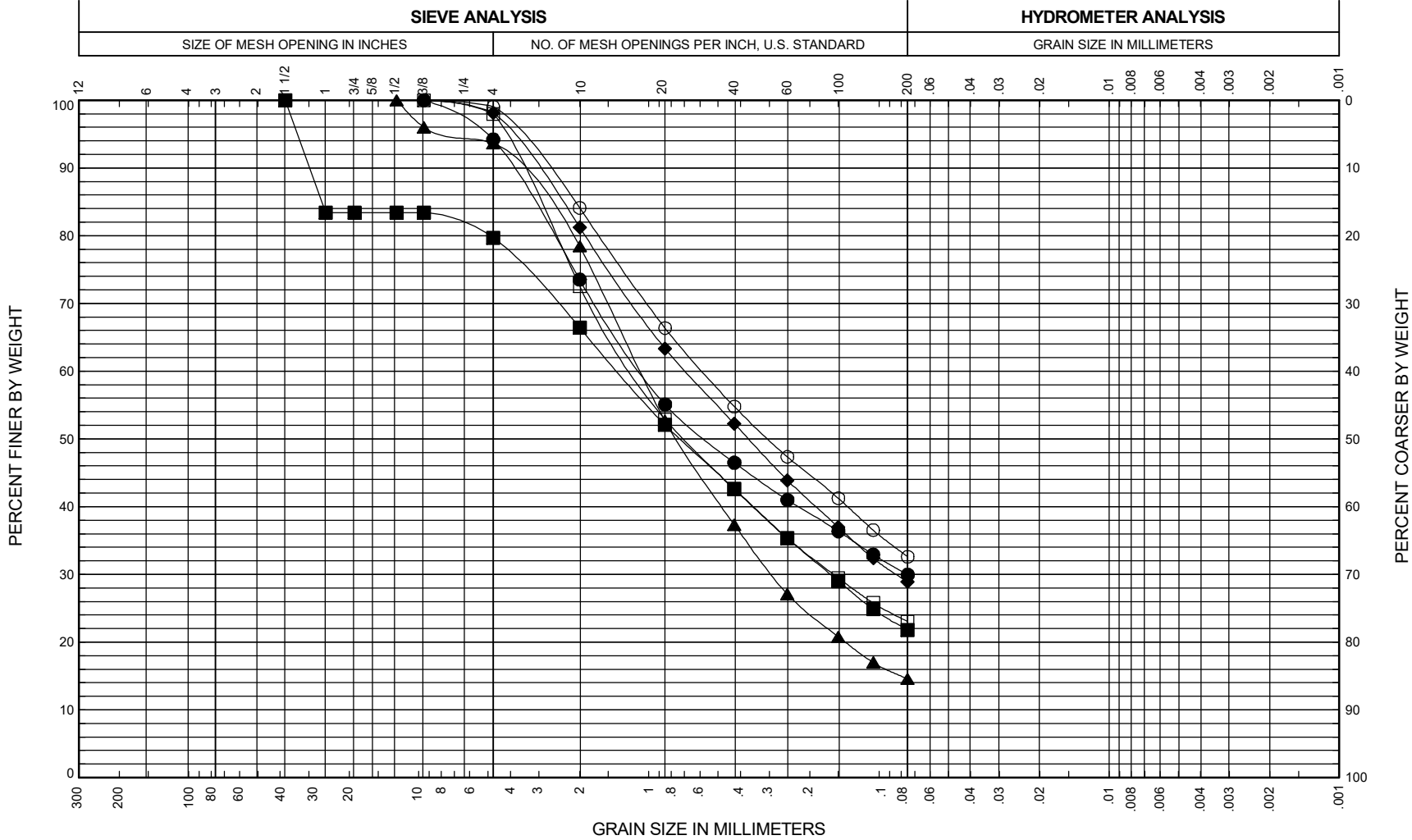
NOTES:

1 Refer to Appendix A, Figure A-1 for definitions.

2 Gravel defined as particles larger than the No. 4 sieve size, sand as particles between the No. 4 and No. 200 sieve sizes, and fines as particles passing the No. 200 sieve.

3 NP = Non Plastic; NV = No Value

4 Non-standard soil sample indicated with "‡". Sample was driven a maximum of 50 total hammer blows due to drill rig limitations in retracting sample from bedrock.



COBBLES	COARSE	FINE	COARSE	MEDIUM	FINE	FINES: SILT OR CLAY
	GRAVEL		SAND			

SAMPLE ID	DEPTH (feet)	U.S.C.S. SYMBOL	SAMPLE DESCRIPTION	FINES %	NAT. W.C. %	LL %	PL %	PI %
● SW-101, S-4	9.0	SC	Clayey Sand; few gravel	29.9	17.4	29	17	12
■ SW-102, G-1	0.0	SC	Clayey Sand with Gravel	21.8	11.8	31	20	11
▲ SW-103, S-2‡	4.0	SM	SANDSTONE [Silty Sand; few gravel]	14.6	13.4	NV	NP	NP
◆ SW-104, S-1	1.0	SC	Clayey Sand; trace gravel	28.9	11.1	32	17	15
○ SW-104, S-2	4.0	SC	SANDSTONE [Clayey Sand; trace gravel]	32.6	9.3	28	16	12
□ SW-105, S-1	1.0	SC	SANDSTONE [Clayey Sand; trace gravel]	23.0	12.3	44	19	25

Highway 105
School Access Lane
El Paso County, Colorado

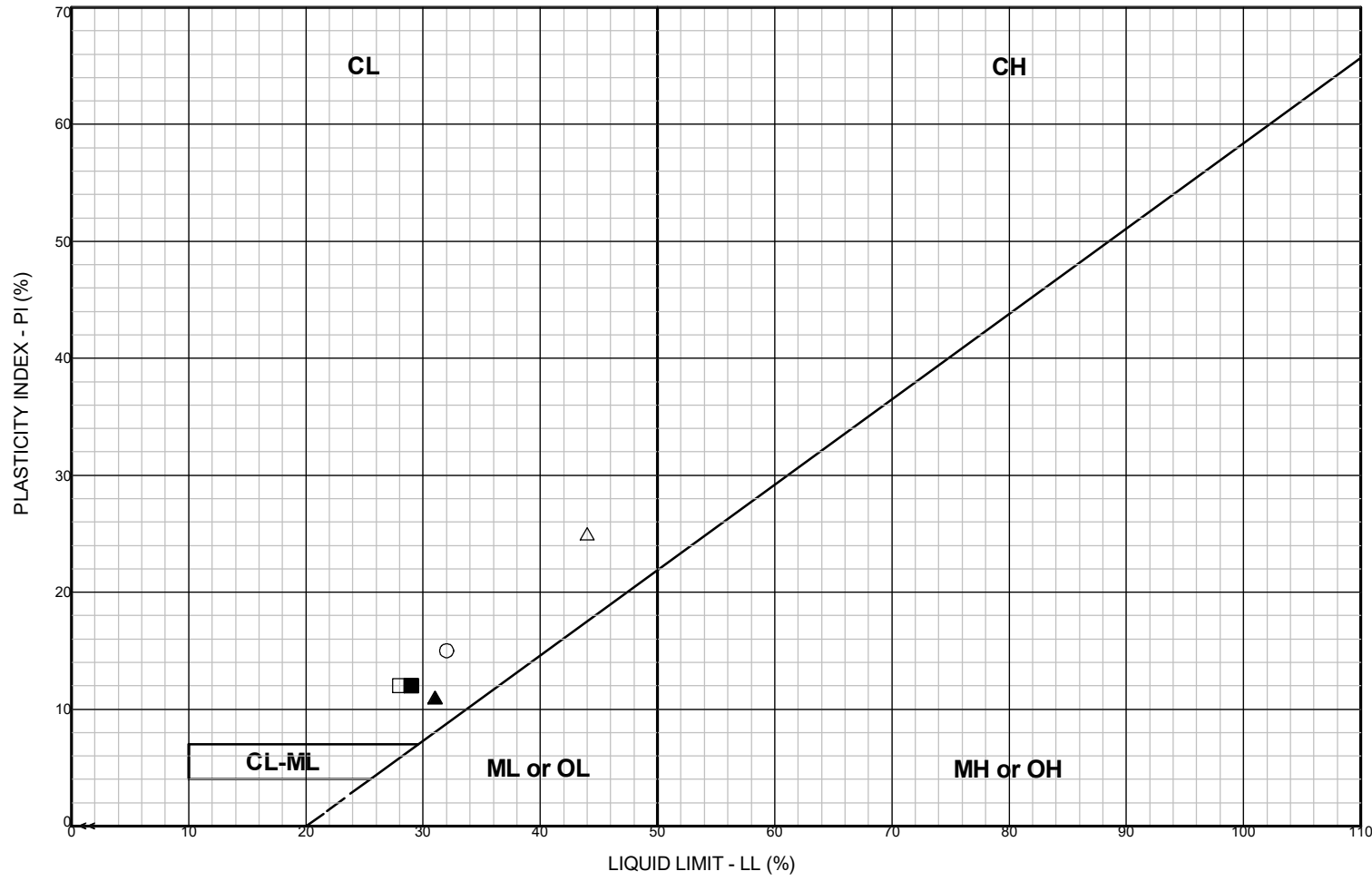
GRAIN SIZE DISTRIBUTION

February 202223-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-1

FIG. B-1



LEGEND

- CL:** Low plasticity inorganic clays; sandy and silty clays
- CH:** High plasticity inorganic clays
- ML or OL:** Inorganic and organic silts and clayey silts of low plasticity
- MH or OH:** Inorganic and organic silts and clayey silts of high plasticity
- CL-ML:** Silty clays and clayey silts

SAMPLE ID	DEPTH (feet)	U.S.C.S. SYMBOL	SOIL CLASSIFICATION	LL %	PL %	PI %	NAT. W.C. %	PASS. #200, %
SW-101, S-1	1.0	SM	Silty Sand	NV	NP	NP	8.0	19.6
■ SW-101, S-4	9.0	SC	Clayey Sand; few gravel	29	17	12	17.4	29.9
▲ SW-102, G-1	0.0	SC	Clayey Sand with Gravel	31	20	11	11.8	21.8
SW-103, S-2†	4.0	SM	SANDSTONE [Silty Sand; few gravel]	NV	NP	NP	13.4	14.6
○ SW-104, S-1	1.0	SC	Clayey Sand; trace gravel	32	17	15	11.1	28.9
□ SW-104, S-2	4.0	SC	SANDSTONE [Clayey Sand; trace gravel]	28	16	12	9.3	32.6
△ SW-105, S-1	1.0	SC	SANDSTONE [Clayey Sand; trace gravel]	44	19	25	12.3	23.0

Highway 105
School Access Lane
El Paso County, Colorado

PLASTICITY CHART

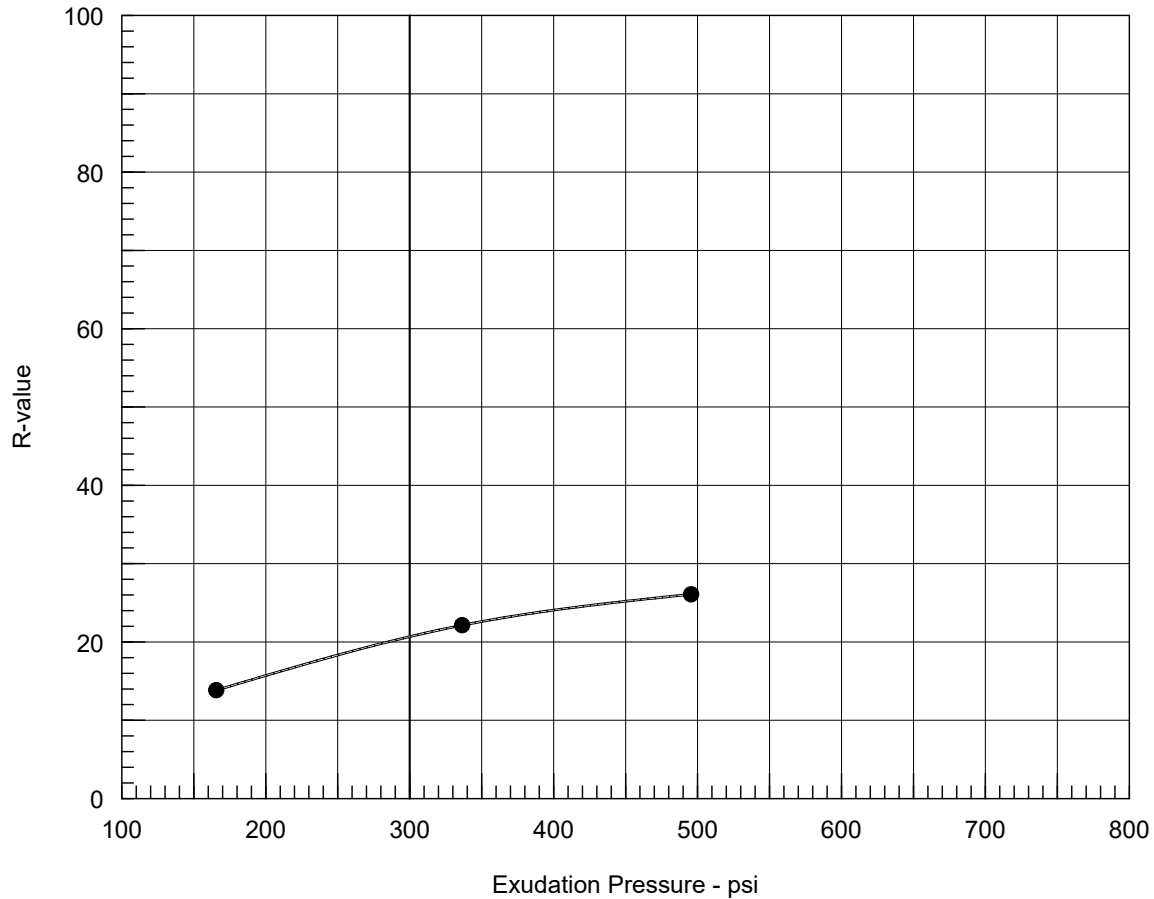
February 202223-1-01311-101

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-2

FIG. B-2

R-VALUE TEST REPORT



Resistance R-Value and Expansion Pressure - AASHTO T 190

No.	Compact. Pressure psi	Density pcf	Moist. %	Expansion Pressure psi	Horizontal Press. psi @ 160 psi	Sample Height in.	Exud. Pressure psi	R Value	R Value Corr.
1	210	124.8	11.6	0.00	102	2.50	336	22.1	22.1
2	150	121.3	13.0	0.00	118	2.40	166	14.8	13.8
3	250	119.5	11.4	0.00	97	2.52	496	26.1	26.1

Test Results	Material Description
R-value at 300 psi exudation pressure = 20.7	SW-02 G-41 Bulk / 0.0-6.0'
Project No.: 23-1-01311-101 Project: SH-105 School Access Lane Location: SW-02 G1 Bulk / 0.0-6.0' Sample Number: S2626 Date: 8/17/2021	Tested by: Juan Romero Checked by: Clay Hollowell Remarks:
R-VALUE TEST REPORT Vine Laboratories	Figure B-3

Appendix C

Pavement Design Calculations

Exhibits

Exhibit C-1: Flexible Pavement 18-kip Equivalent Single-Axle Loading (ESAL)

Exhibit C-2: Flexible Pavement Design Worksheet (2 Sheets)

APPENDIX C: PAVEMENT DESIGN CALCULATIONS

Flexible Pavement 18-kip Equivalent Single-Axle Loading (ESAL) Worksheet

SHANNON & WILSON, INC.

Project No: 23-1-01311-101

Location: Monument Academy Access Roads

Comments:

Notes:

Traffic Study Year: 2020
Paving Year: 2022

% Truck Traffic (TT%): - %
Pavement Design Life (D): 20 years
2020 Two-way Average Daily Traffic (ADT): 1,000 vehicles per day
2022 ADT = 2020 ADT (1 + r / 100)^2 = 1,000 vpd
Estimated 2042 ADT = 2020 ADT (1 + r / 100)^22 = 1,000 vpd
Annually Compounded Growth Rate (r) : 0.00 %

Equations
(d) = (c) x 365 days/yr
(e) = [(1 + r / 100%)^20 yr - 1] / (r / 100%)
(f) = (d) x (e)
(h) = (f) x (g)
(k) = (h) x (i) x (j)

FHWA Vehicle Classification and Description	(c) 2022 ADT	(d) 2022 Total Traffic	(e) Growth Factors	(f) 20 yr 2-way Traffic Volume	(g) Flexible LEF	(h) Roadway Design 18k ESAL	(i) Bi-Directional Lane Dist. Factor	(k) Design Lane 18k ESAL
1. Motorcycles (<i>ignore</i>)								
2. Passenger Cars	1000	365,000	20.00	7,300,007	0.0018	13,140	1.00	13,140
3. Pickups, vans (<i>ignore</i>)	0				-		1.00	
4. School Bus, Typ. A, 2 axle, 10 pass.	0	0	20.00	0	0.110	0	1.00	0
S.B., Typ. C, 2 axle, 40 Passengers	0	0	20.00	0	0.747	0	1.00	0
S.B., Typ. C, 2 axle, 71 Passengers	0	0	20.00	0	2.791	0	1.00	0
City Bus, Single-unit, 2 axle	0	0	20.00	0	3.701	0	1.00	0
City Bus, Articulated, 3 axle	0	0	20.00	0	5.328	0	1.00	0
5. 2-axle, 6-tire Single-Unit Truck	0	0	20.00	0	0.864	0	1.00	0
Delevery Truck (2 per week)	-	104	20.00	2,080	0.864	1,797	1.00	1,797
6. 3-axle, Single-Unit Truck (avg.)	0	0	20.00	0	2.499	0	1.00	0
Fire Truck (2 per year)	-	2.0	20.00	40	9.50	380	1.00	380
Trash Truck (2 per week)	-	104	20.00	2,080	2.499	5,198	1.00	5,198
7. ≥4 axle Single-Unit Truck (avg.)	0	0	20.00	0	1.346	0	1.00	0
8. ≤4 axle Single-Trailer Truck	0	0	20.00	0	2.793	0	1.00	0
9. 5 axle Single-Trailer (78 kip GVW)	0	0	20.00	0	2.322	0	1.00	0
5 axle Single-Trailer (36 kip GVW)	0	0	20.00	0	0.102	0	1.00	0
10. 6 or more axle Single-Trailer Trucks	0	0	20.00	0	1.313	0	1.00	0
11. 5 or less axle Multi-Trailer Truck	0	0	20.00	0	3.747	0	1.00	0
12. 6 axle Multi-Trailer Truck	0	0	20.00	0	1.851	0	1.00	0
13. 7 or more axle Multi-Trailer Truck	0	0	20.00	0	1.027	0	1.00	0
Total	1,000	365,210		7,304,207		20,515		20,515

Notes

- The AADT and frequency of fire truck, delivery truck, and trash trucks provided by HDR. No growth rate was assumed.
- Load Equivalency Factors (LEF) based on Table 4.1G-1 of the 2019 MGPEC Pavement Design Standards.

21,000

Flexible Pavement Design Worksheet

Location: School Access Lane

Comment: Calculated ESAL

HMA over ABC (min)

1. Pavement Design Life:

20.0 years

Traffic Loading (W_{18}):

18k ESALs: 21,000 per lane

3. Serviceability:

 p_0 : 4.2

Value assumed based on 1993 AGDPS

 p_t : 2.0

Table D-1 based on roadway classification

 ΔPSI : 2.24. Subgrade Resilient Modulus (M_R):

R-value: 21

Section D.4.1 (C)

$$S_1 = [(R\text{-value} - 5) / 11.29] + 3$$

$$M_R = 10^{[(S_1 + 18.72) / 6.24]} = 5,104 \text{ psi}$$

 M_R : 5,200 psi

5. Reliability:

R: 75 %

D.4.1 - C

 Z_R : -0.6746. Design Standard Deviation (S_o): S_o : 0.45

D.4.1 - C

7. Required Structural Numbers (SN_i): [Fig. D-1]

Analysis M_R	
32,883	SN_1 : 0.813
5,200	SN_2 : 1.874
-NA-	SN_3 : -NA-

$$\log_{10}(W_{18}) = Z_R S_o + 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \log_{10}(M_R) - 8.07$$

Layer Analysis

8. Pavement Materials Characterization:

Table D-3

Layer	Material	Structural Layer Coefficients	Drainage Coefficients	Layer Modulus (psi)
1	HMA	a_1 : 0.44	-	-
2	ABC	a_2 : 0.11	m_2 : 1.00	32,883
3		a_3 :	m_3 :	

9. Solutions for thicknesses: [Figure 3.2, Part II of 1993 AASHTO]

$$SN^*_1 = a_1 D^*_1 \geq SN_1$$

$$SN^*_2 = a_1 D^*_1 + a_2 D^*_2 m_2 \geq SN_2$$

$$SN^*_3 = a_1 D^*_1 + a_2 D^*_2 m_2 + a_3 D^*_3 m_3 \geq SN_3$$

Recommended Thicknesses				
Layer	Material	Thickness (D^*_i)	SN^*_i	SN_i
1	HMA	3.5 inches	1.540	0.813
2	ABC	4.0 inches	1.980	1.874
3		inches		

Note: Required SN <= Pavement SN, Design is Acceptable

Flexible Pavement Design Worksheet

Location: School Access Lane

Comment: County Min. ESAL

HMA over ABC (min)

1. Pavement Design Life:

20.0 years

Traffic Loading (W_{18}):

18k ESALs: 36,500 per lane

3. Serviceability:

 p_0 : 4.2

Value assumed based on 1993 AGDPS

 p_t : 2.0

Table D-1 based on roadway classification

 ΔPSI : 2.24. Subgrade Resilient Modulus (M_R):

R-value: 21

Section D.4.1 (C)

$$S_1 = [(R\text{-value} - 5) / 11.29] + 3$$

$$M_R = 10^{[(S_1 + 18.72) / 6.24]} = 5,104 \text{ psi}$$

 M_R : 5,200 psi

5. Reliability:

R: 75 %

D.4.1 - C

 Z_R : -0.6746. Design Standard Deviation (S_o): S_o : 0.45

D.4.1 - C

7. Required Structural Numbers (SN_i): [Fig. D-1]

Analysis M_R	
32,883	SN_1 : 0.924
5,200	SN_2 : 2.054
-NA-	SN_3 : -NA-

$$\log_{10}(W_{18}) = Z_R S_o + 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \log_{10}(M_R) - 8.07$$

Layer Analysis

8. Pavement Materials Characterization:

Table D-3

Layer	Material	Structural Layer Coefficients	Drainage Coefficients	Layer Modulus (psi)
1	HMA	a_1 : 0.44	-	-
2	ABC	a_2 : 0.11	m_2 : 1.00	32,883
3		a_3 :	m_3 :	

9. Solutions for thicknesses: [Figure 3.2, Part II of 1993 AASHTO]

$$SN^*_1 = a_1 D^*_1 \geq SN_1$$

$$SN^*_2 = a_1 D^*_1 + a_2 D^*_2 m_2 \geq SN_2$$

$$SN^*_3 = a_1 D^*_1 + a_2 D^*_2 m_2 + a_3 D^*_3 m_3 \geq SN_3$$

Recommended Thicknesses				
Layer	Material	Thickness (D^*_i)	SN^*_i	SN_i
1	HMA	4.0 inches	1.760	0.924
2	ABC	4.0 inches	2.200	2.054
3		inches		

Note: Required SN <= Pavement SN, Design is Acceptable

IMPORTANT INFORMATION

Important Information

About Your Geotechnical Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors that were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining

your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary, because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims

IMPORTANT INFORMATION

being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.