GEOTECHNICAL SUMMARY

KINGMAN – WICKENBURG HIGHWAY (US 93)
US 93, WICKENBURG RANCH WAY TO VISTA ROYALE
ADOT PROJECT NO. 093 YV 189 F0738 01C
FEDERAL AID NO. 093-B(230)T
ADOT CONTRACT NO. 2024-019.02
YAVAPAI COUNTY, ARIZONA

Prepared for:

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ADOT Report No. 25-32-F
Ethos Project No. 2024112
June 3, 2026

June 3, 2026
Ethos Project No. 2024112

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SUBJECT: Geotechnical Summary
Kingman – Wickenburg Highway (US 93)
US 93, Wickenburg Ranch Way to Vista Royale
ADOT Project No. 093 YV 189 F0738 01C
Federal Aid No. 093-B(230)T
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Yavapai County, Arizona

1.0 INTRODUCTION

Ethos Engineering, LLC (Ethos) has compiled geotechnical information related to the United States (US) 93, Wickenburg Ranch Way to Vista Royale project in Yavapai County, Arizona. The overall project comprises two separate design projects, which have been recently combined by the Arizona Department of Transportation (ADOT) for construction purposes. The original design projects include the following:

- US 93, Gap A (ADOT Project No. 093 YV 193 F0125 01D)
- US 93, Vista Royale (ADOT Project No. 093 YV 189 F0738 01C)

The initial US 93, Gap A project extended from Wickenburg Ranch Way to SR 89 with initial design completed around 2020. The Matthie Ranch Road Realignment project was added to the Gap A project in 2025 and included a separate geotechnical report from the original Gap A project. Both projects were ultimately combined with the Vista Royale project (which has a separate geotechnical report) to create the US 93, Wickenburg Ranch Way to Vista Royale project. The individual geotechnical reports for each of the three original projects are presented in appendices attached to this report.

2.0 PROJECT UNDERSTANDING

The overall project combines the Gap A project designed by Stanley Consultants, Inc. (Stanley), and the Vista Royale project designed by AECOM Technical Services, Inc. (AECOM), into a single project referred to as US 93, Wickenburg Ranch Way to Vista Royale. The combined project will be delivered under ADOT Project No. 093 YV 189 F0738 01D, originally assigned to the Vista Royale segment. Descriptions of each design project are summarized below.

US 93, Gap A: The original Gap A project designed by Stanley (ADOT Project No. 093 YV 193 F0125) extended from just north of the existing roundabout at Wickenburg Ranch Way near US 93 milepost (MP) 194 to just south of the BNSF overpass bridge near US 93 MP 193. The design includes widening US 93 to a 4-lane roadway (undivided that transitions to divided), a 3-legged roundabout at the intersection with US 89 near US 93 MP 193.4, and roadway improvements to State Route (SR) 89 for an approximate length of 2,000 feet extending north from the planned roundabout at the intersection with US 93. Final stamped design plans, superseded by the combined project plans, were dated August 06, 2020.

A Geotechnical Report dated September 11, 2019, was prepared by Engineering & Testing Consultants, Inc (ETC) for the project. We understand the project was never bid and Stanley was more recently contracted by ADOT to update the plans to current standards, including the addition of the Matthie Ranch Roadway realignment. Furthermore, we understand the previous Geotechnical Report by ETC for the Gap A segment is acceptable to ADOT for the Gap A segment. As part of the initial Gap A design, ADOT Bridge Group – Geotechnical Section (ADOT Geotech) prepared a memorandum addressing subgrade improvement along the SR 89 portions of the Gap A project. The geotechnical report and memorandum for Gap A are presented in Appendix A.

US 93, Gap A – Matthie Road Realignment: The Gap A segment was recently updated to add the Matthie Ranch Road realignment to the project, which includes approximately 6,000 feet of new two-lane roadway south and west of US 93 adjacent to the Gap A project limits. The geotechnical investigation was completed in April of 2026. A Geotechnical Exploration Report dated June 3, 2026, was prepared by Ethos. The geotechnical report for the Matthie Ranch Road realignment is presented in Appendix B.

US 93, Vista Royale: The original Vista Royale project designed by AECOM extended from just south of the existing BNSF bridge near US 93 MP 193.5 to tie into the existing 4-lane divided highway configuration near MP 190.5. The design includes widening the existing two-lane undivided roadway to a four-lane divided section, with two lanes in each direction separated by a variable width median. The existing Matthie Railroad Overpass (BNSF) will remain for the northbound roadway (Structure Number 00780). A new two-lane BNSF overcrossing bridge will be constructed for the new southbound lanes west of the existing bridge at MP 192.88.

ADOT Bridge Group – Geotechnical Section (ADOT Geotech) prepared a Geotechnical Report dated May 4, 2026, for the Vista Royale segment. As part of the Vista Royale design segment, Ethos prepared a Geotechnical Foundation Report dated November 26, 2025, for the planned bridge structure and mechanically stabilized earth (MSE) walls at the abutments, which is incorporated as an appendix into the geotechnical report by ADOT Geotech. The geotechnical report for the Vista Royale segment is presented in Appendix C.

3.0 CLOSURE

We appreciate the opportunity to be of service to the AECOM and Stanley design teams on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,
Ethos Engineering, LLC

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APPENDICES

APPENDIX A	Geotechnical Report, US 93, Gap A by ETC
APPENDIX B	Geotechnical Exploration Report, Matthie Ranch Road Realignment by Ethos
APPENDIX C	Geotechnical Report, US 93, Vista Royale by ADOT

APPENDIX A

Geotechnical Report

US 93, Gap A by ETC

ENGINEERING & TESTING CONSULTANTS INC.

GEOTECHNICAL REPORT
FOR US 93 / SR 89 ROUNDABOUT
YAVAPAI COUNTY, ARIZONA

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September 11, 2019

ETC File No. 9648

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Engineering & Testing Consultants, Inc., (ETC) has completed the geotechnical investigation for United States Route 93 (US 93) through State Route 89 (SR 89), northwest of Wickenburg, Arizona.

ADOT Project Number 093 YV 193 F0125 01D

The purpose of this investigation was to determine the subgrade soil conditions at the selected locations that provide a basis for engineering evaluation. Our services have been performed in general accordance with the Preliminary Engineering and Design Manual.

This report briefly describes the project information provided to us, the field and laboratory test procedures utilized during this exploration, and presents our findings, evaluations, and recommendations.

2.0 SCOPE OF SERVICES

The purpose of this investigation was to evaluate the general subgrade soil conditions along the areas of proposed improvements to US93 and SR89. A Vicinity Map is presented as Figure 1. Boring Location Maps are presented as Figures 2, 3, & 4.

For this work we present the following:

- Summary of surface and subsurface conditions encountered;
- A description of the project information provided to us;
- A description of subsurface conditions encountered by the exploratory test borings; and,
- Laboratory test results on representative soil samples in order to determine the engineering properties of the subsurface soils encountered.

Included with this report are Appendices A and B, which contain the soil test boring logs and the results of the laboratory testing, respectively.

3.0 SITE AND PROJECT INFORMATION

The project is generally located in the area of the intersection of US93 and SR89, northwest of Wickenburg, Arizona, in Yavapai County, within Sections 17 through 20 of Township 8 North and Range 5 West. A Vicinity Map is included as Figure 1.

General site elevations tend to increase in elevation from the southeast to northwest. Site topography generally consists of hillocky terrain, with significant cut and fill slopes in several locations. Increased changes in topography were more often noted along the southbound side of US 93, with more mild topography along SR 89. Site vegetation includes native grasses, a significant amount of brush, and some trees.

A large stockpile of granular material, up to approximately 1,500 feet in length, and up to approximately 30 feet in height, is located on the southbound side of US 93, in the southern end of the project. The southern end of this stockpile transitions into a native cut, however, the transition from fill to cut is not obvious from observation. ETC performed the quality control testing in Wickenburg Ranch during the generation and stockpiling of this material. The material was placed as a temporary stockpile and was not placed in controlled and compacted lifts. However, the material is very granular, and should be suitable for use as structural fill, where needed.

The proposed project includes reconstruction of an approximately 1¼ mile section of US 93, near Wickenburg, Arizona, from STA 2109+81.40 to STA 2176+42.23. This highway section will be reconstructed to include two lanes of median-separated traffic in each direction. A new roundabout will be constructed at the intersection with SR89.

The project will also include reconstruction of SR 89, from the proposed new roundabout at US 93, to STA 130+87.63. This portion of the project will include 1 lane of traffic in each direction for the improvements to SR 89.

The project will include new entrance and exit lanes for traffic flowing between US 93 and SR 89, along with reconstruction of Matthie Ranch Road.

From review of the preliminary cross-sections, cut and fill slopes of up to approximately 20 feet have been identified. A taller fill slope of up to approximately 30 feet is noted near the northern end of the project, in the vicinity of Station 2176+00. Additional improvements include extensions and new culverts for stormwater drainage control, and other ancillary project elements.

3.1 SITE GEOLOGY

The project site is located northwest of Wickenburg, AZ in the Southern Basin and Range Province of the Major Western Basin and Range Provinces. The project is in the Sonoran Desert Section of the Southern Basin and Range Province. This section is generally orientated northwest to southeast and is bordered by the Salton Trough to the southwest and the Mexican Highlands to the northeast (USDOI Physiographic Province Map). The basins and surrounding mountains were formed by extensional/rifting forces, due to dynamic plate tectonics and other geologic forces like isostatic rebound/uplift.

In the southwest and western US, some 15-5 mya, extensional or rifting forces caused listric normal faulting that forced large blocks or grabens to drop up to 10,000 feet in elevation, forming large basins. The remaining up-faulted blocks, called horst, formed the mountain ranges. These higher horst blocks created the high energy environment needed to weather, erode, and deposit these materials into thick, up to 5,000 feet deep, late Phanerozoic deposits. These late Tertiary to Quaternary deposits of the Phanerozoic Eon comprise majority of the geology in the area. The project is near a transition zone or a basin margin that was a high energy environment able to weather and deposit coarse-grained alluvial material. These sedimentary deposits are found in unconsolidated to consolidated conglomerates, sandstones, and siltstones. Lower energy depositions occurred in small playa lakes and silt flats over these periods; however, this area was mostly formed during moderate to high energy episodes of erosion. The more resilient sedimentary formations form the hills and bluffs in this area. Local and regional drainages, streams, arroyos, and rivers continue to carry and deposit large amounts of sediment and create the geomorphology seen today.

4.0 FIELD EXPLORATION AND LABORATORY ANALYSIS

4.1 FIELD EXPLORATION

ETC performed a total of twenty-two (22) soil test borings for the project, in general accordance with the procedures and guidelines listed in the Preliminary Engineering and Design Manual.

Four additional boring locations were proposed but were not truck-accessible. Two of these borings, B-16 and B-18 were proposed above a cut slope in the vicinity of 2165+00 on the northbound side of US 93. In lieu of borings, the well-exposed face of the cut slope was logged and sampled at these locations. The other two borings, B-2 and B-4, near the southern end of the project, were proposed on top of a large stockpile that was not accessible due to recent fencing. However, large erosion channels on the slope faces exposed the stockpiled material, allowing for logging and sampling. ETC was also on-site full time in the earthwork phases of Wickenburg Ranch during the generation and stockpiling of this material.

The test borings were performed in March of 2019. Borings were located along the proposed improvements of US 93 and SR 89. The borings were located using existing site features, preliminary Plans, and GPS coordinates. Boring Location Maps are presented as Figures 2, 3, and 4.

Exploratory soil test borings were drilled at accessible locations using a subcontracted CME-75 drill rig with hollow stem auger, and our Mobile B-47 truck-mounted drill rig, with 4-inch diameter continuous flight augers. Soil conditions at other locations may differ from the conditions encountered at the specific locations explored.

Standard penetration testing (SPT) was performed in the field by driving a standard split spoon sampler in accordance with ASTM D-1586 specifications. The penetration resistance of the soil, or N-values, represent the number of blows required to drive the split barrel sampler 6 to 18 inches into the soil at the bottom of the borehole using a 140-pound hammer falling 30 inches. These blow counts, as recorded on the boring logs, are a relative indicator of the soil strength and density.

Boring logs, prepared during field drilling operation, utilize the Unified Soil Classification System (USCS) and present a description of the materials encountered by each boring. A summary of the boring logs, key to classification, and terms and symbols are included in Appendix A. The stratification lines on the boring logs represent the field observed boundaries between material types. The actual transition may be more gradual.

Representative bulk soil samples were collected at selected intervals. Larger bulk samples were collected in plastic buckets and labeled. Smaller, representative soil samples were sealed in plastic bags and labeled. All soil samples were transported to our ADOT approved laboratory, or to another ADOT approved laboratory for testing. The borings were backfilled and compacted upon completion and patched. Subsurface water was not encountered during the boring operations.

4.2 LABORATORY TESTING

Laboratory testing was performed on representative soil samples to aid in classification, and to determine the engineering properties of the subgrade soils. The tests performed included

Atterberg limits, grain size distribution, moisture content, in-place density, moisture-density relationship, pH, resistivity, Sulfates, and R-value tests.

Five R-value tests were performed for selected samples of the soils encountered from US 93 and SR 89.

The four tested R-values for US 93 ranged from 25 to 78. The R-value for poor quality soil tested from SR 89 was determined to be 20.

All testing was performed in general accordance with applicable ASTM, AASHTO, and ADOT procedures. A summary of the laboratory test results is presented as Appendix B.

5.0 SUBSURFACE SOIL CONDITIONS

5.1 UNITED STATES ROUTE 93 (US 93)

Five of the test borings were performed within the existing pavement along US 93. At the locations explored, the existing pavement structure encountered was approximately 7 to 9 inches of asphaltic concrete (AC), underlain by approximately 9 to 12 inches of base course material. Boring B-8 was drilled in the low median, near 2137+00. This boring encountered approximately 11.5 inches of weak asphaltic concrete material, underlain by 6.5 inches of what appeared to be the original Asphaltic Concrete layer.

The subgrade soils along US 93 are generally comprised of medium dense to dense, granular materials. The soils are generally comprised of Silty Sand, Clayey Silty Sand, and low to medium plasticity Clayey Sand.

The soils contain varying amounts of gravel, occasional cobbles, and often contain low and moderate calcium carbonate cementation. The soils are typically medium dense to dense. Very dense soils were encountered in the lower reaches of the proposed cut at 2159+50 (B-11), below 5 feet in the proposed cut at boring B-14. However, auger refusal on very dense material was not encountered.

Some clayey soils were encountered along US 93, generally within the southern half of US 93. Some areas of clayey soils may be encountered that do not meet the minimum subgrade criteria, and may require removal. The removed soils may be replaced with other on-site granular soils that are in conformance with the subgrade acceptance criteria.

Loose soils were encountered in embankment fill areas, particular in low areas of existing, natural drainages. Approximately 5.5 feet of loose surface material was encountered by boring B-13, performed near the box culvert drainage channel in the vicinity of 2154+70, in a location of a proposed large embankment fill. Loose soils are also present at other, smaller drainages along the project limits. Where encountered, these loose soils will require removal to firm, native ground. The removed soils may be replaced in moisture conditioned, and adequately compacted lifts.

5.2 STATE ROUTE 89 (SR 89)

At the locations explored, the subgrade soils along SR 89 are generally comprised of low to medium plasticity, medium dense Clayey Sand (SC), dense to very dense, Silty Sand (SM), and stiff to very stiff, low to high plasticity, Sandy Clay (CL).

Stiff to very stiff Sandy Clay (CL) was encountered by boring B-23, drilled along the proposed northern portion of the US 93 northbound exit lane to northbound SR 89. Stiff Clay was also encountered by the next northern boring along northbound SR 89, boring B-25. The most northern SR 89 boring, B-26, encountered more granular soils. Low plasticity granular soils were encountered near the intersection with US 93. However, some clayey soils were encountered along US 93, generally within the southern half of US 93.

The clay soils encountered along SR 89 will likely not meet the minimum subgrade acceptance criteria, requiring removal. Some areas of clayey soils may also be encountered along US 93 that do not meet the criteria. The removed soils may be replaced with other on-site granular soils that are in conformance with the subgrade acceptance criteria.

5.3 GROUNDWATER CONDITIONS

Free groundwater was not encountered during the drilling operations. However, subsurface water may be encountered, particularly along natural drainage channels, especially during seasons of more inclement weather conditions.

6.0 EVALUATION AND RECOMMENDATIONS

6.1 PAVEMENT DESIGN INFORMATION

Laboratory testing was performed for selected soil subgrade samples collected during the boring operation. Laboratory test results are provided herein, and in Appendix B.

A summary of the laboratory tested R-values and the correlated R-values from soils that have been determined to possibly comprise the upper 3 feet of roadway subgrade are presented below in Table 1. The below table includes the calculated R-mean and R-control values.

TABLE 1
SUMMARY OF R-VALUES (Tested and Correlated)

Boring	Route	Station, Offset	Depth (feet)	R-Value Correlated	R-Value Tested
B – 1	US 93	US93 2114+10,	1.75 – 5	51.5	44.6
B – 3	US 93	2119+20, 8R	2 – 4	42.0	25.1
B – 4	US 93	2120+45, 80L	0 – 15	60.8	77.6
B – 5	US 93	2124+10, 8L	1.75 – 3	62.6	
B – 6	US 93	2129+00, 60L	0 – 4.5	35.6	
B – 7	US 93	2133+10, 25R	1.5 – 3	49.7	
B – 9	US 93	2140+10, 30R	2 – 5	51.9	
B – 10	US 93	2140+10, 15R	1 – 5	58.2	
B – 11	US 93	2149+50, 110L	12 – 24	55.2	
B – 14	US 93	2158+00, 17R	0 – 5	59.8	
			7 – 10	40.4	
B – 15	US 93	2161+10, 60L	5 – 9	61.8	58.1
B – 16	US 93	2163+10, 70R	10 – 15	66.7	
B – 17	US 93	2165+75, 60L	2 – 6	77.1	
B – 19	US 93	2170+05, 60L	5 – 25	81.6	
B – 20	US 93	2167+40, 15L	1.25 – 5	79.9	
B – 22	SR 89	107+30, 35L	1 – 5	69.2	
B – 23	SR 89	109+45, 2L	1 – 5	30.1	20.1
B – 24	US 93 / SR 89	2150+70, 150R	9 – 12	61.6	
			12 – 19	74.0	
			29.5 - 35	60.3	
B – 25	SR 89	116+20, 15R	0.75 – 3	15.8	
B – 26	SR 89	122+50, 15R	1 – 5	38.4	
			Average	55.8	45.1
			Adjusted Average	49.3	31.4
			Standard Deviation	16.5	23.7
			Calculated R-mean	47.6	
			Calculated R-control	34.0	
			Design R-Value	**30**	
			Construction Control R-Value	**30**	

The Design R-Value was utilized for pavement design. The Construction Control R-value was utilized to develop the Subgrade Acceptance Charts.

6.2 CONSTRUCTED SLOPES AND EMBANKMENT SUBGRADE

The proposed cut slope along US 93, from approximately 2125+00 to near the southern end of the project, is within a large stockpile of undocumented fill. This stockpiled fill material will require complete removal. The removed material may be replaced, as needed, in controlled, compacted lifts. It is noted that the stockpiled fill is expected to transition to a native cut slope condition near the southern beginning of the project.

Based on the granular soil conditions encountered in the proposed cut slope areas, ETC recommends all Cut Slopes be constructed at a maximum slope angle of 2H:1V. All fill slopes shall be constructed at a maximum slope angle of 2H:1V. All slopes should be constructed in accordance with ADOT Section C-02.10 and C-02.20.

Cobbles or boulders exposed on the face of any cut slope shall be removed to prevent future dislodgement due to weathering. Soil in the top of cut slopes should be rounded back from the slope face to create a gradual transition to natural grade. Water shall be contained and prevented from flowing down the face of constructed slope without adequate revetment protection.

As discussed herein, loose soils in all fill embankment areas shall be removed to firm native ground to at least 3 feet beyond the toe of slope. Loose soils requiring remediation are expected to be up to 2 feet in embankment fill areas, but will likely be greater in the area of natural drainage channels. Loose soils were encountered to a depth of approximately 5.5 feet in the area of boring B-13, performed within the area of a larger drainage channel in the vicinity of 2154+70 where a larger embankment fill is proposed. Removed soils may be replaced in moisture conditioned, and adequately compacted lifts.

Temporary Cut Slopes: ETC recommends Temporary Cut slopes be constructed at a maximum cut slope angle of 1.5:1 (horizontal:vertical). Temporary slopes within the existing roadway prism, and within native cut materials, are expected to be classified as OSHA Type

C soils. Shoring, sloping, benching, etc, of temporary slopes used for construction should be excavated in strict compliance with the Federal Register, Volume 54, No. 209 (October 1989), the United States Department of Labor, Occupational Safety and Health Administration (OSHA), 29 CFR, Part 1926 to maintain stability of excavation sidewalls.

6.3 EARTHWORK FACTORS

Utilizing the laboratory test results, our judgement, and previous experience, ETC anticipates a soil shrink factor of approximately 15 to 20% for material volume loss from native cut volume to compacted fill volume. It is noted that the uncompacted stockpiled material, generally south of 2125+00, is expected to have a much larger shrink factor of approximately 35%.

A ground compaction factor of 0.20 feet should be compensated throughout the project for all embankment sections outside the existing roadway prism, for losses due to clearing and grubbing, and ground surface preparation.

It has been our experience that there can be additional losses during construction from wind-blown losses, the degree of compaction achieved, and additional compaction from construction equipment. It is noted that Contractors with experience during the grading of adjacent Wickenburg Ranch could be contacted for more accurate estimates of expected shrink factors.

6.4 SUBGRADE EXCAVATION

The majority of the native soils typically consisted of medium dense to very dense, granular soils with varying amounts of gravel, some cobbles, and occasional boulders. The majority of excavations required for site development is expected to be accomplished with conventional excavating equipment. The contractor should be prepared to encounter some heavily cemented strata that may require heavy equipment, or other special removal techniques. However, the Contractor shall review site conditions and exposed cut slope conditions, with all other available documentation to make their own assessment of equipment and excavation means and methods that may be required for effective excavation.

6.5 WATER REQUIREMENTS

Approximately 75 gallons of water per cubic yard, should be estimated for compaction of base materials. Approximately 70 gallons of water per cubic yard should be estimated for compaction of subgrade/embankment materials.

The application of water estimated for subgrade materials is greater than the amount calculated based upon the difference between in-situ and optimum compaction moisture content, and includes a conservative overrun for losses due to seepage, evaporation, inadequate mixing, spillage, etc. Precipitation during and/or before construction may reduce the required amount of water.

6.6 PIPE EXTENSIONS AND CORROSION POTENTIAL

Selected site soil samples were tested for pH, resistivity, and Sulfates for use in pipe selections. The site soils tested indicate that soil pH values ranged from 7.40 to 8.75. Minimum resistivity values were found to be 2,523 to 2,973ohm-cm along US 93, and values of 362 and 470ohm-cm along the SR 89 northbound entrance road. Sulfates tested were found to be 10 to 12ppm. Additional details of the testing performed is included in Appendix B.

ETC recommends that storm drain pipe strength classification be verified to be appropriate for the embedment depth, and whether it is under pavement, using a recommended moist unit weight of compacted backfill on the order of 133pcf above the pipe.

6.7 BORROW INFORMATION

There is no Department-furnished source for borrow on this project. Borrow shall be as specified in Section 203-9 of the Standard Specifications.

To maintain the minimum subgrade values used for design, borrow and other subgrade soils placed within three (3) feet of finished subgrade elevation shall meet the following requirements. The Plasticity Index (PI) (AASHTO T90) and the percent passing the No. 200 Sieve (Minus 200) (ARIZ 201) when used in the equation below shall give a value of **X** that does not exceed **87**

$$\mathbf{X} = (\text{Minus } 200) + 2.83 * (\text{PI})$$

Soils that do not meet the above subgrade specifications were generally not encountered during the exploration along US 93. However, inadequate clayey soils that do not meet the above requirements, requiring removal, were encountered along SR 89, in the area of borings B-23 and B-25. The removed soils may be replaced with better quality granular soils that are in conformance with the subgrade acceptance criteria.

6.8 LATERAL DESIGN PARAMETERS

It is ETC's understanding that retaining walls will not be constructed for the project.

7.0 LIMITATIONS

The figures and recommendations in this report were prepared in accordance with accepted professional engineering principles and soil mechanics practices. We make no other warranty, either implied or expressed. The conclusions and recommendations of this report are based upon the results of field exploration borings and field and laboratory tests. The data presented on the boring logs represent the conditions as encountered in that test hole on the date drilled and logged. If during subsequent planning and construction, conditions are different than as indicated, this firm should be notified for evaluation.

FIGURES

APPENDIX A

FIELD EXPLORATION

APPENDIX B

LABORATORY TEST RESULTS

INCLUDING TABLES:

TABLE 1
Summary of Atterberg Limits and Sieve Analysis

Boring	Route	Station, Offset	Depth (feet)	Liquid Limit (%)	Plasticity Index	Moisture Content (%)	Fines Content (%)	Gravel Content (%)	USCS
B – 1	US 93	US93 2114+10,	1.75 – 5	27	9	4.9	22.6	13	SC*
B – 3	US 93	2119+20, 8R	2 – 4	24	11	5.0	31.6	4	SC
B – 4	US 93	2120+45, 80L	0 – 15	29	9	3.0	10.5	18	SP-SC
B – 5	US 93	2124+10, 8L	1.75 – 3	17	2	1.7	28.2	7	SM
B – 6	US 93	2129+00, 60L	0 – 4.5	37	19	6.8	20.9	18	SC
B – 7	US 93	2133+10, 25R	1.5 – 3	21	8	3.5	28.0	9	SC
B – 8	US 93	2137+00, 15L	3 – 5	35	17	9.8	30.8	5	SC
B – 9	US 93	2140+10, 30R	2 – 5	23	2	8.7	41.8	3	SM
B – 10	US 93	2140+10, 15R	1 – 5	23	6	4.0	22.2	2	SC-SM
B – 11	US 93	2149+50, 110L	12 – 24	24	6	5.1	26.0	9	SC-SM*
B – 14	US 93	2158+00, 17R	0 – 5	21	5	4.2	23.1	10	SC-SM*
			7 – 10	27	8	5.0	42.9	6	SC
B – 15	US 93	2161+10, 60L	5 – 9	–	NP	4.4	34.8	3	SM
B – 16	US 93	2163+10, 70R	10 – 15	–	NP	3.2	29.3	3	SM
B – 17	US 93	2165+75, 60L	2 – 6	–	NP	2.2	18.8	12	SM*
B – 19	US 93	2170+05, 60L	5 – 25	–	NP	1.9	14.7	9	SM*
B – 20	US 93	2167+40, 15L	1.25 – 5	–	NP	3.2	16.2	8	SM
B – 22	SR 89	107+30, 35L	1 – 5	–	NP	4.6	26.7	4	SM
B – 23	SR 89	109+45, 2L	1 – 5	31	13	11.8	50.1	4	CL
B – 24	US 93 / SR 89	2150+70, 150R	9 – 12	–	NP	3.5	35.1	12	SM*
			12 – 19	–	NP	2.3	21.8	10	SM*
			29.5 - 35	22	5	3.5	22.4	11	SC-SM
B – 25	SR 89	116+20, 15R	0.75 – 3	44	27	12.5	56.9	6	CL
			3 – 5	45	28	8.2	50.2	4	CL
B – 26	SR 89	122+50, 15R	1 – 5	30	13	5.1	32.5	7	SC*

*Note: Larger gravels and/or cobble present, but not represented in the gradation results.
NP = Non-plastic
USCS = Unified Soil Classification System

TABLE 2
SUMMARY OF R-VALUES (Tested and Correlated)

Boring	Route	Station, Offset	Depth (feet)	R-Value Correlated	R-Value Tested
B – 1	US 93	US93 2114+10,	1.75 – 5	51.5	44.6
B – 3	US 93	2119+20, 8R	2 – 4	42.0	25.1
B – 4	US 93	2120+45, 80L	0 – 15	60.8	77.6
B – 5	US 93	2124+10, 8L	1.75 – 3	62.6	
B – 6	US 93	2129+00, 60L	0 – 4.5	35.6	
B – 7	US 93	2133+10, 25R	1.5 – 3	49.7	
B – 9	US 93	2140+10, 30R	2 – 5	51.9	
B – 10	US 93	2140+10, 15R	1 – 5	58.2	
B – 11	US 93	2149+50, 110L	12 – 24	55.2	
B – 14	US 93	2158+00, 17R	0 – 5	59.8	
			7 – 10	40.4	
B – 15	US 93	2161+10, 60L	5 – 9	61.8	58.1
B – 16	US 93	2163+10, 70R	10 – 15	66.7	
B – 17	US 93	2165+75, 60L	2 – 6	77.1	
B – 19	US 93	2170+05, 60L	5 – 25	81.6	
B – 20	US 93	2167+40, 15L	1.25 – 5	79.9	
B – 22	SR 89	107+30, 35L	1 – 5	69.2	
B – 23	SR 89	109+45, 2L	1 – 5	30.1	20.1
B – 24	US 93 / SR 89	2150+70, 150R	9 – 12	61.6	
			12 – 19	74.0	
			29.5 - 35	60.3	
B – 25	SR 89	116+20, 15R	0.75 – 3	15.8	
B – 26	SR 89	122+50, 15R	1 – 5	38.4	
			Average	55.8	45.1
			Adjusted Average	49.3	31.4
			Standard Deviation	16.5	23.7
			Calculated R-mean	47.6	
			Calculated R-control	34.0	
			Design R-Value	**30**	
			Construction Control R-Value	**30**	

TABLE 3

RESISTIVITY & pH RESULTS (ARIZ.236A), and SULFATES (ASTM D4327)

Boring	Location	Depth (feet)	pH	Resistivity (ohm-cm)	Sulfates (ppm)
---	US 93 2125+50*	0 to 1.5	7.40	---	12
B – 8	US 93 2137+00	1.5 to 3	8.11	2,838	
		3 to 5	8.22	2,973	
B – 9	US 93 2140+10	2 to 5	8.75	2,523	
---	US 93 2156+50*	0 to 1.5	7.60	---	10
B – 25	SR 89 116+20	0.75 to 3	8.19	470	
		3 to 5	8.21	362	
B – 26	SR 89 122+50	1 to 5	8.43	2,926	

*Note: Hand-Sampled from test pit excavated in drainage channel (Southbound side)

TABLE 4

MOISTURE-DENSITY RELATIONSHIP (AASHTO T99D)

Location	Maximum Dry Density (pcf)	Optimum Moisture Content (%)
US 93 Granular Soils – Combined Bulk Sample	129.2	9.6

TABLE 5

IN-PLACE DENSITY (ASTM D6938)

Boring	Depth (feet)	Dry Density (pcf)	Moisture Content (%)
B – 5	2 to 3.5	114.5	2.8
B – 17	4.5 to 6	119.6	3.5

MEMORANDUM

TO: Craig Regulski, PE, PMG

FROM: Patrice Brun, PE, Geotechnical Services and Operations Manager

DATE: May 18, 2021

RE: F0125 Geotechnical Recommendations Update Memorandum

This memorandum is being provided for the purpose of updating the geotechnical recommendations provided by the geotechnical consultant Engineering & Testing Consultants, Inc. (ETC) for this project. ETC provided to ADOT on May 23, 2019 the following reports: Geotechnical Report; Material Design Report; and Pavement Design Summary. The recommendations provided by ETC state that soils which do not meet the subgrade acceptance chart (R-Value = 30) shall be over-excavated to a depth of three (3) feet. Based on the soil conditions and laboratory test results provided in the geotechnical report, over-excavation of the subgrade soils is not warranted for this project due to a variety of considerations. The only area that comes into question (B-25, SR 89, Station 116+20), had clayey soils that were tested to have a plasticity index of 28 and a correlated R-Value of 16. In this general location, anticipate the extent of the clayey soils to extend approximately 500 feet in either linear direction. This distance can be only verified during construction. To remediate the clayey subsurface conditions, be prepared to apply a biaxial geogrid over high survivability non-woven geotextile fabric over the subgrade. Construction methods and procedures of such shall be in compliance with the ADOT 2021 Standard Specifications.

APPENDIX B

Geotechnical Exploration Report

Matthie Ranch Road Realignment by Ethos

FINAL GEOTECHNICAL EXPLORATION REPORT
US 93 WICKENBURG RANCH WAY TO VISTA ROYALE
MATTHIE RANCH ROAD REALIGNMENT
ADOT PROJECT NO. 93 YV 189 F0738 01C
FEDERAL AID NO. 093-B(230)T
ADOT CONTRACT NO. 2022-006.14
YAVAPAI COUNTY, ARIZONA

Prepared for:

Stanley Consultants, Inc
3133 East Camelback Road, Suite 100
Phoenix, AZ 85016

Prepared by:

Ethos Engineering, LLC
9180 South Kyrene Road, Suite 104
Tempe, Arizona 85284

Ethos Project No. 2025061
June 3, 2026

June 3, 2026
Ethos Project No.: 2025061

Karen Hobbs, P.E.
Stanley Consultants, Inc
3133 East Camelback Road, Suite 100
Phoenix, AZ 85016

SUBJECT: Final Geotechnical Exploration Report
US 93 Wickenburg Ranch Way to Vista Royale
Matthie Ranch Road Realignment
ADOT Project No. 93 YV 189 F0738 01C
Federal Aid No. 093-B(230)T
ADOT Contract No. 2022-006.14
Yavapai County, Arizona

Dear Karen:

Ethos Engineering, LLC is pleased to present the findings of the geotechnical exploration for the proposed US 93 Gap A project located in Yavapai County, Arizona. Our services were conducted in general accordance with the scope of services presented in our proposal dated July 8, 2025. The results of our field investigation and laboratory testing, and geotechnical engineering recommendations for support of the roadway and pavement designs are included herein. A Final Pavement Design Summary and Materials Design Report, based on the results included herein, are presented under separate cover.

We appreciate the opportunity to be of service on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,
Ethos Engineering, LLC

Registered Professional Engineer (Civil)
CERTIFICATE NO. 41716
KEVIN L. PORTER
Date Signed 06/03/2026
ARIZONA U.S.A.

Kevin Porter, P.E.
Senior Geotechnical Engineer

Reviewed By:

Francisco J. Garza, P.E.
President/Senior Geotechnical Engineer

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

FIGURES

APPENDICES

1.0 PROJECT DESCRIPTION

This report presents the results of our geotechnical exploration for the Matthie Ranch Realignment project, which is part of the US 93 Wickenburg Ranch Way to Vista Royale project, in Yavapai County, Arizona. The exploration included site reconnaissance, subsurface exploration, soil sampling, field and laboratory testing, engineering analyses, and preparation of this report. The purpose of this report is to provide information regarding the surface and subsurface soil conditions and general site geology, and to provide geotechnical recommendations for design and construction for the proposed Matthie Ranch Road and Wickenburg Ranch Way roadway improvements at the site.

The Matthie Ranch Road Realignment Project, as shown on Figure 1, is located south and west of US 93 about 5 miles north of Wickenburg, Arizona. We understand the project will design and construct about 4,400 feet of new Matthie Ranch Road and about 1,900 feet of new Wickenburg Ranch Way. These roadways will be two-lane roadways through undeveloped rolling topography connecting the existing Matthie Ranch Road to an existing roundabout on US 93 south of its current connection.

The new Wickenburg Ranch Way will connect to the existing US 93 roundabout and traverse in a westerly direction about 1,900 feet and connect to the new Matthie Ranch Road alignment. The typical section will generally consist of two 12-foot travel lanes with 2-foot paved and 4-foot unpaved shoulders. The profile includes cut and fill sections up to about 25 feet in height.

The new Matthie Ranch Road alignment traverses in a northerly direction from the connection with Wickenburg Ranch Way and then transitions in a northwesterly direction, paralleling the US 93 alignment until it connects to the existing Matthie Ranch Road alignment. The typical section will generally consist of two 12-foot travel lanes with 2-foot paved and 4-foot unpaved shoulders. The profile is gently rolling and generally near existing grade except near the connection with Wickenburg Ranch Way where fill depths are on the order of 15 feet.

The project is within the Arizona Department of Transportation (ADOT) Northwest District, and the average project elevation is around 2,400 feet.

2.0 FIELD EXPLORATION

Prior to our field exploration, Ethos coordinated with Stanley to obtain permission to access the site. Upon receipt of permission, we staked the boring locations. Upon locating the borings, Ethos coordinated clearing each area with Arizona 811.

The subsurface exploration for the project was performed on March 26 and 27, 2026, and included 8 exploratory borings for planned roadway improvements. Table 2.1 presents a summary of the drilling program, which includes the boring, location, and depth.

Table 2.1: Subsurface Exploration Details

Location ID	Station, Offset	Latitude (°N)	Longitude (°E)	Depth (feet)
B-1	40+00, 10' R	34.02311	-112.80775	10
B-2	31+50, 5' R	34.02172	-112.80553	10
B-3	24+30, 25' R	34.02050	-112.80365	10
B-4	17+30, 20' L	34.01893	-112.80239	10
B-5	10+00, 5' L	34.01693	-112.80230	10
B-6	1+00, 5' R	34.01450	-112.80276	20
B-7	65+00, 5' R	34.01421	-112.79992	30
B-8	74+00, 10' L	34.01636	-112.79877	20

The boring spacings and depths are generally consistent with ADOT guidelines, with modifications based on our existing knowledge of the project corridor geotechnical support conditions. The exploration locations are shown on the Boring Locations included as Figure 2.

Drilling was performed by Geomechanics Southwest Inc. (GSI) using a track-mounted CME-75 drill rig utilizing hollow-stem auger. Sampling was performed using a standard penetration test (SPT) split spoon sampler with a 1.375-inch ID and 2-inch OD or an open-end drive sampler (2.42-inch-diameter brass rings) at maximum 5-foot intervals in each boring using an automatic hydraulic actuated 140-pound hammer, free falling 30 inches. The SPT and ring samplers were driven 18 and 12 inches or to refusal (i.e. 50 blows for less than a 6-inch interval), respectively. Unless noted otherwise on the boring logs, the sample driving resistance was recorded as number of blows per six inches of penetration. The penetration results are presented on the borings logs adjacent to each sample. Representative bulk samples of near-surface drill cuttings were also collected from selected borings.

Encountered soils were visually inspected, labeled and classified in the field, and logged in general accordance with ASTM D2488, the Unified Soil Classification System (USCS), Arizona Department of Transportation (ADOT), and Ethos guidelines. Field direction, and logging of borings were performed by Ethos personnel. Logs of the completed borings are presented in Appendix A.

The recovered soil samples were removed from the sampler, sealed to reduce moisture loss, and submitted to the Quality Testing, LLC (QT) laboratory. Completed borings were backfilled with cuttings.

3.0 LABORATORY TESTING

Selected laboratory tests were assigned by Ethos and performed by QT on representative samples recovered from the borings to support our field classification and to provide information regarding engineering characteristics and properties of the subsurface soils. The laboratory testing program included the following tests, each followed by a brief discussion of the test relevance:

- Moisture content, sieve analysis and Atterberg limits (plasticity index) – Soil classification and moisture condition, and for computation of correlated R-values for use in pavement design.

- Density of ring samples – Determination of in-place density and moisture, used in compressibility and earthwork computations.
- R-value – Determination of pavement design parameter (subgrade soil strength).
- Moisture-density relationship (Proctor) – Determination of density targets for construction of compacted fills and used to develop earthwork factors when compared to in situ densities.
- pH and resistivity – Determination of appropriate steel pipe type.
- Total soluble sulfates and chlorides – Assessment of the potential impact of the existing soils on concrete. Used to determine which type of concrete should be used.

A summary of the laboratory test results is presented in Table B-1 in Appendix B. The individual results of the laboratory testing program are also included in Appendix B. The results of moisture content and in-place dry density testing are also presented on the boring logs in Appendix A at the corresponding sample depth.

4.0 SITE CONDITIONS AND GEOTECHNICAL PROFILE

4.1 Surface Site Conditions

The proposed Matthie Ranch Road and Wickenburg Ranch Way corridor is undeveloped land with undulating topography and scattered drainages and vegetation. US 93 is located immediately north of the proposed roadway alignments.

4.2 Regional Geologic Setting & Subsurface Profile

The project site is in the Basin and Range Geologic Province of the southwestern United States. The Basin and Range Province is characterized by a modern landscape consisting of broad alluvial valleys interspersed with and bounded by uplifted and fault-block mountain ranges, often with well-developed pediments and alluvial fans. Generally, the mountain ranges and valleys trend in a north-south to northwest-southeast direction. The modern landscape was formed by late Tertiary (Miocene-Pliocene) extensional tectonism and high-angle normal faulting, followed by subsequent erosion of the uplifted mountains and alluvial deposition of the sediments in the newly-formed basins.

Published geological mapping indicates the surficial geological unit at the site consists of Pliocene to middle Miocene deposits. This unit is described as moderately to strongly consolidated conglomerate and sandstone deposited in basins during and after late Tertiary faulting and includes lesser amounts of mudstone, siltstone, limestone, and gypsum. These deposits are generally light gray or tan. They commonly form high rounded hills and ridges in modern basins and locally form prominent bluffs. Deposits of this unit are widely exposed in the dissected basins of southeastern and central Arizona. The soil types encountered in the borings are likely residual soils associated with the mapped geologic units, and may include younger alluvial fan and terrace deposits overlying the older geological units.

The surface soils encountered in the boring were generally medium firm/medium dense to hard/very dense, generally increasing in density with depth to the maximum depth explored. The soil encountered were primarily low to medium plasticity clayey sand (SC), low plasticity silty clayey sand (SC-SM), and non-plastic silty sand (SM) with variable gravel and possible cobbles or boulders. Zones of moderate to strong cementation were also encountered.

4.3 Moisture and Groundwater Conditions

Groundwater was not encountered in the borings and soil moisture conditions were generally described as slightly moist to moist. A review of the groundwater data in the Arizona Department of Water Resources (ADWR) Groundwater Site Inventory database (ADWR 2025) does not indicate any index well sites in the immediate vicinity of the project site with current readings. Historic readings from well sites adjacent to the site indicate groundwater depths on the order of 200 to 300 feet and corresponding groundwater elevations on the order of 2,100 to 2,200 feet.

5.0 ENGINEERING ANALYSES AND RECOMMENDATIONS

5.1 General

Geotechnical engineering recommendations for the support of the proposed improvements are presented in the following sections. These recommendations are based on our understanding of the project, the results of our field exploration and laboratory testing for the site, and engineering analyses.

The following sections of this report present our recommendations regarding slopes, pavement subgrades, site preparations and grading, moisture protection, and excavations.

5.2 Slopes

5.2.1 Permanent Slopes

Non-stabilized embankment cut and fill slopes should be on the order of 3:1 (H:V) or flatter. Flatter slopes will promote re-vegetation and can accept landscaping. Slopes protected with slope paving or rock armored slopes should be not steeper than 2:1 (H:V).

5.2.2 Temporary Slopes

Temporary excavations for construction of footings, drilled shaft caps, etc. can be made with conventional earthmoving equipment. Temporary slopes should be excavated in accordance with OSHA (2020). In accordance with Subpart P, Appendix A, the native soils to a depth of approximately 20 feet are considered to be Type C soils. For excavations less than 20 feet in such soils, Subpart P, Appendix B indicates a maximum allowable unshored slope of 1.5H:1V for Type C soils. Flatter slopes may be required where either sandy soils are encountered or where the soils become excessively wet, and soft.

Should steeper slopes be required due to the proximity of existing structures or other contractor needs, the stability of the slopes should be verified by a registered geotechnical engineer (State of Arizona) who is proficient in slope stability analyses. Based on the overall site conditions, it does appear that steeper slopes will be feasible in some of the more fine-grained areas of the project, pending further analysis.

The perimeter of all excavations should be protected against water runoff and infiltration near the edges to maintain stability. Heavy equipment and spoil piles should not be allowed within 10 feet of the edge of the excavation. The perimeter of all excavations should be protected against water runoff and infiltration near the edges to maintain stability.

5.3 Pavements

5.3.1 Pavement Subgrade Support

Recommended design and construction control R-values were developed based on the results of laboratory testing on the subgrade soils and procedures presented in the ADOT Pavement Design Manual (PDM) (ADOT, 2017). Soil samples used to evaluate the pavement subgrade were obtained from within 5 feet or less of the proposed finished grade and are representative of the materials that will form the final roadway subgrade.

Table 5.1 presents the results of correlated R-values determined using Table 202.02-3 in the ADOT PDM and laboratory R-value tests performed in accordance with ASTM D2844.

Table 5.1 Summary of Subgrade Testing Results

Boring ID	Depth (feet)	USCS	% Passing #200 Sieve	Plasticity Index	Tested R-value	Correlated R-Value
B-1	0-5	SM	19	0	74	77
B-2	0-5	SC	28	9	--	48
B-3	0-5	SM	17	0	--	79
B-4	0-2.5	SC-SM	37	7	--	46
B-5	0-7.5	GC	19	11	33	50
B-6	0-2.5	SM	19	0	--	77
B-7	0-7.5	SC-SM	18	7	45	59
B-8	0-2.5	GC	25	15	--	39
Average					51	59
Standard Deviation					21	16

The design procedure outlined by the ADOT PDM for determining the design R-value resulted in a calculated design R-value of 51 for the project. However, to be consistent with other projects in the area and to allow the majority of existing soils to stay in place, we recommend a design R-value of 30 be used for design of new pavements.

Based on a design R-value of 30, a construction control R-value (Rcc) of 20 (minimum acceptable correlated R-value of soils for construction control purposes) was selected. Site soils identified during construction that do not meet the minimum Rcc should be over-excavated to a minimum depth of 3 feet below the finished subgrade elevation and replaced with soils meeting the construction control R-values outlined herein.

5.3.2 Site Grading for Embankments and Pavement

Recommendations for site grading beneath embankments and pavement are presented in Section 5.6.

5.4 Surface Drainage

Long-term performance of pavement will require that the subgrade soils and backfill be protected against excessive water infiltration and/or saturation. Surface drainage should be established away from pavements to minimize moisture infiltration into the subgrade. Structural fill and backfill should be well compacted to reduce possible moisture infiltration through loose soil intervals.

5.5 Preliminary Soil Corrosion or Degradation Potential

5.5.1 Metal in Contact with Soil

The corrosion potential of near surface soils on corrugated metal pipes was characterized using laboratory pH and electrical resistivity testing, performed on 2 samples in accordance with Arizona Test Method 236. The laboratory pH values were 8.9. The resistivity values ranged from 3,046 to 5,023 ohm-centimeters (ohm-cm) (average 4,035 ohm-cm). It is recommended that the type and/or coating of metal in direct contact with soil be selected in accordance with ADOT Pipe Selection Guidelines (ADOT, 1996). Pipe locations where the pH is greater than 9.0 and/or the resistivity is less than 2,000 ohm-cm require the use of special pipes and/or pipe coatings. Based on the preliminary results, it does not appear that specialized pipes and/or pipe coatings are required. Refer to Table B-1 for the test locations and results for each sample.

5.5.2 Concrete in Contact with Soil

A total of 2 samples from the current investigation were used for soluble sulfates and chlorides (Arizona Test Method 733 and Arizona Test Method 736) to support design of concrete structures. The results of these laboratory tests are included in Appendix B and summarized in Table B-1.

Total soluble sulfate values ranged from 16 to 57 parts per million (ppm) with an average of 37 ppm. The sulfate test measures the water-leachable or “available” sulfate content. These results were compared to Table 19.3.1.1, “Exposure Categories and Classes,” in Section 19.3.1, of the American Concrete Institute’s (ACI’s) *Building Code Requirements for Structural Concrete* (ACI 2019). All of the samples fall within Exposure Class S0 for water-soluble sulfate (SO_4^{2-}) in soil by percent mass (SO_4<0.1% or 1,000 ppm) and are categorized with a severity level of “not applicable” in terms of sulfate exposure. Based on ACI Table 19.3.2.1, “Requirements for Concrete by Exposure Class,” in Section 19.3.2 (ACI 2019), there is no restriction on Portland cement type for concrete structures in contact with these materials.

Chloride values ranged from 7 to 20 ppm with an average of 14 ppm. Regarding chloride attack, Section 19.3.2 (ACI 2019) indicates that when concrete is exposed to external sources of chlorides, concrete should be proportioned to satisfy the requirements for the applicable exposure class in Table 19.3.1.1 (ACI 2019). The anticipated concrete exposure for this segment falls within Exposure Class C1. Table 19.3.2.1 (ACI 2019) should be referred to for requirements for concrete by exposure class. For Exposure Class C1, the minimum compressive strength of concrete specified is 2,500 psi and the maximum water-soluble chloride ion content in concrete, by percent weight of cement, is 0.30% for non-prestressed concrete and 0.06% for prestressed concrete.

5.5.3 Further Evaluation

The results presented in this section are general in nature and may not be representative of site conditions. We recommend that the results of our laboratory testing be reviewed by a person or firm experienced in corrosion protection designs for the actual construction at the site, and/or by the appropriate pipe or material manufacturer. A qualified corrosion engineer should be consulted if corrosion of underground utilities is a concern or if a detailed evaluation is necessary.

5.6 Earthwork

5.6.1 Site Preparation

The following site grading recommendations are intended to provide support for the proposed pavements and associated embankments at the site. The grading activities at the site should be performed under observation and testing directed by a geotechnical engineer.

All vegetation and debris should be removed from areas designated for pavement or embankment fill in accordance with Section 201 of the Standard Specifications (ADOT 2021). This site grading should extend laterally a minimum of 2 feet beyond pavement areas. Within the foundation footprint of each structure, remove all existing vegetation, existing structures, any uncontrolled fill, and any loose or otherwise unstable materials.

The areas should be initially graded to create a relatively flat surface to receive fill. A representative of the Geotechnical Engineer should inspect the final excavated surface prior to subgrade preparation.

5.6.2 Excavations

Based on the materials encountered in our borings, we anticipate excavation to final grades can be accomplished with conventional earthmoving equipment. Some very dense variably cemented zones with possible cobbles should be anticipated.

5.6.3 Subgrade Preparation

Prior to placement of engineered fill beneath the embankment and pavement, or at the existing ground surface when no over excavation is recommended, the exposed ground should be subjected to a single pass with a filled 4,000-gallon water truck to identify soft or loose soils. Additionally, the exposed surfaces upon which fill or pavements are to be placed should be scarified to a depth of 6 inches, adjusted to a moisture content within the range of plus or minus 2 percent of optimum, and compacted to at least 95% of maximum dry density as determined by the applicable ADOT test methods.

A representative of the Geotechnical Engineer should observe the subgrade preparation activities. Excessively soft or loose soils at the excavation bottom that are not remediated by the outlined subgrade preparation should be improved as directed by the Geotechnical Engineer prior to fill placement.

5.6.4 Embankment Fill

Construction of embankment fill should be in accordance with Section 203 of the ADOT Standard Specifications for Road and Bridge Construction (ADOT, 2021) and the project's special provisions. Fill material should be placed in loose lifts no thicker than 10 inches where heavy compaction equipment is used, provided compaction can be achieved throughout the lift thickness. Where hand operated compactors are used, loose lifts should not exceed 6 inches in thickness. Fill lifts should be of uniform thickness when compacted. All fill should be compacted to a minimum of 95% of the maximum dry density at within plus or minus 2% of the optimum moisture content as determined per ASTM D698.

Approximately 85 to 90 percent of the settlement due to placing the embankment is expected to occur during construction with the remaining settlement to occur shortly afterwards.

5.6.5 Earthwork Factors

Development of earthwork factors for near-surface materials was based on the evaluation and analysis of data from density tests on in situ soil samples and laboratory moisture-density relationships. The recommended earthwork factor for on-site materials was calculated using the following equation:

$$\% \text{ Shrink/Swell} = \left[1 - \frac{\gamma_{ex}}{\gamma_{fill}}\right]100$$

Where:

γ_{ex} = in situ dry density of material to be excavated
γ_{fil} = 95 percent of the maximum dry density

The moisture-density relationships (Proctor) were developed using ASTM D698, Method A on 2 samples. The Proctor's that contained ten percent rock (material retained above the No. 4 sieve) or more were rock corrected in accordance with AZ Test Method 227c (ADOT 2019). An average rock-corrected maximum dry density was determined. The rock-corrected maximum dry density average value used for the analysis was 125.4 pcf.

Individual density samples were evaluated using in-situ dry densities and maximum dry densities. Using 95 percent of the maximum dry density and the tested in situ dry density, the following calculation was made:

γ_{fill} = 0.95(125.4) = 119.1 pcf
γ_{ex} = 108.1 pcf
% Shrink/Swell = $\left[1 - \frac{108.1}{119.1}\right] 100$ = 9.2%.

Positive results indicated shrink and negative results indicate swell. Based on the positive result, the material represented by the sample is anticipated to shrink approximately 9.2 percent when compacted to 95 percent of the maximum dry density. Accounting for a likely average compaction percentage greater than 95 percent and the requirement to round to the nearest 5 percent increment (ADOT 2021b), an earthwork factor of 10 percent shrink is recommended.

5.6.6 Ground Compaction Factor

The ground compaction factor is an estimate of the ground height loss, including clearing and grubbing, that will result from compaction of the surface to 95% relative compaction. The impact of clearing and grubbing is a function of the existing ground cover. The existing ground cover across the project is considered sparse to moderate vegetation. On average, the project falls within the moderate vegetation category. The impact from compaction is related to the fill placement height. The proposed roadway is primarily above grade with fills ranging from 0 to 25 feet with the majority falling within the low fill placement category (ADOT 2021b). Based on these factors, the recommended ground compaction factor for the project is 0.10 feet. Settlement of the planned fill embankments and of the near-surface native soils is anticipated in response to embankment construction; however, most settlement is expected to occur during construction of the embankments.

6.0 CLOSURE

The geotechnical services were performed in a manner consistent with that level of care and skill ordinarily exercised by other members of the geotechnical profession practicing in the same locality, under similar conditions and at the date the services were provided. Our conclusions, opinions and recommendations are based on the completed test borings, visual observations and the review of plans prepared by others. It is possible that conditions could vary beyond the data evaluated. Ethos makes no guarantee or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided.

This report may be used only by the Client and their representatives, and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on site and off site), or other factors may change over time, and additional work may be required with the passage of time. Any party other than the Client who wishes to use this report shall notify Ethos of such intended use. Based on the intended use of the report, Ethos may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the Client or anyone else will release Ethos from any liability resulting from the use of this report by any unauthorized party.

7.0 REFERENCES

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FIGURES

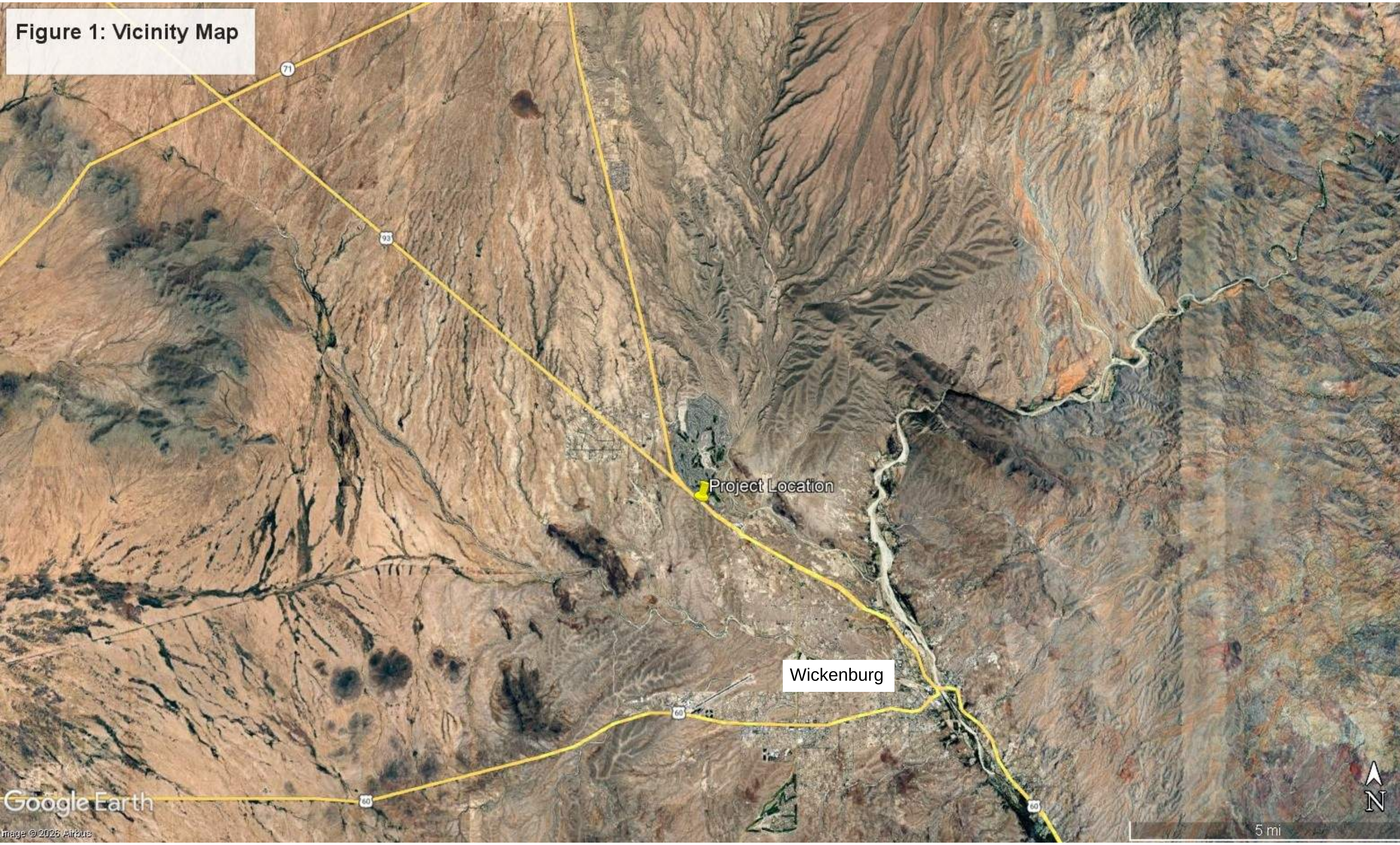


Figure 1: Vicinity Map

Figure 2: Boring Locations

APPENDIX A

Boring Logs

SOILS SAMPLING & BORING LOG INFORMATION

The material and in-situ moisture descriptions of soils presented on the boring logs are based on visual observation and classification in accordance with the Unified Soil Classification System (USCS), presented on the next page. The field logs were modified, where appropriate, based on laboratory testing of selected samples.

The relative density and firmness described on the test boring logs are generally based on standard penetration test (SPT) blows per foot (N) for mostly cohesionless and cohesive soils. 2-inch outside diameter (O.D.) SPT samplers are advanced up to 18 inches into undisturbed soils beyond the base of either a hollow stem auger or drill casing. The samplers are driven with a 140-pound hammer and a 30-inch drop. SPT values are recorded on the boring logs for each 6-inch increment of penetration with sampler refusal based on a penetration of less than 6 inches and a blowcount of 50.

Relative Density

Relative density for mostly cohesionless, uncemented sands and sand and gravel mixtures is described based on the following SPT blowcounts:

N	Relative Density
0-4	Very Loose
5-10	Loose
11-30	Medium Dense
31-50	Dense
>50	Very Dense

Relative Firmness

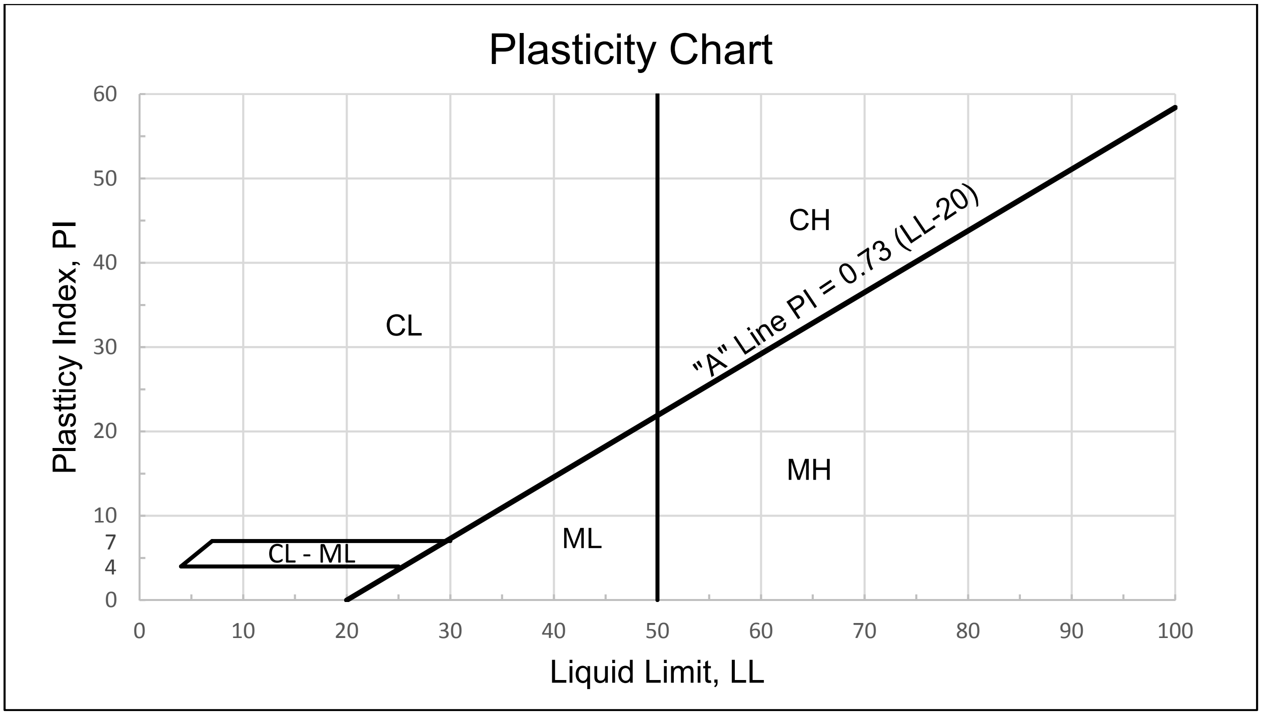
Relative Firmness for cohesive and/or cemented soils including silts, clays and silty to clayey sandy and gravelly soils is described based on the following SPT blowcounts:

N	Relative Firmness
0-4	Very Soft
5-8	Soft
9-15	Moderately Firm
16-30	Firm
31-49	Very Firm
50+	Hard

Undisturbed samples of firmer soils, typically present in the southwest, are obtained with 3-inch O.D. samplers lined with 2.42-inch inside diameter (I.D.) brass rings. The samplers are advanced up to 12 inches into undisturbed soils beyond the base of either a hollow stem auger or drill casing. The samplers are driven with a 140-pound hammer and a 30-inch drop. The N value blowcounts are recorded on the boring logs for each 6-inch increment of penetration with sampler refusal based on a penetration of less than 12 inches and a blowcount of 100.

Unified Soil Classification System
(ASTM D2487)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests				Group Symbol	Group Description
Coarse-Grained Soils (More than 50% Retained on No. 200 Sieve).	Gravels More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravels Less than 5% Fines		GW	Well Graded Gravels, Gravel-Sand Mixtures or Sand-Gravel-Cobble Mixtures.
				GP	Poorly Graded Gravels, Gravel-Sand Mixtures or Sand-Gravel-Cobble Mixtures.
		Gravels with More than 12% Fines	Fines Classify as ML or MH	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			Fines Classify as CL or CH	GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	Sands 50% or More of Coarse Fraction Passes No. 4 Sieve	Clean Sands Less than 5% Fines		SW	Well Graded Sands, Gravelly Sands.
				SP	Poorly Graded Sands, Gravelly Sands.
		Sands with More than 12% Fines	Fines Classify as ML or MH	SM	Silty Sands, Sand-Silt Mixtures
			Fines Classify as CL or CH	SC	Clayey Sands, Sand-Clay Mixtures
Fine-Grained Soils (50% or More Passes No. 200 Sieve).	Silts and Clays (Liquid Limit less than 50)	PI > 7 and Plots on Above "A" Line		CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
		PI <4 or Plots Below "A" Line		ML	Inorganic Silts, Clayey Silts with Low Plasticity
	Silts and Clays (Liquid Limit 50 or More)	PI Plots on Above "A" Line		CH	Inorganic Clays of High Plasticity, Fat Clays, Silty and Sandy Clays of High Plasticity
		PI Plots Below "A" Line		MH	Inorganic Silts of High Plasticity, Silty Soils, Elastic Silts



Angularity	
Angular	
Subangular	
Subrounded	
Rounded	

Soil Particle Definitions	
Material	**Particle Size Range**
Boulders	Greater than 300 mm (12 in.)
Cobbles	300 mm to 75 mm (12 in. to 3
Coarse Gravel	75 mm to 19 mm (3 in. to ¾ in.)
Fine Gravel	19mm (3/4 in.) to No. 4 sieve
Coarse Sand	No. 4 Sieve to No. 10 Sieve
Medium Sand	No. 10 Sieve to No. 40 Sieve
Fine Sand	No. 40 Sieve to No. 200 Sieve
Fines (Silt or Clay)	Less than No. 200 Sieve

Plasticity	
PI = 0	Non-Plastic
1 ≤ PI ≤ 7	Low
8 ≤ PI ≤ 25	Medium
PI ≥ 25	High

Moisture
Slightly Moist
Moist
Wet
(Saturated)

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project		BORING ID: B-1
	PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc		DATE STARTED: 03/26/2026 / DATE COMPLETED: 03/26/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger		HAMMER TYPE: Auto / HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2443'	STATION: 40+00	OFFSET AND OFFSET DIRECTION: 10' R	-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75 / RIG NUMBER: 127
REPORTED DEPTH: 11.5'	GROUNDWATER DEPTH: N/A	REVIEWED BY: K. Porter	LATITUDE: 34.023110 / LONGITUDE: -112.807750

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			SILTY SAND (SM), occasional fine subangular to subrounded gravel, predominantly fine sand, nonplastic, tan to light brown, dense, strong reaction with HCl			10-20-25 (45)				
2440						13-23-21 (44)			NP	19
	5					10-11	2.1	109.8		
2435										
	10					6-16-18 (34)				
			11.5							

Drilling stopped at 10 feet. Sampled to 11.5 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project	BORING ID: B-2
	PROJECT LOCATION: Yavapai County, AZ	AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc	DATE STARTED: 03/26/2026 / DATE COMPLETED: 03/26/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger	HAMMER TYPE: Auto / HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2423'	STATION: 31+50 / OFFSET AND OFFSET DIRECTION: 5' R	-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool / FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75 / RIG NUMBER: 127
REPORTED DEPTH: 11.0'	GROUNDWATER DEPTH: N/A / REVIEWED BY: K. Porter	LATITUDE: 34.021720 / LONGITUDE: -112.805530

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
2420	5		**CLAYEY SAND** (SC), trace fine subangular to subrounded gravel, predominantly fine to medium subangular sand, low plasticity, light reddish brown, firm, moderate reaction with HCl	X	X	3-7-9 (16)			27-18-9	28
			5		X	6-11-17 (28)				
2415	10		**SAND** (SP), occasional to trace fine subangular to subrounded gravel, nonplastic, white, dense, strong reaction with HCl		X	14-18-23 (41)				
			11		X	7-22	1.7	113.5		

Drilling stopped at 10 feet. Sampled to 11 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.

PROJECT NAME: US 93, Gap A Project		**BORING ID:**	**B-3**
PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C	
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc	DATE STARTED: 03/26/2026	DATE COMPLETED: 03/26/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger	HAMMER TYPE: Auto	HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2409'	STATION: 24+30 / OFFSET AND OFFSET DIRECTION: 25' R		-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool / FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 10.8'	GROUNDWATER DEPTH: N/A / REVIEWED BY: K. Porter	LATITUDE: 34.020500	LONGITUDE: -112.803650

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			SILTY SAND (SM), rare fine subangular to subrounded gravel, fine sand, nonplastic, light brown, loose to medium dense, strong reaction with HCl	X	X	3-2-4 (6)			NP	17
2405				X	X	4-5-7 (12)				
	5				X	5-7	1.9	101.1		
2400	10				X	26-50/3"				
	10.8		Note: very dense, gravel increase to trace to some below 10 feet.							

Drilling stopped at 10 feet. Sampler refused at 10.8 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project		BORING ID: **B-4**	
	PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C	
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc		DATE STARTED: 03/26/2026	DATE COMPLETED: 03/26/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2397'	STATION: 17+30	OFFSET AND OFFSET DIRECTION: 20' L		-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 10.8'	GROUNDWATER DEPTH: N/A	REVIEWED BY: K. Porter	LATITUDE: 34.018930	LONGITUDE: -112.802390

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
2395			**SILTY, CLAYEY SAND** (SC-SM), occasional fine subangular to subrounded gravel, fine sand, low plasticity, light brown, moderately firm 2.5	X	X	4-5-9 (14)			23-16-7	37
	5		**SILTY SAND** (SM), occasional fine subangular to subrounded gravel, predominantly fine sand, nonplastic, tan to light brown, medium dense		X	2-7-20 (27)				
2390			Note: possible cobbles at 4 feet		X	5-7-17 (24)				
	10		10							
			SAND WITH SILT AND GRAVEL (SP-SM), some predominantly fine subangular to subrounded gravel, predominantly fine sand, nonplastic, light brown to tan, very dense 10.8		X	20-50/4"				

Drilling stopped at 10 feet. Sampler refused at 10.8 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project		BORING ID: B-5	
	PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C	
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc		DATE STARTED: 03/27/2026	DATE COMPLETED: 03/27/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2387'	STATION: 10+00	OFFSET AND OFFSET DIRECTION: 5' L		-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 11.5'	GROUNDWATER DEPTH: N/A	REVIEWED BY: K. Porter	LATITUDE: 34.016930	LONGITUDE: -112.802300

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			CLAYEY GRAVEL (GC), some to considerable fine to coarse subangular sand, predominantly fine subangular to subrounded gravel, low plasticity, light reddish brown, moderately firm, moderately firm to very firm			10-15-50/1"				
2385										
						4-6-6 (12)			28-17-11	19
	5									
						50/4"				
2380										
	10									
			11.5			8-9-10 (19)				

Drilling stopped at 10 feet. Sampled to 11.5 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project		**BORING ID: B-6**
	PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc		DATE STARTED: 03/27/2026 / DATE COMPLETED: 03/27/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger		HAMMER TYPE: Auto / HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2376'	STATION: 1+00	OFFSET AND OFFSET DIRECTION: 5' R	-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75 / RIG NUMBER: 127
REPORTED DEPTH: 21.5'	GROUNDWATER DEPTH: N/A	REVIEWED BY: K. Porter	LATITUDE: 34.014500 / LONGITUDE: -112.802760

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
2375			**SILTY SAND** (SM), occasional fine subangular to subrounded gravel, fine to medium subangular sand, nonplastic, light reddish brown, loose to very dense			2-2-2 (4)				
						3-50/2"			NP	19
2370	5		Note: dense to very dense, fine to coarse gravel and sand below 5 feet			12-17-19 (36)				
2365	10					7-50/3"				
2360	15		Note: color change to gray below 15 feet			27-50/2"				
2355	20		21.5			15-20-12 (32)				

Drilling stopped at 20 feet. Sampled to 21.5 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.

PROJECT NAME: US 93, Gap A Project		**BORING ID:**	**B-7**
PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C	
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc	DATE STARTED: 03/27/2026	DATE COMPLETED: 03/27/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger	HAMMER TYPE: Auto	HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2430'	STATION: 65+00 / OFFSET AND OFFSET DIRECTION: 5' R		-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool / FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 31.5'	GROUNDWATER DEPTH: N/A / REVIEWED BY: K. Porter	LATITUDE: 34.014210	LONGITUDE: -112.799920

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
	0		**SILTY, CLAYEY SAND** (SC-SM), some to considerable predominantly fine subangular to subrounded gravel, predominantly fine sand, low plasticity, white, very firm to hard, strong reaction with HCl	X	X	5-50/5"				
				X	X	11-18-50/3"			23-16-7	18
2425	5		Note: possible cobbles at 5 feet	X	X	9-13-17 (30)				
2420	10				X	13-10-10 (20)				
2415	15		Note: fine to coarse gravel from 13 to 15 feet		X	50/2"				
2410	20				X	13-50/3"				
2405	25				X	13-28-50/3"				
2400	30		Note: firm, light brown color at 30 feet		X	10-14-15 (29)				
	31.5									

Drilling stopped at 30 feet. Sampled to 31.5 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Gap A Project		BORING ID: B-8
	PROJECT LOCATION: Yavapai County, AZ		AGENCY PROJECT NUMBER: 93 YV 193 F0125 01C
PROJECT NUMBER: 2025061	CLIENT NAME: Stanley Consultants, Inc		DATE STARTED: 03/27/2026 / DATE COMPLETED: 03/27/2026
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 7-1/8" OD Hollow Stem Auger		HAMMER TYPE: Auto / HAMMER EFFICIENCY: 85.5%
SURFACE ELEVATION: 2431'	STATION: 74+00	OFFSET AND OFFSET DIRECTION: 10' L	-
DRILLING FIRM: Geomechanics Southwest, Inc.	DRILLER: J. Pool	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75 / RIG NUMBER: 127
REPORTED DEPTH: 21.1'	GROUNDWATER DEPTH: N/A	REVIEWED BY: K. Porter	LATITUDE: 34.016360 / LONGITUDE: -112.798770

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
2430			**CLAYEY GRAVEL** (GC), some to considerable fine to coarse subangular sand, fine to coarse subangular to subrounded gravel, medium plasticity, light reddish brown, firm, moderate reaction with HCl 2.5	X	X	10-19-10 (29)			33-18-15	25
			SILTY SAND WITH GRAVEL (SM), some predominantly fine subangular to subrounded gravel, predominantly fine sand, nonplastic, white, strong reaction with HCl, medium dense to very dense		X	22-30-27 (57)				
2425	5				X	9-11-12 (23)				
2420	10		Note: fine to coarse sand and light brown to white color below 10 feet		X	13-24-50/1"				
2415	15		Note: possible cobbles at 15 feet		X	50/1"				
2410	20		21.1	X	X	18-35-50/1"				

Drilling stopped at 20 feet. Sample refused at 21.1 feet.
Backfilled with cuttings.

APPENDIX B

Laboratory Test Results

TABLE B-1: SUMMARY OF LABORATORY TEST RESULTS

Boring Number	Sample Depth [feet]		USCS/Group Symbol (ASTM D2487)	Percent Fines (minus #200) (ASTM C136)	Liquid Limit (ASTM D4318)	Plasticity Index (ASTM D4318)	Moisture Content [%] (ASTM D2216/T265)	In-Place Dry Density [pcf] (ASTM D2937)	Optimum Moisture Content [%] [1] (ASTM D698A)	Maximum Dry Density [pcf] [1] (ASTM D698A)	R-Value (ASTM D2844)	pH (AZ 236)	Resistivity [ohm-cm] (AZ 236)	Sulfates [ppm] (AZ 733)	Chlorides [ppm] (AZ 736)
	Begin	End													
B-1	0.0	5.0	SM	19	NV	NP					74	8.9	5,023	57	20
B-1	5.0	6.0	SM				2.1	109.8							
B-2	0.0	5.0	SC	28	27	9									
B-2	10.0	11.0	SP				1.7	113.5							
B-3	0.0	5.0	SM	17	NV	NP			9.5	129.1					
B-3	5.0	6.0	SM				1.9	101.1							
B-4	0.0	2.5	SC-SM	37	23	7									
B-5	0.0	7.5	GC	19	28	11					33				
B-6	0.0	5.0	SM	19	NV	NP						8.9	3,046	16	7
B-7	0.0	7.5	SC-SM	18	23	7			11.4	121.6	45				
B-8	0.0	2.5	GC	25	33	15									
Average				**22.7**	**26.8**	**9.8**	**1.9**	**108.1**	**10.5**	**125.4**	**50.7**	**8.9**	**4034.5**	**36.5**	**13.5**
Standard Deviation				**7.0**	**4.1**	**3.3**	**0.2**	**6.4**	**1.3**	**5.3**	**21.1**	**--**	**1398.0**	**29.0**	**9.2**
Maximum				**36.8**	**33.0**	**15.0**	**2.1**	**113.5**	**11.4**	**129.1**	**74.0**	**8.9**	**5023.0**	**57.0**	**20.0**
Minimum				**16.7**	**NV**	**NP**	**1.7**	**101.1**	**9.5**	**121.6**	**33.0**	**8.9**	**3046.0**	**16.0**	**7.0**
Count				**8**	**8**	**8**	**3**	**3**	**2**	**2**	**3**	**2**	**2**	**2**	**2**

Notes: pcf = pounds per cubic foot; ohm-cm = ohm-centimeters; ppm = parts per million

[1] Values do not include rock correction.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014056**

Project No.	Project Name					Project Number(s)	
22012.10	US 93 Gap A Project - Lab Testing						
Sampled By	**Sample Date**	**Logged By**	**Date Logged**	**Released By**	**Release Date**	**Approved By†**	**Date Approved**
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026
Material Source	**Material Type**	**Sampled From**		**Reference Line**		**Station**	**Offset**
Native	0	B-02 (0.0'-5.0')					
Remarks							

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	100	100	98	94	92	89	86	77	74	65	54	49	43	33	28.2

Tested By: Jessica Pena-Melroy 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
27	18	9

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SC : Clayey Sand

AASHTO Classification (AASHTO M145): A-2-4 (0)

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.

The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014057**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-03 (0.0'-5.0')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	100	100	99	96	94	91	88	80	78	69	55	46	36	23	16.7

Tested By: Charles Patti 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
N/A	N/A	NP

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SM : Silty Sand

AASHTO Classification (AASHTO M145): A-1-b (0)

Compaction Characteristics of Soil

ASTM D698 Method A

Maximum Dry Density, pcf	Optimum Moisture, %
129.1	9.5

Tested By: Mason Millsap 4/1/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014058**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-01 (0.0'-5.0')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	100	98	96	96	94	92	89	83	81	74	60	51	42	27	18.5

Tested By: Charles Patti 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
N/A	N/A	NP

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SM : Silty Sand

AASHTO Classification (AASHTO M145): A-2-4 (0)

pH & Resistivity

ARIZ 236c-PHR

pH	Min Resisitivity ohm-cm
8.9	5023

Tested By: Mason Millsap 4/1/2026

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.

Sample Id **S-014058**

Chlorides

ARIZ 736b

Chlorides (ppm)
20

Tested By: Marco Solano 4/9/2026

Sulfates

ARIZ 733b

Sulfates (ppm)
57

Tested By: Marco Solano 4/9/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014059**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-04 (0.0'-2.5')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	100	100	100	99	98	96	95	92	91	86	79	74	66	47	36.8

Tested By: Jessica Pena-Melroy 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
23	16	7

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SC-SM : Silty clayey Sand

AASHTO Classification (AASHTO M145): A-4 (0)

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.
The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014060**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-05 (0.0'-7.5')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	86	84	80	72	67	62	58	52	51	46	38	35	31	23	19.3

Tested By: Charles Patti 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
28	17	11

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): GC : Clayey Gravel with sand

AASHTO Classification (AASHTO M145): A-2-6 (0)

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014061**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-03 (5.0'-6.0')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
RING	Ring Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

USCS Classification (ASTM D2487):

AASHTO Classification (AASHTO M145): A-1-a (2)

In-Situ Unit Weight / Moisture Content

ASTM D7263

Dry Unit Weight pcf	Percent Moisture
101.10	1.9%

Tested By: David Rowland 4/1/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014062**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-06 (0.0'-2.5')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	100	100	98	98	97	95	92	83	80	67	50	42	35	24	19.2

Tested By: Charles Patti 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
N/A	N/A	NP

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SM : Silty Sand

AASHTO Classification (AASHTO M145): A-1-b (0)

pH & Resistivity

ARIZ 236c-PHR

pH	Min Resisitivity ohm-cm
8.9	3046

Tested By: Mason Millsap 4/1/2026

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.

The test results contained herein relate only to the items inspected or tested.

Sample Id **S-014062**

Chlorides

ARIZ 736b

Chlorides (ppm)
7

Tested By: Marco Solano 4/1/2026

Sulfates

ARIZ 733b

Sulfates (ppm)
16

Tested By: Marco Solano 4/1/2026

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.
The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014063**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Nicholas J Ravenna	4/1/2026	Nicholas J Ravenna	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-07 (0.0'-7.5')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	94	94	93	86	83	77	72	57	53	41	31	28	25	21	17.6

Tested By: Jessica Pena-Melroy 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
23	16	7

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): SC-SM : Silty clayey Sand with gravel

AASHTO Classification (AASHTO M145): A-2-4 (0)

Compaction Characteristics of Soil

ASTM D698 Method A

Maximum Dry Density, pcf	Optimum Moisture, %
121.6	11.4

Tested By: Jacob King 4/1/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014064**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-01 (5.0'-6.0')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
RING	Ring Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

USCS Classification (ASTM D2487):

AASHTO Classification (AASHTO M145): A-1-a (2)

In-Situ Unit Weight / Moisture Content

ASTM D7263

Dry Unit Weight pcf	Percent Moisture
109.80	2.1%

Tested By: David Rowland 4/1/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014065**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-02 (10.0'-11.0')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
RING	Ring Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

USCS Classification (ASTM D2487):

AASHTO Classification (AASHTO M145): A-1-a (2)

In-Situ Unit Weight / Moisture Content

ASTM D7263

Dry Unit Weight pcf	Percent Moisture
113.50	1.7%

Tested By: David Rowland 4/1/2026

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The test results contained herein relate only to the items inspected or tested.

SOIL & AGGREGATE SAMPLE SUMMARY

Sample Id **S-014066**

Project No.	Project Name	Project Number(s)
22012.10	US 93 Gap A Project - Lab Testing	

Sampled By	Sample Date	Logged By	Date Logged	Released By	Release Date	Approved By†	Date Approved
Client	3/31/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/1/2026	Shekhar R. Shah	4/15/2026

Material Source	Material Type	Sampled From	Reference Line	Station	Offset
Native	0	B-08 (0.0'-2.5')			

Remarks

Sample Intended Uses

Material Code	Material Description	Project Activity	Activity Description
BULK	Bulk Sample	01	Soils

Specifications

Material Code	Spec Section	Test Property	Lower Limit	Upper Limit

SPECIFICATION STATUS

Sample In Compliance With Referenced Specifications

TEST RESULTS

Sieve Analysis of Soils and Aggregates

ASTM C136

Percent Passing Sieve Size																	
3" (75)	2 ½" (63)	2" (50)	1 ½" (38)	1" (25)	¾" (19.0)	½" (12.5)	⅜" (9.5)	¼" (6.3)	#4 (4.75)	#8 (2.36)	#10 (2.00)	#16 (1.180)	#30 (0.600)	#40 (0.425)	#50 (0.300)	#100 (0.150)	#200 (0.075)
100	100	100	97	90	82	75	71	64	61	55	53	46	38	35	33	29	25.4

Tested By: Charles Patti 4/1/2026

Atterberg Limits

ASTM D4318

Liquid Limit	Plastic Limit	Plasticity Index
33	18	15

Tested By: Benjamin Cardenas 4/1/2026

USCS Classification (ASTM D2487): GC : Clayey Gravel with sand

AASHTO Classification (AASHTO M145): A-2-6 (1)

† Denotes name of P.E. or his designee who accepts responsibility for the contents of this report, technical or otherwise.

The test results contained herein relate only to the items inspected or tested.

AASHTO T190 R-VALUE AND EXP. PRESSURE OF COMPACTED SOILS

Report Number: 65191270.0105
Service Date: 04/06/26
Report Date: 04/15/26
Task:

Terracon
4685 S Ash Ave, Ste H-4
Tempe, AZ 85282-6767
480-897-8200

Client

Quality Testing LLC
Attn: Jaye Richardson
175 S. Hamilton Place, Bldg 6, Ste 114
Gilbert, AZ 85233

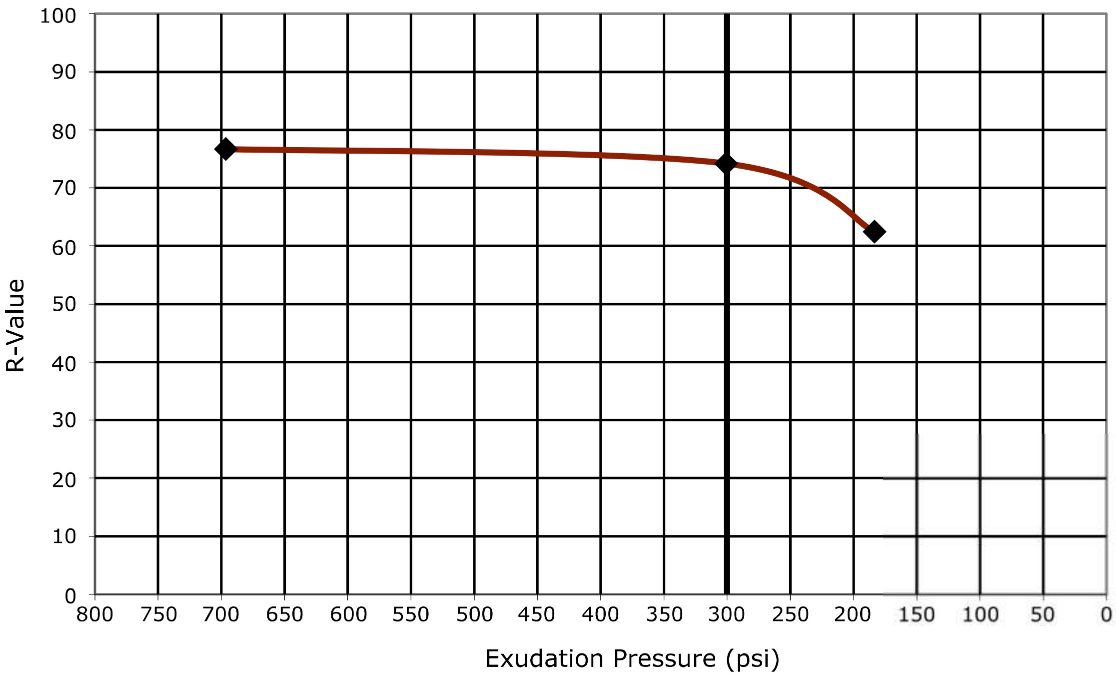
Project

QT Materials Testing
4685 S. Ash Ave, Ste H-4
Tempe, AZ 85282

Project No. 65191270

Material Description:	Silty Sand	**Sample Source:**	QT Project #22012.01, Sample ID: S-14058
Sample Location:	B-1 @ 0'-5'		

Specimen ID:	A	B	C
Moisture Content (%):	11.3%	10.4%	10.0%
Compaction Pressure (psi):	350	350	350
Specimen Height (in):	2.52	2.53	2.5
Dry Density (pcf):	126.6	127.6	129.3
Horizontal Pressure @ 1000 lbs (psi):	18	14	12
Horizontal Pressure @ 2000 lbs (psi):	34	22	20
Displacement (turns):	5.57	5.46	5.32
Expansion Pressure (psi):	0	4.33	12.99
Exudation Pressure (psi):	183	301	696
R-Value:	62.5	74.2	76.7



R-Value at 300 psi: 74

Remarks:

Services:
Terracon Rep:
Reported To:
Contractor:

Report Distribution

(1) Quality Testing LLC, Marco Solano
(1) Quality Testing LLC, Jaye Richardson
(1) Quality Testing LLC, Shekhar Shah, P.E.

Iram Bencomo
Assistant Project Manager

AASHTO T190 R-VALUE AND EXP. PRESSURE OF COMPACTED SOILS

Report Number: 65191270.0106
Service Date: 04/06/26
Report Date: 04/15/26
Task:

Terracon
4685 S Ash Ave, Ste H-4
Tempe, AZ 85282-6767
480-897-8200

Client

Quality Testing LLC
Attn: Jaye Richardson
175 S. Hamilton Place, Bldg 6, Ste 114
Gilbert, AZ 85233

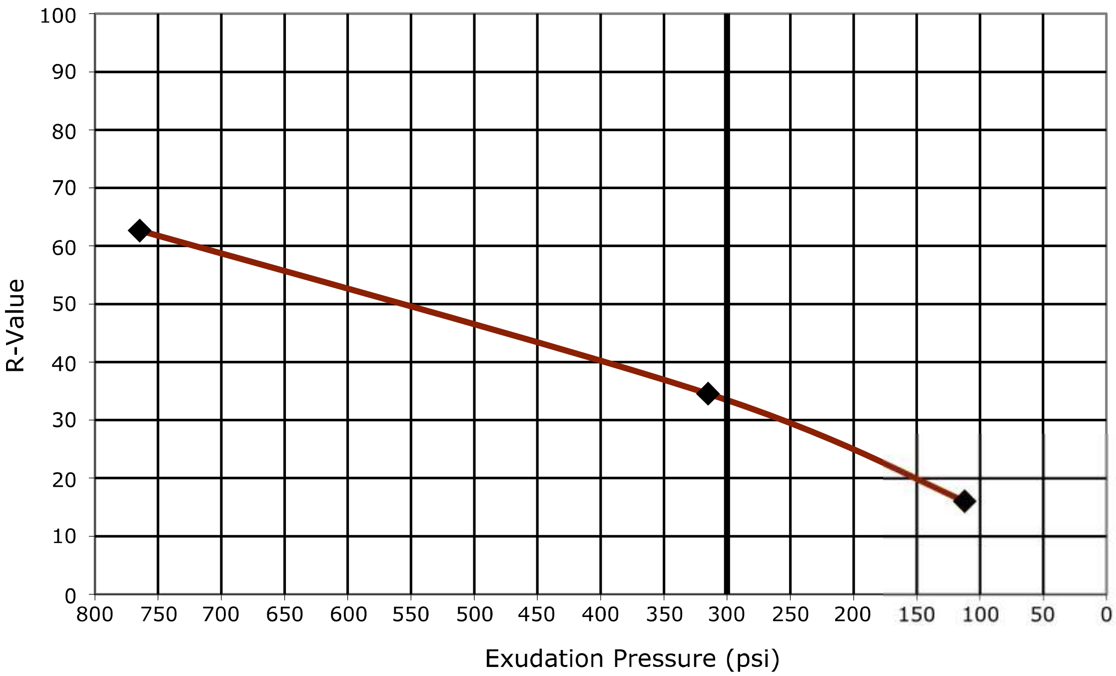
Project

QT Materials Testing
4685 S. Ash Ave, Ste H-4
Tempe, AZ 85282

Project No. 65191270

Material Description:	Sandy Clay with Gravel	**Sample Source:**	QT Project #22012.01, Sample ID: S-14060
Sample Location:	B-5 @ 0'- 7.5'		

Specimen ID:	A	B	C
Moisture Content (%):	11.1%	9.8%	8.5%
Compaction Pressure (psi):	75	125	275
Specimen Height (in):	2.47	2.49	2.4
Dry Density (pcf):	131.7	134.1	138.1
Horizontal Pressure @ 1000 lbs (psi):	55	36	21
Horizontal Pressure @ 2000 lbs (psi):	119	85	41
Displacement (turns):	4.5	4.18	3.92
Expansion Pressure (psi):	0	0	0
Exudation Pressure (psi):	112	315	765
R-Value:	16.1	34.5	62.6



R-Value at 300 psi:
33

Remarks:

Services:
Terracon Rep:
Reported To:
Contractor:

Report Distribution

(1) Quality Testing LLC, Marco Solano
(1) Quality Testing LLC, Jaye Richardson
(1) Quality Testing LLC, Shekhar Shah, P.E.

Iram Bencomo
Assistant Project Manager

AASHTO T190 R-VALUE AND EXP. PRESSURE OF COMPACTED SOILS

Report Number: 65191270.0107
Service Date: 04/06/26
Report Date: 04/15/26
Task:

Terracon
4685 S Ash Ave, Ste H-4
Tempe, AZ 85282-6767
480-897-8200

Client

Quality Testing LLC
Attn: Jaye Richardson
175 S. Hamilton Place, Bldg 6, Ste 114
Gilbert, AZ 85233

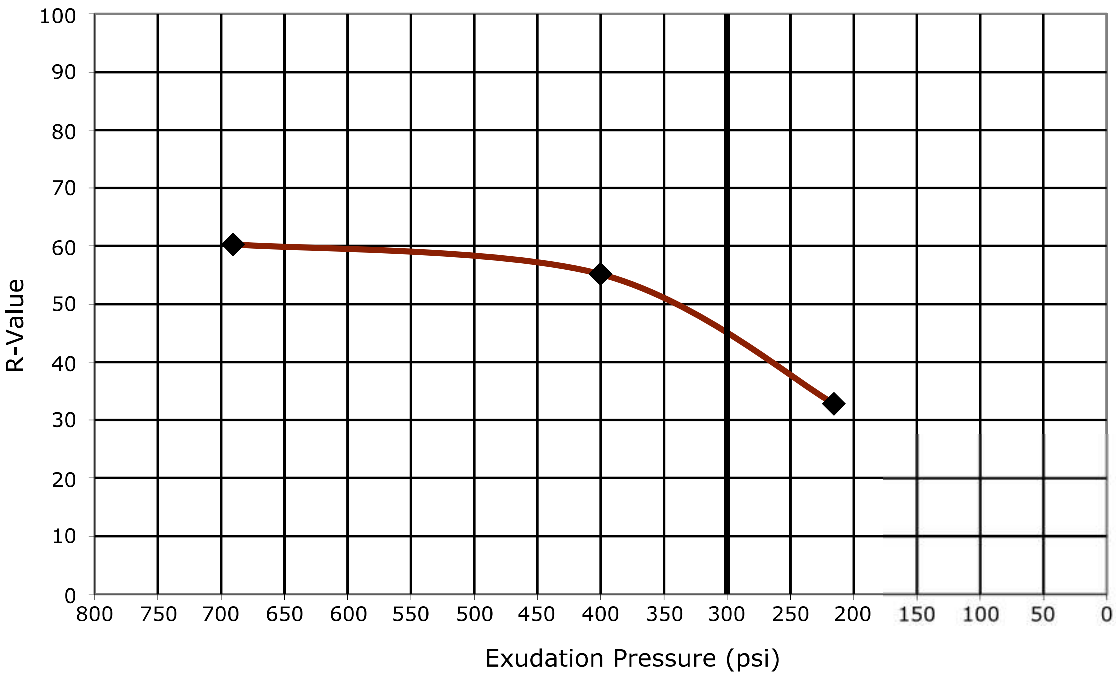
Project

QT Materials Testing
4685 S. Ash Ave, Ste H-4
Tempe, AZ 85282

Project No. 65191270

Material Description:	Clayey Sand	**Sample Source:**	QT Project #22012.10, Sample ID: S-14063
Sample Location:	B-7 @ 0'- 7.5'		

Specimen ID:	A	B	C
Moisture Content (%):	12.7%	11.8%	11.0%
Compaction Pressure (psi):	125	175	200
Specimen Height (in):	2.53	2.53	2.53
Dry Density (pcf):	127.2	127.8	128.8
Horizontal Pressure @ 1000 lbs (psi):	35	23	20
Horizontal Pressure @ 2000 lbs (psi):	82	48	42
Displacement (turns):	4.87	4.74	4.63
Expansion Pressure (psi):	0	0	0
Exudation Pressure (psi):	216	400	691
R-Value:	32.8	55.2	60.3



R-Value at 300 psi: 45

Remarks:

Services:
Terracon Rep:
Reported To:
Contractor:

Report Distribution

(1) Quality Testing LLC, Marco Solano
(1) Quality Testing LLC, Jaye Richardson
(1) Quality Testing LLC, Shekhar Shah, P.E.

Iram Bencomo
Assistant Project Manager

APPENDIX C

Geotechnical Report

US 93, Vista Royale by ADOT

REVISED FINAL GEOTECHNICAL REPORT
Vista Royale
US 93, MP 190 - 193

May 4, 2026

Prepared by
Geotechnical Services
Bridge Group
Arizona Department of Transportation

Registered Professional Engineer (Civil)
CERTIFICATE NO.
45786
TAD C. NIEMYJSKI
Date Signed 05/04/26
ARIZONA U.S.A.

ADOT Project No. 093 YV 190 F0738 01D
Federal Aid No. 093-B(230)T

ARIZONA DEPARTMENT OF
TRANSPORTATION

ARIZONA
— DEPARTMENT OF —
TRANSPORTATION

205 S. 17th Avenue
Phoenix, AZ 85007

KATIE HOBBS
GOVERNOR

JENNIFER TOTH
DIRECTOR

May 4, 2026

Subject:
Revised Final Geotechnical Report
US 93 Vista Royale
ADOT Project No. 093 YV 190 F0738 01D

This revised report updated the Recommended R-values presented in Table 2: Recommended R-Values in the original Final Geotechnical Report dated December 17, 2025.

This report presents the results of geotechnical engineering evaluation services performed to support the Vista Royale widening project on United States Route 93 (US 93) in Yavapai County, Arizona. The project is located approximately 6 miles northwest of Wickenburg within ADOT's Northwest District from milepost (MP) 189.9 to its southern limit at Milepost (MP) 193.03, approximately 0.5-mile northwest of the US 93/SR 89 junction.

The purpose of this project is to widen US 93 to a four-lane divided highway, construct a new bridge for southbound traffic and modifications to the existing bridge over the BNSF railroad overpass.

A geotechnical field investigation included conducting a geotechnical investigation along the new roadway alignment and at the location of the new bridge structure for the purpose of evaluating the surficial and subsurface soil conditions at the site to develop bridge foundation capacities and provide geotechnical pavement parameters for roadway construction.

The results of the field investigation as well as design recommendations for the proposed construction are presented in this report.

Should there be any questions regarding the contents of this report or its appropriate incorporation into designs, please do not hesitate to contact us.

Sincerely,

Registered Professional Engineer (Civil)
CERTIFICATE NO.
45786
TAD C. NIEMYJSKI
Date Signed 05/04/26
ARIZONA U.S.A.

Tad C. Niemyjski, P.E.
Geotechnical Design Team Lead

Reviewed by:

Patrice P. Brun, P.E.
Geotechnical Services Manager

TABLE OF CONTENTS

Figures

Tables

Appendices

1.0 INTRODUCTION

This report presents the results of geotechnical engineering evaluation services performed to support the Vista Royale widening project on United States Route 93 (US 93) in Yavapai County, Arizona. The project is located approximately 6 miles northwest of Wickenburg within ADOT's Northwest District from milepost (MP) 189.9 to its southern limit at Milepost (MP) 193.03, approximately 0.5-mile northwest of the US 93/SR 89 junction.

Geotechnical services were divided between ADOT Geotechnical Operations and an outside consultant, Ethos Engineering LLC (Ethos). ADOT performed test pits and associated laboratory testing (including R-value testing) to support the roadway widening improvements. Ethos performed borings, laboratory testing, and prepared foundation recommendations for the new southbound BNSF Railroad Overpass (drilled shafts and abutment mechanically stabilized earth (MSE) walls) and the four box culverts.

This ADOT report focuses solely on the roadway portion of the geotechnical investigation. It provides over-excavation requirements for cuts and fills and soil parameters (such as R-values and other relevant index properties) for use by pavement designers. Included are the Test Pits Location Plan (Appendix 1), Test Pit Logs (Appendix 2), and associated laboratory testing results (Appendix 3).

Recommendations for the BNSF Railroad southbound overpass (OP) drilled shafts and MSE walls, as well as the four box culverts, are provided in the Ethos Geotechnical Investigation Report – Foundations included as Appendix 4 of this report.

1.1 Project Description

The 3-mile Vista Royale project widens US 93 from two lanes to a four-lane divided highway with two 12-ft lanes each direction separated by a variable median. The new southbound roadway will be built west of the existing alignment, which will remain and serve northbound traffic.

The existing 1964 BNSF Matthie Railroad Overpass (ADOT Str. No. 00780) will remain but be modified for the new traffic pattern and to correct deficiencies. The three-span bridge (41.5-52.5-41.5 ft) on pile-supported abutments and spread-footing piers retains its geometry except for barrier-transition replacement to accommodate new guardrail.

The new parallel southbound bridge will have a 42-ft clear width (two 12-ft lanes, 12-ft outside shoulder, 6-ft inside shoulder), 38-inch single-slope concrete barriers, two-column piers with circular columns and rectangular caps and drilled-shaft foundations. (Source: ADOT Bridge Group, Draft Bridge Type Selection Report, May 5, 2025)

Figure 1: Location of Vista Royale project site

1.2 Site Description

The project area consists of flat to rolling hill terrain with elevations ranging from about 2,450 and 2,600 feet above mean sea level (MSL). This environment is considered high desert plain where the vegetation consists of native grass and sparse shrub land.

Figure 2: Aerial view of Vista Royale project on SR 93 approximated by MP 190-193

The existing bridge structure has three spans of 41.5 feet, 52.5 feet, and 41.5 feet. The existing three-span bridge is supported on driven piles at the elevated abutments and spread footings at the bridge piers

Figure 3: View of the existing Rail Crossing Bridge looking to the north

1.3 Site Geology

The Vista Royale site consists of Quaternary (Q) 0-2 Ma aged alluvial and eolian deposits and Pliocene to Middle Miocene (Tsy) 2-16 Ma aged conglomerate and sandstone. The Q unit consists of unconsolidated to strongly consolidated alluvial and eolian deposits which are coarse, poorly sorted alluvial fan and terrace deposits on middle and upper piedmonts and along large drainages; sand, silt and clay on alluvial plains and playas; and wind-blown sand deposits. While the Tsy unit consists of moderately to strongly consolidated conglomerate and sandstone deposited in basins during and after late Tertiary faulting. Includes lesser amounts of mudstone, siltstone, limestone, and gypsum. These deposits are generally light gray or tan. They commonly form high rounded hills and ridges in modern basins and locally form prominent bluffs. Deposits of this unit are widely exposed in the dissected basins of southeastern and central Arizona.

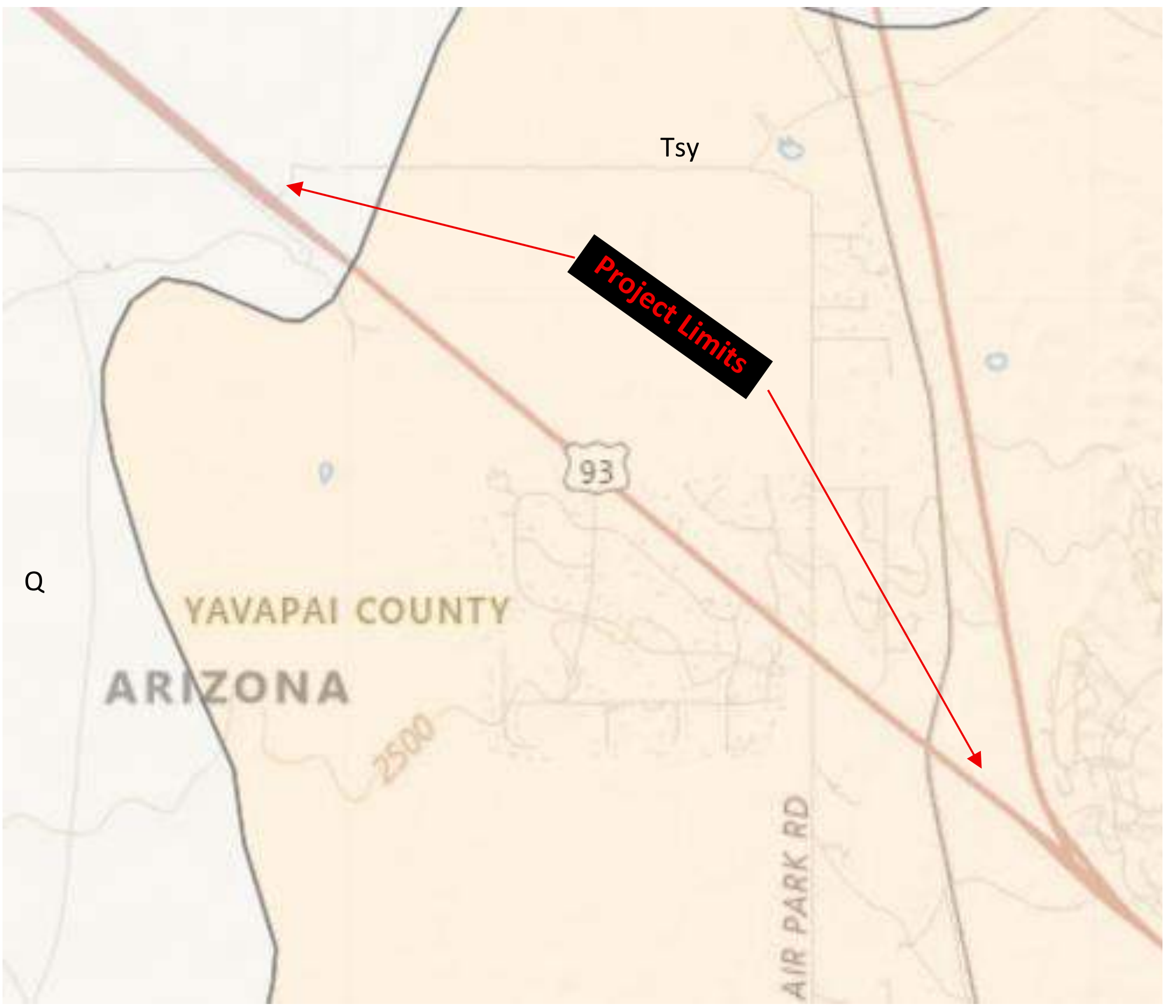


Figure 4: Geology of the Vista Royale project area (Arizona Geological Survey (AGS), 2000)

2.0 SUBSURFACE INVESTIGATION

ADOT's Geotechnical Operations conducted the subsurface investigation for the roadway alignment and Ethos conducted the subsurface investigation for the bridge and retaining wall foundations. Laboratory tests were performed by ADOT along the roadway alignment and Ethos provided the laboratory testing for their exploratory borings.

2.1 Test Pits

ADOT Geotechnical Operations performed the subsurface investigation for the proposed roadway by excavating 18 backhoe test pits along the southbound side of the existing US 93 roadway. Test pit locations are shown on the Test Pits Location Plan (Appendix 1), and detailed test pit logs are provided in Appendix 2.

Boring logs for the new southbound BNSF Railroad OP and the four box culverts are contained in Appendix A of the Ethos Geotechnical Investigation Report – Foundations (Appendix 4 of this report).

2.2 Laboratory Testing

Soil samples recovered from the 18 roadway test pits were tested by the ADOT Materials Group Central Laboratory. Selected samples were tested in general accordance with the procedures listed in the table below.

Soil samples from the bridge and culvert borings were tested by Ethos Engineering; laboratory test results are presented in their Geotechnical Investigation Report – Foundations (Appendix 4 of this report).

Table 1: Test Methods for Soil and Rock Samples

Geotechnical Test	Test Procedure
Sieve Analysis (Grain Size)	ASTM C136 & C117
Atterberg Limits (Plasticity)	ASTM D4318
R-Value (Subgrade Support)	AASHTO 89 and T 90
Moisture Content of Soils	ASTM D2216
In-Place Dry Density	ASTM D2937
Moisture-Density (Standard Proctor)	ASTM D698, Method A

3.0 SUBSURFACE CONDITIONS

The following section outlines the conditions encountered by ADOT Geotechnical Operations in the 18 test pits. Detailed test pit logs of the roadway subsurface can be found in Appendix 2 of this report.

For subsurface conditions encountered at the BNSF OP and the culverts, detailed boring logs of the subsurface soils of the bridge and culvert locations can be found in the Ethos report in Appendix 4 of this report.

3.1 Surficial Soils

The near surface soils along the proposed roadway widening were primarily medium dense clayey sands with a few locations containing silty sands and clays. Heavily cemented soils were refused on with the backhoe at test pits P-SB-14 (sta 310+90 40'L) and P-SB-15 (sta 318+90 50'L).

The near surface soils on the north side of Santa Maria River were found to consist primarily of very dense silty to clayey sands with some isolated areas of clay with low to high plasticity. The plasticity indices (PI) of these soils ranged from non-plastic (NP) to 31. At depth, some test pit locations encountered a strongly cemented soil (caliche) horizon strong enough to cause refusal with our backhoe bucket.

For surficial soils encountered at the BNSF OP and the culverts, see the Ethos report in Appendix 4 of this report.

3.2 Rock Conditions

Bedrock was not encountered in any of the 18 test pits within the explored depths of 3 to 11 feet below ground surface (bgs). Heavily cemented soil (caliche) that refused further excavation by the backhoe was encountered at 5 feet bgs in Test Pit P-SB-14 (Sta. 310+90, 40 ft LT) and at 3 feet bgs in Test Pit P-SB-15 (Sta. 318+90, 50 ft LT).

Rock conditions at the new southbound BNSF Railroad OP and the four box culverts are described in the Ethos Geotechnical Investigation Report – Foundations (Appendix 4 of this report).

3.3 Groundwater Conditions

Groundwater was not encountered in any of the 18 test pits (maximum explored depth ≈11 ft bgs) or in the structure borings performed by Ethos. Soil moisture in the test pits was generally described as slightly moist to moist.

The absence of groundwater within the explored depths, combined with ADWR historic well data showing groundwater at approximately 200–300 ft bgs (elev. 2,100–2,200 ft) in the vicinity, indicates that significant groundwater inflow is unlikely during typical roadway excavation and construction. ADWR (2025).

Contractors should remain alert for localized perched water or seepage after heavy precipitation. If encountered, appropriate dewatering measures should be implemented.

Groundwater conditions at the new southbound BNSF Railroad OP and the four box culverts are addressed in the Ethos Geotechnical Investigation Report – Foundations (Appendix 4 of this report).

4.0 GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

It is anticipated that the native soils would be appropriate for the support of MSE retaining walls, spread footing and drilled shaft foundations. The following subsections provide geotechnical design parameters for the design of shallow and deep foundations.

4.1 Drilled Shafts, MSE Walls, Spread Footings, and Culverts

For geotechnical analysis and recommendations related to drilled shafts and MSE walls related to the new southbound BNSF Railroad OP and the four box culverts, see the Ethos Geotechnical Investigation Report – Foundations (Appendix 4 of this report).

4.2 Cut Slopes

No significant cut slopes are required within the project limits. Where minor cuts are necessary, construct them at a maximum steepness of 3H:1V.

4.3 Embankment Fill Slopes

It is anticipated that the planned embankment fills will be constructed using locally available materials derived from the project excavations and/or borrow sources. In general, permanent slopes in roadway fill and embankment slopes for the project should be no steeper than 3H:1V.

New roadway embankment with fill heights up to approximately 25 feet will be constructed throughout the project segment. The near surface native soils outside of the existing roadway prism are relatively soft or loose and not considered suitable for direct support of embankments without treatment.

Consolidation of the loose near surface native soils is expected to occur in response to embankment construction, however much of the settlement expected to occur during the construction of embankment fills. Based on the results of the field investigation and laboratory testing, over-excavation and recompaction of the near surface native soils should be performed in some areas in accordance with recommendations provided in Section 5.2 of this report.

5.0 ROADWAY RECOMMENDATIONS

It is anticipated that the native soils would be appropriate for the support of the roadway pavement structure and the construction of cut and fill slopes. The following subsections provides geotechnical design parameters for the development of this project.

5.1 Pavement Design Information

The recommended R-values are presented in the table below.

Table 2: Recommended R-Values

Recommended R-Values		
Station	**R-mean**	**R-control**
Entire project	30	20

R-value testing at five of the 18 test pit locations (P-SB-05, P-SB-06, P-SB-07, P-SB-08, and P-SB-18) yielded results below the minimum design/construction control R-values of 25 and 20 typically required by ADOT. These areas will require over-excavation and replacement of unsuitable material within approximately 3 feet of finished subgrade elevation during construction. Table 3 outlines the estimated over-excavation limits beneath the proposed southbound lanes, east frontage road, and pavement areas. Unsuitable material excavated from within these limits must be wasted or placed outside of pavement areas and more than 3 feet below finished subgrade elevation.

Table 3: Mainline Over-Excavation Limits Beneath Pavement

US 93 Mainline Limits	Pavement Element	Depth
STA 242+74 to STA 25875 and STA 336+45 to 341+10	US 93 Southbound Lanes & East Frontage Road	Existing materials within 3 feet of finished subgrade beneath pavement areas

Notes:
1. Over-excavation applies to existing materials within 3 feet of finished subgrade elevation and should extend laterally 2 feet beyond the edge of pavement.
2. The areas in this table represent areas of over-excavation due to low R-values only.
3. Additional over-excavation areas due to other geotechnical considerations (e.g., embankment areas) are not included in this table.

R-mean should be used to design pavement structure. R-control values should be used to develop the Subgrade Acceptance Chart. Material that is excavated within the project limits and is used as a fill material within three feet below the finished subgrade elevation shall meet the Subgrade Acceptance Chart. Recommendations for pavement design are presented in separate Materials Design Report (MDR) and Pavement Design Summary (PDS) prepared by ADOT Roadway Group - Pavement Design Section.

5.2 Embankment Fill Over-excavation

The near surface native soils beneath new embankment construction were found to be prone to settlement. Post construction settlement would be minimized by over-excavating a depth of native soils and recompacting prior to the placement of new roadway embankment fills. Table 4 provides recommendations for the depth of over-excavation and recompaction of the native soils that would limit the amount of post construction settlement.

Table 4: Minimum Recommended Over-Excavation Depths

Embankment Height (feet)	Over-excavation Below Existing Grade (feet)
+5 to 10	1.0
+10 to 20	1.5
+20	2.0

Soil placed within three feet of the finished subgrade elevation in pavement areas should meet the construction control R-value discussed in Section 5.1 of this report.

Construction of the embankment shall follow the requirements of ADOT Standard Specifications for Road and Bridge Construction (2021) Section 203-10.03. (ADOT 2021)

5.3 Earthwork Factors

Earthwork factors are dependent on the existing soil conditions, contractor methods of handling the materials, wind losses and compaction achieved during construction. Potential bidders should consider these factors in preparing the estimates and are encouraged to review all available data and make their own conclusions regarding excavation conditions. For the purpose of estimating earthwork volume, estimation, the recommended Earthwork Factors for this project are provided in the following table.

Table 5: Earthwork Factors

Earthwork Factors		
Station	**Ground Compaction**	**Excavation Factor**
Entire project	0.10 feet	10% shrink

5.4 Slopes

Except for the cut and embankment fill slopes analyzed in Sections 4.2 and 4.3 of this report, the slopes within the affected reconstruction area should be constructed in conformance to ADOT standard construction drawings C-02.21 (Slopes, Rural Divided Highways). The slope within the affected reconstruction area should be constructed in accordance with the standard specifications.

Temporary un-shored or un-braced cut slopes in the existing roadway embankment fills and within the native site soils can be considered Type B soils.

All excavations must comply with applicable local, state, and federal safety regulations including the current OSHA Excavation and Trench Safety Standards. Construction site safety generally is the sole responsibility of the contractor, who shall also be solely responsible for the means, methods and sequencing of construction operations.

5.5 Water Requirements

Approximately 85 gallons of water per cubic yard may be estimated for compaction of base and subgrade materials. This estimate is based on the tested optimum compaction moisture content on similar projects and includes a conservative overrun for losses due to seepage, evaporation, inadequate mixing, spillage, etc. Precipitation before and/or during construction may also reduce the required amount of water significantly.

5.6 Excavation

The majority of existing surface and subsurface soils consist of native sands and sandy clays with variable gravel and cobble content. These materials are generally excavatable using conventional earthmoving equipment.

Heavily cemented (caliche) layers that refused further backhoe excavation were encountered at 5 ft bgs in Test Pit P-SB-14 (Sta. 310+90, 40 ft LT) and at 3 ft bgs in Test Pit P-SB-15 (Sta. 318+90, 50 ft LT).

The Contractor is responsible for reviewing all provided geotechnical data and performing an independent assessment to determine the equipment and methods required to complete the work in accordance with the plans and specifications.

5.7 Borrow Information

There is no Department-furnished source for borrow on this project. Borrow shall be as specified in Section 203-9 of the Standard Specifications. Borrow placed within three feet of finished subgrade shall meet the following requirements. The Plasticity Index (PI) and the percent passing the #200 sieve (Minus 200), when used in the equation below, shall give a value of X that does not exceed 87.

X= (Minus 200) + [2.83 (PI)]

5.8 Pipe Extensions and Corrosion Potential

The existing site concrete box culverts (CBC) and corrugated metal pipes (CMP) were reported to be in satisfactory condition with no or minimal evidence of corrosion.

Laboratory test results indicate the on-site soils at the culvert locations have pH in the range of 8.5 to 8.9, minimum resistivity values in the range of 2,740 to 7,580 ohm-centimeters, chlorides in the range of 3 to 30 ppm and sulfates in the range of 10 to 39 ppm. These values should be used for the selection of various pipe installations for this project. For all results related to pH, resistivity, chlorides and sulfates, refer to Table B-1 Summary of Laboratory Test Results in Appendix B of the Geotechnical Investigation Report provided by Ethos Engineering, LLC (Appendix 4).

6.0 TEST BORING (SUBGRADE) LOG LIMITATIONS

General soil strata descriptions and indicated boundaries are based on engineering interpretation of available subsurface information by the geotechnical engineer and may not reflect actual variation in subsurface conditions between test pit/test boring and sample locations. The locations of the contacts between strata shown on the logs are approximate, and changes between material types may be gradual rather than abrupt. Classification of soil materials is in general accordance with ASTM D2488 and is based on field observation unless accompanied by mechanical analysis.

The observed groundwater levels and/or moisture conditions indicated on the logs are as recorded at the time of exploration. These groundwater levels and/or moisture conditions may vary considerably, with time, according to the prevailing climate, rainfall or other factors and are otherwise dependent upon the duration of and methods used in the exploration program.

Sound engineering judgment was exercised in preparing the subsurface information presented on the subgrade logs. This information was prepared for and is intended for design and preliminary quantity estimate purposes. Its presentation on the plans or elsewhere is for the purpose of providing intended users with access to the same information as the State and its designers. This subsurface information and interpretation is presented in good faith and is not intended as a substitute for independent investigation, interpretation or judgment of the contractor or other users of this report.

7.0 REFERENCES

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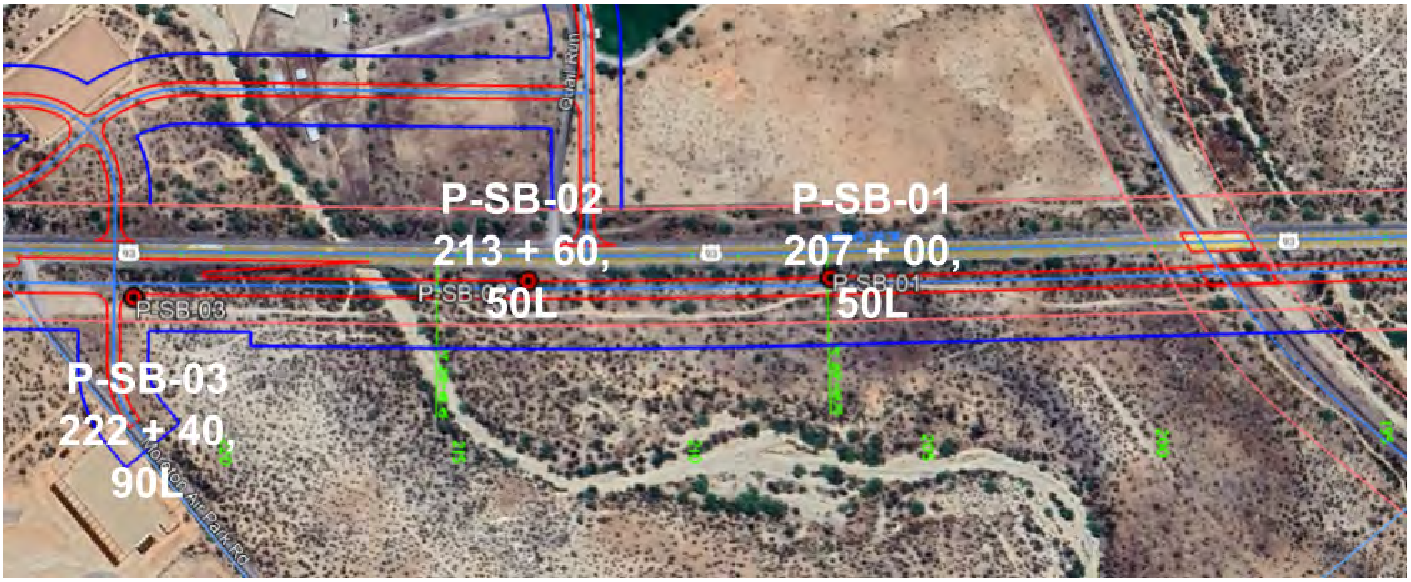
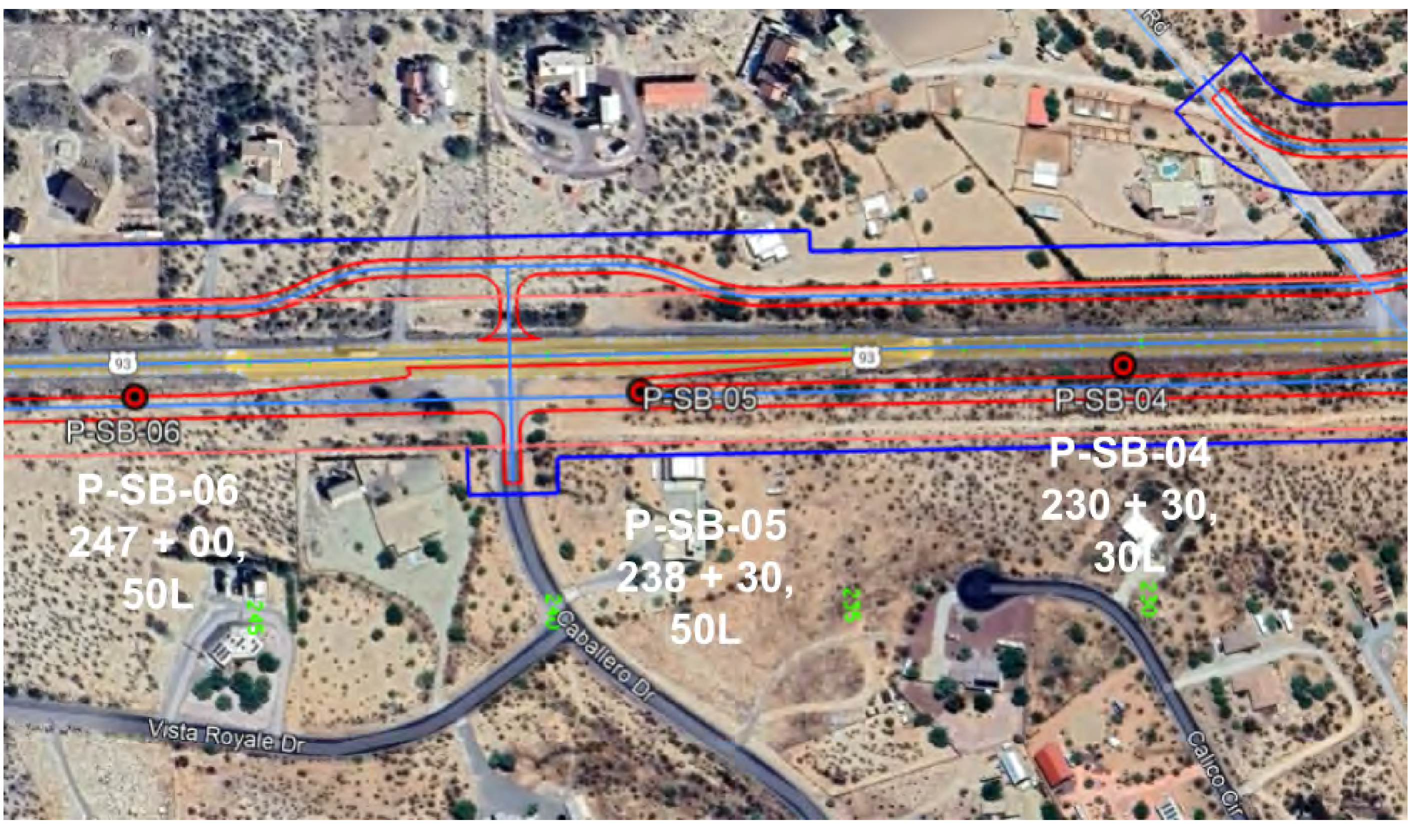
APPENDIX 1

Test Pit Location Plan

093 190 F0738 01D, Vista Royale
Test Pit Geotechnical Investigation Site Plan





Test Pit Location

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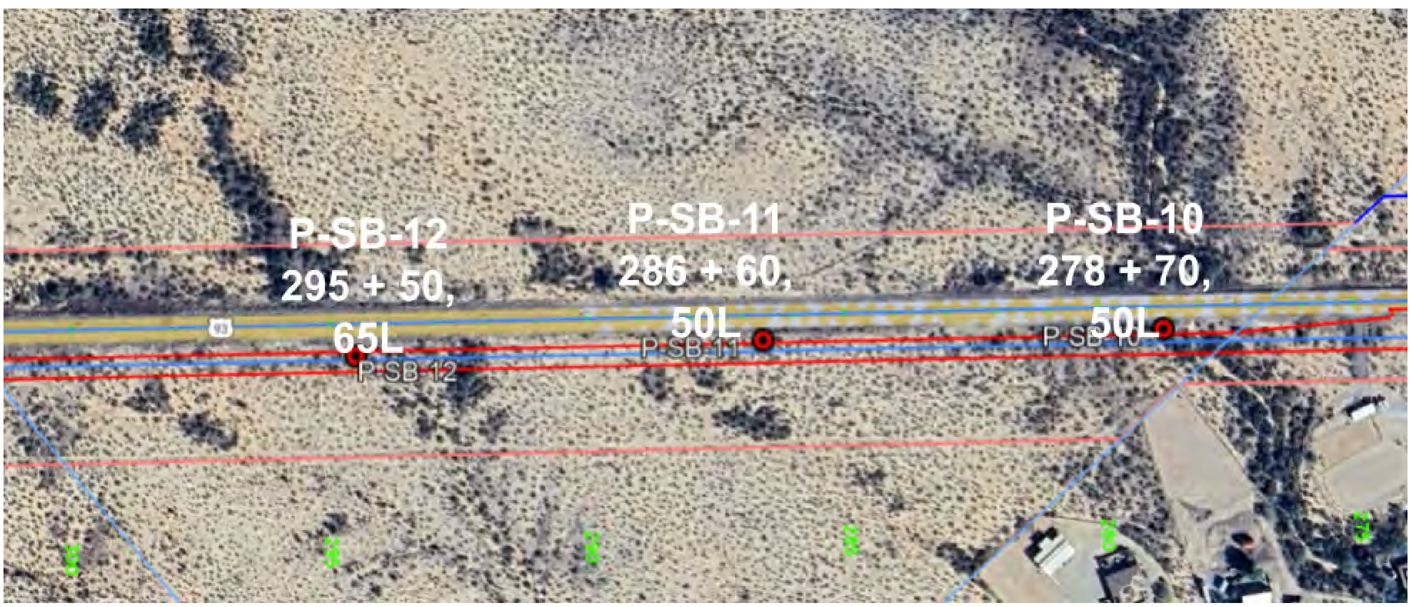
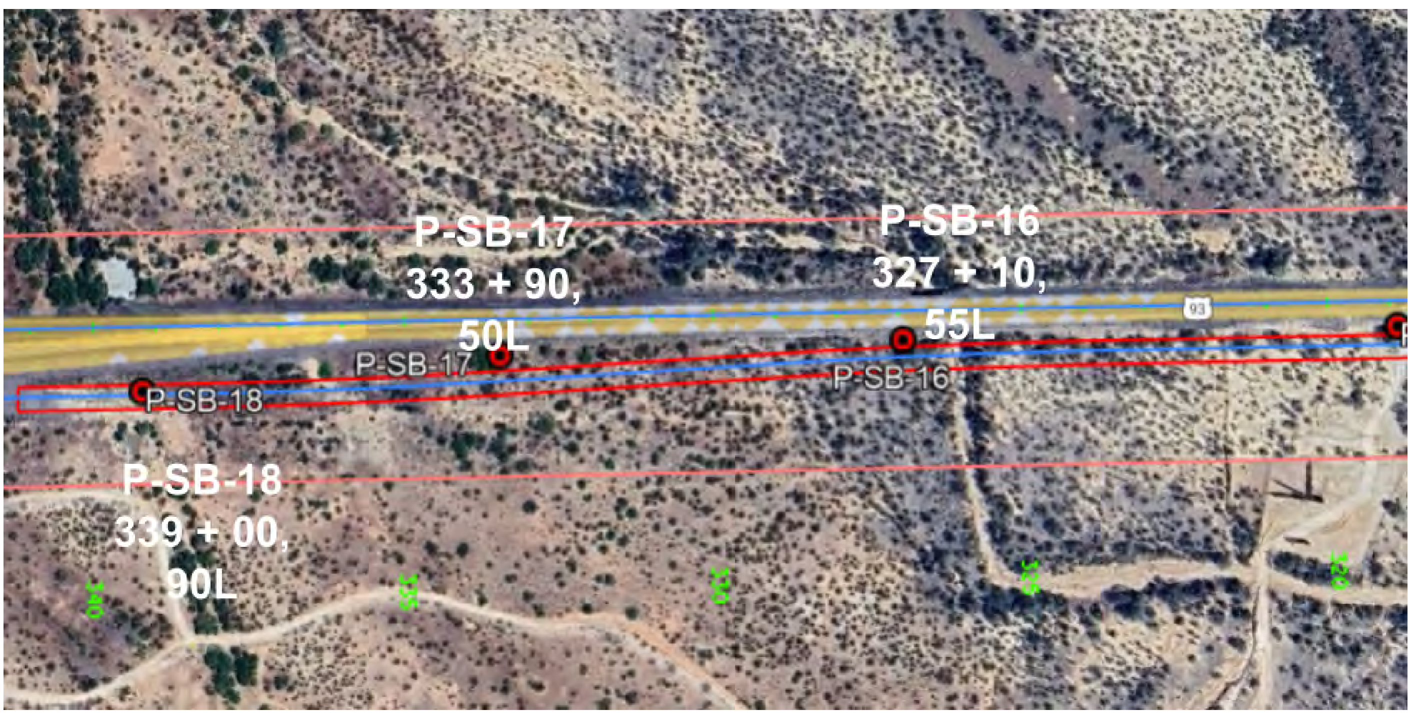
093 190 F0738 01D, Vista Royale
Test Pit Geotechnical Investigation Site Plan



Test Pit Location

N

093 190 F0738 01D, Vista Royale
Test Pit Geotechnical Investigation Site Plan



Test Pit Location

APPENDIX 2

Test Pit Logs

Project Name	Vista Royale	Test Pit
Project No.	093 190 F0738 01D	
Location	SR 93 MP 192.7	**P-SB-1**
Station, Offset	207+00 50 L	
Lat/Long, elev	34.03211, -112.81964, at 2484'	
Field Engineer	T. Niemyjski	Date: 04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe: CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	% Gravel	% Sand	% Fines	Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4)	2480 (at 4)		Bulk	**CLAYEY SAND** (**SC**): light brown, medium plasticity, weak cementation, slightly damp.	12	71	17	25-16-9
5				5				

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale
Project No.	093 190 F0738 01D
Location	SR 93 MP 192.6
Station, Offset	213+60 50 L
Lat/Long, elev	34.03323, -112.82132, at 2490'
Field Engineer	T. Niemyjski
Field Operator	ADOT Geotechnical Operations

Test Pit

P-SB-2

Date	04/30/2025
Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4, 5)	2485		Bulk	**WELL-GRADED SAND WITH CLAY** (**SW-SC**): light brown, medium plasticity, weak cementation, slightly damp. 5	17	71	12	29-14-15

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit
Project No.	093 190 F0738 01D	
Location	SR 93 MP 192.4	P-SB-3
Station, Offset	222+40 90 L	
Lat/Long, elev	34.03463, -112.82356, at 2493'	
Field Engineer	T Niemyjski	Date: 05/01/1925
Field Operator	ADOT Geotechnical Operations	Backhoe: CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–5	2490 (at 3 ft)		Bulk	**CLAYEY SAND** (**SC**): brown, medium plasticity, weak cementation, slightly damp. 5	3	71	26	26-17-9

Stopped test pit excavation at 5 feet and encountered cobbles.No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D		
Location	SR 93 MP 192.25	**P-SB-4**	
Station, Offset	230+30 30 L		
Lat/Long, elev	34.03623, -112.82553, at 2500'		
Field Engineer	T Niemyjski	Date	04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–3			Bulk	**CLAYEY SAND** (**SC**): tan, high plasticity, no cementation, slightly damp. 3	3	76	21	35-17-18
3–5	2495			weak cementation at 3' 5				

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit	
Project No.	093 190 F0738 01D	P-SB-5	
Location	SR 93 MP 192.1		
Station, Offset	238+50 50 L		
Lat/Long, elev	34.03761, -112.82765, at 2525'		
Field Engineer	T Niemyjski	Date	04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–5	2520 (at 5)		Bulk	**CLAYEY SAND** (**SC**): tan, high plasticity, weak cementation, slightly damp.	4	50	46	36-15-21

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D	**P-SB-6**	
Location	SR 93 MP 191.95		
Station, Offset	247+00 50 L		
Lat/Long, elev	34.03912, -112.82977, at 2533'		
Field Engineer	T Niemyjski	Date	04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–3	2530		Bulk	**FAT CLAY** (**CH**): light brown, high plasticity, no cementation, slightly damp. 3	3	46	51	50-21-29
3–5				**WELL-GRADED SAND WITH SILT** (**SW-SM**): tan, non-plastic, weak cementation, slightly damp. 5	16	75	9	NP

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

	Project Name	Vista Royale	**Test Pit**	
	Project No.	093 190 F0738 01D	**P-SB-7**	
	Location	SR 93 MP 191.8		
	Station, Offset	254+75 40 L		
	Lat/Long, elev	34.04053, -112.83172, at 2542'		
	Field Engineer	T Niemyjski	Date	05/01/2025
	Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–2 (1, 2)	2540		Bulk	**CLAYEY SAND** (**SC**): light brown, high plasticity, no cementation, slightly damp. 2	8	44	48	49-18-31
2–5 (3, 4, 5)			Bulk	**WELL-GRADED SAND WITH SILT** (**SW-SM**): tan, non-plastic, no cementation, slightly damp. 5	8	82	10	NP

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit	
Project No.	093 190 F0738 01D	**P-SB-8**	
Location	SR 93 MP 191.65		
Station, Offset	262+70 40 L		
Lat/Long, elev	34.04192, -112.83373, at 2534'		
Field Engineer	T Niemyjski	Date	04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4, 5)	2530 (at 4)		b	**LEAN CLAY** (**CL**): light brown, high plasticity, weak cementation, slightly damp. 5	6	39	55	36-18-18

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D	**P-SB-9**	
Location	SR 93 MP 191.5		
Station, Offset	270+00 50 L		
Lat/Long, elev	34.04331, -112.83578, at 2540'		
Field Engineer	T Niemyjski	Date	04/30/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	% Sand	% Fines	Atterberg Limits (LL-PL-PI)
0–1				**FILL**: sand and gravel fill				
1–5	2535		Bulk	**SILTY SAND** (**SM**): light brown to brown, high plasticity, weak cementation, slightly damp.	7	81	12	45-27-18

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D	**P-SB-10**	
Location	SR 93 MP 191.3		
Station, Offset	278+70 50 L		
Lat/Long, elev	34.04475, -112.8378, at 2548'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4, 5)	2545 (at 3)		Bulk	**CLAYEY SAND** (**SC**): light brown, medium plasticity, moderate cementation, slightly damp. 5	6	67	27	36-24-12

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit	
Project No.	093 190 F0738 01D	P-SB-11	
Location	SR 93 MP 191.2		
Station, Offset	286+60 50 L		
Lat/Long, elev	34.04613, -112.8398, at 2571'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–3	2570		Bulk	**CLAYEY SAND** (**SC**): tan, medium plasticity, weak cementation, slightly damp. 3	5	62	33	37-21-16
3–11	2565, 2560		Bulk	**SILTY SAND** (**SM**): tan, low plasticity, weak cementation, slightly damp. 11	3	81	17	39-37-2

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Stopped test pit excavation at 11 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit	
Project No.	093 190 F0738 01D	**P-SB-12**	
Location	SR 93 MP 191.05		
Station, Offset	295+50 65 L		
Lat/Long, elev	34.0475, -112.84183, at 2568'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4, 5)	2565 (at 3)		Bulk	**SILTY SAND** (**SM**): light brown, non-plastic, moderate cementation, slightly damp. 5	2	86	12	NP

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit
Project No.	093 190 F0738 01D	
Location	SR 93 MP 190.9	P-SB-13
Station, Offset	303+00 50 L	
Lat/Long, elev	34.04903, -112.84394, at 2578'	
Field Engineer	T Niemyjski	Date: 04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe: CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–3	2575		Bulk	**CLAYEY SAND** (**SC**): tan, medium plasticity, weak cementation, slightly damp. 3	8	58	34	29-17-12
3–5			Bulk	**CLAYEY SAND** (**SC**): tan, medium plasticity, moderate cementation, slightly damp. 5	5	73	22	33-22-11

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit	
Project No.	093 190 F0738 01D		
Location	SR 93 MP 190.75	**P-SB-14**	
Station, Offset	310+90 40 L		
Lat/Long, elev	34.05045, -112.84591, at 2587'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
			Bulk	**CLAYEY SAND** (**SC**): tan, high plasticity, weak cementation, slightly damp.	3	57	40	38-19-19
1								
2	2585							
3								
4								
5				5				

Backhoe refusal at 5' on heavily cemented soils. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit
Project No.	093 190 F0738 01D	
Location	SR 93 MP 190.6	P-SB-15
Station, Offset	318+90 50 L	
Lat/Long, elev	34.05184, -112.848795, at 2590'	
Field Engineer	T Niemyjski	Date: 04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe: CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab % Gravel	Lab % Sand	Lab % Fines	Lab Atterberg Limits (LL-PL-PI)
0–2			Bulk	**CLAYEY SAND** (**SC**): tan, medium plasticity, weak cementation, slightly damp. 2	5	65	30	29-18-11
2–3			Bulk	**CLAYEY SAND** (**SC**): tan, medium plasticity, moderate cementation, slightly damp. 3	4	68	28	32-18-14

Backhoe refusal at 3' on heavily cemented soils. No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D		
Location	SR 93 MP 190.4	**P-SB-16**	
Station, Offset	327+10 55 L		
Lat/Long, elev	34.05325, -112.850, at 2595'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–5	2590 (at 5 ft)		Bulk	**SILTY CLAYEY WITH SAND** (**SC-SM**): light brown, low plasticity, weak cementation, slightly damp.	4	80	16	23-16-7

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	**Test Pit**	
Project No.	093 190 F0738 01D	**P-SB-17**	
Location	SR 93 MP 190.3		
Station, Offset	333+90 50 L		
Lat/Long, elev	34.05438, -112.85168, at 2603'		
Field Engineer	T Niemyjski	Date	04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe	CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–5	2600 (at 3 ft)		Bulk	**CLAYEY SAND** (**SC**): light brown, medium plasticity, weak cementation, slightly damp. 5	2	83	15	28-14-14

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

Project Name	Vista Royale	Test Pit
Project No.	093 190 F0738 01D	P-SB-18
Location	SR 93 MP 190.2	
Station, Offset	339+00 90 L	
Lat/Long, elev	34.0553, -112.85323, at 2609'	
Field Engineer	T Niemyjski	Date: 04/29/2025
Field Operator	ADOT Geotechnical Operations	Backhoe: CAT 420

Depth (ft)	Elevation (ft)	Graphic Log	Sample Type	Visual Classification	Lab: % Gravel	Lab: % Sand	Lab: % Fines	Lab: Atterberg Limits (LL-PL-PI)
0–5 (1, 2, 3, 4)	2605 (at 4)		Bulk	**LEAN CLAY** (**CL**): brown, medium plasticity, no cementation, slightly damp. 5	1	43	56	31-12-19
5								

Stopped test pit excavation at 5 feet. No groundwater encountered in test pit.

APPENDIX 3

Laboratory Test Summary

093 190 F0738 01D, Vista Royale

LABORATORY TEST SUMMARY																										
Test Location	Station, Offset	Depth (feet)	Sample Source	MECHANICAL PROPERTIES																FIELD TESTS		PARTICLE SIZE PERCENTAGE				Test Location
				Percent Passing							PI	LL	USCS	R-Value		Corrosivity		Moisture/Density		In-situ Moisture/Density		Particle Type				
				3"	1½"	¾"	#4	#8	#40	#200				Corr.	Tested	pH	Minimum Resistivity (ohm-cm)	Max. Dry Density (pcf)	Opt. Moisture Content (%)	Dry Density (pcf)	Moisture Content (%)	Cobbles	Gravel	Sands	Fines (Clay/Silt)	
P-SB-01	207+00, 50L	0.0 - 5.0	Bulk	100	98	96	88	79	37	17.3	9	25	SC	55	60			130.9	9.9	104.9	5.6	0	12	71	17	P-SB-01
P-SB-02	213+60, 50L	0.0 - 5.0	Bulk	100	96	92	83	68	26	11.8	15	29	SW-SC	47								0	17	71	12	P-SB-02
P-SB-03	222+40, 90L	0.0 - 6.0	Bulk	100	100	99	97	94	60	25.8	9	26	SC	49								0	3	71	26	P-SB-03
P-SB-04	230+30, 30L	0.0 - 5.0	Bulk	100	100	99	97	90	38	21.5	18	35	SC	37								0	3	76	22	P-SB-04
P-SB-05	238+50, 50L	0.0 - 5.0	Bulk	100	100	98	96	87	64	46.0	21	36	SC	23						107.3	7.9	0	4	50	46	P-SB-05
P-SB-06	247+00, 50L	0.0 - 3.0	Bulk	100	100	99	97	93	67	51.2	29	50	CH	16	9			114.8	12.2			0	3	46	51	P-SB-06
P-SB-06	247+00, 50L	3.0 - 5.0	Bulk	100	98	93	84	75	40	8.7	NP		SW-SM	89								0	16	75	9	P-SB-06
P-SB-07	254+75, 40L	0.0 - 2.0	Bulk	100	99	98	92	86	60	48.5	31	49	SC	15								0	8	44	49	P-SB-07
P-SB-07	254+75, 40L	2.0 - 5.0	Bulk	100	100	98	92	83	35	10.5	NP		SW-SM	86								0	8	82	11	P-SB-07
P-SB-08	262+70, 40L	0.0 - 5.0	Bulk	100	100	99	94	91	71	55.2	18	36	CL	23								0	6	39	55	P-SB-08
P-SB-09	270+00, 50L	1.0 - 5.0	Bulk	100	100	100	93	74	32	12.4	18	45	SM	42								0	7	81	12	P-SB-09
P-SB-10	278+70, 50L	0.0 - 5.0	Bulk	100	100	99	94	81	50	27.0	12	36	SC	43	64			107.5	18.1	101.9	7.4	0	6	67	27	P-SB-10
P-SB-11	286+60, 50L	0.0 - 3.0	Bulk	100	100	96	95	84	47	33.3	16	37	SC	34								0	5	62	33	P-SB-11
P-SB-11	286+60, 50L	3.0 - 11.0	Bulk	100	99	99	97	84	48	16.5	2	39	SM	74								0	3	81	17	P-SB-11
P-SB-12	295+50, 65L	0.0 - 5.0	Bulk	100	100	99	98	63	37	12.2	NP		SM	84		7.3	1,296					0	2	86	12	P-SB-12
P-SB-13	303+00, 50L	0.0 - 3.0	Bulk	100	99	98	92	85	55	33.9	12	29	SC	39								0	8	58	34	P-SB-13
P-SB-13	303+00, 50L	3.0 - 5.0	Bulk	100	100	98	95	74	38	21.9	11	33	SC	48								0	5	73	22	P-SB-13
P-SB-14	310+90, 40L	0.0 - 5.0	Bulk	100	99	99	97	86	58	40.2	19	38	SC	27								0	3	57	40	P-SB-14
P-SB-15	318+90, 50L	0.0 - 2.0	Bulk	100	100	100	95	84	47	29.9	11	29	SC	43	31			127.0	10.3	111.0	5.3	0	5	65	30	P-SB-15
P-SB-15	318+90, 50L	2.0 - 3.0	Bulk	100	100	99	96	79	44	28.0	14	32	SC	39								0	4	68	28	P-SB-15
P-SB-16	327+10, 55L	0.0 - 5.0	Bulk	100	100	99	96	85	36	16.5	7	23	SC-SM	61								0	4	80	17	P-SB-16
P-SB-17	333+90, 50L	0.0 - 5.0	Bulk	100	100	100	98	91	30	14.8	14	28	SC	47								0	2	83	15	P-SB-17
P-SB-18	339+00, 90L	0.0 - 5.0	Bulk	100	100	100	99	95	71	56.5	10	27	CL	31	19			125.6	8.9	112.4	8.5	0	1	43	57	P-SB-18

APPENDIX 4

Geotechnical Investigation Report – Foundations, Ethos Engineering, LLC

ARIZONA
— DEPARTMENT OF —
TRANSPORTATION

GEOTECHNICAL INVESTIGATION REPORT – FOUNDATIONS

US 93, VISTA ROYALE
US 93 – SOUTHBOUND BNSF OVERPASS BRIDGE
ADOT TRACS F0738 01D
ADOT CONTRACT NO. 2024-019.02
YAVAPAI COUNTY, ARIZONA

Prepared for:

AECOM

AECOM Technical Services, Inc.
7720 North 16th Street, Suite 100
Phoenix, Arizona 85020

Prepared by:

ethos
ENGINEERING, LLC.

Ethos Engineering, LLC
9180 South Kyrene Road, Suite 104
Tempe, Arizona 85284

Ethos Project No. 2024112
November 26, 2025

Registered Professional Engineer (Civil)
CERTIFICATE NO.
47791
JESSE R
HUSTON
Date Signed 11/26/2025
ARIZONA, U.S.A.

November 26, 2025
Ethos Project No. 2024112

Dale Wiggins, PE
AECOM Technical Services, Inc.
7720 North 16th Street, Suite 100
Phoenix, Arizona 85020

SUBJECT: Geotechnical Investigation Report – Foundations
US 93, Vista Royale
US 93 – Southbound BNSF Overpass Bridge
ADOT TRACS F0738 01D
ADOT Contract No. 2024-019.02
Yavapai County, Arizona

Dear Dale:

Ethos Engineering, LLC (Ethos) is pleased to present the results of a geotechnical exploration performed for the US 93 southbound (SB) overpass (OP) bridge at the BNSF railroad crossing as part of the US 93, Vista Royale project located in Yavapai County, Arizona. Our scope of services was performed in general accordance with our proposal dated September 19, 2024. The results of our field investigation, laboratory testing, and geotechnical engineering recommendations for support of select project improvements are presented herein.

The geotechnical scope for this project was performed by both Ethos and ADOT Geotechnical Operations (ADOT Geotech). Ethos performed the geotechnical investigation with borings for the planned structures, including the SB BNSF OP (Matthie Railroad Overpass) and four (4) planned box culverts, with boring depths greater than 10 feet. ADOT Geotechnical Operations performed the geotechnical exploration with test pits for design of the roadway improvements, including R-value testing. Additionally, Ethos prepared drilled shaft axial resistance charts for the new bridge foundations. The results of Ethos' geotechnical scope is presented herein. We understand our report will be included as an appendix to the ADOT Geotech report for the project.

We appreciate the opportunity to be of service to the AECOM Technical Services, Inc. (AECOM) design team on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,
Ethos Engineering, LLC

Registered Professional Engineer (Civil)
CERTIFICATE NO.
47791
JESSE R
HUSTON
Date Signed 11/26/2025
ARIZONA, U.S.A.

Jesse Huston, P.E.
Principal/Senior Geotechnical Engineer

Reviewed By:

Kevin Porter, P.E.
Senior Geotechnical Engineer

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TABLE OF CONTENTS

FIGURES

APPENDICES

1.0 PROJECT DESCRIPTION

The Arizona Department of Transportation (ADOT) is planning to widen a 3.0-mile segment of United States (US) 93 between milepost (MP) 189.9 and MP 193.0 approximately 10 miles northwest of Wickenburg in Yavapai County, Arizona. US 93 is on the National Highway System (NHS) and is functionally classified as a Principal Arterial Rural Route. This project's improvements will consist of widening the existing two-lane undivided roadway to a four-lane divided section, with two lanes in each direction separated by a variable width median. The existing northbound BNSF OP (Matthie Railroad Overpass), owned by Burlington Northern Santa Fe (BNSF), will remain for the northbound roadway (Str. No. 00780). A new 2-lane BNSF overcrossing bridge will be constructed for the US 93 southbound lanes west of the existing bridge at MP 192.88 (SB BNSF OP). There will be numerous pipe and box culvert extensions. The project location is shown on the Vicinity Map included as Figure 1.

The proposed project includes:

- 3-mile reconstruction to a four-lane divided highway; adjust the vertical alignment to increase passing sight distances and tie into the adjacent north and south project limits.
- Re-vegetation of any ground disturbance caused by the project with a native seed mix.
- Removing and replacing guardrail and guardrail end treatments, to current Manual for Assessing Safety Hardware (MASH) standards, as needed.
- New southbound (SB) BNSF overpass (OP) bridge at MP 192.88.
- Relocation of affected utilities, as necessary.
- Extending, removing, and replacing culverts, as necessary.

The geotechnical scope for this project was performed by both Ethos and ADOT Geotechnical Operations (ADOT Geotech). Ethos performed the geotechnical investigation with borings for the planned structures, including the SB BNSF OP (Matthie Railroad Overpass) and four (4) planned box culverts, with boring depths greater than 10 feet. ADOT Geotechnical Operations performed the geotechnical exploration with test pits for design of the roadway improvements, including R-value testing. Additionally, Ethos prepared drilled shaft axial resistance charts for the new bridge foundations. The results of Ethos' geotechnical scope is presented herein. We understand our report will be included as an appendix to the ADOT Geotech report for the project.

2.0 FIELD EXPLORATION

2.1 Field Coordination and Permitting

Prior to our field exploration, Ethos prepared a Field Investigation Plan (FIP) to document the planned field exploration, and for use in environmental clearance and permitting. Ethos obtained ADOT right-of-way use permit #1235790, dated April 23, 2025, and a BNSF License for Non-Environmental Soil Boring Tests, dated April 11, 2025, for the field exploration. Ethos staked the planned boring locations in the field and coordinated utility clearance of each location with Arizona 811. Various traffic control plans were prepared for this work by Bullway Barricades LLC, as a subcontractor to Ethos, and approved by the ADOT Northwest District prior to performing the work.

2.2 Subsurface Exploration

The subsurface exploration was performed between April 29 and June 19, 2025. Four (4) borings (S-1 to S-4) were advanced at the locations of the proposed new bridge foundation substructure elements to approximate depths of 80 and 100 feet each, with a total drill footage of approximately 360 linear feet. An additional four (4) borings (D-SB-01 to D-SB-04) were advanced at the locations of proposed drainage box culvert structures to an approximate depth of 30 feet each, with a total drill footage of approximately 120 linear feet. The boring locations are shown on the Site Plans Showing Boring Locations included as Figures 2 to 5. Logs of the borings are presented in Appendix A.

Drilling was performed by Resilient Drilling Services LLC (Resilient) and ACS Services LLC (ACS) using track-mounted and truck-mounted CME-75 drill rigs. The bridge borings used the percussion hammer (Tubex) drilling method. Drainage borings utilized the hollow-stem auger drilling method. Drive sampling was performed using standard penetration test (SPT) split spoon samplers or open-end drive samplers (2.42-inch-diameter brass rings) at maximum 5-foot intervals in each boring using a calibrated automatic hydraulic-actuated 140-pound hammer, free falling 30 inches. The hammer efficiency is noted in the heading of each boring log. The SPT and ring samplers were driven 18 and 12 inches, respectively, or to refusal (i.e. 50 blows for less than a 6-inch interval). Unless noted otherwise on the boring logs, the sample penetration resistance was recorded as the number of blows per six inches of penetration and are presented on the borings logs adjacent to each sample. Additionally, representative bulk samples of the near-surface soils were obtained from the drill cuttings.

The recovered soil samples were removed from the sampler, sealed to reduce moisture loss, and stored for subsequent review and laboratory testing. Upon completion, the borings were backfilled to the surface with drill cuttings.

Encountered soils were visually inspected, labeled and classified in the field, and logged in general accordance with ASTM D2488, the Unified Soil Classification System (USCS), Arizona Department of Transportation (ADOT), and Ethos guidelines. Field direction and logging of borings were performed by Ethos personnel.

3.0 LABORATORY TESTING

Selected laboratory tests were assigned by Ethos on representative samples recovered from the borings to support our field classification and to provide information regarding engineering characteristics and properties of the subsurface materials. Table 3.1 lists the laboratory tests performed by Ethos for the project. A summary of the laboratory test results along with individual test worksheets are presented in Appendix B. The results of moisture content, in-place dry density, Atterberg Limits, and fines content (i.e., percent passing the #200 sieve) are also presented on the boring logs in Appendix A at the corresponding sample depth.

Table 3.1: Laboratory Testing Program

Item/Description	Number of Tests
Grain Size Analysis (Total - Coarse and Fine) - ASTM C136 & C117	24
Atterberg Limits (Plasticity Index) - ASTM D4318	24
Moisture Content - ASTM D2216	29
In-Place Dry Density - ASTM D2937	6
Moisture-Density (standard Proctor) - ASTM D698, Method A	1
pH and Resistivity - AZ Method 236e	8
Sulfates and Chlorides - AZ Method 733b	15
Consolidation - ASTM D2435	1
Direct Shear - ASTM D3080	3

4.0 GEOTECHNICAL PROFILE

4.1 General Geologic Setting

The project site is in the Basin and Range Geologic Province of the southwestern United States. The Basin and Range Province is characterized by a modern landscape consisting of broad alluvial valleys interspersed with and bounded by uplifted and fault-block mountain ranges, often with well-developed pediments and alluvial fans. Generally, the mountain ranges and valleys trend in a north-south to northwest-southeast direction. The modern landscape was formed by late Tertiary (Miocene-Pliocene) extensional tectonism and high-angle normal faulting, followed by subsequent erosion of the uplifted mountains and alluvial deposition of the sediments in the newly-formed basins.

Published geological mapping indicates the surficial geological unit at the site consists of Pliocene to middle Miocene deposits. This unit is described as moderately to strongly consolidated conglomerate and sandstone deposited in basins during and after late Tertiary faulting and includes lesser amounts of mudstone, siltstone, limestone, and gypsum. These deposits are generally light gray or tan. They commonly form high rounded hills and ridges in modern basins and locally form prominent bluffs. Deposits of this unit are widely exposed in the dissected basins of southeastern and central Arizona. The soil types encountered in the borings are likely residual soils associated with the mapped geologic units, and may include younger alluvial fan and terrace deposits overlying the older geological units.

4.2 Generalized Subsurface Profile

Borings S-1 through S-4 were drilled to evaluate subsurface conditions for foundation design of the new 3-span SB BNSF OP Bridge. Two subsurface profiles were identified, one for the south abutment and piers (Abutment 1, Piers 1 and 2), and another for the north abutment (Abutment 2). The generalized subsurface profiles are presented in Tables 4.1 and 4.2.

Table 4.1: Generalized Subsurface Profile for BNSF OP Bridge

Profile 1 – Abutment 1, Piers 1 and 2

Stratum	Approximate Bottom Elevations (feet)[1,2,3]	USCS Material Types and Cementation	Relative Firmness / Density
1	2,435	Sand with variable amounts Silt, Clay and Gravel (SM, SP-SM, SC-SM); Uncemented to Weak Cementation	Firm to Very Firm / Medium Dense to Dense
2	Below 2,435	Sand with variable amounts of Silt and Clay (SC-SM, SM, SP-SM); Silty Clay with Sand (CL-ML); Weak to Moderate Cementation (Possible Residual Soils)	Very Firm to Hard / Dense to Very Dense

Notes:

(1) The existing native ground surface elevation was estimated at approximately 2,450 feet at the centerline of the planned new SB bridge at the existing BNSF tracks. Elevations should be considered approximate.

(2) Based on the conditions encountered in borings S-1 to S-3.

(3) Lowest elevation explored was approximately 2,350 feet in borings S-2 and S-3.

Table 4.2: Generalized Subsurface Profile for BNSF OP Bridge

Profile 2 – Abutment 2

Stratum	Approximate Bottom Elevations (feet)[1,2,3]	USCS Material Types and Cementation	Relative Firmness / Density
1	2,450	Sand with variable amounts Silt, Clay and Gravel (SM, GP, SP-SM); Uncemented to Weak Cementation	Hard / Very Dense
2	Below 2,450	Sand with variable amounts of Silt, Clay and Gravel (SC-SM, SM, SP-SM, GP); Weak to Moderate Cementation (Possible Residual Soils)	Hard / Very Dense

Notes:

(1) The existing native ground surface elevation was estimated at approximately 2,468 feet at the location of boring S-4. Elevations should be considered approximate.

(2) Based on the conditions encountered in Boring S-4.

(3) Lowest elevation explored was approximately 2,385 feet in the boring S-4.

4.3 Groundwater Conditions

Groundwater was not encountered in the borings and soil moisture conditions were generally described as slightly moist to moist. A review of the groundwater data in the Arizona Department of Water Resources (ADWR) Groundwater Site Inventory database (ADWR 2025) does not indicate any index well sites in the immediate vicinity of the project site with current readings. Historic readings from well sites adjacent to the site indicate groundwater depths on the order of 200 to 300 feet and corresponding groundwater elevations on the order of 2,100 to 2,200 feet.

5.0 FOUNDATION RECOMMENDATIONS

5.1 General

The following sections of this report discuss our development of axial resistance charts for drilled shaft foundations at the planned BNSF OP bridge foundations. These recommendations are based on our understanding of the project, the results of the field exploration and laboratory testing performed for the project, and engineering analyses.

The axial compression capacities of the drilled-shaft foundations were determined using ADOT's Geotechnical Design Policy DS-1 memorandum (ADOT, 2010a). The ADOT memorandum outlines the development of drilled shaft axial resistance charts based on methods specified in AASHTO LRFD Bridge Design Specifications, 5th Edition (AASHTO, 2010). The 6th Edition of the AASHTO LRFD Bridge Design Specifications (AASHTO, 2012) has been published, and was used for this foundation design.

The recommended design criteria presented herein are applicable to drilled, cast-in-place concrete shaft foundations. The drilled shaft foundations for the project were designed using the Beta and IGM methods based on the subsurface profile at the planned bridge location.

A summary of the drilled shaft design charts is presented in Table 5.1. The drilled shaft design charts are presented in Appendix C by foundation structure. Development of strength and service limit charts is further discussed in the following sections.

Table 5.1: Summary of Drilled Shaft Design Charts

Structure	Substructure	Strength Limit State	Service Limit State
US 93, SB BNSF OP	Abutment 1	C1	C2 to C5
	Piers	C6	C7 to C10
	Abutment 2	C11	C12 to C15

5.2 Drilled Shaft Axial Resistance

The axial resistance design charts presented in Appendix C were developed using both tip and side resistance and are applicable for redundant conditions. For non-redundant conditions, the resistance should be reduced by 20%. The provided design charts in Appendix C can be used for non-redundant conditions by increasing the applied loads by a factor that is the inverse of the reduction factor, and then entering the charts with the increased loads. A resistance factor of 0.8 (i.e., 80%) for non-redundant conditions corresponds to a load factor of 1.25 (i.e., 1/0.8 = 1.25) or an increase in the load by 25%.

The upper 5 feet of soil resistance below the top of shaft was disregarded for development of the axial resistance charts. The N values used for development of tip resistance were taken as the average of the value at that depth and the next 10 feet below the tip. The N values were normalized to a 60 percent hammer efficiency and limited to a maximum value of 50 (beta method) or 100 (IGM method) in accordance with the design procedure.

5.2.1 Strength Limit State

Resistance factors used in the determination of the vertical resistance for drilled shafts are a function of the design methodology. The drilled-shaft capacities were calculated using the beta and IGM methods for side resistance and tip resistance. The corresponding resistance factors for geotechnical resistance of drilled shafts are 0.55 and 0.5 for beta method side and tip resistance, and 0.60 and 0.55 for IGM method side and tip resistance, respectively, as presented in Table 10.5.5.2.4-1 of AASHTO (2012). These resistance factors assume redundant foundations as defined in Section 10.5.5.2.4 of AASHTO (2012) and Section 10.5.5.2.4 of the ADOT Bridge Practice Guidelines (2011).

5.2.2 Service Limit State

The vertical resistance provided by the soil is a function of the relative movement between the drilled shaft and the surrounding soil. Article 10.8.2.2.2 of AASHTO (2012) and ADOT (2010a) provide relationships for the development of skin friction and tip resistance as a function of settlement normalized to the drilled-shaft diameter for various soil types. The trend line normalized load transfer curves were used in the analyses. The vertical resistances for the drilled shafts at settlements of 0.25, 0.5, 0.75, and 1 inch were calculated using these relationships. The service limit state charts are not applicable for the evaluation of settlement resulting from downdrag (i.e., abutments), as further discussed herein.

5.2.3 Group Effects – Axial

Design criteria for reductions in axial resistance resulting from group effects are presented in Section 10.8.3.6 of the AASHTO (2012) manual. For cohesionless materials, the individual nominal resistance of each shaft in a group should be reduced by a factor, ŋ, presented in Table 10.8.3.6.3-1 of AASHTO (2012) and reproduced in Table 5.2:

Table 5.2: Group Reduction Factors for Drilled Shafts

Shaft Group Configuration	Shaft Center-to-Center Spacing	Special Conditions	Reduction Factor for Group Effects (ŋ)
Single Row	2D	---	0.90
	3D or more	---	1.0
Multiple Row	2.5D	---	0.67
	3D	---	0.80
	4D or more	---	1.0
Single and Multiple Rows	2D or more	Shaft group cap in intimate contact with ground consisting of medium dense or denser soil, and no scour below the shaft cap is anticipated	1.0
Single and Multiple Rows	2D or more	Pressure grouting is used along the shaft sides to restore lateral stress losses caused by shaft installation, and the shaft tip is pressure grouted	1.0

The design charts presented in Appendix C apply to single shafts, and therefore do not include a group reduction factor. For axial capacity reductions due to group effects, the factored loads should be increased by the inverse of the appropriate reduction factor when using the design charts.

For a single row of drilled shafts, the minimum center-to-center (CTC) spacing should be two diameters, and the appropriate reduction factors determined by linear interpolation for CTC spacing between two and three diameters. The reduction factors should be applied equally to all shafts within the group regardless of location within the group.

5.2.4 Downdrag

Drilled shafts supporting abutments, subject to new embankment fill surcharges, may experience downdrag loads. The new embankment fill soil, if in contact with the drilled shaft, can move downward as it settles, relative to the drilled shaft, and “drag” the shaft down, and/or the new embankment fill soil can cause the existing ground to settle and the existing ground can move downward relative to the shaft. The design charts in Appendix C do not account for these additional downdrag forces or settlements. To limit potential downdrag forces and downward movements of drilled shaft foundations adjacent to embankment fills at the bridge approaches, Ethos recommends the construction sequence begin with constructing the embankment fills and MSE walls, and then allowing the associated settlement to occur prior to constructing the drilled shaft foundations. We anticipate 85 to 90 percent of the settlement will be complete at the end of embankment construction, with most of the remaining settlement to occur within about 1 month or less.

However, we understand drilled shaft foundations at the bridge abutments will likely be installed prior to construction of the adjacent embankment fills and MSE walls for the bridge approaches due to space limitations adjacent to the BNSF railroad tracks. In this scenario, drilled shafts at the abutments would be subjected to additional settlement and loading associated with downdrag. Settlement of foundations constructed prior to placement of adjacent embankment fills will include the following:

- settlement associated with embankment proximity (i.e., from fill),
- settlement due to downdrag loading, and
- settlement due to foundation loading.

Downdrag loads for this construction sequence were calculated using procedures outlined in Article 3.11.8 (AASHTO 2012) and the Federal Highway Administration (FHWA) Drilled Shafts Manual (2018). The side shear and end bearing in the founding stratum were assigned based on the results of the vertical resistance analyses, as described in Section 5.2.1.2.

Ethos has evaluated the settlement and downdrag loading that will occur at the bridge abutment locations due to the planned foundation construction and embankment fill placement sequence. The downdrag analyses were performed using drilled shaft foundation diameters, elevations and loading provided by the design team. Based on the results of the analyses, the settlements of the drilled shafts due to downdrag loading does not exceed the failure criterion of the soil and therefore downdrag loads do not need to be considered at the geotechnical strength limit state. For strength limit evaluations, downdrag loading should be limited to evaluation of the structural strength limit state only (FHWA, 2018).

Based on the analyses, including subsurface conditions and the heights of new fill at the abutments, downdrag is applicable at Abutment 1 only. Table 5.3 summarizes the results of the downdrag analyses.

Table 5.3: Drilled Shaft Downdrag Loading

Structure Element	Shaft Diameter [feet]	Shaft Length [feet]	Shaft Settlement [inches]			Downdrag Load per Shaft [kips]
			From Fill[1]	From Loading[2]	Total	
Abutment 1	5.0	33	0.2	0.3	0.5	50
Abutment 2	5.0	37	Negligible – use shaft charts in Appendix C			---

Notes:

(1) Settlement of the soil below the shaft resulting in downward movement of the shaft and surrounding soil.

(2) Movement of the shaft relative to the surrounding soil required to develop resistance.

The downdrag loads presented in Table 5.3 consider the columns above the existing grade will be constructed in front of the MSE wall as is currently designed. Additional downdrag loads would be applicable in scenarios where embankment fill is in contact with the columns (i.e., embedded within the MSE wall).

5.3 Drilled Shaft Lateral Resistance

Lateral soil-structure interaction analyses of single shafts are typically performed by modeling the lateral load-displacement behavior using a finite difference technique based on elastic beam column theory and soil reaction (p)-displacement (y) curves. The p-y curves define the behavior of the soil surrounding the laterally loaded shaft. These curves are nonlinear and are developed using soil strength, depth below ground and shaft diameter amongst other parameters. Many programs are available that use this approach with the most common locally being LPILE. The soil input parameters below are for use in LPILE.

5.3.1 LPILE Input Parameters

Recommended soil input parameters for use in LPILE analyses are provided in Tables 5.4 and 5.5. The soil input parameters were developed using the LPILE technical manual (Ensoft, 2019) and results of the geotechnical investigation.

Table 5.4: LPILE Input Parameters – US 93 BNSF SB OP Bridge

Profile 1 – Abutment 1, Piers 1 and 2

Stratum	Elevation [feet]	Soil Type in LPILE	Effective Unit Weight [pcf]	Friction Angle [degrees]	Cohesion [psf]	Soil Strain Ratio ε_{50}	Horizontal Subgrade Modulus, k [pci]
1	2,450 to 2,435	Sand	115	32	---	---	80
2	Below 2,435	Silt	120	32	100	0.007	350

Notes: pcf – pounds per cubic foot; psf – pounds per square foot; pci – pounds per cubic inch.

Table 5.5: LPILE Input Parameters – US 93 BNSF SB OP Bridge

Profile 2 – Abutment 2

Stratum	Elevation [feet]	Soil Type in LPILE	Effective Unit Weight [pcf]	Friction Angle [degrees]	Cohesion [psf]	Soil Strain Ratio ε_{50}	Horizontal Subgrade Modulus, k [pci]
1	2,465 to 2,450	Sand	115	32	---	---	80
2	Below 2,450	Silt	120	32	100	0.007	350

Notes: pcf – pounds per cubic foot; psf – pounds per square foot; pci – pounds per cubic inch.

Where embankments in front of drilled shafts slope downward away from the bridge abutment, the lateral soil resistance against drilled shafts should be reduced. It is conservatively recommended that lateral soil pressures (for loading normal to the column line) be neglected within the zone above the catch point (on the slope) of a horizontal line projected outward a distance of three shaft diameters (e.g., a horizontal distance of 12 feet to the catch point on the slope for a 4-foot-diameter shaft) from the front of these shafts.

5.3.2 Group Effects – Lateral

The design of laterally loaded drilled shafts must account for the influence from adjacent shafts in a group. Article 10.7.2.4 (AASHTO, 2012) defines a drilled-shaft group with respect to lateral loading as drilled shafts spaced less than five diameters CTC in the direction parallel and normal to the applied load. When the drilled shafts are in a group, the lateral resistance of the soil is reduced to account for the influence of adjacent drilled shafts by multiplying the p values of the p-y curves by P-multiplier values (P_m). The values of P_m vary as a function of the CTC spacing and the drilled shaft position within the group. The loading direction and spacing are shown on Figure 10.7.2.4.1 from AASHTO (2012).

Recommendations for P_m are shown in Table 5.6, based on AASHTO Table 10.7.2.4 1 (AASHTO, 2012) for CTC spacing of 3B and 5B. When determining P-multiplier values for two shafts of different diameters, the larger shaft diameter should be used to calculate the CTC spacing.

Table 5.6: P-Multipliers for Multiple Row Shading

CTC Spacing in the Direction of Loading	P-Multipliers, P_m		
	Row 1	Row 2	Row 3
3B	0.8	0.4	0.3
5B	1.0	0.85	0.7

Notes:

(1) B = drilled shaft diameter.

5.4 Drilled Shaft Construction

All construction techniques should be in accordance with Section 609 of the ADOT Standard Specifications and the project-specific special provisions. Quality control during the drilled-shaft construction should include those items specifically called out in Section 609 of the ADOT Standard Specifications. A quality control report should be submitted for each shaft, stating that all details were monitored and meet the project requirements.

Straight, drilled shaft excavations will likely be advanced with single-flight-auger or bucket auger bits to the recommended depth. Cleaning of the drilled-shaft excavations should be performed in accordance with Section 609 of the ADOT Standard Specifications. It should be verified by inspection and measurement that the excavation is open to that depth. The shaft excavation should be cleaned so no more than 2 inches of slough or loose material is present in the bottom of the excavation.

5.5 MSE Wall Structures

MSE wall structures are planned at the bridge approaches at the SB BNSF OP Bridge. Typical cross sections from each wall were evaluated to establish minimum strap length to wall height ratios. The results presented herein only include overall stability associated with external stability analyses of the MSE walls. These analyses were performed to determine the minimum required reinforcement lengths for external stability. Internal stability analyses of the planned MSE walls are the responsibility of the wall designer and should be performed considering the actual design reinforcement type and lengths. Metallic, inextensible reinforcements are recommended to limit long term deformation of the wall.

Recommendations for the external stability of the MSE wall structures were developed in accordance with FHWA Geotechnical Engineering Circular (GEC) No. 11, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes (FHWA 2009) and AASHTO Design Specifications (2012). GEC No. 11 or AASHTO (2012) should be used for internal stability calculations of the MSE walls, and meet the requirements in ADOT Special Provisions Section 929. Table 5.7 is a summary of FHWA's minimum requirements for MSE walls for strap length and embedment. These were used as starting points for our analyses.

Table 5.7: Minimum Requirements for MSE Walls

Parameter or Condition	Value
Minimum Reinforcement Length	70% of the wall height (H) with 8-foot minimum
Minimum Embedment Depth	
Minimum	2 feet below finished grade
Wall on Level Ground	H/20
Wall on Sloping Ground	H/10

Five potential external failure mechanisms are considered in sizing MSE walls. These mechanisms are listed below and further discussed in the following sections:

- Bearing resistance
- Sliding resistance
- Eccentricity

- Overall stability
- Settlement

The soil parameters used for the evaluation of MSE walls are presented in Table 5.8.

Table 5.8: Soil Parameters for Evaluation of MSE Walls

Soil Description[1]	Cohesion (c) [psf]	Friction Angle (ϕ) [degrees]	Effective Unit Weight (γ) [pcf]
Reinforced Backfill	---	34	110/130[2]
Retained Backfill / Foundation Soils (Embankment)	0	30	120
Foundation Soils	0	32	115

Notes: psf – pounds per square foot; pcf – pounds per cubic foot

(1) Refer to stability plots for specific conditions evaluated.
(2) Stability evaluated using both values and report lower factor of safety/capacity to demand ratio.

The analyses also considered surcharge loads due to traffic above the MSE walls. A uniform surcharge load of 250 psf was applied to account for the traffic live load. The live load traffic surcharge was incorporated into the external stability analyses as specified in GEC No. 11.

The bearing resistance, sliding and eccentricity analyses for MSE walls were evaluated using the computer program MSEW 3.0, developed by ADAMA Engineering, Inc. These analyses were performed to determine the minimum strap length required to ensure the capacity to demand ratio (CDR) was equal to or greater than 1.0. Details for these evaluations are discussed in the following sections.

5.5.1 Bearing Resistance

The factored bearing resistance at the strength limit is calculated by multiplying the nominal bearing resistance by the appropriate resistance factor. The resistance factor used in the determination of the factored bearing resistance is a function of the design methodology, wall type, soil type, and test method used to determine the strength of the soil. The resistance factor used for bearing resistance of MSE walls was 0.65, as presented in Table 11.5.7-1 of AASHTO (2012).

5.5.2 Sliding Resistance

Sliding resistance of MSE walls can consist of two components: sliding along the base of the wall or sliding along a weak layer near the base of the wall. For MSE walls bearing on site derived engineered fill, sliding along the base of the wall is considered applicable. The resistance factor for sliding along the base of an MSE wall is 1.0 per Table 11.5.7-1 (AASHTO 2012). The internal friction angle used for sliding should be the lesser of the friction angle of the reinforced wall fill, the friction angle of foundation soil, or the friction angle of the interface between reinforcement and soil for cases of sheet reinforcement such as geotextiles. For site derived engineered fill, a friction angle of 30 degrees is recommended for sliding calculations.

Live load surcharge was not considered as a stabilizing force when checking sliding. The nominal passive resistance of soil at the toe of MSE walls was also neglected when checking sliding as required by GEC No. 11 and AASHTO (2012).

5.5.3 Eccentricity

The maximum allowable eccentricity, e_{max}, of loading at the strength limit state for MSE walls should be as follows in accordance with AASHTO (2012) and ADOT Special Provisions Section 929:

- e_{max} = L/3 for walls on soil.

Where:

L = The length of the soil reinforcement measured from the back face of the wall facing unit. In the case of grid type reinforcements, the length of the soil reinforcement is measured from the back face of the wall to the last full transverse member. For modular block facing units, the total length of the reinforcement, as measured from the front face of the wall, is the length L as defined above plus the width of the modular block unit (the horizontal dimension of the block unit measured perpendicular to the wall face).

5.5.4 Overall Stability

Ethos performed slope stability analyses using the geotechnical software Slope/W, and incorporated soil strength parameters determined from the geotechnical investigation. Stability models were developed for critical wall sections to evaluate the minimum strap length required to meet or exceed the minimum required factor of safety for global stability of 1.5. The results of the stability models analyzed are included in Appendix D.

5.5.5 Settlement

Preliminary estimates of the settlement for the MSE walls were determined using the program Settle3D by Rocscience. The soil profile was extended to a depth below the existing ground at which point the stress increase due to the wall/embankment was generally less than ten (10) percent of the existing overburden stress. The moduli values used in the analyses are based on the N_{60} values developed from the field investigation and are summarized in Table 5.9.

Table 5.9: Soil Parameters for Settlement Analyses

Depth [feet]	Moist Unit Weight (γ_{sat}) [pcf]	Elastic Moduli Values (E) [ksf]
0 to 15	115	330
15 to 60	115	2,280
Below 60	120	3,940

Notes: pcf – pounds per cubic foot; ksf – kips per square foot

The maximum settlement of the overall MSE wall embankment was evaluated, and was generally located near the center of the new embankment footprint. Settlement was also evaluated along the MSE wall faces, including differential settlement along each wall face. The results of the settlement analyses outlined herein are included in Appendix E and summarized in Table 5.10.

Table 5.10: Summary of Calculated Settlement

	Estimated Settlement (inches)[1,2]	
MSE Wall ID	**Maximum Embankment**	**Maximum MSE Wall Face**
Abutment 1	2.0	0.9
Abutment 2	1.0	0.7

Notes: psf – pounds per square foot; pcf – pounds per cubic foot

(1) Maximum settlement associated with the new embankment will occur near the center of the embankment widening footprint, which occurs behind the wall ace around wall STA 10+80 at Abutment 1 and around wall STA 11+36 at Abutment 2.

(2) Estimated differential settlement along each wall face is presented in Appendix E.

5.5.6 MSE Wall Summary

Based on the analyses discussed above, the recommended minimum reinforcement lengths for MSE walls are summarized in Table 5.11.

Table 5.11: Minimum Reinforcement Lengths for MSE Walls

MSE Wall ID	MSE Wall Station	Wall Heights (feet)	Slope Below Toe of Wall	Foundation Soil	Minimum Reinforcement Length (L/H)[1,2]
Abutment 1	10+00 to 10+22	6 to 25	Level[3]	Existing Embankment Fill	0.7
	10+22 to 10+36	25 to 30	3H:1V	Existing Embankment Fill	1.2
	10+36 to 10+51	35	3H:1V	Existing Embankment Fill	0.8
	10+51 to 11+71	40 to 5	Level	Native	0.7
Abutment 2	10+00 to 11+07	7 to 26	8H:1V	Native	0.7
	11+07 to 11+40	26	Level	Native	0.7
	11+40 to 11+58	20 to 7	Level[3]	Native / Existing Embankment Fill	0.7

Notes: L = length of reinforcement; H = height of wall

(1) Wall height is measured from top of wall to top of leveling pad.

(2) Minimum reinforcement length shall not be less than 8 feet per AASHTO C11.10.2.1.

(3) MSE wall face is perpendicular to existing slope.

5.5.7 Subsurface Drainage

The need for subsurface drainage for MSE walls was evaluated considering the potential for subsurface and surface water to enter into and stay within the MSE wall backfill resulting in the development of hydrostatic pressures on the wall. The purpose of a drainage system is to allow unimpeded flow of water through the wall and/or collect and remove the water before it enters the zone of influence of the wall (FHWA 2009).

The potential for water to enter into the MSE wall backfill for the project is low for two reasons. First, subsurface water is not expected to be present for the project given the depth to groundwater is greater than 100 feet at the MSE wall locations. Second, the surface drainage improvements for the project will lead the surface water away from the limits of the walls.

Though unlikely, should water enter the zone of influence, it would be expected to flow unimpeded through the wall because the MSE wall reinforced backfill material (as specified in ADOT Special Provisions Section 929) is similar to AASHTO No. 57 stone, which is considered to be free draining (FHWA 2009). The potential for flows through the wall will require the use of a geotextile filter at all vertical and horizontal joints in the wall face. This is the only subsurface drainage element needed for the MSE walls. The use of a separation fabric to encapsulate the reinforced backfill material is required and should meet the requirements of ADOT Special Provisions Section 929.

5.6 Spread Footings

Spread footings will be utilized to support reinforced concrete box culvert (RCBC) extensions at US 93 crossings of several large drainages at locations listed below:

- RCBCs at US 93 Station 196+05
- RCBCs at US 93 Station 216+69
- RCBCs at US 93 Station 277+93
- RCBCs at US 93 Station 325+05

Based on a review of the Stage III plans, the RCBC extensions will have lengths varying from approximately 98 to 135 feet, and widths varying from approximately 12 to 40 feet. Four (4) borings, identified as D-SB-1 through D-SB-4, were performed to evaluate the subgrade conditions at each of the planned RCBC extensions. Similar subgrade support conditions were encountered at each of the planned RCBC extension locations.

The strength and service limit state design analyses for spread footings were completed per the methods presented in Sections 10.5 and 10.6, respectively, of AASHTO (2012), and ADOT Geotechnical Design Policy SF-1 (2010b), and are further described in the following sections. Considering the consistent subgrade conditions at each RCBC extension location, a single bearing resistance design chart was developed for the RCBCs and is presented in Appendix F.

5.6.1 Strength Limit State

The factored net bearing resistance, q_{Rn}, at the strength limit state was determined using the net nominal bearing resistance (ultimate bearing capacity), q_{nn}, calculated per Section 10.6.3.1.2a and bearing resistance factor, φ_b, from Section 10.5.5.2.2 of AASHTO (2012) for spread footings on level ground. The parameters presented below in Table 5.12 were used for the nominal resistance and strength limit state analyses.

Table 5.12: Strength Limit State Design Parameters

Parameter	Symbol	RCBCs
		Value
Soil Angle of Internal Friction [degrees]	ϕ_f	30
Soil Total Unit Weight [pcf]	γ_{total}	120
Cohesion [psf]	c	0
Maximum Footing Length [feet]	L	140
Footing Bearing Depth [feet]	D_f	0
Effective Footing Width [feet]	B_f	10 to 40
Bearing Resistance Factor [dim]	φ_b	0.45

Notes: pcf – pounds per cubic foot; psf – pounds per square foot; dim – dimensionless.

5.6.2 Service Limit State

Per ADOT Geotechnical Design Policy SF-1 (2010b), the modified Schmertmann method presented in Section 8.5 of the Federal Highway Administration Soils and Foundation Reference Manual (Samtani and Nowatzki 2006) was used to calculate settlements at the service limit state. The parameters are based on the measured soil densities, N values at and below the bearing elevations, and elastic modulus (E_s) to N value correlations from Kulhawy and Mayne (1990). The bearing resistance charts present the family of service limit state curves developed per ADOT Geotechnical Design Policy SF-1 (2010b) for design settlements of 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 inches.

5.6.3 Sliding Resistance

The factored sliding resistance, R_R, for limit state design should be determined using the nominal sliding resistance between soil and foundation, R_τ, and nominal passive resistance, R_{ep}, per Section 10.6.3.4, and corresponding resistance factors, φ_τ and φ_{ep}, from Section 10.5.5.2.2 of AASHTO LRFD (2012). We recommend the parameters presented in Table 5.13 be used for analyzing sliding resistance.

Table 5.13: Parameters for Sliding Resistance of Spread Footings

Parameter	Symbol	Value
Factored Sliding Resistance		
Resistance Factor for Shear between Soil and Foundation	φ_τ	0.80
Resistance Factor for Passive Resistance	φ_{ep}	0.50
Nominal Sliding Resistance		
Soil Angle of Internal Friction	ϕ_f	30 degrees
Soil Total Unit Weight	γ	120 pcf
Cohesion	c	0 psf
Passive Earth Pressure Coefficient	K_p	3.0

Notes: pcf – pounds per cubic foot; psf – pounds per square foot; dim – dimensionless.

Passive lateral soil resistance should be neglected in the upper 3 feet of finished grade due to the potential for disturbance. Below a depth of 3 feet, the nominal passive resistance can be estimated assuming a hydrostatic pressure distribution of 360 psf per foot.

5.6.4 Eccentricity

The eccentricity in the L (long) dimension of an abutment or wall footing is typically negligible, such that L = L'. The effective footing length (B') in the B (short) dimension is calculated as B' = B – $2e_B$, where e_B is the B dimension eccentricity determined by the structural engineer. The maximum allowable eccentricity at the strength limit state should be calculated in accordance with ADOT Geotechnical Design Policy SF-2 (ADOT 2010c).

5.7 Preliminary Soil Corrosion or Degradation Potential

5.7.1 Metal in Contact with Soil

The corrosion potential of near surface soils on corrugated metal pipes was characterized using laboratory pH and electrical resistivity testing, performed on 8 samples in accordance with Arizona Test Method 236. The laboratory pH values ranged from 8.5 to 8.9 (average 8.7). The resistivity values ranged from 2,740 to 7,580 ohm-centimeters (ohm-cm) (average 4,791ohm-cm). It is recommended that the type and/or coating of metal in direct contact with soil be selected in accordance with ADOT Pipe Selection Guidelines (ADOT, 1996). The test results are included in Appendix B and summarized in Table B-1.

5.7.2 Concrete in Contact with Soil

A total of 15 samples from the current investigation were tested for soluble sulfates and chlorides (Arizona Test Method 733 and Arizona Test Method 736) to support design of concrete structures. The test results are included in Appendix B and summarized in Table B-1.

Total soluble sulfate values ranged from 10 to 59 parts per million (ppm) with an average of 25 ppm. The sulfate test measures the water-leachable or "available" sulfate content. These results were compared to Table 19.3.1.1, "Exposure Categories and Classes," in Section 19.3.1, of the American Concrete Institute's (ACI's) *Building Code Requirements for Structural Concrete* (ACI 2019). All of the samples fall within Exposure Class S0 for water-soluble sulfate (SO_4^{2-}) in soil by percent mass (SO_4<0.1% or 1,000 ppm) and are categorized with a severity level of "not applicable" in terms of sulfate exposure. Based on ACI Table 19.3.2.1, "Requirements for Concrete by Exposure Class," in Section 19.3.2 (ACI 2019), there is no restriction on Portland cement type for concrete structures in contact with these materials.

Chloride values ranged from 3 to 30 ppm with an average of 10 ppm. Regarding chloride attack, Section 19.3.2 (ACI 2019) indicates that when concrete is exposed to external sources of chlorides, concrete should be proportioned to satisfy the requirements for the applicable exposure class in Table 19.3.1.1 (ACI 2019).

The anticipated concrete exposure for this segment falls within Exposure Class C1. Table 19.3.2.1 (ACI 2019) should be referred to for requirements for concrete by exposure class. For Exposure Class C1, the minimum compressive strength of concrete specified is 2,500 psi and the maximum water-soluble chloride ion content in concrete, by percent weight of cement, is 0.30% for non-prestressed concrete and 0.06% for prestressed concrete.

5.7.3 Further Evaluation

The results presented in this section are general in nature and may not be representative of site conditions. We recommend that the results of our laboratory testing be reviewed by a person or firm experienced in corrosion protection designs for the actual construction at the site, and/or by the appropriate pipe or material manufacturer. A qualified corrosion engineer should be consulted if corrosion of underground utilities is a concern or if a detailed evaluation is necessary.

The corrosion potential of reinforced zone soils with respect to metal MSE straps are not addressed herein. Testing of the reinforced soil materials should be performed during construction in accordance with the ADOT Special Provisions Section 929.

5.8 Earthwork

The following earthwork recommendations are intended to provide support for the proposed MSE walls and box culverts. Subgrade preparation in other project areas should be performed as specified ADOT in the Geotech Report for the overall project. The recommendations presented in this report are contingent upon performing the earthwork recommended herein.

5.8.1 Site Preparation

Completely remove all vegetation (including roots) and other organics, debris, any unstable (soft, loose, disturbed, water softened, etc.) soils, any uncontrolled fill, structural elements not intended to remain, and other deleterious materials from proposed pavement, embankment and structure areas prior to construction. This site grading should extend laterally a minimum of 2 feet beyond pavement, embankment and structure areas unless noted otherwise. All areas of excavation should be observed and approved by a representative of the Geotechnical Engineer after clearing and before any filling operations begin at the site.

5.8.2 Subgrade Preparation and Over-Excavation

New roadway embankment with fill heights up to approximately 25 feet will be constructed at the bridge approaches. To help provide uniform support conditions for the new embankments and MSE walls, over-excavation is recommended beneath new embankment areas at the bridge approaches to help minimize the potential for post-construction settlement. Table 5.14 presents recommended over-excavation depths beneath new roadway embankments at the bridge approaches.

Table 5.14: Recommended Over-excavation Beneath Embankments

Embankment Height (feet)	Over-excavation Depth (feet)
+5 to 10	1.0
+10 to 20	1.5
+20	2.0

For all areas, prior to placement of fill or aggregate base, the exposed subgrade should be scarified to a minimum depth of 6 inches, adjusted to a moisture content within the range of plus or minus 2 percent of optimum, and compacted to at least 95% of maximum dry density as determined by the applicable ADOT test methods.

When placing new embankment against the existing embankment slopes, the existing embankment should be cut a minimum of 6 feet horizontally as the new embankment is brought up in layers to limit slippage between the new and existing embankment per Section 203-10.03 of the ADOT Standard Specifications.

6.0 CLOSURE

The geotechnical services were performed in a manner consistent with that level of care and skill ordinarily exercised by other members of the geotechnical profession practicing in the same locality, under similar conditions and at the date the services were provided. Our conclusions, opinions and recommendations are based on the completed test borings, visual observations and the review of plans prepared by others. It is possible that conditions could vary beyond the data evaluated. Ethos makes no guarantee or warranty, express or implied, regarding the services, communication (oral or written), report, opinion, or instrument of service provided.

This report may be used only by the Client and their representatives, and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on site and off site), or other factors may change over time, and additional work may be required with the passage of time. Any party other than the Client who wishes to use this report shall notify Ethos of such intended use. Based on the intended use of the report, Ethos may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the Client or anyone else will release Ethos from any liability resulting from the use of this report by any unauthorized party.

7.0 REFERENCES

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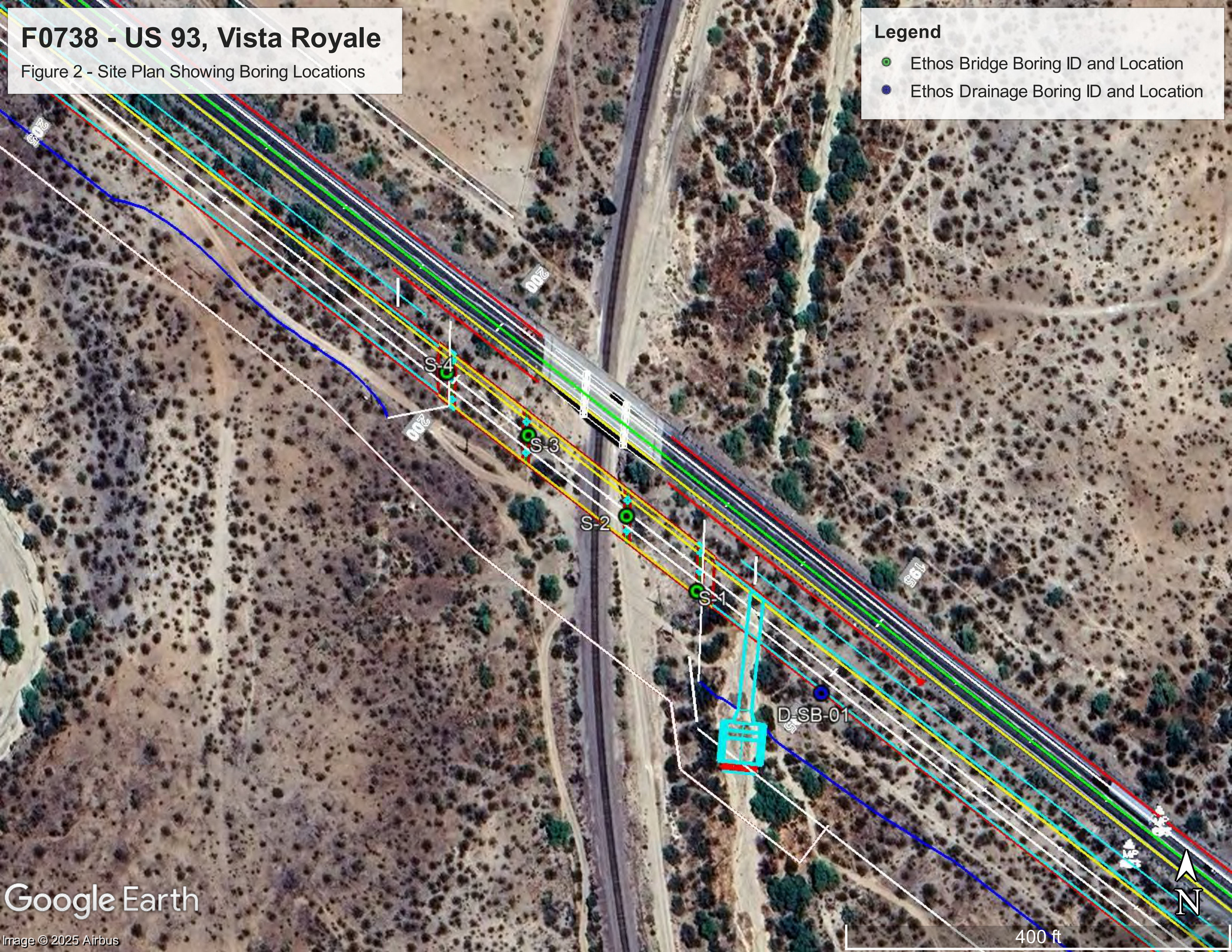
FIGURES

F0738 - US 93, Vista Royale

Figure 1 - Vicinity Map



F0738 - US 93, Vista Royale

Figure 2 - Site Plan Showing Boring Locations

F0738 - US 93, Vista Royale

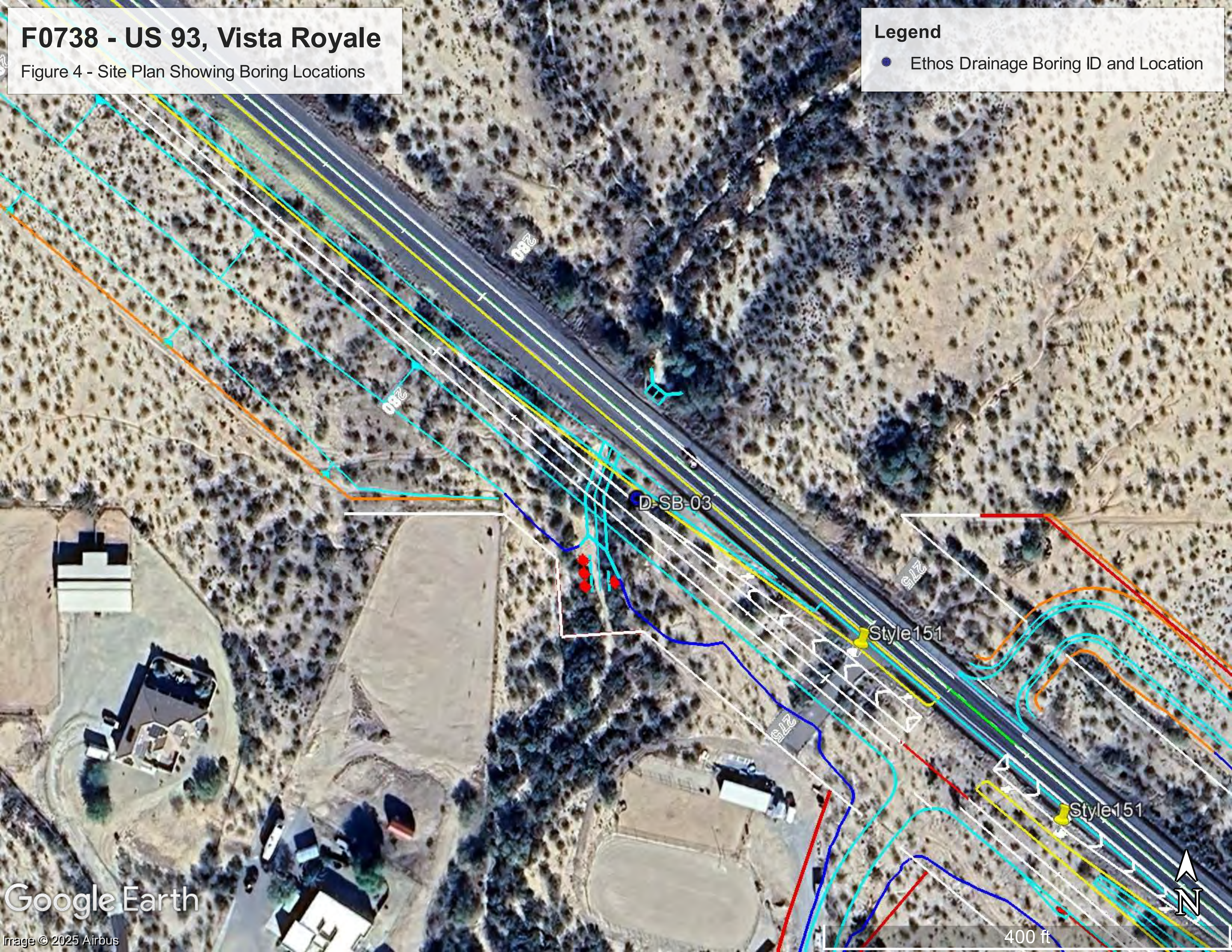
Figure 3 - Site Plan Showing Boring Locations

F0738 - US 93, Vista Royale

Figure 4 - Site Plan Showing Boring Locations

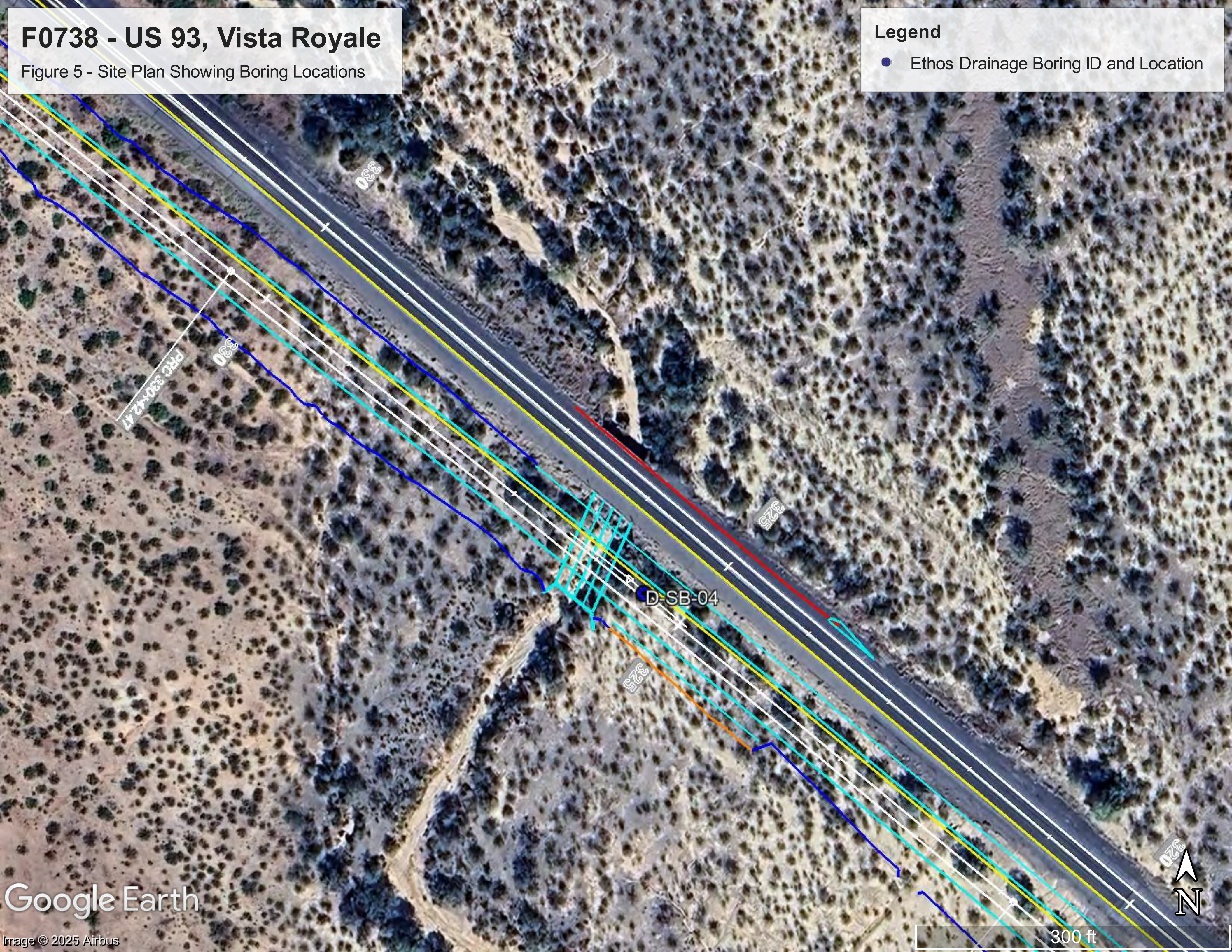
Legend

● Ethos Drainage Boring ID and Location



F0738 - US 93, Vista Royale

Figure 5 - Site Plan Showing Boring Locations



APPENDIX A

Boring Logs

SOILS SAMPLING & BORING LOG INFORMATION

The material and in-situ moisture descriptions of soils presented on the boring logs are based on visual observation and classification in accordance with the Unified Soil Classification System (USCS), presented on the next page. The field logs were modified, where appropriate, based on laboratory testing of selected samples.

The relative density and firmness described on the test boring logs are generally based on standard penetration test (SPT) blows per foot (N) for mostly cohesionless and cohesive soils. 2-inch outside diameter (O.D.) SPT samplers are advanced up to 18 inches into undisturbed soils beyond the base of either a hollow stem auger or drill casing. The samplers are driven with a 140-pound hammer and a 30-inch drop. SPT values are recorded on the boring logs for each 6-inch increment of penetration with sampler refusal based on a penetration of less than 6 inches and a blowcount of 50.

Relative Density

Relative density for mostly cohesionless, uncemented sands and sand and gravel mixtures is described based on the following SPT blowcounts:

N	Relative Density
0-4	Very Loose
5-10	Loose
11-30	Medium Dense
31-50	Dense
>50	Very Dense

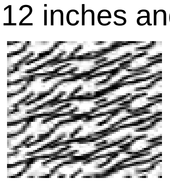
Relative Firmness

Relative Firmness for cohesive and/or cemented soils including silts, clays and silty to clayey sandy and gravelly soils is described based on the following SPT blowcounts:

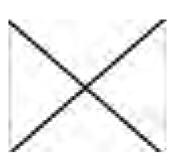
N	Relative Firmness
0-4	Very Soft
5-8	Soft
9-15	Moderately Firm
16-30	Firm
31-49	Very Firm
50+	Hard

Undisturbed samples of firmer soils, typically present in the southwest, are obtained with 3-inch O.D. samplers lined with 2.42-inch inside diameter (I.D.) brass rings. The samplers are advanced up to 12 inches into undisturbed soils beyond the base of either a hollow stem auger or drill casing. The samplers are driven with a 140-pound hammer and a 30-inch drop. The N value blowcounts are recorded on the boring logs for each 6-inch increment of penetration with sampler refusal based on a penetration of less than 12 inches and a blowcount of 100.

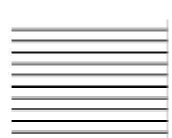
Boring Log Sample Type Legend:



BULK



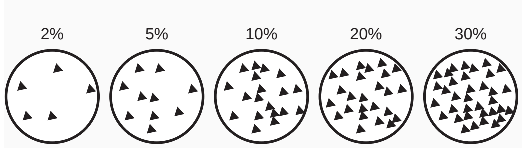
SPT



RING

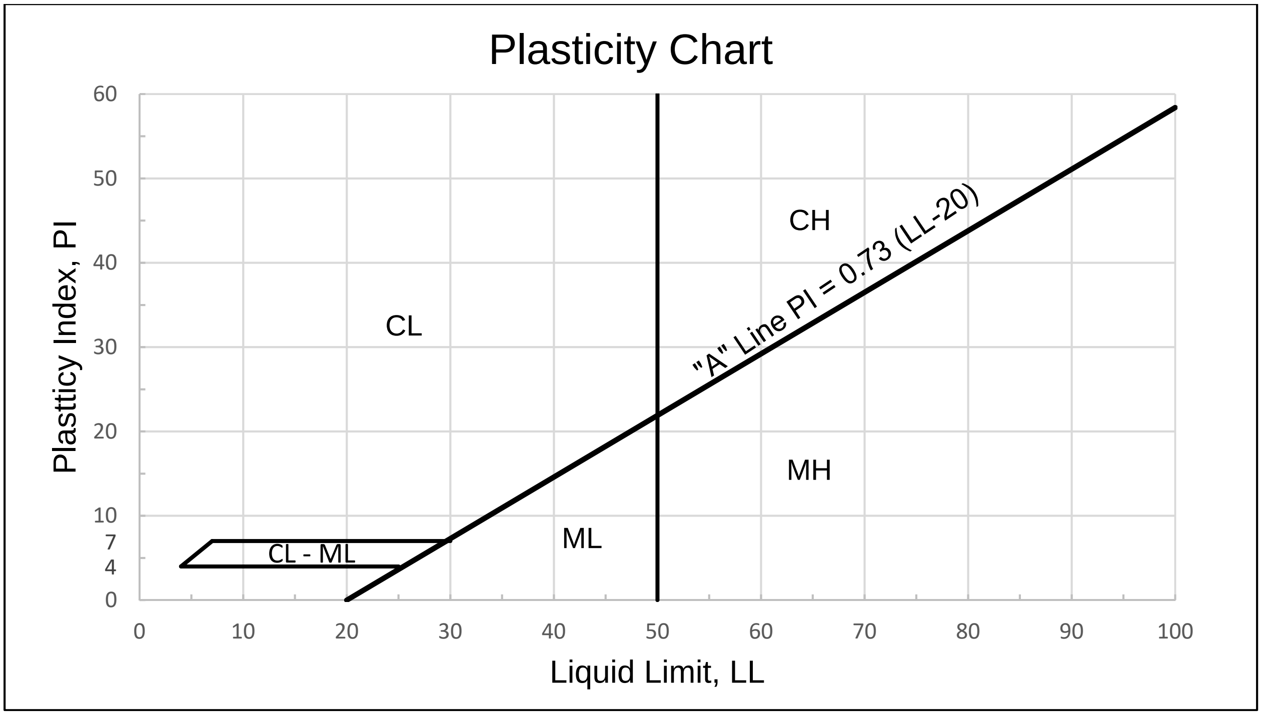
Unified Soil Classification System
(ASTM D2487)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests				Group Symbol	Group Description
Coarse-Grained Soils (More than 50% Retained on No. 200 Sieve).	Gravels More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravels Less than 5% Fines		GW	Well Graded Gravels, Gravel-Sand Mixtures or Sand-Gravel-Cobble Mixtures.
				GP	Poorly Graded Gravels, Gravel-Sand Mixtures or Sand-Gravel-Cobble Mixtures.
		Gravels with More than 12% Fines	Fines Classify as ML or MH	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			Fines Classify as CL or CH	GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	Sands 50% or More of Coarse Fraction Passes No. 4 Sieve	Clean Sands Less than 5% Fines		SW	Well Graded Sands, Gravelly Sands.
				SP	Poorly Graded Sands, Gravelly Sands.
		Sands with More than 12% Fines	Fines Classify as ML or MH	SM	Silty Sands, Sand-Silt Mixtures
			Fines Classify as CL or CH	SC	Clayey Sands, Sand-Clay Mixtures
Fine-Grained Soils (50% or More Passes No. 200 Sieve).	Silts and Clays (Liquid Limit less than 50)	PI > 7 and Plots on Above "A" Line		CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
		PI <4 or Plots Below "A" Line		ML	Inorganic Silts, Clayey Silts with Low Plasticity
	Silts and Clays (Liquid Limit 50 or More)	PI Plots on Above "A" Line		CH	Inorganic Clays of High Plasticity, Fat Clays, Silty and Sandy Clays of High Plasticity
		PI Plots Below "A" Line		MH	Inorganic Silts of High Plasticity, Silty Soils, Elastic Silts



Amount Modifiers

Rare	<2% (coarse only)
Occ	<5% (coarse only)
Trace	10%
Some	20%
Cons	30%



Angularity	
Angular	
Subangular	
Subrounded	
Rounded	

Soil Particle Definitions	
Material	Particle Size Range
Boulders	Greater than 300 mm (12 in.)
Cobbles	300 mm to 75 mm (12 in. to 3
Coarse Gravel	75 mm to 19 mm (3 in. to ¾ in.)
Fine Gravel	19mm (3/4 in.) to No. 4 sieve
Coarse Sand	No. 4 Sieve to No. 10 Sieve
Medium Sand	No. 10 Sieve to No. 40 Sieve
Fine Sand	No. 40 Sieve to No. 200 Sieve
Fines (Silt or Clay)	Less than No. 200 Sieve

Plasticity	
PI = 0	Non-Plastic
1 ≤ PI ≤ 7	Low
8 ≤ PI ≤ 25	Medium
PI ≥ 25	High

Moisture
Slightly Moist
Moist
Wet
(Saturated)

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		**BORING ID:**	**D-SB-1**
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 06/19/2025	DATE COMPLETED: 06/19/2025
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 6-5/8" OD Hollow Stem Auger		HAMMER TYPE: auto	HAMMER EFFICIENCY: 71%
SURFACE ELEVATION: 2450'	STATION: 195+00	OFFSET AND OFFSET DIRECTION: 95' L	US 93 Cst CL	
DRILLING FIRM: ACS Drilling Services, LLC	DRILLER: N. Zamora	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 51
REPORTED DEPTH: 30.4'	GROUNDWATER DEPTH: N/A	REVIEWED BY: J. Huston	LATITUDE: 34.03000	LONGITUDE: -112.81659

Elevation (feet)	Depth (feet)	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Blow Counts/6"	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (LL-PL-PI)	Fines (%)
	0	**SILTY SAND** (SM), trace fine subrounded gravel, predominantly fine to medium sand, nonplastic, light brown, slightly moist, medium dense	X (0–5)	X	9-10-17 (27)	2.0		NP	26.0
	2.5	Note: light brown to light reddish brown at 2.5 feet		X	7-10-16 (26)				
2445	5	Note: light reddish brown to reddish brown below 5 feet		X	5-15				
	7.5	Note: white, very dense, moderate to strong cementation below 7.5 feet		X	27-50/5"				
2440	10			X	50/3"				
2435	15			X	25-38-50/5"				
2430	20	20.0 **SAND WITH SILT AND GRAVEL** (SP-SM), trace to some fine subrounded gravel, predominantly fine sand, moderate to strong cementation, nonplastic, white, slightly moist, very dense		X	50/4"				
2425	25			X	31-50/3"				
2420	30	30.4		X	50/5"				

Auger stopped at 30 feet. Sampler refused at 30.4 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.

PROJECT NAME: US 93, Vista Royale		**BORING ID:**	**D-SB-2**
PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc	DATE STARTED: 06/19/2025	DATE COMPLETED: 06/19/2025
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 6-5/8" OD Hollow Stem Auger	HAMMER TYPE: auto	HAMMER EFFICIENCY: 71%
SURFACE ELEVATION: 2475'	STATION: 217+30; OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: ACS Drilling Services, LLC	DRILLER: N. Zamora; FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 51
REPORTED DEPTH: 30.9'	GROUNDWATER DEPTH: N/A; REVIEWED BY: J. Huston	LATITUDE: 34.03386	LONGITUDE: -112.82232

Elevation (feet)	Depth (feet)	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Blow Counts/6"	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (LL-PL-PI)	Fines (%)
2475	0	**SILTY SAND WITH GRAVEL** (SM), some fine to coarse subrounded gravel, predominantly fine to medium sand, weak cementation, nonplastic to low plasticity, light brown, slightly moist, medium dense to dense	Bulk (0–5)	X	4-8-20 (28)			NP	20.0
	2.5			Ring	26-22	2.1	105.6		
2470	5			X	10-9-23 (32)				
	7.5	Note: very dense at 7.5 feet		Ring	50/5"				
2465	10	10.0 **SILTY SAND** (SM), trace fine to coarse subrounded gravel, predominantly fine to medium sand, weak to moderate cementation, nonplastic, light brown, slightly moist, dense to very dense		X	14-16-24 (40)				
2460	15	Note: gray at 15 feet		X	32-50/5"				
2455	20			X	35-50/2"				
2450	25			X	19-30-49 (79)	3.1		NP	29.0
	28	28.0 **CLAYEY SAND** (SC), trace fine subrounded gravel, predominantly fine to medium sand, moderate to strong cementation, medium plasticity, light brown to white, slightly moist 30.9							
2445	30			X	35-50/5"				

Auger stopped at 30 feet. Sampler refused at 30.9 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale	BORING ID: D-SB-3	
	PROJECT LOCATION: Yavapai County, Arizona	AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc	DATE STARTED: 06/19/2025	DATE COMPLETED: 06/19/2025
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 6-5/8" OD Hollow Stem Auger	HAMMER TYPE: auto	HAMMER EFFICIENCY: 71%
SURFACE ELEVATION: 2545'	STATION: 276+50 / OFFSET AND OFFSET DIRECTION: 55' L	US 93 Cst CL	
DRILLING FIRM: ACS Drilling Services, LLC	DRILLER: N. Zamora / FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 51
REPORTED DEPTH: 30.1'	GROUNDWATER DEPTH: N/A / REVIEWED BY: J. Huston	LATITUDE: 34.04453	LONGITUDE: -112.83753

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Blow Counts/6"	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (LL-PL-PI)	Fines (%)
			CLAYEY SAND (SC), occasional fine subrounded gravel, predominantly fine to medium subangular sand, moderate cementation, medium plasticity, light brown, slightly moist, very firm to hard	Bulk	X	9-17-35 (52)				
				Bulk	Ring	27-48	3.5	98.3	30-16-14	18.0
2540	5		Note: predominately fine sand below 5 feet		X	7-16-41 (57)				
					X	50/5"				
2535	10				Ring	14-50/5"				
2530	15		Note: strong cementation below 15 feet		X	30-50/1"				
2525	20		Note: fine to medium subangular sand below 20 feet		X	37-50/1"				
2520	25					50/1"				
2515	30		30.1			50/1"				

Auger stopped at 30 feet. Sampler refused at 30.1 feet. Backfilled with cuttings.

PROJECT NAME: US 93, Vista Royale		BORING ID: D-SB-4	
PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	

PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 06/19/2025	DATE COMPLETED: 06/19/2025
DRILLING METHOD(S): Hollow Stem Auger	TOOLING: 6-5/8" OD Hollow Stem Auger		HAMMER TYPE: auto	HAMMER EFFICIENCY: 71%
SURFACE ELEVATION: 2590'	STATION: 325+50	OFFSET AND OFFSET DIRECTION: 70' L		US 93 Cst CL
DRILLING FIRM: ACS Drilling Services, LLC	DRILLER: N. Zamora	FIELD ENGINEER: R. Bohon	RIG TYPE: CME-75	RIG NUMBER: 51
REPORTED DEPTH: 30.4'	GROUNDWATER DEPTH: N/A	REVIEWED BY: J. Huston	LATITUDE: 34.05294	LONGITUDE: -112.84969

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
	0		**CLAYEY SAND** (SC), occasional to trace fine subangular to subrounded gravel, predominantly fine to medium sand, weak to moderate cementation, low to medium plasticity, slightly moist, very firm to hard			7-8-30 (38)				
						50/5"				
2585	5					9-19-50/4"	2.8		28-18-10	41.0
			Note: moderate to strong cementation, light brown to white, hard below 8 feet			50/5"				
2580	10					50/3"				
2575	15					50/5"				
2570	20					50/5"				
2565	25					45-50/5"				
2560	30		30.4			50/5"				

Auger stopped at 30 feet. Sampler refused at 30.4 feet. Backfilled with cuttings.

ethos ENGINEERING, LLC.

PROJECT NAME: US 93, Vista Royale		**BORING ID:**	**S-1**
PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc	DATE STARTED: 04/29/2025	DATE COMPLETED: 04/30/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer	HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 196+65 / OFFSET AND OFFSET DIRECTION: 90' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza / FIELD ENGINEER: J. Brown	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A / REVIEWED BY: M. Meza	LATITUDE: 34.03031	LONGITUDE: -112.81704

Elevation (feet)	Depth (feet)	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Blow Counts/6"	Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (LL-PL-PI)	Fines (%)
2450	0	**SILTY SAND** (SM), trace fine subangular gravel, predominantly fine to medium subangular sand, weak cementation, nonplastic, gray to light brown, slightly moist, firm	Bulk (0–5 ft)						
	1			Driven	18-18	1.7	120.8	NP	
	2					1.4		NP	12.0
2445	5								
2440	10			Driven	16-24	10.4	109.7		
2435	15	Note: moderate to strong cementation, hard below 15 feet		Driven	50/4"				
2430	20			Driven	30-50/5"				
2425	25			Driven	20-35-35 (70)				
2420	30			Driven	18-30-40 (70)	2.5		NP	18.0
	34.0	**SAND WITH SILT** (SP-SM), trace fine subangular gravel, predominantly fine to medium subangular sand, moderate cementation, nonplastic, gray to light brown, slightly moist, very dense							
2415	35			Driven	27-25-36 (61)				

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID: S-1	
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 04/29/2025	DATE COMPLETED: 04/30/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 196+65	OFFSET AND OFFSET DIRECTION: 90' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03031	LONGITUDE: -112.81704

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SAND WITH SILT** (SP-SM), trace fine subangular gravel, predominantly fine to medium subangular sand, moderate cementation, nonplastic, gray to light brown, slightly moist, very dense							
2410	40				X	20-50/5"				
2405	45				X	16-26-28 (54)				
2400	50				X	50/5"				
	53.0		**SILTY CLAY WITH SAND** (CL-ML), some to considerable predominantly fine sand, weak cementation, low plasticity, brown, slightly moist to moist, very firm							
2395	55				X	17-14-19 (33)	11.5		27-21-6	75.0
	59.0		**SILTY, CLAYEY SAND** (SC-SM), considerable predominantly fine to medium subangular sand, strong cementation, nonplastic to low plasticity, light brown, slightly moist, hard							
2390	60				X	30-50/5"				
	63.0		**SILTY CLAY WITH SAND** (CL-ML), considerable predominantly fine sand, moderate cementation, low plasticity, brown, slightly moist to moist, hard							
2385	65				X	16-24-37 (61)				
	68.0		**SILTY, CLAYEY SAND** (SC-SM), occasional fine subangular gravel, predominantly fine sand, moderate cementation, low plasticity, light gray to light brown, slightly moist to moist, very firm to hard							
2380	70				X	26-28-50/5"				

PROJECT NAME: US 93, Vista Royale	BORING ID: S-1	
PROJECT LOCATION: Yavapai County, Arizona	AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	

PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 04/29/2025	DATE COMPLETED: 04/30/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 196+65	OFFSET AND OFFSET DIRECTION: 90' L		US 93 Cst CL
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03031	LONGITUDE: -112.81704

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SILTY, CLAYEY SAND** (SC-SM), occasional fine subangular gravel, predominantly fine sand, moderate cementation, low plasticity, light gray to light brown, slightly moist to moist, very firm to hard		X	19-50/5"				
2370	80		81.5		X	21-22-26 (48)	10.4		25-20-5	47.0

Hammer stopped at 80 feet. Sampler stopped at 81.5 feet.
Backfilled with cuttings.

ethos ENGINEERING, LLC.	**PROJECT NAME:** US 93, Vista Royale		**BORING ID:**	**S-2**
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 04/30/2025	DATE COMPLETED: 05/01/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 197+70	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03041	LONGITUDE: -112.81721

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
	0		**SILTY SAND** (SM), trace fine subangular gravel, predominantly fine to medium subangular sand, nonplastic, gray to light brown, slightly moist, firm	Bulk (0–5)						
	1				Driven	11-10	1.2		NP	14.0
2445	5				Driven	8-11	0.8	108.9		
2440	10		Note: hard below 10 feet		Driven	15-50/5"				
	14.0									
2435	15		**SANDY SILTY CLAY** (CL-ML), rare fine subangular gravel, considerable predominantly fine sand, moderate to strong cementation, low plasticity, slightly moist, hard		Driven	37-50/5"				
2430	20				Driven	20-37-50/5"	5.7		26-21-5	57.0
2425	25				Driven	23-31-50/3"				
2420	30				Driven	27-50/5"				
	34.0									
2415	35		**SILTY SAND** (SM), trace predominantly fine subangular gravel, predominantly fine to medium subangular sand, weak to moderate cementation, light brown to light gray, slightly moist, hard		Driven	17-31-29 (60)				

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale			BORING ID:	S-2
	PROJECT LOCATION: Yavapai County, Arizona			AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc			DATE STARTED: 04/30/2025	DATE COMPLETED: 05/01/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer			HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 197+70	OFFSET AND OFFSET DIRECTION: 70' L		US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown		RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza		LATITUDE: 34.03041	LONGITUDE: -112.81721

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SILTY SAND** (SM), trace predominantly fine subangular gravel, predominantly fine to medium subangular sand, weak to moderate cementation, light brown to light gray, slightly moist, hard							
2410	40				X	27-36-40 (76)	4.9		NP	29.0
2405	45				X	18-50/5"				
2400	50		50.0							
			SILTY CLAY WITH SAND (CL-ML), some to considerable predominantly fine sand, weak cementation, low plasticity, brown, slightly moist to moist, hard		X	30-50/5"				
2395	55				X	13-21-50/4"				
2390	60				X	22-34-50/5"				
2385	65				X	17-23-28 (51)				
			67.0							
			SILTY SAND (SM), rare fine subangular gravel, predominantly fine sand, weak cementation, nonplastic, light gray to light brown, slightly moist, very firm							
2380	70				X	21-17-18 (35)	6.0		NP	34.0
			72.0							
			SAND WITH SILT (SP-SM), occasional predominantly fine subangular gravel, predominantly fine to medium subangular sand, strong cementation, nonplastic, gray to light brown, slightly moist							

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID: S-2	
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 04/30/2025	DATE COMPLETED: 05/01/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 197+70	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03041	LONGITUDE: -112.81721

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SAND WITH SILT** (SP-SM), occasional predominantly fine subangular gravel, predominantly fine to medium subangular sand, strong cementation, nonplastic, gray to light brown, slightly moist 77.0		X	25-30-50/5"				
2370	80		**SILTY, CLAYEY SAND** (SC-SM), rare fine subangular gravel, predominantly fine to medium subangular sand, moderate cementation, low plasticity, light brown to white, slightly moist, very firm to hard		X	20-14-27 (41)				
2365	85				X	26-24-40 (64)				
2360	90				X	25-31-50/5"	4.9		NP	21.0
2355	95				X	30-50/5"				
			Note: decreased fines at 99 feet 99.9		X	30-50/5"				

Hammer stopped at 99 feet. Sampler refused at 99.9 feet.
Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID: S-3	
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 05/01/2025	DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 199+05	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown/ L. Sulzen	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03074	LONGITUDE: -112.81761

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
	0–12.0		**SAND WITH SILT** (SP-SM), trace fine subangular gravel, predominantly fine to medium subangular sand, nonplastic, light brown, slightly moist, medium dense to dense	X (0–5)						
	1				X	4-13	1.1		NP	9.9
2445	5				X	15-28	1.1	111.1		
2440	10				X	35-21				
	12.0–19.0		**SAND** (SP), trace fine to coarse subangular gravel, predominantly fine to medium subangular sand, nonplastic, light brown, slightly moist, dense to very dense							
2435	15				X	18-18-32 (50)	3.4		NP	4.6
	19.0–		**SILTY SAND** (SM), occasional fine to coarse subangular gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, light gray to light brown, slightly moist, very firm to hard							
2430	20				X	26-22-25 (47)				
2425	25				X	36-22-22 (44)				
2420	30				X	23-30-40 (70)	6.3		NP	35.0
2415	35				X	31-50/3"				

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID:	S-3
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 05/01/2025	DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 199+05	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown/ L. Sulzen	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03074	LONGITUDE: -112.81761

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page							
2410	40		**SILTY SAND** (SM), occasional fine to coarse subangular gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, light gray to light brown, slightly moist, very firm to hard		X	18-25-25 (50)				
2405	45		Note: occasional fine subangular gravel below 45 feet		X	19-17-24 (41)	3.3		NP	13.0
2400	50		50.0							
			SILTY, CLAYEY SAND (SC-SM), occasional fine subangular gravel, predominantly fine to medium subangular sand, weak cementation, low plasticity, light brown, slightly moist, hard		X	19-26-25 (51)				
2395	55				X	15-18-28 (46)				
2390	60		60.0							
			SILTY SAND (SM), occasional fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, light brown to gray, slightly moist, hard		X	20-32-35 (67)	3.5		NP	22.0
2385	65				X	40-50/5"				
2380	70				X	27-32-50/3"				

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID: S-3	
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 05/01/2025	DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 86%
SURFACE ELEVATION: 2450'	STATION: 199+05	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: J. Brown/ L. Sulzen	RIG TYPE: CME-75	RIG NUMBER: 113
REPORTED DEPTH: 100'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03074	LONGITUDE: -112.81761

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SILTY SAND** (SM), occasional fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, light brown to gray, slightly moist, hard		X	50/5"				
2370	80				X	34-50/5"				
2365	85		Note: slightly moist to moist below 85 feet		X	26-50/5"				
2360	90				X	20-50/4"				
2355	95				X	26-33-50/4"	3.2		NP	13.0
	99.4				X	50/5"				

Hammer stopped at 99 feet. Sampler refused at 99.4 feet.
Backfilled with cuttings.

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		**BORING ID: S-4**
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 05/02/2025 / DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto / HAMMER EFFICIENCY: 84%
SURFACE ELEVATION: 2468'	STATION: 200+10	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: S. Singhar	RIG TYPE: CME-75 / RIG NUMBER: 127
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03092 / LONGITUDE: -112.81789

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
2465			**SILTY SAND** (SM), some cobbles, trace predominantly fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak cementation, nonplastic, light gray to brown, slightly moist to moist, hard	X	X	19-20-38 (58)	4.2		NP	28.0
2460	5				X	35-30-25 (55)				
2455	10		12.0		X	7-24-28 (52)				
			GRAVEL WITH SAND (GP), predominantly fine subangular to subrounded gravel, considerable predominantly fine to medium subangular sand, nonplastic, grayish brown, slightly moist, very dense 14.0							
2450	15		**SAND WITH SILT** (SP-SM), predominantly fine sand, nonplastic, brown, slightly moist, very dense 19.0		X	50/5"				
2445	20		**SILTY, CLAYEY SAND** (SC-SM), trace predominantly fine subangular gravel, predominantly fine sand, moderate to strong cementation, low plasticity, brown, slightly moist, hard 23.0		X	34-50/3"				
2440	25		**SAND WITH SILT** (SP-SM), trace fine subangular to subrounded gravel, predominantly fine to medium subangular sand, nonplastic, grayish brown, slightly moist, very dense 30.0		X	21-22-38 (60)	1.1		NP	7.1
2435	30		**SAND WITH SILT AND GRAVEL** (SP-SM), some fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, brown to light brown, slightly moist, very dense		X	22-37-35 (72)				
	35				X	25-23-38 (61)				

PROJECT NAME: US 93, Vista Royale		BORING ID: S-4	
PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc	DATE STARTED: 05/02/2025	DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer	HAMMER TYPE: Auto	HAMMER EFFICIENCY: 84%
SURFACE ELEVATION: 2468'	STATION: 200+10 / OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza / FIELD ENGINEER: S. Singhar	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A / REVIEWED BY: M. Meza	LATITUDE: 34.03092	LONGITUDE: -112.81789

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Laboratory Results: Dry Density (pcf)	Laboratory Results: Atterberg Limits (LL-PL-PI)	Laboratory Results: Fines (%)
			... continued from previous page **SAND WITH SILT AND GRAVEL** (SP-SM), some fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak to moderate cementation, nonplastic, brown to light brown, slightly moist, very dense							
	40				X	28-25-33 (58)	2.8		NP	10.0
2425										
	45				X	20-24-29 (53)				
2420			Note: gravel lens between 47 to 49 feet							
	50		50.0							
	50		**SILTY SAND** (SM), trace to some fine subangular to subrounded gravel, predominantly fine to medium subangular sand, moderate to strong cementation, nonplastic, brown, slightly moist, hard		X	31-50/5"				
2415										
	55				X	50/4"				
2410										
	60				X	50/5"				
			62.0							
2405			**GRAVEL WITH SAND** (GP), considerable fine to medium subangular sand, predominantly fine subangular to subrounded gravel, nonplastic, grayish brown, slightly moist, very dense							
	65				X	40-25-30 (55)				
2400			68.0							
			SAND WITH SILT (SP-SM), occasional fine subangular to subrounded gravel, predominantly fine to medium subangular sand, weak lime cementation, nonplastic, grayish brown, slightly moist, very dense							
	70				X	30-50/5"	1.9		NP	6.8
2395										

ethos ENGINEERING, LLC.	PROJECT NAME: US 93, Vista Royale		BORING ID: S-4	
	PROJECT LOCATION: Yavapai County, Arizona		AGENCY PROJECT NUMBER: ADOT TRACS F0738 01D	
PROJECT NUMBER: 2024112	CLIENT NAME: AECOM Technical Services, Inc		DATE STARTED: 05/02/2025	DATE COMPLETED: 05/02/2025
DRILLING METHOD(S): Tubex	TOOLING: 4-1/2" OD Downhole Percussion Hammer		HAMMER TYPE: Auto	HAMMER EFFICIENCY: 84%
SURFACE ELEVATION: 2468'	STATION: 200+10	OFFSET AND OFFSET DIRECTION: 70' L	US 93 Cst CL	
DRILLING FIRM: Resilient Drilling Services, LLC	DRILLER: F. Esparza	FIELD ENGINEER: S. Singhar	RIG TYPE: CME-75	RIG NUMBER: 127
REPORTED DEPTH: 80'	GROUNDWATER DEPTH: N/A	REVIEWED BY: M. Meza	LATITUDE: 34.03092	LONGITUDE: -112.81789

Elevation (feet)	Depth (feet)	Graphic Log	Soil Description and Remarks	Samples: Bulk	Samples: Driven	Samples: Blow Counts/6"	Laboratory Results: Moisture Content (%)	Dry Density (pcf)	Atterberg Limits (LL-PL-PI)	Fines (%)
2390	80		**SILTY SAND WITH GRAVEL** (SM), some fine subangular to subrounded gravel, predominantly fine to medium subangular sand, nonplastic, grayish brown, slightly moist, hard Note: reddish brown at 75 feet 81.4		X	40-37-30 (67)				
					X	21-35-50/5"				

Hammer stopped at 80 feet. Sampler refused at 81.4 feet.
Backfilled with cuttings.

APPENDIX B

Laboratory Test Results

TABLE B-1: SUMMARY OF LABORATORY TEST RESULTS

Boring Number	Depth (feet)		USCS/Group Symbol (ASTM D2487)	Percent Fines (minus #200) (ASTM C136)	Liquid Limit (ASTM D4318)	Plasticity Index (ASTM D4318)	Moisture Content (%) (ASTM D2216/T265)	In-Place Dry Density (pcf) (ASTM D2937)	Optimum Moisture Content (%)[1] (ASTM D698A)	Maximum Dry Density (pcf)[1] (ASTM D698A)	pH (AZ 236)	Resistivity (ohm-cm) (AZ 236)	Sulfates (ppm) (AZ 733)	Chlorides (ppm) (AZ 736)	Consolidation (%) (ASTM D2435)	Direct Shear (ASTM D3080)
	Begin	End														
D-SB-1	0.0	5.0	SM	26	NV	NP	2.0				8.8	3,610	18	3		
D-SB-2	0.0	5.0	SM	20	NV	NP	1.8				8.9	5,340	11	14		
D-SB-2	2.5	3.5					2.1	105.6								
D-SB-2	25.0	26.5	SM	29	NV	NP	3.1									
D-SB-3	0.0	5.0									8.8	2,740	12	15		
D-SB-3	2.5	3.5	SC	18	30	14	3.5	98.3								
D-SB-4	0.0	5.0									8.8	3,320	10	27		
D-SB-4	5.0	6.3	SC	41	28	10	2.8									
S-1	0.0	5.0	SM	12	NV	NP	1.4		9.3	121.7	8.8	7,580	31	4		
S-1	1.0	2.0					1.7	120.8					20	30	X	
S-1	10.0	11.0					10.4	109.7								X
S-1	30.0	31.5	SM	18	NV	NP	2.5									
S-1	55.0	56.5	CL-ML	75	27	6	11.5									
S-1	65.0	66.5											28	11		
S-1	80.0	81.5	SC-SM	47	25	5	10.4									
S-2	0.0	4.0	SM	14	NV	NP	1.2				8.6	4,910	21	3		
S-2	5.0	6.0					0.8	108.9								X
S-2	20.0	21.4	CL-ML	57	26	5	5.7									
S-2	35.0	36.5											59	14		

TABLE B-1: SUMMARY OF LABORATORY TEST RESULTS

Boring Number	Depth (feet)		USCS/Group Symbol (ASTM D2487)	Percent Fines (minus #200) (ASTM C136)	Liquid Limit (ASTM D4318)	Plasticity Index (ASTM D4318)	Moisture Content (%) (ASTM D2216/T265)	In-Place Dry Density (pcf) (ASTM D2937)	Optimum Moisture Content (%)[1] (ASTM D698A)	Maximum Dry Density (pcf)[1] (ASTM D698A)	pH (AZ 236)	Resistivity (ohm-cm) (AZ 236)	Sulfates (ppm) (AZ 733)	Chlorides (ppm) (AZ 736)	Consolidation (%) (ASTM D2435)	Direct Shear (ASTM D3080)
	Begin	End														
S-2	40.0	41.5	SM	29	NV	NP	4.9									
S-2	70.0	71.5	SM	34	NV	NP	6.0									
S-2	80.0	81.5											26	3		
S-2	90.0	91.4	SM	21	NV	NP	4.9									
S-3	0.0	5.0	SP-SM	9.9	NV	NP	1.1				8.5	6,280	28	3		
S-3	5.0	6.0					1.1	111.1								
S-3	15.0	16.5	SP	4.6	NV	NP	3.4									X
S-3	30.0	31.5	SM	35	NV	NP	6.3									
S-3	40.0	41.5											39	3		
S-3	45.0	46.5	SM	13	NV	NP	3.3									
S-3	60.0	61.5	SM	22	NV	NP	3.5									
S-3	70.0	71.2											25	11		
S-3	95.0	96.3	SM	13	NV	NP	3.2									
S-4	0.0	5.0	SM	28	NV	NP	4.2				8.6	4,550	24	3		
S-4	25.0	26.5	SP-SM	7.1	NV	NP	1.1									
S-4	30.0	31.5											18	3		
S-4	40.0	41.5	SP-SM	10	NV	NP	2.8									
S-4	70.0	70.9	SP-SM	6.8	NV	NP	1.9									

TABLE B-1: SUMMARY OF LABORATORY TEST RESULTS

Boring Number	Depth (feet) Begin	Depth (feet) End	USCS/Group Symbol (ASTM D2487)	Percent Fines (minus #200) (ASTM C136)	Liquid Limit (ASTM D4318)	Plasticity Index (ASTM D4318)	Moisture Content (%) (ASTM D2216/T265)	In-Place Dry Density (pcf) (ASTM D2937)	Optimum Moisture Content (%)[1] (ASTM D698A)	Maximum Dry Density (pcf)[1] (ASTM D698A)	pH (AZ 236)	Resistivity (ohm-cm) (AZ 236)	Sulfates (ppm) (AZ 733)	Chlorides (ppm) (AZ 736)	Consolidation (%) (ASTM D2435)	Direct Shear (ASTM D3080)
Average				---	---	---	3.7	109.1	9.3	121.7	8.7	4791.3	24.7	9.8	---	---
Standard Deviation				---	---	---	2.8	6.7	---	---	0.1	1505.6	11.9	8.7	---	---
Maximum				75	30	0	11.5	120.8	9.3	121.7	8.9	7,580	59	30	---	---
Minimum				5	NV	NP	0.8	98.3	9.3	121.7	8.5	2,740	10	3	---	---
Count				24	24	24	29	6	1	1	8	8	15	15	1	3

Notes: pcf = pounds per cubic foot; ohm-cm = ohm-centimeters; ppm = parts per million; NV = no value; NP = nonplastic
1) Values include rock correction, see test worksheet for additional details.

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-3057-1	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	6/26/2025
Project City	Yavapai County	Tested By:	Mahalia Davis
Sample Location:	D-SB-1 @ 0 - 5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)			
Sieve Size	**% Retained**	**% Passed**	**Specs**
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	1	99	
3/8"	1	98	
1/4"	1	97	
#4	1	96	
#8	8	88	
#10	2	85	
#16	12	74	
#30	18	56	
#40	8	48	
#50	7	41	
#100	9	31	
#200	6	26	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	2.0
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC	**Laboratory Soil Test Results**

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-3057-3	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	6/26/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	D-SB-2 @ 0 - 5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	11	89	
1 1/2"	0	89	
1"	2	87	
3/4"	0	87	
1/2"	1	86	
3/8"	1	85	
1/4"	2	83	
#4	2	82	
#8	6	76	
#10	2	73	
#16	8	65	
#30	13	52	
#40	7	45	
#50	7	38	
#100	11	27	
#200	7	20	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.8

USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND with gravel

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-3057-5	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	6/26/2025
Project City	Yavapai County	Tested By:	Mahalia davis
Sample Location:	D-SB-2 @ 25.0 - 26.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	3	97	
3/4"	0	97	
1/2"	2	96	
3/8"	1	95	
1/4"	1	94	
#4	1	92	
#8	4	88	
#10	1	87	
#16	6	81	
#30	12	69	
#40	7	63	
#50	7	56	
#100	15	40	
#200	11	29	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	3.1
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC	Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-3057-7	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	6/26/2025
Project City	Yavapai County	Tested By:	Mahalia Davis
Sample Location:	D-SB-3 @ 2.5 - 3.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	1	99	
3/8"	0	99	
1/4"	1	98	
#4	1	97	
#8	9	88	
#10	3	85	
#16	15	69	
#30	19	50	
#40	9	41	
#50	8	33	
#100	9	24	
#200	6	18	

Liquid Limit (ASTM D4318)	30
Plastic Limit (ASTM D4318)	16
Plasticity Index (ASTM D4318)	14
Moisture Content (ASTM D2216)	3.5
USCS Soil Classification	SC

Group Name (ASTM D2487)
Clayey SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-3057-9	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	6/26/2025
Project City	Yavapai County	Tested By:	Mahalia Davis
Sample Location:	D-SB-4 @ 5 - 6.3	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)			
Sieve Size	**% Retained**	**% Passed**	**Specs**
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	100	
1/4"	1	99	
#4	1	98	
#8	7	91	
#10	2	89	
#16	10	79	
#30	13	67	
#40	5	62	
#50	5	57	
#100	8	49	
#200	8	41	

Liquid Limit (ASTM D4318)	28
Plastic Limit (ASTM D4318)	18
Plasticity Index (ASTM D4318)	10
Moisture Content (ASTM D2216)	2.8

USCS Soil Classification	SC

Group Name (ASTM D2487)
Clayey SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-1	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/16/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-1 @ 0 - 5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	1	99	
3/8"	1	98	
1/4"	3	94	
#4	3	92	
#8	9	83	
#10	3	80	
#16	10	70	
#30	18	52	
#40	10	41	
#50	10	31	
#100	12	19	
#200	6	12	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.4
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-5	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-1 @ 30 - 31.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	1	99	
3/8"	2	97	
1/4"	3	94	
#4	2	91	
#8	6	85	
#10	2	83	
#16	6	77	
#30	14	63	
#40	9	55	
#50	12	43	
#100	16	27	
#200	9	18	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	2.5
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-6	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-1 @ 55 - 56.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	100	
1/4"	0	100	
#4	0	100	
#8	1	99	
#10	0	99	
#16	1	98	
#30	2	96	
#40	1	95	
#50	1	93	
#100	7	86	
#200	11	75	

Liquid Limit (ASTM D4318)	27
Plastic Limit (ASTM D4318)	21
Plasticity Index (ASTM D4318)	6
Moisture Content (ASTM D2216)	11.5

USCS Soil Classification	CL-ML

Group Name (ASTM D2487)
SILTY CLAY with sand

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-8	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Colin Eggebrecht
Sample Location:	S-1 @ 80 - 81.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	100	
1/4"	1	98	
#4	1	98	
#8	2	96	
#10	1	95	
#16	2	93	
#30	5	88	
#40	4	84	
#50	6	78	
#100	15	63	
#200	16	47	

Liquid Limit (ASTM D4318)	25
Plastic Limit (ASTM D4318)	20
Plasticity Index (ASTM D4318)	5
Moisture Content (ASTM D2216)	10.4

USCS Soil Classification	SC-SM

Group Name (ASTM D2487)
Silty, clayey SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-9	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/16/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-2 @ 0 - 4	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	1	99	
3/8"	1	98	
1/4"	3	95	
#4	2	93	
#8	7	86	
#10	2	84	
#16	9	75	
#30	18	57	
#40	10	47	
#50	11	36	
#100	15	21	
#200	7	14	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.2
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-11	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-2 @ 20 - 21.4	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	100	
1/4"	1	99	
#4	1	99	
#8	2	97	
#10	1	96	
#16	2	94	
#30	5	89	
#40	3	86	
#50	4	82	
#100	11	71	
#200	14	57	

Liquid Limit (ASTM D4318)	26
Plastic Limit (ASTM D4318)	21
Plasticity Index (ASTM D4318)	5
Moisture Content (ASTM D2216)	5.7
USCS Soil Classification	CL-ML

Group Name (ASTM D2487)
Sandy SILTY CLAY

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-13	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-2 @ 40 - 41.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	3	97	
1/2"	4	94	
3/8"	1	93	
1/4"	3	90	
#4	2	87	
#8	6	82	
#10	1	80	
#16	5	76	
#30	9	67	
#40	6	60	
#50	7	53	
#100	14	40	
#200	11	29	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	4.9

USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-14	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-2 @ 70 - 71.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	99	
1/4"	0	99	
#4	0	99	
#8	1	98	
#10	0	97	
#16	2	95	
#30	5	90	
#40	5	85	
#50	8	77	
#100	23	55	
#200	21	34	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	6.0

USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-16	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-2 @ 90 - 91.4	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	2	98	
3/8"	0	97	
1/4"	2	96	
#4	1	95	
#8	4	91	
#10	1	89	
#16	6	84	
#30	13	70	
#40	9	61	
#50	12	49	
#100	19	30	
#200	9	21	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	4.9
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-17	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-3 @ 0 - 5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	2	98	
1"	0	98	
3/4"	0	97	
1/2"	2	96	
3/8"	2	94	
1/4"	3	91	
#4	2	89	
#8	7	81	
#10	2	79	
#16	10	69	
#30	11	58	
#40	11	47	
#50	20	27	
#100	12	15	
#200	5	9.9	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.1
USCS Soil Classification	SP-SM

Group Name (ASTM D2487)
Poorly graded SAND with silt

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-19	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-3 @ 15 - 16.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)			
Sieve Size	**% Retained**	**% Passed**	**Specs**
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	3	97	
3/8"	0	97	
1/4"	1	96	
#4	1	95	
#8	6	89	
#10	2	87	
#16	12	75	
#30	28	47	
#40	15	32	
#50	12	19	
#100	11	8	
#200	3	4.6	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	3.4
USCS Soil Classification	SP

Group Name (ASTM D2487)
Poorly graded SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-20	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-3 @ 30 - 31.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	4	96	
1/2"	1	96	
3/8"	0	95	
1/4"	0	95	
#4	0	94	
#8	3	91	
#10	1	90	
#16	3	87	
#30	7	79	
#40	5	74	
#50	7	67	
#100	17	50	
#200	15	35	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	6.3
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-22	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-3 @ 45 - 46.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	1	99	
1/4"	1	98	
#4	1	97	
#8	4	93	
#10	1	92	
#16	5	87	
#30	15	73	
#40	12	61	
#50	15	46	
#100	24	23	
#200	10	13	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	3.3
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-23	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-3 @ 60 - 61.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	2	98	
3/8"	1	97	
1/4"	2	95	
#4	1	93	
#8	5	88	
#10	1	87	
#16	6	81	
#30	13	68	
#40	9	59	
#50	9	50	
#100	15	35	
#200	13	22	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	3.5
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-25	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Colin Eggebrecht
Sample Location:	S-3 @ 95 - 96.3	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	0	100	
1/4"	0	100	
#4	0	100	
#8	3	96	
#10	1	95	
#16	6	90	
#30	12	77	
#40	12	66	
#50	18	48	
#100	26	22	
#200	9	13	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	3.2
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS SERVICES LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-26	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/19/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-4 @ 0 - 5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	1	99	
3/4"	0	99	
1/2"	2	98	
3/8"	2	96	
1/4"	3	92	
#4	3	90	
#8	6	84	
#10	2	81	
#16	6	76	
#30	10	66	
#40	7	59	
#50	8	51	
#100	14	37	
#200	9	28	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	4.2
USCS Soil Classification	SM

Group Name (ASTM D2487)
Silty SAND

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC	Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-27	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-4 @ 25 - 26.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	2	98	
3/8"	2	96	
1/4"	2	94	
#4	2	92	
#8	5	87	
#10	2	85	
#16	7	78	
#30	21	57	
#40	14	44	
#50	14	30	
#100	16	13	
#200	6	7.1	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.1

USCS Soil Classification	SP-SM

Group Name (ASTM D2487)
Poorly graded SAND with silt

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC	**Laboratory Soil Test Results**

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-29	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/20/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-4 @ 40 - 41.5	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	7	93	
3/8"	5	88	
1/4"	5	83	
#4	4	79	
#8	8	71	
#10	2	70	
#16	6	63	
#30	12	52	
#40	8	43	
#50	11	33	
#100	15	17	
#200	7	10	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	2.8
USCS Soil Classification	SP-SM

Group Name (ASTM D2487)
Poorly graded SAND with silt and gravel

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield
Laboratory Manager

Keagen Mayfield
Signature

ACS Services LLC

Laboratory Soil Test Results

ACS PROJECT #	2501369	Material Type:	Soils
ACS Lab #	25-2593-30	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	5/23/2025
Project City	Yavapai County	Tested By:	Austin Archibald
Sample Location:	S-4 @ 70 - 70.9	Reviewed By:	Keagen Mayfield

Sieve Analysis (ASTM C-136 / AASHTO T 27 / ARIZ 201)

Sieve Size	% Retained	% Passed	Specs
6"	0	100	
3"	0	100	
2 1/2"	0	100	
2"	0	100	
1 1/2"	0	100	
1"	0	100	
3/4"	0	100	
1/2"	0	100	
3/8"	1	99	
1/4"	1	98	
#4	2	97	
#8	8	89	
#10	2	87	
#16	10	77	
#30	21	56	
#40	13	43	
#50	13	31	
#100	17	14	
#200	7	6.8	

Liquid Limit (ASTM D4318)	
Plastic Limit (ASTM D4318)	
Plasticity Index (ASTM D4318)	NP
Moisture Content (ASTM D2216)	1.9

USCS Soil Classification	SP-SM

Group Name (ASTM D2487)
Poorly graded SAND with silt

Testing sizes reduced from standard minimums due to lack of material

Keagen Mayfield

Laboratory Manager

Keagen Mayfield

Signature

ACS Services LLC

Job #	2501369	Material Type:	Soils
Lab #	25-3057	Extraction Date:	6/23/2025
Client:	Ethos Engineering, LLC	Extracted By:	Client
Project Name:	US93 Vista Royale	Laboratory Test Date	6/26/2025
Project Address:	Yavapai County	Laboratory Tested By:	Mahalia Davis
Project City:	Yavapai County	Reviewed By:	Keagen Mayfield
Material Source:	-		

Density of Soil in Place by the Drive-Cylinder Method (ASTM D2937)

ID #	Sample Location	Wet Wt. (g)	Moisture Dry Wt. (g)	**Moist Content**	# Of Rings	Wet Wt'+Rings (g)	Wt. of Rings (g)	**Dry Density (pcf)**
25-3057-4	D-SB-2 @ 2.5 - 3.5	651.1	637.6	2.1%	5	866.8	215.7	105.6
25-3057-7	D-SB-3 @ 2.5 - 3.5	491.3	474.9	3.5%	4	664.9	173.6	98.3

ACS Services LLC

Job #	2501369	Material Type:	Soils
Lab #	25-2593	Extraction Date:	5/6/2025
Client:	Ethos Engineering, LLC	Extracted By:	Client
Project Name:	US93 Vista Royale	Laboratory Test Date	5/15/2025
Project Address:	Yavapai County	Laboratory Tested By:	Colin Eggebrecht
Project City:	Yavapai County	Reviewed By:	Keagen Mayfield
Material Source:	-		

Density of Soil in Place by the Drive-Cylinder Method (ASTM D2937)

ID #	Sample Location	Wet Wt. (g)	Moisture Dry Wt. (g)	**Moist Content**	# Of Rings	Wet Wt'+Rings (g)	Wt. of Rings (g)	**Dry Density (pcf)**
25-2593-2	S-1 @ 1 - 2	445.2	437.8	1.7%	3	578.4	133.2	120.8

ACS Services LLC	Maximum Dry Density & Optimum Moisture
	☐ AASHTO T 99 | ☐ AASHTO T 180 | ☑ ASTM D698 | ☐ ASTM D1557

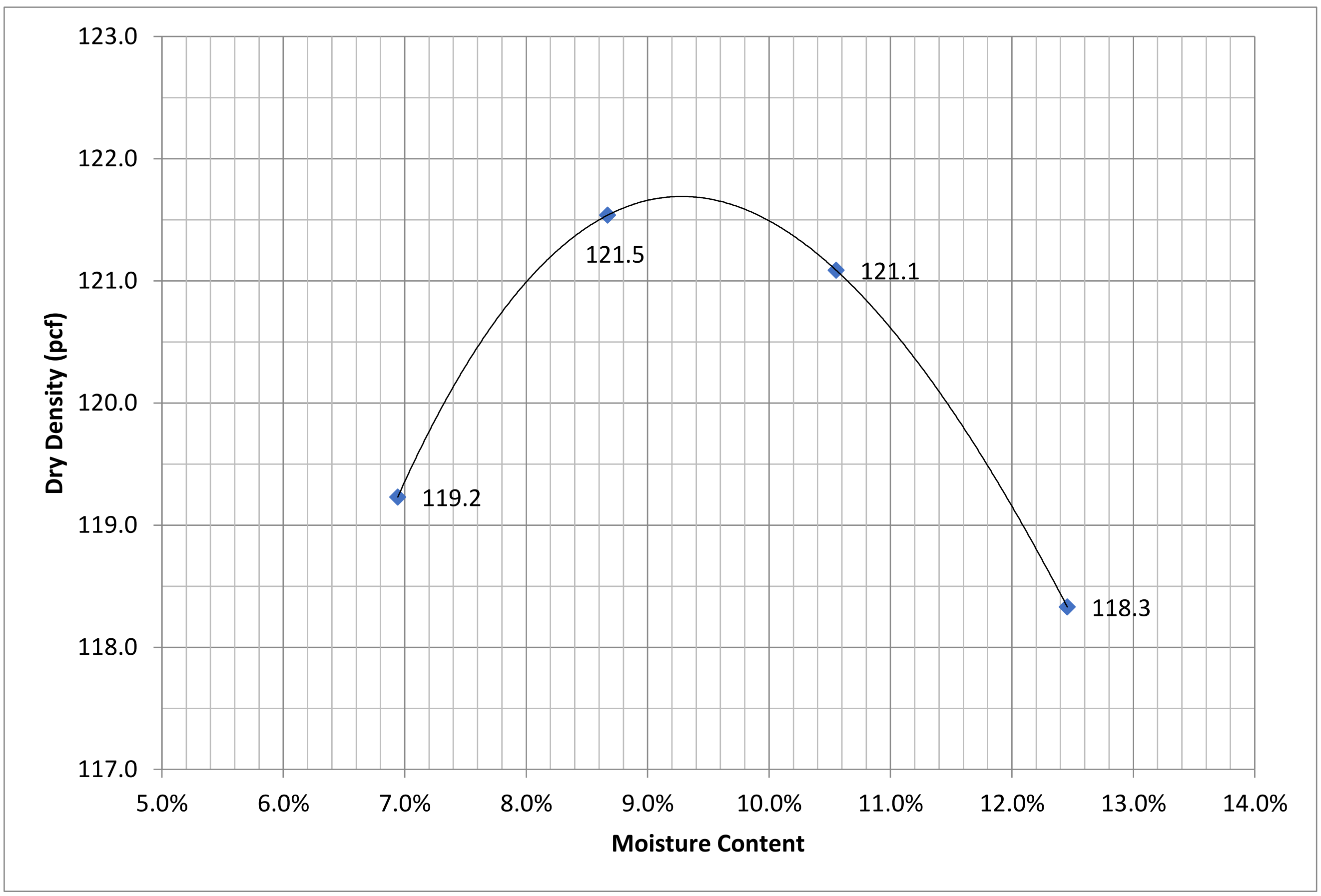
ACS Project #	2501369	Material Type:	Soils
ACS Lab #	25-2593-1	Material Supplier:	Client
Client Name:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Date Tested:	5/19/2025
Project City:	Yavapai County	Tested By:	Austin Archibald
		Reviewed By:	Keagen Mayfield

Sample Location: S-1 @ 0 - 5

Method: ☑ A ☐ B ☐ C ☐ D

Dry Density	119.2	121.5	121.1	118.3
Moisture Content	6.9%	8.7%	10.6%	12.5%

Uncorrected Dry Density	121.7	Uncorrected Moisture Content	9.3
% Rock	9	% Passing	91
Rock Corrected Dry Density	**124.5**	Rock Corrected Moisture Content	**8.6**
Specific Gravity of Oversize Aggregate	**2.600**		



Keagen Mayfield

Project Manager

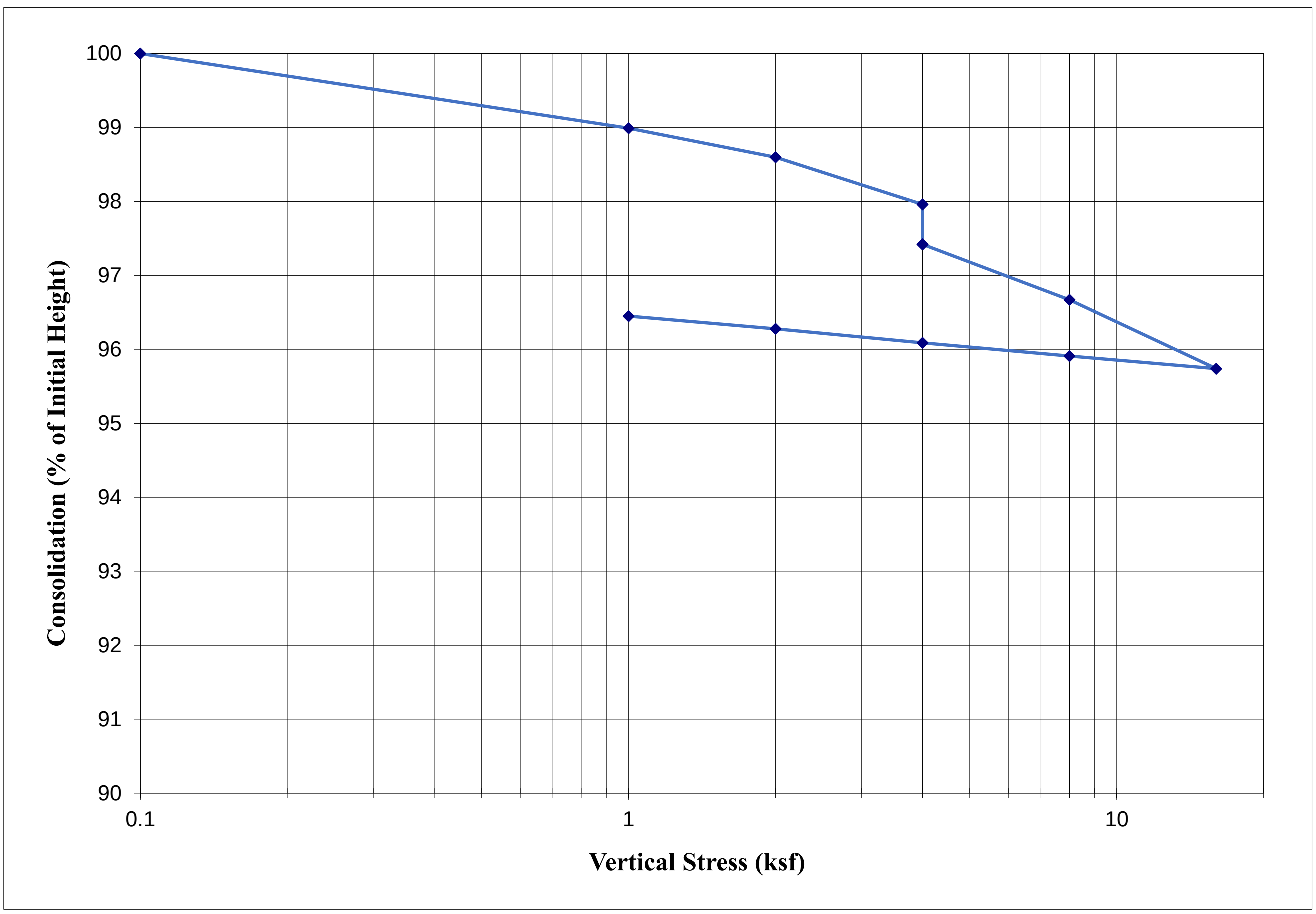
ACS Services LLC

ENGINEERING DESIGN • MATERIAL TESTING • CONSTRUCTION INSPECTION

* ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

ACS Project No.:	**2501369**		
Lab No.:	**25-2593-2**	Material Type:	Soils
Client:	Ethos Engineering, LLC	Date of Extraction:	5/6/2025
Project Name:	US93 Vista Royale	Extracted By:	Client
Project Address:	Yavapai County	Date of Lab Test:	5/16/2025
Project City:	Yavapai County	Lab Tested By:	Colin Eggebrecht
Sample Location:	S-1 @ 1 - 2	Reviewed By:	Keagen Mayfield

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.49
INITIAL MOISTURE CONTENT	1.9%	FINAL MOISTURE CONTENT	13.7%
INITIAL DRY DENSITY(pcf)	110.2	FINAL DRY DENSITY(pcf)	113.1
INITIAL DEGREE OF SATURATION	10%	FINAL DEGREE OF SATURATION	78%
INITIAL VOID RATIO	0.5	FINAL VOID RATIO	0.5
ESTIMATED SPECIFIC GRAVITY	2.65	SATURATED AT	4 ksf



ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-3057-1	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Friday, June 27, 2025
Project City:	Yavapai County	Tested By:	Mahalia Davis
Sample Source:	D-SB-1 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.8

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	5.0	100	3610
50	7.22	5.7	100	4120

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-3057-3	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Friday, June 27, 2025
Project City:	Yavapai County	Tested By:	Mahalia Davis
Sample Source:	D-SB-2 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.9

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	7.4	100	5340
50	7.22	7.9	100	5700

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-3057-6	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Friday, June 27, 2025
Project City:	Yavapai County	Tested By:	Mahalia Davis
Sample Source:	D-SB-3 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.8

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	5.1	100	3680
50	7.22	3.8	100	2740
50	7.22	4.1	100	2960

Colin Eggebrecht
Lab Supervisor

Keagen Mayfeild
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-3057-8	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	6/23/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Friday, June 27, 2025
Project City:	Yavapai County	Tested By:	Mahalia davis
Sample Source:	D-SB-4 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.8

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	4.7	100	3390
50	7.22	4.6	100	3320
50	7.22	4.8	100	3470

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-2593-1	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Thursday, May 22, 2025
Project City:	Yavapai County	Tested By:	Mahalia davis
Sample Source:	S-1 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.80

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	1.1	1000	7940
50	7.22	10.5	100	7580
50	7.22	10.8	100	7800

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-2593-9	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Thursday, May 22, 2025
Project City:	Yavapai County	Tested By:	Mahalia Davis
Sample Source:	S-2 @ 0 - 4	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.57

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	7.3	100	5270
50	7.22	6.8	100	4910
50	7.22	6.9	100	4980

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-2593-17	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Tuesday, May 20, 2025
Project City:	Yavapai County	Tested By:	Mahalia Davis
Sample Source:	S-3 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.49

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	8.7	100	6280
50	7.22	8.9	100	6430

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

ACS Services LLC	Soil pH and Resistivity Determination AASHTO T-289 AASHTO T-288 / ARIZ 236

Project #	2501369	Material Type:	Soils
Lab #	25-2593-26	Supplier:	Client
Client:	Ethos Engineering, LLC	Sample Date:	5/6/2025
Project Name:	US93 Vista Royale	Sampled By:	Client
Project Address:	Yavapai County	Test Date:	Tuesday, May 20, 2025
Project City:	Yavapai County	Tested By:	Colin Eggebrecht
Sample Source:	S-4 @ 0 - 5	Resistivity Box:	
		Reviewed By:	Keagen Mayfield

pH Reading = 8.61

P = (SBF) x R x M

Where:

SBF = Soil Box Factor, cm
R = Dial Reading, OHMS
M = Multiplier

Water Added	SBF (cm)	Dial Reading (OHMS)	Multiplier	**P** (OHM-cm)
200	7.22	9.6	100	6930
50	7.22	6.7	100	4840
50	7.22	6.3	100	4550
50	7.22	6.5	100	4690

Colin Eggebrecht
Lab Supervisor

Keagen Mayfield
Laboratory Manager

MOTZZ LABORATORY, INC.

Report: 956340
Reported: 7/2/2025
Received: 6/30/2025
PO: 2501369

Laboratory Analysis Report

ACS Services LLC
Keagen Mayfield
2235 W Broadway Road
Mesa, AZ 85202

Project: 2501369

Lab Number	Sample ID	
956340-1	25-3057-8	D-SB-4 (0-5')

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	10	ppm
Chloride	ARIZ 736b	27	ppm

Lab Number	Sample ID	
956340-2	25-3057-1	D-SB-1 (0-5')

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	18	ppm
Chloride	ARIZ 736b	<3	ppm

Lab Number	Sample ID	
956340-3	25-3057-6	D-SB-3 (0-5')

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	12	ppm
Chloride	ARIZ 736b	15	ppm

Lab Number	Sample ID	
956340-4	25-3057-3	D-SB-2 (0-5')

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	11	ppm
Chloride	ARIZ 736b	14	ppm

MOTZZ LABORATORY, INC.

Report: 955654
Reported: 5/21/2025
Received: 5/19/2025
PO: 2501369

Laboratory Analysis Report

ACS Services LLC
Keagen Mayfield
2235 W Broadway Road
Mesa, AZ 85202

Project: 2501369

Lab Number	Sample ID	
955654-1	25-2593-1	S-1 (0-5)

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	31	ppm
Chloride	ARIZ 736b	4	ppm

Lab Number	Sample ID	
955654-2	25-2593-4	S-1 (1-2)

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	20	ppm
Chloride	ARIZ 736b	30	ppm

Lab Number	Sample ID	
955654-3	25-2593-7	S-1 (65-66.5)

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	28	ppm
Chloride	ARIZ 736b	11	ppm

Lab Number	Sample ID	
955654-4	25-2593-9	S-2 (0-4)

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	21	ppm
Chloride	ARIZ 736b	< 3	ppm

Lab Number	Sample ID	
955654-5	25-2593-12	S-2 (35-36.5)

Test Parameter

Test	Method	Result	Units
Sulfate	ARIZ 733b	59	ppm
Chloride	ARIZ 736b	14	ppm

MOTZZ LABORATORY, INC.

Report: 955654
Reported: 5/21/2025
Received: 5/19/2025
PO: 2501369

Laboratory Analysis Report

ACS Services LLC
Keagen Mayfield
2235 W Broadway Road
Mesa, AZ 85202

Project: 2501369

Lab Number	Sample ID	
955654-6	25-2593-15	S-2 (80-81.5)

Test Parameter

Test	*Method*	*Result*	*Units*
Sulfate	ARIZ 733b	26	ppm
Chloride	ARIZ 736b	< 3	ppm

Lab Number	Sample ID	
955654-7	25-2593-17	S-3 (0-5)

Test Parameter

Test	*Method*	*Result*	*Units*
Sulfate	ARIZ 733b	28	ppm
Chloride	ARIZ 736b	< 3	ppm

Lab Number	Sample ID	
955654-8	25-2593-21	S-3 (40-41.5)

Test Parameter

Test	*Method*	*Result*	*Units*
Sulfate	ARIZ 733b	39	ppm
Chloride	ARIZ 736b	< 3	ppm

Lab Number	Sample ID	
955654-9	25-2593-24	S-3 (70-71.2

Test Parameter

Test	*Method*	*Result*	*Units*
Sulfate	ARIZ 733b	25	ppm
Chloride	ARIZ 736b	11	ppm

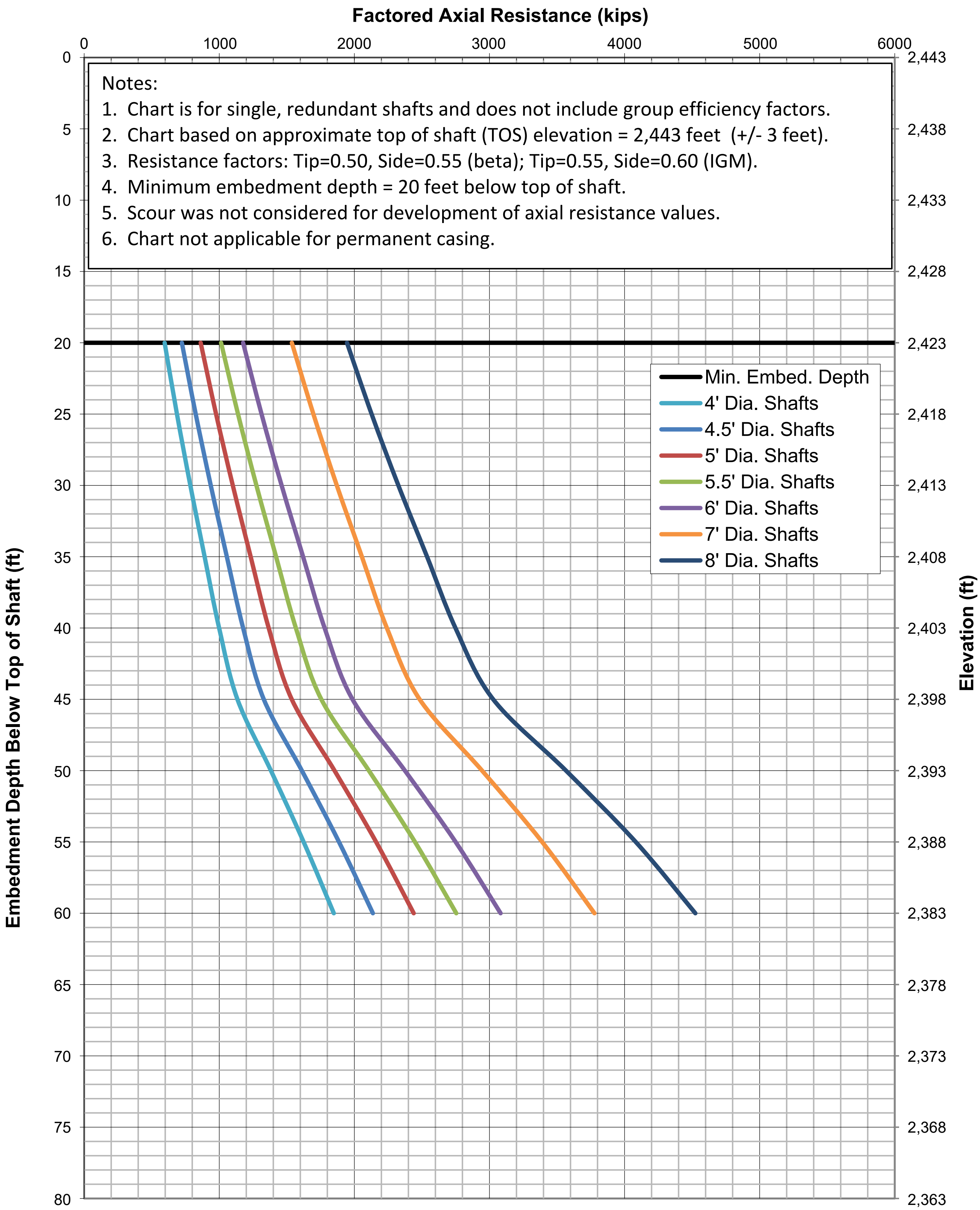
Lab Number	Sample ID	
955654-10	25-2593-26	S-4 (0-5)

Test Parameter

Test	*Method*	*Result*	*Units*
Sulfate	ARIZ 733b	24	ppm
Chloride	ARIZ 736b	< 3	ppm

APPENDIX C

Drilled Shaft Axial Resistance Charts



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	10/31/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

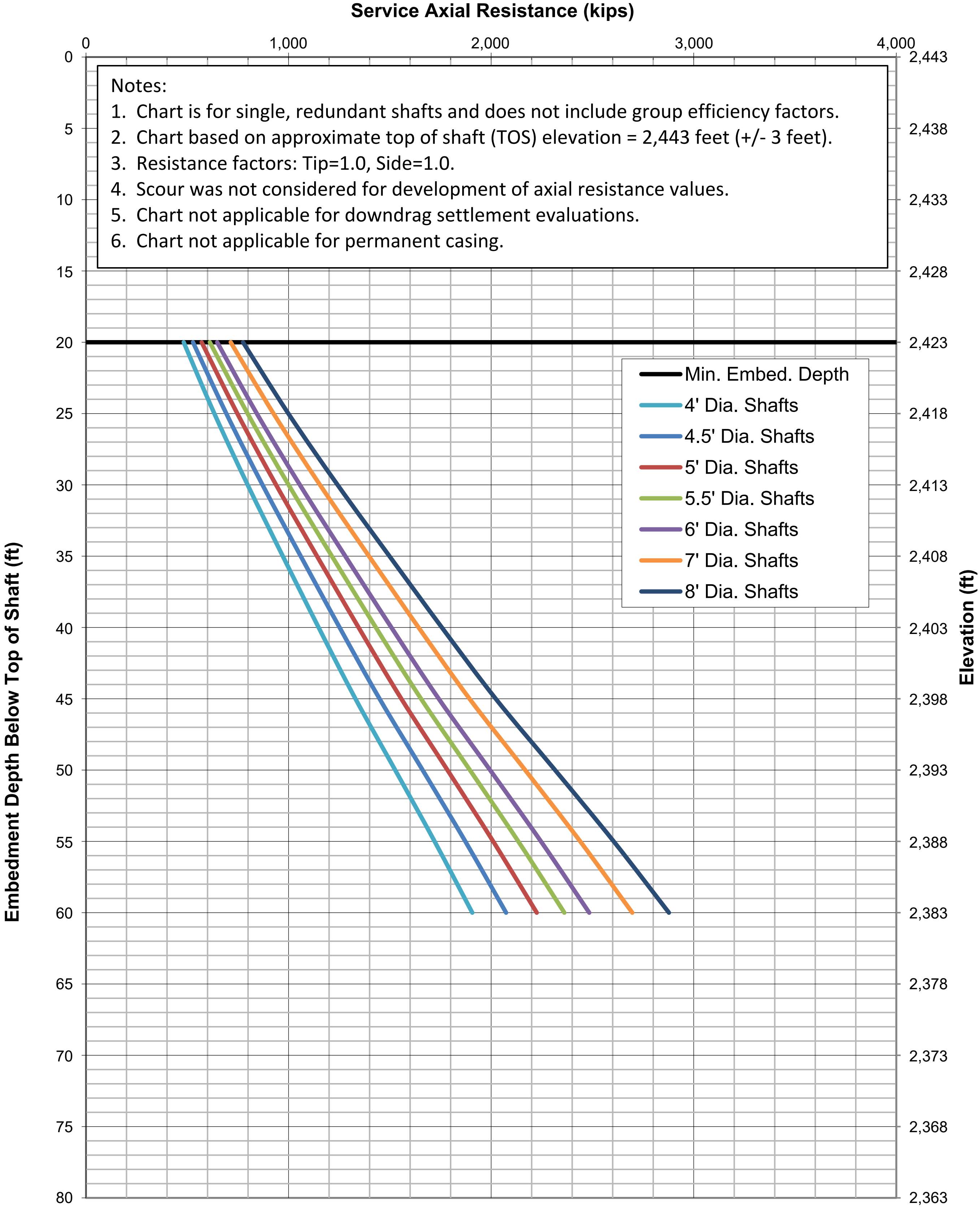
Strength Limit Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 1

Figure

C1



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	10/31/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

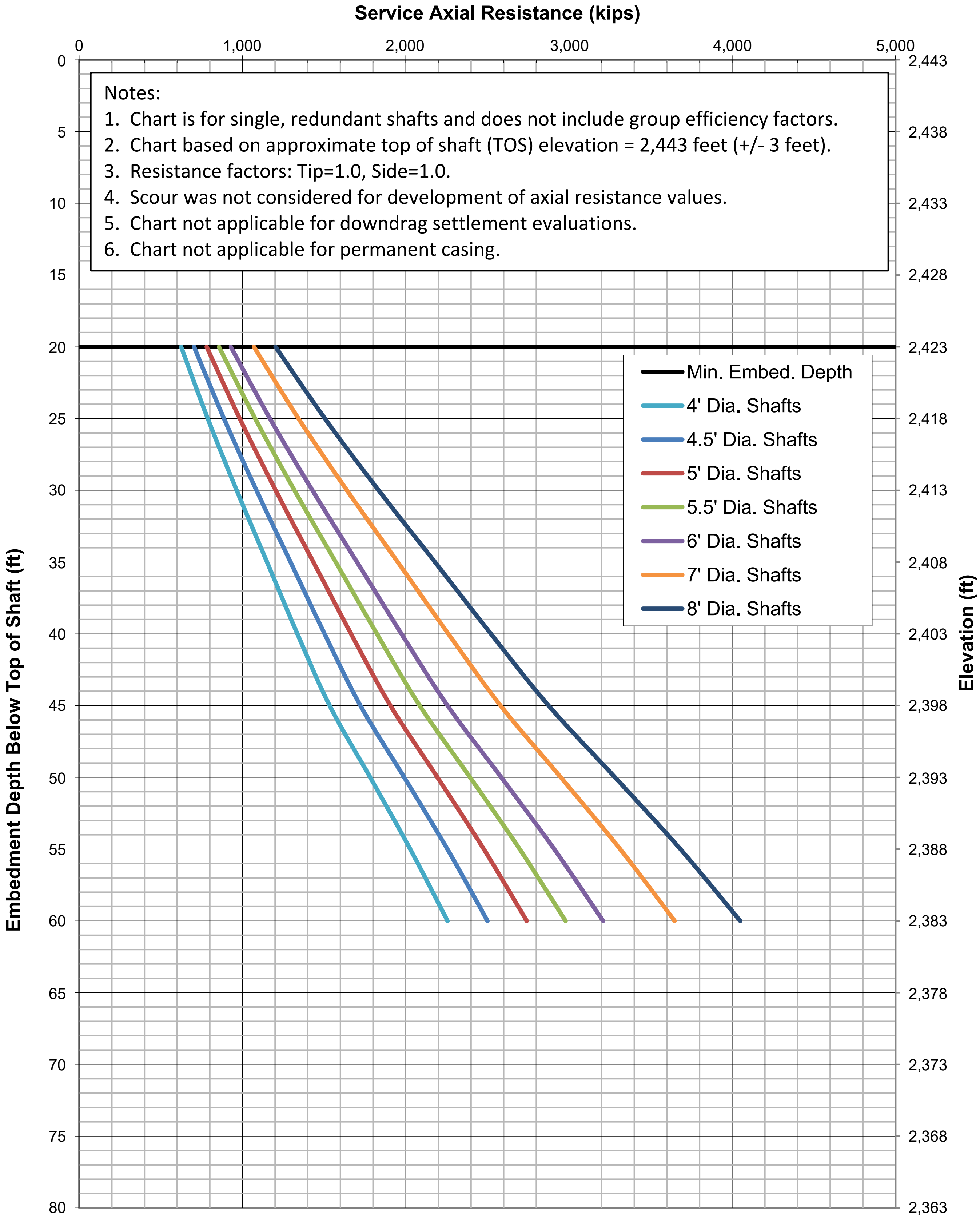
Service Limit (0.25-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 1

Figure

C2



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	10/31/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

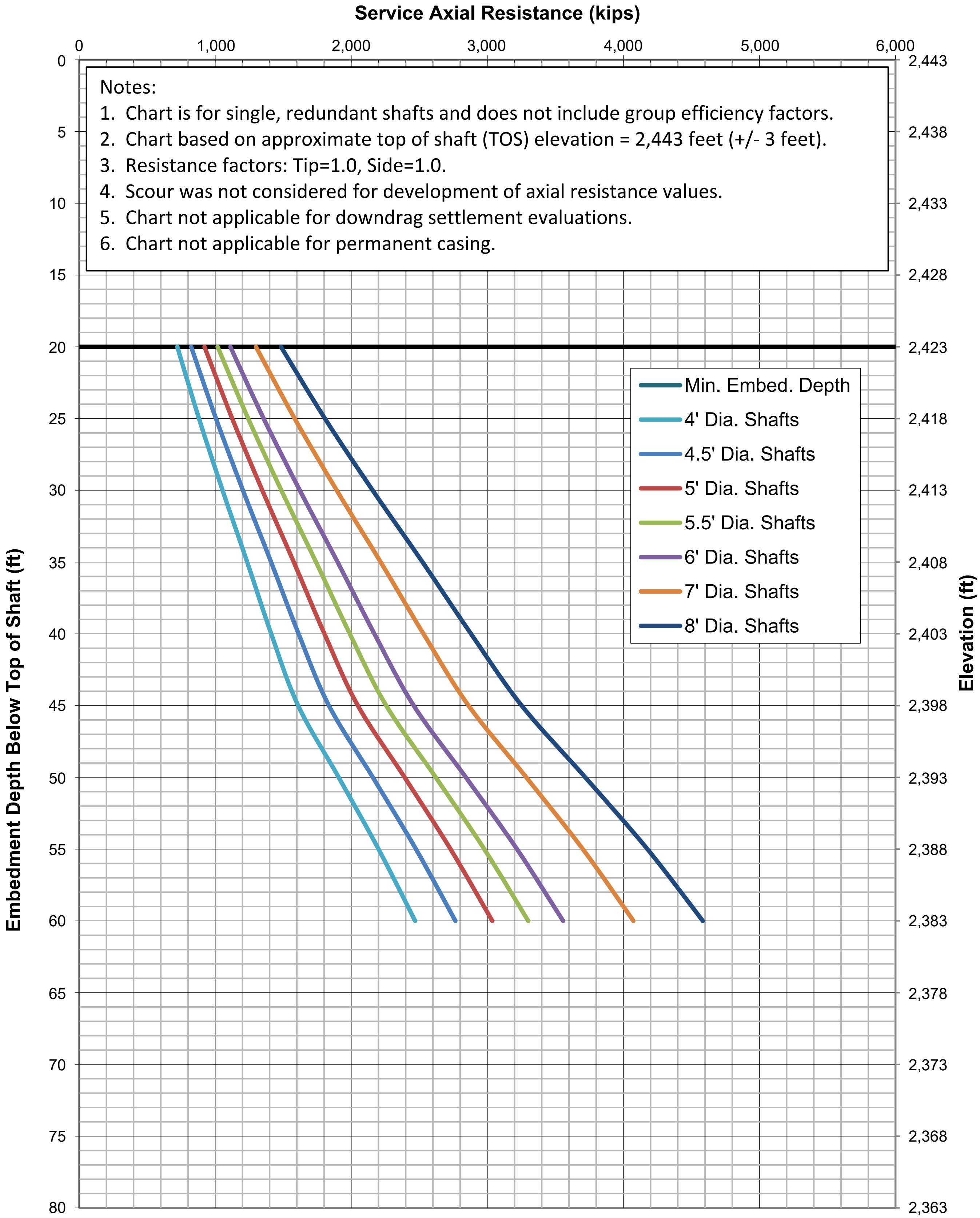
Service Limit (0.5-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 1

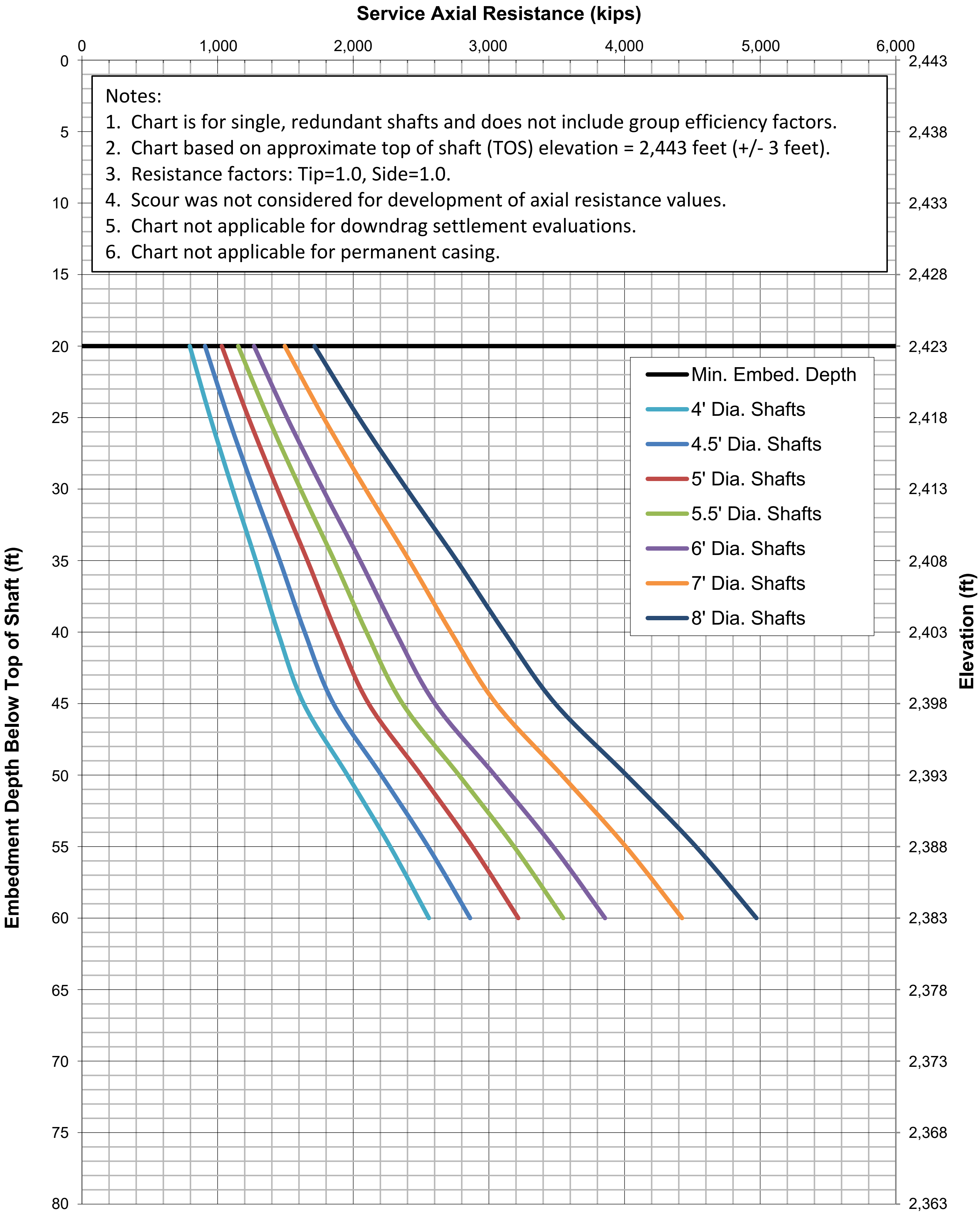
Figure

C3



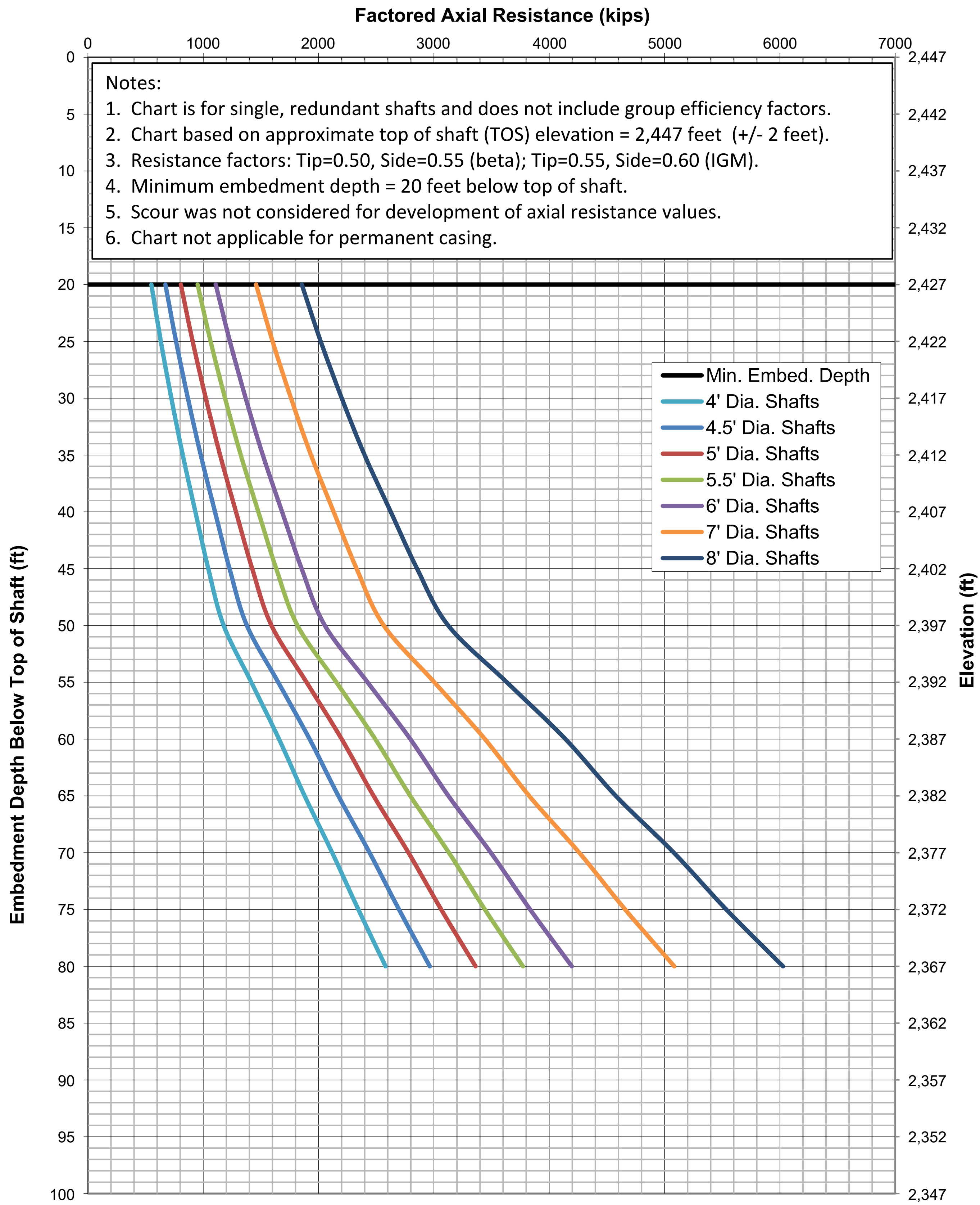
ethos ENGINEERING, LLC.	DRILLED SHAFT FOUNDATION DESIGN CHART Service Limit (0.75-Inch Settlement) - Axial Resistance in Kips US 93, Vista Royale Southbound BNSF Overpass Bridge Abutment 1	Figure C4

Designer:	Date:
K. Mackay	10/31/2025



ethos ENGINEERING, LLC.	DRILLED SHAFT FOUNDATION DESIGN CHART Service Limit (1 Inch Settlement) - Axial Resistance in Kips US 93, Vista Royale Southbound BNSF Overpass Bridge Abutment 1	Figure C5

Designer:	Date:
K. Mackay	10/31/2025



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

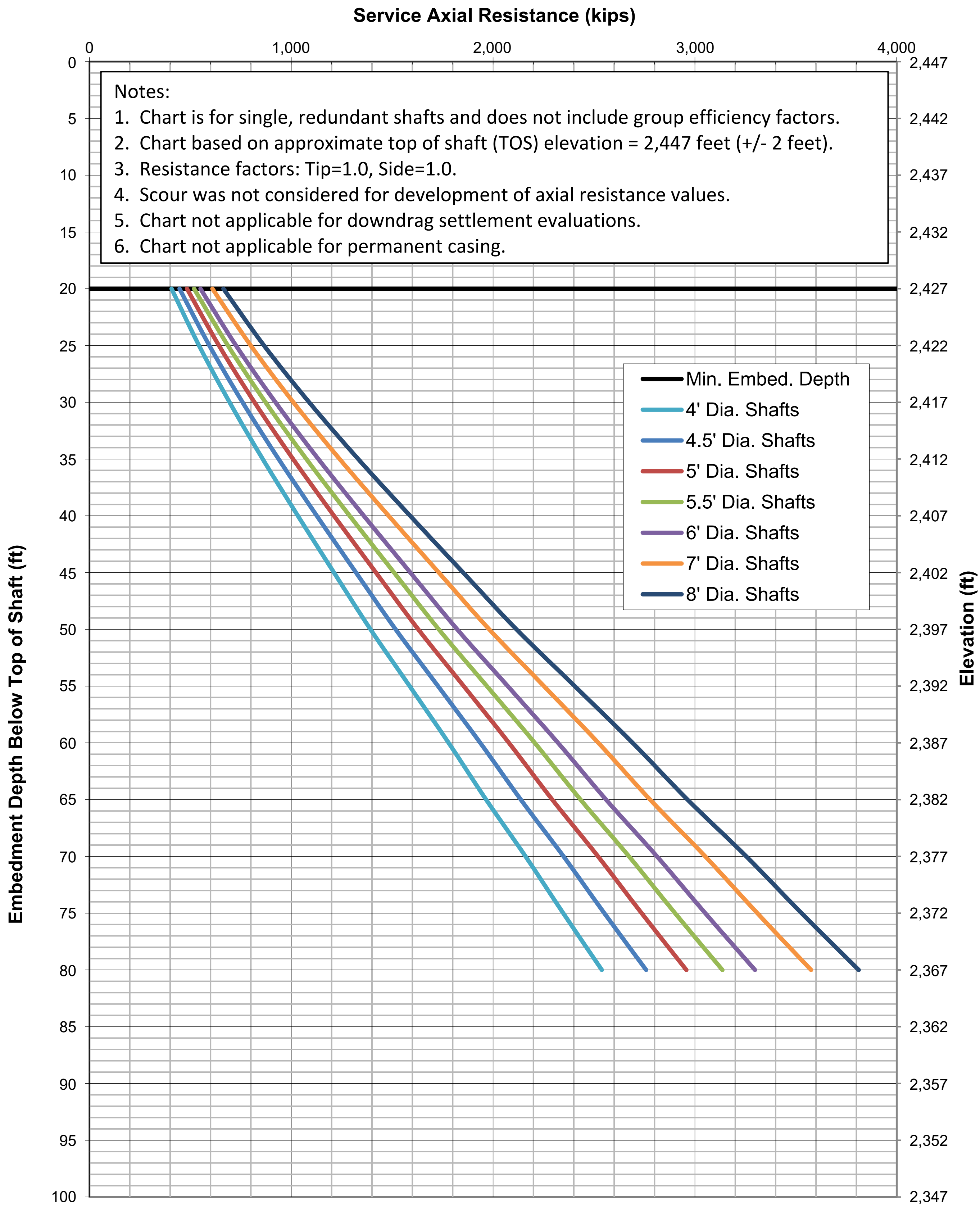
Strength Limit Axial Resistance in Kips

US 93, Vista Royale

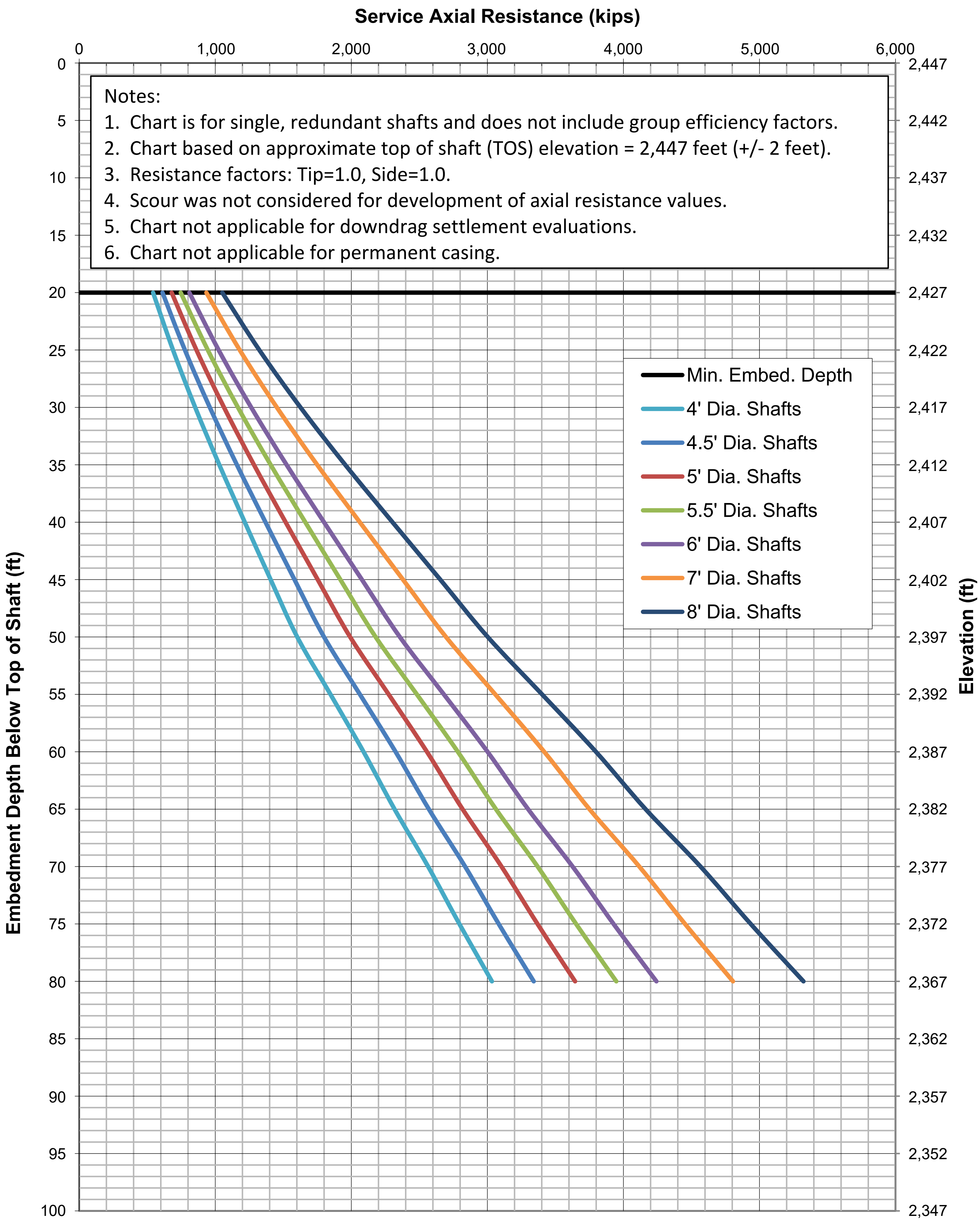
Southbound BNSF Overpass Bridge
Piers

Figure

C6



ethos ENGINEERING, LLC.		**DRILLED SHAFT FOUNDATION DESIGN CHART** **Service Limit (0.25-Inch Settlement) - Axial Resistance in Kips** **US 93, Vista Royale** **Southbound BNSF Overpass Bridge** **Piers**	Figure C7
Designer:	Date:		
K. Mackay	11/3/2025		



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

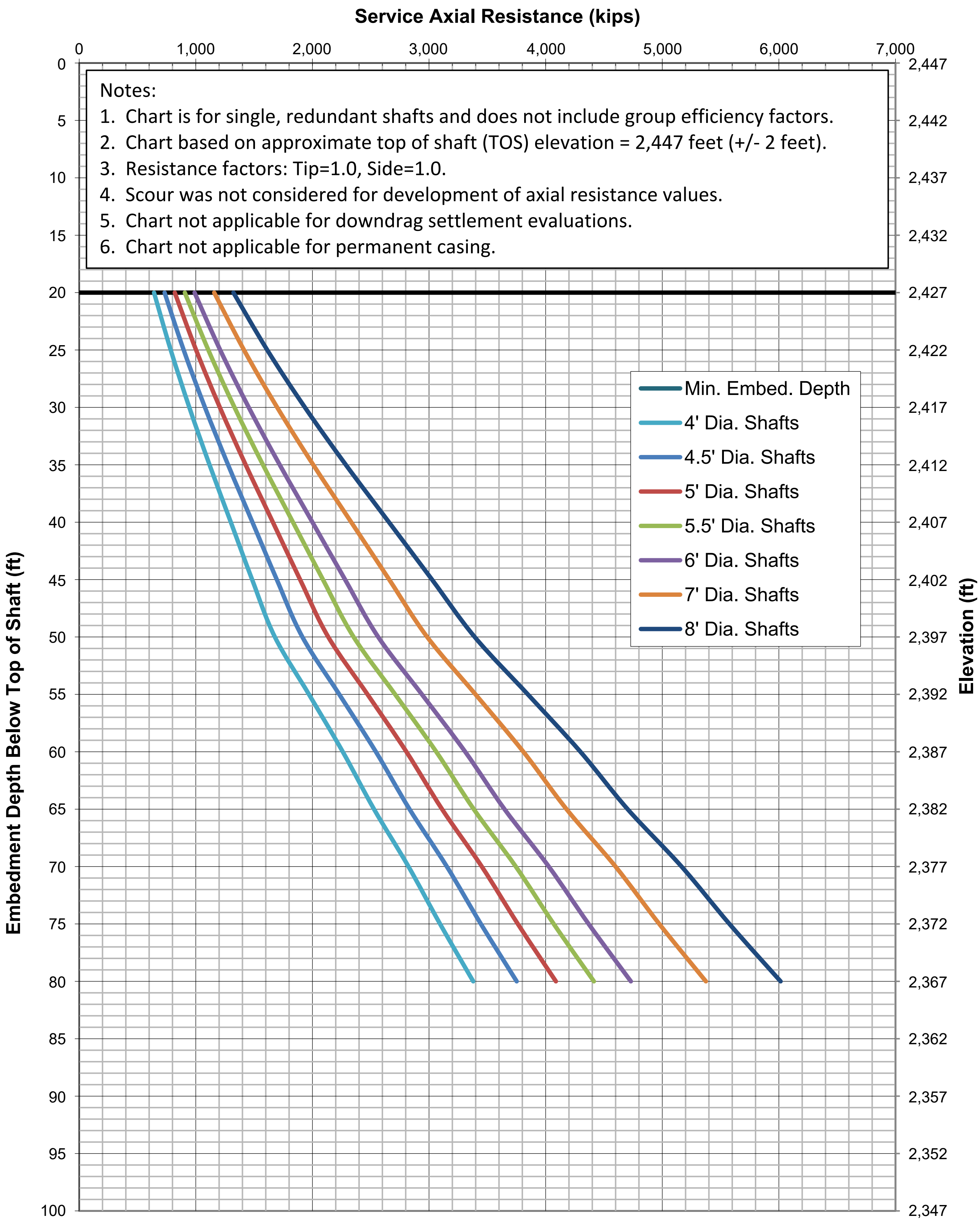
Service Limit (0.5-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Piers

Figure

C8



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

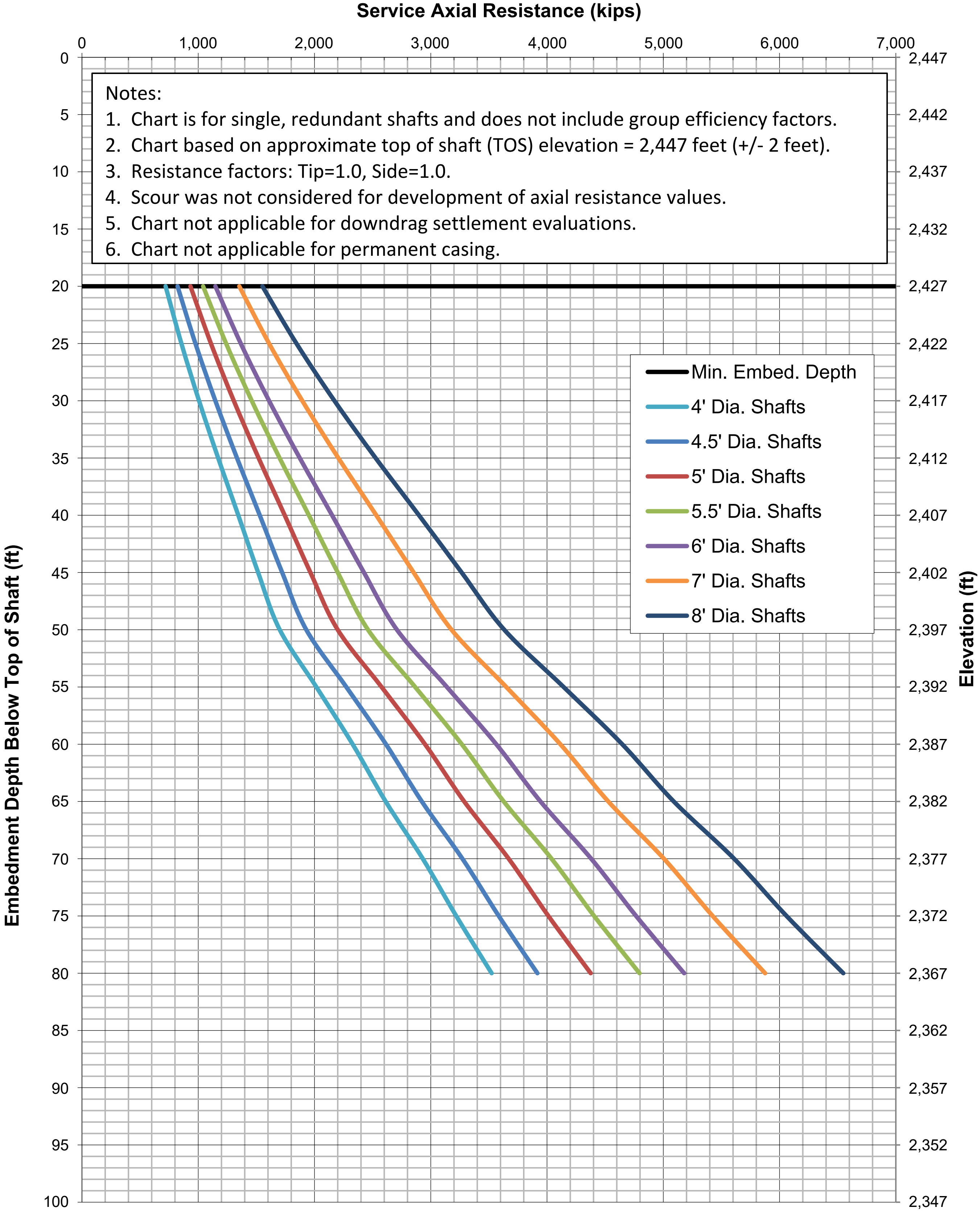
Service Limit (0.75-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Piers

Figure

C9



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

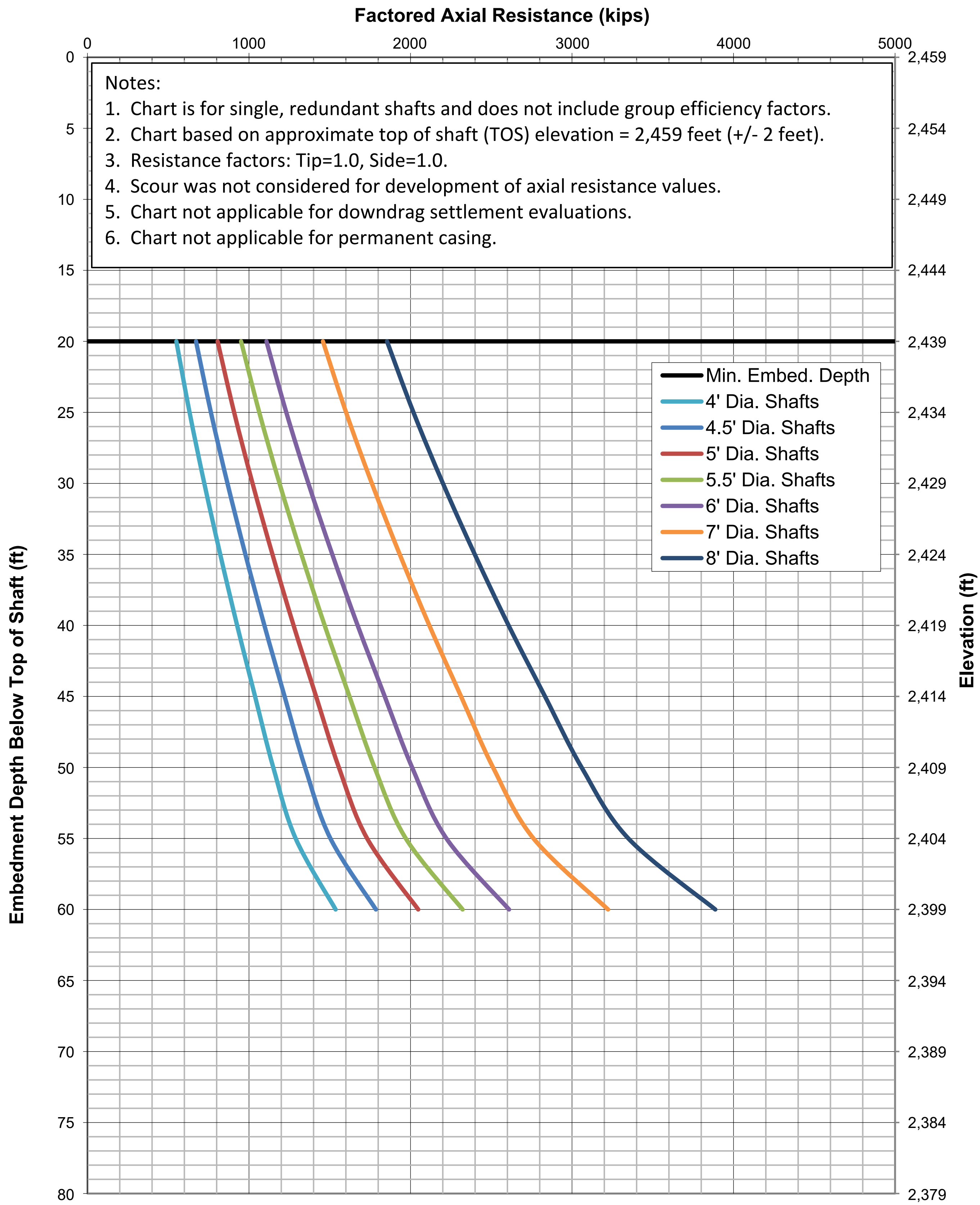
Service Limit (1 Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge Piers

Figure

C10



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

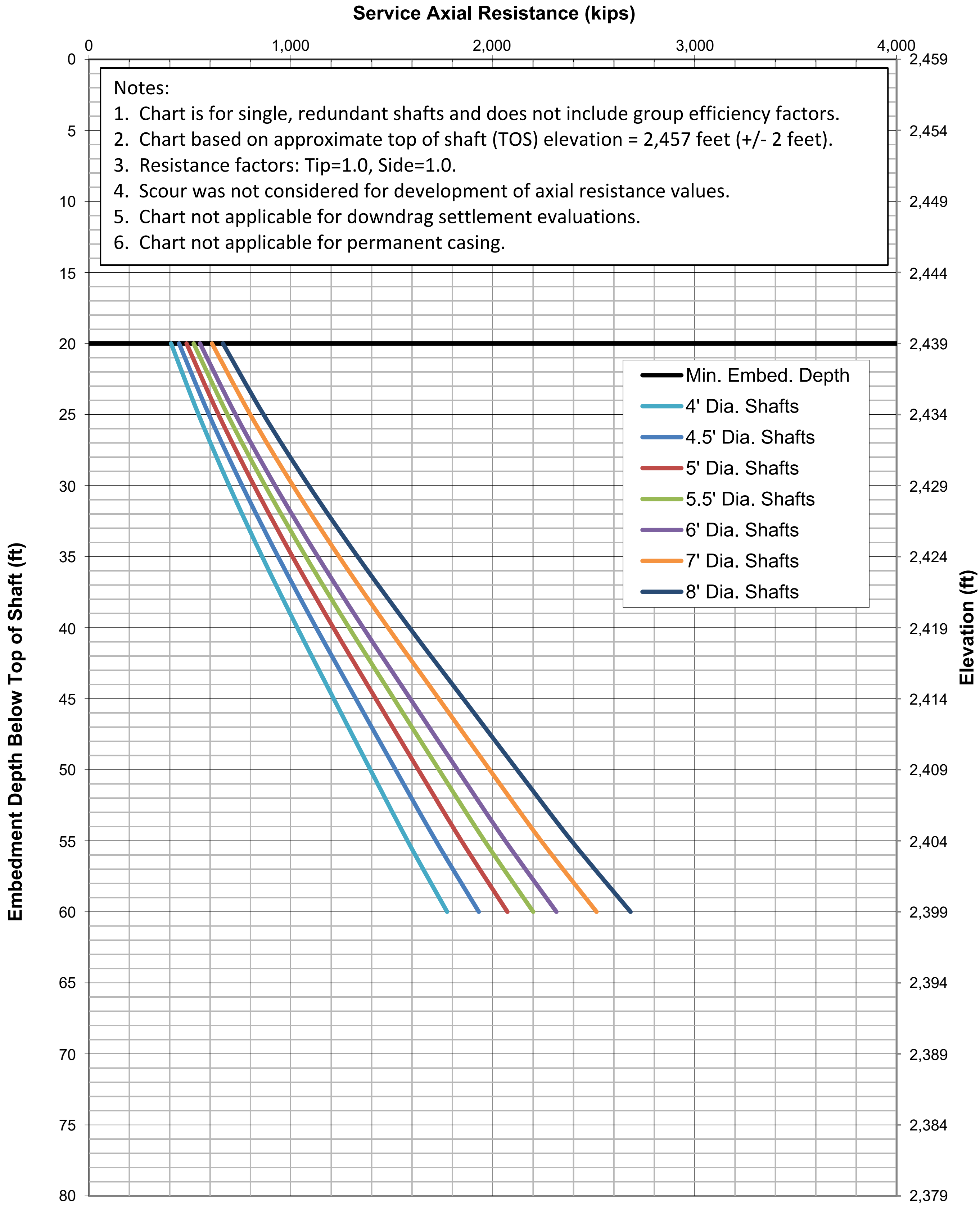
Strength Limit Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 2

Figure

C11



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

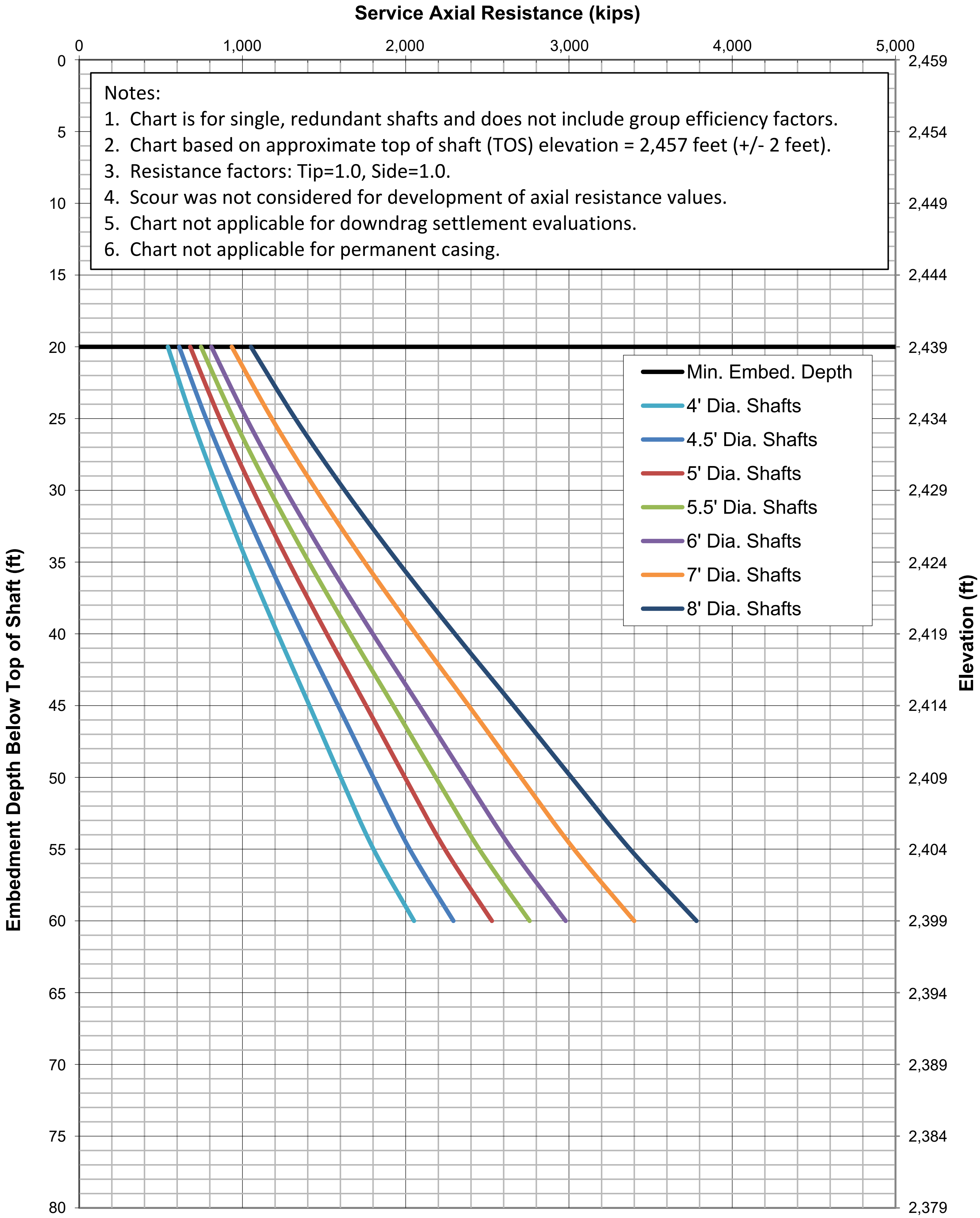
Service Limit (0.25-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 2

Figure

C12



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

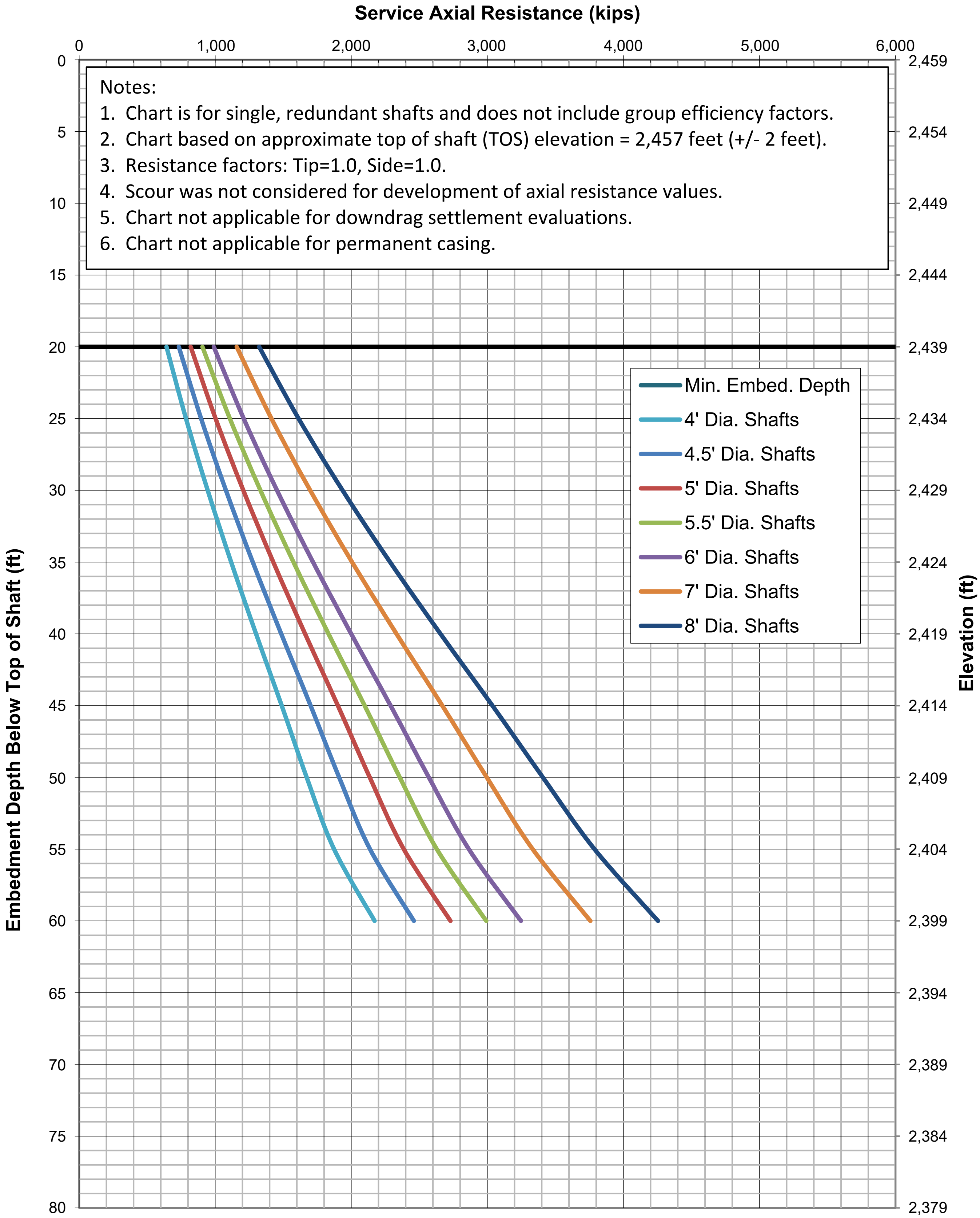
Service Limit (0.5-Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 2

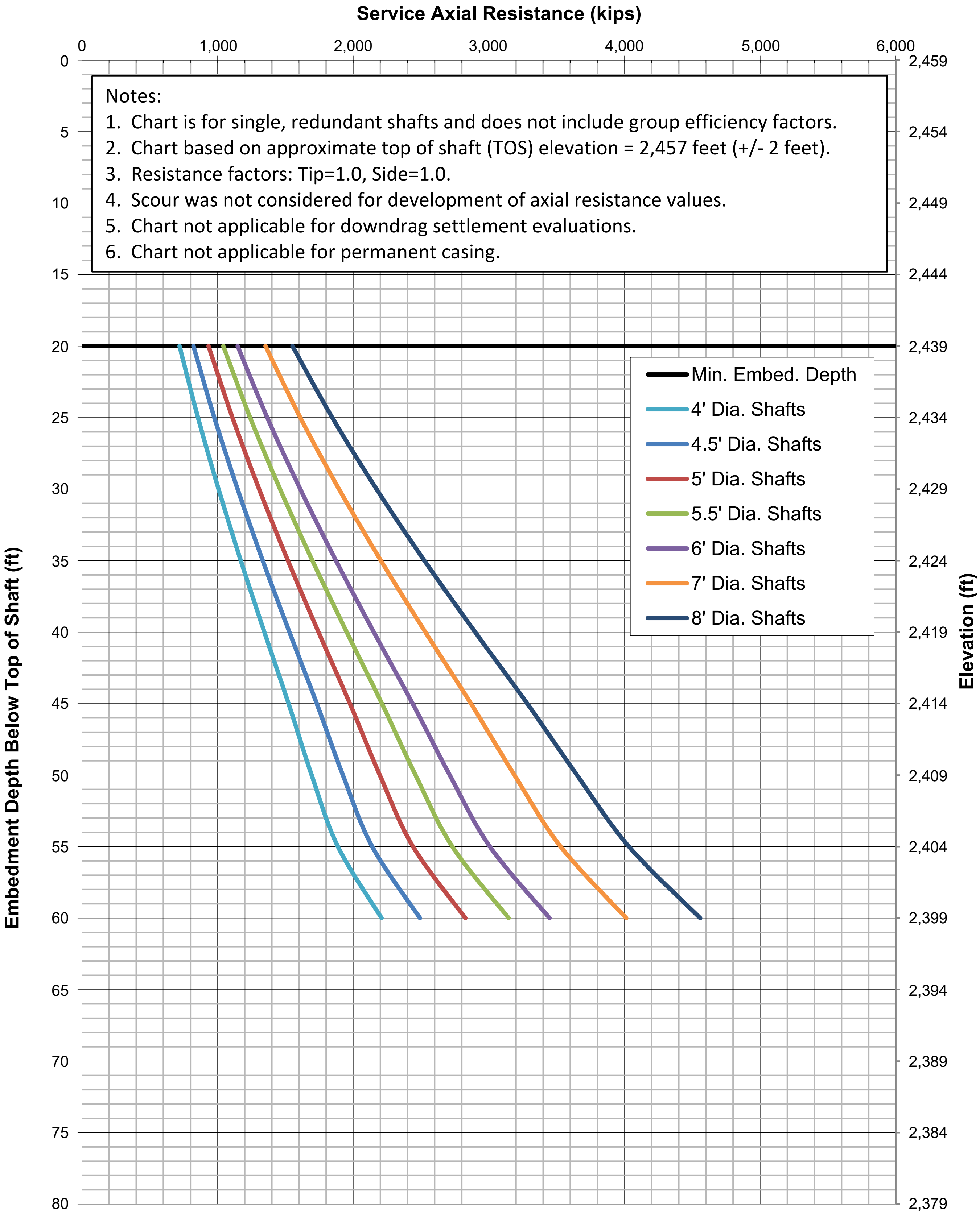
Figure

C13



ethos ENGINEERING, LLC.	DRILLED SHAFT FOUNDATION DESIGN CHART Service Limit (0.75-Inch Settlement) - Axial Resistance in Kips US 93, Vista Royale Southbound BNSF Overpass Bridge Abutment 2	Figure C14

Designer:	Date:
K. Mackay	11/3/2025



ethos ENGINEERING, LLC.

Designer:	Date:
K. Mackay	11/3/2025

DRILLED SHAFT FOUNDATION DESIGN CHART

Service Limit (1 Inch Settlement) - Axial Resistance in Kips

US 93, Vista Royale

Southbound BNSF Overpass Bridge
Abutment 2

Figure

C15

APPENDIX D

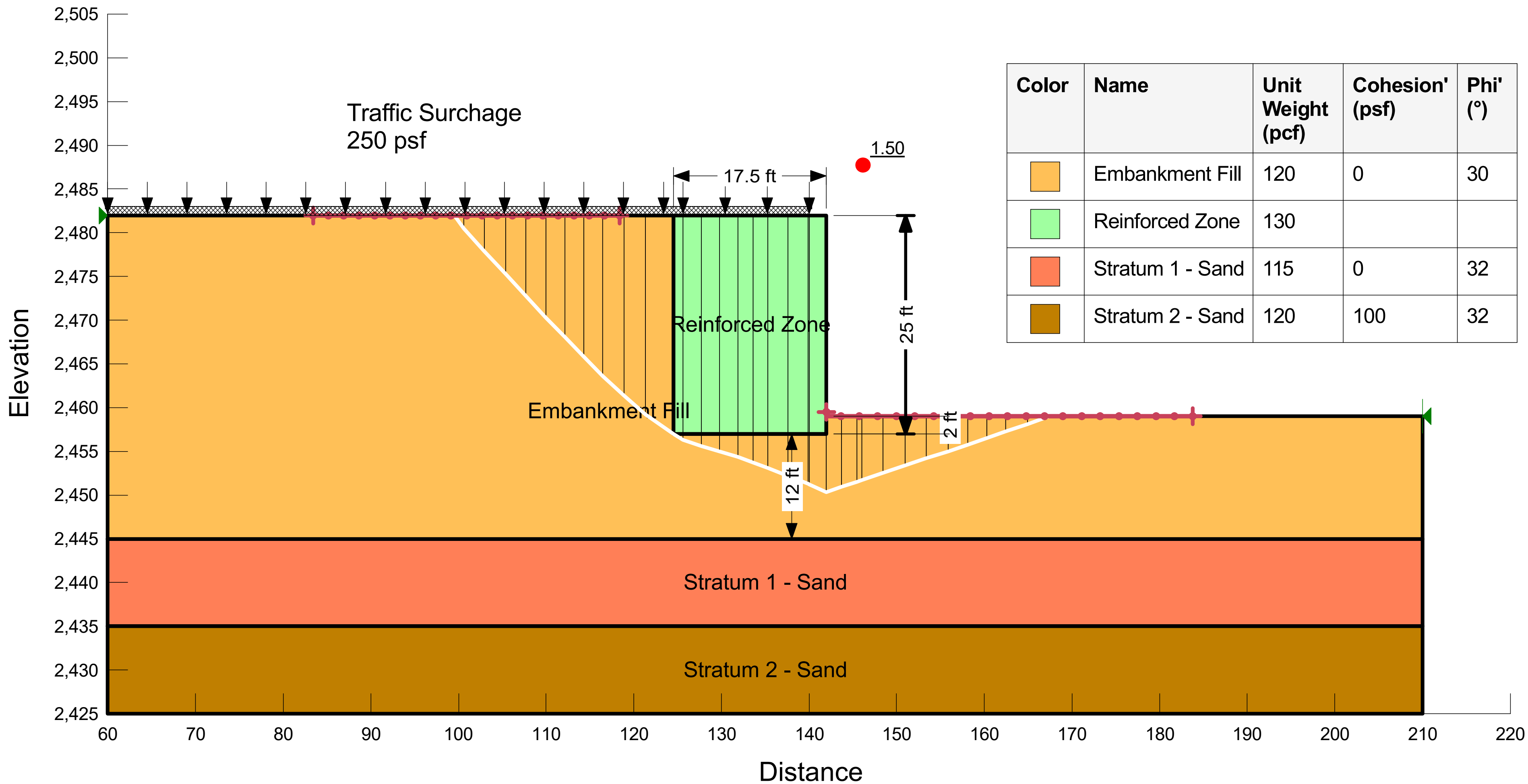
MSE External Stability Results

Name: Abutment 1, STA 10+00 to 10+22
Method: Spencer
Factor of Safety: 1.50

Abutment 1
STA 10+00 to STA 10+22
25' Wall Height on 12' Fill
0.7H Strap Length

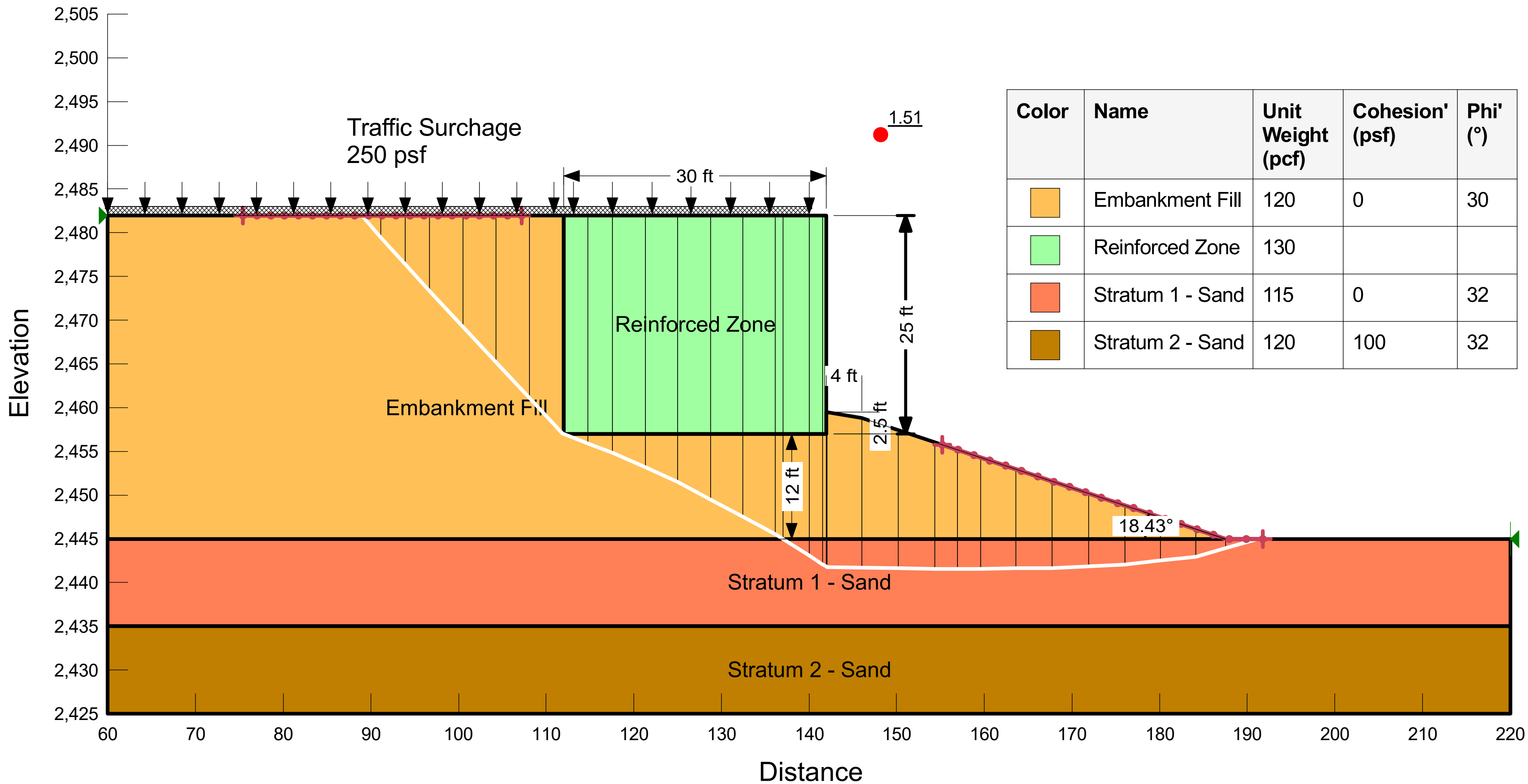
ethos ENGINEERING, LLC.

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32



Name: Abutment 1, STA 10+22 to 10+26
Method: Spencer
Factor of Safety: 1.51

Abutment 1
STA 10+22 to STA 10+26
25' Wall Height on 12' Fill
1.2H Strap Length

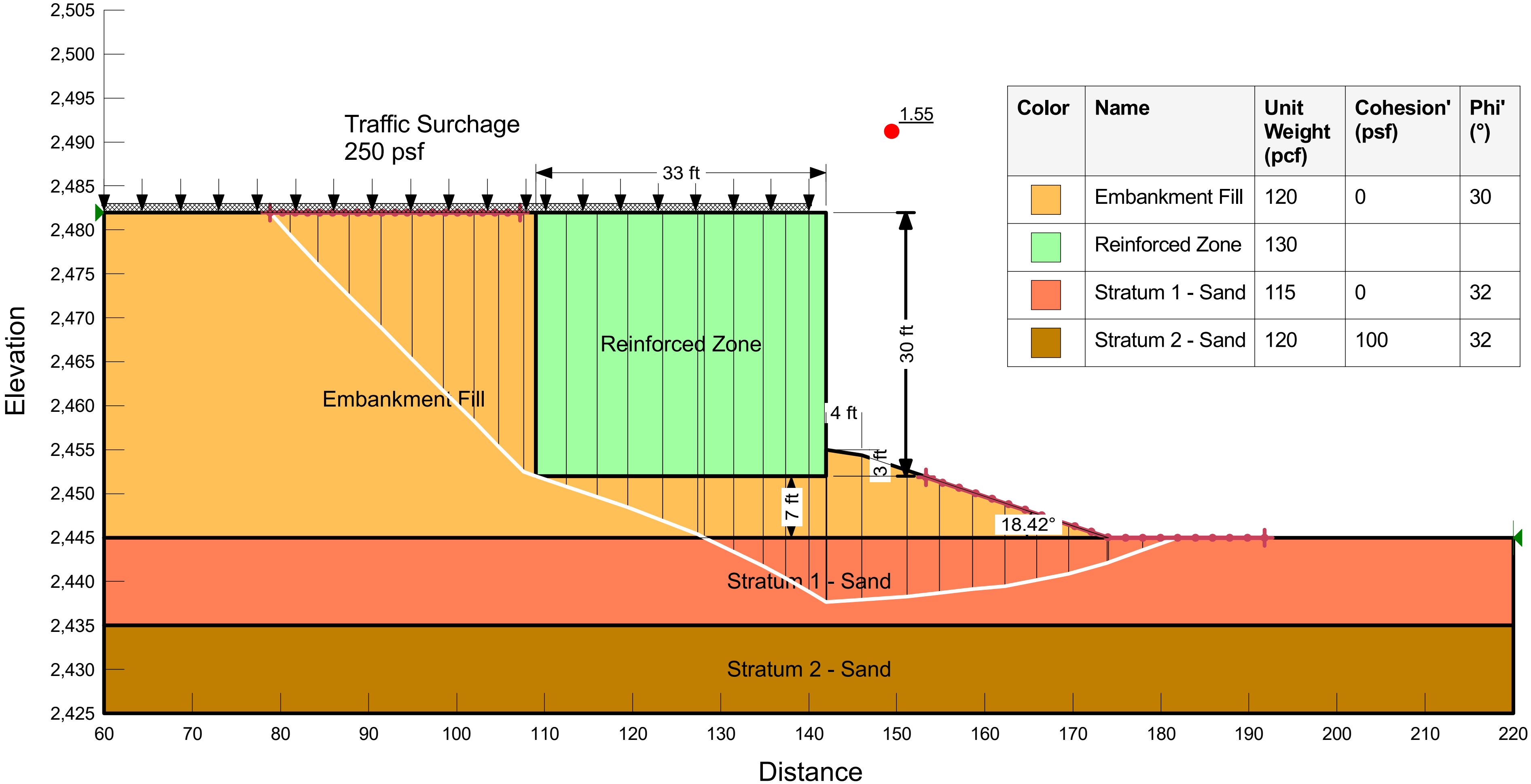


Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

Name: Abutment 1, STA 10+26 to 10+36
Method: Spencer
Factor of Safety: 1.55

Abutment 1
STA 10+26 to STA 10+36
30' Wall Height on 7' Fill
1.1H Strap Length

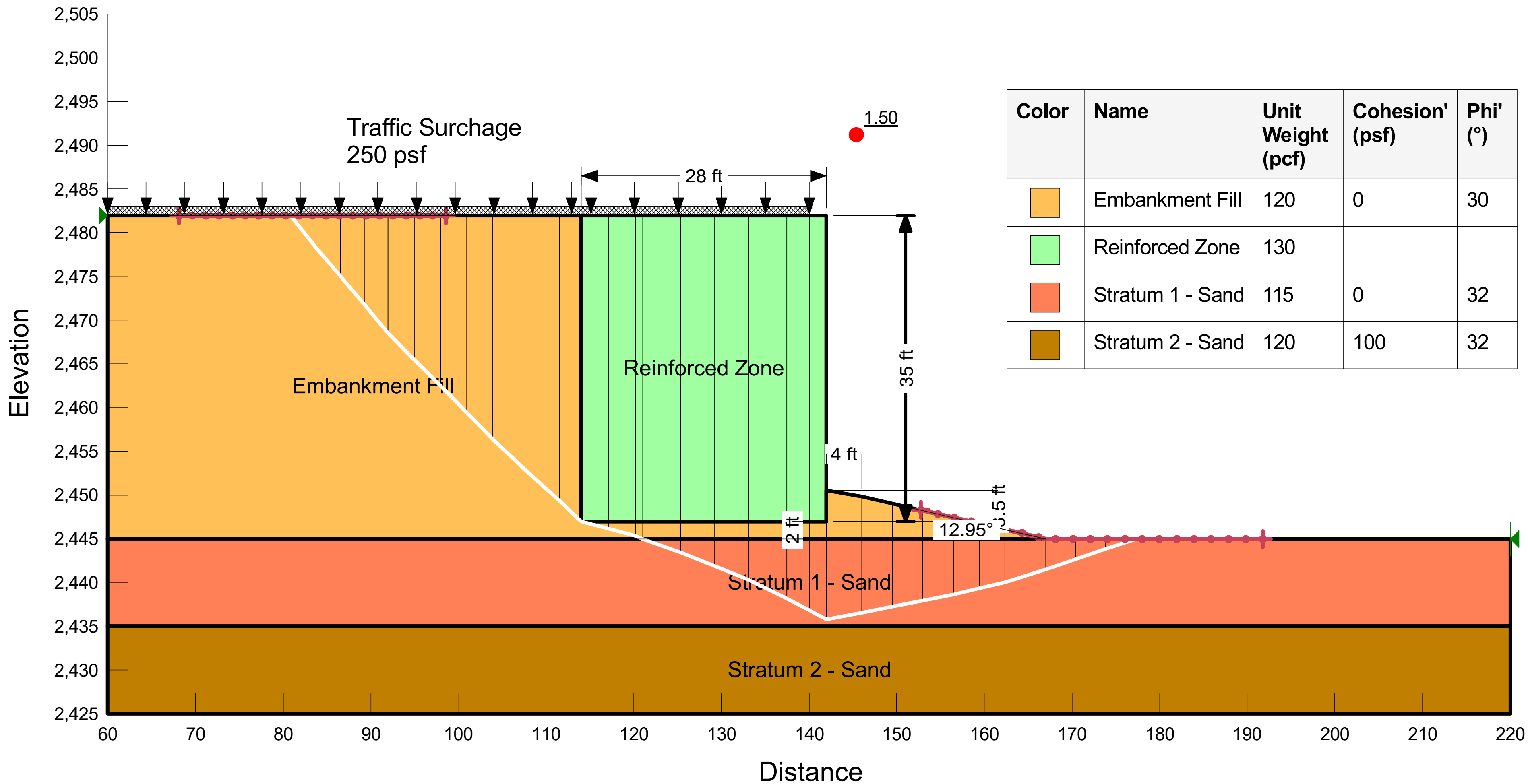
ethos ENGINEERING, LLC.



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

Name: Abutment 1, STA 10+36 to 10+51
Method: Spencer
Factor of Safety: 1.50

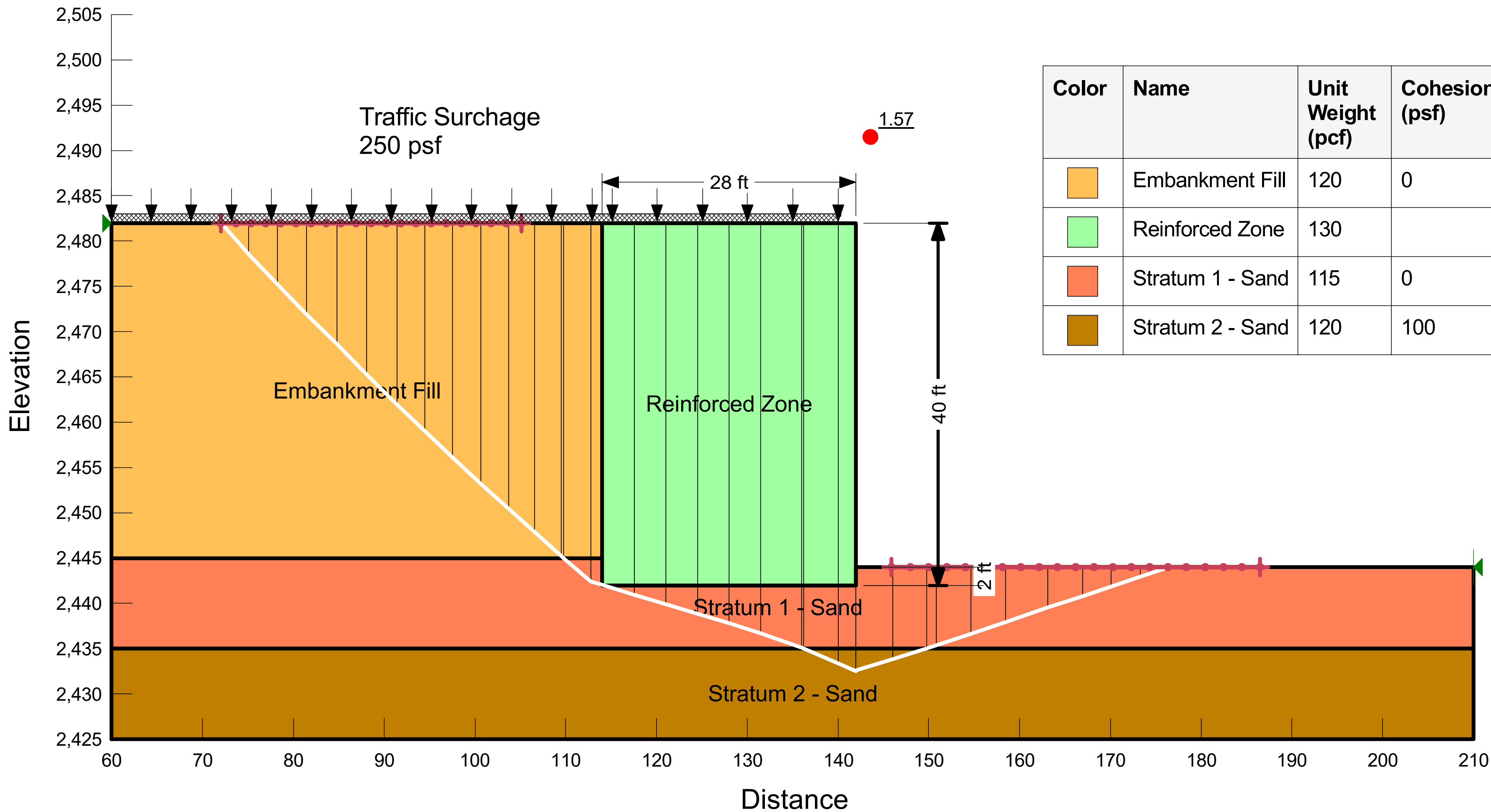
Abutment 1
STA 10+36 to STA 10+51
35' Wall Height on 2' Fill
0.8H Strap Length



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

Name: Abutment 1, STA 10+51 to 10+83
Method: Spencer
Factor of Safety: 1.57

Abutment 1
STA 10+51 to STA 11+71
40' Wall Height on Native
0.7H Strap Length



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - STA 1000 to 1022

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title:	US 93, Val Vista - STA 1000 to 1022
Project Number:	2024112
Client:	
Designer:	Katie Mackay
Station Number:	

Description:

25H over 12F no toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284
Telephone #: 602.573.0000
Fax #:
E-Mail: ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 1 STA 10+00.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 17.57 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 30.14 N_γ= 22.40

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

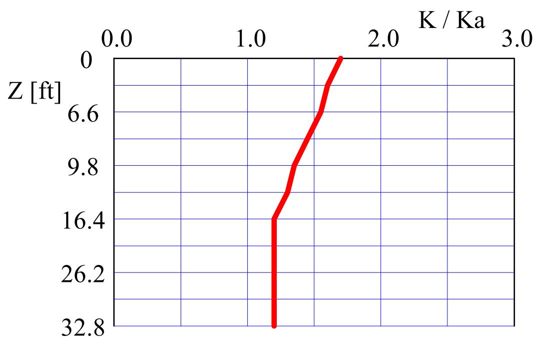
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

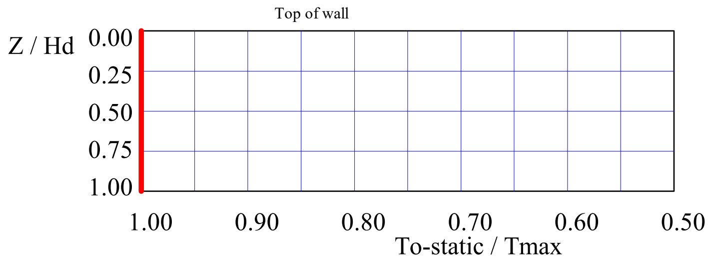
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection (Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

program kept breaking when I used 25' so I increased to 25.1' and it ran.

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 25.10 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 23.10 ft }

Soil in front of wall is Horizontal.

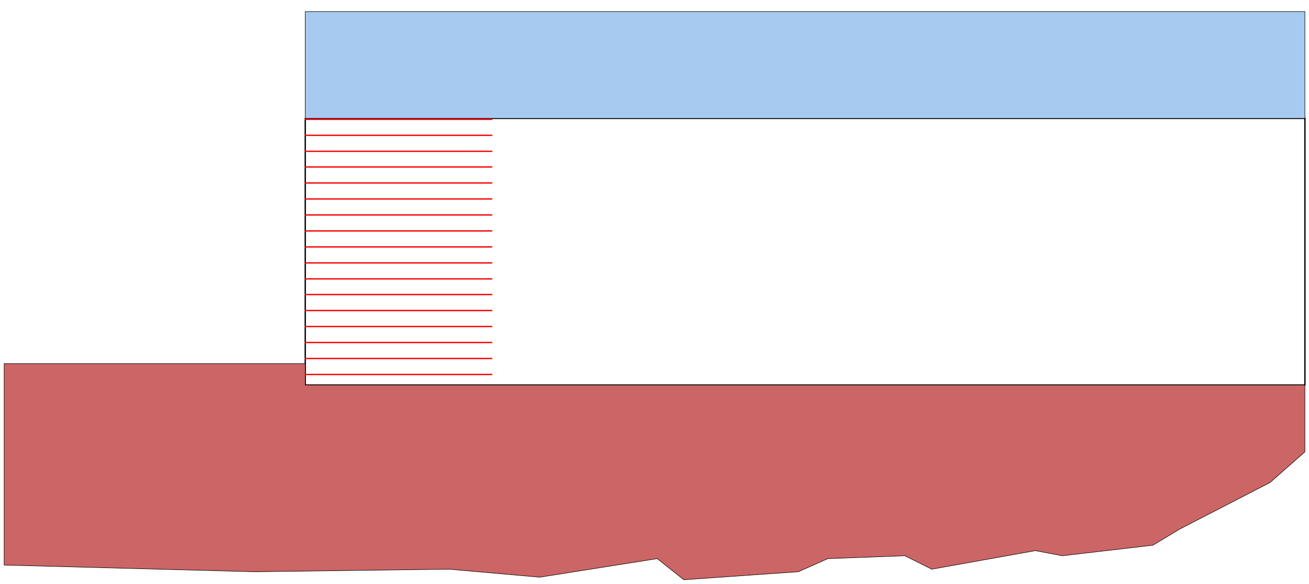
Batter, ω	0.0	[deg]
Backslope, β	0.0	[deg]
Backslope rise	0.0	[ft]

Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

UNIFORM SURCHARGE

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND: (1) Connection strength √ Satisfactory
(2) Metal strip strength ⊗ Unsatisfactory
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

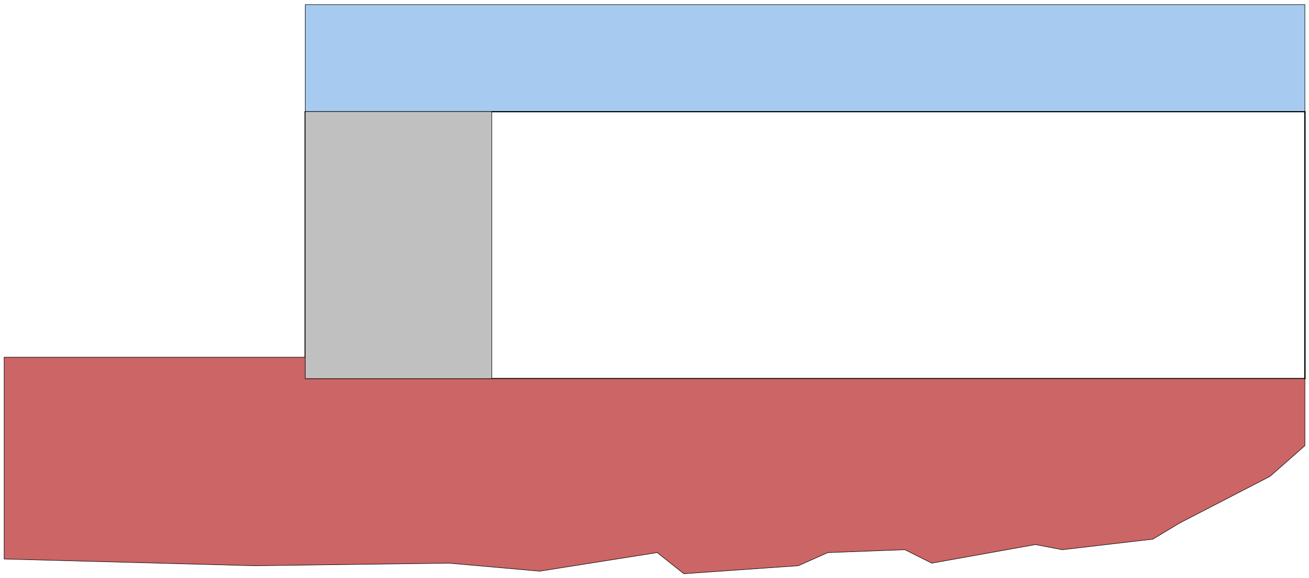
Bearing capacity: √
Foudation Interface: Direct sliding √ Eccentricity √

#	Metal Strip Elevation [ft]	Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	17.57	N/A	√	√	√	√	√
2	2.50	17.57	N/A	√	√	√	√	√
3	4.00	17.57	N/A	√	√	√	√	√
4	5.50	17.57	N/A	√	√	√	√	√
5	7.00	17.57	N/A	√	√	√	√	√
6	8.50	17.57	N/A	√	√	√	√	√
7	10.00	17.57	N/A	√	√	√	√	√
8	11.50	17.57	N/A	√	√	√	√	√
9	13.00	17.57	N/A	√	√	√	√	√

#	Metal Strip Elevation [ft]	Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
10	14.50	17.57	N/A	√	√	√	√	√
11	16.00	17.57	N/A	√	√	√	√	√
12	17.50	17.57	N/A	√	√	√	√	√
13	19.00	17.57	N/A	√	√	√	√	√
14	20.50	17.57	N/A	√	√	√	√	√
15	22.00	17.57	N/A	√	√	√	√	√
16	23.50	17.57	N/A	√	√	√	√	√
17	25.00	17.57	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	11160	N/A	[lb/ft ²]
Factored bearing load, σ_V	6661.2	N/A	[lb/ft ²]
Eccentricity, e	2.40	N/A	[ft]
Eccentricity, e/L	0.137	N/A	
CDR calculated	1.68	N/A	
Base length	17.57	N/A	[ft]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.467

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	17.57	1.730	N/A	N/A	---
2	2.50	17.57	1.824	N/A	N/A	---
3	4.00	17.57	1.930	N/A	N/A	---
4	5.50	17.57	2.051	N/A	N/A	---
5	7.00	17.57	2.237	N/A	N/A	---
6	8.50	17.57	2.393	N/A	N/A	---
7	10.00	17.57	2.573	N/A	N/A	---
8	11.50	17.57	2.782	N/A	N/A	---
9	13.00	17.57	3.028	N/A	N/A	---
10	14.50	17.57	3.322	N/A	N/A	---
11	16.00	17.57	3.678	N/A	N/A	---
12	17.50	17.57	4.121	N/A	N/A	---
13	19.00	17.57	4.685	N/A	N/A	---
14	20.50	17.57	5.428	N/A	N/A	---
15	22.00	17.57	6.451	N/A	N/A	---
16	23.50	17.57	7.948	N/A	N/A	---
17	25.00	17.57	10.351	N/A	N/A	---

ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.2026; Overturning: CDR-static = 2.47

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	17.57	0.1885	N/A	N/A	---
2	2.50	17.57	0.1683	N/A	N/A	---
3	4.00	17.57	0.1493	N/A	N/A	---
4	5.50	17.57	0.1313	N/A	N/A	---
5	7.00	17.57	0.1145	N/A	N/A	---
6	8.50	17.57	0.0988	N/A	N/A	---
7	10.00	17.57	0.0843	N/A	N/A	---
8	11.50	17.57	0.0708	N/A	N/A	---
9	13.00	17.57	0.0585	N/A	N/A	---
10	14.50	17.57	0.0473	N/A	N/A	---
11	16.00	17.57	0.0372	N/A	N/A	---
12	17.50	17.57	0.0282	N/A	N/A	---
13	19.00	17.57	0.0204	N/A	N/A	---
14	20.50	17.57	0.0136	N/A	N/A	---
15	22.00	17.57	0.0080	N/A	N/A	---
16	23.50	17.57	0.0035	N/A	N/A	---
17	25.00	17.57	0.0002	N/A	N/A	---

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - STA 1022 to 1026

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title: US 93, Val Vista - STA 1022 to 1026 (Abutment 1)
Project Number: 2024112
Client:
Designer: Katie Mackay
Station Number:

Description:

25H over 12F with 3:1 toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284
Telephone #: 602.573.0000
Fax #:
E-Mail: ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 1 STA 10+22.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 17.57 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 0.00 N_γ= 10.00

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

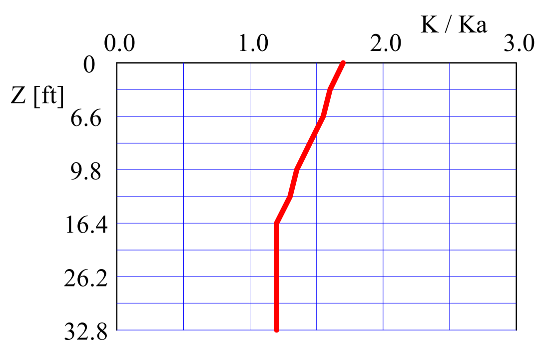
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

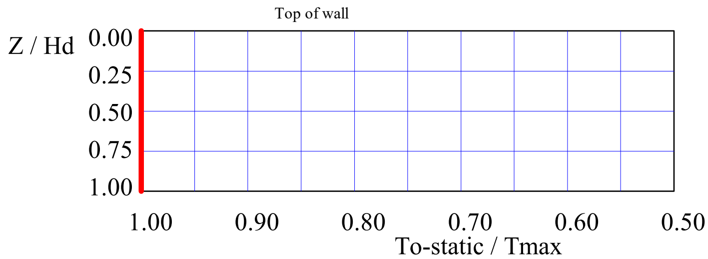
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection
(Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

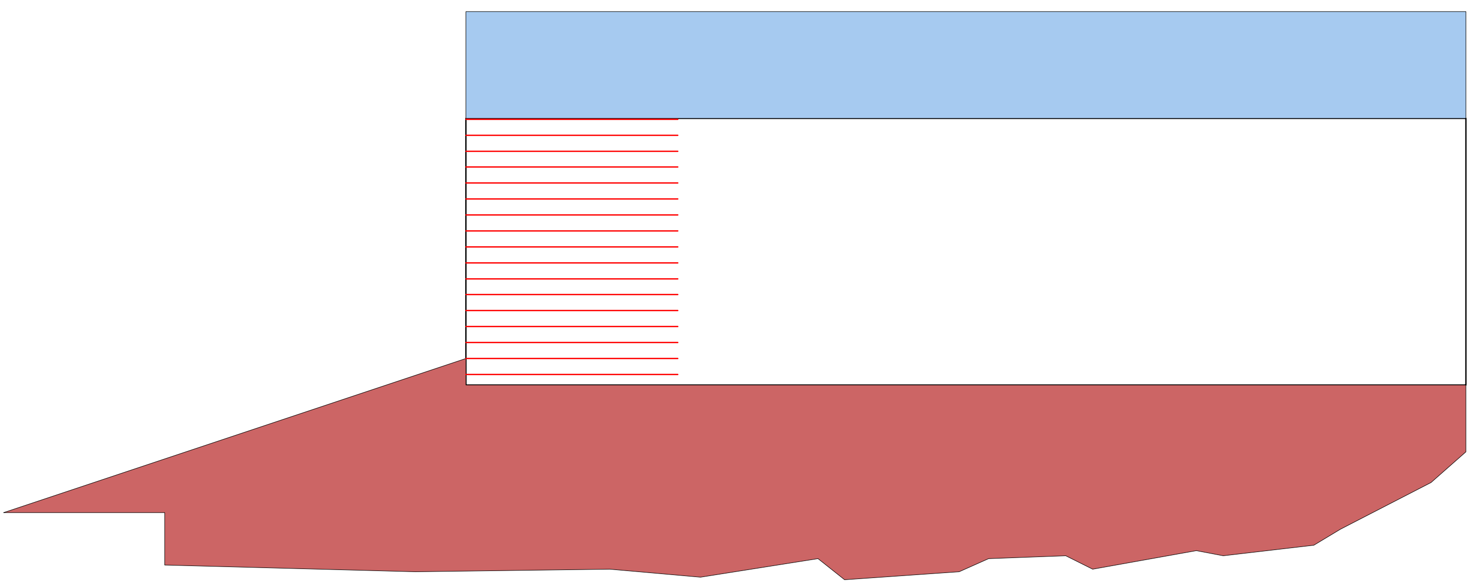
Design height, Hd 25.10 [ft] { Embedded depth is E = 2.50 ft, and height above top of finished bottom grade is H = 22.60 ft }
Soil in front of the wall is inclined at 3H:1V. Hs = 6.56 ft.

Batter, ω 0.0 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND:
(1) Connection strength
(2) Metal strip strength
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

√ Satisfactory
⊗ Unsatisfactory

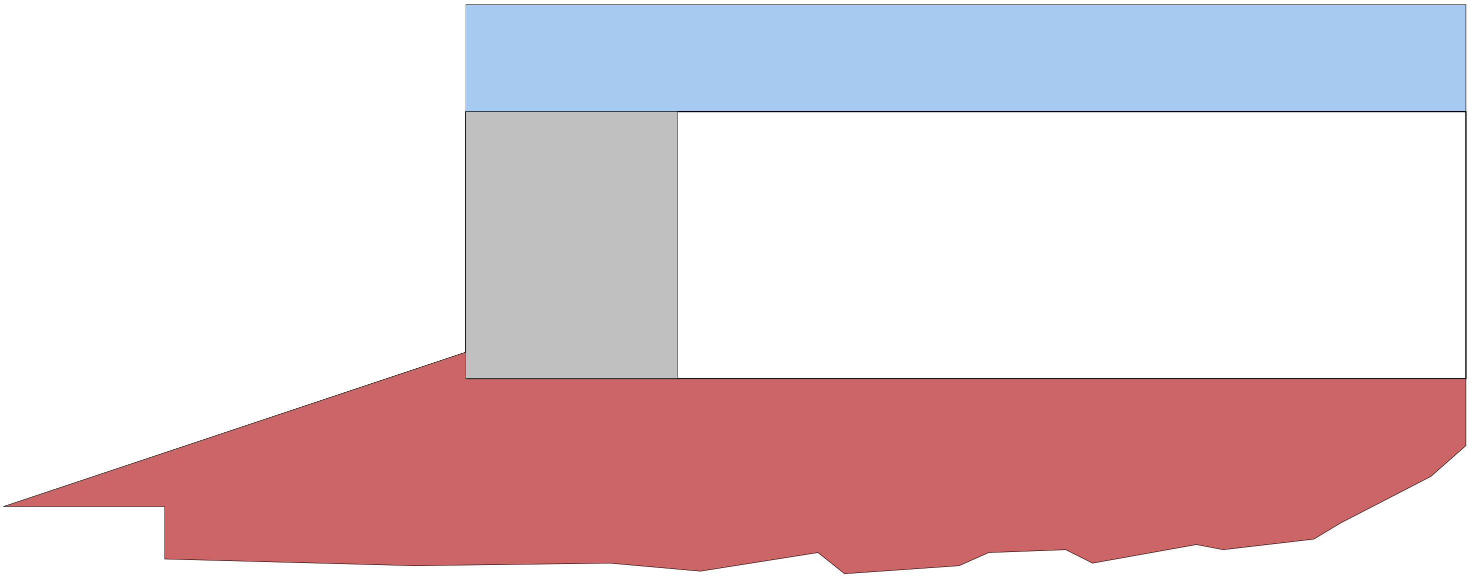
Bearing capacity: √
Foudation Interface: Direct sliding √ Eccentricity √

#	Elevation [ft]	Metal Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	19.97	N/A	√	√	√	√	√
2	2.50	19.97	N/A	√	√	√	√	√
3	4.00	19.97	N/A	√	√	√	√	√
4	5.50	19.97	N/A	√	√	√	√	√
5	7.00	19.97	N/A	√	√	√	√	√
6	8.50	19.97	N/A	√	√	√	√	√
7	10.00	19.97	N/A	√	√	√	√	√
8	11.50	19.97	N/A	√	√	√	√	√
9	13.00	19.97	N/A	√	√	√	√	√

#	Elevation [ft]	Metal Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
10	14.50	19.97	N/A	√	√	√	√	√
11	16.00	19.97	N/A	√	√	√	√	√
12	17.50	19.97	N/A	√	√	√	√	√
13	19.00	19.97	N/A	√	√	√	√	√
14	20.50	19.97	N/A	√	√	√	√	√
15	22.00	19.97	N/A	√	√	√	√	√
16	23.50	19.97	N/A	√	√	√	√	√
17	25.00	19.97	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	6141	N/A	[lb/ft ²]
Factored bearing load, σ_V	6140.9	N/A	[lb/ft ²]
Eccentricity, e	2.11	N/A	[ft]
Eccentricity, e/L	0.106	N/A	
CDR calculated	1.00	N/A	
Base length	19.97	N/A	[ft]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.667

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	19.97	1.966	N/A	N/A	---
2	2.50	19.97	2.073	N/A	N/A	---
3	4.00	19.97	2.193	N/A	N/A	---
4	5.50	19.97	2.331	N/A	N/A	---
5	7.00	19.97	2.542	N/A	N/A	---
6	8.50	19.97	2.719	N/A	N/A	---
7	10.00	19.97	2.924	N/A	N/A	---
8	11.50	19.97	3.161	N/A	N/A	---
9	13.00	19.97	3.441	N/A	N/A	---
10	14.50	19.97	3.774	N/A	N/A	---
11	16.00	19.97	4.180	N/A	N/A	---
12	17.50	19.97	4.683	N/A	N/A	---
13	19.00	19.97	5.324	N/A	N/A	---
14	20.50	19.97	6.168	N/A	N/A	---
15	22.00	19.97	7.330	N/A	N/A	---
16	23.50	19.97	9.032	N/A	N/A	---
17	25.00	19.97	11.763	N/A	N/A	---

ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1569; Overturning: CDR-static = 3.19

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	19.97	0.1460	N/A	N/A	---
2	2.50	19.97	0.1304	N/A	N/A	---
3	4.00	19.97	0.1156	N/A	N/A	---
4	5.50	19.97	0.1017	N/A	N/A	---
5	7.00	19.97	0.0887	N/A	N/A	---
6	8.50	19.97	0.0765	N/A	N/A	---
7	10.00	19.97	0.0652	N/A	N/A	---
8	11.50	19.97	0.0548	N/A	N/A	---
9	13.00	19.97	0.0453	N/A	N/A	---
10	14.50	19.97	0.0366	N/A	N/A	---
11	16.00	19.97	0.0288	N/A	N/A	---
12	17.50	19.97	0.0218	N/A	N/A	---
13	19.00	19.97	0.0158	N/A	N/A	---
14	20.50	19.97	0.0106	N/A	N/A	---
15	22.00	19.97	0.0062	N/A	N/A	---
16	23.50	19.97	0.0027	N/A	N/A	---
17	25.00	19.97	0.0001	N/A	N/A	---

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - STA 1026 to 10362

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title: US 93, Val Vista - STA 1026 to 1036 (Abutment 1)
Project Number: 2024112
Client:
Designer: Katie Mackay
Station Number:

Description:

30H over 7F with 3:1 toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284
Telephone #: 602.573.0000
Fax #:
E-Mail: ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
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Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 21.00 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 0.00 N_γ= 10.00

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

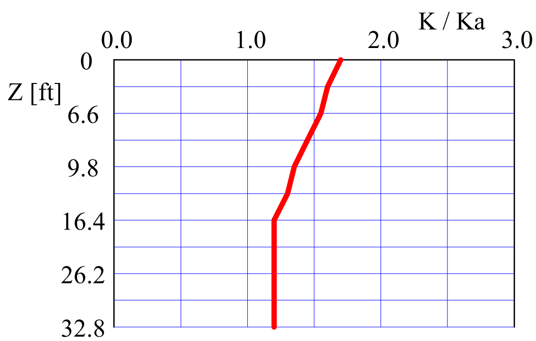
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

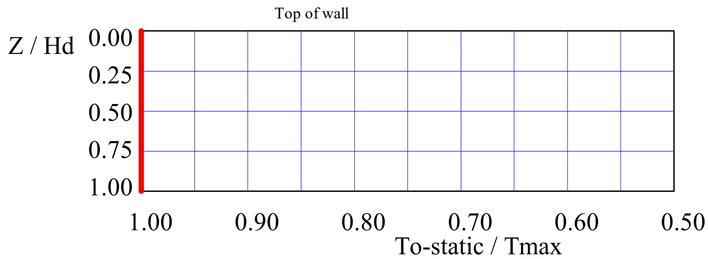
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection (Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 30.00 [ft] { Embedded depth is E = 3.00 ft, and height above top of finished bottom grade is H = 27.00 ft }

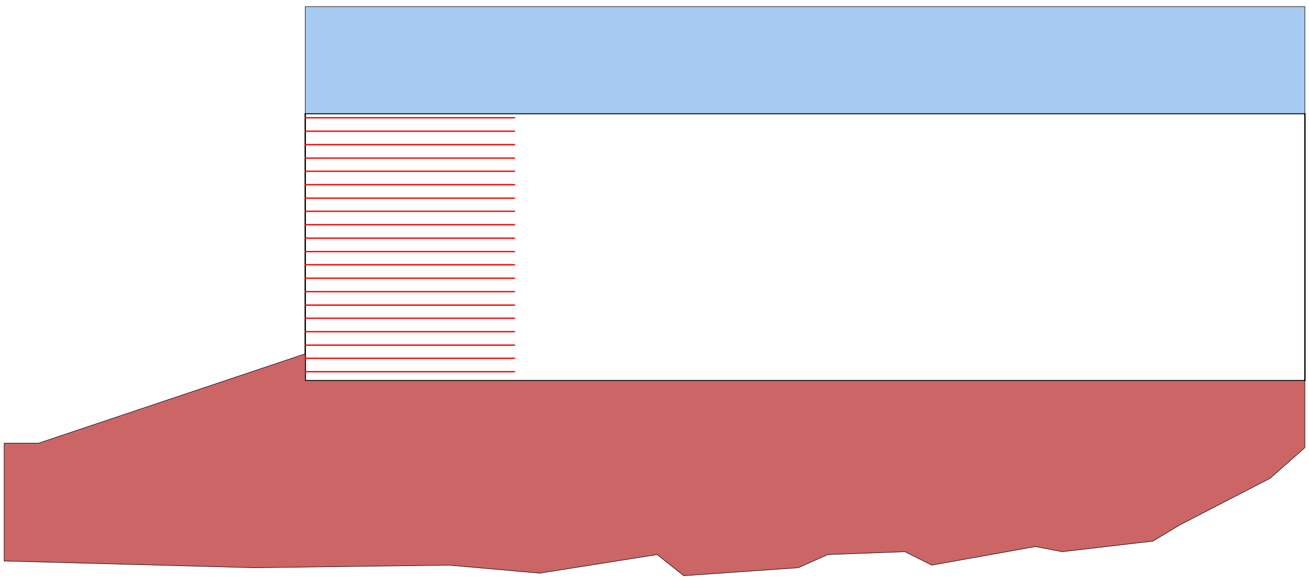
Soil in front of the wall is inclined at 3H:1V. Hs = 6.56 ft.

Batter, ω 0.0 [deg]
Backslope, β 0.0 [deg]
Backslope rise 0.0 [ft] Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND: (1) Connection strength √ Satisfactory
(2) Metal strip strength ⊗ Unsatisfactory
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

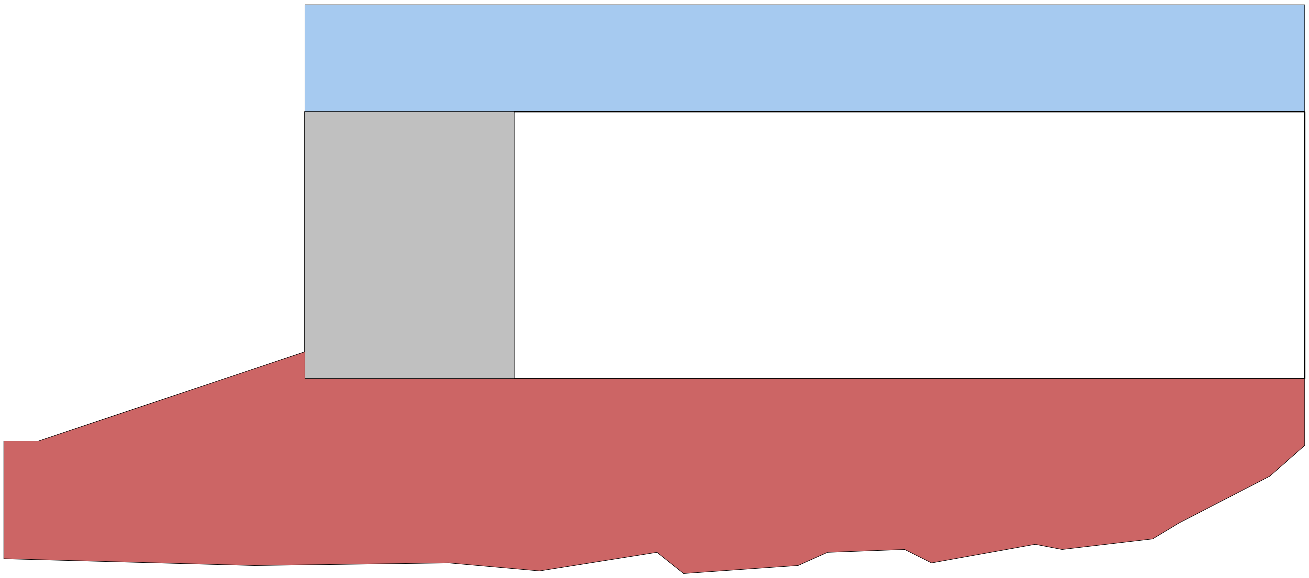
Bearing capacity: ⊗
Foudation Interface: Direct sliding √ Eccentricity √

#	Metal Elevation [ft]	Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	23.55	N/A	√	√	√	√	√
2	2.50	23.55	N/A	√	√	√	√	√
3	4.00	23.55	N/A	√	√	√	√	√
4	5.50	23.55	N/A	√	√	√	√	√
5	7.00	23.55	N/A	√	√	√	√	√
6	8.50	23.55	N/A	√	√	√	√	√
7	10.00	23.55	N/A	√	√	√	√	√
8	11.50	23.55	N/A	√	√	√	√	√
9	13.00	23.55	N/A	√	√	√	√	√
10	14.50	23.55	N/A	√	√	√	√	√

#	Metal Elevation [ft]	Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
11	16.00	23.55	N/A	√	√	√	√	√
12	17.50	23.55	N/A	√	√	√	√	√
13	19.00	23.55	N/A	√	√	√	√	√
14	20.50	23.55	N/A	√	√	√	√	√
15	22.00	23.55	N/A	√	√	√	√	√
16	23.50	23.55	N/A	√	√	√	√	√
17	25.00	23.55	N/A	√	√	√	√	√
18	26.50	23.55	N/A	√	√	√	√	√
19	28.00	23.55	N/A	√	√	√	√	√
20	29.50	23.55	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	7237	N/A	[lb/ft ^{2}]
Factored bearing load, σ_V	7238.4	N/A	[lb/ft ^{2}]
Eccentricity, e	2.50	N/A	[ft]
Eccentricity, e/L	0.106	N/A	
CDR calculated	1.00	N/A	
Base length	23.55	N/A	[ft]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.690

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	23.55	1.983	N/A	N/A	---
2	2.50	23.55	2.075	N/A	N/A	---
3	4.00	23.55	2.176	N/A	N/A	---
4	5.50	23.55	2.287	N/A	N/A	---
5	7.00	23.55	2.410	N/A	N/A	---
6	8.50	23.55	2.547	N/A	N/A	---
7	10.00	23.55	2.701	N/A	N/A	---
8	11.50	23.55	2.937	N/A	N/A	---
9	13.00	23.55	3.149	N/A	N/A	---
10	14.50	23.55	3.381	N/A	N/A	---
11	16.00	23.55	3.650	N/A	N/A	---
12	17.50	23.55	3.965	N/A	N/A	---
13	19.00	23.55	4.340	N/A	N/A	---
14	20.50	23.55	4.794	N/A	N/A	---
15	22.00	23.55	5.353	N/A	N/A	---
16	23.50	23.55	6.059	N/A	N/A	---
17	25.00	23.55	6.981	N/A	N/A	---
18	26.50	23.55	8.234	N/A	N/A	---
19	28.00	23.55	10.034	N/A	N/A	---
20	29.50	23.55	12.841	N/A	N/A	---

ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1551; Overturning: CDR-static = 3.22

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	23.55	0.1459	N/A	N/A	---
2	2.50	23.55	0.1327	N/A	N/A	---
3	4.00	23.55	0.1200	N/A	N/A	---
4	5.50	23.55	0.1080	N/A	N/A	---
5	7.00	23.55	0.0966	N/A	N/A	---
6	8.50	23.55	0.0858	N/A	N/A	---
7	10.00	23.55	0.0757	N/A	N/A	---
8	11.50	23.55	0.0662	N/A	N/A	---
9	13.00	23.55	0.0573	N/A	N/A	---
10	14.50	23.55	0.0490	N/A	N/A	---
11	16.00	23.55	0.0413	N/A	N/A	---
12	17.50	23.55	0.0343	N/A	N/A	---
13	19.00	23.55	0.0279	N/A	N/A	---
14	20.50	23.55	0.0221	N/A	N/A	---
15	22.00	23.55	0.0170	N/A	N/A	---
16	23.50	23.55	0.0124	N/A	N/A	---
17	25.00	23.55	0.0085	N/A	N/A	---
18	26.50	23.55	0.0052	N/A	N/A	---
19	28.00	23.55	0.0026	N/A	N/A	---
20	29.50	23.55	0.0005	N/A	N/A	---

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - STA 1036 to 1051

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title:	US 93, Val Vista - STA 1036 to 1051
Project Number:	2024112
Client:	
Designer:	Katie Mackay
Station Number:	

Description:

35H over 2F with 3:1 toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284

Telephone #:	602.573.0000
Fax #:	
E-Mail:	ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 1 STA 10+36.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

Version MSEW+ Version MSEW+

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 24.50 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 0.00 $N\gamma$= 10.00

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ^{3}
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ^{3}
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ^{2}

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

Version MSEW+ Version MSEW+

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

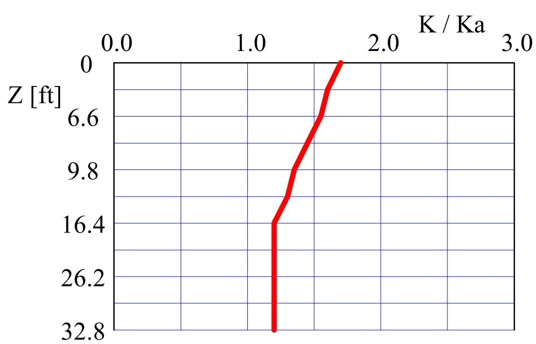
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

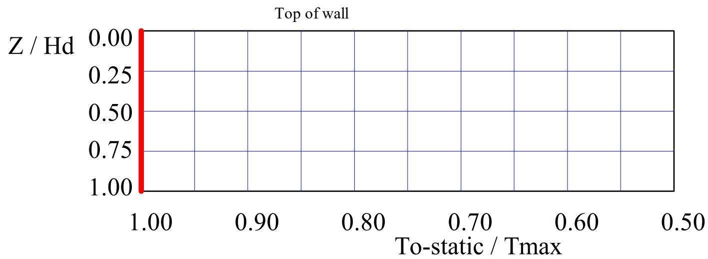
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection (Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 35.00 [ft] { Embedded depth is E = 3.50 ft, and height above top of finished bottom grade is H = 31.50 ft }

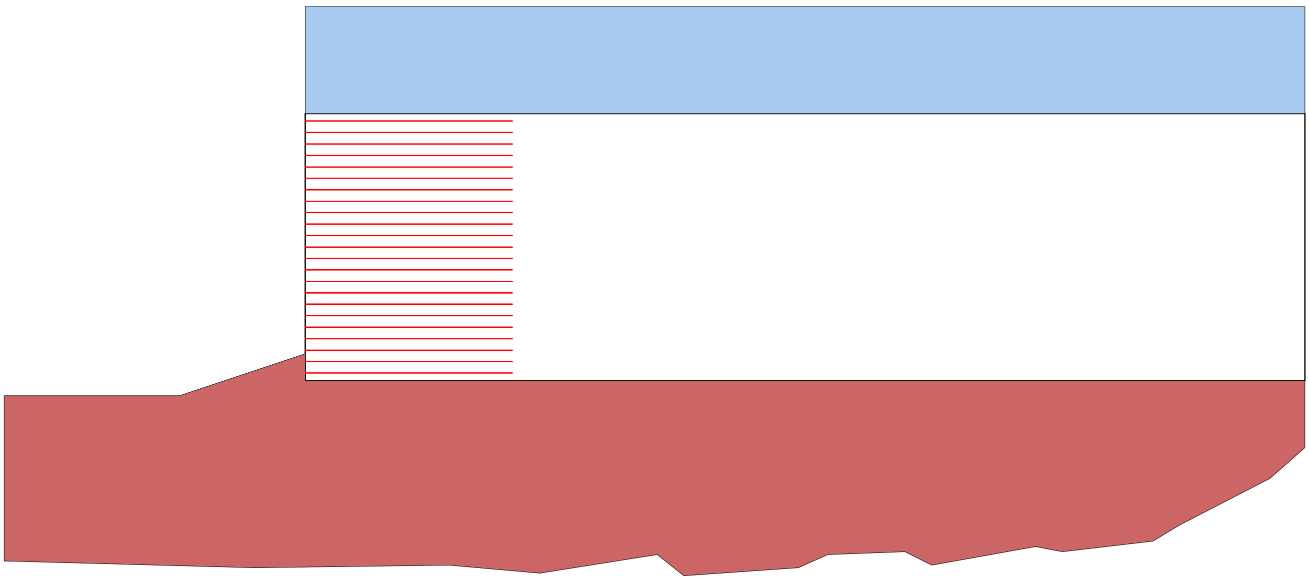
Soil in front of the wall is inclined at 3H:1V. Hs = 6.56 ft.

Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_{τ}	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_{τ}	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND: (1) Connection strength √ Satisfactory
(2) Metal strip strength ⊗ Unsatisfactory
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

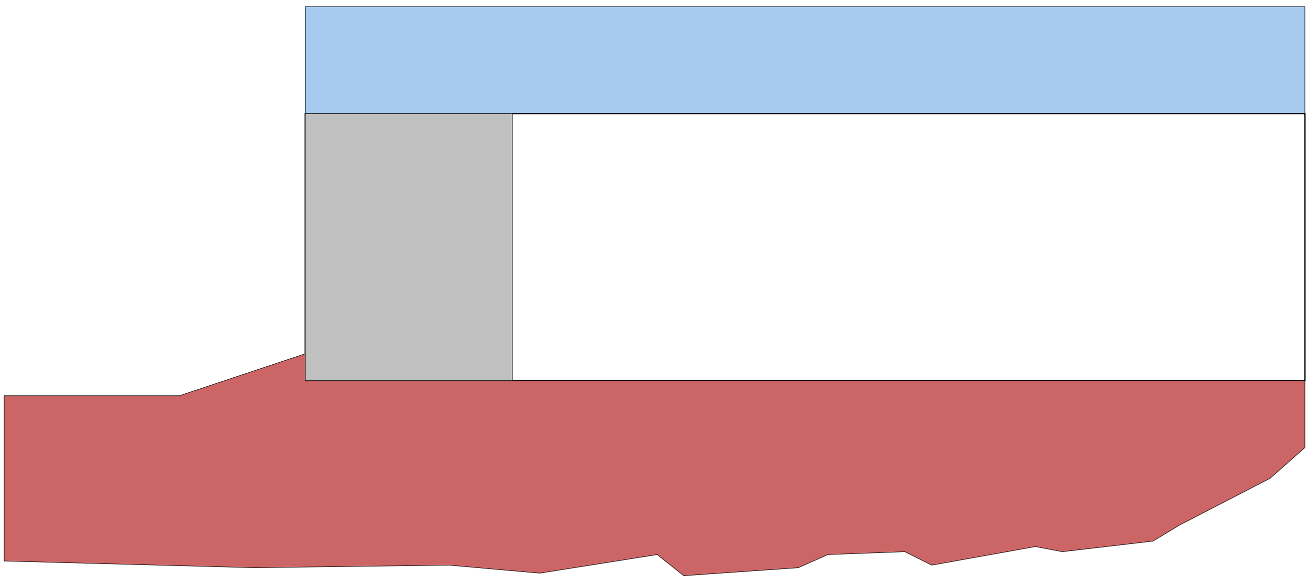
Bearing capacity: ⊗
Foudation Interface: Direct sliding √ Eccentricity √

#	Elevation [ft]	Metal Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	27.21	N/A	√	√	√	√	√
2	2.50	27.21	N/A	√	√	√	√	√
3	4.00	27.21	N/A	√	√	√	√	√
4	5.50	27.21	N/A	√	√	√	√	√
5	7.00	27.21	N/A	√	√	√	√	√
6	8.50	27.21	N/A	√	√	√	√	√
7	10.00	27.21	N/A	√	√	√	√	√
8	11.50	27.21	N/A	√	√	√	√	√
9	13.00	27.21	N/A	√	√	√	√	√
10	14.50	27.21	N/A	√	√	√	√	√
11	16.00	27.21	N/A	√	√	√	√	√
12	17.50	27.21	N/A	√	√	√	√	√
13	19.00	27.21	N/A	√	√	√	√	√
14	20.50	27.21	N/A	√	√	√	√	√
15	22.00	27.21	N/A	√	√	√	√	√
16	23.50	27.21	N/A	√	√	√	√	√
17	25.00	27.21	N/A	√	√	√	√	√
18	26.50	27.21	N/A	√	√	√	√	√
19	28.00	27.21	N/A	√	√	√	√	√
20	29.50	27.21	N/A	√	√	√	√	√
21	31.00	27.21	N/A	√	√	√	√	√
22	32.50	27.21	N/A	√	√	√	√	√
23	34.00	27.21	N/A	√	√	√	√	√

Version MSEW+ Version MSEW+

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	8357	N/A	[lb/ft ²]
Factored bearing load, σ_V	8357.2	N/A	[lb/ft ²]
Eccentricity, e	2.89	N/A	[ft]
Eccentricity, e/L	0.106	N/A	
CDR calculated	1.00	N/A	
Base length	27.21	N/A	[ft]



SCALE:

0 5 10 15 20 25 30 [ft]

Version MSEW+ Version MSEW+

Version MSEW+ Version MSEW+

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.708

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	27.21	1.996	N/A	N/A	---
2	2.50	27.21	2.077	N/A	N/A	---
3	4.00	27.21	2.163	N/A	N/A	---
4	5.50	27.21	2.258	N/A	N/A	---
5	7.00	27.21	2.361	N/A	N/A	---
6	8.50	27.21	2.474	N/A	N/A	---
7	10.00	27.21	2.598	N/A	N/A	---
8	11.50	27.21	2.736	N/A	N/A	---
9	13.00	27.21	2.888	N/A	N/A	---
10	14.50	27.21	3.059	N/A	N/A	---
11	16.00	27.21	3.292	N/A	N/A	---
12	17.50	27.21	3.557	N/A	N/A	---
13	19.00	27.21	3.813	N/A	N/A	---
14	20.50	27.21	4.108	N/A	N/A	---
15	22.00	27.21	4.453	N/A	N/A	---
16	23.50	27.21	4.861	N/A	N/A	---
17	25.00	27.21	5.352	N/A	N/A	---
18	26.50	27.21	5.953	N/A	N/A	---
19	28.00	27.21	6.706	N/A	N/A	---
20	29.50	27.21	7.676	N/A	N/A	---
21	31.00	27.21	8.976	N/A	N/A	---
22	32.50	27.21	10.805	N/A	N/A	---
23	34.00	27.21	13.570	N/A	N/A	---

ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1538; Overturning: CDR-static = 3.25

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	27.21	0.1458	N/A	N/A	---
2	2.50	27.21	0.1343	N/A	N/A	---
3	4.00	27.21	0.1233	N/A	N/A	---
4	5.50	27.21	0.1127	N/A	N/A	---
5	7.00	27.21	0.1027	N/A	N/A	---
6	8.50	27.21	0.0930	N/A	N/A	---
7	10.00	27.21	0.0839	N/A	N/A	---
8	11.50	27.21	0.0752	N/A	N/A	---
9	13.00	27.21	0.0669	N/A	N/A	---
10	14.50	27.21	0.0592	N/A	N/A	---
11	16.00	27.21	0.0519	N/A	N/A	---
12	17.50	27.21	0.0451	N/A	N/A	---
13	19.00	27.21	0.0387	N/A	N/A	---
14	20.50	27.21	0.0328	N/A	N/A	---
15	22.00	27.21	0.0274	N/A	N/A	---
16	23.50	27.21	0.0224	N/A	N/A	---
17	25.00	27.21	0.0180	N/A	N/A	---
18	26.50	27.21	0.0139	N/A	N/A	---
19	28.00	27.21	0.0104	N/A	N/A	---
20	29.50	27.21	0.0073	N/A	N/A	---
21	31.00	27.21	0.0047	N/A	N/A	---
22	32.50	27.21	0.0025	N/A	N/A	---
23	34.00	27.21	0.0009	N/A	N/A	---

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - STA 1051 to 1171

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title:	US 93, Val Vista - STA 1051 to 1171 (Abutment 1)
Project Number:	2024112
Client:	
Designer:	Katie Mackay
Station Number:	

Description:

40H on native

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284

Telephone #:	602.573.0000
Fax #:	
E-Mail:	ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 1 STA 10+51.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 28.07 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 35.49 $N\gamma$= 30.21

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	115.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	32.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

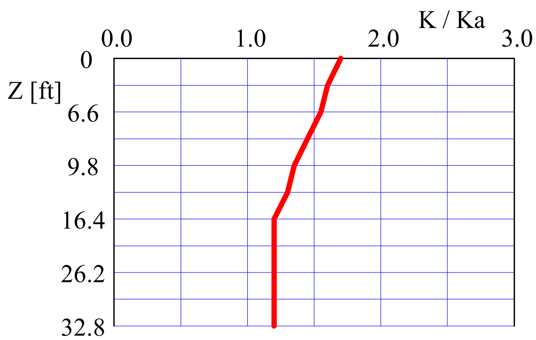
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

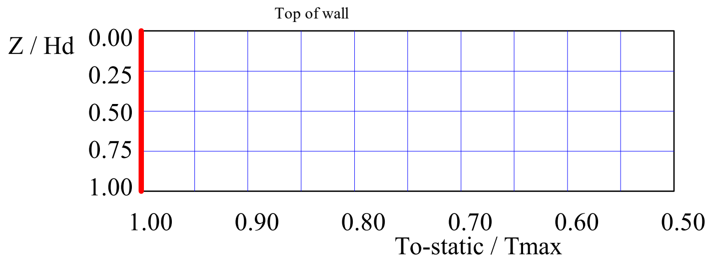
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection
(Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 40.10 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 38.10 ft }

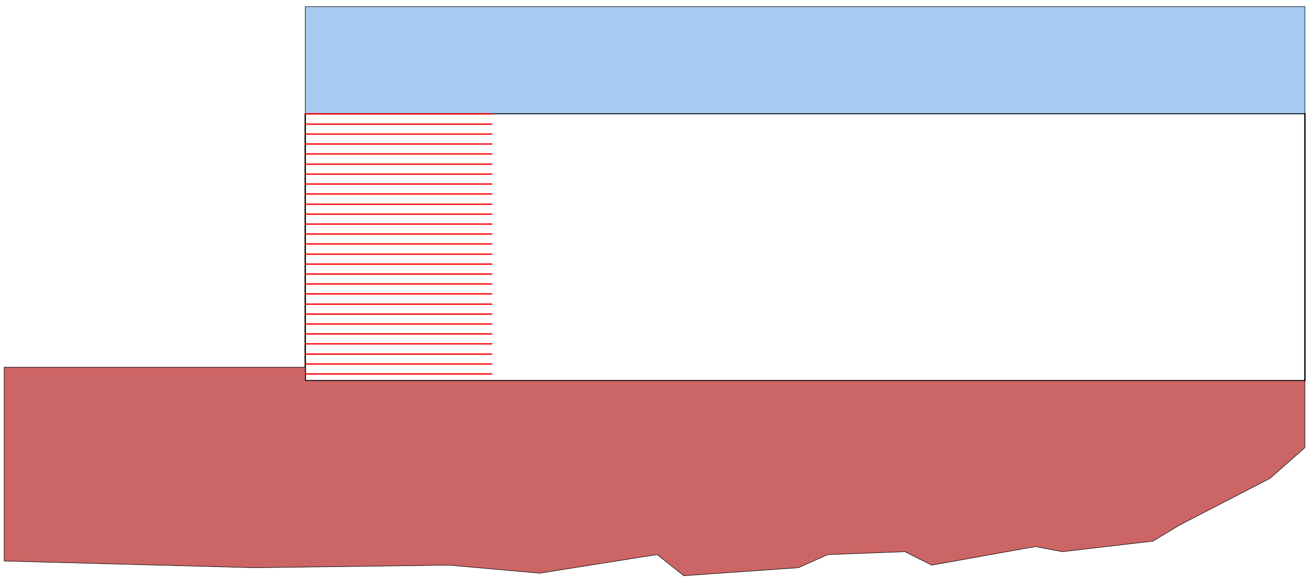
Soil in front of wall is Horizontal.

Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M   S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 5 10 15 20 25 30 [ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_{τ}	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_{τ}	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND: (1) Connection strength √ Satisfactory
(2) Metal strip strength ⊗ Unsatisfactory
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

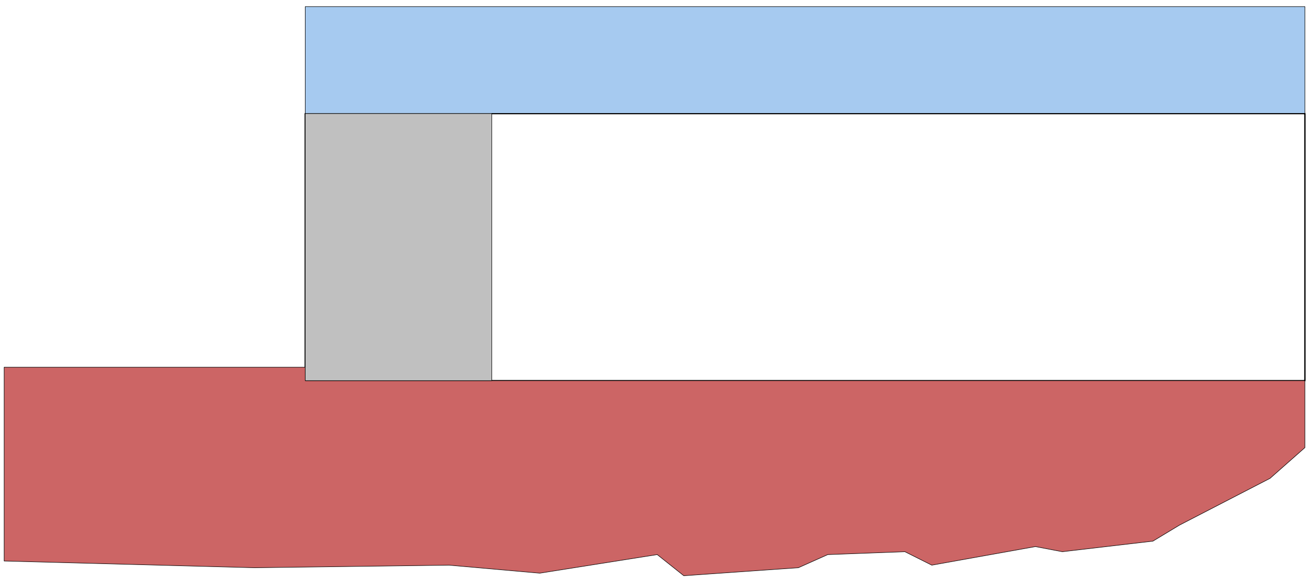
Bearing capacity: √
Foudation Interface: Direct sliding √ Eccentricity √

#	Metal Elevation [ft]	Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	28.07	N/A	√	√	√	√	√
2	2.50	28.07	N/A	√	√	√	√	√
3	4.00	28.07	N/A	√	√	√	√	√
4	5.50	28.07	N/A	√	√	√	√	√
5	7.00	28.07	N/A	√	√	√	√	√
6	8.50	28.07	N/A	√	√	√	√	√
7	10.00	28.07	N/A	√	√	√	√	√
8	11.50	28.07	N/A	√	√	√	√	√
9	13.00	28.07	N/A	√	√	√	√	√
10	14.50	28.07	N/A	√	√	√	√	√
11	16.00	28.07	N/A	√	√	√	√	√
12	17.50	28.07	N/A	√	√	√	√	√
13	19.00	28.07	N/A	√	√	√	√	√
14	20.50	28.07	N/A	√	√	√	√	√

#	Metal Elevation [ft]	Strip Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
15	22.00	28.07	N/A	√	√	√	√	√
16	23.50	28.07	N/A	√	√	√	√	√
17	25.00	28.07	N/A	√	√	√	√	√
18	26.50	28.07	N/A	√	√	√	√	√
19	28.00	28.07	N/A	√	√	√	√	√
20	29.50	28.07	N/A	√	√	√	√	√
21	31.00	28.07	N/A	√	√	√	√	√
22	32.50	28.07	N/A	√	√	√	√	√
23	34.00	28.07	N/A	√	√	√	√	√
24	35.50	28.07	N/A	√	√	√	√	√
25	37.00	28.07	N/A	√	√	√	√	√
26	38.50	28.07	N/A	√	√	√	√	√
27	40.00	28.07	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	23496	N/A	[lb/ft ²]
Factored bearing load, σ_V	10084.7	N/A	[lb/ft ²]
Eccentricity, e	3.63	N/A	[ft]
Eccentricity, e/L	0.129	N/A	
CDR calculated	2.33	N/A	
Base length	28.07	N/A	[ft]



SCALE:

0 5 10 15 20 25 30 [ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.691

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	28.07	1.821	N/A	N/A	---
2	2.50	28.07	1.885	N/A	N/A	---
3	4.00	28.07	1.954	N/A	N/A	---
4	5.50	28.07	2.028	N/A	N/A	---
5	7.00	28.07	2.108	N/A	N/A	---
6	8.50	28.07	2.195	N/A	N/A	---
7	10.00	28.07	2.289	N/A	N/A	---
8	11.50	28.07	2.392	N/A	N/A	---
9	13.00	28.07	2.504	N/A	N/A	---
10	14.50	28.07	2.627	N/A	N/A	---
11	16.00	28.07	2.763	N/A	N/A	---
12	17.50	28.07	2.914	N/A	N/A	---
13	19.00	28.07	3.083	N/A	N/A	---
14	20.50	28.07	3.277	N/A	N/A	---
15	22.00	28.07	3.573	N/A	N/A	---
16	23.50	28.07	3.823	N/A	N/A	---
17	25.00	28.07	4.110	N/A	N/A	---
18	26.50	28.07	4.444	N/A	N/A	---
19	28.00	28.07	4.837	N/A	N/A	---
20	29.50	28.07	5.307	N/A	N/A	---
21	31.00	28.07	5.877	N/A	N/A	---
22	32.50	28.07	6.584	N/A	N/A	---
23	34.00	28.07	7.485	N/A	N/A	---
24	35.50	28.07	8.672	N/A	N/A	---
25	37.00	28.07	10.306	N/A	N/A	---
26	38.50	28.07	12.698	N/A	N/A	---
27	40.00	28.07	16.538	N/A	N/A	---

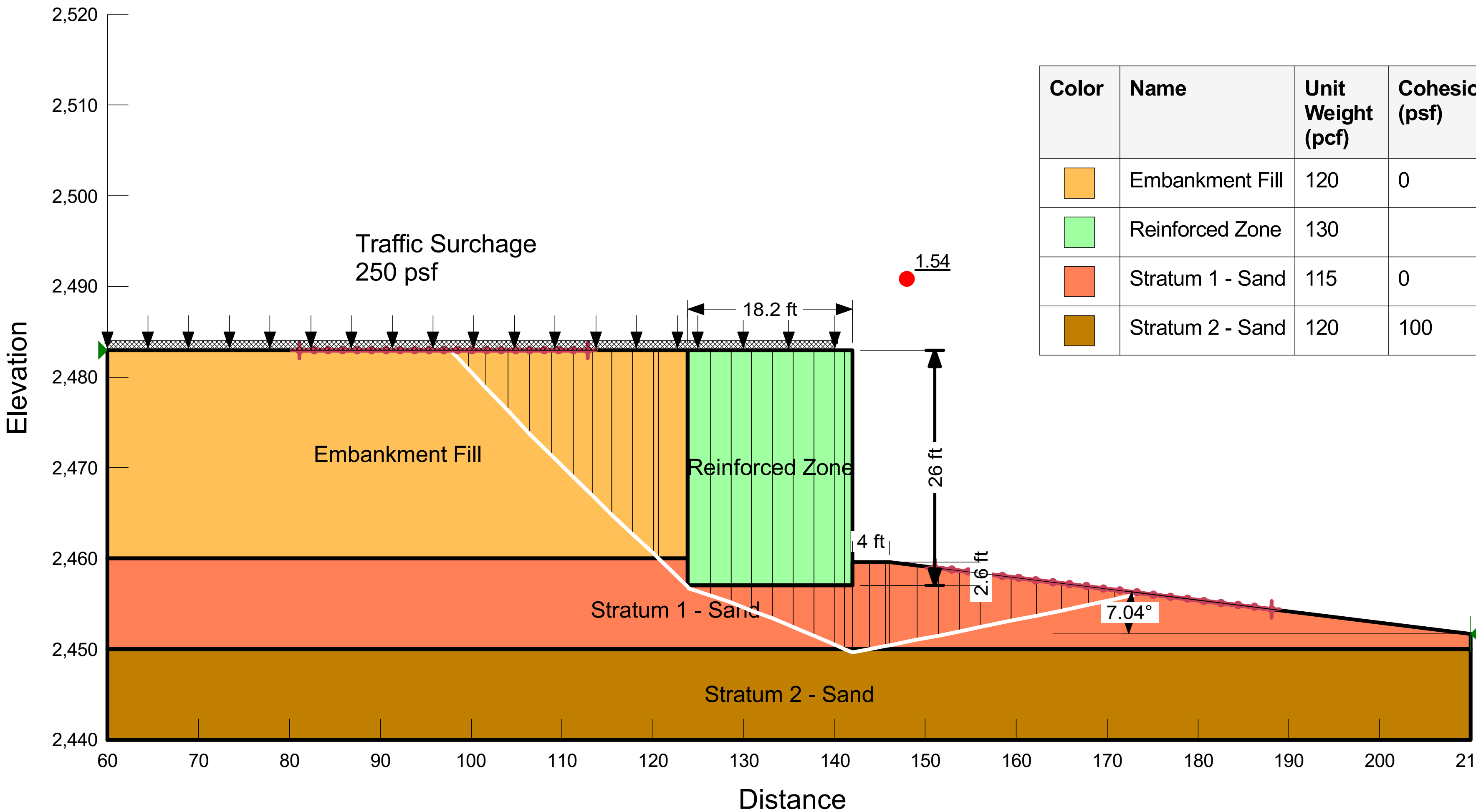
ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.1855; Overturning: CDR-static = 2.69

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	28.07	0.1771	N/A	N/A	---
2	2.50	28.07	0.1648	N/A	N/A	---
3	4.00	28.07	0.1529	N/A	N/A	---
4	5.50	28.07	0.1415	N/A	N/A	---
5	7.00	28.07	0.1305	N/A	N/A	---
6	8.50	28.07	0.1200	N/A	N/A	---
7	10.00	28.07	0.1099	N/A	N/A	---
8	11.50	28.07	0.1002	N/A	N/A	---
9	13.00	28.07	0.0910	N/A	N/A	---
10	14.50	28.07	0.0822	N/A	N/A	---
11	16.00	28.07	0.0739	N/A	N/A	---
12	17.50	28.07	0.0660	N/A	N/A	---
13	19.00	28.07	0.0585	N/A	N/A	---
14	20.50	28.07	0.0515	N/A	N/A	---
15	22.00	28.07	0.0449	N/A	N/A	---
16	23.50	28.07	0.0387	N/A	N/A	---
17	25.00	28.07	0.0330	N/A	N/A	---
18	26.50	28.07	0.0277	N/A	N/A	---
19	28.00	28.07	0.0229	N/A	N/A	---
20	29.50	28.07	0.0185	N/A	N/A	---
21	31.00	28.07	0.0146	N/A	N/A	---
22	32.50	28.07	0.0110	N/A	N/A	---
23	34.00	28.07	0.0080	N/A	N/A	---
24	35.50	28.07	0.0053	N/A	N/A	---
25	37.00	28.07	0.0031	N/A	N/A	---
26	38.50	28.07	0.0014	N/A	N/A	---
27	40.00	28.07	0.0001	N/A	N/A	---

Name: Abutment 2, STA 10+71 to 11+07
Method: Spencer
Factor of Safety: 1.54

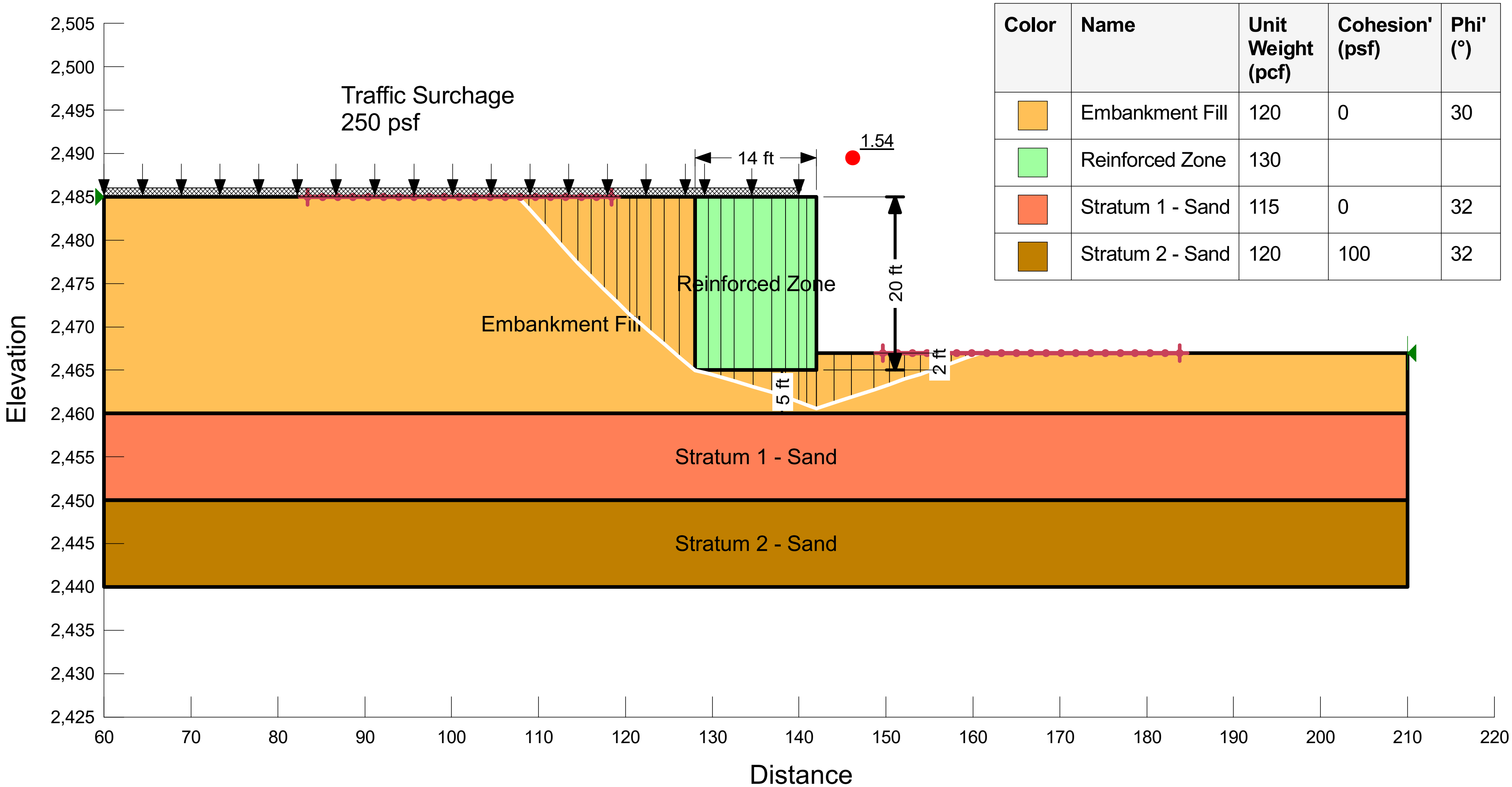
Abutment 2
STA 10+00 to STA 11+40
26' Wall Height on Native with Toe Slope
0.7H Strap Length



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

Name: Abutment 2, STA 11+40 to 11+58
Method: Spencer
Factor of Safety: 1.54

Abutment 2
STA 11+40 to STA 11+58
20' Wall Height on 5' Fill
0.7H Strap Length



Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment Fill	120	0	30
	Reinforced Zone	130		
	Stratum 1 - Sand	115	0	32
	Stratum 2 - Sand	120	100	32

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - Abutment 2 STA 10+00

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title:	US 93, Val Vista - Abutment 2 STA 10+00
Project Number:	2024112
Client:	
Designer:	Katie Mackay
Station Number:	

Description:

26H on native with 7 degree toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284
Telephone #: 602.573.0000
Fax #:
E-Mail: ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 2 STA 10+00.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 18.20 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: $N_c = 0.00$ $N_\gamma = 14.99$

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft³
Equivalent internal angle of friction, $\phi_{equiv.}$	32.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

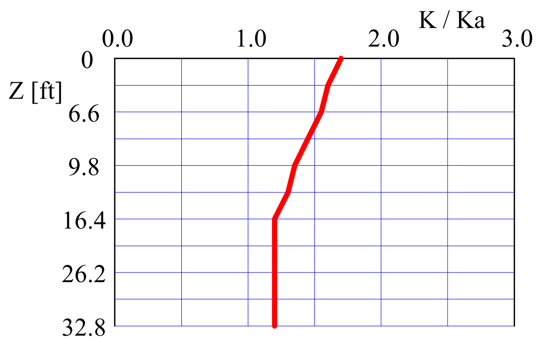
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

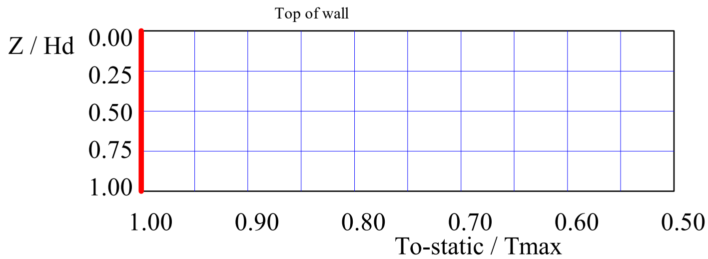
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection (Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 26.00 [ft] { Embedded depth is E = 2.60 ft, and height above top of finished bottom grade is H = 23.40 ft }
Soil in front of the wall is inclined at 3H:1V. Hs = 6.56 ft.

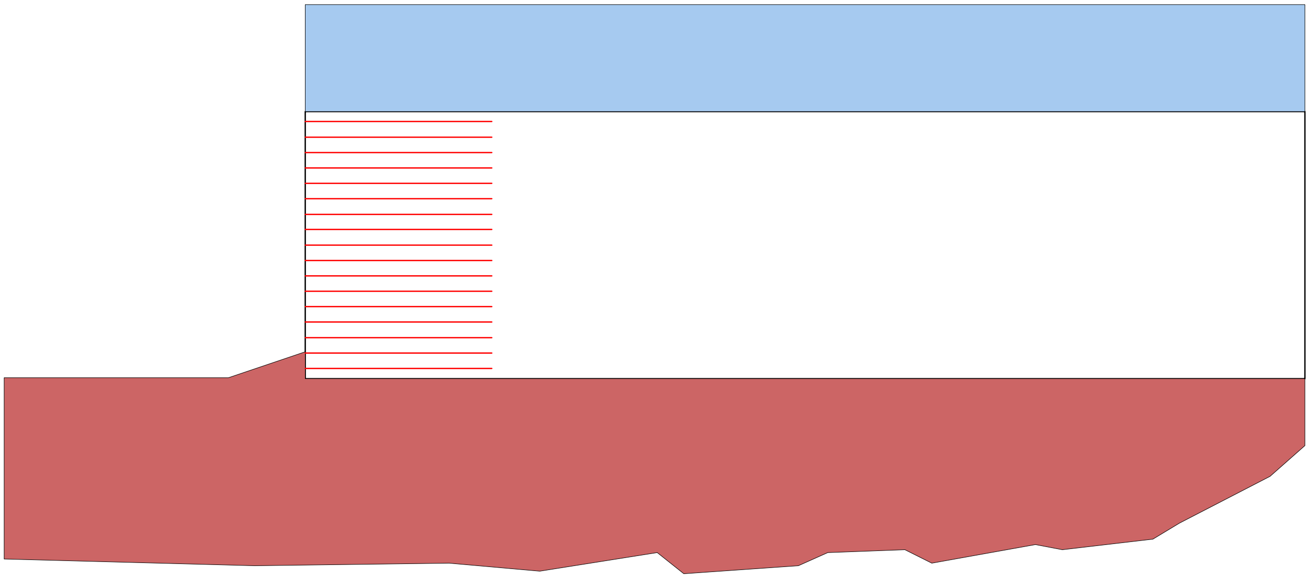
Batter, ω	0.0	[deg]
Backslope, β	0.0	[deg]
Backslope rise	0.0	[ft]

Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND:
(1) Connection strength — √ Satisfactory
(2) Metal strip strength — ⊗ Unsatisfactory
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

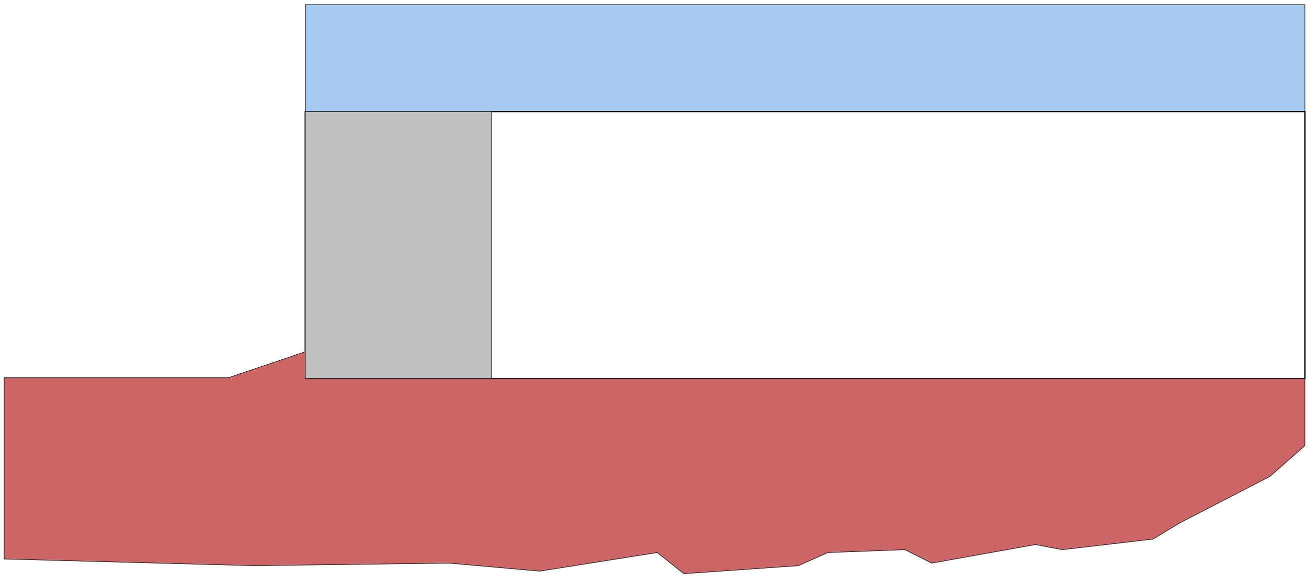
Bearing capacity: √
Foudation Interface: Direct sliding √ Eccentricity √

#	Metal Elevation [ft]	Length [ft]	Strip Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	18.20	N/A	√	√	√	√	√
2	2.50	18.20	N/A	√	√	√	√	√
3	4.00	18.20	N/A	√	√	√	√	√
4	5.50	18.20	N/A	√	√	√	√	√
5	7.00	18.20	N/A	√	√	√	√	√
6	8.50	18.20	N/A	√	√	√	√	√
7	10.00	18.20	N/A	√	√	√	√	√
8	11.50	18.20	N/A	√	√	√	√	√
9	13.00	18.20	N/A	√	√	√	√	√

#	Metal Elevation [ft]	Length [ft]	Strip Type #	(1)	(2)	(3)	(4)	(5)
10	14.50	18.20	N/A	√	√	√	√	√
11	16.00	18.20	N/A	√	√	√	√	√
12	17.50	18.20	N/A	√	√	√	√	√
13	19.00	18.20	N/A	√	√	√	√	√
14	20.50	18.20	N/A	√	√	√	√	√
15	22.00	18.20	N/A	√	√	√	√	√
16	23.50	18.20	N/A	√	√	√	√	√
17	25.00	18.20	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	7749	N/A	[lb/ft ²]
Factored bearing load, σ_V	6866.4	N/A	[lb/ft ²]
Eccentricity, e	2.47	N/A	[ft]
Eccentricity, e/L	0.136	N/A	
CDR calculated	1.13	N/A	
Base length	18.20	N/A	[ft]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.597

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	18.20	1.738	N/A	N/A	---
2	2.50	18.20	1.830	N/A	N/A	---
3	4.00	18.20	1.932	N/A	N/A	---
4	5.50	18.20	2.046	N/A	N/A	---
5	7.00	18.20	2.202	N/A	N/A	---
6	8.50	18.20	2.379	N/A	N/A	---
7	10.00	18.20	2.550	N/A	N/A	---
8	11.50	18.20	2.748	N/A	N/A	---
9	13.00	18.20	2.978	N/A	N/A	---
10	14.50	18.20	3.251	N/A	N/A	---
11	16.00	18.20	3.580	N/A	N/A	---
12	17.50	18.20	3.981	N/A	N/A	---
13	19.00	18.20	4.485	N/A	N/A	---
14	20.50	18.20	5.134	N/A	N/A	---
15	22.00	18.20	6.003	N/A	N/A	---
16	23.50	18.20	7.227	N/A	N/A	---
17	25.00	18.20	9.076	N/A	N/A	---

ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

At interface with foundation: e/L static = 0.2010; Overturning: CDR-static = 2.49

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	18.20	0.1875	N/A	N/A	---
2	2.50	18.20	0.1680	N/A	N/A	---
3	4.00	18.20	0.1497	N/A	N/A	---
4	5.50	18.20	0.1323	N/A	N/A	---
5	7.00	18.20	0.1160	N/A	N/A	---
6	8.50	18.20	0.1008	N/A	N/A	---
7	10.00	18.20	0.0865	N/A	N/A	---
8	11.50	18.20	0.0734	N/A	N/A	---
9	13.00	18.20	0.0613	N/A	N/A	---
10	14.50	18.20	0.0502	N/A	N/A	---
11	16.00	18.20	0.0402	N/A	N/A	---
12	17.50	18.20	0.0312	N/A	N/A	---
13	19.00	18.20	0.0232	N/A	N/A	---
14	20.50	18.20	0.0163	N/A	N/A	---
15	22.00	18.20	0.0105	N/A	N/A	---
16	23.50	18.20	0.0057	N/A	N/A	---
17	25.00	18.20	0.0019	N/A	N/A	---

AASHTO 2007-2010 (LRFD)
US 93, Val Vista - Abutment 2 STA 11+4-

MSEW+: Update # 2025.11

PROJECT IDENTIFICATION

Title: US 93, Val Vista - Abutment 2 STA 11+4-
Project Number: 2024112
Client:
Designer: Katie Mackay
Station Number:

Description:

20H over 5F no toe slope

Company's information:

Name: Ethos Engineering, LLC.
Street: 9180 S Kyrene Rd, #104

Tempe, AZ 85284
Telephone #: 602.573.0000
Fax #:
E-Mail: ethosengineers.com

File path and name: \\VR-File\Projects\2024112 - AECOM - US 93, Vista Royal.....
.....ent 2 STA 11+40.BENp

Original date and time of creating this file: 11/11/25

PROGRAM MODE: DESIGN
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

DESIGN DATA

DESIGN OBJECTIVES

Minimum Capacity Demand Ratio in pullout, CDR-po	1.00
Minimum Capacity Demand Ratio in direct sliding, CDR-sliding	1.00
Maximum allowable eccentricity ratio at each reinforcement level, e/L	0.2500
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-static	1.30
Minimum Capacity Demand Ratio in compound and overall failure, CDR-comp-seismic	1.10

Prescribed minimum resistive length to prevent pullout, Le = 3.28 ft.
Prescribed minimum normalized length of each layer is: L/Hd = 0.70 --> L = 14.00 ft.
Prescribed minimum absolute total length of each layer is: L = 8.00 ft.

BEARING CAPACITY

Bearing capacity is controlled by general shear.

Maximum permissible eccentricity ratio (soil), e/L	0.2500
Min. Capacity Demand Ratio with respect to ultimate bearing capacity (Meyerhof approach)	1.00

Bearing capacity factors: Nc = 30.14 N_γ= 22.40

SOIL DATA

REINFORCED SOIL

Unit weight, γ	130.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.3333 (if batter is less than 10°, Ka is calculated from eq. 16. Otherwise, eq. 17 is utilized)

SEISMICITY

Not Applicable

INPUT DATA: Metal strips
(Optimally spaced single type reinforcement)

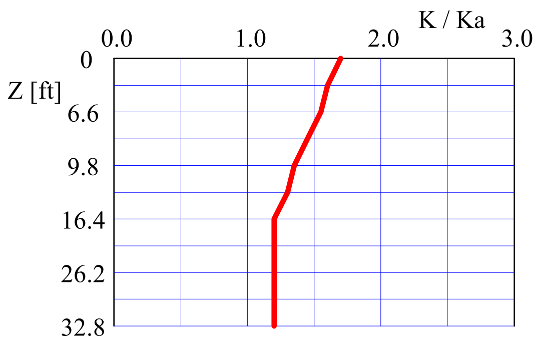
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.3	N/A	N/A	N/A	N/A
Strength reduction factor, FS	1.000	N/A	N/A	N/A	N/A
or: Fs = 1 / FS	1.000	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	6.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.500	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	32.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	1.80	N/A	N/A	N/A	N/A
@ 19.7 ft or below	0.62	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth

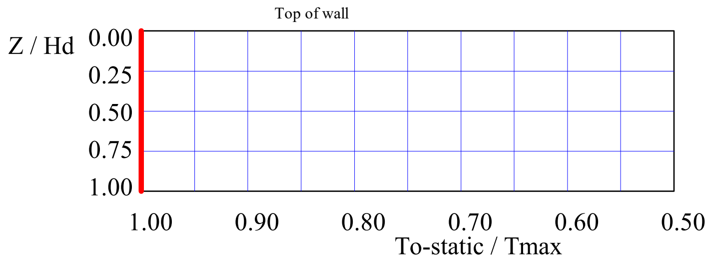
Z	K / Ka
0 ft	1.70
3.3 ft	1.60
6.6 ft	1.55
9.8 ft	1.45
13.1 ft	1.35
16.4 ft	1.30
19.7 ft	1.20



INPUT DATA: Facia and Connection (Design)

FACIA type: Segmental precast concrete panels.
Depth of panel is 1.31 ft. Horizontal distance to Center of Gravity of panel is 0.66 ft.
Average unit weight of panel is γ_f = 152.78 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	---	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	0.90	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 20.00 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 18.00 ft }

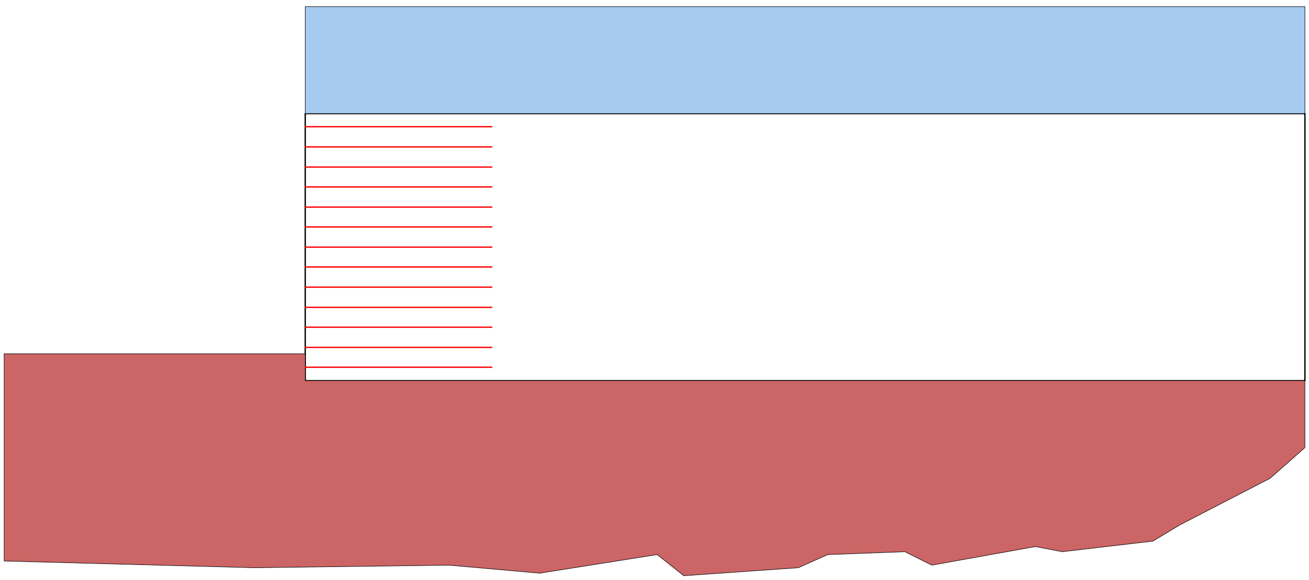
Soil in front of wall is Horizontal.

Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

DESIGNED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10 [ft]

AASHTO 2007-2010 (LRFD) – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static	Combined Static/Seismic	
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor of active lateral earth pressure during earthquake (does not multiply P_{AE} and P_{IR}):	$(\gamma_{p\text{-}EH})_{EQ}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

REINFORCEMENT LAYOUT AND DESIGN CRITERIA

LEGEND:
(1) Connection strength
(2) Metal strip strength
(3) Pullout resistance
(4) Direct sliding
(5) Eccentricity

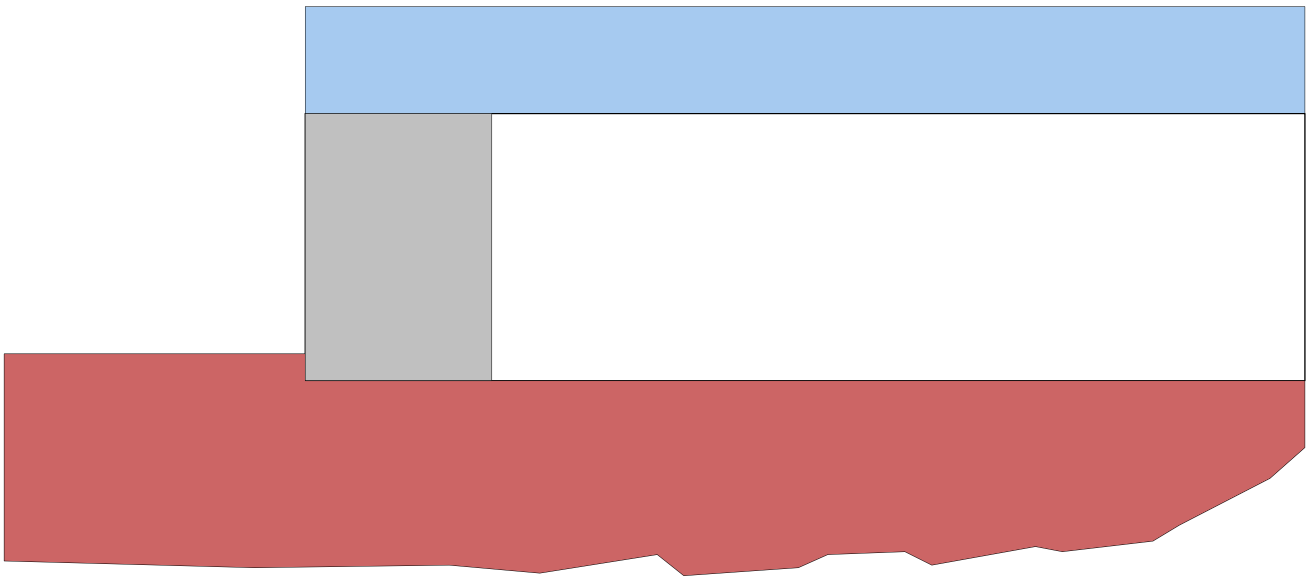
√ Satisfactory
⊗ Unsatisfactory

Bearing capacity: √
Foudation Interface: Direct sliding √ Eccentricity √

#	Metal Strip Elevation [ft]	Length [ft]	Type #	(1)	(2)	(3)	(4)	(5)
1	1.00	14.00	N/A	√	√	√	√	√
2	2.50	14.00	N/A	√	√	√	√	√
3	4.00	14.00	N/A	√	√	√	√	√
4	5.50	14.00	N/A	√	√	√	√	√
5	7.00	14.00	N/A	√	√	√	√	√
6	8.50	14.00	N/A	√	√	√	√	√
7	10.00	14.00	N/A	√	√	√	√	√
8	11.50	14.00	N/A	√	√	√	√	√
9	13.00	14.00	N/A	√	√	√	√	√
10	14.50	14.00	N/A	√	√	√	√	√
11	16.00	14.00	N/A	√	√	√	√	√
12	17.50	14.00	N/A	√	√	√	√	√
13	19.00	14.00	N/A	√	√	√	√	√

BEARING CAPACITY for DESIGNED LAYOUT

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-r=(fi)*q-n	8780	N/A	[lb/ft ²]
Factored bearing load, σ_V	5499.4	N/A	[lb/ft ²]
Eccentricity, e	1.98	N/A	[ft]
Eccentricity, e/L	0.141	N/A	
CDR calculated	1.60	N/A	
Base length	14.00	N/A	[ft]



SCALE:

0 2 4 6 8 10 [ft]

DIRECT SLIDING for DESIGNED LAYOUT (for METAL STRIPS reinforcements)

Specified CDR-static = 1.000

Along reinforced and foundation soils interface: CDR-static = 1.409

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.00	14.00	1.694	N/A	N/A	---
2	2.50	14.00	1.830	N/A	N/A	---
3	4.00	14.00	1.962	N/A	N/A	---
4	5.50	14.00	2.114	N/A	N/A	---
5	7.00	14.00	2.291	N/A	N/A	---
6	8.50	14.00	2.501	N/A	N/A	---
7	10.00	14.00	2.754	N/A	N/A	---
8	11.50	14.00	3.063	N/A	N/A	---
9	13.00	14.00	3.450	N/A	N/A	---
10	14.50	14.00	3.949	N/A	N/A	---
11	16.00	14.00	4.618	N/A	N/A	---
12	17.50	14.00	5.559	N/A	N/A	---
13	19.00	14.00	6.982	N/A	N/A	---

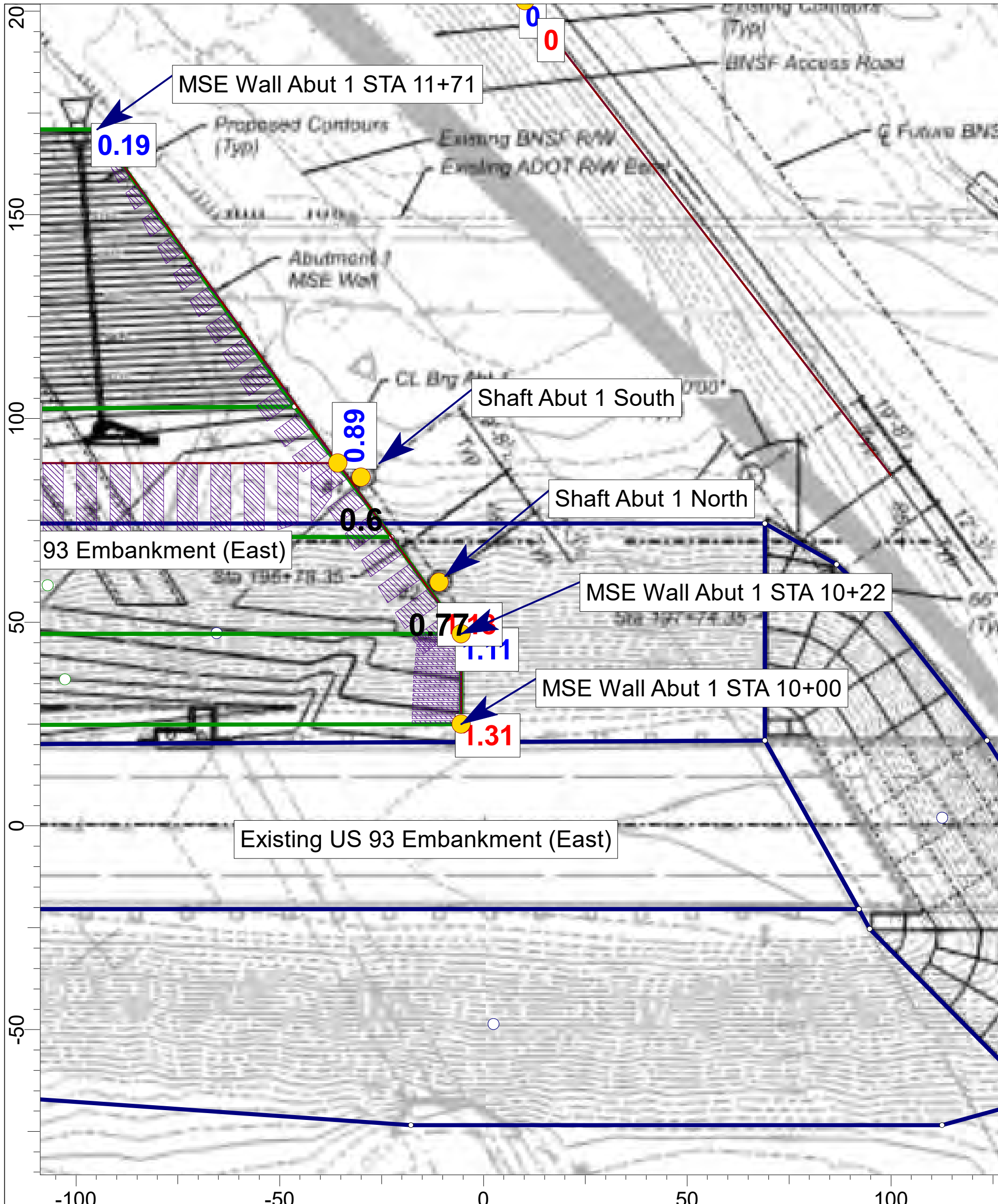
ECCENTRICITY for DESIGNED LAYOUT (for Simplified Method)

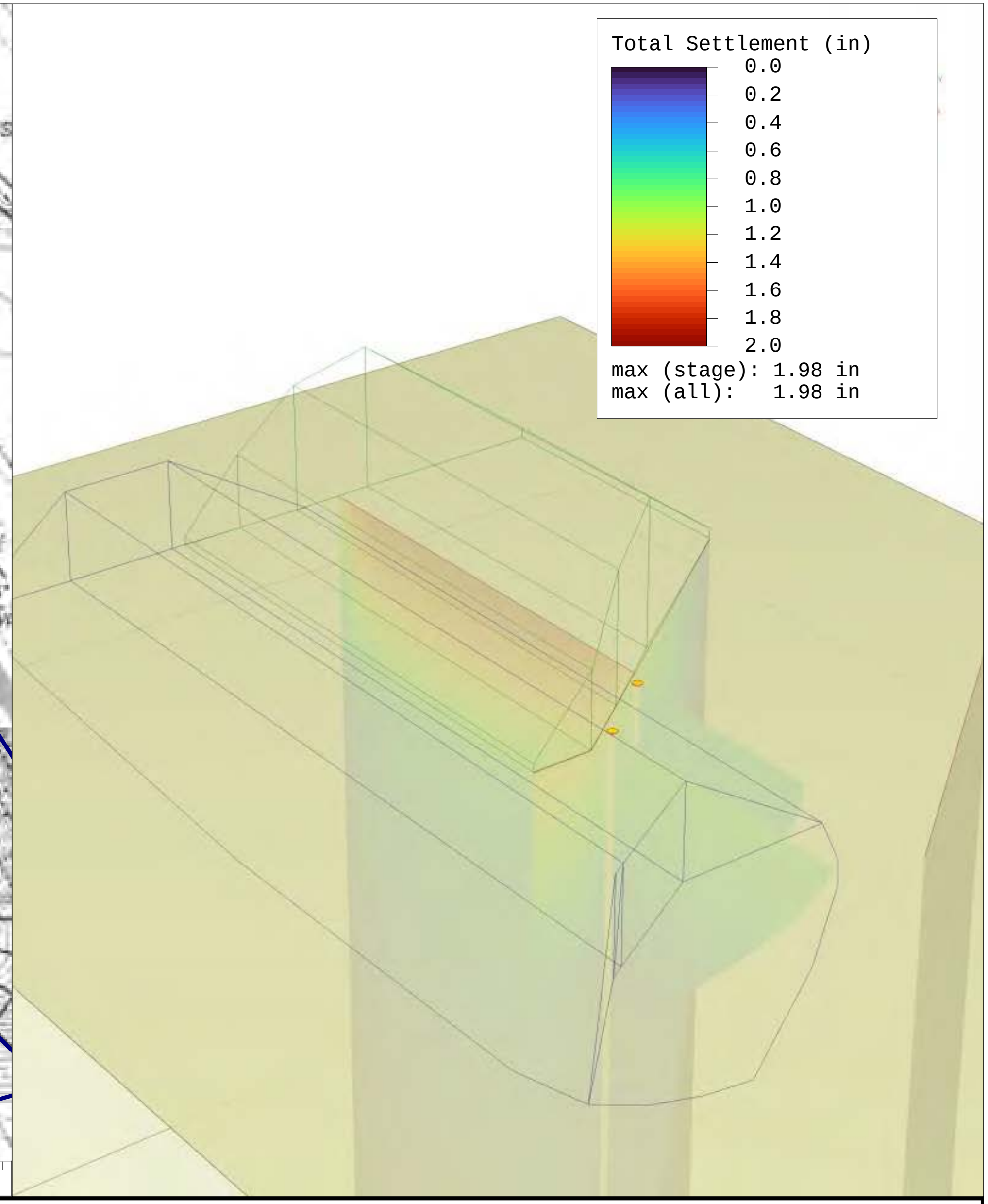
At interface with foundation: e/L static = 0.2142; Overturning: CDR-static = 2.33

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.00	14.00	0.1961	N/A	N/A	---
2	2.50	14.00	0.1703	N/A	N/A	---
3	4.00	14.00	0.1463	N/A	N/A	---
4	5.50	14.00	0.1240	N/A	N/A	---
5	7.00	14.00	0.1035	N/A	N/A	---
6	8.50	14.00	0.0848	N/A	N/A	---
7	10.00	14.00	0.0679	N/A	N/A	---
8	11.50	14.00	0.0527	N/A	N/A	---
9	13.00	14.00	0.0393	N/A	N/A	---
10	14.50	14.00	0.0276	N/A	N/A	---
11	16.00	14.00	0.0177	N/A	N/A	---
12	17.50	14.00	0.0096	N/A	N/A	---
13	19.00	14.00	0.0033	N/A	N/A	---

APPENDIX E

Settlement Results

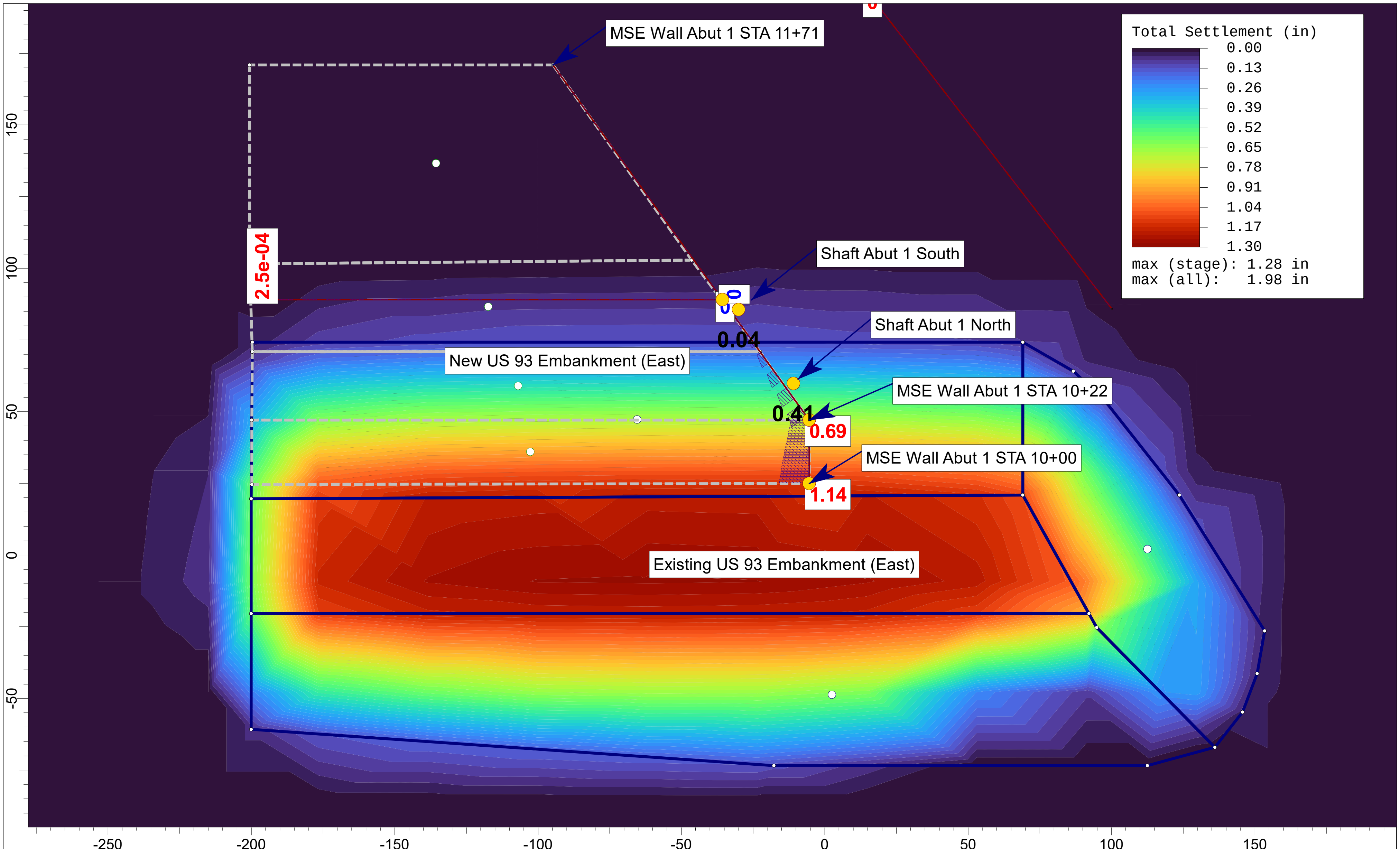




ethos ENGINEERING, LLC.

SETTLE3 5.026

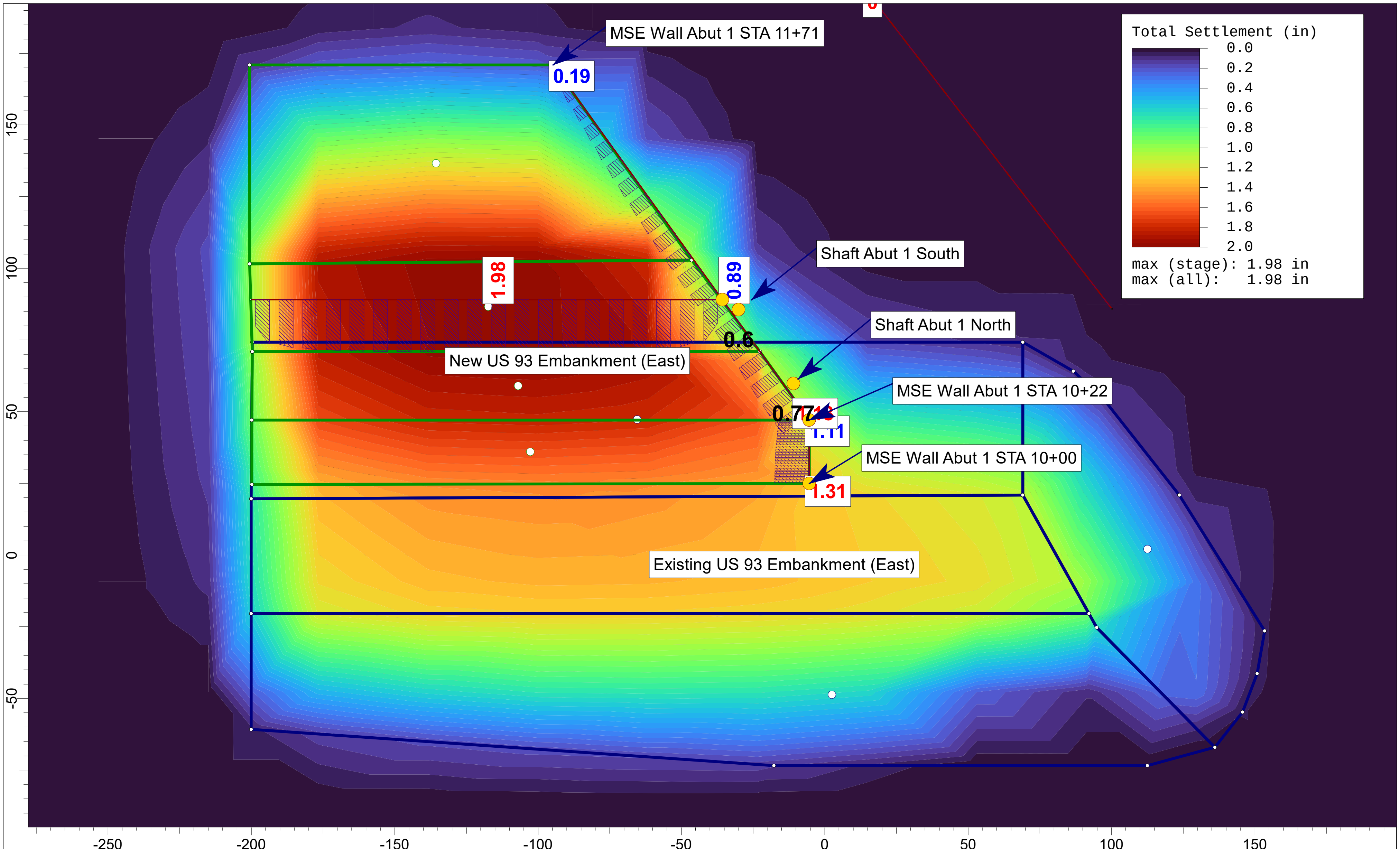
Project	US 93, Vista Royale		
Analysis Description	Abutment 1 Settlement		
Drawn By	Katie Mackay	*Company*	Ethos
Date	11/24/2025, 6:05:24 PM	*File Name*	US 93 Abutment 1 Settlement.s3z



Project	US 93, Vista Royale		
Analysis Description	Abutment 1 Settlement Stage 1 - Existing Embankment		
Drawn By	Katie Mackay	Company	Ethos
Date	11/24/2025, 6:05:24 PM	File Name	US 93 Abutment 1 Settlement.s3z

ETHOS ENGINEERING, LLC.

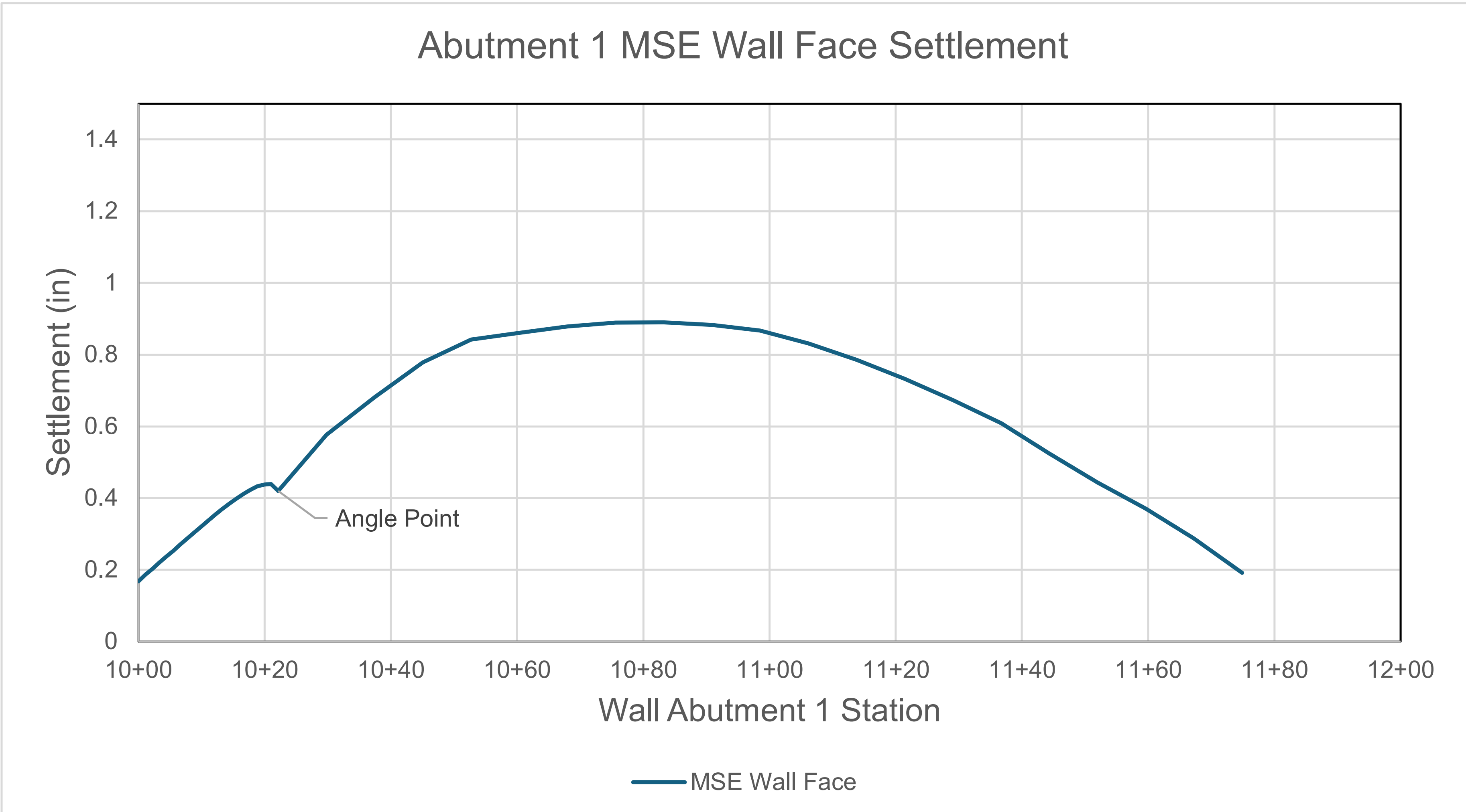
SETTLE3 5.026



ENGINEERING, LLC.

SETTLE3 5.026

Project	US 93, Vista Royale		
Analysis Description	Abutment 1 Settlement Stage 2 - New Embankment		
Drawn By	Katie Mackay	*Company*	Ethos
Date	11/24/2025, 6:05:24 PM	*File Name*	US 93 Abutment 1 Settlement.s3z


Abutment 1 MSE Wall Face Settlement
Settlement (in)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10+00
10+20
10+40
10+60
10+80
11+00
11+20
11+40
11+60
11+80
12+00
Wall Abutment 1 Station
Angle Point
MSE Wall Face

ROCSCIENCE

US 93, Vista Royale
Ethos
Report Creation Date: 2025/11/24, 20:08:39

(Abutment 1)

Table of Contents

Settle3 Analysis Information

US 93, Vista Royale (Abutment 1)

Project Settings

Document Name	US 93 Abutment 1 Settlement.s3z
Project Title	US 93, Vista Royale
Analysis	Abutment 1 Settlement
Author	Katie Mackay
Company	Ethos
Date Created	11/24/2025, 6:05:24 PM
Last saved with Settle3 version	5.026
Stress Computation Method	Westergaard
Stress Units	Imperial, stress as ksf
Settlement Units	inches

Advanced Settings

Calculate settlement with mean stress	
Start of secondary consolidation (% of primary)	95
Min. stress for secondary consolidation (% of initial)	1
Reset time when load changes for secondary consolidation	No
Use settlement cutoff	
Load/Insitu vertical stress ratio	0.1
Minimum settlement ratio for subgrade modulus	0.9
Use average poisson's ratio to calculate layered stresses	
Update Cv in each time step (improves consolidation accuracy)	
Ignore negative effective stresses in settlement calculations	
Add field points to load edges	

Soil Profile

Layer Option	Horizontal Soil Layers
Vertical Axis	Depth below ground surface

Stage Settings

Stage #	Name
1	Existing Embankment
2	New Embankment

Results

Time taken to compute: 1.0005 seconds

Stage: Existing Embankment

Data Type	Minimum	Maximum
Total Settlement [in]	0	1.27849
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	1.27849
Loading Stress ZZ [ksf]	-0.000128631	2.89298
Loading Stress XX [ksf]	-0.0567277	1.61389
Loading Stress YY [ksf]	-0.0567277	1.61389
Mean Stress [ksf]	0	2.04149
Total Stress ZZ [ksf]	-0.000128631	13.5239
Total Stress XX [ksf]	-0.0567277	12.8933
Total Stress YY [ksf]	-0.0567277	12.8933
Modulus of Subgrade Reaction (Total) [ksf/ft]	-8.20082e-05	1689.68
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	-8.20082e-05	1689.68
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.00556996
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.0174046	13.5189
Over-consolidation Ratio	1	1
Void Ratio	0	0
Hydroconsolidation Settlement [in]	0	0
Undrained Shear Strength	0	0.0693061

Stage: New Embankment

Data Type	Minimum	Maximum
Total Settlement [in]	0	1.97933
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	1.97933
Loading Stress ZZ [ksf]	-0.594334	4.69
Loading Stress XX [ksf]	-0.0567277	1.61389
Loading Stress YY [ksf]	-0.0567277	1.61389
Mean Stress [ksf]	-8.00342e-06	3.30939
Total Stress ZZ [ksf]	-0.594334	14.4524
Total Stress XX [ksf]	-0.0567277	12.8933
Total Stress YY [ksf]	-0.0567277	12.8933
Modulus of Subgrade Reaction (Total) [ksf/ft]	-7.09198	193.374
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	-7.09198	193.374
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.009017
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.0180893	14.4476
Over-consolidation Ratio	1	1
Void Ratio	0	0
Hydroconsolidation Settlement [in]	0	0
Undrained Shear Strength	0	0.102421

Loads

1. Polygonal Load: "Existing US 93 S front slope"

Label	Existing US 93 S front slope
Load Type	Flexible
Area of Load	5639.25 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
69.02	20.936	2.89
94.788	-25.33	2.89
136.053	-67.041	0
145.645	-54.773	0
150.775	-41.39	0
153.384	-26.492	0
123.584	20.936	0
97.141	54.514	0
86.648	64.167	0
69.02	74.241	0

2. Polygonal Load: "Existing US 93 E Main"

Label	Existing US 93 E Main
Load Type	Flexible
Area of Load	11443.9 ft2
Load	2.89 ksf
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates

X [ft]	Y [ft]
92.0911	-20.4877
69.02	20.936
-200.067	19.594
-200.067	-20.4877

3. Polygonal Load: "Polygonal Load 3"

Label	Polygonal Load 3
Load Type	Flexible
Area of Load	14513.1 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
69.02	74.241	0
-199.659	74.241	0
-200.067	19.594	2.89
69.02	20.936	2.89

4. Polygonal Load: "Existing US 93 E North Slope"

Label	Existing US 93 E North Slope
Load Type	Flexible
Area of Load	15518.4 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
94.788	-25.33	0
92.0911	-20.4877	2.89
-200.067	-20.4877	2.89
-200.067	-60.847	0
-17.794	-73.483	0
112.52	-73.483	0
136.053	-67.041	0

5. Polygonal Load: "New US 93 E South Slope"

Label	New US 93 E South Slope
Load Type	Flexible
Area of Load	8947.26 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
-94.796	170.962	0.33
-200.567	170.962	0.33
-200.567	101.597	4.69
-46.378	102.898	4.69

6. Polygonal Load: "New US 93 E STA 10+00 to 10+22"

Label	New US 93 E STA 10+00 to 10+22
Load Type	Flexible
Area of Load	4335.82 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
-5.426	47.08	2.42
-199.862	47.08	2.42
-199.862	24.618	0.26
-5.426	24.943	0.26

7. Polygonal Load: "New US 93 E STA 10+22 to 10+51"

Label	New US 93 E STA 10+22 to 10+51
Load Type	Flexible
Area of Load	4425.71 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
-22.6142	70.9058	4.15
-199.684	70.9058	4.15
-199.862	47.08	2.42
-5.426	47.08	2.42

8. Polygonal Load: "New US 93 E STA 10+51 to 10+83"

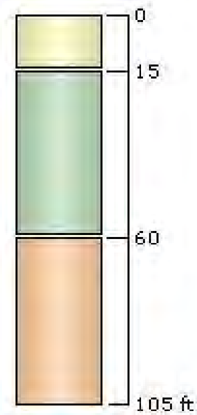
Label	New US 93 E STA 10+51 to 10+83
Load Type	Flexible
Area of Load	5199.12 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
-46.378	102.898	4.69
-200.567	101.597	4.69
-199.684	70.9058	4.15
-22.6142	70.9058	4.15

Soil Layers

Layer #	Type	Thickness [ft]	Depth [ft]
1	1. SM	15	0
2	2. SC-SM	45	15
3	3. Cemented SC-SM	45	60



Soil Properties

Property	1. SM	2. SC-SM	3. Cemented SC-SM
Color			
Unit Weight [kips/ft3]	0.115	0.12	0.12
Poisson's Ratio	0.325	0.375	0.375
K0	1	1	1
Immediate Settlement	Enabled	Enabled	Enabled
E [ksf]	330	2280	3940
Eur [ksf]	330	2280	3940
Undrained Su A [kips/ft2]	0	0	0
Undrained Su S	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8

Query

Query Points

Point #	Query Point Name	(X,Y) Location	Number of Divisions
1	Abutment 1 North	-10.871, 59.804	Auto: 47
2	Abutment 1 South	-30.043, 85.562	Auto: 27

Query Lines

Line #	Query Line Name	Start Location	End Location	Horizontal Divisions	Vertical Divisions
1	MSE Wall Abut 1 10+00 to 10+22	-5.426, 24.943	-5.426, 47.08	20	Auto: 47
2	MSE Wall Abut 1 10+22 to 11+71	-5.426, 47.08	-94.796, 170.962	20	Auto: 47
3	Railroad Tracks East	10.179, 202.6	100.121, 85.809	20	Auto: 27
4	Max Embankment	-35.6968, 89.0404	-200.206, 89.0404	20	Auto: 27

Field Point Grid

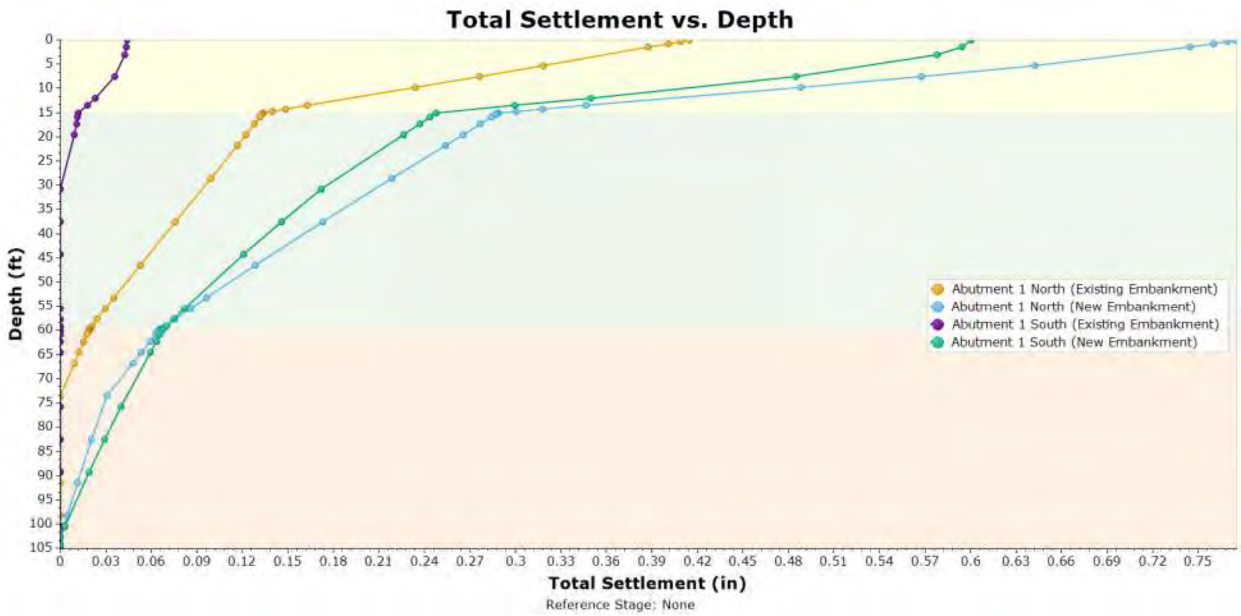
Number of points	409
Expansion Factor	2

Grid Coordinates

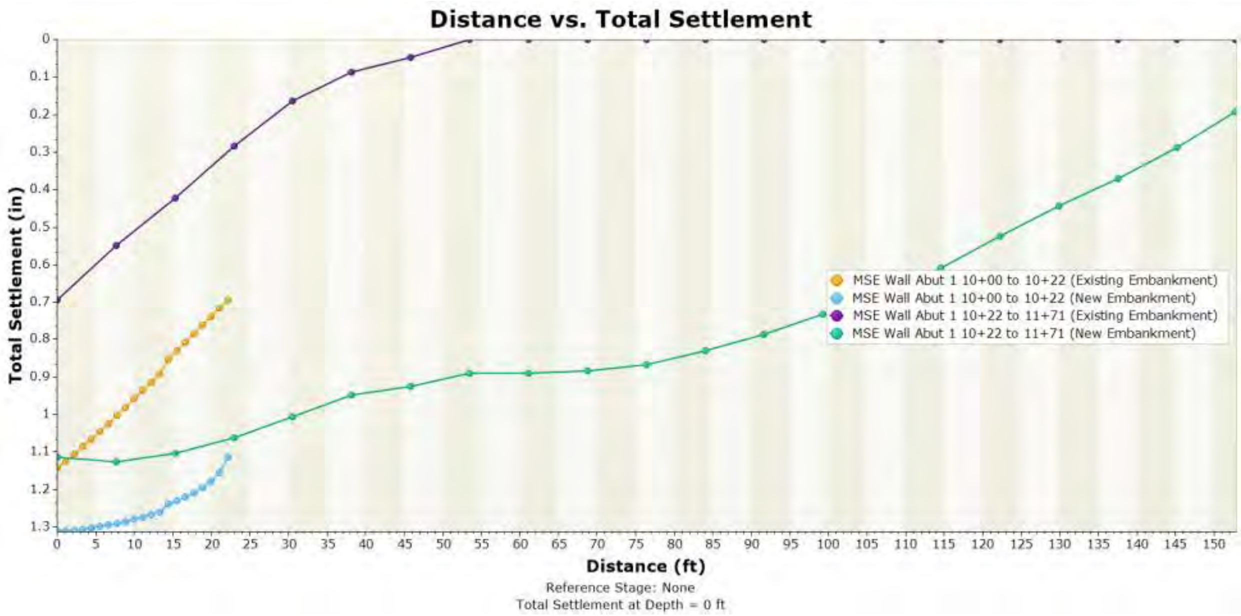
X [ft]	Y [ft]
320.944	338.522
320.944	-241.043
-368.127	-241.043
-368.127	338.522

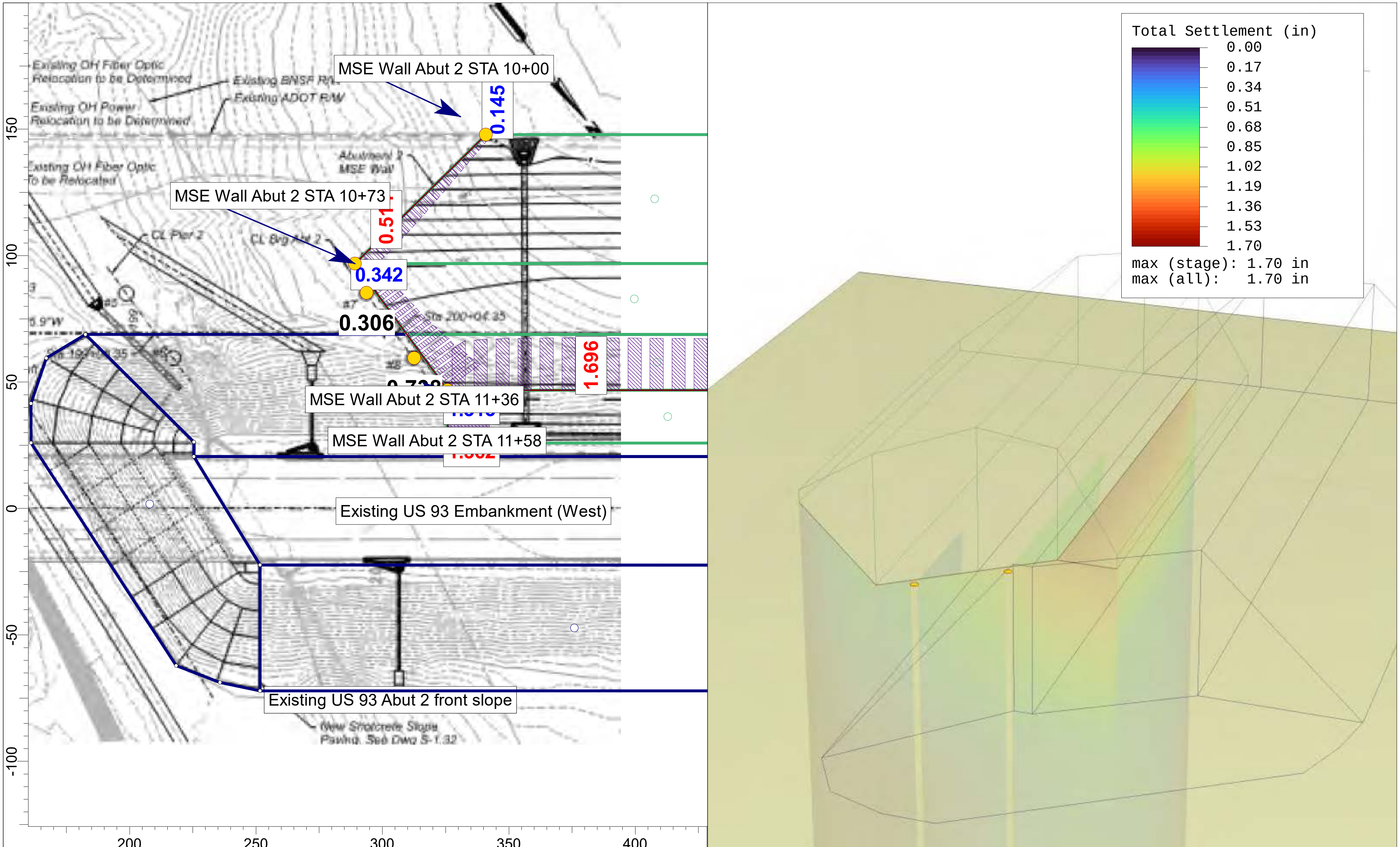
Report Views

Drilled Shafts Settlement 1



Settlement at MSE Wall 2

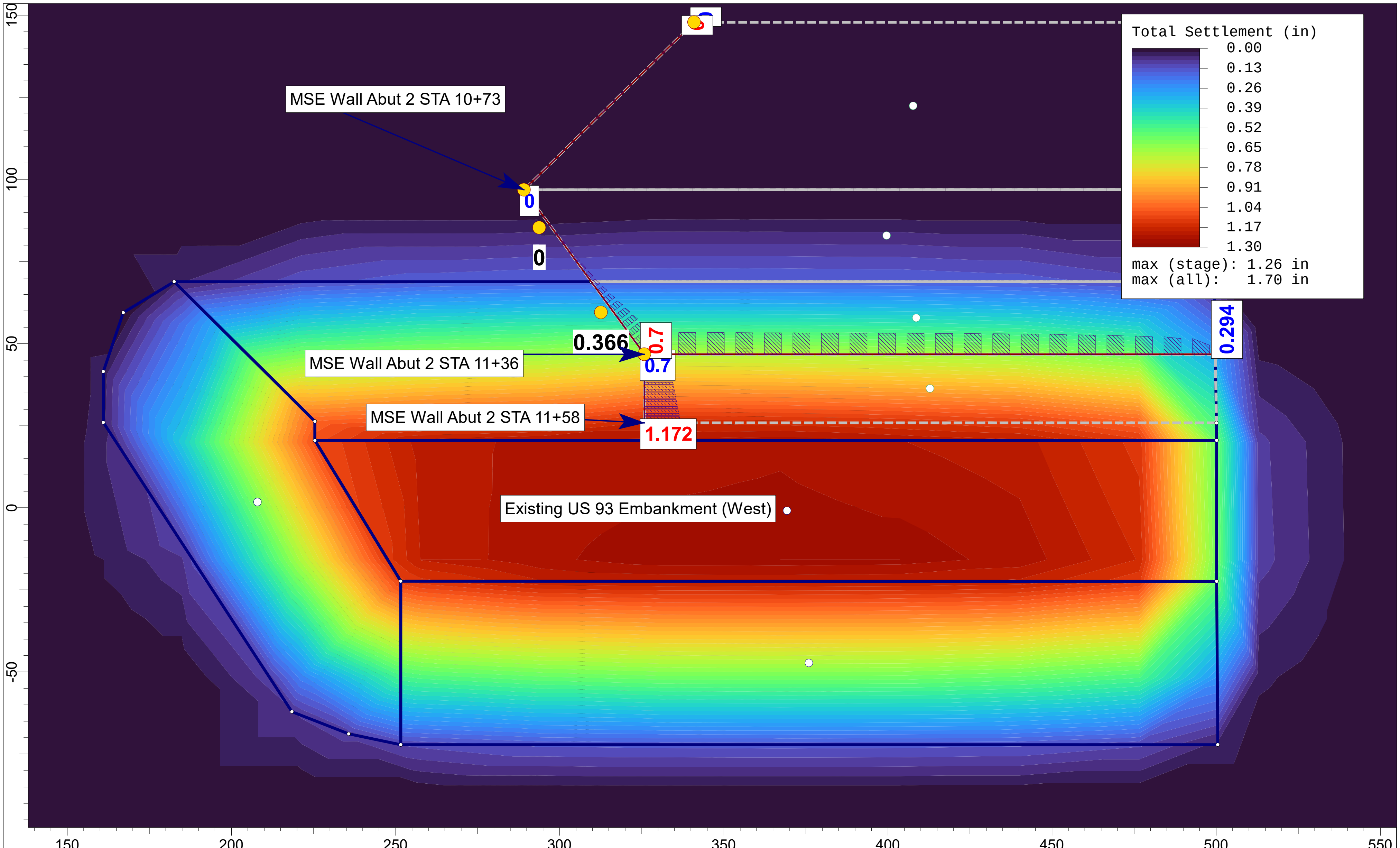




ethos ENGINEERING, LLC.

SETTLE3 5.026

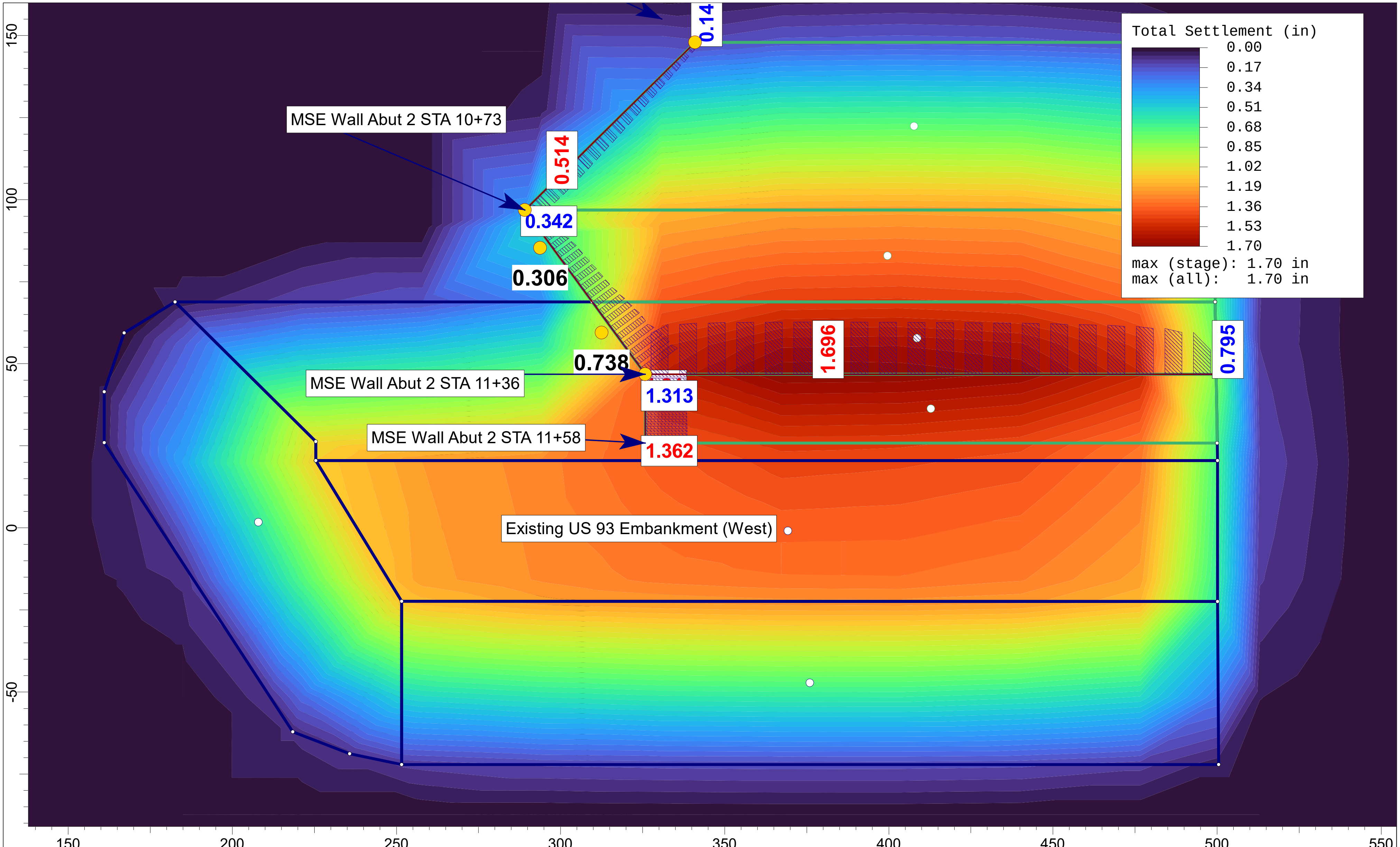
Project	US 93, Vista Royale		
Analysis Description	Abutment 2 Settlement		
Drawn By	Katie Mackay	*Company*	Ethos
Date	10/27/2025, 6:05:24 PM	*File Name*	US 93 Abutment 2 Settlement.s3z



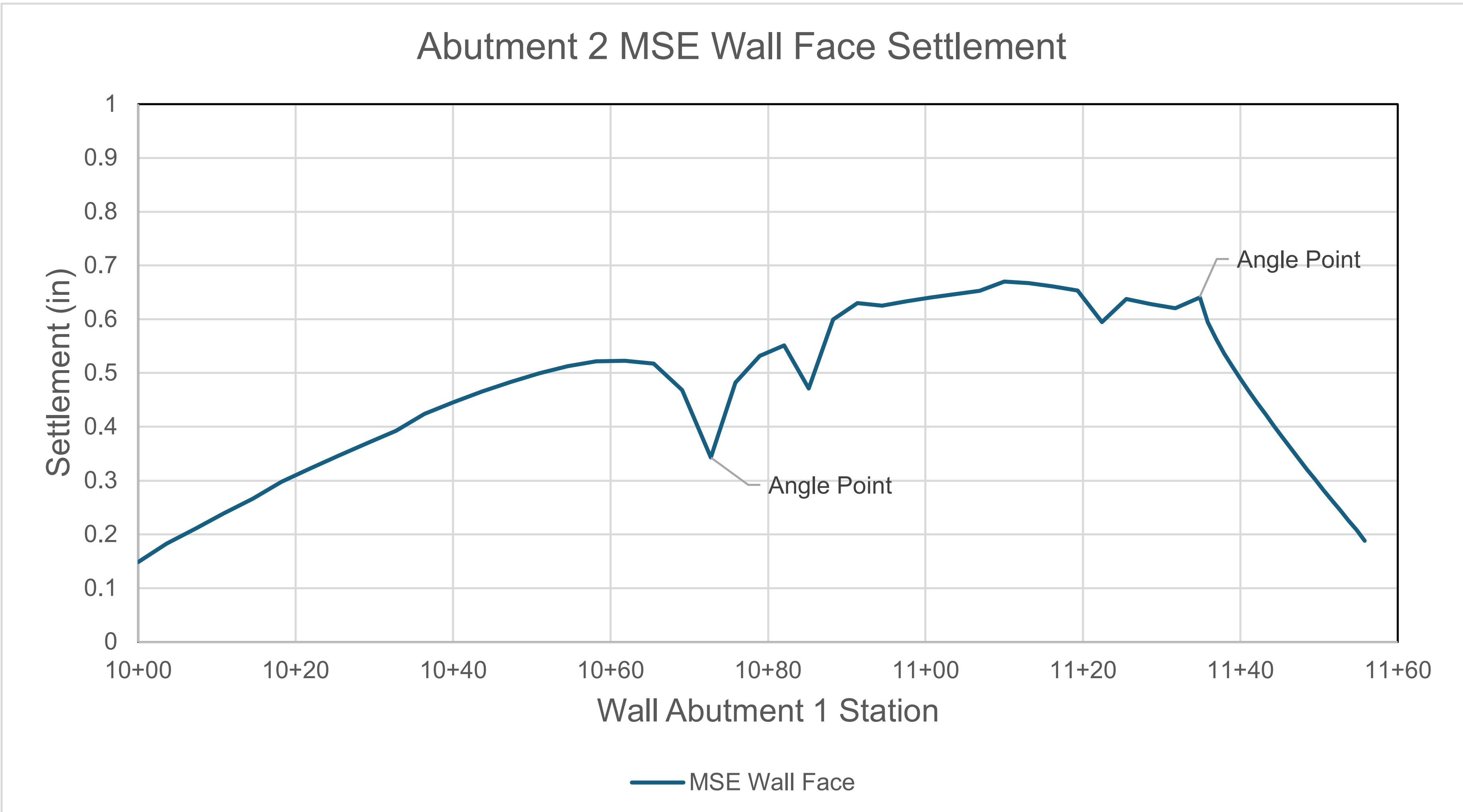
ENGINEERING, LLC.

SETTLE3 5.026

Project	US 93, Vista Royale		
Analysis Description	Abutment 2 Settlement Stage 1 - Existing Embankment		
Drawn By	Katie Mackay	*Company*	Ethos
Date	10/27/2025, 6:05:24 PM	*File Name*	US 93 Abutment 2 Settlement.s3z



ETHOS ENGINEERING, LLC.	*Project*	US 93, Vista Royale	
	Analysis Description	Abutment 2 Settlement Stage 2 - New Embankment	
	Drawn By Katie Mackay	*Company* Ethos	
SETTLE3 5.026	*Date* 10/27/2025, 6:05:24 PM	*File Name* US 93 Abutment 2 Settlement.s3z	


Abutment 2 MSE Wall Face Settlement
Settlement (in)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10+00
10+20
10+40
10+60
10+80
11+00
11+20
11+40
11+60
Wall Abutment 1 Station
Angle Point
Angle Point
MSE Wall Face

ROCSCIENCE

US 93, Vista Royale
Ethos
Report Creation Date: 2025/11/24, 20:32:11
(Abutment 2)

Table of Contents

Settle3 Analysis Information

US 93, Vista Royale (Abutment 2)

Project Settings

Document Name	US 93 Abutment 2 Settlement.s3z
Project Title	US 93, Vista Royale
Analysis	Abutment 2 Settlement
Author	Katie Mackay
Company	Ethos
Date Created	10/27/2025, 6:05:24 PM
Last saved with Settle3 version	5.026
Stress Computation Method	Westergaard
Stress Units	Imperial, stress as ksf
Settlement Units	inches

Advanced Settings

Calculate settlement with mean stress	
Start of secondary consolidation (% of primary)	95
Min. stress for secondary consolidation (% of initial)	1
Reset time when load changes for secondary consolidation	No
Use settlement cutoff	
Load/Insitu vertical stress ratio	0.1
Minimum settlement ratio for subgrade modulus	0.9
Use average poisson's ratio to calculate layered stresses	
Update Cv in each time step (improves consolidation accuracy)	
Ignore negative effective stresses in settlement calculations	
Add field points to load edges	

Soil Profile

Layer Option	Horizontal Soil Layers
Vertical Axis	Depth below ground surface

Stage Settings

Stage #	Name
1	Existing Embankment
2	New Embankment

Results

Time taken to compute: 0.703305 seconds

Stage: Existing Embankment

Data Type	Minimum	Maximum
Total Settlement [in]	0	1.26428
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	1.26428
Loading Stress ZZ [ksf]	-0.00110405	3.18858
Loading Stress XX [ksf]	-0.0334569	1.61389
Loading Stress YY [ksf]	-0.0334569	1.61389
Mean Stress [ksf]	0	2.24995
Total Stress ZZ [ksf]	-0.00110405	13.5222
Total Stress XX [ksf]	-0.0334569	12.8907
Total Stress YY [ksf]	-0.0334569	12.8907
Modulus of Subgrade Reaction (Total) [ksf/ft]	-0.134032	2018.61
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	-0.134032	2018.61
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0	0.00602564
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.0174724	13.5172
Over-consolidation Ratio	1	1
Void Ratio	0	0
Hydroconsolidation Settlement [in]	0	0
Undrained Shear Strength	0	0.0681939

Stage: New Embankment

Data Type	Minimum	Maximum
Total Settlement [in]	0	1.69598
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	1.69598
Loading Stress ZZ [ksf]	-5.46476	3.92865
Loading Stress XX [ksf]	-0.0334569	1.61389
Loading Stress YY [ksf]	-0.0334569	1.61389
Mean Stress [ksf]	-3.88605e-05	2.77217
Total Stress ZZ [ksf]	-5.46476	14.1173
Total Stress XX [ksf]	-0.0334569	12.8907
Total Stress YY [ksf]	-0.0334569	12.8907
Modulus of Subgrade Reaction (Total) [ksf/ft]	-68.0799	332.252
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	-68.0799	332.252
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	-0.0100593	0.00755301
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.0189014	14.1124
Over-consolidation Ratio	1	1
Void Ratio	0	0
Hydroconsolidation Settlement [in]	0	0
Undrained Shear Strength	0	0.0871537

Loads

1. Polygonal Load: "Existing US 93 Abut 2 front slope"

Label	Existing US 93 Abut 2 front slope
Load Type	Flexible
Area of Load	6604.48 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
225.421	26.277	2.89
182.564	68.83	0
167.062	59.408	0
160.983	41.475	0
160.983	25.973	0
218.43	-62.173	0
235.756	-68.86	0
251.577	-72.157	0
251.577	-22.381	2.89
225.421	20.502	2.89

2. Polygonal Load: "Existing US 93 Abut 2 Main"

Label	Existing US 93 Abut 2 Main
Load Type	Flexible
Area of Load	11228.6 ft2
Load	2.89 ksf
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates

X [ft]	Y [ft]
225.421	20.502
251.577	-22.381
500.122	-22.457
500.122	20.502

3. Polygonal Load: "Existing US 93 Abut 2 N Slope"

Label	Existing US 93 Abut 2 N Slope
Load Type	Flexible
Area of Load	12370.5 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
251.577	-72.157	0
500.458	-72.157	0
500.122	-22.457	2.89
251.577	-22.381	2.89

4. Polygonal Load: "Existing US 93 Abut 2 S Slope"

Label	Existing US 93 Abut 2 S Slope
Load Type	Flexible
Area of Load	14170.3 ft2
Depth	0 ft
Installation Stage	Existing Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
225.421	20.502	2.89
500.122	20.502	2.89
499.406	68.83	0
182.564	68.83	0
225.421	26.277	2.89

5. Polygonal Load: "New US 93 Abut 2 STA 10+00 to 10+73"

Label	New US 93 Abut 2 STA 10+00 to 10+73
Load Type	Flexible
Area of Load	9456.33 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
289.102	96.819	2.8
500.366	96.872	2.8
500.366	147.871	0.27
340.952	147.871	0.27

6. Polygonal Load: "Abut 2 STA 10+73 to 11+09"

Label	Abut 2 STA 10+73 to 11+09
Load Type	Flexible
Area of Load	5617.58 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
309.655	68.83	3.1
499.406	68.83	3.1
500.366	96.872	2.8
289.102	96.819	2.8

7. Polygonal Load: "Abut 2 STA 11+09 to 11+36"

Label	Abut 2 STA 11+09 to 11+36
Load Type	Flexible
Area of Load	4012.6 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
325.793	46.764	2.43
499.733	46.764	2.43
499.406	68.83	3.1
309.655	68.83	3.1

8. Polygonal Load: "Abut 2 STA 11+36 to 11+58"

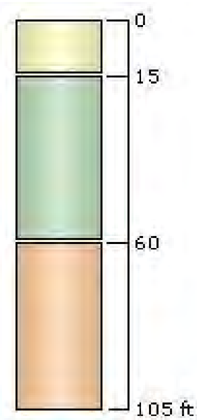
Label	Abut 2 STA 11+36 to 11+58
Load Type	Flexible
Area of Load	3647.99 ft2
Depth	0 ft
Installation Stage	New Embankment

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
325.793	25.81	0.3
500.043	25.81	0.3
499.733	46.764	2.43
325.793	46.764	2.43

Soil Layers

Layer #	Type	Thickness [ft]	Depth [ft]
1	1. SM	15	0
2	2. SC-SM	45	15
3	3. Cemented SC-SM	45	60



Soil Properties

Property	1. SM	2. SC-SM	3. Cemented SC-SM
Color			
Unit Weight [kips/ft3]	0.115	0.12	0.12
Poisson's Ratio	0.325	0.375	0.375
K0	1	1	1
Immediate Settlement	Enabled	Enabled	Enabled
E [ksf]	330	2280	3940
Eur [ksf]	330	2280	3940
Undrained Su A [kips/ft2]	0	0	0
Undrained Su S	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8

Query

Query Points

Point #	Query Point Name	(X,Y) Location	Number of Divisions
3	Abut 2 South Shaft	293.77, 85.266	Auto: 27
4	Abut 2 North Shaft	312.558, 59.476	Auto: 47

Query Lines

Line #	Query Line Name	Start Location	End Location	Horizontal Divisions	Vertical Divisions
4	Abut 2 STA 10+00 to 10+73	340.952, 147.871	289.102, 96.819	20	Auto: 47
5	Abut 2 STA 10+73 to STA 11+36	289.102, 96.819	325.793, 46.764	20	Auto: 47
6	Abut 2 STA 10+36 to 11+58	325.793, 46.764	325.793, 25.81	20	Auto: 47
8	Abutment 2 - Max Embankment	325.793, 46.764	499.733, 46.764	20	Auto: 47

Field Point Grid

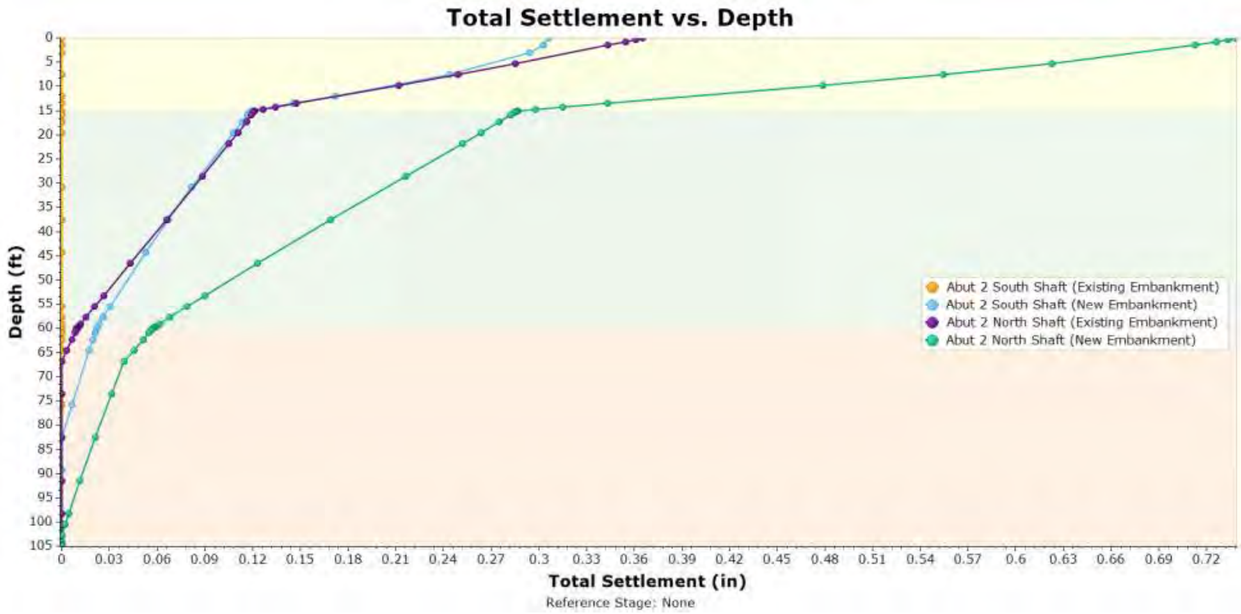
Number of points	401
Expansion Factor	2

Grid Coordinates

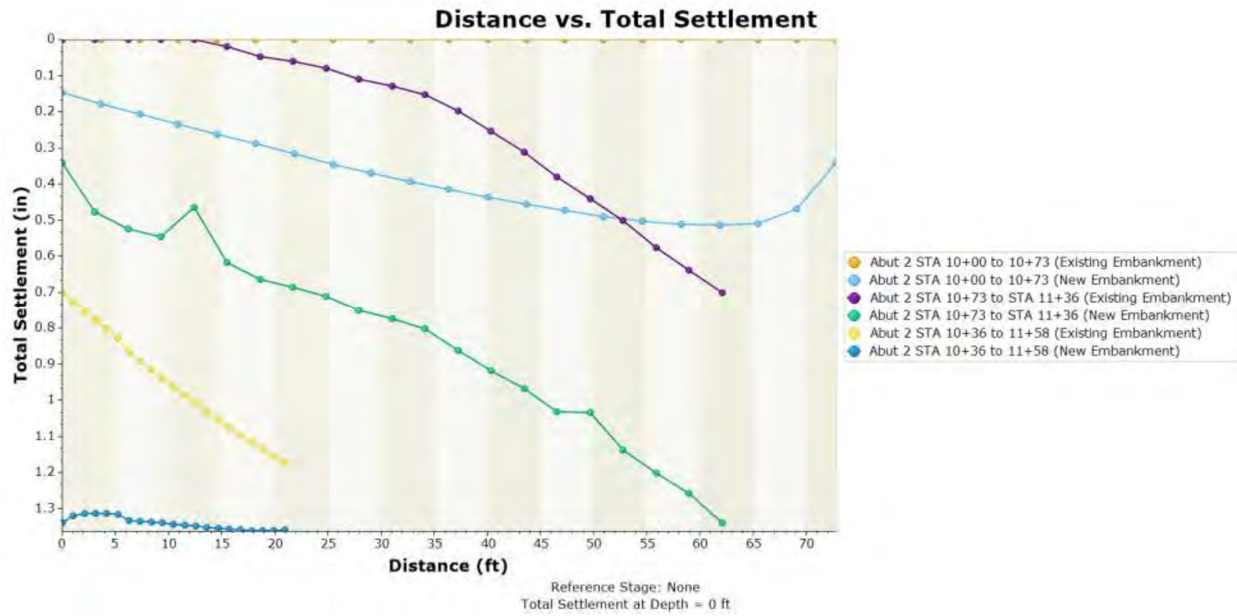
X [ft]	Y [ft]
658.901	306.314
658.901	-230.6
2.54	-230.6
2.54	306.314

Report Views

Drilled Shaft Settlement 1



Abutment Face Settlement 2



APPENDIX F

Spread Footing Bearing Resistance Chart

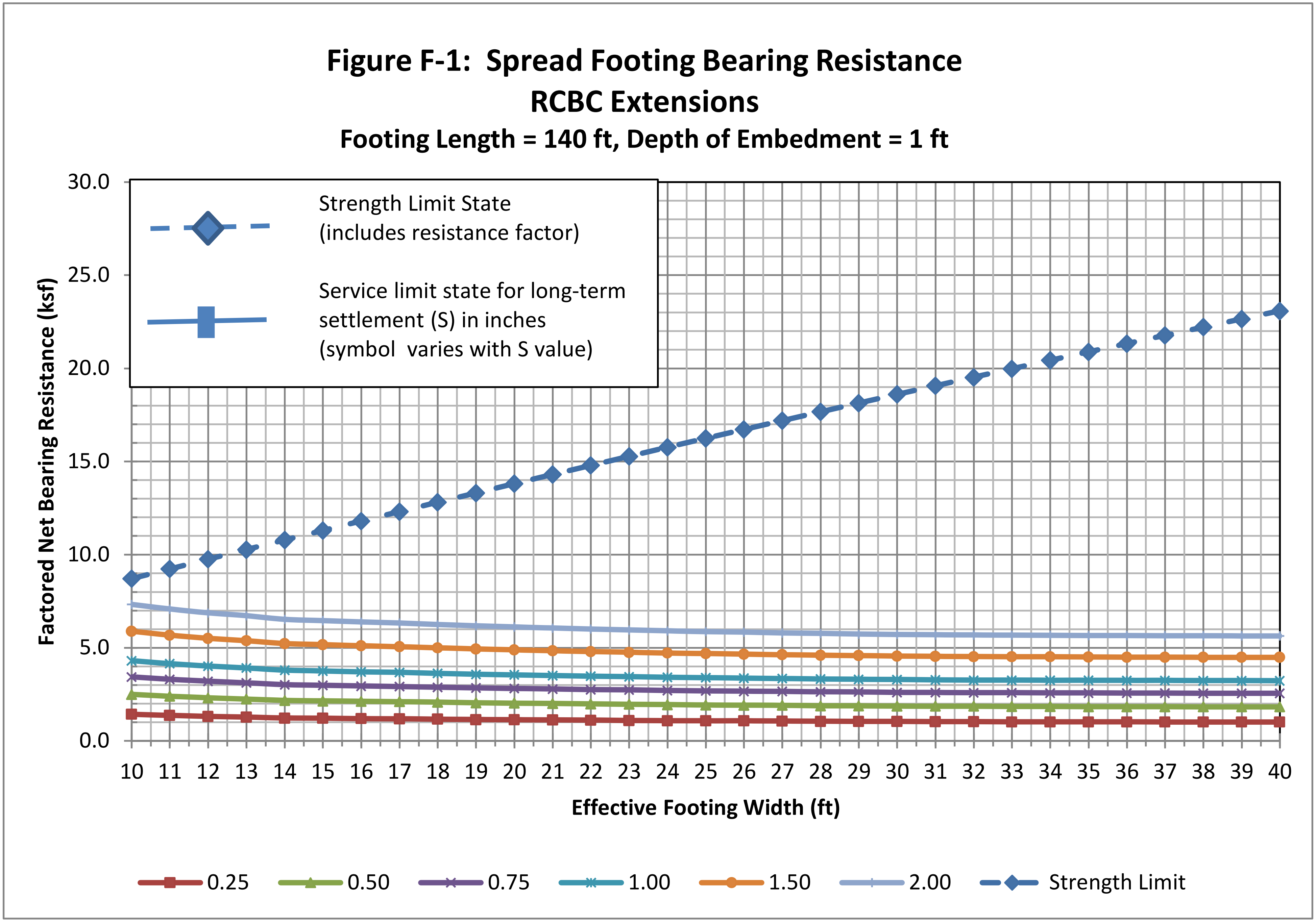


Figure F-1: Spread Footing Bearing Resistance
RCBC Extensions
Footing Length = 140 ft, Depth of Embedment = 1 ft
Strength Limit State
(includes resistance factor)
Service limit state for long-term
settlement (S) in inches
(symbol varies with S value)
Factored Net Bearing Resistance (ksf)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Effective Footing Width (ft)
0.25
0.50
0.75
1.00
1.50
2.00
Strength Limit