



COLORADO
Department of Transportation

*CDOT Project NO. FBR R200-266
CDOT Subaccount No. 23558*

STRUCTURE ALTERNATIVES EVALUATION REPORT

Region 2 Bridge Bundle Design Build Grant Project
Preliminary Design and Procurement Support Services

Structure I-13-G

(Region 2 – SH 24 MP 227.095)



Prepared for: Colorado Department of Transportation Region 2
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*Stanley Consultants Project No. 29715
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1. EXECUTIVE SUMMARY

1.1. PROJECT DESCRIPTION

The CDOT Region 2 Bridge Bundle Design Build Project consists of the replacement of seventeen (17) rural bridges on essential highway corridors in southeastern and central Colorado. The key corridors (US 350, US 24, CO 239 and CO 9) provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The 2 other bridges are Additionally Requested Elements (AREs) in the design build project. There is a total of nineteen (19) structures bundled under this project.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant and funds from the Colorado Bridge Enterprise (14 structures, project number 23558). The 5 additional structures are funded solely by Colorado Bridge Enterprise (project number 23559). These projects are combined to form one design-build project.

The nineteen bridges identified to be included in the ‘Region 2 Bridge Bundle’ were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1.2. PURPOSE OF THE REPORT

This report presents the findings of the preliminary level multidisciplinary investigation of the existing conditions of the given structure. The objective of this report is not to select a new structure type but to develop guidelines that will be addressed in the Design-Build documents and make recommendations based on the available information. All the information obtained in the survey, geotechnical investigation, hydrology and hydraulics, existing utilities, and environmental investigation is discussed in this report. The study evaluates feasible structure alternatives for the site and identifies all known constraints.

1.3. STRUCTURE SELECTION PROCESS

The following criteria for comparing and evaluating the structural alternatives is discussed below and will need to be considered during design-build processes:

- Hydraulic Opening Requirements
- Roadway alignments
- ROW Impacts
- Constructability
- Construction costs
- Maintenance
- Durability
- Traffic Control

The recommendations of the report are based on the overall consideration of all these elements as appropriate to this site and bridge.

1.4. STRUCTURE RECOMMENDATIONS

Based on the subsequent discussion, the recommended proposed overpass structure will consist of the ALBC 71 Arch Structure by Contech Solutions. The proposed 7 ft 8 in clear vertical span will maintain cattle crossing at this location. The width of proposed construction must accommodate two 12.0 ft lanes of traffic with 8.0 ft minimum shoulders and the Colorado current standard Guardrail on each side. The proposed length will be 64 ft. Wingwalls will be required on four corners to retain the roadway fill.

The contractor may select a different structure type based on their investigation, meeting the criteria described in this report.

2. SITE DESCRIPTION AND DESIGN FEATURES

2.1. EXISTING STRUCTURE

The existing I-13-G structure is a three-span treated timber stringer bridge built in 1937. The existing structure allows two seasonal washes that converge upstream of the structure to cross under State Highway (SH) 24, forming a single deep channel downstream. The existing bridges were based on a CDOT Standard P-117-B-H. The existing bridge consist of three 23.0 ft long spans, for a total structure length of 70.5 ft. The width of the existing structure is 29.0 ft curb to curb, 30.0 ft out to out of deck. The existing vertical clearance varies from 8.0 ft to 9.0 ft. The existing framing consists of 14 rows of 6 in x 20 in wood stringers, spaced at 2 ft 2 ¾ in. The bridge deck consists of 3 in x 6 in wood planks.

The piers are wood piers with (6) 1.0 ft diameter piles and a diagonal wood brace. The pier cap is a 1.0 ft square wood beam. The pile spacings are approximately 6.0 ft.

The abutments consist of 1.0 ft square wood abutment caps, supported on (7) 1.0 ft diameter piles. The pile spacings at the abutment are approximately 5.0 ft. There are 4 wood wingwalls at the existing bridge. The wingwalls are approximately 16.0 ft long and vary in height. The wingwalls are supported by (4) 12.0 in diameter piles.

There is a short 2.0 ft to 3.0 ft high wood retaining wall in front of the abutments. The wall is supported by 12.0 in wood piles spaced at approximately 5.0 ft. Fill and a riprap system are placed between the abutment and lower wall at an approximate 1.5:1 slope. The existing structure is currently used as a cattle crossing.

The existing bridge railing is attached to the outside edge of the deck and consists of a timber rail with 6"x8"x5'-0" post and single 3"x8" rail.

Existing I-13-G structure is located on SH 24 at Mile Post 227.095, approximately 12.0 miles west of Hartsel, CO. Table 1 summarizes bridge information.

National Bridge Structure Number	I-13-G
Year Built	1937
Construction Type	Treated timber stringer
Condition Rating	Poor
Load Restricted	No
Bridge Length	70.5 feet
Bridge Width	30 feet
Number of spans	3
Water Crossing	Seasonal wash
AADT	1900
Percent Commercial Traffic	8.0%

Table 1 – Bridge I-13-G Summary Information



Picture 1 – Bridge I-13-G General Location

The replacement of Bridge I-13-G is warranted due to the age and deteriorating conditions. Based on visual inspection and provided bridge inspection report, 26% of the existing girders are split or repaired. Eight girders have been repaired with lag bolts, so it is now considered a temporary structure. Other issues include:

- All piles have cracks penetrating 2-25% of pile thickness. Three piles are severely split.
- Both abutments have weathered backing planks.
- All wingwalls are weathered, and cracks are present in most support piles.

- Heavy erosion is found upstream of the seasonal wash.
- Several guard rails are weathered and splintered, and four timber posts are broken.
- Rot, mold, water staining, and deterioration are present throughout numerous primary structural components



Picture 2 – Typical pile split and existing riprap



Picture 3 – Existing beam lag bolts

2.2. RIGHT OF WAY IMPACT

The existing right of way (ROW) is located approximately 103.0 ft from the centerline of the existing road on the south side of the structure and 99.0 ft on the north side of the structure. Any alternative selected by a design-build team shall not make an impact on the existing right of way. No permanent ROW acquisitions are planned on either side of the SH 24.

Temporary construction easements may be required for detour or drainage erosion control.

2.3. TRAFFIC DETOUR OR SHOOFLY

As stated by the CDOT grant application, the roadway shall not be closed for construction. Two other alternatives were investigated:

1. Phasing the constructions to keep one lane open. To meet all typical CDOT roadway phased construction criteria, this alternative can be constructed keeping half of the existing bridge open to traffic.
2. Building a two-lane shoofly on the north side of the existing bridge with a temporary pipe placed for drainage. A detour to the south should be avoided because of the wetlands present on south side of the structure. This is the preferred alternative for this project.

2.4. UTILITIES

Stanley subcontracted with Lamb-Star Engineering to provide utility location services in the vicinity of the structure.

There is an overhead electric line located along the north ROW line running parallel to the existing road. There is an existing telephone underground line along the south ROW line. Based on the Lamb-Star Engineering investigation, there are no other existing utilities in the vicinity of the structure.

2.5. GEOTECHNICAL SUMMARY

Stanley subcontracted with Yeh and Associates, Inc. to perform the geotechnical investigation of all bridges in this project. Full Preliminary Geotechnical Study is provided in the Appendix D.

Two bridge borings, I-13-G-B-1 and I-13-G-B-2 were drilled by Yeh in the vicinity of the existing structure, and two pavement borings, I-13-G-P-1 and I-13-G-P-2, were drilled along the existing pavement approximately 250 feet from the structure.

The bridge borings encountered variable amounts of lean clay, sand, and gravel overlaying sandstone bedrock. Table 2 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

Boring ID	Location (Northing, Easting)	Ground Surface Elevation at Time of Drilling (feet)	Approx. Depth to Top of Competent Bedrock	Approx. Elevation to Top of Competent Bedrock	Approx. Groundwater Depth (feet)	Approx. Groundwater Elevation (feet)
I-13-G-B-1	398454.5, 871499.5	9124.5	95.0	9029.5	30.0	9094.5
I-13-G-B-2	398450.9, 871411.7	9125.0	Not Encountered	Not Encountered	27.0	9098.0

Table 2 – Summary of Bedrock and Groundwater Conditions

If a bridge structure is selected, the recommended substructure foundation types for this site include drilled shafts and driven H-piles. If a CBC structure is selected, then the structure will be founded on shallow mat foundation. Wingwalls for the bridge and CBC structures will be founded on shallow strip foundations. If an arch structure is selected, the arch and wingwalls will be founded on shallow strip foundations.

2.6. HYDRAULICS SUMMARY

Bridge I-13-G crosses a seasonal wash flowing north from Kaufman Ridge. The project site is not within a Federal Emergency Management Agency (FEMA) floodplain. The 25-year design flow rate is 360 cfs, and the 100-year flow rate is 679 cfs. An SRH-2D model was developed at this location. The proposed model indicates that a 20 ft x 7 ft CBC would carry the design flow and a 100-year event flow will not increase the water surface elevations by more than 0.5 ft. Another option investigated was a single span arch, ALBC 71 with an opening width of 23 ft 4 in and vertical height of 7 ft 8 in. A one-span 45.0 ft long bridge alternative was evaluated and was also shown to have an adequate opening to carry the design flows.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 2 feet of freeboard would typically be required. The proposed bridge alternative meets this freeboard requirement. The culvert option must meet Headwater Depth to Structure Depth ratio (HW/D) of 1.5 per the CDOT Drainage Design Manual. The HW/D for this culvert is 0.5. A Preliminary Hydraulic Report has been completed and can provide more information about the existing and proposed hydraulics conditions.

2.7. ENVIRONMENTAL CONCERNS

Based on field investigation performed by Stanley Consultants Environmental team, the area in the vicinity of the existing bridge has the following key findings:

- The Project is located along an unnamed intermittent stream, which the Project bridge spans
- Potential Waters of the U.S

- The Project has the potential to impact 0.06 acres of US Army Corps of Engineers (USACE) jurisdictional wetlands
- The Project has the potential to impact 0.44 acres (or 680 linear feet) of USACE jurisdictional tributaries
- Sensitive Species
 - The Project has no potential to impact species listed under the federal Endangered Species Act
 - The Project has the potential to impact two species listed by Colorado Parks and Wildlife as endangered or threatened
 - Burrowing owl (*Athene cunicularia*) – State Threatened
 - There is potential for Migratory Bird Treaty Act (MBTA) species occur
- Floodplains
 - The Project is not located within a Federal Emergency Management Agency (FEMA) floodplain
- Hazardous Waste
 - None of the surrounding properties are known hazardous waste sites
 - Several stockpiles of gravel from an unknown source with an unknown potential for contaminants were noted on the southwest side of the PRA
- Archaeological, Historic and Paleontological Resources
 - These resources are being assessed by CDOT and will be provided under separate cover

Refer to Desktop Study and wetland reports for additional information.

2.8. ROADWAY FEATURES

2.8.1. Cross Section

The existing SH 24 is a 2-lane roadway with two-way traffic. Both lanes are 12.0 ft wide and there are 3.0 ft exterior shoulders on both sides. The existing guardrail is a type 10R, present on both sides of the road.

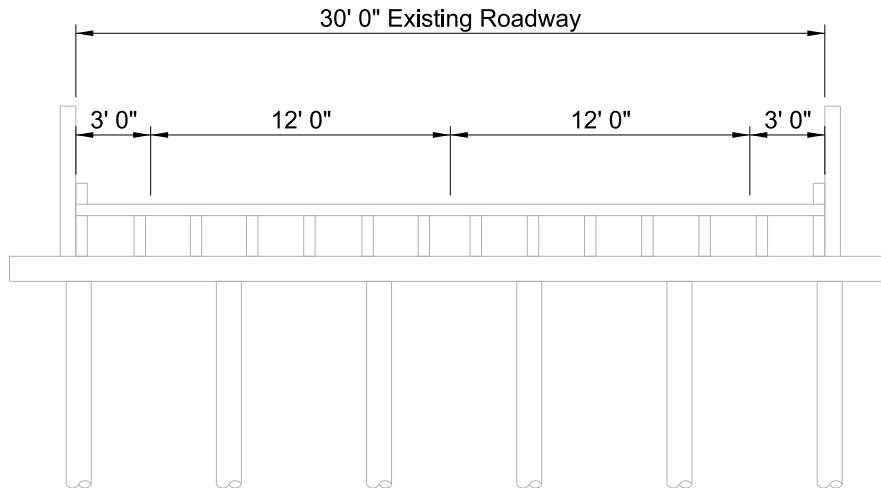


Figure 1 – Existing Section

The proposed roadway section width is based on the on the current traffic volumes and the requirements of the current CDOT Roadway Design Guide. Lane width is expected to be 12.0 ft in each direction with 8.0 ft shoulders. Total required roadway width over proposed structure is 40.0 ft.

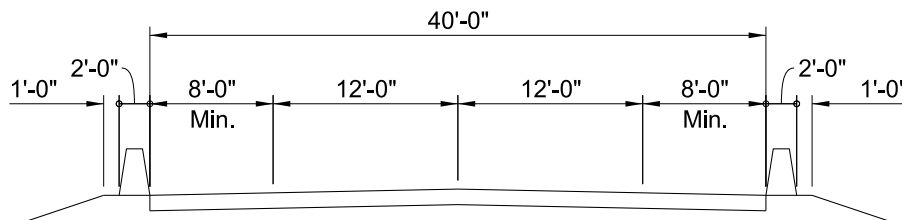


Figure 2 – Proposed Roadway Section

2.8.2. Vertical Alignment

The existing vertical profile has two substandard curves with a small tangent section over the existing structure. The grades transition from a -4.40% to 3.38%; the tangent section over the structure is -0.79%. The existing conditions have not resulted in adverse effects to the traveling public. Due to the high costs associated in raising the profile approximately six feet to bring US 24 up to current standards, the proposed vertical alignment matches the existing roadway.

2.8.3. Horizontal Alignment

The horizontal alignment of the existing bridge has no skew. The bridge is on a continuous horizontal tangent. It is understood that the proposed structure will be constructed in the same location as the existing, but it will be skewed at 30° degrees to better match the geometry of the existing channel.

3. STRUCTURAL DESIGN CRITERIA

3.1. DESIGN SPECIFICATIONS

- AASHTO LRFD Bridge Design Specifications, 9th Edition
- CDOT LRFD Bridge Design Manual
- CDOT Bridge Rating Manual
- CDOT Bridge Detail Manual

3.2. CONSTRUCTION SPECIFICATIONS

Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, 2019.

3.3. LOADING

Live Loads: HL-93 Design Truck or Tandem, Design Lane Load, Colorado Permit Vehicle

Future Dead Load: Design for additional 6 feet of fill for future roadway raise.

Bridge Barrier: Bridge Rail Type 9 or Type 10MASH per the Colorado current standard

Future Wearing Surface: 36.67 lbs per square foot (3 in minimum)

Utilities: per plan details if required at final design

Collision Load: the substructure will not require collision loading design. In cases where Bridge Rail is attached to the structure, the effects of vehicular collision on the barrier must be considered in accordance with AASHTO.

Earthquake Load: The structure is located within Seismic Zone 1 and must meet the AASHTO connection and detailing requirements.

Stream Forces and Scour Effects: stream force effects must be evaluated during final design when applicable. Possible cases include stream forces on the substructure and superstructure in addition to buoyancy from overtopping. Evaluation from scour will be performed per the CDOT Bridge Design Manual and AASHTO.

4. STRUCTURE SELECTION

4.1. SELECTION CRITERIA

The goal of this report is to identify which structural alternatives best meet the project requirements. The following criteria were established as a basis for evaluating the suitability of each structure type: hydraulic opening, constructability, construction cost, maintenance & durability, ROW and roadway impacts. The discussion below expands on these factors as it pertains to each alternative. Summary of Structure Alternatives Evaluation Table can be found at the end of Section 4.

4.2. REHABILITATION ALTERNATIVES

Rehabilitation of I-13-G will not be performed due to the age and type of the bridge. Constructed in 1937, this structure was in service for over 80 years and is showing signs of deterioration and aging that are inconsistent with practical and cost-effective rehabilitation.

4.3. STRUCTURE LAYOUT ALTERNATIVES

Layout of the proposed structure is controlled by the width of the proposed roadway section, stream geometry, hydraulic opening requirements, phased construction considerations and the position of the existing bridge substructure.

The horizontal alignment of the proposed structure will be skewed at 30° degrees to follow the converged seasonal wash.

The proposed bridge will provide adequate freeboard based on the 100-year water surface elevations provided in the hydraulics report. Refer to CDOT Bridge Design Manual and CDOT Drainage Manual for additional clearance requirements information.

Any bridge structure selected for final construction must satisfy the live load deflection requirement for the selected girder types specified in AASHTO LRFD Bridge Design Manual.

4.4. SUPERSTRUCTURE ALTERNATIVES

4.4.1. Reinforced Concrete Pipe Alternative

Based on discussions with CDOT an RCP alternative would be a maintenance issue and were not acceptable at this location.

4.4.2. Concrete Box Culvert Alternative

Concrete box culverts are a cost-effective solution in both short- and long-term due to ease of construction and maintenance. The benefit of this structure type is that the culverts can be cast-in-place (CIP) or precast off-site and transported to the site for placement to streamline the construction process. In addition, CBC size can be selected from CDOT M&S Standards that cover wide array of single-cell and multi-cell culvert sizes.

For I-13-G, a 20 ft x 7 ft box culvert is required to carry the design flow. The box can be constructed as CIP or precast. The proposed box culvert will be skewed at 30° degrees so the inlet of structure can accommodate the merge of the seasonal washes. The minimum design cover over the top slab of the proposed CBC is approximately 2.5 ft.

Both of the structure's headwalls will be 1.5 ft tall and will support the roadway embankments. The concrete box culvert proposed total length is 64 ft. Wingwalls will be provided on 4 sides on the box culvert and will be 20 ft long. Wingwalls will be per CDOT M-601-20 standard.

Concrete box culvert alternative will require riprap apron on the downstream side of the structure as an energy dissipation countermeasure.

4.4.3. Steel Arch Alternative

In order to provide a structure with a natural river bottom, a steel arch alternative was evaluated. This alternative requires a steel ALBC 71 arch by Contech Solutions. The horizontal width of the cell is 23 ft 3 in with a vertical clearance of 7 ft 8 in. Cast in place footings will be required to support the ends of the arch. The footings will be constructed below the natural river bottom. The arch will have approximately 2.5 ft of cover.

Similarly, to the CBC alternative, the headwalls will be 1.5 ft tall and will support the roadway embankments. The steel arch proposed total length is 64 ft.

4.4.4. Concrete Girder Bridge Alternatives

Selected materials and structure components must exhibit high durability to provide longevity of the bridge. A precast prestressed concrete girder bridge requires minimum maintenance and have been shown to be highly durable under Colorado's harsh conditions. For this project, viable concrete alternatives include precast prestressed box girders or Colorado bulb tee (CBT) shapes.

Proposed girder sizes were selected based on the Table 5B-1 and Figures 5B-1, 5B-2, 5B-4 in the CDOT Bridge Design Manual. Based on this information, (4) BX 18x48 girder section spaced at 12.0 ft was chosen as a cost-effective precast concrete solution for the required 45.0 ft span. A standard 8.0 in deep reinforced concrete deck will be used.

4.4.5. Steel Girder Bridge Alternatives

At this location a concrete box culvert and concrete girder bridge alternatives have been evaluated. Since steel girders are not usually cost effective for short spans, we have not evaluated a steel girder option at this location. Steel girders also require future maintenance and are not a preferred alternative.

4.4.6. Span Configurations

A one-span 45.0 ft long bridge length proposed bridge alternative was determined based on the requirements of the hydraulics opening. The proposed bridge embankments will have a 2:1 slope. The proposed arch and box culvert lengths of 64 ft were determined based on hydraulic requirements and embankments.

4.5. SUBSTRUCTURE ALTERNATIVES

The preferred concrete bridge substructure type considered in this study are integral abutments supported on H-Piles.

Integral abutment alternative with the depth of 5.0 ft will be used for concrete bridge alternative (see Figure 11-1 in CDOT Bridge Design Manual). Abutment cap will be supported by (5) HP 12x53 piles. This type of abutment will have an embankment that is susceptible to scour, which shall be mediated by placing riprap on geotextile material on the embankments of the abutments and wingwalls. Wingwalls for this alternative will consist of either integral wingwalls attached to the abutment cap (up to 20.0 ft max), or a combination of 10.0 ft integral wingwalls with an independent wingwall to achieve the required design length.

The steel arch alternative will have 2.0 ft wide by 1 ft 4 in deep cast in place footings under each leg per Contech Solutions standards.

4.6. ACCELERATED BRIDGE CONSTRUCTION (ABC)

CDOT has developed an Accelerated Bridge Construction (ABC) decision making process. The intent of this process is to apply some form of ABC on most projects. The design-build team is encouraged to use these recourses to evaluate cost efficiency of implementing ABC design.

4.7. CONSTRUCTION PHASING

As discussed in Section 2.3, building a shoofly is feasible on the north side of the existing structure and is the preferred alternative for this site. The shoofly will support the detoured two-way traffic and must comply with CDOT Roadway standards.

4.8. CONSTRUCTABILITY

Constructing concrete box culvert or steel arch would require less construction time and using precast sections would further reduce construction time. No known constructability issues are expected at this location.

4.9. MAINTENANCE AND DURABILITY

Typical CDOT specified materials and construction methods must be used for the construction of the proposed structure. Following accepted current practice in designing and constructing the structure will provide a durable bridge to meet the required 100-year service life with minimal required maintenance.

Concrete box and steel arch alternatives may require routine cleaning. There is very little maintenance associated with the concrete girder bridge alternative.

4.10. CORROSIVE RESISTANCE

Epoxy coated reinforcing must be used for all reinforced concrete elements. A waterproofing membrane and stone matrix asphalt will be used on top of the concrete deck or CBC to prevent water and salt intrusion.

4.11. CONSTRUCTION COST

Construction costs are one of the most important factors in the structure type selections. Preliminary construction cost estimates are prepared for all selected structure alternatives to be compared as discussed above. High level construction cost for each structure type is summarized in the table below. Detailed calculations of the cost can be found in the Appendix C of this report. Individual items cost was obtained from recent CDOT Cost Data Books. A 30% contingency multiplier was used in cost calculations.

Alternative	Construction Cost (30% Contingency)	Area	Cost per sf	Cost Rating
Concrete Box Culvert	\$ 498,415.00	1397 sf	\$ 357	1.3
Steel Arch	\$ 406,894.00	1664 sf	\$ 245	1.6
Concrete Bridge	\$ 640,040.00	1935 sf	\$ 331	1.0

Table 3 – Construction Cost Summary

4.12. CONCLUSIONS AND RECOMMENDATIONS

Table below provides a summary or feasible alternatives evaluation based on the established selection criteria

Criteria	CBC	Steel Arch	Concrete Bridge
Hydraulic Opening	Satisfies the requirements	Satisfies the requirements. Preferable for cattle crossing	Satisfies the requirements. Preferable for cattle crossing
Constructability	No expected constructability issues. Can be precast to streamline construction	No expected constructability issues. Delivered to site in ready to install sections	No expected constructability issues
Construction Cost Rating	1.3	1.6	1.0
Maintenance & Durability	May require routine cleaning	May require routine cleaning	Concrete girders require minimal maintenance. Integral abutment on H-Piles will require scour protection.
ROW and Roadway Impacts	No ROW impacts	No ROW impacts	No ROW impacts.

Table 4 – Summary of Structure Alternatives Evaluation

Based on the criteria discussed above, the steel arch alternative is the recommended alternative to replace existing I-13-G structure. The contractor may select a different structure type based on their investigations, meeting the criteria described in this report. See Appendix A for the selected General Layout and Typical Section.

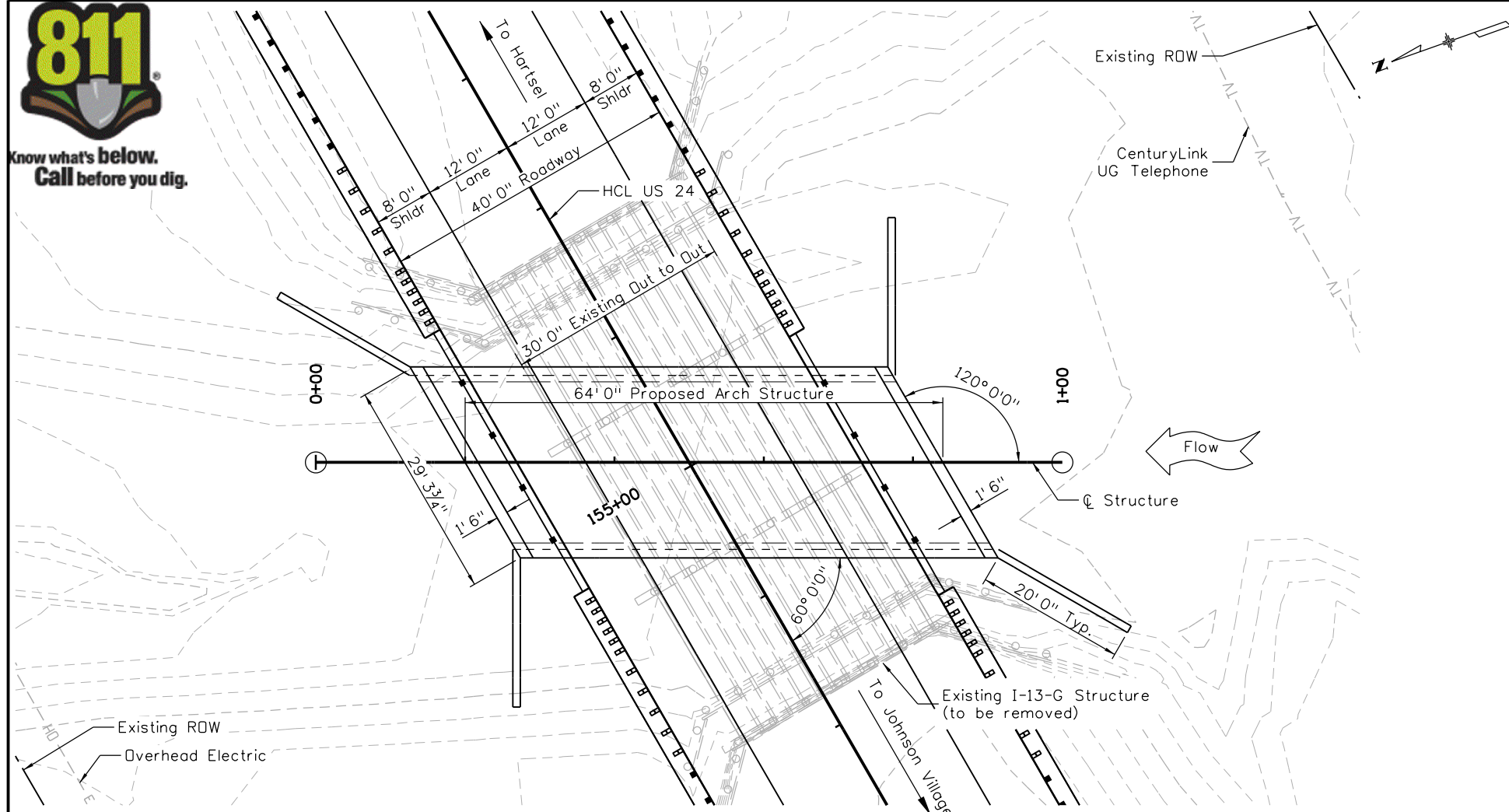
APPENDIX A

General Layout and Typical Section

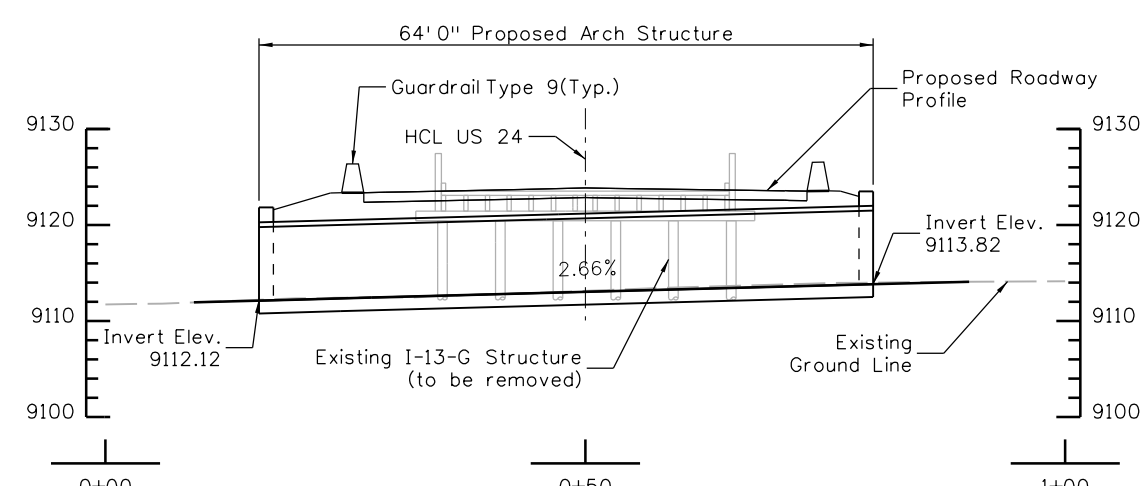
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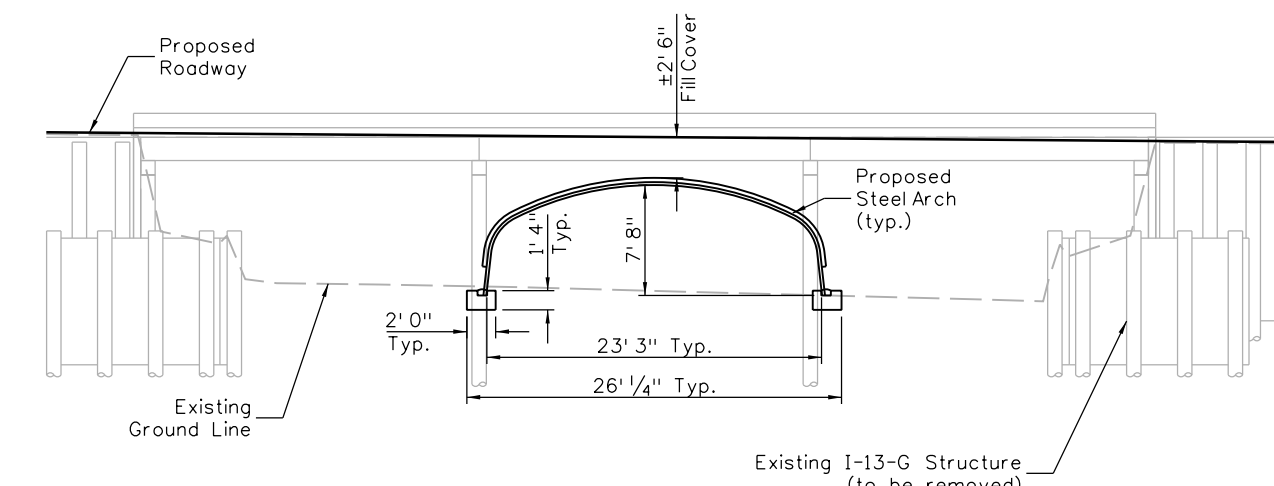
Know what's below.
Call before you dig.



PLAN



PROFILE
(Taken Along CL Structure)



SECTION
(Taken Normal to CL Structure)

- Notes:
- Dimensions are based on recent survey and existing as-built drawings.

Print Date: 1/10/2021 File Name: 23558STR_General Layout I-13-G-SH24 MP 227.09.dgn
 Horiz. Scale: Vert. Scale: As Noted

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 Suite 500
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Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
 5615 Wills Blvd
 Pueblo, CO 81008
 Phone: 719-546-5753
 FAX: 719-546-5402

 Region 2 JLS

As Constructed	REGION 2 BRIDGE BUNDLE		Project No./Code
No Revisions:	US 24 OVER SEASONAL DRAW		
Revised:	Designer: I. Pushkarova	Structure No. I-13-G	Sheet Number
Void:	Detailer: I. Pushkarova	M.P. US 24 227.095	
Sheet Subset: STR		Subset Sheets: 1 of 1	

APPENDIX B

Structure Selection Report Checklist

Structure Selection Report QA Checklist

This checklist is to serve as a general guideline for structure selection process. It is to be filled out by the project Engineer of Record or designee to indicate all items that are to be discussed in the Structure Selection Report. This checklist is to be included as an appendix to the Structure Selection Report and must be signed by Staff Bridge Unit Leader or designee prior to submittal of FIR documents to the Region.

Project Name _____

Project Location _____

Project Number _____ Subaccount _____

Structure Number(s) _____

Engineer of Record _____ Date _____

Cover Sheet

- Name of the Project and Site Address
- Structure(s) Number
- Property Owner Name and Contact Information
- Report Preparer Name and Contact Information
- Seal and Signature of the Designer
- Submittal and Revision Dates as Applicable

Executive Summary

- Project Description
- Purpose of the Report
- Structure Selection Process
- Structure Recommendations

Site Description and Design Features

- Existing Structures
- ROW Impact
- Traffic Detour
- Utilities
- Geotechnical Summary
- Hydraulics Summary
- Environmental Concerns
- Roadway Design Features
 - Cross Section
 - Vertical Alignment
 - Horizontal Alignment

Structural Design Criteria

- Design Specifications
- Construction Specifications
- Loading
 - Collision Load
 - Earthquake Load
- Software to be used by the Designer
- Software to be used by the Independent Design Checker

Structure Selection

- Selection Criteria
- Rehabilitation Alternatives
- Structure Layout Alternatives:
 - Vertical Clearances
 - Horizontal Clearances
 - Deflection
 - Skew

- Superstructure Alternatives:
 - Concrete Girder Alternatives * CBC Alternative
 - Steel Girder Alternatives * RCP Alternative
 - Span Configurations
- Substructure Alternatives:
 - Abutment Alternatives (GRS, Integral, Semi-integral, etc.)
 - Pier Alternatives
- Wall Alternatives
- Construction Phasing
- Possible Future Widening
- Use of Existing Bridge in Phasing / Partial Configuration
- ABC Design
- Constructability
- Aesthetic Design
- Maintenance and Durability
- Corrosive Resistance
- Load Testing Requirements
- Use of Lightweight Concrete
- Construction Cost
- Life Cycle Cost Analysis

Other

Figures and Appendices

- Vicinity Map
- Alternative Typical Sections
- General Layout of the Selected Structure
- Summary of Structure Type Evaluation Table
- Summary of Quantities and Cost Estimate Tables
- Inspection Report
- Hydraulics Investigation Results
- Geotechnical Investigation Results

Recommendations

If you need more space, use an additional sheet(s) of paper.

List of Variances

If you need more space, use an additional sheet(s) of paper.

CDOT Staff Bridge Quality Assurance Sign-off

By signing this checklist Staff Bridge Unit Leader or designee acknowledges approval of the Structure Selection Report findings, recommendations, and all design deviations from the CDOT Structural Standards and design criteria.

Print Name Signature Date

APPENDIX C

Construction Cost Estimate

APPENDIX D

Geotechnical Report



December 11, 2020

Project No. 220-063

Mr. Ron Gibson, P.E.
Stanley Consultants
8000 South Chester Street, Suite 500
Centennial, Colorado 80112

**Subject: Preliminary Geotechnical Study - DRAFT
Structure I-13-G
23558/23559 Region 2 Bridge Bundle
CDOT Region 2, Colorado**

Dear Mr. Gibson:

This memorandum presents the results of Yeh and Associates, Inc.'s (Yeh) preliminary geotechnical engineering study for the proposed replacement of the Bridge Structure I-13-G as part of the CDOT Region 2 Bridge Bundle Project.

The CDOT Region 2 Bridge Bundle Design-Build Project consists of the replacement of a total of 19 structures bundled together as a single project. These structures are rural bridges on essential highway corridors (US 350, US 24, CO 239, and CO 9) in southeastern and central Colorado. These key corridors provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The design-build project consists of 17 bridges and two Additionally Requested Elements (ARE) structures.

This design-build project is jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, Project No. 23558) and the Colorado Bridge Enterprise (five structures, Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

The nineteen bridges identified to be included in the Region 2 Bridge Bundle were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted, limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle includes nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1 PROJECT UNDERSTANDING

Bridge I-13-G is part of the Region 2 Bridge Bundle Design-Build Project. Our preliminary geotechnical study was completed to support the 30% design level that will be included in the design-build bid package. We understand the existing structure will be replaced with either a concrete box culvert (CBC) or a bridge structure. The new

structure will be constructed along the current roadway alignment and existing roadway grade will be maintained. No significant cut or fills are required for construction of the proposed replacement structure.

2 SUBSURFACE CONDITIONS

Two bridge borings, I-13-G-B-1 and I-13-G-B-2, were drilled by Yeh in the vicinity of the existing bridge, and two pavement borings, I-13-G-P-1 and I-13-G-P-2, were drilled along the existing pavement approximately 250 feet from the bridge. The approximate boring locations are shown on the engineering geology sheet in Appendix A. The legend and boring logs are included in Appendix B. Laboratory test results are provided in Appendix C and are shown on the boring logs.

The bridge borings encountered variable amounts of lean clay, sand, and gravel overlying sandstone bedrock. Table 1 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

Table 1. Summary of Bedrock and Groundwater Conditions

Boring ID	Location ¹ (Northing, Easting)	Ground Surface Elevation at Time of Drilling ¹ (feet)	Approx. Depth to Top of Competent Bedrock ¹ (feet)	Approx. Elevation to Top of Competent Bedrock ¹ (feet)	Approx. Groundwater Depth ^{1, 2} (feet)	Approx. Groundwater Elevation ^{1, 2} (feet)
I-13-G - B-1	398454.5, 871499.5	9124.5	95.0	9029.5	30.0	9094.5
I-13-G - B-2	398450.9, 871411.7	9125.0	Not Encountered	Not Encountered	27.0	9098.0

Notes:

(1) Surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. Location and elevation are provided by project surveyor.

(2) Groundwater depths and elevations are based on observations during drilling.

3 BRIDGE FOUNDATION RECOMMENDATIONS

We understand that the replacement structure will consist of either a new bridge structure or a concrete box culvert structure (CBC). If a bridge structure is selected, then the abutments and piers will be supported on driven H-piles or drilled shafts. If CBC structure is selected, then the structure will be founded on a shallow mat foundation. Wing walls for the bridge and CBC structures will be founded on shallow strip foundations.

Based on the subsurface conditions encountered during our preliminary study, engineering analysis, and experience with similar projects it is our opinion that driven H-pile and drilled shaft foundations are suitable for support of the bridge structure. Shallow foundations are suitable for support of the CBC and wing wall structures. Recommendations for the drilled shafts are presented in Section 3.2, driven H-pile recommendations are provided in Section 3.3, and CBC foundation recommendations are presented in Section 3.4.

The soil and bedrock properties were estimated from penetration resistance, material descriptions, and laboratory data. The design and construction of the foundation elements should comply with all applicable requirements and guidelines listed in AASHTO (2020) and the CDOT Standard Specifications (CDOT 2019).



3.1 Shallow Foundation Recommendations

Based on the depth to competent bedrock and the anticipated loading requirements, it is our opinion that shallow foundations are not suitable to support the bridge abutments.

3.2 Drilled Shaft Recommendations

3.2.1 Drilled Shaft Nominal Axial Resistance

The estimated bearing resistance should be developed from the side and tip resistance in the underlying competent bedrock or the stiff gravelly clay at about 55 feet BGS. The resistance from the overburden soil should be neglected. The design approach in Abu-Hejleh et al. (2003) provides recommendations for the use of an updated Colorado SPT-based (UCSB) design method. In this design method, the nominal side and tip resistance of a drilled shaft in the sedimentary bedrock is proportional to the driven sampler penetration resistance. This approach was generally used to estimate the axial resistance. Based on local practice, the modified California penetration resistance is considered to be equivalent to a standard penetration test (SPT) penetration resistance, i.e. N value, in bedrock.

Table 2a and 2b contain the recommended values for the nominal side and tip resistance for drilled shafts founded in the underlying competent bedrock and gravelly clay, respectively. The upper three feet of competent bedrock penetration shall not be used for drilled shaft resistance due to the likelihood of construction disturbance and possible additional weathering. To account for axial group effects, the minimum spacing requirements between drilled shafts should be three diameters from center-to-center.

Table 2a. Recommended Drilled Shaft Axial Resistance- Founded in Rock

Reference Boring	Approximate Top of Competent Bedrock Elevation (feet)	Tip Resistance (ksf)		Side Resistance, (ksf)	
		Nominal	Factored ($\Phi=0.5$)	Nominal	Factored ($\Phi=0.45$)
I-13-G-B-1	9029.5	43	21.5	3.5	1.58
I-13-G-B-2	Not Encountered				

Table 2b. Recommended Drilled Shaft Axial Resistance – Founded in Soil

Reference Boring	Approximate Top of Bearing Soil Elevation (feet)	Tip Resistance (ksf)		Side Resistance, (ksf)	
		Nominal	Factored ($\Phi=0.40$)	Nominal	Factored ($\Phi=0.45$)
I-13-G-B-1	9069.5	24	9.6	1.9	0.86
I-13-G-B-2	9070.0	21	8.4	1.7	0.77

3.2.2 Drilled Shaft Lateral Resistance

The input parameters provided in Table 3 are recommended for use with the computer program LPILE to develop the soil models used to evaluate the drilled shaft response to lateral loading. Table 3 provides the estimated values associated with the soil types encountered in the borings. They can also be used for driven H-piles, which will be described in Section 3.3. The nature and type of loading should be considered carefully. Individual soil



layers and their extent can be averaged or distinguished by referring to the boring logs at the locations of the proposed bridge. The soils and/or bedrock materials prone to future disturbance, such as from utility excavations or frost heave, should be neglected in the lateral load analyses to the depth of disturbance, which may require more than but should not be less than three feet.

Recommendations for p-y multiplier values (P_m values) to account for the reduction in lateral capacity due to group effects are provided in Section 10.7.3.12 of AASHTO (2020). The P_m value will depend on the direction of the applied load, center-to-center spacing, and location of the foundation element within the group.

Table 3. LPILE Parameters

Soil Type	LPILE Soil Criteria	Effective Unit Weight (pcf)		Friction Angle, (deg.)	Undrained Cohesion, (psf)	Strain Factor, ϵ_{50}	p-y modulus kstatic (pci)	
		AGT ¹	BGT ²				AGT ¹	BGT ²
Class 1 Structure Backfill	Sand (Reese)	130	67.5	34	-	-	90	60
Clay	Stiff Clay w/o Free Water (Reese)	120	57.5	-	200	0.01	-	-
Sandy Clay	Stiff Clay w/o Free Water (Reese)	120	57.5	-	1,800	0.007	-	-
Clayey Gravel, Sand with Gravel, Clayey Sand	Sand w/o Free Water (Reese)	125	62.5	33	-	-	90	60
Shale Bedrock	Stiff Clay w/o Free Water (Reese)	130	130	-	8,000	0.004	-	-

Note: ¹Above Groundwater Table
²Below Groundwater Table

3.2.3 General Drilled Shaft Recommendations

The following recommendations can be used in the design and construction of the drilled shafts.

- Groundwater and potentially caving soils may be encountered during drilling depending on the time of year and location. The Contractor shall construct the drilled shafts using means and methods that maintain a stable hole.
- Bedrock may be very hard at various elevations. The contractor should mobilize equipment of sufficient size and operating condition to achieve the required design bedrock penetration.
- Drilled shaft construction shall not disturb previously installed drilled shafts. The drilled shaft concrete should have sufficient time to cure before construction on a drilled shaft within three shaft diameters (center to center spacing) begins to prevent interaction between shafts during excavation and concrete placement.
- Based on the results of the field investigation and experience with similar properly constructed drilled shaft foundations, it is estimated that foundation settlement will be less than approximately ½ inch when designed according to the criteria presented in this report. Drilled shafts founded in soil will have an estimated settlement of 1-inch.
- A representative of the Contractor’s engineer should observe drilled shaft installation operations on a full-time basis.



3.3 Driven H-pile Recommendations

3.3.1 Driven H-pile Axial Resistance

Steel H-piles may be designed for a nominal axial resistance equal to 28 kips per square inch (ksi) multiplied by the cross sectional area of the pile for piles composed of Grade 50 ksi steel for use with LRFD Strength Limit State design. Piles should be driven to the nominal resistance and have a minimum penetration of 55 feet below the existing ground surface. A wave equation analysis using the Contractor's pile driving equipment is necessary to estimate pile drivability.

3.3.2 Driven H-Pile Axial Resistance Factors

Assuming a pile driving analyzer (PDA) is used to monitor pile driving per Section 502 of CDOT (2019), a resistance factor of 0.65 may be used per AASHTO (2020) Table 10.5.5.2.3-1. Section 502.05 of CDOT (2019) stipulates that if PDA is used, a minimum of one PDA monitoring per bridge bent be performed to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2020) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring. Per AASHTO (2020) recommendations, a resistance factor of 0.75 may be used if a successful static load test is conducted per site condition.

3.3.3 Driven H-Pile Lateral Resistance

The information provided previously in Section 3.2.2 may be used to evaluate H-pile lateral resistance.

3.3.4 General Driven H-Pile Recommendations

The following recommendations are for the design and construction of driven H-piles.

1. Based on the results of the field exploration and our experience with similar properly constructed driven pile foundations, it is estimated that settlement will be approximately 1 inch when designed according to the criteria presented in this report.
2. A minimum spacing requirement for the piles should be three diameters (equivalent) center to center.
3. Driven piles should be driven with protective cast steel pile points or equivalent to provide better pile tip seating and to prevent potential damage from coarse soil particles, which may be present at the site.
4. A qualified representative of the Contractor's engineer should observe pile-driving activities on a full-time basis. Piles should be observed and checked for crimping, buckling, and alignment. A record should be kept of embedment depths and penetration resistances for each pile.
5. It is estimated that the piles will penetrate approximately 3 to 5 feet into competent bedrock (see Table 1 for the estimated elevation for the top of competent bedrock). The final tip elevations will depend on bedrock conditions encountered during driving.
6. If the pile penetration extends below the estimated pile penetration into bedrock by 10 feet or more, the pile driving operations should be temporarily suspended for dynamic monitoring with PDA. We recommend that the subject pile be allowed to rest overnight or longer before restriking and monitoring the beginning-of-restrike with a PDA. The data collected with the PDA shall then be reduced using the software CAPWAP to determine the final nominal pile resistance. The pile driving criteria may be modified by CDOT's or the Contractor's engineer based on the PDA/CAPWAP results.



3.4 CBC Foundation Recommendations

To assure adequate foundation support and to minimize the potential for differential settlement, we recommend that the exposed subgrade soils should be scarified a minimum of 6 inches; moisture conditioned, and re-compacted in accordance with Section 203.07 of the CDOT Standard Specifications (2019) before the placement of structural elements or structural backfill. If unsuitable or soft materials are encountered after the excavation, the materials may be removed and replaced with CDOT Class 1 Structure Backfill in accordance with Section 203.07 of the CDOT Standard Specifications (2019). Visual inspection of the foundation excavations should be performed by a qualified representative of the Geotechnical Engineer of record to identify the quality of the foundation materials prior to placement of backfill and the CBC. Groundwater may be encountered during excavation for the subgrade preparation. Groundwater control systems may be required to prevent seepage migrating into the construction zone by creating groundwater cut-off and/or dewatering systems.

The recommended nominal bearing resistance using Strength Limit State for the CBC and associated wing walls for both moist and saturated conditions are provided in Table 4. We assume the materials in contact with the bottom of the proposed CBC and wing walls will consist of native, medium stiff to stiff sandy clay and/or clay with sand or CDOT Class 1 Structure Backfill placed in accordance with Section 203.07 of the CDOT Standard Specifications (2019). The reduced footing width due to eccentricity can be calculated based on the recommendations in Sections 11.6.3.2 and 11.10.5.4 of AASHTO (2020). A bearing resistance factor of 0.45 may be used for shallow foundations based on the recommendations in Table 10.5.5.2.2-1 of AASHTO (2020).

Table 4. Bearing Resistance for CBC and Wing Walls on Shallow Foundation

Soil Conditions	Nominal Bearing Resistance (ksf) ^{1, 2}
Moist	$2.5 + 1.3 * B'$
Saturated	$1.3 + 0.7 * B'$

¹ B' is the footing width in feet reduced for eccentricity (e). $B' = B - 2e$, where B is the nominal foundation width.

²The calculated nominal bearing resistance shall be limited to 15 ksf.

The proposed CBC will be at the location of the existing bridge and as needed, portion of the CBC will be in a cut area, therefore it is estimated that the total settlement of the structure will be minimal and will occur during construction. The structure settlement is partially controlled by the weight of the adjacent embankment fill. Thus, it is recommended that the embankment fill on both sides of the CBC be placed at a relatively uniform elevation.

Resistance to sliding at the bottom of foundations can be calculated based on a coefficient of friction at the interface between the pre-cast concrete and the existing native soils or compacted CDOT Class 1 Structure Backfill. The recommended nominal coefficients of friction and the corresponding resistance factors for Class 1 Structure Backfill and native soils are provided in Table 5.

Table 5. Coefficients of Friction for CBC and Wing Walls on Shallow Foundation

Foundation Soil Type	Coefficient of Friction	Resistance Factor
Class 1 Structure Backfill	0.53	0.9
Native Clay	0.30	0.8



Backfill adjacent to the CBC should be Class 1 Structure Backfill, compacted with moisture density control. Backfill materials shall have a Class 0 for severity of sulfate exposure. Fill should be tested for severity of sulfate exposure prior to acceptance.

The passive pressure against the sides of the foundation is typically ignored; however, passive resistance can be used if long-term protection from disturbance, such as frost heave, future excavations, etc., is assured. Table 6 presents recommendations for the passive soil resistances for the encountered soil conditions. The passive resistance estimates are calculated from Figure 3.11.5.4-1 in AASHTO (2020) where a portion of the slip surface is modeled as a logarithmic spiral, the backslope is horizontal and the passive soil/concrete interface friction angle is equal to 60 percent of the soil’s friction angle.

The recommended passive earth pressure resistances are presented in terms of an equivalent fluid unit weight for moist and saturated conditions. The recommended passive earth pressure values assume mobilization of the nominal soil/concrete foundation interface shear strength. A suitable resistance factor should be included in the design to limit the strain, which will occur at the nominal shear strength, particularly in the case of passive resistance. The resultant passive earth force, calculated from the equivalent fluid unit weight, should be applied at a point located 1/3 of the height of the soil (in contact with the foundation) above the base of the foundation, directed upward at an angle of 20 degrees from the horizontal.

Table 6. Passive Soil Resistance for CBC

	Soil Type	Nominal Resistance	Resistance Factor
Passive Soil Resistance	Moist	332 psf/ft	0.50
	Saturated	166 psf/ft	0.50

3.5 Lateral Earth Pressures

External loads used in the analyses of the bridge abutments and wing walls should include earth pressure loads, traffic loads, and any other potential surcharge loads. Typical drainage details consisting of inlets near the abutments, geocomposite strip drains, and perforated pipes shall be included in the design to properly contain and transfer surface and subsurface water without saturating the soil around the abutments and walls.

All abutment and wing wall backfill materials should meet the requirements for CDOT Structure Backfill Class 1 in accordance with CDOT (2019). All backfill adjacent to the abutments and walls shall be placed and compacted in accordance with CDOT (2019). It is recommended that compaction of backfill materials be observed and evaluated by an experienced Contractor’s engineer or Contractor’s engineer’s representative.

A lateral wall movement or rotation of approximately 0.1 to 0.2 percent of the wall height may be required to mobilize active earth pressure for the recommended backfill materials. If the estimated wall movement is less than this amount, an at-rest soil pressure should be used in design. In order to mobilize passive earth pressure, lateral wall movement or rotation of approximately 1.0 to 2.0 percent of the wall height may be required for the recommended backfill materials. It should be carefully considered if this amount of movement can be accepted before passive earth pressure is used in the design.

Earth pressure loading within and along the back of the bridge abutments and wing walls shall be controlled by the structural backfill. We recommend that active, at-rest, and passive lateral earth pressures used for the design of the structures be based on an effective angle of internal friction of 34 degrees, and a unit weight of



135 pounds per cubic foot (pcf) for CDOT Structure Backfill Class 1. The following can be used for design assuming a horizontal backslope:

- Active earth pressure coefficient (k_a) of 0.28
- Passive earth pressure coefficient (k_p) of 3.53
- At-rest earth pressure coefficient (k_0) of 0.44

Lateral earth pressures for a non-horizontal backslope can be estimated using section 3.11 in AASHTO (2020).

3.6 Bridge Scour Parameters

A bulk sample of the creek bed soils/rock below the existing bridge was collected for gradation analysis. The results of the grain size analysis are presented in Appendix C.

4 BRIDGE APPROACH PAVEMENT

Pavement borings were located approximately 250 feet beyond the existing bridge abutments on each side. Prior to drilling, the existing pavement was cored with a 4-inch nominal diameter core barrel. Photos of the pavement core, logs of the subsurface soils/rock, and results of geotechnical and analytical laboratory testing are presented in the appendices. Bulk soil samples were collected from the pavement borings and combined for classification, strength (R-value), and analytical testing. The asphalt pavement thicknesses, aggregate base thicknesses (if present), subgrade soil classifications, and subgrade R-values are presented in Table 7. Analytical test results are presented in Table 8. Preliminary pavement design will be completed by CDOT Staff Materials.

Table 7. Existing Pavement Section and Subgrade Properties

Boring ID	Existing Asphalt Concrete Thickness (in)	Aggregate Base Thickness (in)	Subgrade Soil Classification (AASHTO) ¹	R-Value ¹
I-13-G-P-1	7.0	Not Encountered	A-6 (6)	7
I-13-G-P-2	8.5	Not Encountered		

1. Subgrade Classification and R-value test results based on combined bulk sample from each pavement boring.

5 ANALYTICAL TEST RESULTS

Analytical testing was completed on representative samples of soils encountered in the borings. The test results can be found in Appendix C and are summarized in Table 8. The Analytical results should be used to select the proper concrete type for the project in accordance with CDOT Standard Specifications (2019). A qualified corrosion engineer should review the laboratory data and boring logs to determine the appropriate level of corrosion protection for materials in contact with these soils.

Table 8. Analytical Test Results

Boring ID	Material	Water Soluble Sulfates, %	Water Soluble Chlorides, %	pH	Resistivity, ohm-cm
I-13-G-P-1/P-2	Lean Clay (Fill)	0.008	0.0127	-	-
I-13-G-B-1	Silty Sand	0.579	0.0004	7.9	1487
I-13-G-B-2	Gravelly Lean Clay	0.382	0.0003	7.1	655



6 SEISMIC CONSIDERATIONS

No active faults are known to exist in the immediate vicinity of the proposed bridge location. Based on the site class definitions provided in Table 3.10.3.1-1 of AASHTO LRFD (2020), the site can be categorized as Site Class E. Also based on the recommendations in Table 3.10.6-1 of AASHTO LRFD (2020), the bridge site can be classified as Seismic Zone 1.

The peak ground acceleration (PGA) and the short- and long- period spectral acceleration coefficients (S_s and S_1 , respectively) for Site Class B (reference site class) were determined using the seismic design maps from the USGS website. The seismic design parameters for Site Class E are shown in Table 9.

Table 9. Seismic Design Parameters

PGA (0.0 sec)	S_s (0.2 sec)	S_1 (1.0 sec)
0.078 g	0.163 g	0.044 g
A_s (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
0.195 g	0.406 g	0.154 g

7 LIMITATIONS

Our scope of services was performed, and this report was prepared in accordance with generally accepted principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied.

The classifications, conclusions, and recommendations submitted in this report are based on the data obtained from published and unpublished maps, reports, and geotechnical analyses. Our conclusions and recommendations are based on our understanding of the project as described in this report and the site conditions as interpreted from the explorations. This data may not necessarily reflect variations in the subsurface conditions and water levels occurring at other locations.

The nature and extent of subsurface variations may not become evident until excavation is performed. Variations in the data may also occur with the passage of time. If during construction, fill, soil, rock, or groundwater conditions appear to be different from those described in this report, this office should be advised immediately so we could review these conditions and reconsider our recommendations. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations concerning the changed conditions or time lapse. We recommend on-site observation of foundation excavations and foundation subgrade conditions by an experienced geotechnical engineer or engineer's representative.

The scope of services of this study did not include hazardous materials sampling or environmental sampling, investigation, or analyses. In addition, we did not evaluate the site for potential impacts to natural resources, including wetlands, endangered species, or environmentally critical areas.



8 REFERENCES

AASHTO LRFD, 9th Edition. AASHTO Load Resistance Factor Design (LRFD) Bridge Design Specifications, Eight Edition. Washington, DC: American Association of State Highway and Transportation Officials. 2020.

Abu-Hejleh, N., O'Neill, M.W., Hanneman, Dennis, Atwooll, W.J., 2003. Improvement of the Geotechnical Axial Design Methodology for Colorado's Drilled Shafts Socketed in Weak Rocks, Final Report: Colorado Department of Transportation Research Branch, July 2003, Report No. CDOT-DTD-R-2003-6.

Colorado Department of Transportation, 2019. CDOT Standard Specifications for Road and Bridge Construction. 2019 Edition.

Respectfully Submitted,
YEH AND ASSOCIATES, INC.

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Independent Technical Review by:

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Attachments:

Appendix A
Appendix B
Appendix C

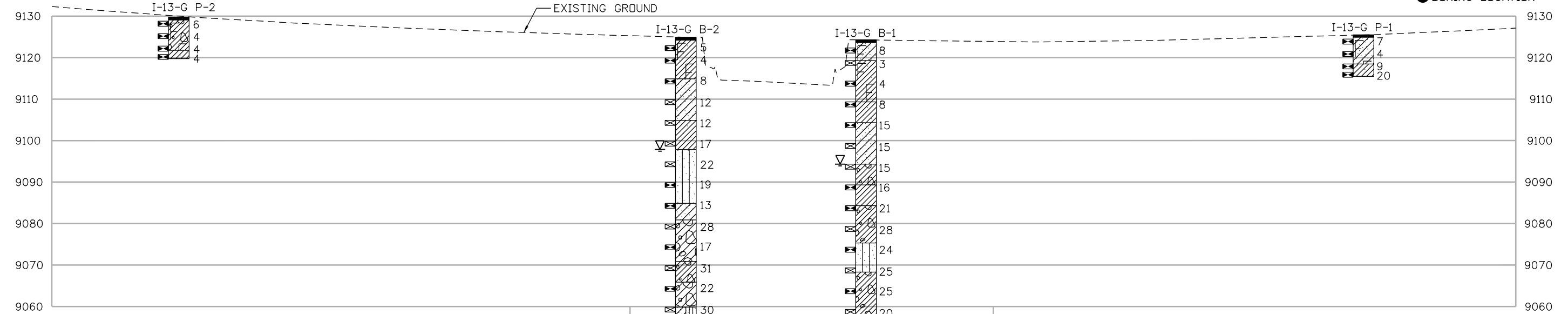
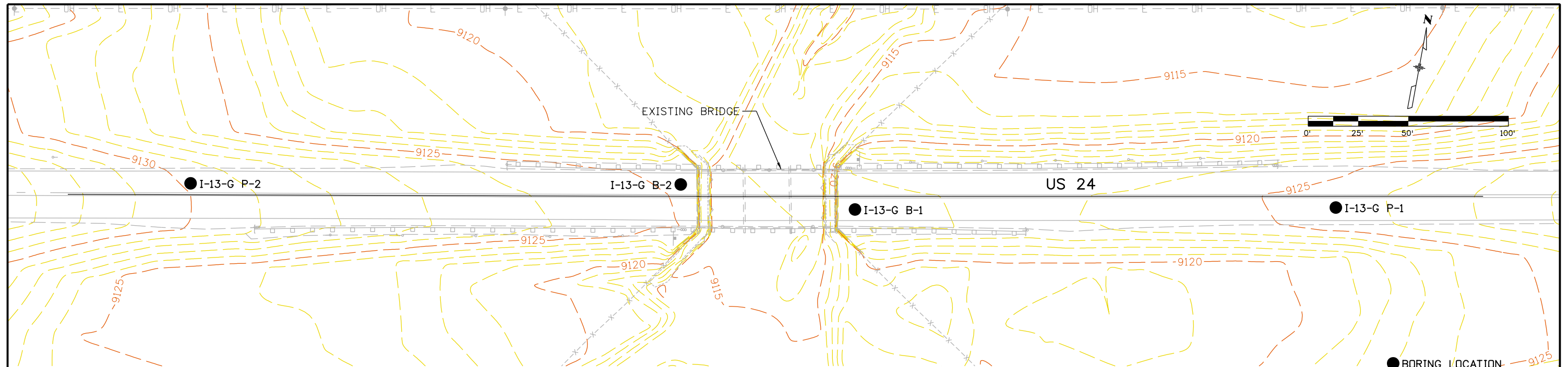


APPENDIX A

ENGINEERING GEOLOGY SHEET

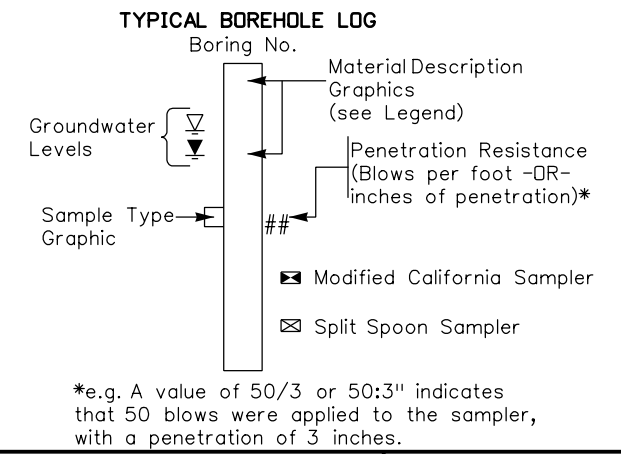


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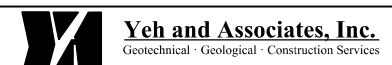


LEGEND

Asphalt	USCS Clayey Sand	Fill
Low Plasticity Sandy Clay	Low Plasticity Gravelly Clay	USCS Lean/Low Plasticity Clay
USCS Silty Sand	USCS Clayey Gravel	USCS Clayey Sand
Weathered Bedrock	Sandstone	Shale



Print Date: 12/4/2020 File Name: 23558GEOE\Engineering Geology I-13-G.dgn Horiz. Scale: 1:50 Vert. Scale: As Noted Unit Information Unit Leader Initials	Sheet Revisions <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Date:</th> <th>Comments</th> <th>Init.</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>	Date:	Comments	Init.										Colorado Department of Transportation 1480 Quail Lake Loop, Suite A Colorado Springs, CO 80906 Phone: 719-634-2323 FAX: 719-227-3298 Region 2	As Constructed No Revisions: Revised: Void:	R2 BRIDGE BUNDLE ENGINEERING GEOLOGY Designer: JTM Structure Numbers: I-13-G Detailer: MJW Sheet Subset: Geology Subset Sheets: 1 of 1	Project No./Code STM R200-262 23558 Sheet Number
Date:	Comments	Init.															



APPENDIX B

KEY TO BORING LOGS
BORING LOGS
PAVEMENT CORE PHOTOS



Legend for Symbols Used on Borehole Logs

Sample Types



Bulk Sample of auger/odex cuttings



Rock core



Modified California Sampler (2.5 inch OD, 2.0 inch ID)



Standard Penetration Test (ASTM D1586)

Drilling Methods



CORING



HOLLOW-STEM AUGER

Lithology Symbols (see Boring Logs for complete descriptions)



Asphalt



Cobbles and gravel



USCS Fat/High Plasticity Clay



USCS Lean/Low Plasticity Clay



Fill with Clay as major soil



Fill with Gravel as major soil



USCS Clayey Gravel



USCS Silty, Clayey Gravel



USCS Poorly-graded Gravel



USCS Poorly-graded Gravel with Clay



Low Plasticity Gravelly Clay



USCS Silt



USCS Low Plasticity Organic silt or clay



High Plasticity Sandy Clay



Poorly-graded Sandy Gravel



Low Plasticity Sandy Clay



USCS Clayey Sand



USCS Clayey Sand



USCS Silty Sand



USCS Poorly-graded Sand



Diorite



Gneiss



Granite



Limestone



Sandstone



Shale



Weathered Bedrock

Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487
(Fines = % Passing #200 Sieve)	
Sand = % Passing #4 Sieve, but not passing #200 Sieve)	

Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Collapse (ASTM D4546)
UCCS	Unconfined Compressive Strength (Soil - ASTM D2166, Rock - ASTM D7012)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

Notes

1. Visual classifications are in general accordance with ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)".
2. "Penetration Resistance" on the Boring Logs refers to the uncorrected N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California (MC) sampler, drive depth is 12 inches, and "Penetration Resistance" refers to the sum of all blows. Where blow counts were > 50 for the 3rd increment (SPT) or 2nd increment (MC), "Penetration Resistance" combines the last and 2nd-to-last blows and lengths; for other increments with > 50 blows, the blows for the last increment are reported.
3. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.
4. "ER" for the hammer is the Reported Calibrated Energy Transfer Ratio for that specific hammer, as provided by the drilling company.



Boring Began: 9/24/2020
Boring Completed: 9/24/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 101.5 ft
Ground Elevation: 9124.5
Coordinates: N: 398454.5 E: 871499.5
Location: US 24, westbound outside lane
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 50s
Inclination from Horiz.: Vertical
Night Work:

Groundwater Levels:			
Symbol	∇		
Depth	30.0 ft	-	-
Date	9/24/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
							0.0 - 0.7 ft. ASPHALT (8 inches).										
							0.7 - 5.0 ft. Clayey SAND with gravel (SC) (Fill), brown, dry to moist, loose.										
9120	5			5-3	8												
							5.0 - 15.0 ft. Sandy lean CLAY (CL) (Fill), brown, moist, soft.										
9115	10			2-2	4			23.7	95.0								S/C=0%
9110	15			5-3	8		15.0 - 20.0 ft. Sandy lean CLAY with gravel (CL), brown mottled with yellow, moist, medium stiff.										
9105	20			5-10	15		20.0 - 30.0 ft. Clayey SAND (SC), brown, moist, medium dense.										
9100																	

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
				5-7-8	15		20.0 - 30.0 ft. Clayey SAND (SC), brown, moist, medium dense. Seam of sandy fat clay, dark brown, from 26-26.4 feet.										
9095	30			5-7-8	15		30.0 - 35.0 ft. Interlayered sandy lean CLAY (CH), clayey SAND (SC), and clayey GRAVEL (GC), brown, moist to wet, medium dense, very stiff.										
9090	35			5-11	16		35.0 - 40.0 ft. Gravelly lean CLAY (CL), black, moist, stiff, rock structure apparent (shale residuum), high carbon content.										
9085	40			10-11	21		40.0 - 49.0 ft. Interlayered gravelly lean CLAY (CL) and clayey GRAVEL (GC), black, moist, medium dense, very stiff, sandstone gravels; rock structure apparent (sandstone and shale residuum), high carbon content.										
9080	45			7-17-11	28												
9075	50			13-11	24		49.0 - 56.0 ft. Silty SAND (SM), gray, moist, medium dense, weakly cemented (sandstone residuum).	11.5		21.0	50.6	28.4	16	0	A-2-4 (0) SM	pH=7.9 S=0.579% ChI=0.0004% Re=1487ohm-cm	
9070	55																

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests	
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index			
		X		5-12-13	25		56.0 - 75.0 ft. Gravelly lean CLAY (CL) , black, moist, very stiff to hard, rock structure apparent (shale residuum), high carbon content. - sand seam (1' thickness) at 60'.										
9065	60	X		10-15	25												
9060	65	X		5-8-12	20												
9055	70	X		11-23	34												
9050	75	X		16-20-29	49			75.0 - 90.0 ft. Clayey GRAVEL (GC) , black, moist, dense, shale residuum, high carbon content.									
9045	80	X		12-27	39												
9040	85	X															

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index		
		X		12-20-27	47		75.0 - 90.0 ft. Clayey GRAVEL (GC) , black, moist, dense, shale residuum, high carbon content.									
9035	90	X		14-40	54		90.0 - 95.0 ft. DECOMPOSED SHALE , dark gray to black, predominantly decomposed to decomposed, hard.	7.6		5.0	38.0	57.0	31	14	A-6 (5) CL	UCCS=97.7 psi
9030	95	X		32-50:6"	50:6"		95.0 - 96.0 ft. SANDSTONE , gray, decomposed, hard.									
							96.0 - 100.0 ft. SHALE , dark brown to black, decomposed to slightly weathered, hard.									
9025	100	X		14-15-20	35		100.0 - 101.5 ft. SANDSTONE , gray, decomposed, hard.									
Bottom of Hole at 101.5 ft.																
9020																
9015																
9010																

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



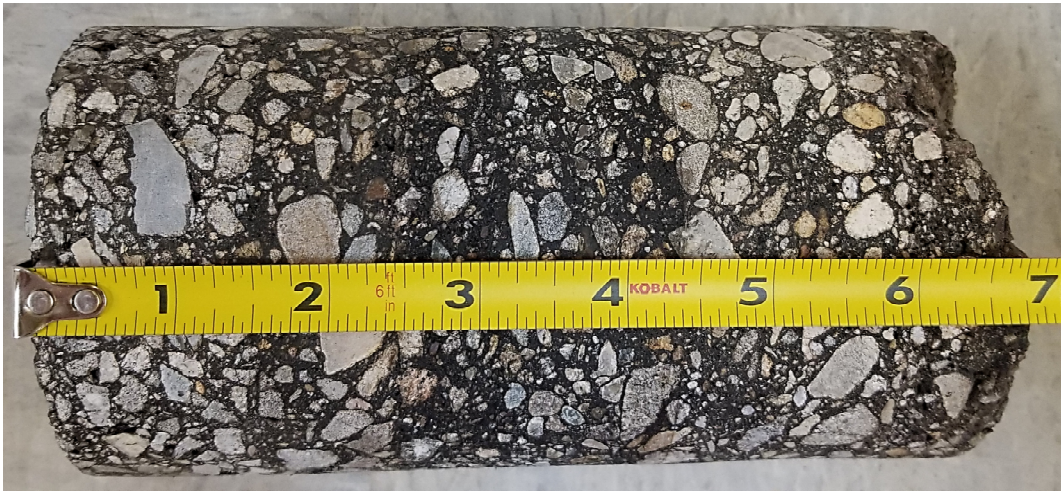
Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index		
				5-6-11	17		20.0 - 27.0 ft. Interlayered clayey SAND with gravel (SC) and sandy CLAY with gravel (CL), dark brown and yellow, moist, medium dense, stiff to very stiff.									
							27.0 - 40.0 ft. Silty SAND (SM), brown-tan mottled with black, moist to wet, medium dense, locally gravelly.									
9095	30			4-10-12	22											
9090	35			8-11	19			19.2		0.0	58.0	42.0	NV	NP	A-4 (0) SM	UCCS=17 psi
9085	40			6-7	13		40.0 - 44.0 ft. Clayey SAND with gravel (SC), tan mottled with dark brown, wet, medium dense.									
9080	45			3-14-14	28		44.0 - 54.0 ft. Clayey GRAVEL (GC), black, wet, medium dense, rock structure apparent (residuum of shale), high carbon content.									
9075	50			5-12	17											
9070	55															

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index		
				5-12-19	31		54.0 - 59.0 ft. Gravelly fat CLAY (CH) , black, moist, hard, rock structure apparent (residuum of shale), high carbon content.									
9065	60			5-17	22		59.0 - 65.0 ft. Clayey GRAVEL (GC) , black, wet, medium dense, rock structure apparent (residuum of shale), high carbon content.									
9060	65			9-14-16	30		65.0 - 70.0 ft. Silty, clayey SAND with gravel (SC-SM) , black, dense, hard, high carbon content.	14.8		15.0	38.5	46.5	27	7	A-4 (1) SC-SM	pH=7.1 S=0.382% ChI=0.0003% Re=655ohm·cm
9055	70			8-16	24		70.0 - 71.0 ft. Lean CLAY (CL) , black and gray, moist, very stiff, rock structure locally apparent (residuum of siltstone).	15.6		0.0	11.0	89.0	26	11	A-6 (8) CL	UCCS=25.6 psi
							Bottom of Hole at 71.0 ft.									

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/4/20



Boring:	P-1	AC:	7"
Roadway:	US 24	PCC:	-
Direction:	Westbound	Base:	-
Lane:	Outside	Notes:	-



Boring:	P-2	AC:	8.5"
Roadway:	US 24	PCC:	-
Direction:	Eastbound	Base:	-
Lane:	Outside	Notes:	-



Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Pavement Core Photographs

FIGURE

PROJECT NO. 220-063 DATE: 11/25/2020
 FIGURE BY: BHL YEH OFFICE: Colorado Springs
 CHECKED BY: JTM

CDOT Region 2 Bridge Bundle
Structure I-13-G

B-1

APPENDIX C

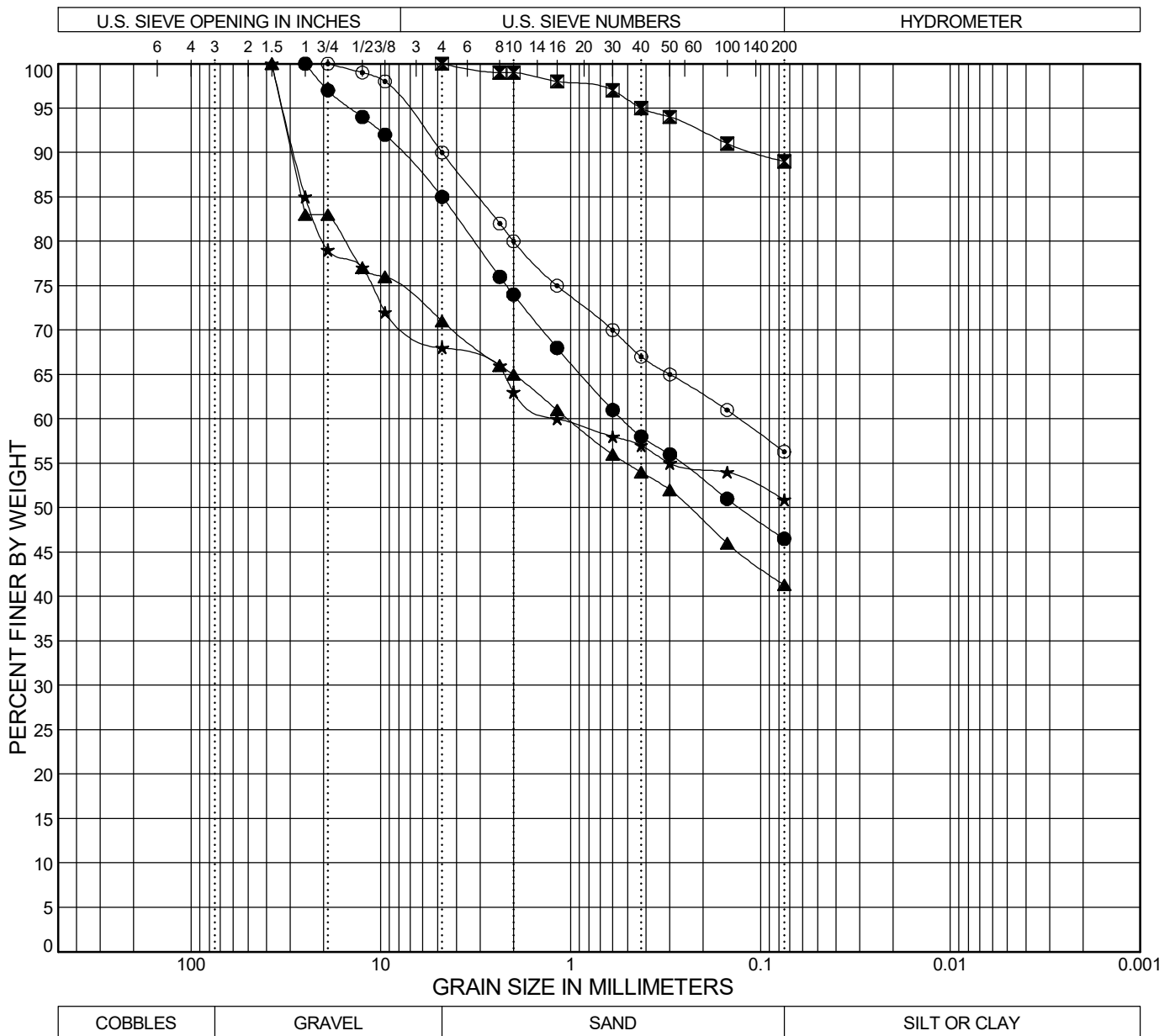
SUMMARY OF LABORATORY TEST RESULTS



Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 12-04-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
I-13-G B-1	10.0	MC	23.7	95.0		35.5	64.5	26	17	9					0 @ 1000			A-4 (3)	CL
I-13-G B-1	50.0	MC	11.5		21.0	50.6	28.4	16	20	0	7.9	0.579	0.0004	1487				A-2-4 (0)	SM
I-13-G B-1	90.0	MC	7.6		5.0	38.0	57.0	31	17	14						97.7		A-6 (5)	CL
I-13-G B-2	5.0	MC	14.6	110.8		41.8	58.2	28	16	12					-0.3 @ 500			A-6 (4)	CL
I-13-G B-2	35.0	MC	19.2		0.0	58.0	42.0	NV	NP	NP						17		A-4 (0)	SM
I-13-G B-2	65.0	SPT	14.8		15.0	38.5	46.5	27	20	7	7.1	0.382	0.0003	655				A-4 (1)	SC-SM
I-13-G B-2	70.0	MC	15.6		0.0	11.0	89.0	26	15	11						25.6		A-6 (8)	CL
I-13-G P-1	4.0	MC	18.6	100.2	29.0	29.7	41.3	41	24	17					0.3 @ 200			A-7-6 (3)	SC
I-13-G P-2	4.0	MC	15.8	108.4	32.0	17.1	50.9	35	19	16					0 @ 200			A-6 (5)	CL
I-13-G Scour	0	BULK	1.3		45.0	44.1	10.9	27	18	9								A-2-4 (0)	GW-GC
I-13-G-P-1/P-2	2.5	BULK	15.9		10.0	33.7	56.3	34	19	15		0.008	0.0127				7	A-6 (6)	CL



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● I-13-G B-2	65.0	A-4 (1)	SC-SM	27	20	7	15.0	38.5	46.5	
☒ I-13-G B-2	70.0	A-6 (8)	CL	26	15	11	0.0	11.0	89.0	
▲ I-13-G P-1	4.0	A-7-6 (3)	SC	41	24	17	29.0	29.7	41.3	
★ I-13-G P-2	4.0	A-6 (5)	CL	35	19	16	32.0	17.1	50.9	
◎ I-13-G-P-1/P-2	2.5	A-6 (6)	CL	34	19	15	10.0	33.7	56.3	



SIEVE ANALYSIS

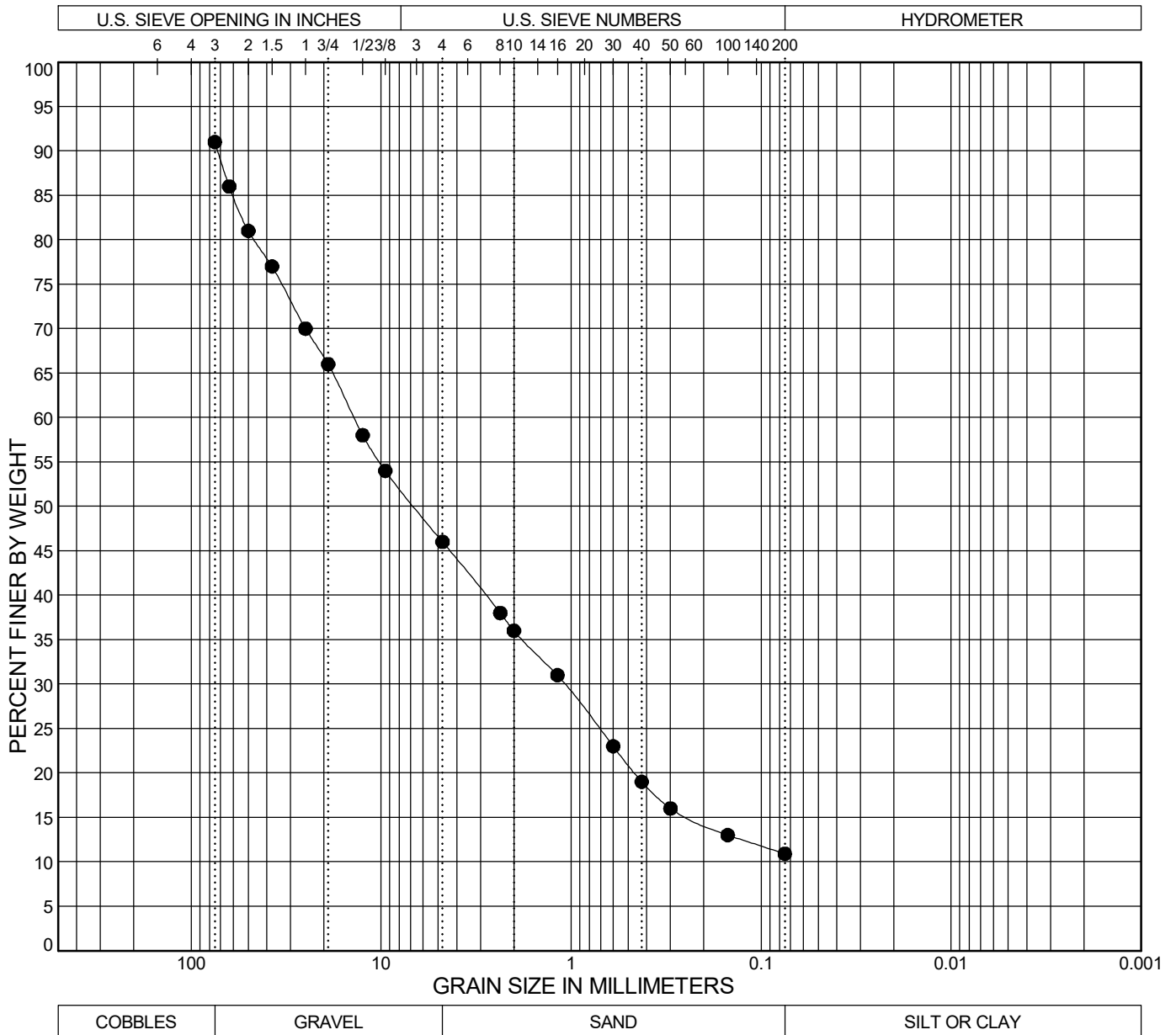
FIGURE

Project No. 220-063 Date: 11-30-2020
 Report By: D. Gruenwald Yeh Lab: Colorado Springs
 Checked By: J. McCall


CDOT Region 2 Bridge Bundle
 Structure I-13-G

C-3

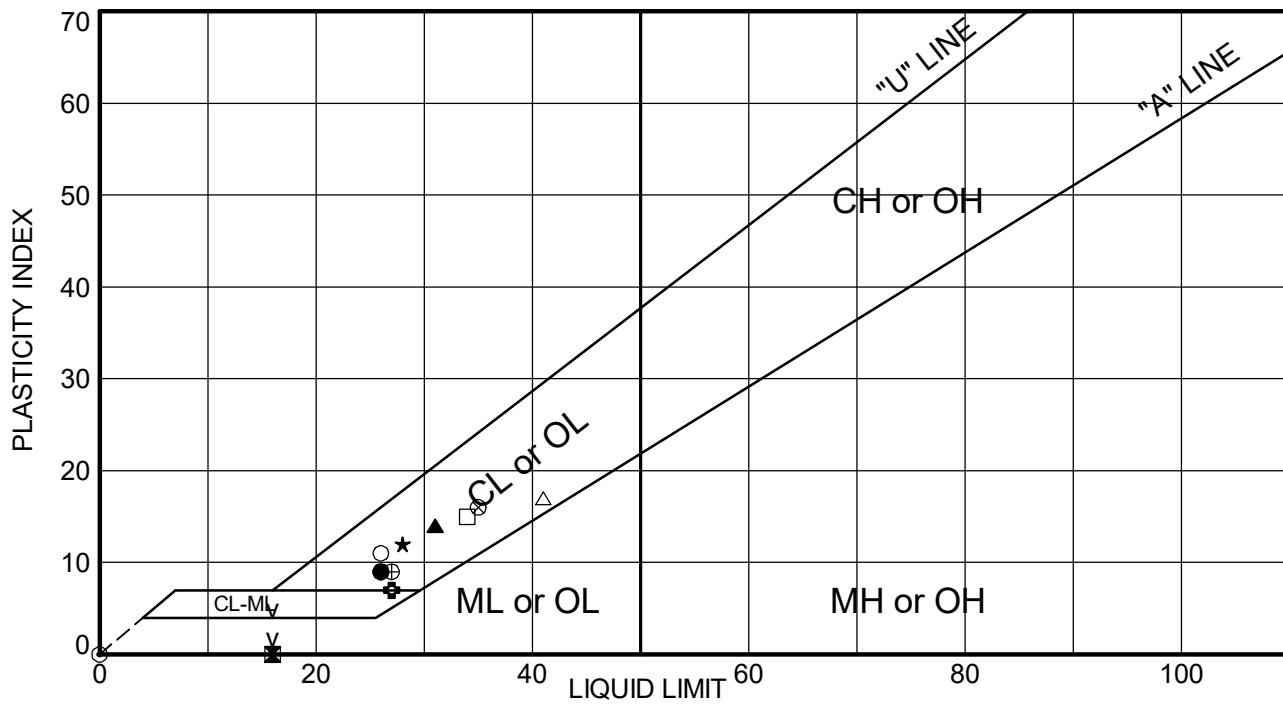
03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/30/20




BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● I-13-G Scour	0.0	A-2-4 (0)	GW-GC	27	18	9	45.0	35.1	10.9	

 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	<h2>SIEVE ANALYSIS</h2>	<h2>FIGURE</h2>

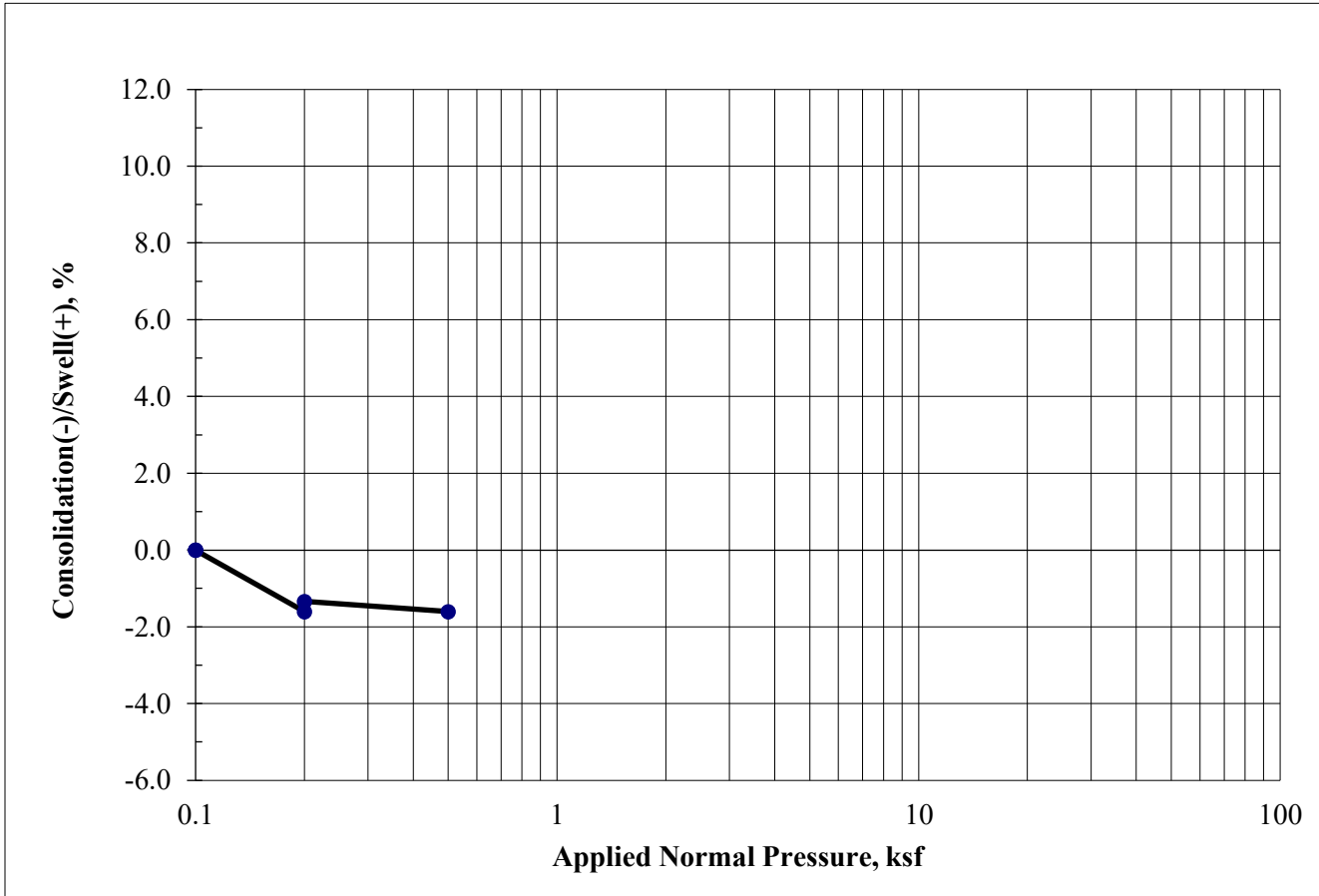
01 ATTERBERG LIMITS YEH - ALL BORINGS 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/30/20



BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
● I-13-G B-1	10.0	26	17	9	64.5	SANDY LEAN CLAY (CL)	A-4 (3)
☒ I-13-G B-1	50.0	16	20	NP	28.4	SILTY SAND with GRAVEL (SM)	A-2-4 (0)
▲ I-13-G B-1	90.0	31	17	14	57.0	SANDY LEAN CLAY (CL)	A-6 (5)
★ I-13-G B-2	5.0	28	16	12	58.2	SANDY LEAN CLAY with GRAVEL (CL)	A-6 (4)
⊙ I-13-G B-2	35.0	NV	NP	NP	42.0	SILTY SAND (SM)	A-4 (0)
⊕ I-13-G B-2	65.0	27	20	7	46.5	SILTY, CLAYEY SAND with GRAVEL (SC-SM)	A-4 (1)
○ I-13-G B-2	70.0	26	15	11	89.0	LEAN CLAY (CL)	A-6 (8)
△ I-13-G P-1	4.0	41	24	17	41.3	CLAYEY SAND with GRAVEL (SC)	A-7-6 (3)
⊗ I-13-G P-2	4.0	35	19	16	50.9	GRAVELLY LEAN CLAY with SAND (CL)	A-6 (5)
⊕ I-13-G Scour	0.0	27	18	9	10.9	WELL-GRADED GRAVEL with CLAY and SAND (GW-GC)	A-2-4 (0)
□ I-13-G-P-1/P-2	2.5	34	19	15	56.3	SANDY LEAN CLAY (CL)	A-6 (6)


 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	ATTERBERG LIMITS	FIGURE C - 5

SWELL/CONSOLIDATION TEST - ASTM D 4546

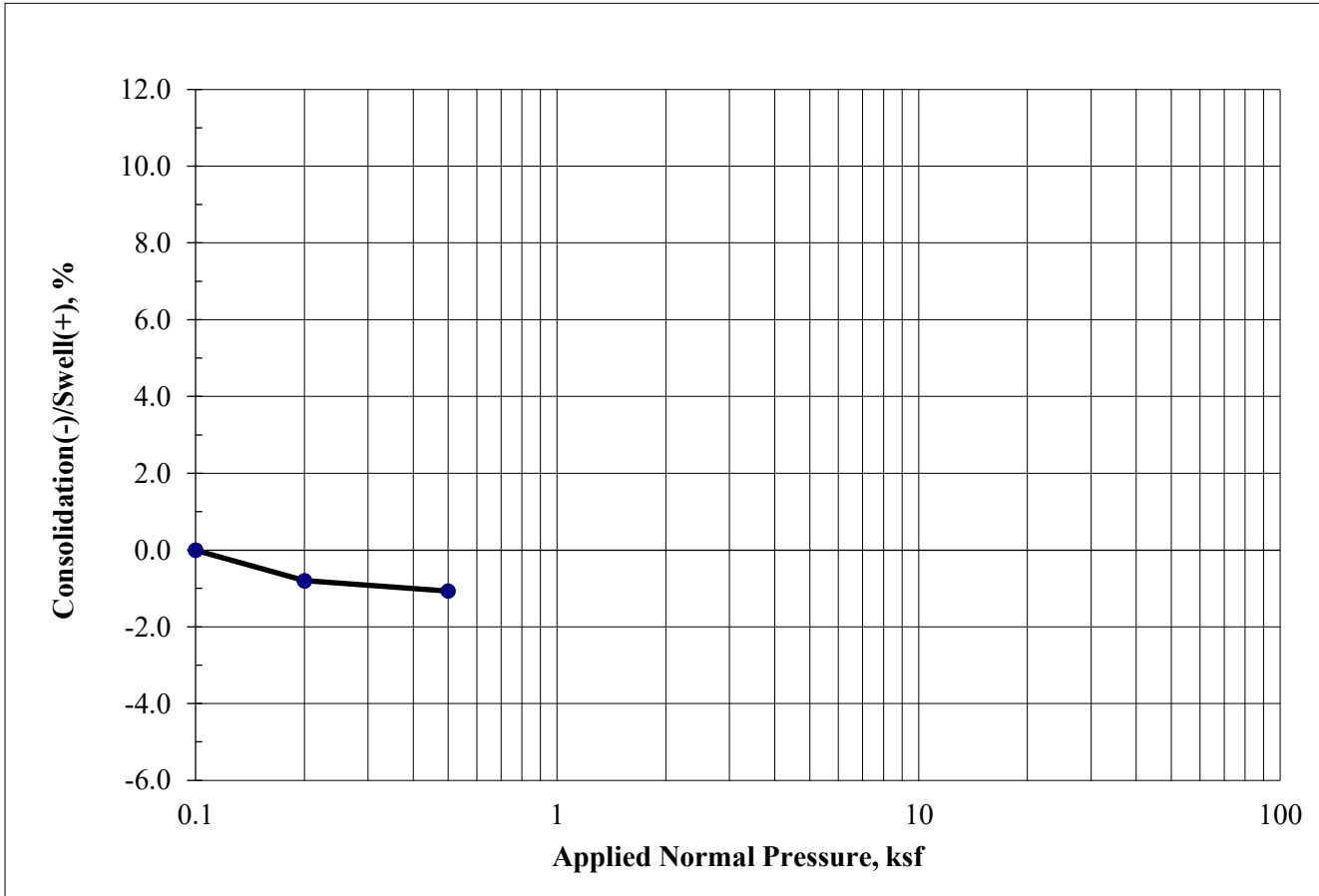


Boring ID	P-1
Sample Depth (ft)	4.0
Date Sampled	9/24/2020

Swell/ Consolidation (%)	0.3
Natural Moisture Content (%)	18.6
Saturated Moisture Content (%)	19.7
Dry Density (pcf)	100.2


 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	SWELL/ CONSOLIDATION TEST RESULTS		FIGURE C-6
	Project No. 220-063 Date: 11/30/2020 Report By: DG Yeh Lab: Colorado Springs Checked By: JTM	CDOT Region 2 Bridge Bundle Structure I-13-G	

SWELL/CONSOLIDATION TEST - ASTM D 4546

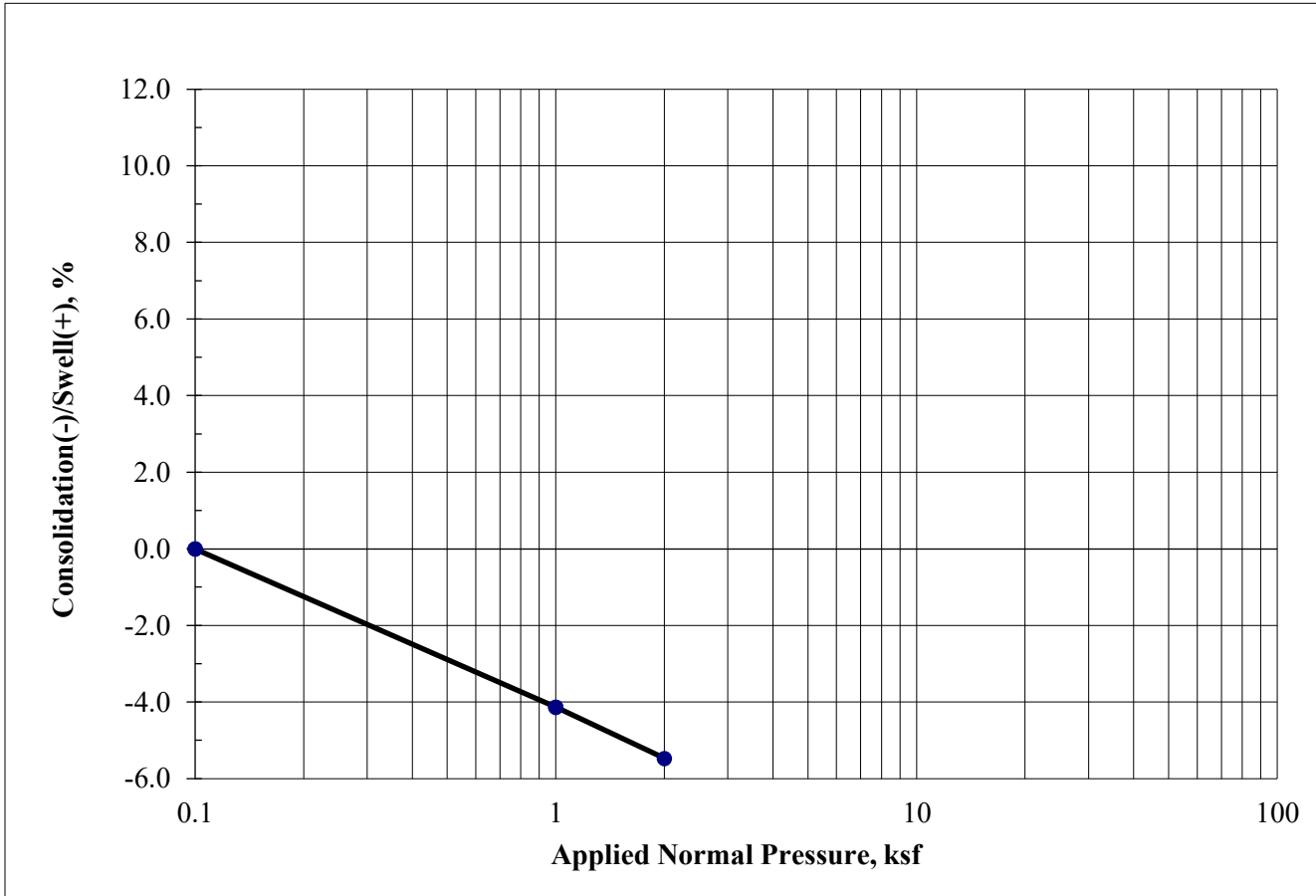


Boring ID	P-2
Sample Depth (ft)	4.0
Date Sampled	9/24/2020

Swell/ Consolidation (%)	0.0
Natural Moisture Content (%)	15.8
Saturated Moisture Content (%)	17.5
Dry Density (pcf)	108.4


 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	SWELL/ CONSOLIDATION TEST RESULTS		FIGURE C-7
	Project No. 220-063 Date: 11/30/2020 Report By: DG Yeh Lab: Colorado Springs Checked By: JTM	CDOT Region 2 Bridge Bundle Structure I-13-G	

SWELL/CONSOLIDATION TEST - ASTM D 4546

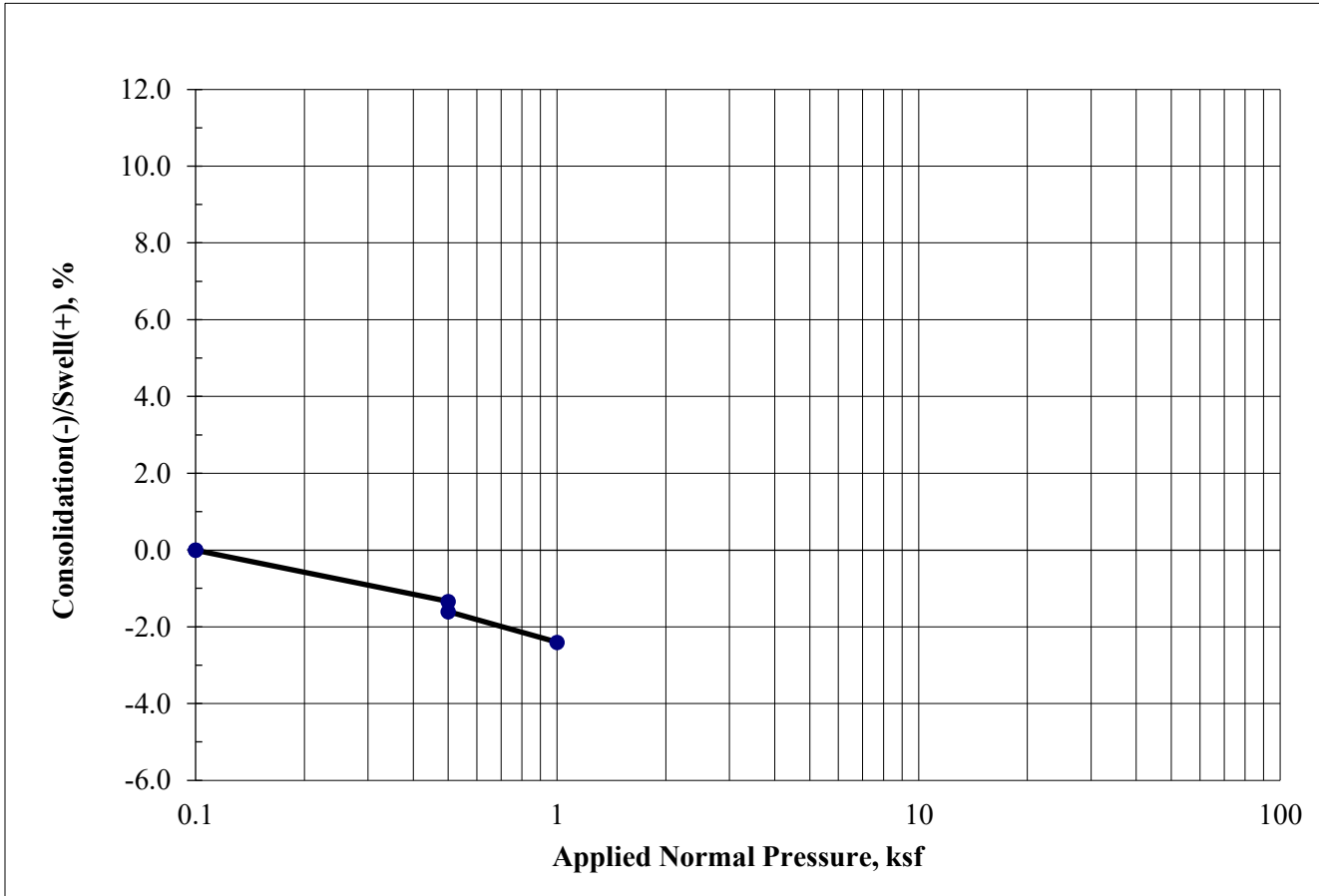


Boring ID	B-1
Sample Depth (ft)	10.0
Date Sampled	9/24/2020

Swell/ Consolidation (%)	0.0
Natural Moisture Content (%)	23.7
Saturated Moisture Content (%)	28.9
Dry Density (pcf)	95


 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	SWELL/ CONSOLIDATION TEST RESULTS		FIGURE C-8
	Project No. 220-063 Date: 11/30/2020 Report By: DG Yeh Lab: Colorado Springs Checked By: JTM	CDOT Region 2 Bridge Bundle Structure I-13-G	

SWELL/CONSOLIDATION TEST - ASTM D 4546



Boring ID	B-2
Sample Depth (ft)	5.0
Date Sampled	9/24/2020

Swell/ Consolidation (%)	-0.3
Natural Moisture Content (%)	14.6
Saturated Moisture Content (%)	17.6
Dry Density (pcf)	110.8

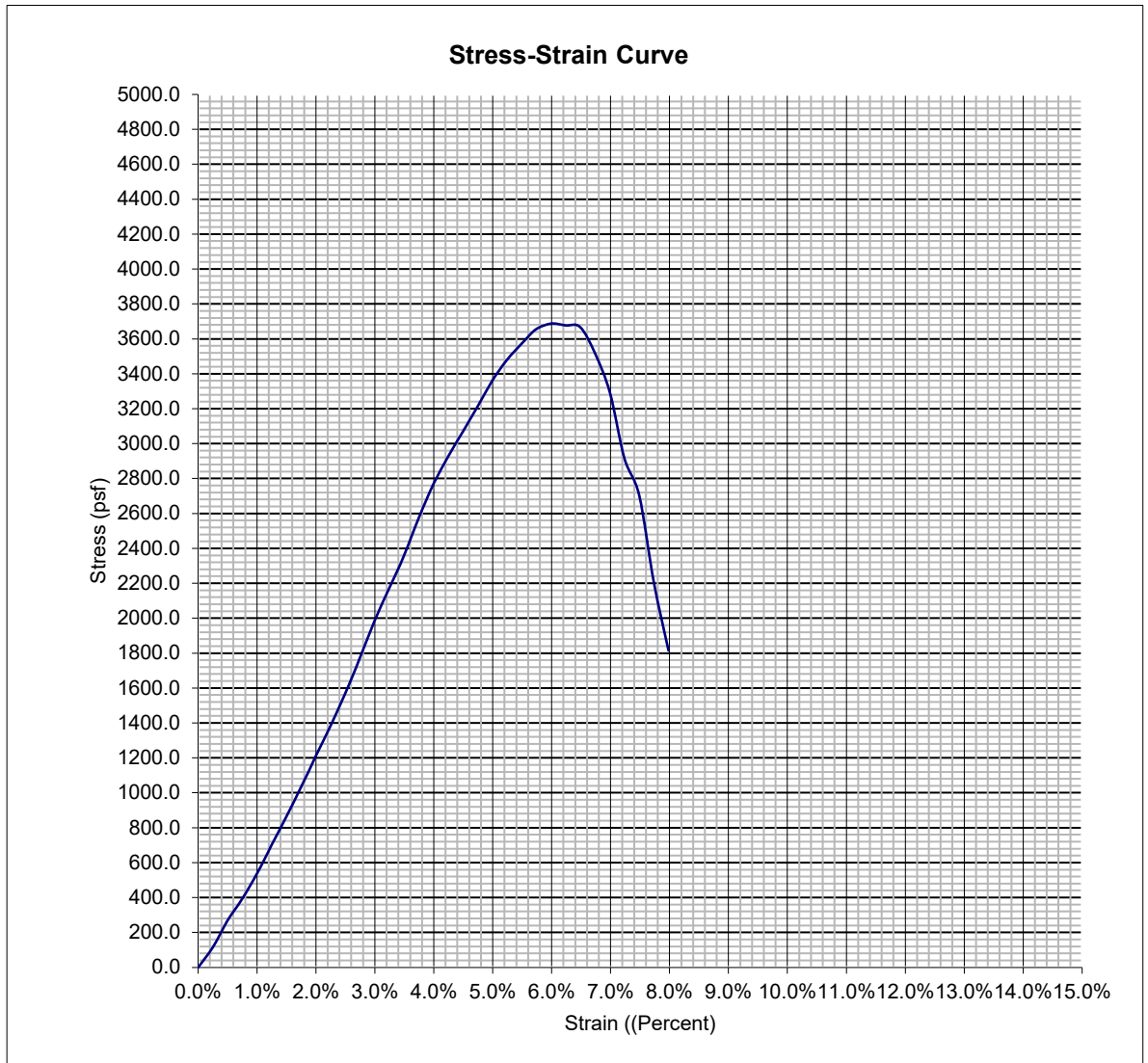
 Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	SWELL/ CONSOLIDATION TEST RESULTS		FIGURE C-9
	Project No. 220-063 Date: 11/30/2020 Report By: DG Yeh Lab: Colorado Springs Checked By: JTM	CDOT Region 2 Bridge Bundle Structure I-13-G	



**STRESS-STRAIN CURVE
OF COHESIVE SOIL (ASTM D 2166)**

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle I-13-G
 Sampled by: CW Date Sampled: 9/24/2020 Date Tested: 11/12/20
 Boring No: B-2 Depth (ft): 70 Blow Counts: _____
 Tested by: M.A Checked by: JTM
 Soil Classification: A-6 (8) / CL

Axial Strain (%)	Axial Stress (psf)
0.0%	0.0
0.2%	117.2
0.5%	268.0
0.7%	393.7
1.0%	538.1
1.2%	701.2
1.5%	863.4
1.7%	1034.4
2.0%	1209.4
2.2%	1383.4
2.5%	1570.9
2.7%	1771.6
3.0%	1985.6
3.2%	2174.7
3.5%	2358.2
3.7%	2573.6
4.0%	2769.1
4.2%	2926.0
4.5%	3068.1
4.7%	3214.0
5.0%	3359.1
5.2%	3480.2
5.5%	3572.9
5.7%	3655.8
6.0%	3687.5
6.2%	3677.7
6.5%	3667.9
6.7%	3516.6
7.0%	3293.1
7.2%	2916.3
7.5%	2704.6
7.7%	2200.3
8.0%	1815.9



Unconfined Compressive Strength (q_u) = 3688 psf @ 6.0% Strain

Natural Moisture: 15.6 %
Natural Density(Dry): 119.4 pcf
Average Diameter (D): 1.935 inches
Average High (L): 4.009 inches
L/D Ratio: 2.07



R Value ASTM D2844

CLIENT	Yeh & Associates	BORING NO.	P-1/P-2
JOB NO.	2546-129	DEPTH	Combined Bulk
PROJECT	CDOT R2 Bridge Bundle_G-12-C	SAMPLE NO.	I-13-G
PROJECT NO.	220-063	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	12/03/20	DESCRIPTION	--
TECHNICIAN	ALH		

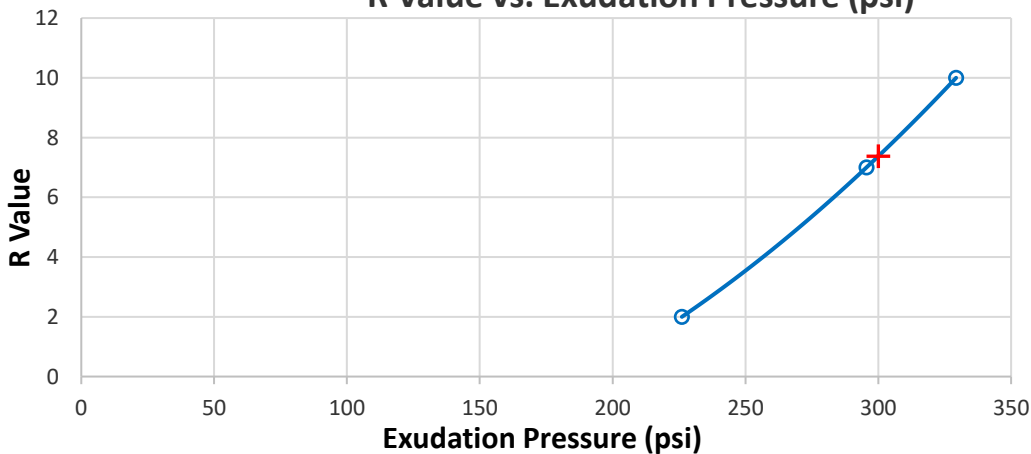
Sample Conditions

Mass of Wet Soil & Pan (g):	1897.3	1895.5	1981.2
Mass of Dry Soil & Pan (g):	1727.8	1744.5	1835.4
Mass of Pan (g):	791.0	792.6	843.1
Mass of Wet Soil & Mold (g):	3227.3	3212.0	3240.5
Mass of Mold (g):	2110.9	2104.3	2101.8
Sample Height (in):	2.63	2.56	2.60
Wet Density (pcf):	128.7	131.2	132.8
Dry Density (pcf):	109.0	113.2	115.8
Wet Density (kg/m³):	2061	2101	2127
Dry Density (kg/m³):	1746	1814	1854
Moisture (%):	18.1	15.9	14.7

R Value Data

Exudation Pressure (lbs):	2841	3714	4138
Exudation Pressure (psi):	226.1	295.6	329.3
2000 lbs. Dial Reading (psi):	153	138	134
Displacement Turns:	5.93	5.34	5.05
Uncorrected R Value:	2	7	9
Corrected R Value:	2	7	10

R Value vs. Exudation Pressure (psi)



Corrected R Value at 300 psi
Exudation Pressure

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NOTES:

Data entry by: ALH
 Checked by: WAR
 File name: 2546129_R Value ASTM D2844_2.xlsm

Date: 12/04/20
 Date: 12/07/20