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 G-12-C

(Region 2 – CO 9 MP 71.445)

Prepared for: Colorado Department of Transportation Region 2
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Stanley Consultants Project No. 29715
January 2021

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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 constrains.

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 prosses:

- 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 two ALBC 74 Arch Structures by Contech Solutions. The width of proposed construction must accommodate two 12.0 ft lanes of traffic with 6.0 ft minimum shoulders, 2.0 ft curb offset, and the Colorado current standard Bridge Rail on each side. The proposed length will be 47 ft 3 in. Wingwalls will be required on three corners to retain the roadway fill. North west corner of the structure will be placed in-line with the proposed retaining wall and will not have a wingwall.

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 G-12-C structure is a two-cell 10 ft x 10 ft, concrete box culvert built in 1938 to allow for the Middle Fork of the South Platte River to cross under State Highway (CO) 9. The structure has no skew and is 38.0 ft long. The existing culvert has four concrete wingwalls at each corner, approximately 18.0 ft long.

Existing G-12-C structure is located on CO 9 at Mile Post 71.445, approximately 0.8 miles north of Alma, CO. Table 1 summarizes bridge information.

National Bridge Structure Number	G-12-C
Year Built	1938
Construction Type	Two Cell Box Culvert, (2) 10 ft. x 10 ft.
Condition Rating	Poor
Load Restricted	No
Bridge Length	23 feet
Bridge Width	36 feet
Number of spans	2
Water Crossing	Middle Fork of South Platte River
AADT	3800
Percent Commercial Traffic	3.7%

Table 1 – Bridge G-12-C Summary Information

The Middle Fork of the South Platte River runs northwest to southeast and crosses CO 9 perpendicular. The upstream channel curves north and parallel to CO 9. When the road was constructed the river channel was relocated. The old channel is adjacent to the CO 9 ROW on the northwest corner.

Picture 1 – Bridge G-12-C General Location

The replacement of Bridge G-12-C is warranted due to the age and deteriorating conditions. Severe deterioration at both ends and both faces of the divider wall with exposed rebar and in cell 1 at midspan and right end. There is light cracking throughout, some with efflorescence in walls. Pictures on the next page show some of the structure deterioration.

Picture 2 – Center Wall Loss of Section

Picture 3 – Wingwall Exposed Reinforcement

2.2. RIGHT OF WAY IMPACT

The existing right of way (ROW) is located approximately 50.0 ft from the centerline of the existing road on the west side of the structure and 65.0 ft on the east 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 CO 9. Temporary construction easements may be required for drainage erosion control.

Due to the proximity of the ROW line on the west side of the proposed structure, a retaining wall will be required on the north-west corner of the proposed structure. The proposed retaining wall will be placed parallel to the widened roadway.

2.3. TRAFFIC DETOUR

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 culvert open to traffic.
2. Building a one-lane or two-lane shoofly on either side of the existing bridge with a temporary pipe placed for drainage. The impacts to wetlands make this option less desirable.

Alternative 1 (phased construction with one lane open) was identified as a preferred traffic alternative for this structure. More information on traffic detour options can be found in the Traffic Design Memorandum for this structure.

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 west ROW line and running parallel to the existing road. 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, G-12-C-B-1 and G-12-C-B-2 were drilled by Yeh in the vicinity of the existing structure, and two pavement borings, G-12-C-P-1 and G-12-C-P-2, were drilled along the existing pavement approximately 250 feet from the structure.

The bridge borings encountered poorly graded sands and gravels, locally interlayered with lean clay soils, overlying 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)
G-12-C-B-1	1205571.5, 2185359.5	10,389.50	58	10,389.50	13	10,376.50
G-12-C-B-2	1205534.9, 2185338.6	10,389.00	48	10,389.00	13	10,376.00

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 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 arch alternative is used, it will be supported on a shallow foundation system such as reinforced concrete strip footing. Design and construction for the shallow foundation system should take into consideration the scour potential at the proposed site. The bottom of the shallow foundation should be a minimum of 36-inches below the exterior ground surface for frost protection and should be founded on a minimum of 2 ft of properly placed CDOT Class 1 Structure Backfill.

2.6. HYDRAULICS SUMMARY

Bridge G-12-C crosses the Middle Fork of the South Platte River. The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A. The design flow rate is 2,885 cfs. An SRH-2D model was developed at this location. The proposed model indicates that there is that a two-cell 20 ft x 10 ft CBC would carry the design flow. Another option investigated was two span arches, ALBC 74 with an opening width of 23 ft 10 in and vertical height of 10 ft 1 in. A one-span 55.0 ft long Bridge alternative was evaluated and was also shown to have an adequate opening to carry the design flows.

The channel was identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 4 feet of freeboard would typically be required. However, the existing 100-year floodplain overtops the roadway, and due to funding and site constraints, it is not feasible to raise the bridge enough to obtain this freeboard. The proposed preliminary design improves the conditions by passing the 100-year flow without overtopping the road.

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 the Middle Fork of the South Platte River, which the Project bridge spans
- Potential Waters of the U.S
    - The Project has the potential to impact 0.12 acres of US Army Corps of Engineers (USACE) jurisdictional wetlands
    - The Project has the potential to impact 0.18 acres (or 456 linear feet) of USACE jurisdictional tributaries
    - The wetlands within the Project Review Area could be associated with a highly protected fen wetland located upstream, within 0.25 miles
- 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
        - Boreal toad (*Bufo boreas boreas*) – State Endangered
        - River otter (*Lontra canadensis*) – State Threatened
- Floodplains
    - The Project is located within a Federal Emergency Management Agency (FEMA) Zone A Floodplain (100-year floodplain).

  - The Project will be designed to meet the floodplain standards established by CDOT, FEMA, and the Park County Floodplain Administrator. By lowering the water surface elevation to avoid overtopping in the 100-year event, the floodplain will be altered. Because of this, a Letter of Map Change (LOMC) will likely be required, following FEMA requirements.
- 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

Existing CO 9 is a 2-lane roadway with two-way traffic. The existing north-bound lane is 12.0 ft wide with 1.0 ft shoulder, and the south-bound lane is 11.0 ft wide with 1.0 ft shoulder. There is no existing guardrail on either side of the road.

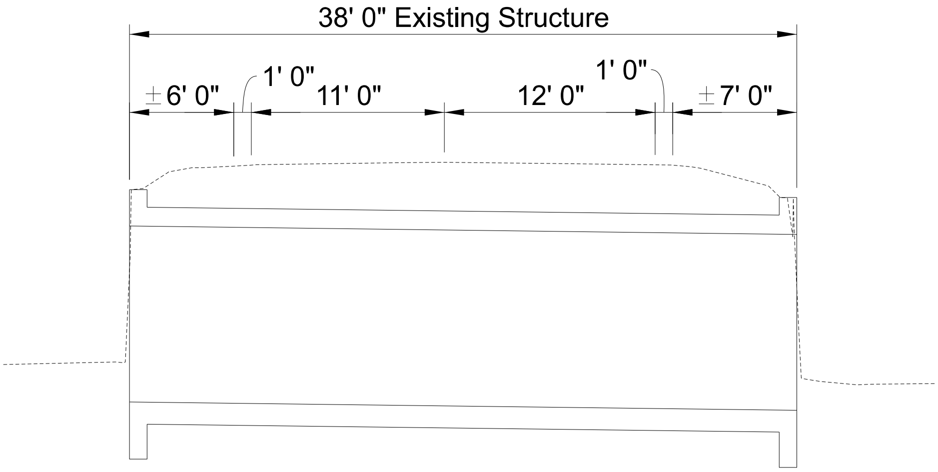

Figure 1 – Existing Section

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. Additional roadway width is needed for phased construction and is discussed in the Section 4.7 Construction Phasing.

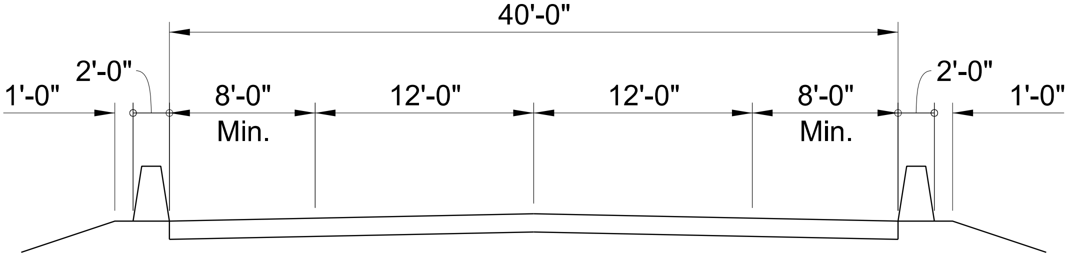

Figure 2 – Proposed Roadway Section

2.8.2. Vertical Alignment

The proposed vertical profile of CO 9 must be set as close to the existing as allowed by the results of the hydrology study to avoid any ROW acquisitions and to limit impacts to the existing roadway section beyond the length of the structure.

The proposed bridge profile is on a 800.00 ft vertical sag curve that matches the existing roadway profile. The incoming grade is -1.164%, and outgoing grade is 2.466%. The proposed bridge profile slope in the vicinity of the structure is approximately 0.7%.

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 with no change to the horizontal alignment of the road and no skew.

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

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 G-12-C will not be performed due to the age and type of the bridge. Constructed in 1938, 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 not have skew.

As noted in Section 2.6, the existing 100-year floodplain overtops the roadway, and due to funding and site constraints, it is not feasible to raise the bridge above the 100-year floodplain. The proposed preliminary design improves the conditions. If a bridge alternative is selected, the design build team will need to take this into considerations and provide design that satisfies this loading condition.

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 prosses. In addition, CBC size can be selected from CDOT M&S Standards that cover vide array of single-cell and multi-cell culvert sizes.

For G-12-C a two-cell 20 ft x 10 ft box culvert is required to carry the design flow. The box can be constructed as CIP or precast. The centerline of the proposed box culvert will be placed inline with the centerline of the existing box culvert. The minimum design cover over the top slab of the proposed CBC is approximately 1.5 ft.

The west headwall of the proposed CBC will need to be placed in line with the proposed retaining wall located on the north-west side of the structure. The east headwall will be places as required accommodate phased construction. The concrete box culvert proposed total length is 47 ft 3 in.

Wingwalls will be provided on 3 sides on the box culvert. 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 two steel arch structures, ALBC 74 by Contech Solutions. The horizonal width of each cell is 23 ft 10 in with a vertical clearance of 10 ft 1 in. Cast in place footings will be required to support the ends of each arch. The footings will be constructed below the natural river bottom. The arches will have approximately 3.0 ft of cover.

Similarly to the CBC alternative, the west headwall of the proposed structure will be placed in line with the proposed retaining wall located on the north-west side of the structure. The east headwall will be places as required accommodate phased construction. The steel arch proposed total length is 47 ft 3 in.

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, (6) BX 18x48 girder section spaced at 8.0 ft was chosen as a cost-effective precast concrete solution for the required 55.0 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

Total length of the proposed concrete box culvert and steel arch alternatives was determined based on the requirements of the construction phasing and is discussed below.

A one-span 55.0 ft long bridge length proposed bridge alternative was determined based on the requirements of the hydraulics opening. The proposed alternative provides same bottom of the channel width as the existing box culvert. The proposed bridge embankments will have 2:1 slope.

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 a maximum allowed depth of 6.0 ft will be used for concrete bridge alternative (see Figure 11-1 in CDOT Bridge Design Manual). Abutment cap will be supported by (6) HP 12x53 piles. This type of abutment will have an embankment that is susceptible to scour can be mediated by placing riprap on geotextile material on the embankments of the abutments and wingwalls. Wingwalls for this alternative will consist of ether integral wingwall attached to the abutment cap (up to 20.0 ft max), or a combination of 10.0 ft integral wingwall with an independent wingwall to achieve the required design length.

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. 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 at this location would have additional impacts to the existing wetlands. Phased construction is feasible and recommended.

Based on the CDOT Roadway requirements, a minimum required roadway configuration for each phase of the construction must consist of 11.0 ft lane, 2.0 ft shoulder on each side, 2.0 ft wide temporary concrete barrier, 1.0 ft min. work zone buffer with pinned barrier and 2.0 ft min. work zone buffer with non-pinned barrier. To accommodate these requirements, all proposed alternatives will require some amount of overbuild (compared to the approaching roadway section). Figures below show required phasing configurations for all three alternatives. More information on phased construction can be found in the Traffic Design Memorandum for this structure.

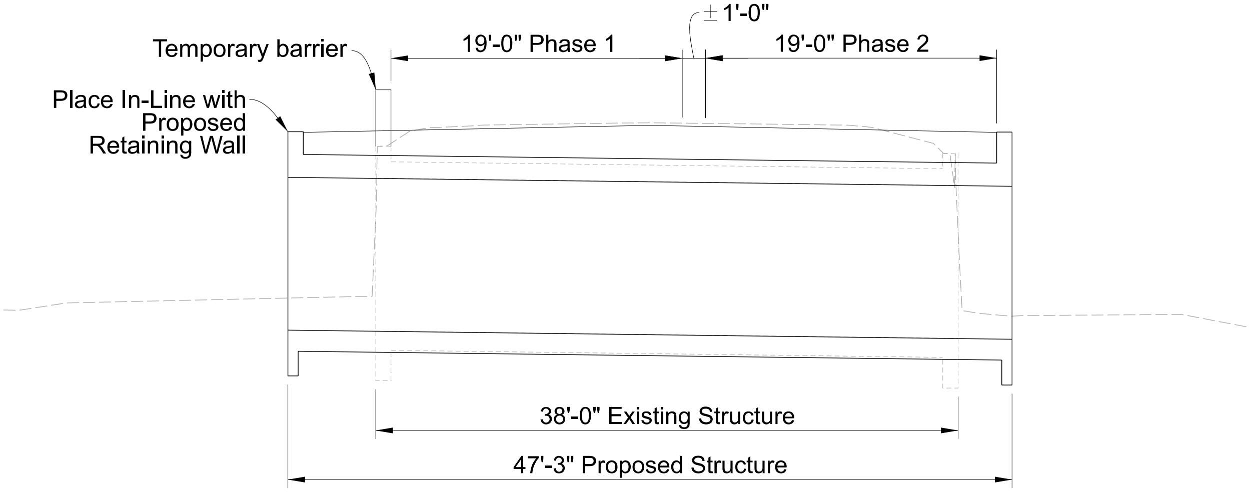

Figure 3 - Phased Construction: CBC

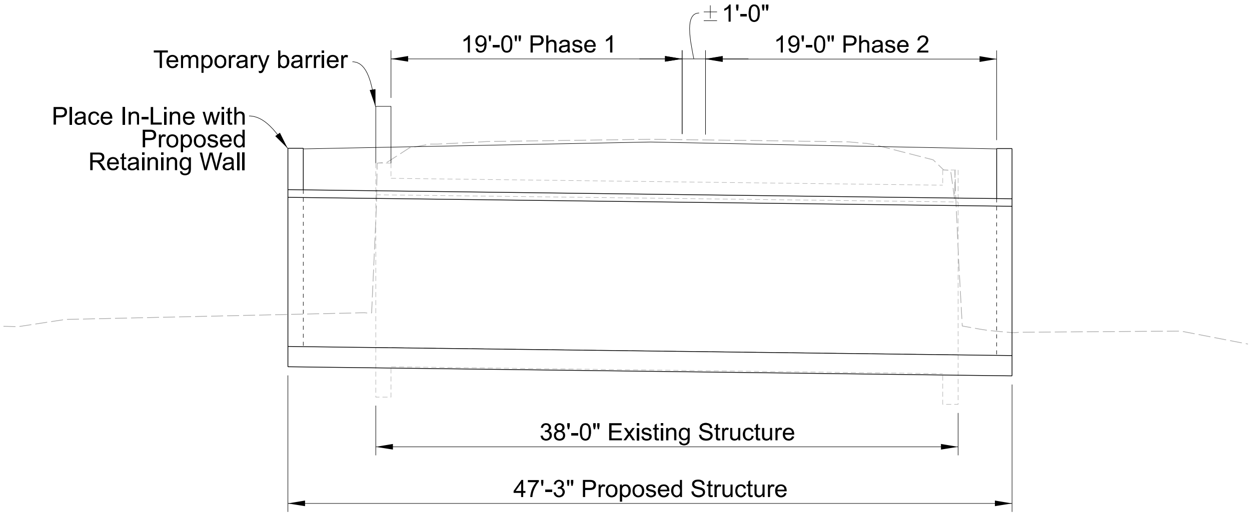

Figure 4 - Phased Construction: Steel Arch

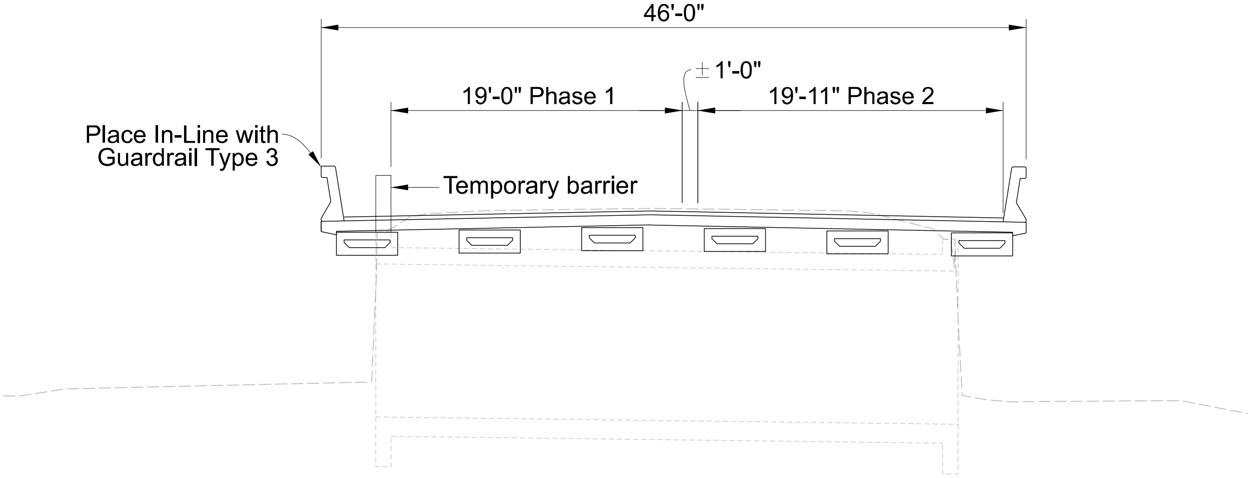

Figure 5 - Phased Construction: Concrete Bridge

4.8. CONSTRUCTABILITY

All the alternatives are proposed to be constructed in phases. Shoring will be required to construct any of the proposed alternatives. Constructing concrete box culvert or steel arch would require less construction time and using precast sections would further reduce construction time.

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	$ 753,000.00	2032 sf	$ 370	1.1
Steel Arch	$ 701,000.00	2457 sf	$ 285	1.1
Concrete Bridge	$ 786,000.00	2645 sf	$ 297	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. Provides natural bottom favorable for fish and wildlife	Satisfies the requirements. Provides natural bottom favorable for fish and wildlife
Constructability	Phased construction requires shoring. Can be precast to streamline the construction	Phased construction requires shoring. Delivered to site in ready to install sections	Phased construction requires shoring.
Construction Cost Rating	1.1	1.1	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	Retaining wall will be constructed to prevent ROW impacts	Retaining wall will be constructed to prevent ROW impacts	Retaining wall will be constructed to prevent 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 G-12-C 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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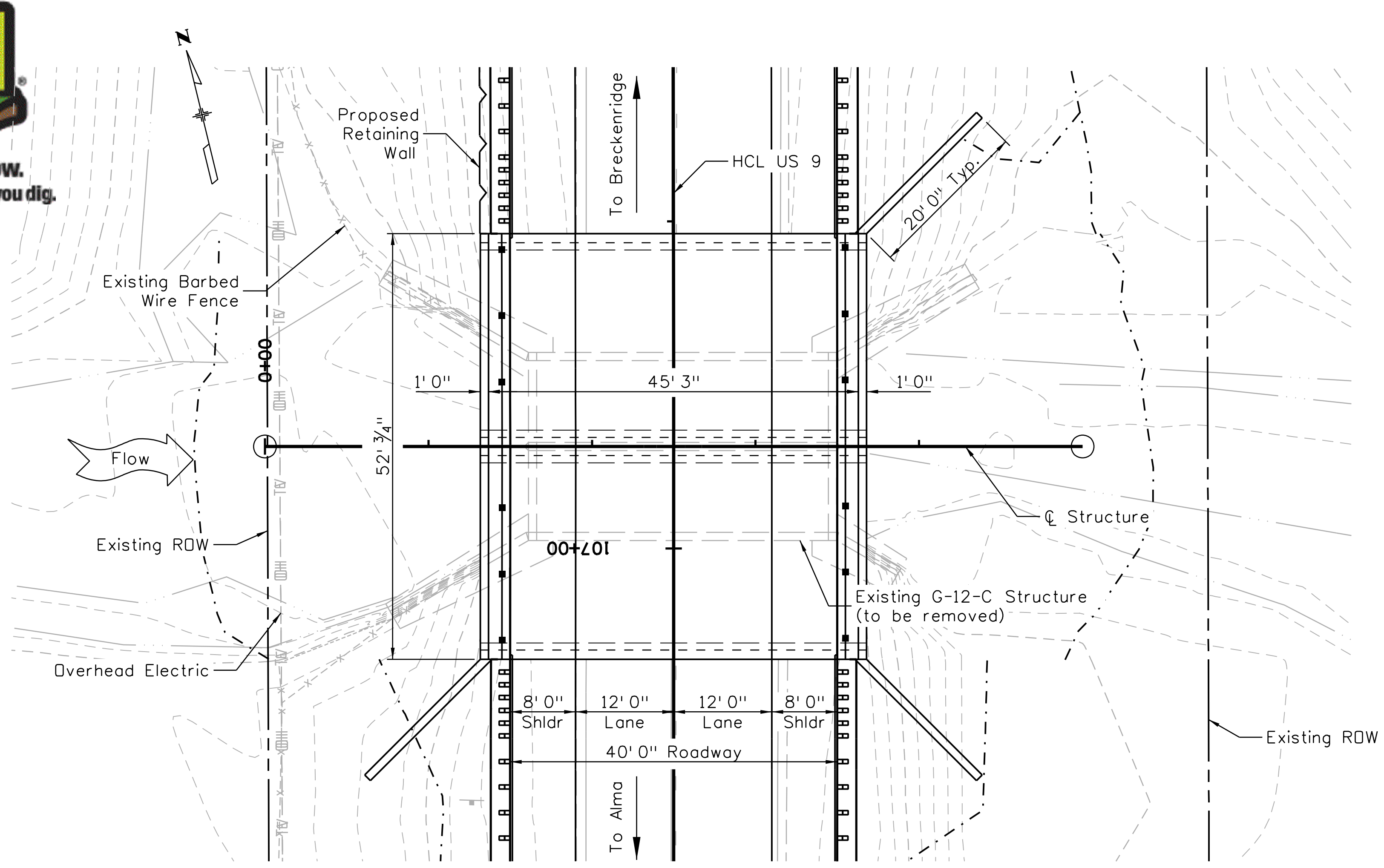
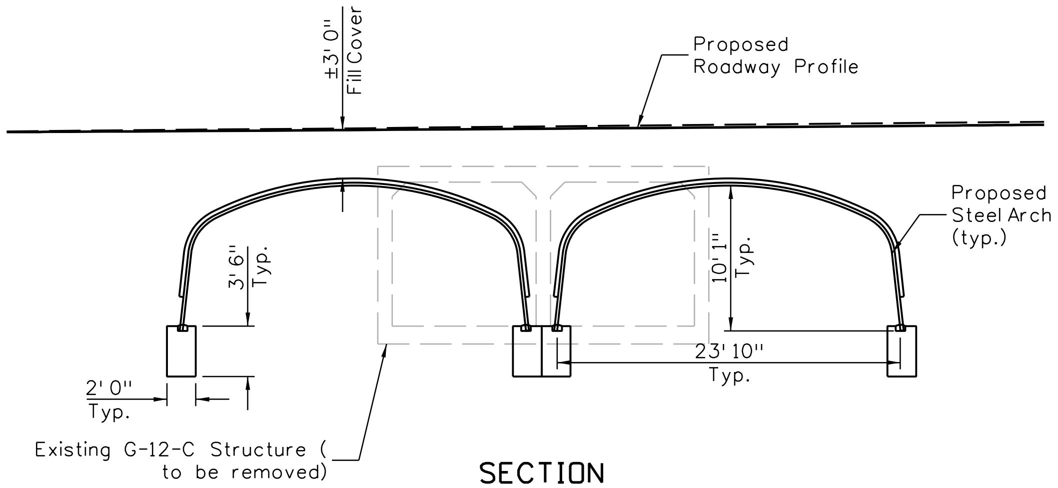
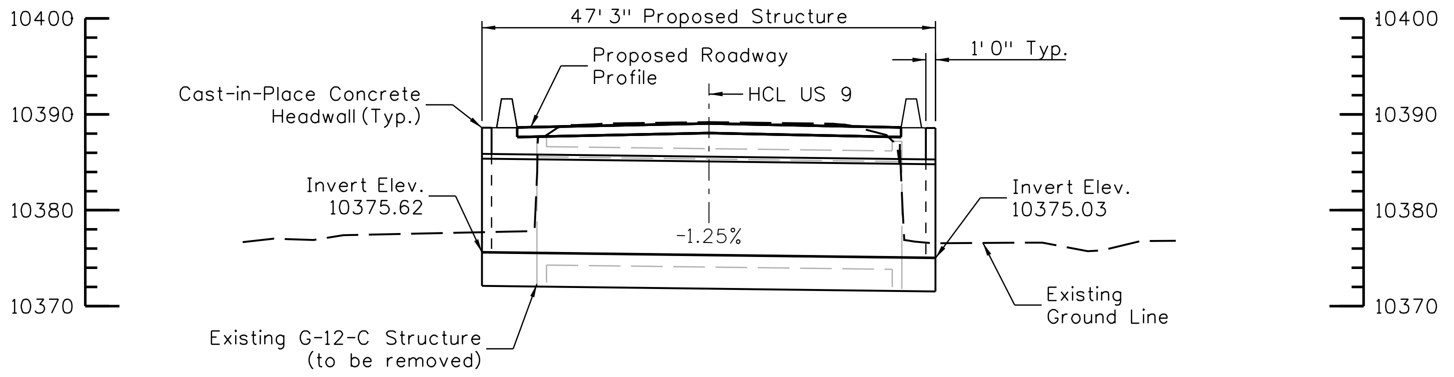


PLAN



SECTION

(Taken Normal to ℄ Structure)



PROFILE

(Taken Along ℄ Structure)

Notes:

1. Dimensions are based on recent survey and existing as-built drawings.
2. Shallow foundation system must be placed on a minimum of 2'-0" of properly placed CDOT Class 1 Structure Backfill.
3. The bottom of the shallow foundation must be a minimum of 3'-0" below the final ground surface for frost protection.

Print Date: 2/3/2021
File Name: 23558STR_GeneralLayout G-12-C SH9 MP 71.44.dgn.dgn
Horiz. Scale:
Vert. Scale: As Noted

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Sheet Revisions		
Date:	Comments	Init.

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Region 2
JLS

As Constructed
No Revisions:
Revised:
Void:

REGION 2 BRIDGE BUNDLE
US 9 OVER PLATTE GULCH
GENERAL LAYOUT AND TYP. SECTION

Designer: I. Pushkarova
Detailer: I. Pushkarova
Sheet Subset: STR
Structure No. G-12-C
M.P. US 9 71.445
Subset Sheets: 1 of 1

Project No./Code

Sheet Number

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
    - ☐ Steel Girder Alternatives
    - ☐ Span Configurations
- ☐ Substructure Alternatives:
    - ☐ Abutment Alternatives (GRS, Integral, Semi-integral, etc.)
    - ☐ Pier Alternatives
- ☐ Wall Alternatives
- ☐ Construction Phasing
- ☐ Possible Future Widenings
- ☐ 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

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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

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List of Variances

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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

Project No.: CDOT #23558 (Stanley #29715)

Date: 2/3/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - G-12-C ARCH Alternative

Client: CDOT Region 2

ARCH Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**1324**	$ 26,480
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**769**	$ 26,915
206-01750	Shoring	L S	**$ 12,000.00**	**2**	$ 24,000
420-00102	Geotextile (Erosion Control) (Class 1)	SY	**$ 7.00**	**1172**	$ 8,204
506-00000	Riprap	CY	**$ 120.00**	**664**	$ 79,680
510-20100	Structural Plate Arch (Special)	LF	**$ 1,540.00**	**95**	$ 146,300
601-04550	Concrete Class G	CY	**$ 900.00**	**116**	$ 104,400
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**137**	$ 1,918
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**20712**	$ 31,068
Subtotal of accounted construction items =>					$ 538,965
Contingency Multiplier =>					30%
Subtotal of construction items =>					**$ 700,655**
Deck area (SF) =>					2457.00
Cost per SF =>					**$ 285**

Project No.: CDOT #23558 (Stanley #29715) Date: 2/3/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - G-12-C CBC Alternative

Client: CDOT Region 2

CBC Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**986**	$ 19,720
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**412**	$ 14,420
206-01750	Shoring	L S	**$ 12,000.00**	**2**	$ 24,000
506-00000	Riprap	CY	**$ 120.00**	**62**	$ 7,440
515-00120	Waterproofing (Membrane)	SY	**$ 22.50**	**281**	$ 6,323
601-04550	Concrete Class G	CY	**$ 900.00**	**317**	$ 285,300
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**169**	$ 2,366
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**86207**	$ 129,311

Subtotal of accounted construction items =>	$ 578,879
Contingency Multiplier =>	30%
Subtotal of construction items =>	**$ 752,543**
Deck area (SF) =>	2031.75
Cost per SF =>	**$ 370**

Project No.: CDOT #23558 (Stanley #29715) Date: 2/3/2021
Project Name: Region 2 Bridge Bundle Design Build Grant Project
Subject: Quantity Calculations - G-12-C Concrete Bridge Alternative
Client: CDOT Region 2

Concrete Bridge Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**794**	$ 15,880
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**512**	$ 17,920
206-01750	Shoring	L S	**$ 12,000.00**	**2**	$ 24,000
420-00102	Geotextile (Erosion Control) (Class 1)	SY	**$ 7.00**	**1056**	$ 7,392
502-00200	Drive Steel Piling	LF	**$ 18.00**	**576**	$ 10,368
502-00460	Pile Tip	EACH	**$ 150.00**	**12**	$ 1,800
502-02010	Dynamic Pile Test	EACH	**$ 3,100.00**	**2**	$ 6,200
502-11253	Steel Piling (HP 12x53)	LF	**$ 71.00**	**576**	$ 40,896
506-00000	Riprap	CY	**$ 120.00**	**664**	$ 79,680
515-00120	Waterproofing (Membrane)	SY	**$ 22.50**	**330**	$ 7,425
601-04550	Concrete Class G	CY	**$ 900.00**	**164**	$ 147,600
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**325**	$ 4,550
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**35063**	$ 52,595
606-10900	Bridge Rail Type 9	LF	**$ 152.00**	**115**	$ 17,480
618-01992	Prestressed Concrete Box (Depth Less Than 32 Inches)	SF	**$ 60.00**	**1344**	$ 80,640
				Subtotal of accounted construction items =>	$ 604,426
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	**$ 785,753**
				Deck area (SF) =>	2645.00
				Cost per SF =>	**$ 297**

APPENDIX D

Geotechnical Report

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

2000 Clay Street, Suite 200
Denver, CO 80211
(303) 781-9590
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February 10, 2021

Project No. 220-063

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

Subject: Preliminary Geotechnical Study
Structure G-12-C
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 Structure G-12-C 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 19 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

Structure G-12-C 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, G-12-C-B-1 and G-12-C-B-2 were drilled by Yeh in the vicinity of the existing structure, and two pavement borings, G-12-C-P-1 and G-12-C-P-2, were drilled along the existing pavement approximately 250 feet from the structure. 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 poorly graded, silty, and clayey sands and gravels 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)
G-12-C-B-1	1205571.5, 2185359.5	10,389.5	58.0	10,331.5	13.0	10,376.5
G-12-C-B-2	1205534.9, 2185338.6	10,389.0	48.0	10,341.0	13.0	10,376.0

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, arch 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 an arch or CBC structure is selected, then the structure will be founded on shallow foundations. Wing walls for the structures will be founded on shallow strip foundations.

Based on the subsurface conditions encountered during our preliminary study, our engineering analysis, and our 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 arch, 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 Arch Structure Shallow Foundation Recommendations

We understand the arch structure will be supported on a shallow foundation system such as reinforced concrete strip footings. Design and construction for the shallow foundation system should take into consideration the scour potential at the proposed bridge site. The bottom of the foundations should be a minimum of 36-inches below the exterior ground surface for frost protection.

We anticipate that the bearing resistance of the shallow foundations will meet the project loading requirements provided that the shallow foundations are founded on a minimum of 2 feet of properly placed CDOT Class 1 Structure Backfill.

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 construction of the foundation. 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.

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. The resistance from the overburden soil should be neglected. We used unconfined compressive strength (UCS) and Standard Penetration Test (SPT) values to evaluate side and tip resistances in accordance with AASTHO LRFD (2020). 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 in the bedrock where UCS test results were unavailable. Based on local practice, the modified California penetration resistance is considered to be equivalent to SPT penetration resistance, i.e. N value, in bedrock.

Table 2 contains the recommended values for the nominal side and tip resistance for drilled shafts founded in the underlying competent bedrock. 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 2. Recommended Drilled Shaft Axial Resistance

Reference Boring	Approximate Top of Competent Bedrock Elevation (feet)	Tip Resistance (ksf)		Side Resistance, (ksf)	
		Nominal	Factored (Φ=0.5)	Nominal	Factored (Φ=0.55)
G-12-C-B-1	10,331.5	150	75	15	8.2
G-12-C-B-2	10,341.0	150	75	15	8.2

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

Material Type	LPILE Soil Criteria	Effective Unit Weight (pcf)		Friction Angle, (deg.)	Undrained Cohesion, (psf)	Unconfined Compressive Strength (psi)	Strain Factor, ε50	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
Sand and Gravel	Sand (Reese)	125	62.5	32	-	-	-	90	60
Sandstone Bedrock	Weak Rock (Reese)	130	130	-	-	5,000	0.004	-	-

Note: [1]Above Groundwater Table
[2]Below 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.

- 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 driven into bedrock may be designed for a nominal axial resistance equal to 32 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 refusal into the underlying bedrock as defined in Section 502.05 of CDOT (2019). A wave equation analysis using the Contractor's pile driving equipment is necessary to estimate pile drivability.

Based on the strength of the sandstone bedrock encountered during our investigation, it is likely that refusal will be met within the upper 1 to 2 feet of bedrock. Holes may need to be pre-drilled to meet the requirement for pile design tip elevations.

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 less than approximately ½ 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 1 to 2 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 sands and gravels 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	3.1 + 1.8 * B'
Saturated	1.5 + 0.9 * B'

[1] B' is the footing width in feet reduced for eccentricity (e). B' = B - 2e, where B is the nominal foundation width.
[2] The calculated nominal bearing resistance is based on a minimum 12 inches of embedment and shall be limited to 15 ksf.

The proposed CBC will be at the location of the existing CBC, and as needed, a 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 Sand/Gravel	0.35	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

Passive Soil Resistance	Soil Type	Nominal Resistance	Resistance Factor
	Moist	406 psf/ft	0.50
	Saturated	203 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 CBC 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]
G-12-C-P-1	6.5	Not Encountered	A-2-6(0)	12
G-12-C-P-2	8.0	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
G-12-C-P-1/P-2	Clayey Sand (Fill)	0.009	0.0116	-	-
G-12-C-B-1	Silty, Clayey Sand	0.007	0.0007	8.0	5345
G-12-C-B-2	Silty, Clayey Gravel	0.005	0.0006	8.0	8333

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 D. 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 D are shown in Table 9.

Table 9. Seismic Design Parameters

PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
0.077 g	0.159 g	0.041 g
A_s (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
0.123 g	0.254 g	0.099 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

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Respectfully Submitted,
YEH AND ASSOCIATES, INC.

Prepared by:

Cory S. Wallace, EIT, GIT
Staff Engineer

Reviewed by:

COLORADO LICENSED
JG THOMAS MCCALL
56485
2-10-2021
PROFESSIONAL ENGINEER

JG T. McCall, PE
Senior Project Engineer

Independent Technical Review by:

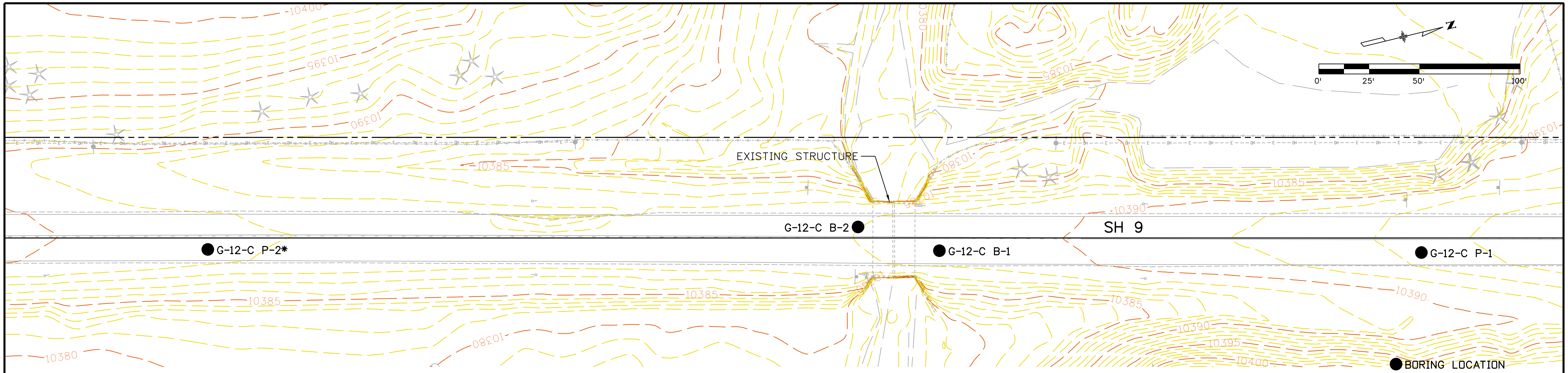
Hsing-Cheng Liu, PE, PhD
Senior Project Manager

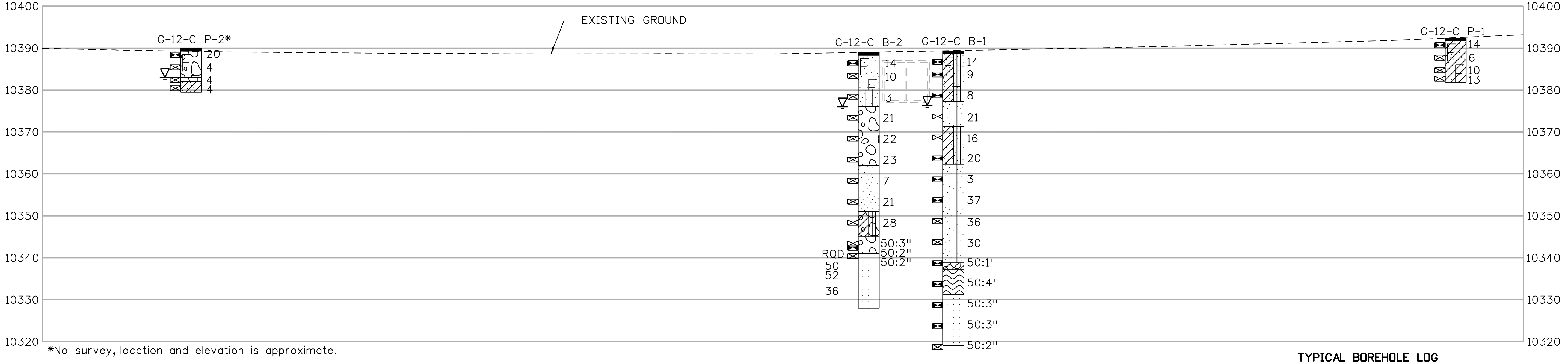
Attachments:
Appendix A
Appendix B
Appendix C

APPENDIX A

ENGINEERING GEOLOGY SHEET

mwolz 1:59:10 PM pw:\\cdot-pw.bentley.com:cdot-pw-01P\Documents\01 Major Projects\R2B2 (REGION 2 BRIDGE BUNDLE)\Legacy Data\23558 - R2B2 (REGION 2 BRIDGE BUNDLE) (GRANT)\Materials_Geotechnical\Drawings\23558GEOT_Engineering Geology G-12-C.



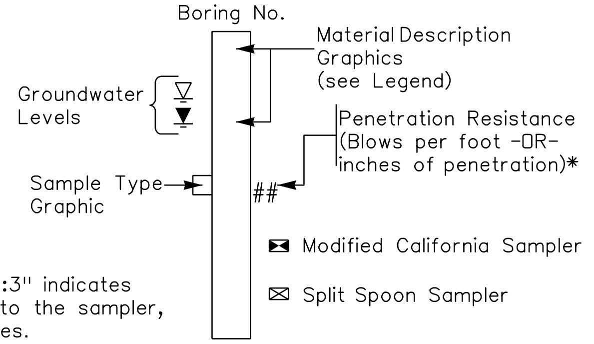


*No survey, location and elevation is approximate.

LEGEND

- ■ Asphalt
- ▥ USCS Silty Sand
- USCS Poorly-graded Gravel
- ▥ USCS Clayey Sand
- USCS Clayey Gravel
- USCS Silty, Clayey Gravel
- Fill
- USCS Poorly-graded Sand
- ▨ USCS Clayey Sand
- Weathered Bedrock
- Sandstone

TYPICAL BOREHOLE LOG



*e.g. A value of 50/3 or 50:3" indicates that 50 blows were applied to the sampler, with a penetration of 3 inches.

Print Date: 12/4/2020
File Name: 23558GEOT_Engineering Geology G-12-C.dgn
Horiz. Scale: 1:50 Vert. Scale: As Noted
Unit Information Unit Leader Initials

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

Sheet Revisions		
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	G-12-C	
Detailer: MJW			
Sheet Subset: Geology	Subset Sheets: 1 of 1		

Project No./Code
STM R200-262
23558
Sheet Number

APPENDIX B

KEY TO BORING LOGS

BORING LOGS

PAVEMENT CORE PHOTOS

ROCK CORE PHOTOS

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Project: CDOT Region 2 Bridge Bundle

Project Number: 220-063

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.

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Project Name: CDOT Region 2 Bridge Bundle

PAGE 1 of 1

Project Number: 220-063

Boring No.: **G-12-C P-1**

Boring Began: 9/22/2020
Boring Completed: 9/22/2020
Drilling Method(s): Coring / Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.5 ft
Ground Elevation: 10392.5
Coordinates: N: 1205804.3 E: 2185416.0
Location: State Highway 9, northbound outside lane
Logged By: C. Wallace
Final By: J. McCall

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

Groundwater Levels: Not Observed			
Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.6 ft. (6.5 inches).									
							0.6 - 10.5 ft. Clayey SAND with gravel (SC) (Fill), brown to dark brown, moist, loose to medium dense.									
				8-6	14			8.0		37.0	48.2	14.8	28	10	A-2-4 (0) SC	
10390																
	5			4-4-2	6											
10385				3-5-5	10											
	10			3-5-8	13											
10380																
10375																
10370																

Bottom of Hole at 10.5 ft.

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Project Name: CDOT Region 2 Bridge Bundle

PAGE 1 of 1

Project Number: 220-063

Boring No.: **G-12-C P-2**

Boring Began: 9/22/2020
Boring Completed: 9/22/2020
Drilling Method(s): Coring / Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.5 ft
Ground Elevation: 10390
Coordinates:
Location: State Highway 9, southbound outside lane
Logged By: C. Wallace
Final By: J. McCall

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

Groundwater Levels:

Symbol	▽		
Depth	7.0 ft	-	-
Date	9/22/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. ASPHALT (8 inches).									
				8-12	20		**0.7 - 7.0 ft. Clayey SAND with gravel (SC) (Fill)**, dark brown to black, moist, medium dense, granite gravels, very coarse gravel.									
10385	5			2-2-2	4			3.4		24.0	56.9	19.1				
	▽															
				1-2-2	4		**7.0 - 8.0 ft. Poorly graded GRAVEL with sand (GP)**, brown, wet, loose.									
							8.0 - 10.5 ft. Clayey SAND with gravel (SC), dark gray, wet, loose, rootlets.									
10380	10			3-2-2	4											

Bottom of Hole at 10.5 ft.

10375

10370

Boring Began: 9/21/2020
Boring Completed: 9/21/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 70.2 ft
Ground Elevation: 10389.5
Coordinates: N: 1205571.5 E: 2185359.5
Location: State Highway 9, northbound outside lane

Logged By: R. Desterhouse
Final By: J. McCall

Weather Notes: Clear, 40s
Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels:			
Symbol	∇		
Depth	13.0 ft	-	-
Date	9/21/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. ASPHALT (8 inches).									
							0.7 - 12.0 ft. Silty, clayey SAND with gravel (SC-SM) (Fill), with gravel, brown to dark brown, moist, loose.									
				6-8	14											
10385	5			5-4	9			15.5		21.0	61.2	17.8	23	6	A-1-b (0) SC-SM	
10380	10			2-6	8											
							12.0 - 18.0 ft. Silty SAND (SM), with gravel, gray to brown, wet, medium dense.									
	∇															
10375	15			10-11-10	21											
							18.0 - 27.0 ft. Silty, clayey SAND (SC-SM), brown, wet, medium stiff.									
10370	20			9-9-7	16			10.5		13.0	52.8	34.2	20	6	A-2-4 (0) SC-SM	pH=8.0 S=0.007% Chl=0.0007% Re=5345ohm·cm
10365																

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
		⧗		4-16	20		**18.0 - 27.0 ft. Silty, clayey SAND (SC-SM)**, brown, wet, medium stiff.									
							27.0 - 50.5 ft. Silty SAND (SM), with variable amounts of gravel, occasional clay lenses, light brown to dark gray, wet, very loose to dense.									
10360	30	⧗		1-2	3											
10355	35	⧗		6-31	37											
10350	40	☒		10-19-17	36											
10345	45	☒		6-9-21	30											
10340	50	⧗		50:1"	50:1"			7.5								UCCS=15.8 psi
							50.5 - 52.0 ft. Clayey GRAVEL (GC), greenish gray, moist, very dense.									
							52.0 - 58.0 ft. WEATHERED SANDSTONE, gray, moderately weathered, hard.									
10335	55	⧗														

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063

Boring No.: **G-12-C B-1**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples Blows per 6 in	Soil Samples Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits Liquid Limit	Atterberg Limits Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
				50:4"	50:4"											
							58.0 - 70.2 ft. SANDSTONE, dark gray, green, and pink, slightly weathered, very hard, micaceous, weakly metamorphosed and foliated, (MINTURN FORMATION).									
10330																**59.0 ft** - Coring attempted 59-60 feet. Difficulty coring sand so returned to auger.
	60			50:3"	50:3"											
10325																
	65			50:3"	50:3"											
10320																
	70			50:2"	50:2"											
							Bottom of Hole at 70.2 ft.									
10315																
10310																
10305																

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Project Name: CDOT Region 2 Bridge Bundle

PAGE 1 of 3

Project Number: 220-063

Boring No.: **G-12-C B-2**

Boring Began: 9/22/2020

Boring Completed: 9/22/2020

Drilling Method(s): Hollow-Stem Auger / Wireline Coring

Driller: Vine Laboratories

Drill Rig: CME 750X Buggy

Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 61.0 ft

Ground Elevation: 10389

Coordinates: N: 1205534.9 E: 2185338.6

Location: State Highway 9, southbound outside lane

Logged By: C. Wallace

Final By: J. McCall

Weather Notes: Clear, 40s

Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels:

Symbol	∇		
Depth	13.0 ft	-	-
Date	9/22/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Rock: Recovery (%)	Rock: RQD (%)	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
									0.0 - 0.7 ft. ASPHALT (8 inches).									
						8-6	14		**0.7 - 9.0 ft. Poorly graded SAND with gravel (SP) (Fill)**, brown, moist, medium dense.									
10385	5					5-5-5	10											
10380									**9.0 - 13.0 ft. Silty SAND with gravel (SM)**, dark brown to black, moist, very loose, abundant organic material, rootlets.									
	10					1-2-1	3			23.0		27.0	45.3	27.7	44	9	A-2-5 (0) SM	
	∇								**13.0 - 27.0 ft. Poorly graded GRAVEL with sand (GP)**, brown, wet, medium dense, angular, primarily granite gravels.									
10375	15					9-13-8	21											
10370	20					6-9-13	22											
10365																		

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **G-12-C B-2**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Rock: Recovery (%)	Rock: RQD (%)	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
						12-12-11	23											
									27.0 - 38.0 ft. Poorly graded SAND with gravel (SP), brown, wet, loose.									
10360																		
	30					5-3-4	7											
10355																		
	35					10-10-11	21											
									38.0 - 44.0 ft. Silty, clayey GRAVEL with sand (GC-GM), blue-gray, moist to wet, medium dense, micaceous.									
10350																		
	40					6-11-17	28			6.6		40.0	33.1	26.9	24	6	A-2-4 (0) GC-GM	pH=8.0 S=0.005% Chl=0.0006% Re=8333ohm·cm
10345									**44.0 - 48.0 ft. Poorly graded GRAVEL with sand (GP)**, pink and gray, wet, very dense, primarily pink sandstone gravels.									
	45					50:3"	50:3"											
						50:2"	50:2"											
						50:2"	50:2"		**48.0 - 61.0 ft. SANDSTONE**, reddish brown to greenish gray, very hard, irregular fractures, close spacing with rough surfaces and clay infilling. Low to moderate angle bedding planes. Locally micaceous, local siltstone layers, weakly metamorphosed and foliated. Slightly weathered to predominantly decomposed., (MINTURN FORMATION). Shear zone at 54-55 feet.									
10340																		
	50			100	50													
				100	52													UCCS=11410 psi
10335																		
	55																	

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063

Boring No.: **G-12-C B-2**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Rock		Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
				Recovery (%)	RQD (%)	Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index		
10330	60			86	36													

Bottom of Hole at 61.0 ft.

10325

10320

10315

10310

10305

Boring:	**P-1**	AC:	**6.5"**
Roadway:	**State Highway 9**	PCC:	**-**
Direction:	**Northbound**	Base:	**-**
Lane:	**Outside**	Notes:	**-**

Boring:	**P-2**	AC:	**8"**
Roadway:	**State Highway 9**	PCC:	**-**
Direction:	**Southbound**	Base:	**-**
Lane:	**Outside**	Notes:	**-**

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Pavement Core Photographs

FIGURE

B-1

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

CDOT Region 2 Bridge Bundle
Structure G-12-C

Yeh and Associates, Inc.
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Rock Core Photos
Boring: B-2
Depth: 49' - 60'

FIGURE

B-2

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

CDOT Region 2 Bridge Bundle
Structure G-12-C

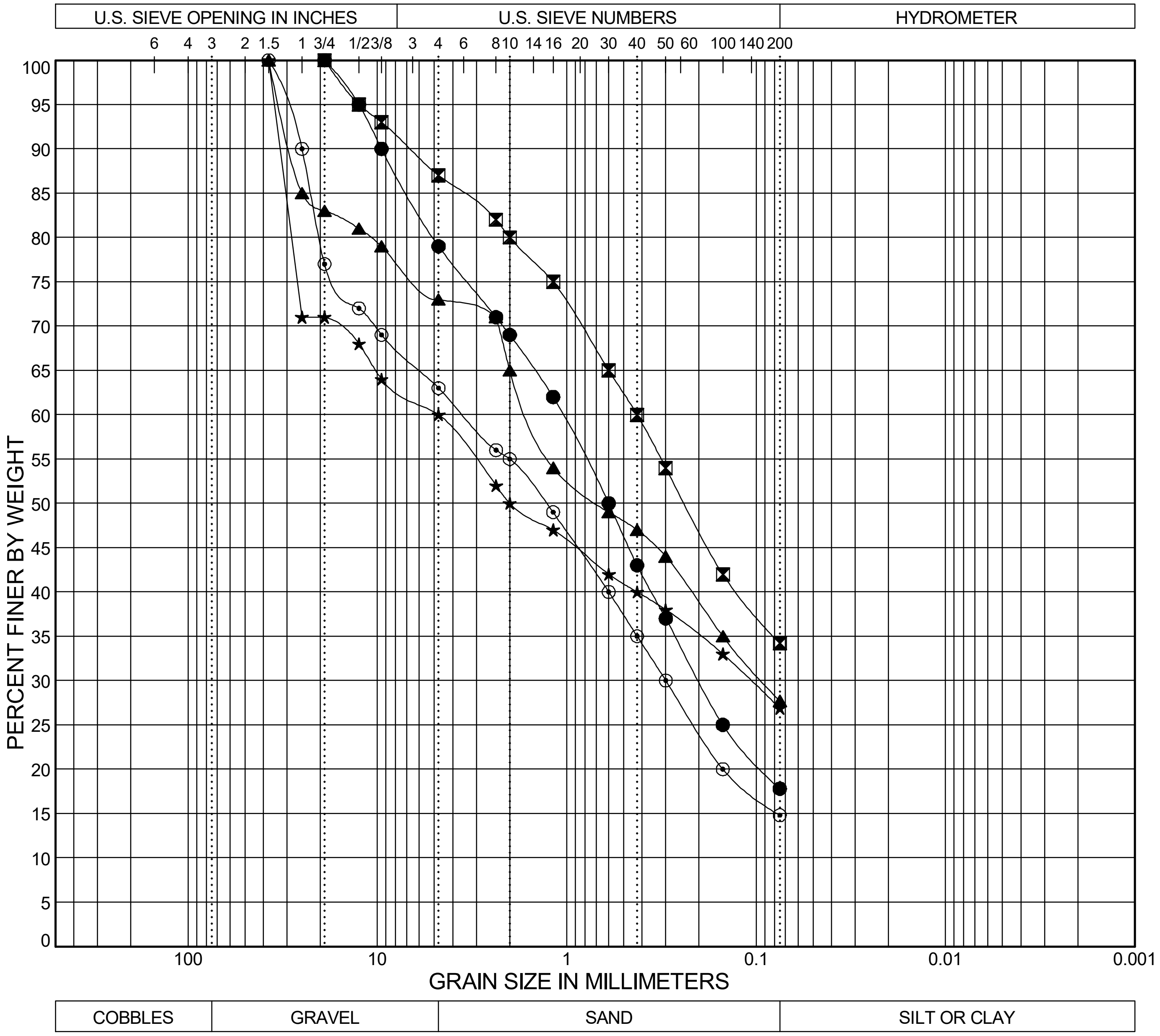
APPENDIX C

SUMMARY OF LABORATORY TEST RESULTS

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 12-28-2020

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
G-12-C B-1	5.0	MC	15.5		21.0	61.2	17.8	23	17	6								A-1-b (0)	SC-SM
G-12-C B-1	20.0	MC	10.5		13.0	52.8	34.2	20	14	6	8.0	0.007	0.0007	5345				A-2-4 (0)	SC-SM
G-12-C B-1	50.0	MC	7.5													15.8			
G-12-C B-2	10.0	SPT	23		27.0	45.3	27.7	44	35	9								A-2-5 (0)	SM
G-12-C B-2	40.0	MC	6.6		40.0	33.1	26.9	24	18	6	8.0	0.005	0.0006	8333				A-2-4 (0)	GC-GM
G-12-C B-2	53.0	CORE														11410			
G-12-C P-1	1.0	MC	8		37.0	48.2	14.8	28	18	10								A-2-4 (0)	SC
G-12-C P-1/P-2	2.5	BULK	7.8		23.0	51.5	25.5	31	19	12		0.009	0.0116				12	A-2-6 (0)	SC
G-12-C P-2	4.0	SPT	3.4		24.0	56.9	19.1												
G-12-C Scour	0	BULK	0.4		83.0	16.6	0.4	NV	NP	NP								A-1-a (0)	GP



BOREHOLE		DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**G-12-C B-1**	**5.0**	**A-1-b (0)**	**SC-SM**	**23**	**17**	**6**	**21.0**	**61.2**	**17.8**	
☒	**G-12-C B-1**	**20.0**	**A-2-4 (0)**	**SC-SM**	**20**	**14**	**6**	**13.0**	**52.8**	**34.2**	
▲	**G-12-C B-2**	**10.0**	**A-2-5 (0)**	**SM**	**44**	**35**	**9**	**27.0**	**45.3**	**27.7**	
★	**G-12-C B-2**	**40.0**	**A-2-4 (0)**	**GC-GM**	**24**	**18**	**6**	**40.0**	**33.1**	**26.9**	
⊙	**G-12-C P-1**	**1.0**	**A-2-4 (0)**	**SC**	**28**	**18**	**10**	**37.0**	**48.2**	**14.8**	

Yeh and Associates, Inc.
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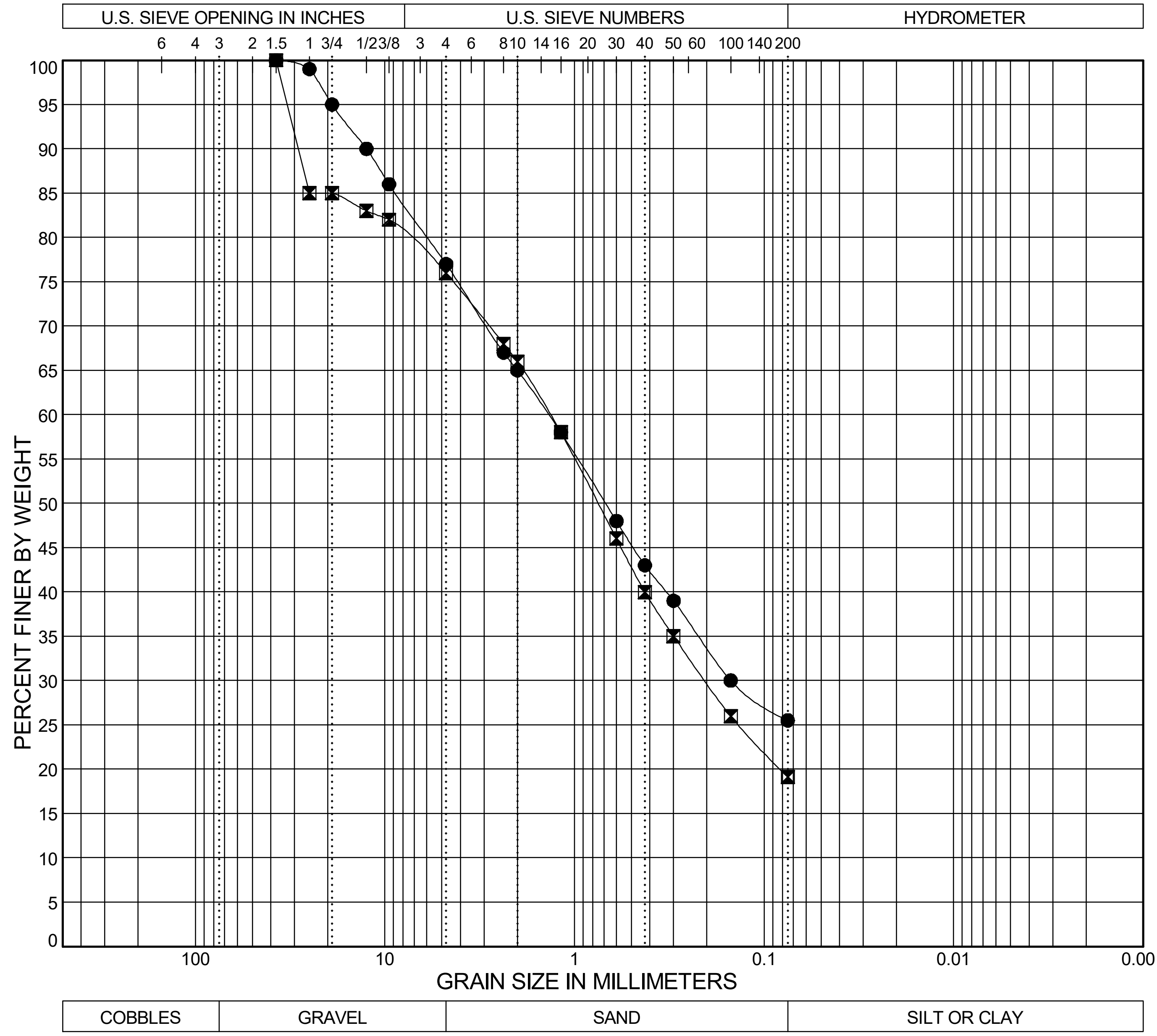
SIEVE ANALYSIS

FIGURE

C- 1

Project No. 220-063 Date: 12-28-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure G-12-C



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**G-12-C P-1/P-2**	**2.5**	**A-2-6 (0)**	**SC**	**31**	**19**	**12**	**23.0**	**51.5**	**25.5**	
☒	**G-12-C P-2**	**4.0**						**24.0**	**56.9**	**19.1**	

Yeh and Associates, Inc.
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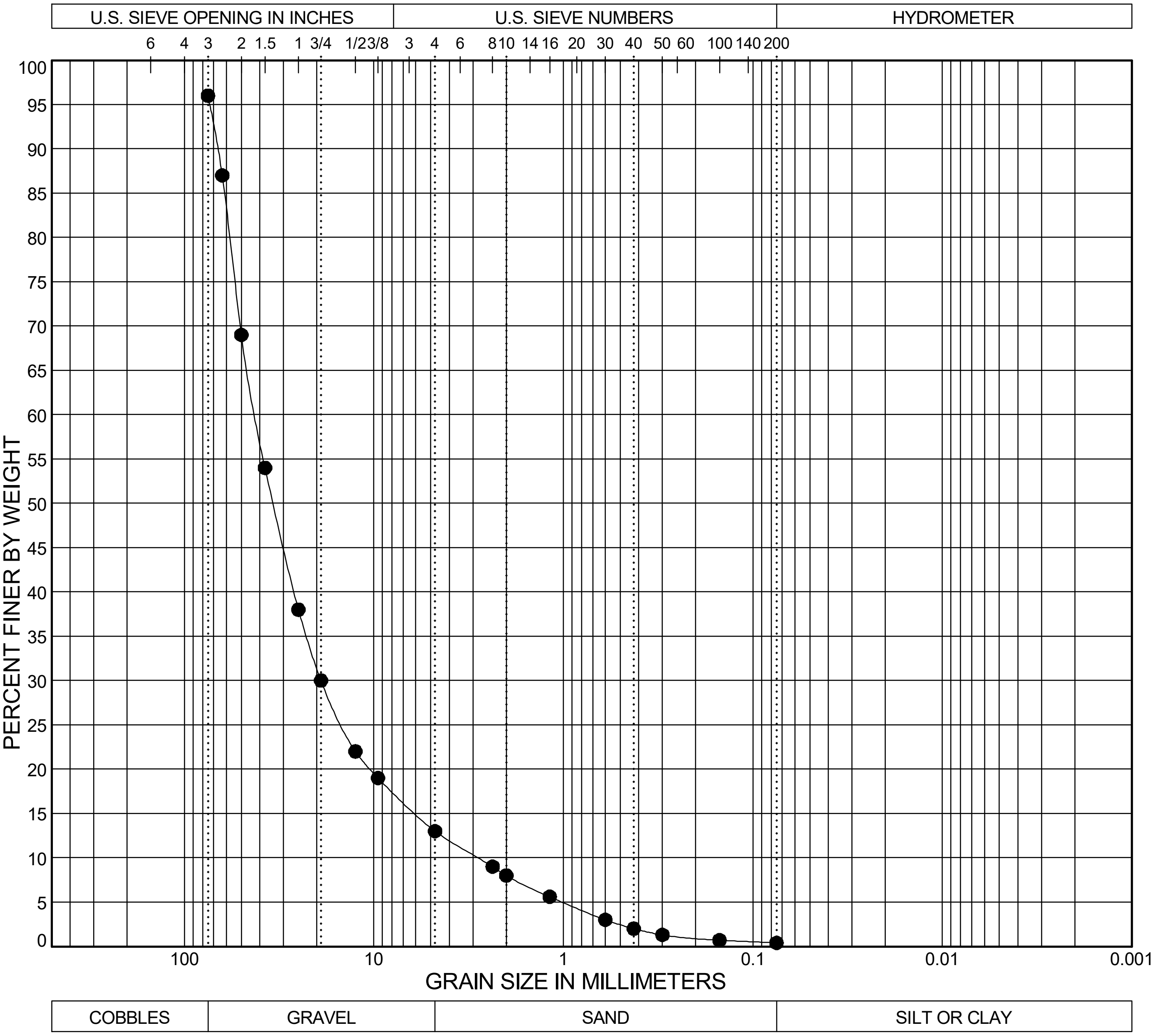
SIEVE ANALYSIS

FIGURE

C- 2

Project No. 220-063 Date: 12-28-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure G-12-C



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**G-12-C Scour**	**0.0**	**A-1-a (0)**	**GP**	**NV**	**NP**	**NP**	**83.0**	**12.6**	**0.4**	

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SIEVE ANALYSIS

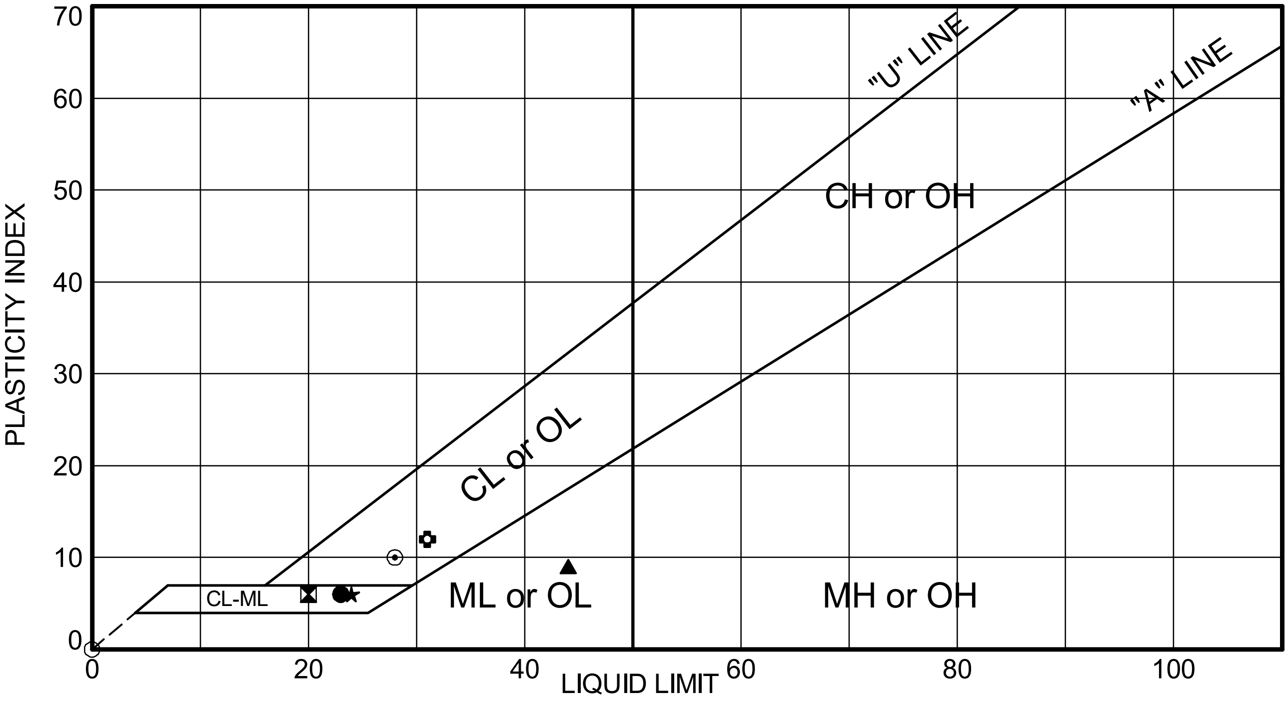
FIGURE

C- 3

Project No.	220-063	Date:	12-28-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

CDOT Region 2 Bridge Bundle
Structure G-12-C

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE FIXED FORMATTING 12-11-2020.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/28/20



	BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
●	**G-12-C B-1**	**5.0**	**23**	**17**	**6**	**17.8**	**SILTY, CLAYEY SAND with GRAVEL (SC-SM)**	**A-1-b (0)**
⧗	**G-12-C B-1**	**20.0**	**20**	**14**	**6**	**34.2**	**SILTY, CLAYEY SAND (SC-SM)**	**A-2-4 (0)**
▲	**G-12-C B-2**	**10.0**	**44**	**35**	**9**	**27.7**	**SILTY SAND with GRAVEL (SM)**	**A-2-5 (0)**
★	**G-12-C B-2**	**40.0**	**24**	**18**	**6**	**26.9**	**SILTY, CLAYEY GRAVEL with SAND (GC-GM)**	**A-2-4 (0)**
⊙	**G-12-C P-1**	**1.0**	**28**	**18**	**10**	**14.8**	**CLAYEY SAND with GRAVEL (SC)**	**A-2-4 (0)**
✿	**G-12-C P-1/P-2**	**2.5**	**31**	**19**	**12**	**25.5**	**CLAYEY SAND with GRAVEL (SC)**	**A-2-6 (0)**
○	**G-12-C Scour**	**0.0**	**NV**	**NP**	**NP**	**0.4**	**POORLY GRADED GRAVEL (GP)**	**A-1-a (0)**

Yeh and Associates, Inc.
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ATTERBERG LIMITS

Project No. 220-063
Date: 12-28-2020
Report By: D. Gruenwald
Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure G-12-C

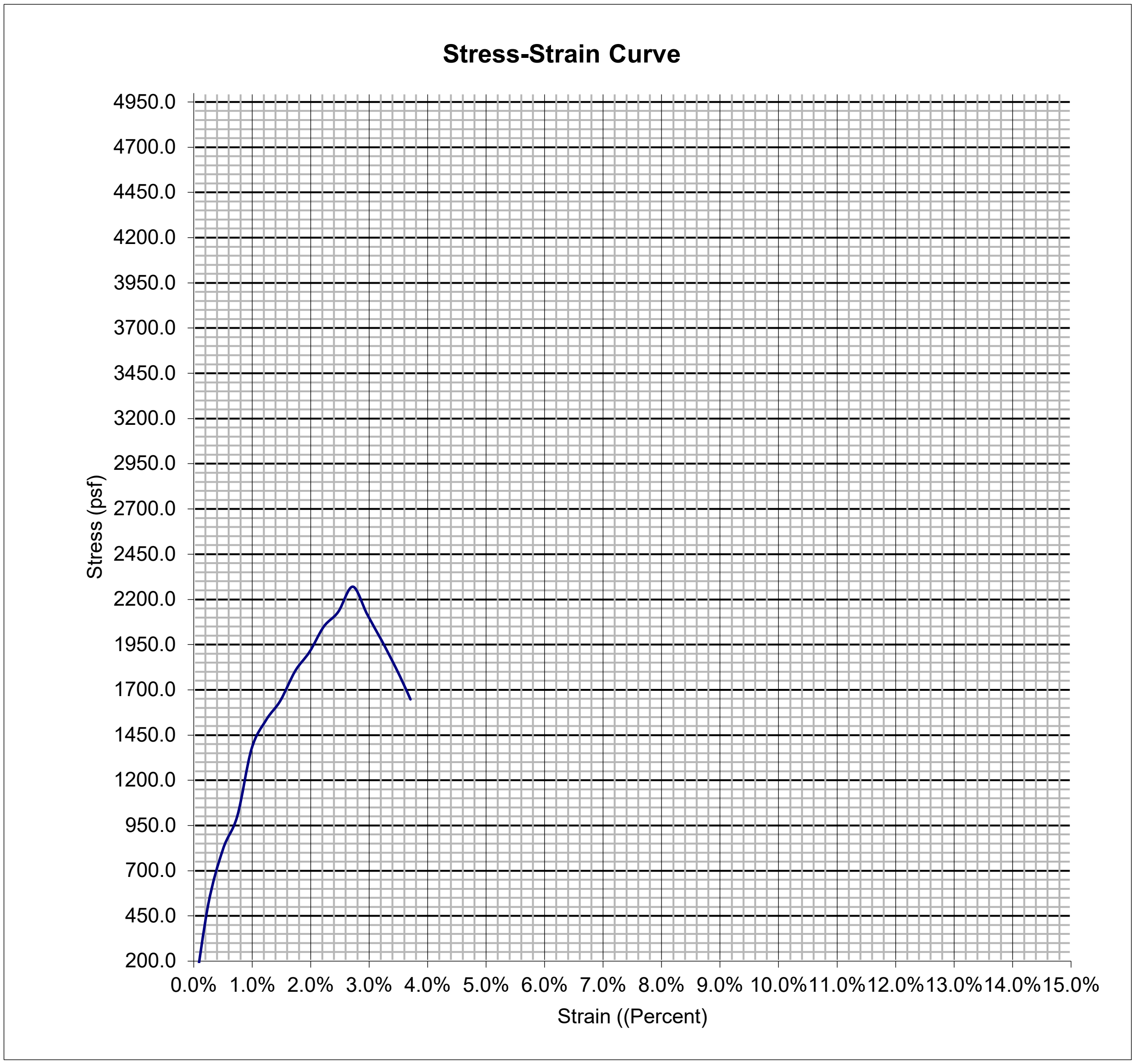
FIGURE

C - 4

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

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle G-12-C
Sampled b CW Date Sampled: 9/22/2020 Date Tested: 11/12/20
Boring No: B-1 Depth (ft): 50 Blow Counts:
Tested by: M.A Checked by: JTM
Soil Classification: --

Axial Strain (%)	Axial Stress (psf)
0.0%	0.0
0.2%	513.1
0.5%	817.0
0.7%	1001.5
1.0%	1376.1
1.2%	1533.9
1.5%	1642.1
1.7%	1803.3
2.0%	1910.2
2.2%	2050.5
2.5%	2132.1
2.7%	2271.1
3.0%	2116.5
3.2%	1972.3
3.5%	1819.3
3.7%	1647.9
4.0%	1382.4



Unconfined Compressive Strength (q_u) = **2271** **psf** @ **2.7%** **Strain**
%

Natural Moisture:	7.5	%
Natural Density(Dry):	132.3	pcf
Average Diameter (D):	1.925	inches
Average High (L):	4.047	inches
L/D Ritio:	2.10	

ADVANCED TERRA TESTING

R Value

ASTM D2844

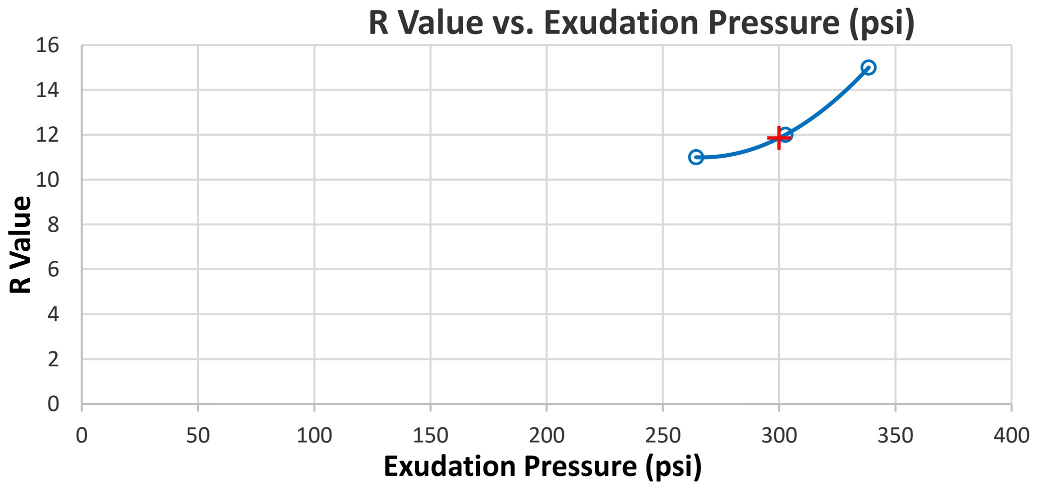
CLIENT	Yeh & Associates	BORING NO.	P-1/P-2
JOB NO.	2546-129	DEPTH	Combined Bulk
PROJECT	CDOT R2 Bridge Bundle_G-12-C	SAMPLE NO.	G-12-C
PROJECT NO.	220-063	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	12/03/20	DESCRIPTION	--
TECHNICIAN	ALH		

Sample Conditions

Mass of Wet Soil & Pan (g):	1546.8	1538.7	1183.8
Mass of Dry Soil & Pan (g):	1436.9	1430.4	1082.1
Mass of Pan (g):	371.8	394.1	14.0
Mass of Wet Soil & Mold (g):	3291.0	3252.7	3270.6
Mass of Mold (g):	2114.2	2100.9	2096.1
Sample Height (in):	2.56	2.51	2.54
Wet Density (pcf):	139.4	139.1	140.2
Dry Density (pcf):	126.3	126.0	128.0
Wet Density (kg/m³):	2232	2228	2245
Dry Density (kg/m³):	2024	2018	2050
Moisture (%):	10.3	10.5	9.5

R Value Data

Exudation Pressure (lbs):	3803	3321	4254
Exudation Pressure (psi):	302.6	264.3	338.5
2000 lbs. Dial Reading (psi):	127	128	118
Displacement Turns:	5.05	5.32	4.97
Uncorrected R Value:	11	11	15
Corrected R Value:	12	11	15



Corrected R Value at 300 psi Exudation Pressure

12

NOTES:

Data entry by:	ALH	Date: 12/04/20
Checked by:	WAR	Date: 12/07/20
File name:	2546129__R Value ASTM D2844_1.xlsm	