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 N-21-F

(Region 2 – US 350 MP 48.744)

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 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 is a two-span 122.0 ft long bridge with a concrete deck over (5) BX 24x48 precast prestressed concrete box girders spaced at 10.0 ft. The superstructure will be supported by two integral abutments and a multi column pier both cast in place. The width of the proposed construction must accommodate two 12.0 ft lanes of traffic with 6.0 ft shoulders, 2.0 ft curb offset, and the Colorado current standard Bridge Rail on each side. All (4) wingwalls will be parallel to US 350 to retain the roadway section and stay within the right of way.

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 structure is a four-span concrete deck, steel I beam girder bridge built in 1937 to span the Sheep Canyon Arroyo. The bridge is on a 45-degree skew. The existing bridge consists of four spans each 39 ft 6 in, with a total length of 166 ft 2 in. The width of the existing bridge is 30.0 ft curb to curb, and 33 ft 6 in out to out of deck. The existing vertical clearance varies from 4 ft 6 in to 12 ft 6 in.

The existing bridge has 5 rows of girders. The interior girders are W30x116 beams and the two exterior girders are W30x108. The concrete deck is a 9 in reinforced concrete deck with a 2.5 in asphalt overlay. The railing is a 9 in tall concrete curb with a 2.0 ft tall decorative concrete railing. Steel diaphragms are placed at 1/3 points of the span and at the supports.

The piers consist of 2 ft 6 in x 2 ft 8 in concrete pier caps supported by 10 timber piles with diagonal timber bracing. Timber piles have a 12 in diameter and are spaced at approximately 5 ft 3 in.

The abutments consist of reinforced stub abutments supported by 8 timber piles. The abutment caps are measured at 2 ft 6 in x 2 ft 8 in with a 1.0 ft wide backwall. The abutment piles are spaced at approximately 6.0 ft.

There is a short 3.0 ft high wood retaining wall 6.0 ft in front of the north abutment. The wall is supported by wood piles spaced at approximately 5.0 ft. Fill is placed between the abutment and lower wall at an approximate 1.5:1 slope.

There are 4 wood wingwalls at the existing bridge. The wingwalls at abutment 1 are 15 ft 7 in and 23.0 ft long. The wingwalls at abutment 5 are 14 ft 6 in and 24.0 ft long. The wingwalls are all supported by 12 in diameter piles.

It is located on US 350, southwest of La Junta, at milepost 48.744. Table 1 summarizes the bridge information.

National Bridge Structure Number	N-21-F
Year Built	1937
Construction Type	Concrete on I-Beam
Condition Rating	Poor
Load Restricted	No
Bridge Length	166.2 feet
Bridge Width	33.5 feet
Number of spans	4
Water Crossing	Sheep Canyon Arroyo
AADT	520
Percent Commercial Traffic	17.7%

Table 1 - Bridge N-21-F Summary Information

Picture 1 - Bridge N-21-F

The replacement of Bridge N-21-F is warranted due to the age and deteriorating conditions. There is a minor spall in the backwall at the left end of Abutment 1. Abutment 5 is pushing/rotating against the span 4 girders at the backwall. The girders at abutment 5 have shifted up as much as 3 inches off the left edge of the masonry plates, due to the abutment push.

Due to the deterioration and leaking of the existing deck joints, corrosion can be found on most of the girders at the top flanges where the leaking occurs. Cracks and efflorescence can be found throughout the deck, which has led to deterioration and exposed corroded rebar.

There are checks penetrating 5% - 50% of the wood pile thickness in most of the piles. The joints above the caps are leaking. Delamination cracks up to 0.125 in wide are present in the rear side of the Pier 2 cap. Spalling with corroded rebar is present in the top of Pier 2 towards the ends along with the Pier 4 cap.

Picture 2 - Pier, Overhang, Deck, Girders

Picture 3 - Corrosion, Exposed Aggregate

2.2. RIGHT OF WAY IMPACT

The existing right of way (ROW) is located approximately 75 feet on each side from the centerline of the existing road. 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 US 350. Temporary construction easements may be required for detour or drainage erosion control.

Fencing is located along the existing right-of-way. Fencing extends perpendicular to the bridge which allows for a cattle crossing.

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 will require overbuilding the proposed bridge on both sides. The width of the proposed structure is contingent upon the girder type and width and may wary for different superstructure types.
2. Building a two-lane shoofly on one side of the existing bridge with a temporary pipe placed for drainage. The existing ROW provides enough clearance to construct a shoofly

on either side of the bridge. However, due to the relatively long existing bridge structure and consistently high existing vertical clearance under the bridge, this alternative is less cost effective than phased construction.

Alternative 1 was identified as the 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. Based on their investigation, there is an underground CenturyLink telephone line approximately 40 ft east of the centerline of US 350 that runs parallel to the existing ROW line. This telephone line emerges from the ground near both abutments and is attached to the east side of the eastern most girder. There is also an abandoned telephone line that closely follows the ROW line to the east 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. The full Preliminary Geotechnical Study is provided in the Appendix D.

Two bridge borings, N-21-F-B-1 and N-21-F-B-2, were drilled near the existing bridge abutments, and two pavement borings, N-21-F-P-1 and N-21-F-P-2, were drilled along the existing pavement approximately 250 feet from the bridge on either end.

The bridge borings encountered clayey gravel and lean clay soils overlying shale 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 (feet)	Approx. Elevation to Top of Competent Bedrock (feet)	Approx. Groundwater Depth (feet)	Approx. Groundwater Elevation (feet)
N-21-F-B-1	395619.5 474214.5	4626.5	47.0	4579.5	44.0	4582.5
N-21-F-B-2	395469.3 474082.6	4626.5	47.0	4579.5	38.0	4588.5

Table 2 - Summary of Bedrock and Groundwater Conditions

Based on the recommendations of the Geotechnical Study, either driven H-pile or drilled shaft foundations are suitable for support of the structures.

2.6. HYDRAULICS SUMMARY

Bridge N-21-F crosses the Sheep Canyon Arroyo that flows from the south to the north toward Timpas Creek. There is a railroad bridge approximately 375 ft north of the N-21-F bridge.

The drainage is mapped in floodplain Zone A with a 100-year design flow rate of 4355.0 cfs. An SRH-2D model was developed at this location, which indicates that there is no available CBC alternative that would carry the design flow. A two-span 122.0 ft long bridge alternative was evaluated and was shown to have a sufficient opening to carry design flows. Preliminary analysis shows this bridge has 1.89 ft of freeboard above the 100-year water surface elevation, less than required 2 feet. A more detailed analysis in the final design will need to be completed to determine if this option meets freeboard requirements set forth in the CDOT Drainage Design Manual.

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 the field investigation and desktop analysis performed by the Stanley Consultants Environmental team, no wetland nor waters of the US were identified in the Project area. However, the project is adjacent to the USFS Comanche National Grasslands and as such has a potential to impact several species, as well as one specie (burrowing owl) that is regulated by the CPW.

2.8. ROADWAY FEATURES

2.8.1. Cross Section

Existing US 350 is a 2-lane roadway with two-way traffic. Both lanes are 11.0 ft wide with approximately 3.0 ft shoulders and a 1.0 ft curb offset within the limits of the structure.

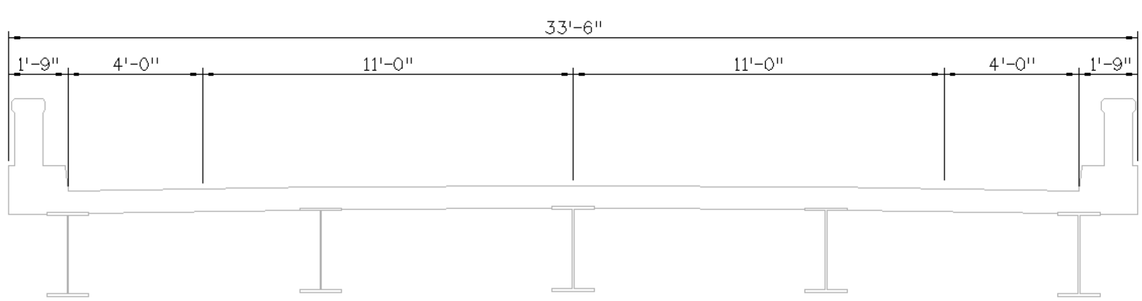


Figure 1 - Existing Section

The proposed roadway section width is based on the 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 6.0 ft shoulders, and a 2.0 ft curb offset. The AADT for this section of the road is 520 veh/day, and the design speed is 75 mph. Total required roadway width over the proposed structure is 40.0 ft. Additional roadway width is needed for phased construction and is discussed further in Section 4.7 Construction Phasing.

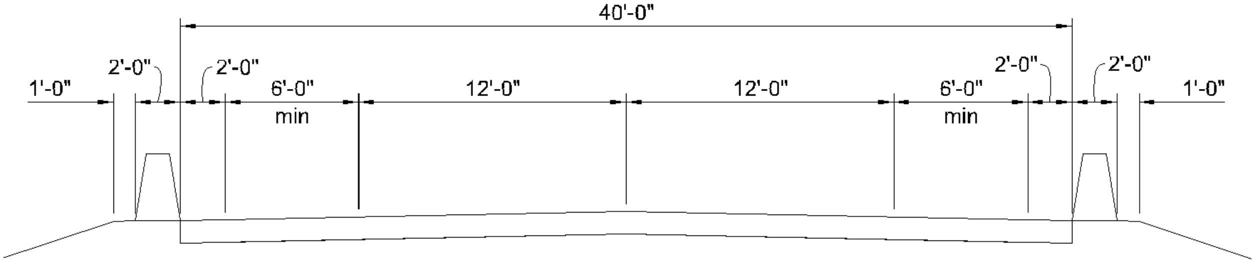


Figure 2 - Proposed Roadway Section

2.8.2. Vertical Alignment

The proposed vertical profile of US 350 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 constant tangent with a slope of -0.01% matching the existing grade. The profile grade is less than 0.5% min recommended by FHWA for bridge decks. Refer to section 4.3 for more information.

2.8.3. Horizontal Alignment

The horizontal alignment of the existing bridge has a 45-degree 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 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: Colorado current standard Bridge Rail (Bridge Rail Type 9)

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 the 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 N-21-F 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

The 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 piers can either be partially removed during phased construction or left in place. If the existing pier is chosen to be left in place, any of the proposed superstructure alternatives must be shallow enough to be installed over the existing pier. Existing superstructure is 43.0 in deep. Hydraulic investigation of 122.0 ft long two-span bridge alternative with a 33.0 in superstructure depth was shown to satisfy hydraulic opening requirements. Based on the preliminary analysis the proposed bridge alternative has 1.89 ft of freeboard, which does not meet the 2 ft of freeboard that is required. However, this condition is not worse than the existing bridge condition.

Refer to CDOT Bridge Design Manual and CDOT Drainage Manual for additional clearance requirements information.

The horizontal alignment of the proposed structure will have the same 45-degree skew to follow the Sheep Canyon Arroyo.

The FHWA Design of Bridge Deck Drainage, Hydraulic Engineering publications referred to by the CDOT Bridge Design manual states that if the proposed vertical grade is less than 0.5%, the designer must specify a gutter grade that will run the water to the inlet boxed from high points between the boxes. As stated in Section 2.8.2, the proposed vertical roadway grade is approximately -0.01%, matching the existing roadway profile. The design team will need to address drainage issues during the final design.

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. Concrete Girder Bridge Alternative

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.

As explained in Section 4.3, any of the proposed beams must be shallow enough to be installed over the existing pier cap if it is left in place during phased construction. 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, (5) BX 24x48 girder sections spaced at 10.0 ft was chosen as a cost-effective precast concrete solution for the required 122.0 ft span. The concrete box girder alternative will use a standard 8.0 in deep reinforced concrete deck.

4.4.2. Steel Girder Bridge Alternative

Steel rolled beams or plate girders are also suitable for the given span length. Steel bridges are historically more expensive than concrete bridges in Colorado but can provide longer spans compared to the concrete girder alternatives under equal loading conditions.

A LEAP Bridge Steel model was created to provide a preliminary composite steel girder design for the span configurations described below. Like the concrete girder alternatives, steel girder section must be shallow enough to span over the existing pier if the piers are chosen to be left in place during phased construction. Proposed steel girders are 29 5/8 in deep and spaced at 6.5 ft with a standard 8.0 in deep reinforced concrete deck.

4.4.3. Span Configurations

The total length of the existing structure is 166 ft 2 in. The existing piers, abutments, and wingwalls are all supported by timber piles. Determining the appropriate span length for the proposed structure was an iterative process with the Hydrology Team. The proposed structure was chosen to be placed towards the northern end of the existing bridge with abutment 2 directly behind the existing abutment 5 to capture the deepest section of the arroyo. A two-span 122.0 ft long bridge was selected as the shortest bridge length that meets the flow requirements of the arroyo.

4.5. SUBSTRUCTURE ALTERNATIVES

The preferred substructure type considered in this study is integral abutments supported on H-Piles and a multi column pier supported on Drilled Shafts.

Integral abutment alternative with a maximum allowed depth of 6.0 ft will be used for the 122.0 ft span (see Figure 11-1 in CDOT Bridge Design Manual). Abutment caps will be supported by (8) HP12x53 H-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. It is assumed that by providing a deeper abutment cap and channel grading, it will be possible to avoid building an MSE retaining wall in front of the integral abutment. Wingwalls for this alternative will consist of ether integral wingwalls attached to the abutment caps (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 proposed multicolumn pier will be supported by (6) 36.0 in drilled shafts spaced at 12.0 ft.

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 shoefly at this location might not be cost effective. 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 an 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 a 2.0 ft min. work zone buffer with non-pinned barrier. To accommodate these requirements, bridge deck section will require some amount of overbuild (compared to the approaching roadway section). Figures 3 & 4 show the required phasing configurations for the superstructure alternatives. More information on phased construction can be found in the Traffic Design Memorandum for this structure.

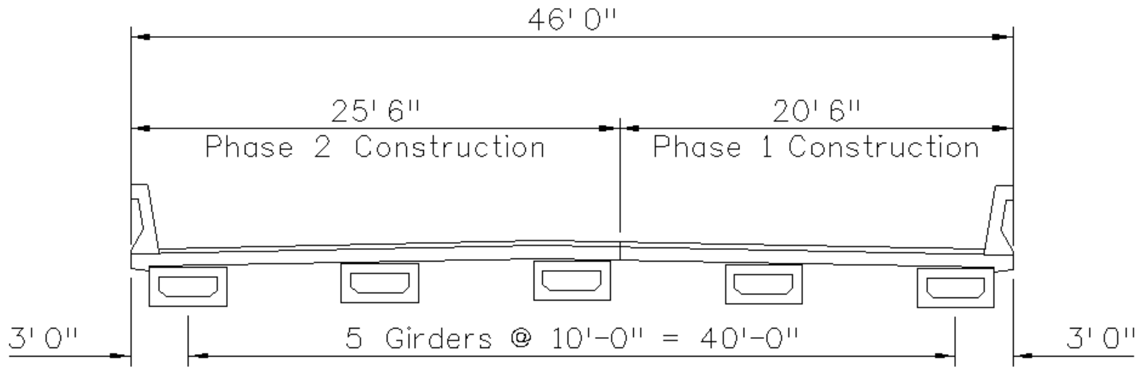


Figure 3 - Phased Construction Concrete Bridge Alternative

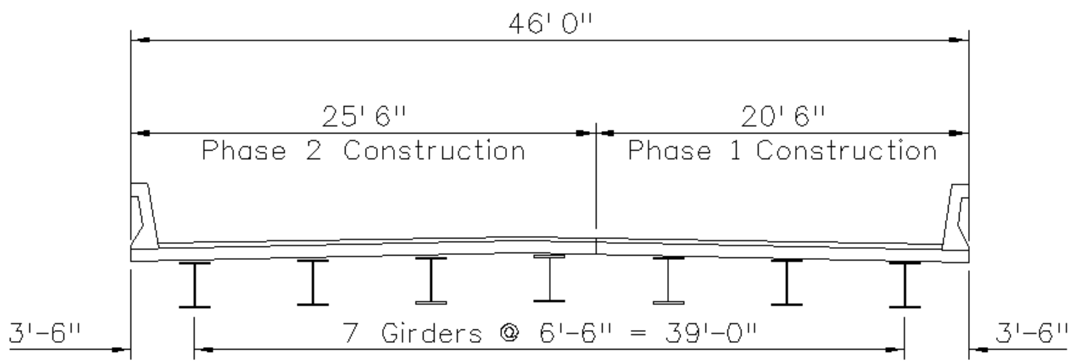


Figure 4 - Phased Construction Steel Bridge Alternative

4.8. CONSTRUCTABILITY

The bedrock sits approximately 47.0 ft below the existing grade at both abutments.

Preliminary Geotechnical Study report notes that bedrock may be very hard at various elevations. If drilled shaft option is chosen as final foundation alternative, the contractor should mobilize equipment of sufficient size and operating condition to achieve the required design bedrock penetration.

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.

Painted steel superstructures require frequent routine maintenance and repainting. Weathering steel can be used to eliminate the maintenance issues of painting, but it has other similar maintenance issues as painted steel.

Concrete structures typically have less maintenance than steel structures and are preferred.

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 to prevent water and salt intrusion.

The steel bridge alternative must use weathered or painted steel girders.

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. 30% contingency multiplier was used in cost calculations.

Summary of the alternatives:

Concrete Bridge Alternative – 122.0 ft span length, 46.0 ft superstructure width, (5) BX 24x48 girders at 10.0 ft spacing, 8.0 in reinforced deck, integral abutments on (8) HP12x53 piles spaced at 10.0 ft, integral wingwalls.

Steel Bridge Alternative – 122.0 ft span length, 46.0 ft superstructure width, (7) 29 5/8 in deep steel plate girders spaced at 6.5 ft, 8.0 in reinforced deck, integral abutments on (8) HP12x53 piles spaced at 10.0 ft, integral wingwalls

Alternative	**Construction Cost (30% Contingency)**	**Area**	**Cost per sq.ft**	**Cost Rating**
Concrete Bridge Alternative	$ 1,457,217.00	2806 sq.ft	$ 528.00	1.1
Steel Bridge Alternative	$ 1,477,889.00	2806 sq.ft	$ 535.00	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	RCP	CBC	Concrete Bridge	Steel Bridge
Hydraulic Opening	Does not satisfy requirements	Does not satisfy requirements	Satisfies the requirements	Satisfies the requirements
Constructability	n/a	n/a	Drilling into the existing hard bedrock to the min 3D depth or enough achieve longitudinal capacity may present some difficulty	Drilling into the existing hard bedrock to the min 3D depth or enough achieve longitudinal capacity may present some difficulty
Construction Cost Rating	n/a	n/a	1.1	1.0
Maintenance & Durability	n/a	n/a	Concrete girders require minimal maintenance. Integral abutment on H-Piles will require scour protection.	Steel girders require regular cleaning and/or painting. Integral abutment on H-Piles will require scour protection.
ROW and Roadway Impacts	n/a	n/a	No ROW impacts	No ROW impacts.

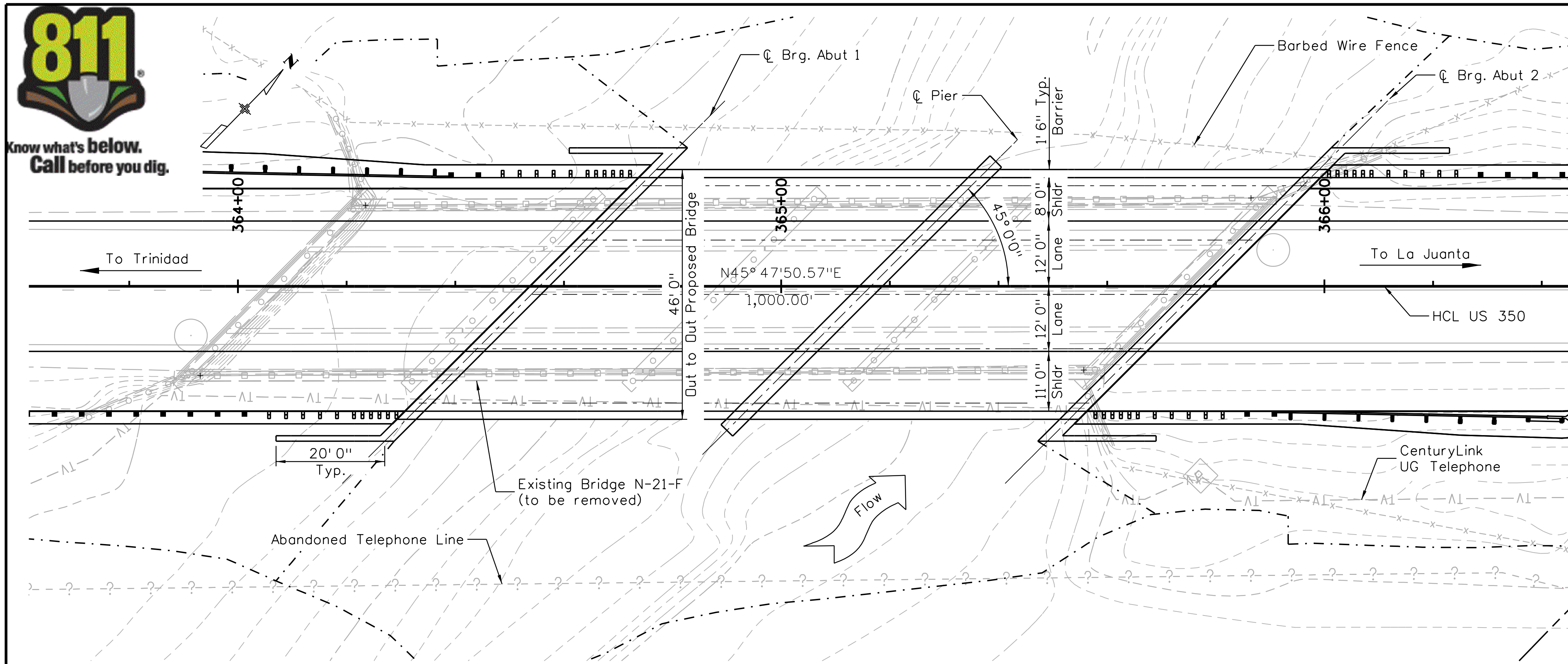
Table 4 - Summary of Structure Alternatives Evaluation

Based on the criteria discussed above, the concrete bridge alternative is the recommended alternative to replace existing N-21-F bridge. 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

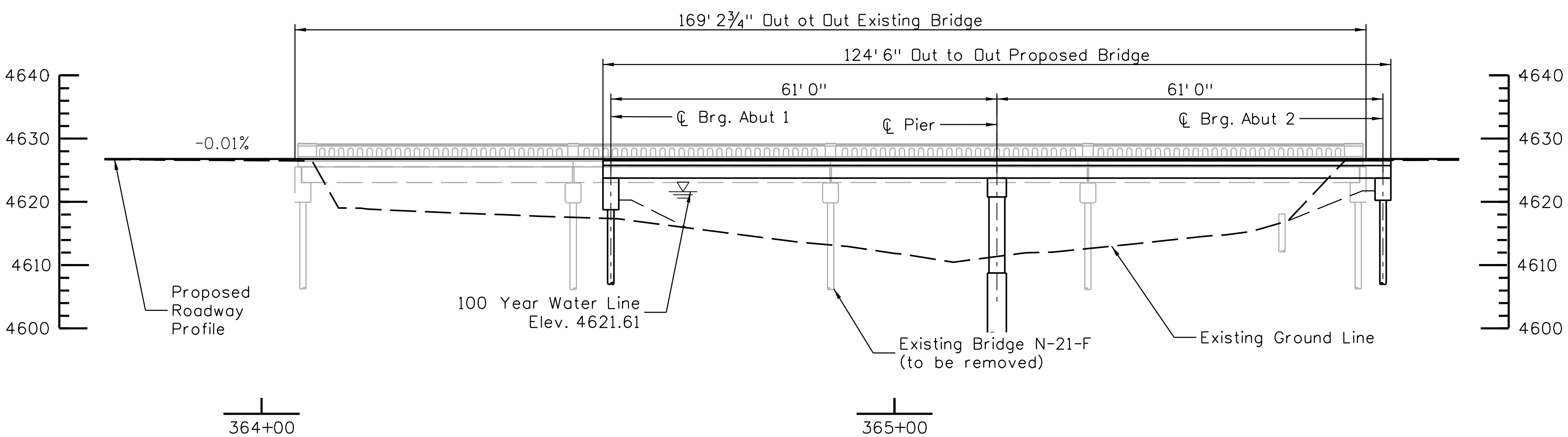
811 Know what's below. Call before you dig.



PLAN

Notes:

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



ELEVATION
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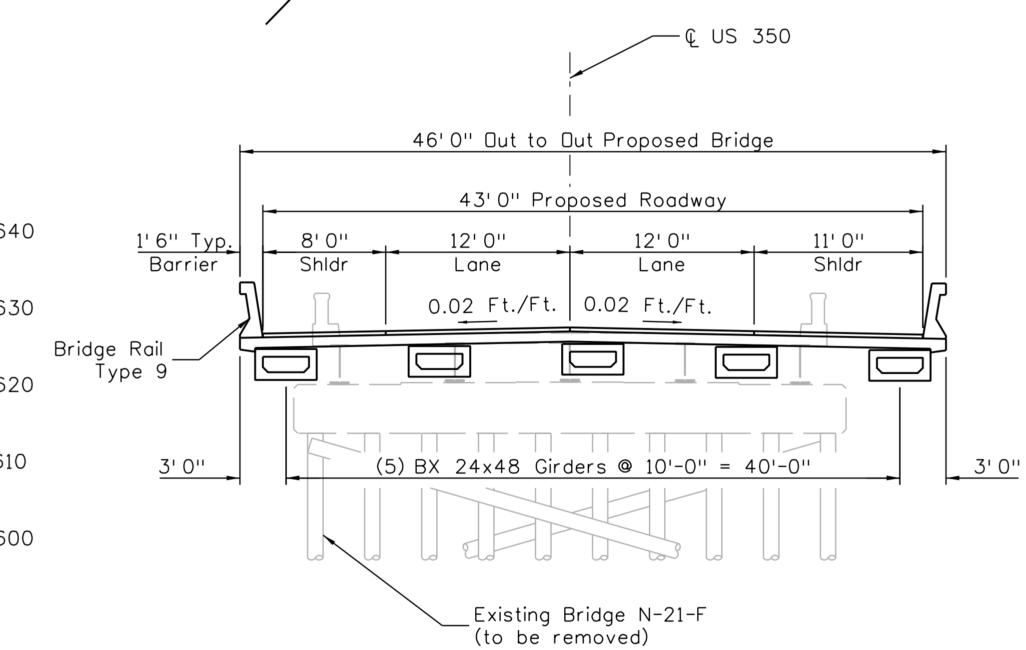

SECTION
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Sheet Revisions

Date:	Comments	Init.

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As Constructed
No Revisions:
Revised:
Void:

REGION 2 BRIDGE BUNDLE
US350 OVER SHEEP CANYON ARROYO
GENERAL LAYOUT AND TYP. SECTION

Designer: I. PUSKAROVA	Structure No. N-21-F
Detailer: I. PUSKAROVA	M.P. US 350 48.744
Sheet Subset: STR	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

* CBC Alternative

* RCP Alternative

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

List of Variances

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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

Project No.: CDOT #23558 (Stanley #29715) Date: 2/1/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - N-21-F 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	**$ 90,000.0**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**402**	$ 8,037
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**657**	$ 22,985
206-01750	Shoring	L S	**$ 12,000.00**	**2**	$ 24,000
420-00102	Geotextile (Erosion Control) (Class 1)	SY	**$ 7.00**	**1103**	$ 7,722
502-00200	Drive Steel Piling	LF	**$ 18.00**	**752**	$ 13,536
502-00460	Pile Tip	EACH	**$ 150.00**	**16**	$ 2,400
502-02010	Dynamic Pile Test	EACH	**$ 3,100.00**	**2**	$ 6,200
502-11253	Steel Piling (HP 12x53)	LF	**$ 68.00**	**752**	$ 51,136
503-00036	Drilled Shaft (36 Inch)	LF	**$ 330.00**	**240**	$ 79,200
506-00218	Riprap (18 Inch)	CY	**$ 120.00**	**653**	$ 78,360
515-00120	Waterproofing (Membrane)	SY	**$ 22.5**	**255**	$ 5,735
601-04550	Concrete Class G	CY	**$ 900.00**	**309**	$ 277,713
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**1051**	$ 14,715
602-00000	Reinforcing Steel	LB	**$ 3.72**	**68857**	$ 256,149
606-10900	Bridge Rail Type 9	LF	**$ 152.00**	**249**	$ 37,848
618-01992	Prestressed Concrete Box (Depth Less Than 32 Inches)	SF	**$ 60.00**	**2420**	$ 145,200
				Subtotal of accounted construction items =>	$ 1,120,936
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	**$ 1,457,217**
				Deck area (SF) =>	2760
				Cost per SF =>	**$ 528**

Project No.: CDOT #23558 (Stanley #29715) Date: 2/1/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - N-21-F Steel Bridge Alternative

Client: CDOT Region 2

STEEL BRIDGE ALTERNATIVE					
Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	$ 90,000.0	1	$ 90,000
206-00000	Structure Excavation	CY	$ 20.00	402	$ 8,037
206-00100	Structure Backfill (Class 1)	CY	$ 35.00	657	$ 22,985
206-01750	Shoring	L S	$ 12,000.00	2	$ 24,000
420-00102	Geotextile (Erosion Control) (Class 1)	SY	$ 7.00	1103	$ 7,722
502-00200	Drive Steel Piling	LF	$ 18.00	752	$ 13,536
502-00460	Pile Tip	EACH	$ 150.00	16	$ 2,400
502-02010	Dynamic Pile Test	EACH	$ 3,100.00	2	$ 6,200
502-11253	Steel Piling (HP 12x53)	LF	$ 68.00	752	$ 51,136
503-00036	Drilled Shaft (36 Inch)	LF	$ 330.00	240	$ 79,200
506-00218	Riprap (18 Inch)	CY	$ 120.00	653	$ 78,360
509-00000	Structural Steel	LB	$ 2.50	70970	$ 177,425
515-00120	Waterproofing (Membrane)	SY	$ 22.5	255	$ 5,735
601-04550	Concrete Class G	CY	$ 900.00	304	$ 273,760
601-40300	Structural Concrete Coating	SY	$ 14.00	518	$ 7,248
602-00000	Reinforcing Steel	LB	$ 3.72	67539	$ 251,247
606-10900	Bridge Rail Type 9	LF	$ 152.00	249	$ 37,848
				Subtotal of accounted construction items =>	$ 1,136,838
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	**$ 1,477,889**
				Deck area (SF) =>	2760
				Cost per SF =>	**$ 535**

APPENDIX D

Geotechnical Report

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

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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 N-21-F
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 N-21-F as part of the CDOT Region 2 Bridge Bundle Design-Build 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

Bridge N-21-F 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, N-21-F-B-1 and N-21-F-B-2, were drilled by Yeh in the vicinity of the existing bridge, and two pavement borings, N-21-F-P-1 and N-21-F-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 subsurface material encountered in the bridge borings consisted of lean and fat clays, sands, and gravels overlying shale 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)
N-21-F-B-1	395619.503, 474214.499	4626.5	47.0	4579.5	44	4582.5
N-21-F-B-2	395469.312, 474082.644	4626.5	47.0	4579.5	38	4588.5

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 a 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, 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 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. Bedrock is anticipated about 30 feet below the existing channel bottom, and the relatively soft clays observed above the bedrock are not suitable for support of shallow foundations.

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=0.45)
N-21-F-B-1	4579.5	125	62.5	14	6.3
N-21-F-B-2	4579.5	125	62.5	14	6.3

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)	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
Clay	Stiff Clay [3] (Reese)	120	57.5	-	300	0.01	-	-
Sand and Gravel	Sand (Reese)	125	62.5	32	-	-	90	60
Shale Bedrock	Stiff Clay w/o Free Water (Reese)	130	130	-	8,000	0.004	-	-

Note: [1]Above Groundwater Table
[2]Below Groundwater Table
[3]Stiff Clay w/ Free Water (Reese) for clay below groundwater table and Stiff Clay w/o Free Water (Reese) for clay above groundwater

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 30 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.

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 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 clay soils 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	1.4 + 0.6 * B’
Saturated	0.8 + 0.3 * 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 is based on a minimum 12 inches of embedment and resistance shall be limited to 10 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 Clay	0.26	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	284 psf/ft	0.50
	Saturated	136 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.

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]
N-21-F-P-1	5.0	Not Encountered	A-6 (12)	10
N-21-F-P-2	3.0	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
N-21-F-P-1/P-2	Sandy Lean Clay (Fill)	0.731	0.0029	-	-
N-21-F-B-1	Lean Clay	0.111	0.0042	7.9	444
N-21-F-B-2	Shale	0.238	0.0007	7.6	667

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)
0.047 g	0.102 g	0.032 g
A_s (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
0.076 g	0.163 g	0.076 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.

Prepared by:

Cory S. Wallace, EIT, GIT
Staff Engineer

Reviewed by:

JG T. McCall, PE
Senior Project Engineer

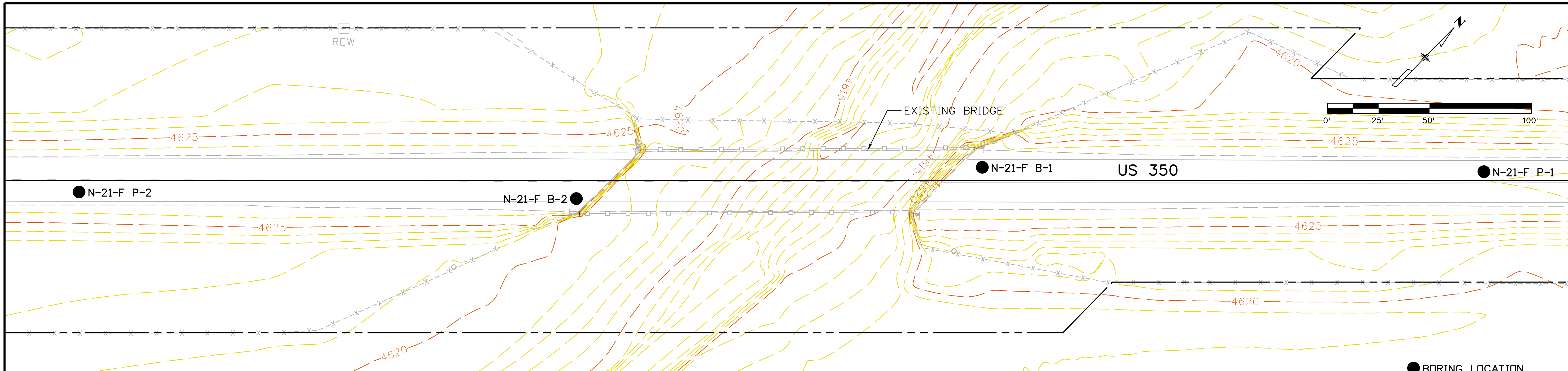
Independent Technical Review by:

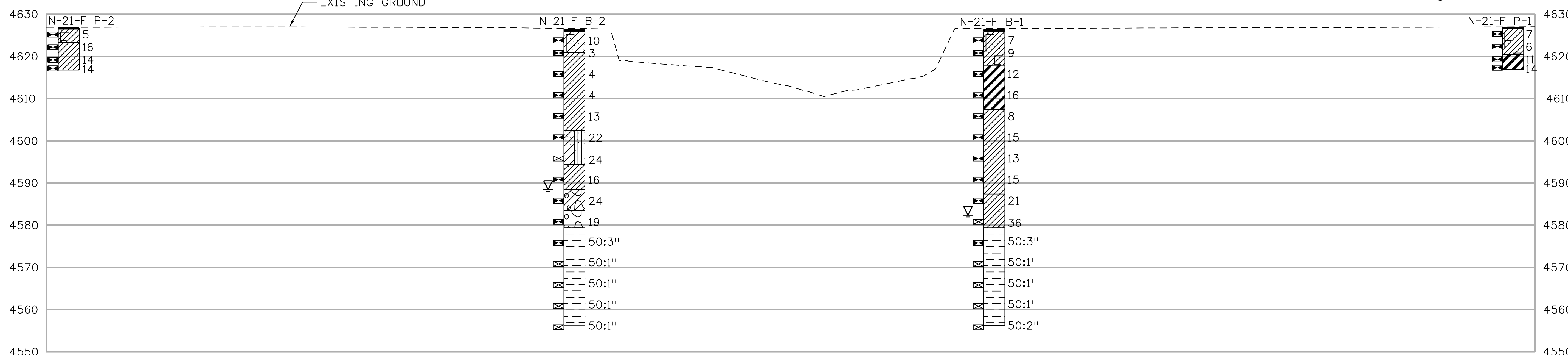
Hsing-Cheng Liu, PE, PhD
Senior Project Manager

Attachments:
Appendix A
Appendix B
Appendix C

APPENDIX A

ENGINEERING GEOLOGY SHEET

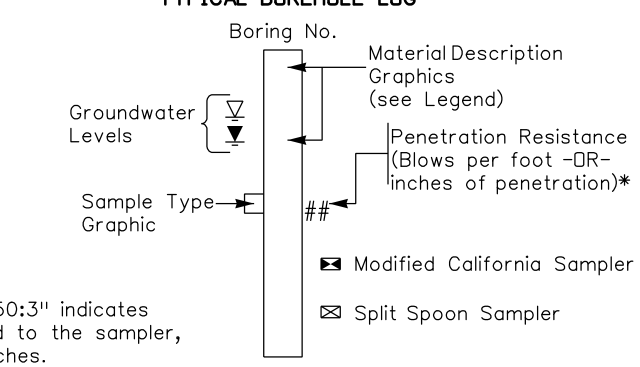




LEGEND

Asphalt	Low Plasticity Sandy Clay	USCS Fat/High Plasticity Clay	Fill
USCS Lean/Low Plasticity Clay	USCS Clayey Sand	USCS Clayey Sand	
USCS Clayey Gravel	USCS Poorly-graded Gravel	Shale	

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 N-21-F.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	N-21-F
Detailer:	MJW		
Sheet Subset:	Geology	Subset Sheets:	1 of 1

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

mwaiz 10:21:12 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 N-21-F.dgn

APPENDIX B

KEY TO BORING LOGS
BORING LOGS
PAVEMENT CORE PHOTOS

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

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

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063   *Boring No.:* **N-21-F-P-1**

Boring Began: 8/27/2020
Boring Completed: 8/27/2020
Drilling Method(s): Coring / Solid-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.0 ft
Ground Elevation: 4627
Coordinates: N: 395789.9 E: 474392.3
Location: US 350, southbound outside lane
Logged By: B. Lykins
Final By: J. McCall

Weather Notes: Partly Cloudy, 79F
Inclination from Horiz.: Vertical
Night Work: ☐

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

Elevation (feet)	Depth (feet)	Blows per 6 in	Penetration Resistance	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit	Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				0.0 - 0.4 ft. ASPHALT (5 inches).									
				0.4 - 6.5 ft. Lean CLAY with sand (CL) (Fill), brown and orange, moist, medium stiff.									
		3-4	7										
4625													
		2-4	6		21.3	102.7		13.7	86.3	41	25	A-7-6 (21) CL	S/C=0.9%
	5												
				6.5 - 10.0 ft. Fat CLAY (CH), with trace gravel, light brown, medium stiff, calcareous.									
4620		4-7	11										
		6-8	14										
	10			Bottom of Hole at 10.0 ft.									
4615													
4610													
4605													

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	Project Name: CDOT Region 2 Bridge Bundle	PAGE 1 of 1
	Project Number: 220-063	Boring No.: **N-21-F-P-2**

Boring Began: 8/27/2020
Boring Completed: 8/27/2020
Drilling Method(s): Coring / Solid-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.0 ft
Ground Elevation: 4626.76
Coordinates: N: 395301.1 E: 473905.6
Location: US 350, northbound outside lane
Logged By: B. Lykins
Final By: J. McCall

Weather Notes: Sunny, 77F
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 Classifications	Field Notes and Other Lab Tests
	0.0						**0.0 - 0.3 ft. ASPHALT** (3 inches).									
4625				2-3	5		**0.3 - 3.5 ft. Lean CLAY (CL) (Fill)**, light brown to brown, dry to moist, medium stiff. - calcareous below 3'.									
	5			6-10	16		**3.5 - 10.0 ft. Lean CLAY (CL)**, brown, moist, medium stiff.	19.4	105.5	0.0	1.3	98.7	38	22	A-6 (22) CL	S/C=2%
4620				5-9	14											
	10			4-10	14											
4615							Bottom of Hole at 10.0 ft.									
4610																
4605																

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Geotechnical • Geological • Construction Services

Project Name:	CDOT Region 2 Bridge Bundle	PAGE 1 of 3
Project Number: 220-063	Boring No.: **N-21-F-B-1**	

Boring Began: 8/27/2020
Boring Completed: 8/27/2020
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: 4626.5
Coordinates: N: 395619.5 E: 474214.5
Location: US 350, southbound outside lane
Logged By: B. Lykins
Final By: J. McCall

Weather Notes: Sunny, 98F
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol	⊻		
Depth	44.0 ft	-	-
Date	8/27/20	-	-

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 Classifi-cations	Field Notes and Other Lab Tests
							0.0 - 0.5 ft. ASPHALT (6 inches).									
4625							**0.5 - 8.5 ft. Lean CLAY with sand and gravel (CL) (Fill)**, tan-brown with white, moist, medium stiff.									
				3-4	7											
	5			4-5	9											
4620																
							8.5 - 19.0 ft. Fat CLAY with sand (CH), light brown, moist, stiff, calcareous.									
	10			4-8	12			20.2	128.4		18.9	81.1	50	32	A-7-6 (26) CH	
4615																
	15			6-10	16											
4610																
							19.0 - 39.0 ft. Lean CLAY (CL), brown, moist, medium stiff to stiff, calcareous.									
	20			3-5	8											
4605																

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
				5-10	15		**19.0 - 39.0 ft. Lean CLAY (CL)**, brown, moist, medium stiff to stiff, calcareous.	18.4	110.0	0.0	11.2	88.8	39	24	A-6 (21) CL	pH=7.9 S=0.111% Chl=0.0042% Re=444ohm·cm
4600																
	30			5-8	13											
4595																
	35			6-9	15											
4590																
							39.0 - 47.0 ft. Sandy lean CLAY (CL), with gravel, tan-brown with white, moist, very stiff to hard.									
	40			8-13	21											
4585																
	∇															
	45			3-9-27	36											
4580																
							47.0 - 70.2 ft. SHALE, gray to dark gray, slightly weathered, hard, petroliferous at 55 ft.									
	50			50:3"	50:3"											
4575																
	55															

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
				50:1"	50:1"											
4570																
	60			50:1"	50:1"											
4565																
	65			50:1"	50:1"											
4560																
	70			50:2"	50:2"		Bottom of Hole at 70.2 ft.									
4555																
4550																
4545																

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

Project Name:	CDOT Region 2 Bridge Bundle
Project Number:	220-063
Boring No.:	**N-21-F-B-2**

Boring Began: 8/27/2020
Boring Completed: 8/27/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 70.1 ft
Ground Elevation: 4626.5
Coordinates: N: 395469.3 E: 474082.6
Location: US 350, northbound outside lane
Logged By: B. Lykins
Final By: J. McCall

Weather Notes: Sunny, 83F
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol	⊻		
Depth	38.0 ft	-	-
Date	8/27/20	-	-

Elevation (feet)	Depth (feet)	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	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 - 0.5 ft. ASPHALT** (6 inches).									
4625				**0.5 - 5.5 ft. Clayey SAND with gravel (SC) (Fill)**, tan and light brown, dry, loose.									
		7-3	10		9.2		23.0	39.6	37.4				
	5	2-1	3	**5.5 - 24.0 ft. Lean CLAY (CL)**, brown, moist, soft to stiff.									
4620													
	10	2-2	4		23.5	99.0	0.0	5.4	94.6	36	19	A-6 (18) CL	S/C=-1.2%
4615													
	15	2-2	4										
4610													
	20	4-9	13										
4605													

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
				8-14	22		**24.0 - 32.0 ft. Silty, clayey SAND (SC-SM)**, light brown, moist, medium dense.	9.6	109.3		58.8	41.2	20	4	A-4 (0) SC-SM	
4600																
	30			9-18-6	24											
4595																
							32.0 - 38.0 ft. Lean CLAY with sand (CL), light brown, moist, stiff.									
	35			6-10	16											
4590																
	∇															
							38.0 - 43.0 ft. Clayey GRAVEL (GC), tan-brown to orange, wet, medium dense.									
	40			12-12	24											
4585																
							43.0 - 47.0 ft. Poorly graded GRAVEL (GP), tan-brown to orange, wet, medium dense.									
	45			7-12	19											
4580																
							47.0 - 70.1 ft. SHALE, gray, very hard.									
	50			50:3"	50:3"			9.4		0.0	0.0	100.0	28	9	A-4 (8) CL	pH=7.6 S=0.238% Chl=0.0007% Re=667ohm·cm
4575																
	55															

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
				50:1"	50:1"											
4570																
	60			50:1"	50:1"											
4565																
	65			50:1"	50:1"											
4560																
	70			50:1"	50:1"		Bottom of Hole at 70.1 ft.									
4555																
4550																
4545																

Boring:	**P-1**	AC:	**5"**
Roadway:	**US 350**	PCC:	**-**
Direction:	**Southbound**	Base:	**-**
Lane:	**Outside**	Notes:	**-**

Boring:	**P-2**	AC:	**3"**
Roadway:	**US 350**	PCC:	**-**
Direction:	**Northbound**	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 N-21-F

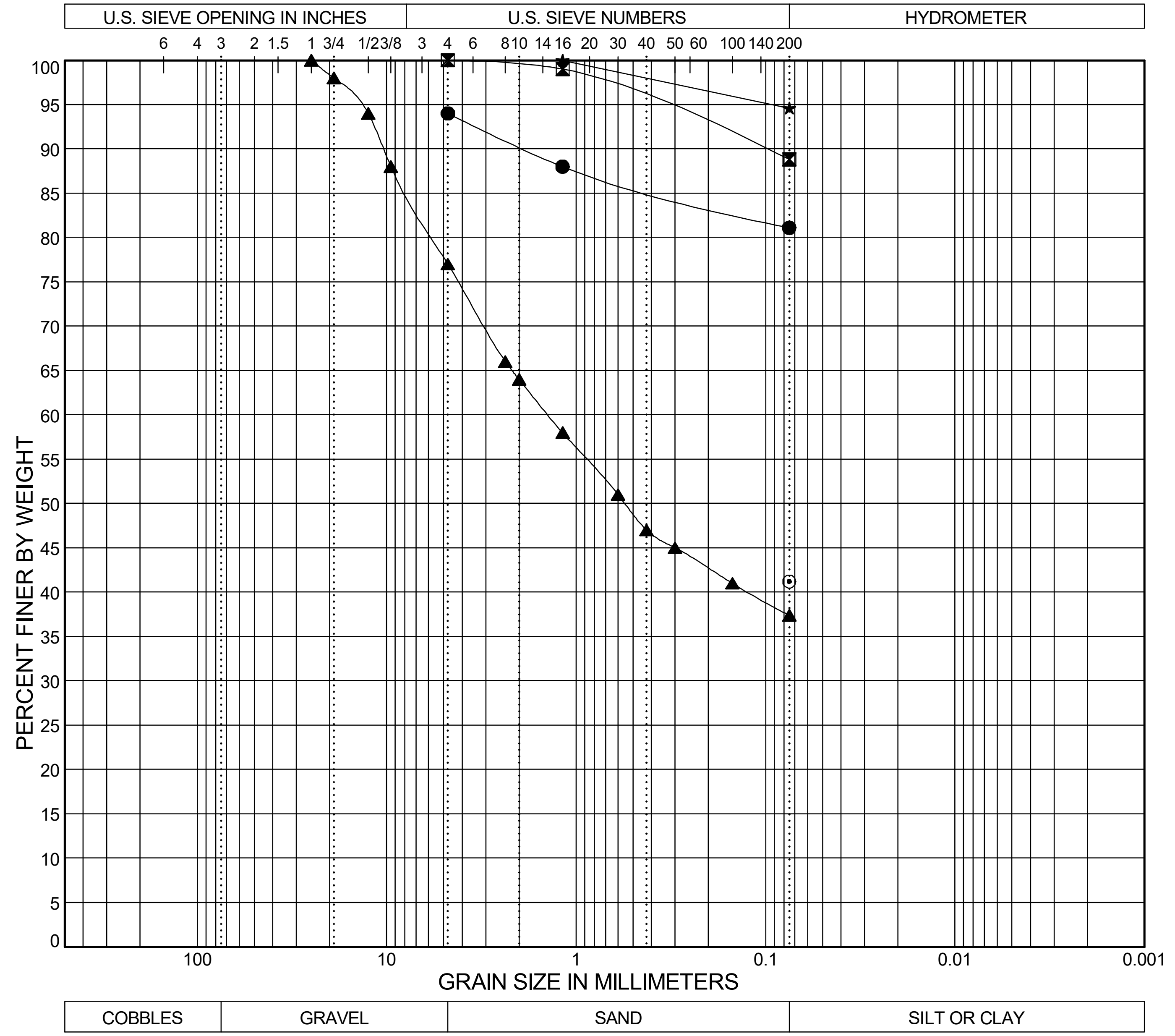
APPENDIX C

SUMMARY OF LABORATORY TEST RESULTS

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 11-30-2020

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
N-21-F Scour	0	BULK	11.8		2.0	16.4	81.6												
N-21-F-B-1	10.0	MC	20.2	128.4		18.9	81.1	50	18	32								A-7-6 (26)	CH
N-21-F-B-1	25.0	MC	18.4	110.0	0.0	11.2	88.8	39	15	24	7.9	0.111	0.0042	444				A-6 (21)	CL
N-21-F-B-2	2.0	MC	9.2		23.0	39.6	37.4												
N-21-F-B-2	10.0	MC	23.5	99.0	0.0	5.4	94.6	36	17	19					-1.2 @ 1000			A-6 (18)	CL
N-21-F-B-2	25.0	MC	9.6	109.3		58.8	41.2	20	16	4								A-4 (0)	SC-SM
N-21-F-B-2	50.0	MC	9.4		0.0	0.0	100.0	28	19	9	7.6	0.238	0.0007	667				A-4 (8)	CL
N-21-F-P-1	4.0	MC	21.3	102.7		13.7	86.3	41	16	25					0.9 @ 200			A-7-6 (21)	CL
N-21-F-P-1/P-2	2.5	BULK	15.8		10.0	21.5	68.5	36	14	22		0.731	0.0029				10	A-6 (12)	CL
N-21-F-P-2	4.0	MC	19.4	105.5	0.0	1.3	98.7	38	16	22					2 @ 200			A-6 (22)	CL



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	N-21-F-B-1	10.0	A-7-6 (26)	CH	50	18	32		12.9	81.1	
⌧	N-21-F-B-1	25.0	A-6 (21)	CL	39	15	24	0.0	11.2	88.8	
▲	N-21-F-B-2	2.0						23.0	39.6	37.4	
★	N-21-F-B-2	10.0	A-6 (18)	CL	36	17	19	0.0	5.4	94.6	
⊙	N-21-F-B-2	25.0	A-4 (0)	SC-SM	20	16	4			41.2	

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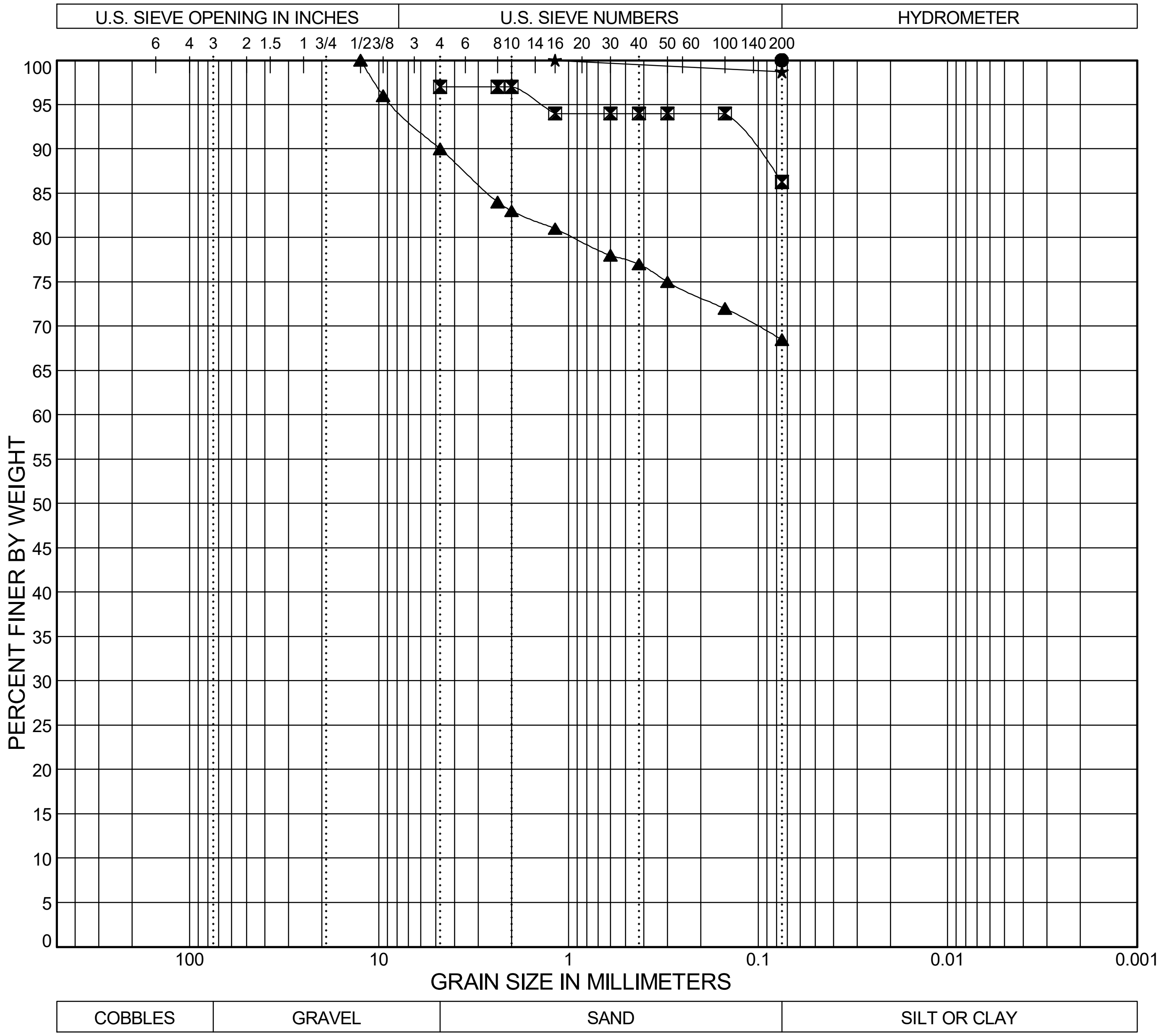
SIEVE ANALYSIS

FIGURE C- 1

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 N-21-F



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
●	**N-21-F-B-2**	**50.0**	**A-4 (8)**	**CL**	**28**	**19**	**9**	**0.0**	**0.0**	**100.0**	
⧗	**N-21-F-P-1**	**4.0**	**A-7-6 (21)**	**CL**	**41**	**16**	**25**		**10.7**	**86.3**	
▲	**N-21-F-P-1/P-2**	**2.5**	**A-6 (12)**	**CL**	**36**	**14**	**22**	**10.0**	**21.5**	**68.5**	
★	**N-21-F-P-2**	**4.0**	**A-6 (22)**	**CL**	**38**	**16**	**22**	**0.0**	**1.3**	**98.7**	

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Geotechnical • Geological • Construction Services

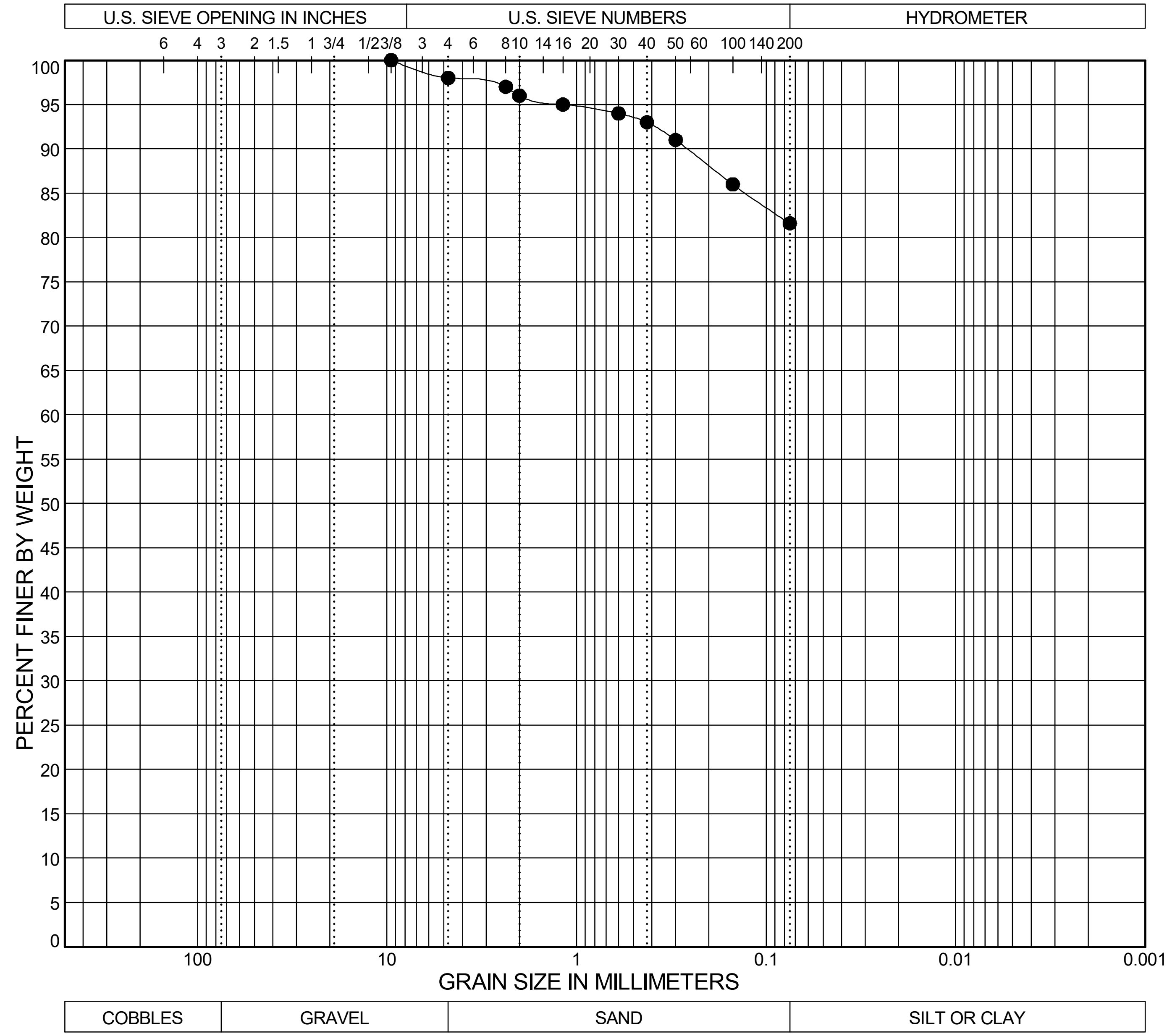
SIEVE ANALYSIS

FIGURE C- 2

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 N-21-F

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	%Fines: %Clay
● **N-21-F Scour**	**0.0**						**2.0**	**16.4**	**81.6**	

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

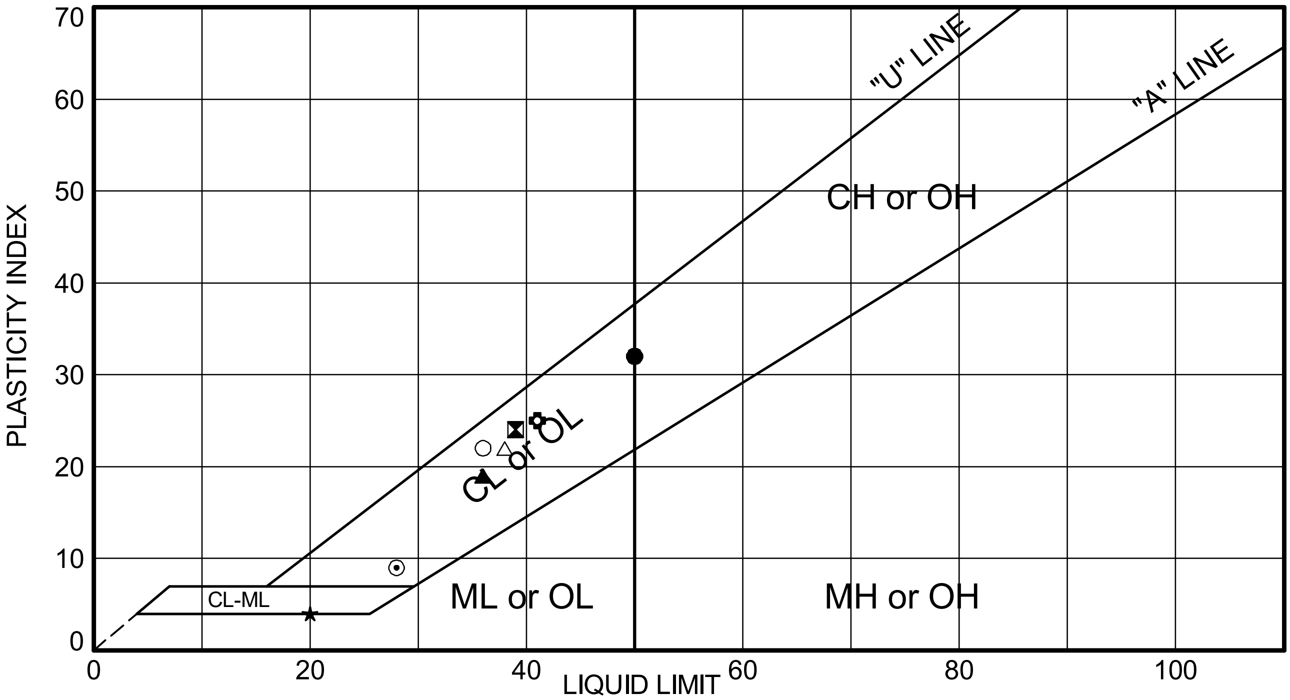
SIEVE ANALYSIS

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 N-21-F

FIGURE

C- 3



	BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
●	**N-21-F-B-1**	**10.0**	**50**	**18**	**32**	**81.1**	**FAT CLAY with SAND (CH)**	**A-7-6 (26)**
⧗	**N-21-F-B-1**	**25.0**	**39**	**15**	**24**	**88.8**	**LEAN CLAY (CL)**	**A-6 (21)**
▲	**N-21-F-B-2**	**10.0**	**36**	**17**	**19**	**94.6**	**LEAN CLAY (CL)**	**A-6 (18)**
★	**N-21-F-B-2**	**25.0**	**20**	**16**	**4**	**41.2**	**SILTY, CLAYEY SAND (SC-SM)**	**A-4 (0)**
⊙	**N-21-F-B-2**	**50.0**	**28**	**19**	**9**	**100.0**	**LEAN CLAY (CL)**	**A-4 (8)**
✿	**N-21-F-P-1**	**4.0**	**41**	**16**	**25**	**86.3**	**LEAN CLAY (CL)**	**A-7-6 (21)**
○	**N-21-F-P-1/P-2**	**2.5**	**36**	**14**	**22**	**68.5**	**SANDY LEAN CLAY (CL)**	**A-6 (12)**
△	**N-21-F-P-2**	**4.0**	**38**	**16**	**22**	**98.7**	**LEAN CLAY (CL)**	**A-6 (22)**

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ATTERBERG LIMITS

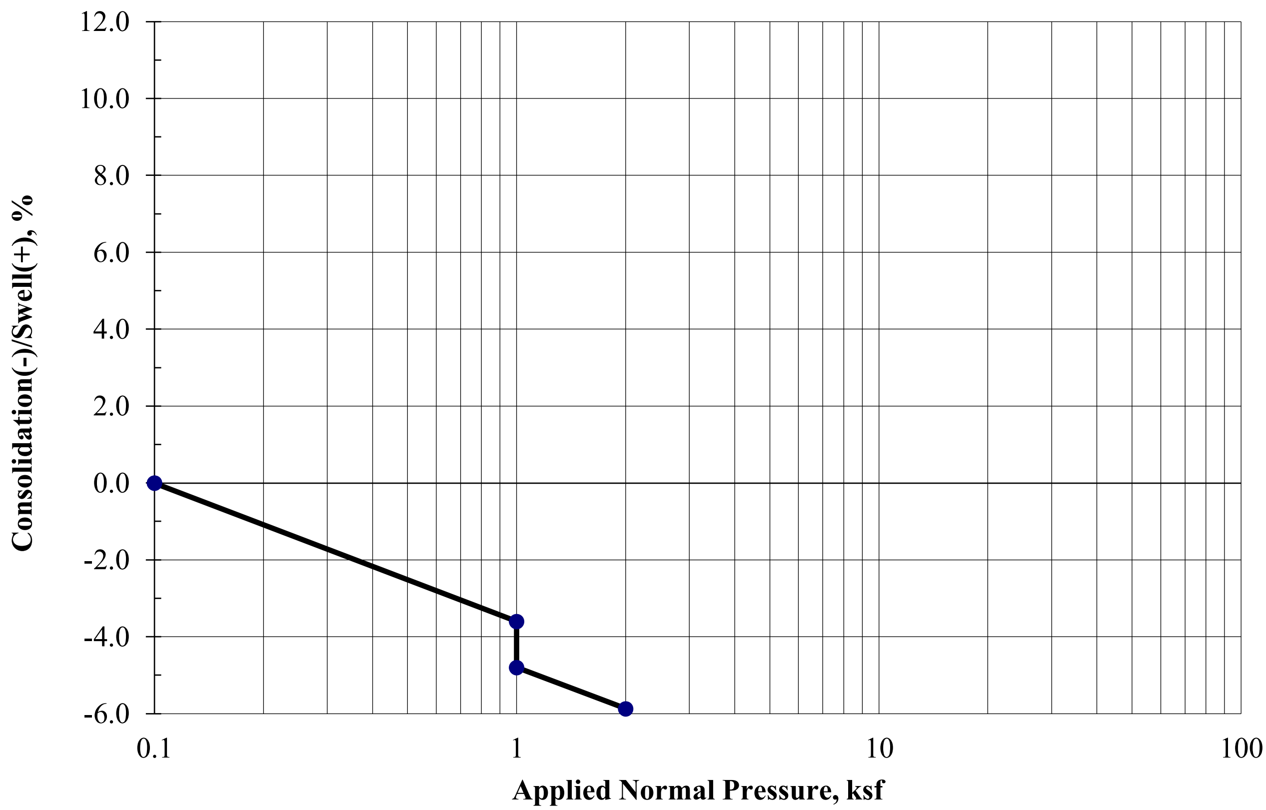
FIGURE

C - 4

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 N-21-F

SWELL/CONSOLIDATION TEST - ASTM D 4546



Boring ID	B-2
Sample Depth (ft)	10.0
Date Sampled	8/27/2020

Swell/ Consolidation (%)	-1.2
Natural Moisure Content (%)	23.5
Saturated Moisture Content (%)	22.1
Dry Density (pcf)	99

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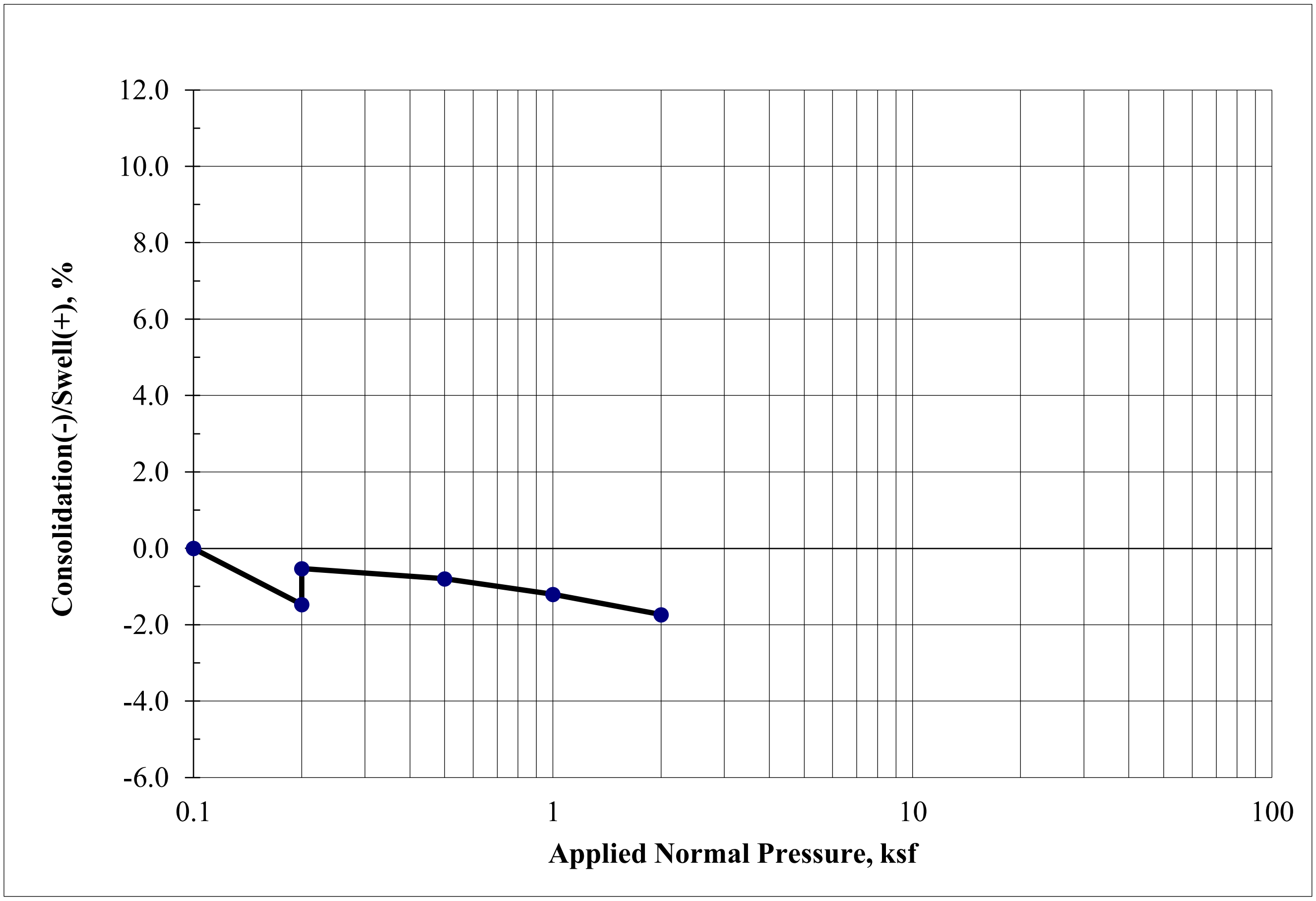
SWELL/ CONSOLIDATION TEST RESULTS

FIGURE C-5

Project No.	220-063	Date:	11/30/2020
Report By:	DG	Yeh Lab:	Colorado Springs
Checked By:	JTM		

CDOT Region 2 Bridge Bundle
Structure N-21-F

SWELL/CONSOLIDATION TEST - ASTM D 4546

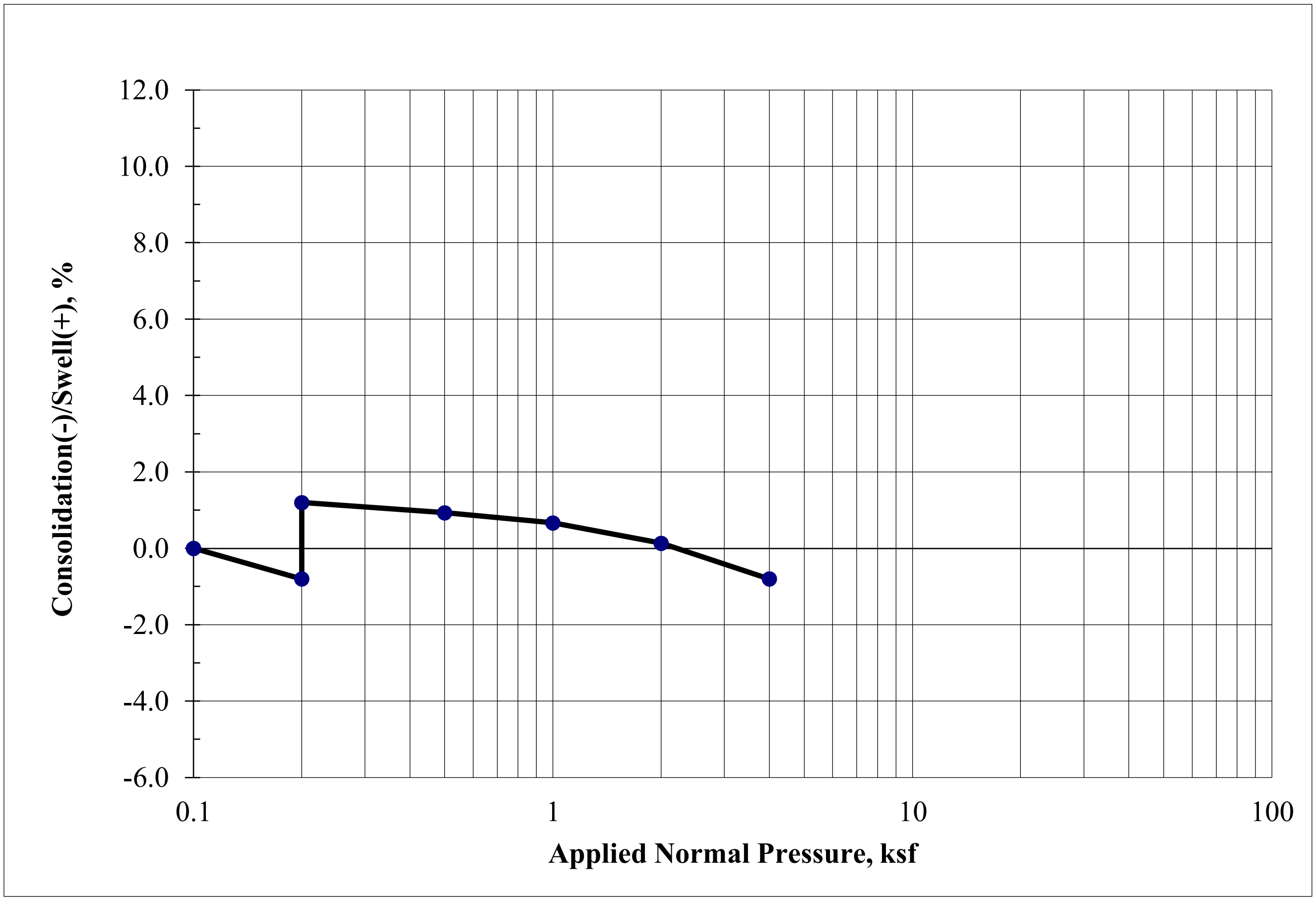


Boring ID	P-1
Sample Depth (ft)	4.0
Date Sampled	8/27/2020

Swell/ Consolidation (%)	0.9
Natural Moisure Content (%)	21.3
Saturated Moisture Content (%)	22.6
Dry Density (pcf)	102.7

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services				**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No.	220-063	Date:	11/30/2020	CDOT Region 2 Bridge Bundle Structure N-21-F	**C-6**
Report By:	DG	Yeh Lab:	Colorado Springs		
Checked By:	JTM				

SWELL/CONSOLIDATION TEST - ASTM D 4546



Boring ID	P-2
Sample Depth (ft)	4.0
Date Sampled	8/27/2020

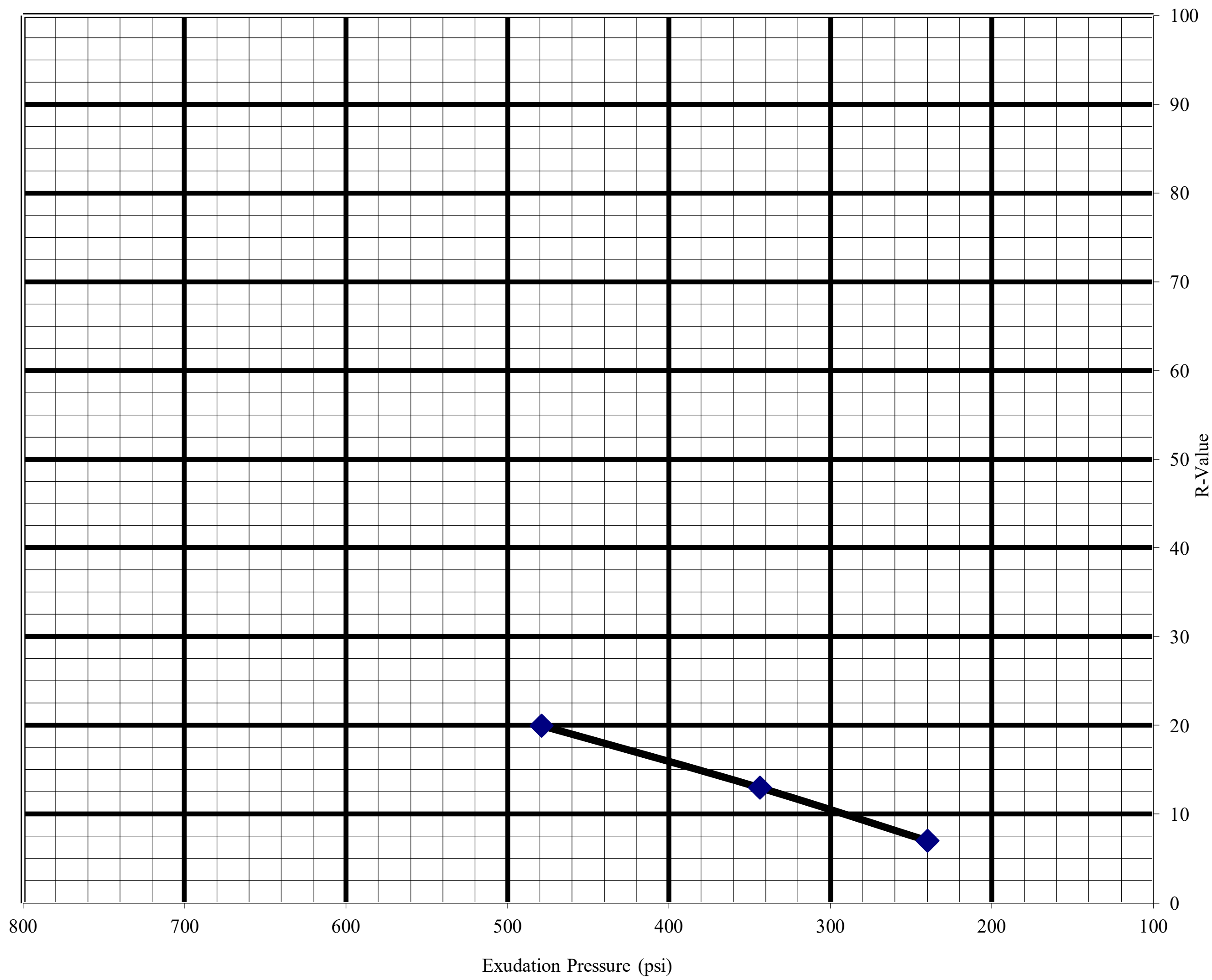
Swell/ Consolidation (%)	2.0
Natural Moisure Content (%)	19.4
Saturated Moisture Content (%)	21.1
Dry Density (pcf)	105.5

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services				**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No.	220-063	Date:	11/30/2020	CDOT Region 2 Bridge Bundle	**C-7**
Report By:	DG	Yeh Lab:	Colorado Springs	Structure N-21-F	
Checked By:	JTM				

YEH AND ASSOCIATES, INC
R-Value Test Report

Project Number: 220-063
Project Name: CDOT Region 2 Bridge Bundle
Sample Id: P-1 / P-2
Depth (ft): 2.5
Location: N-21-F
Station: --
Date Sampled: 8/27/2020
Date Tested: 10/7/2020

R-Value at 300 psi exudation pressure = **10**



Test No.	Compact. Press. (psi)	Density (pcf)	Moist. (%)	Horizont. Pressure (psi)'@ 160 psi	Sample Height (in).	Exud. Pressure (psi)	R Value	R Value Correct.
1	350	110.1	16.0	115	2.47	479	20	20
2	350	110.3	18.0	129	2.46	344	13	13
3	350	110.3	20.0	142	2.46	240	7	7

Sampled by: BHL
Tested by: K.Lyons
Checked by: M.A

Rev. 08-16-2018