PRELIMINARY HYDRAULICS REPORT
STRUCTURE N-21-C REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
OTERO COUNTY, COLORADO

Section 3, Township 27 South, Range 58 West of the 6th P.M.,
County of Otero, Colorado

February 12, 2021

Prepared for:

Colorado Department of Transportation
Region 2
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1. INTRODUCTION

1.1 Background and Purpose

The CDOT Region 2 Bridge Bundle Design Build Project consists of the replacement of a total of nineteen (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 seventeen (17) bridges and two (2) Additionally Requested Elements (AREs) structures.

The fourteen (14) of the structures in this design build project are jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant and the Colorado Bridge Enterprise (Project No. 23558). The remaining five (5) structures are funded solely by the Colorado Bridge Enterprise (Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

The nineteen bridges identified to be included in the 'Region 2 Bridge Bundle' were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted, limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle 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 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure N-21-C as a part of the Colorado Department of Transportation (CDOT) Region 2 Bridge Bundle Project. The project is located within Otero County at Mile Post 47.131 along US 350 between Trinidad and La Junta. Structure N-21-C crosses over the Jack Treese Arroyo. Just downstream of N-21-C is a 16'x10' concrete arch culvert with a natural channel bottom that flows underneath a railroad bridge. The project is located in Section 3, Township 27 South, Range 58 West of the 6^{th} P.M., County of Otero, Colorado. **Appendix C – Figure C1** shows the project area.

The report will document preliminary hydrology, hydraulic, and scour analysis/outlet protection to support the proposed structure replacement design.

The project site is not in a Federal Emergency Management Agency (FEMA) floodplain, as determined by the Flood Insurance Rate Map (FIRM) No. 0801320275B, effective August 19, 1985. Since N-21-C is not in a Special Flood Hazard Area (SFHA), this project will meet CDOT and state requirements. For rural, two-lane highways, the design flow for bridges and culverts is the 25-year storm event. However, the CDOT DDM requires all non-jurisdictional flood areas to follow Colorado Water Conservation Board's guidelines, which state that any development or construction should not raise the 100-year flood event WSEs more than 0.5'. While this is not a statewide requirement, best practice is to follow these guidelines. Bridge N-21-C falls into this category, but because the existing structure passes the 100-year flows, the proposed structures must be sized accordingly.

2. HYDROLOGY

Preliminary hydrology for the watershed tributary to this structure was provided by CDOT. A memorandum provided by CDOT has been provided that summarizes basin areas, runoff methodology and approximate flowrates derived from the preliminary analysis. Table 1 is a summary of the approximate flowrates provided by CDOT of structure N-21-C.

Table 1: Summary of Peak Discharge for Bridge N-21-C

River Location	Design Storm	25-year (cfs)	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	25-year	389	629	765	959

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing structure is a three-span treated timber stringer bridge built in 1936 to span a seasonal wash. The bridge is tangent. The existing bridge were based on a CDOT Standard P-117-B-H. The existing bridge consist of three 22’-6” spans and a width of 29’-0” curb to curb, 30’-0” out to out of deck between rails. The existing vertical clearance varies from 12’-0” to 16’-0”. The existing bridge has 14 rows of stringers, 6”x20” wood stringers, spaced at 2’-3 1/4”. The deck consists of wood planks, 3”x6”.

3.2 Watershed Overview

The Jack Treese Arroyo is a dry arroyo that flows from the southeast to the northwest toward Timpas Creek. The watershed tributary to Jack Treese Arroyo is approximately 1.58 square miles in area. The watershed generally slopes to the northwest. The stream bed does not have a base flow.

The stream flows at an angle to the current structure with an approximate angle of attack of 20 degrees. The area surrounding the bridge is rural with undeveloped land to both upstream and downstream sides of the bridge.

Downstream of the roadway bridge, approximately 260 feet to the northwest, the channel crosses under the railroad prior to the confluence with Timpas Creek. The hydraulic conveyance structure for the railroad is a 16’x10’ concrete arch culvert with a natural channel bottom.

3.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic and geomorphic features of the stream at the project site and of the overall watershed. This investigation found no obvious scour damage at the base of the abutments or piers, however, timber retaining walls were constructed about 5 feet from the base of each abutment that is evidence that the scour could have occurred at the base of the abutments in the past. Site photos are included in **Appendix C**.

4. HYDRAULIC ANALYSIS

A two-dimensional (2D) hydraulic model was developed using the Sediment and River Hydraulics 2D model (SRH-2D) software developed by the USBR in 2008. A 2D model was chosen to represent this area due to the complexity of the stream and for the preliminary scour countermeasure design. The Surface Water Modeling System (SMS) was used to develop the inputs for the SRH-2D Version 13.0 model, as well as post-process the results. For this analysis, three models were developed:

- Existing Conditions
- Proposed Conditions: Bridge Replacement
- Proposed Conditions: Box Culvert Replacement

4.1 Debris potential

The potential for debris production and delivery is estimated to be low (minimal) based on guidance from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 20. The flowchart for potential debris production is presented in Figure 1. The channel banks near the bridge are vegetated with tall grasses and shrubs, and no trees present, as confirmed with the site visit in August 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix C**.

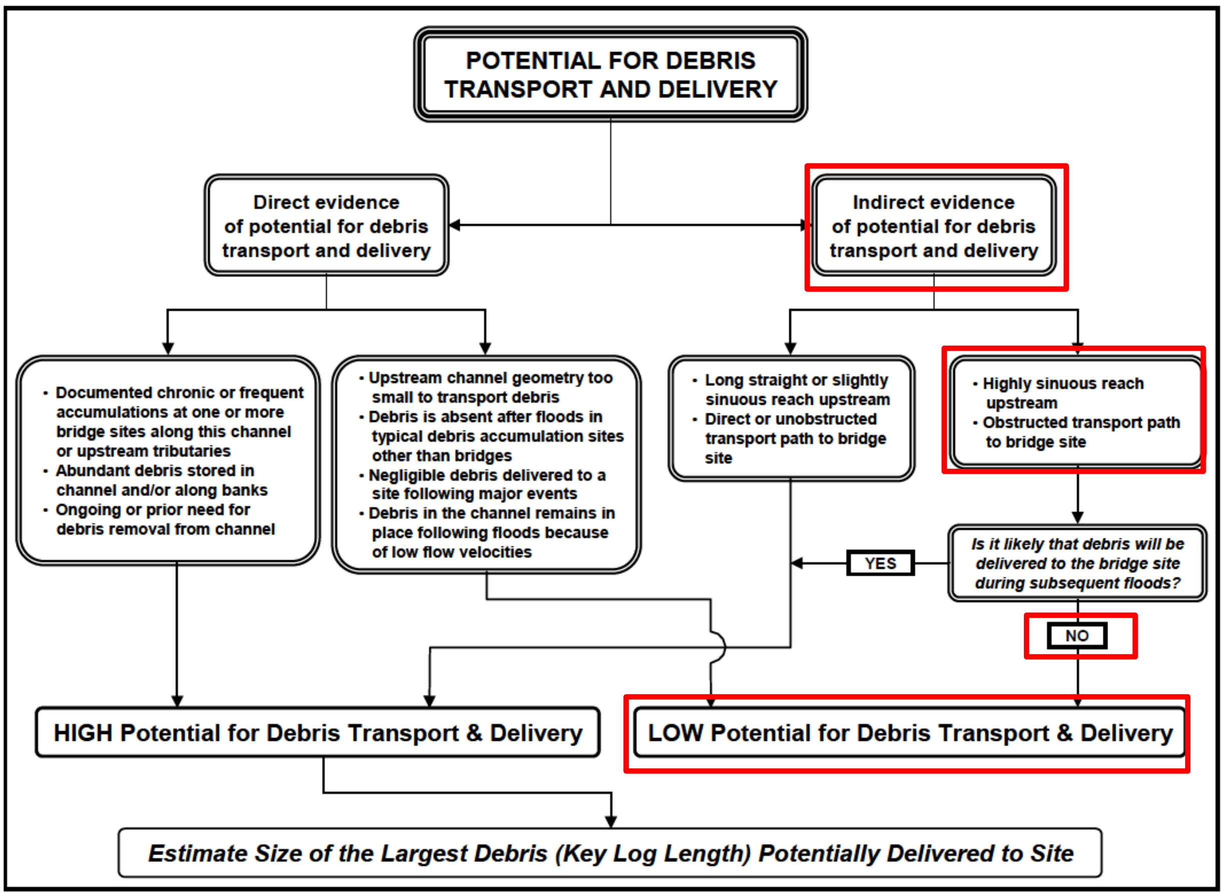


Figure 1: Flow Chart for Potential Debris Production (FHWA, HEC 20)

4.2 Freeboard

The CDOT Drainage Design Manual (2019) specifies freeboard requirements for all bridges. Freeboard is the minimum clearance between the design approach WSE and the low chord of the bridge. It is a factor of safety that acts as a buffer to account for unknown factors that could increase the height of the calculated WSE. Streams classified as high debris streams shall have a minimum of 4 feet of freeboard. Low-to-moderated streams CDOT highly encourages 2 feet be provided, where practical. The elevation of the water surface 50 to 100 feet upstream of the face of the bridge shall be the elevation to which the freeboard is added to get the bottom or low-girder elevation of the bridge.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 2 feet of freeboard would typically be required. The proposed preliminary design will not increase the 100-year WSE as described below.

4.3 Modeling Parameters

4.3.1 Elevation Data

The existing conditions survey for the bridge and channel cross sections was performed by CDOT in June 2020. Stanley Consultants performed a drone survey of the site in August 2020 which was used to add elevation detail at the railroad bridges downstream of each N-21-C. These data sources were used for modeling the surface elevation.

A local, custom projection was used for the data collection in the existing conditions survey. The survey was converted into NAD 1983 Colorado State Plane South US Survey Feet for the hydraulic modeling. All elevations are referenced to NAVD 88 (feet).

4.3.2 Computational Mesh

The computational mesh is an unstructured mesh, which allows for the use of triangles and quadrilaterals, with variable element sizes. Roadways and the channel used quadrilaterals, with the face lined up perpendicular to flow. Triangles were typically used in the overbanks. The total number of mesh elements is 3,779, and the mesh extends approximately 1,400 feet upstream of the bridge and 350 feet downstream of the bridge.

4.3.3 Surface Roughness

Surface roughness, represented by the Manning's roughness coefficient, is presented in Table 2. A Manning's n-value was assigned to each land use based on aerial imagery, topography, a site visit in August 2020, and engineering judgment. Photos from the site visit used to confirm the n-values selected are shown in **Appendix C**, and a map showing existing conditions materials coverages is shown in **Appendix D**.

Table 2: Manning's n-values

Land Use	n-value
Channel	0.045
Smooth Earth	0.035
Overbanks	0.055
Rough Wood	0.02
Stone Riprap	0.06
Roadway	0.016
Concrete	0.012

4.3.4 Boundary Conditions

The boundary conditions include a steady state inflow and outflow.

The peak flows developed in Table 1 were used to develop a steady-state inflow boundary condition. The inflow boundary condition extends the full length of the inundation boundary in the upstream portion of the project location. The model was set to a dry initial condition.

For the downstream boundary condition, the subcritical outflow option was selected. This outflow condition uses the inputs of anticipated flow, Manning's n-value, channel slope, and terrain data to determine the outflow constant water surface elevation. Table 3 presents the boundary condition values.

Table 3: Model Boundary Condition Inputs

Frequency Storm	Inflow (cfs)	Outflow Constant WSE (ft)
100-Year	629	4646.51

4.3.5 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4666.00 feet, not accounting for the railings, while the low chord is 4663.80 feet. The low chord of the bridge is over 10' above the highest water surface elevation during the 100-year event, so the bridge area is modeled as an open channel.

The existing bridge piers were modeled as holes in the computational mesh, allowing flow to run around the piers which replicated true hydraulic conditions.

The existing 16'x10' concrete railroad culvert was modeled using a boundary condition that utilizes HY-8. HY-8 analyzes flow through this culvert in one dimension (1D) by producing a profile of the water surface elevation through the culvert based on various input water surface elevations.

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.5 second time step for 0.5 hours until a steady state solution is met. The parabolic turbulence method is used with a coefficient of 0.7.

4.4 Model Results

4.4.1 Existing Conditions

The depths experienced in the channel at the bridge during the 100-year event range from dry ground to 4.7 feet. Figure 5 presents the depth for the entire channel and the bridge. The results also demonstrate that the railroad culvert causes a backwater effect due to the smaller opening size. Existing conditions 100-year depths of flow are shown in **Appendix D**.

4.4.2 Alternatives Analysis

An alternatives/risk analysis was completed in the preliminary design process to determine the most feasible options for the hydraulic conveyance structure. Both a bridge and reinforced concrete box culvert (RCBC) option were analyzed. Many factors were taken into consideration when determining the preferred alternative for this preliminary analysis. These factors included cost, constructability, effects on the stream hydraulics, environmental impacts, among others.

<u>Proposed RCBC</u>

This option was modeled using the SRH-2D model for the existing conditions as a base. Modifications included adding a single 20’x10’ reinforced concrete box culvert where the existing roadway crosses over the arroyo. The RCBC was modeled as an open channel with the assumption that the water surface elevation would not approach the 10’ ceiling height of the culvert. The proposed model has 2,690 mesh elements.

The preliminary model shows the roadway embankment sloping at 3:1, with the proposed culvert being 90 feet in length. The height of the box is primarily to avoid having excessive embankment altering the natural structure of the steep-sided arroyo and shorten the culvert. This project site is also a designated cattle crossing, which requires a structure height of at least 7 feet. The 20-foot wide by 10-foot tall RCBC structure size was determined to allow less than 0.5 feet of rise in the 100-year WSEs of the channel.

Depths and velocity grids for the proposed RCBC show depths from 2.00 feet to 4.03 feet and velocities from 6.78 fps to 13.07 fps. See **Appendix E** for 100-year depths and velocities graphics for this option.

<u>Proposed Bridge</u>

This option was modeled using the SRH-2D model for the existing conditions as a base. Modifications included replacing the current structure with a single span bridge, with 1:1 slopes from the proposed bridge abutments to a 33.5-foot-wide channel bottom. The proposed bridge is 74 feet long with a 71.5-foot single span opening at a skew of 20 degrees, with the low chord of the bridge at 4,662.64 feet elevation, and the high chord at 4,666 feet elevation. The proposed model has 2,550 mesh elements.

Depths and velocity grids for the proposed bridge show depths from 0.49 feet to 2.74 feet and velocities from 2.84 fps to 9.01 fps. See **Appendix F** for 100-year depths and velocities graphics for this option.

5. WATER SURFACE ELEVATION ANALYSIS

This project site is located in a FEMA designated Zone C, which is not a SFHA, as determined by the FIRM #0801320275 B effective August 19, 1985, as shown Appendix A. Because the existing structure passes the 100-year flood event flows without overtopping the road, the proposed structure must do the same without raising the 100-year WSEs by more than 0.5 feet. The CDOT DDM requires all non-jurisdictional flood areas to follow Colorado Water Conservation Board's guidelines, which state that any development or construction should not raise the 100-year flood event WSEs more than 0.5'. While this is not a statewide requirement, best practice is to follow these guidelines.

<u>Proposed RCBC</u>

Based on modeling results, the proposed RCBC will not increase the WSE by more than 0.5 feet. Because the culvert is narrower than the bridge opening, there is some concentration of flow, which results in a WSE rise of 0.50 feet immediately upstream of the culvert wing walls. The flow becomes super critical through the culvert; however, the proposed riprap at the culvert outlet causes a hydraulic jump that slows the velocity such that there is a WSE rise of 0.12 feet immediately upstream of the railroad culvert.

In order to perform a comparison between the existing and proposed WSE, 7 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. The average WSE was determined for both existing and the proposed RCBC option, as shown in **Appendix G – Figure G1**. The WSE comparison at these sections is shown in **Table 4.**

Table 4: Existing vs. Proposed RCBC WSE

Cross Section	Location Relative to Structure	Existing WSE (ft)	Proposed RCBC WSE (ft)	Difference (ft)
1	Upstream	4655.73	4655.73	0.00
2	Upstream	4654.94	4654.98	0.04
3	Upstream	4654.04	4654.06	0.02
4	Upstream	4652.97	4653.47	0.50
5	Upstream	4651.35	4651.63	0.28
6	Downstream	4650.34	4650.77	0.43
7	Downstream	4649.47	4649.44	-0.03
8	Downstream	4648.95	4649.07	0.12
9	Downstream	4648.91	4648.91	0.00

Proposed Bridge

The model for the proposed bridge will not increase the 100-year WSE by more than 0.37 feet. The bridge opening for this option will have 1:1 slopes from the abutments rather than the wood retaining walls of the existing structure, so there is some attenuation of channel for the proposed structure compared to the existing, which causes a WSE rise of up to 0.37 feet upstream of the bridge in a 100-year event. Just downstream of the structure, however, there is a slight decrease in the 100-year WSE.

For the proposed bridge option, upstream of Bridge N-21-C (Cross Sections 1-4), the WSE increases a maximum of 0.33 feet between existing and proposed. Downstream of Bridge N-21-C (Cross Sections 5-7), the WSE decreases up to 0.14 feet between existing and proposed. **Appendix G – Figure G2** shows the cross sections used for the proposed bridge option as well as the floodplain limit changes between existing and proposed for this scenario. **Table 5** also shows a WSE comparison at each section for the proposed bridge option.

Table 5: Existing vs. Proposed Bridge WSE

Cross Section	Location Relative to Structure	Existing WSE (ft)	Proposed Bridge WSE (ft)	Difference (ft)
1	Upstream	4655.73	4655.73	0.00
2	Upstream	4654.94	4654.99	0.05
3	Upstream	4654.04	4654.17	0.13
4	Upstream	4652.93	4653.30	0.37
5	Upstream	4651.35	4651.69	0.34
6	Downstream	4650.35	4650.66	0.32
7	Downstream	4649.47	4649.33	-0.14
8	Downstream	4648.95	4649.01	0.06
9	Downstream	4648.91	4648.90	0.00

6. RCBC OUTLET ENERGY DISSIPATION

The design procedure recommended in section 11.4 of the DDM was followed for outlet protection and energy dissipation at the outlet of the box culvert. All hydraulic data from the proposed culvert was gathered including height, width, length, slope, etc. The culvert control was determined to be outlet controlled, from which outlet depth, velocity, and Froude number were determined. To determine tailwater data, the downstream channel information was gathered from the survey data, field inspection, and the SRH-2D model.

Allowable scour estimation was completed using HY-8. Soil parameters of the downstream channel were extracted from the soils reports and geotechnical investigation. The estimated scour hole was then determined using HY-8. Due to large scour hole estimates, energy dissipation was then considered.

The energy dissipation alternative selected for this RCBC outlet is a riprap apron based on the Froude number of 1.46, which is less than 3. See results from HY-8 energy dissipation analysis in **Appendix H**.

7. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge N-21-C. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary floodplain analysis and scour analysis.

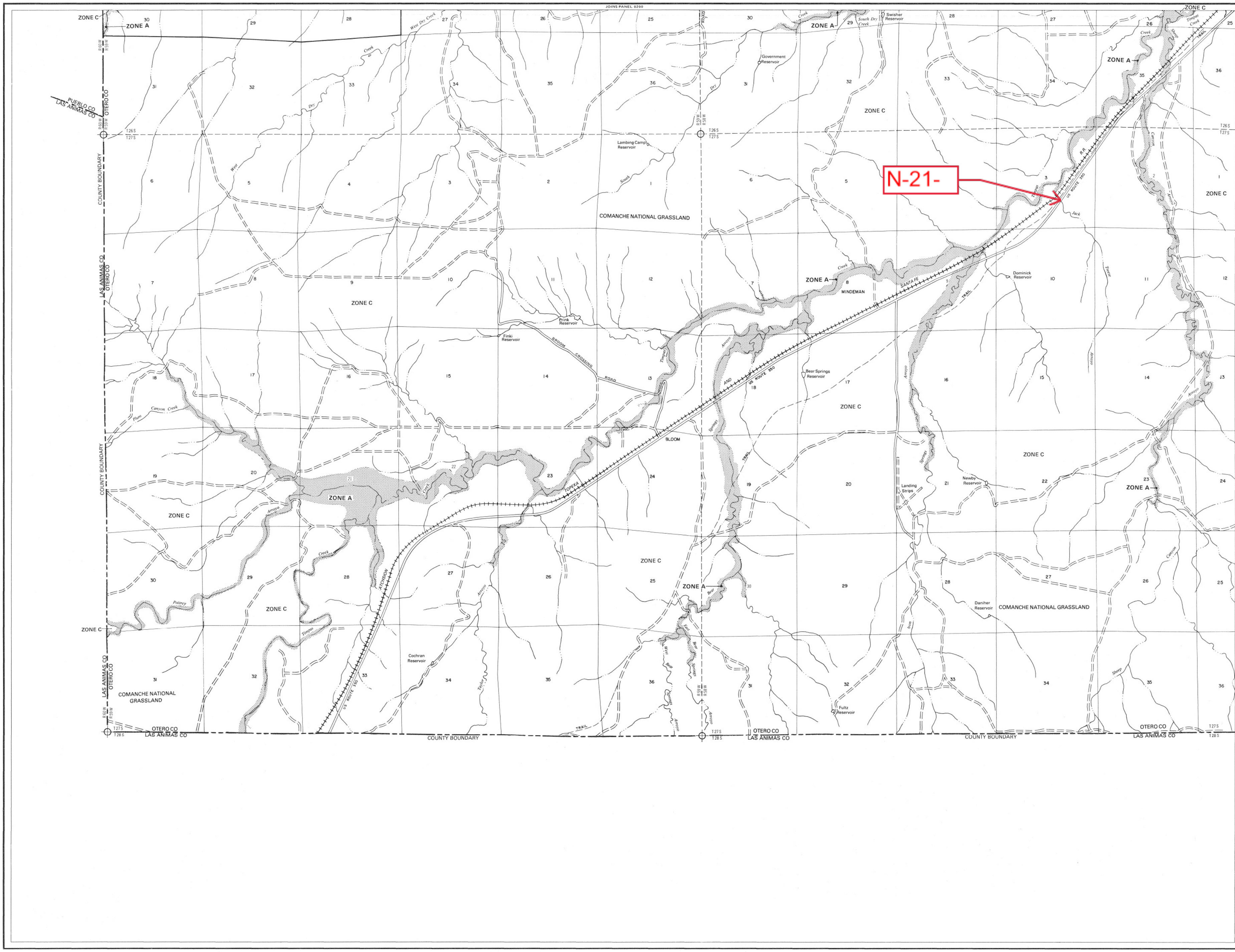
A two-dimensional model was developed to analyze the flows through the existing bridge and compare the WSEs and velocities to the proposed design. This model was utilized to optimize the proposed solution to replacement of the existing bridge.

Based on the hydraulic analysis, the proposed replacement for this bridge is a single 20'x10' reinforced concrete box culvert. Floodplain analysis demonstrates that the proposed culvert opening will not cause a rise in flood levels of more than 0.5 feet during the 100-year design event. This meets Colorado Water Conservation Board guidelines. The energy dissipation alternative selected for this RCBC outlet is a riprap apron. No floodplain development permit is required.

8. REFERENCES

1. “Colorado Department of Transportation Drainage Design Manual”, Colorado Department of Transportation, 2019.
2. Mile High Flood District, Urban Storm Drainage Criteria Manual (USDCM), Volumes I, II, and III, August 2018.
3. “Hydraulic Engineering Circular No. 18 – Evaluating Scour At Bridges Fifth Edition”. U.S. Department of Transportation Federal Highway Administration, April 2012.
4. “Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures”. U.S. Department of Transportation Federal Highway Administration, April 2012.
5. “Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance – Third Edition,” U.S. Department of Transportation, Federal Highway Administration, September 2009.
6. CDOT Region 2 2D Quick Check Hydrology Summary Report and Matrix, Colorado Department of Transportation, 2020

APPENDIX A FEMA FIRM



KEY TO MAP

SPECIAL FLOOD HAZARD AREA	ZONE A ZONE B
Base Flood Elevation Line With Elevation In Feet**	513
Base Flood Elevation in Feet Where Uniform Within Zone**	(EL 987)
Elevation Reference Mark	RM7×
Zone D Boundary	
River Mile	•M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION:
NOVEMBER 22, 1974

FLOOD HAZARD BOUNDARY MAP REVISIONS:
NOVEMBER 8, 1977

FLOOD INSURANCE RATE MAP EFFECTIVE:
AUGUST 19, 1985

Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620.

APPROXIMATE SCALE IN FEET
2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

OTERO COUNTY, COLORADO
(UNINCORPORATED AREAS)

PANEL 275 OF 325
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
080132 0275 B

EFFECTIVE DATE:
AUGUST 19, 1985

Federal Emergency Management Agency

APPENDIX B NRCS SOIL SURVEY

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for
Otero County, Colorado

November 16, 2020

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map


103° 53' 2" W
103° 52' 46" W
598370
598430
598490
598550
598610
598670
598730
37° 43' 24" N
37° 43' 6" N
4175690
4175630
4175570
4175510
4175450
4175390
4175330
4175270
4175210
Us Hwy 350
350
LoB
Mv
Soil Map may not be valid at this scale.
N
Map Scale: 1:2,610 if printed on A portrait (8.5" x 11") sheet.
Meters
0 35 70 140 210
Feet
0 100 200 400 600
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Otero County, Colorado
Survey Area Data: Version 18, Jun 5, 2020

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 31, 2020—Apr 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
LoB	Limon silty clay, 0 to 3 percent slopes	0.8	6.7%
Mv	Minnequa-Manvel silt loams, 1 to 6 percent slopes, dry	11.7	93.3%
Totals for Area of Interest		**12.6**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Otero County, Colorado

LoB—Limon silty clay, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 35kz
Elevation: 3,000 to 6,000 feet
Mean annual precipitation: 11 to 14 inches
Mean annual air temperature: 52 to 54 degrees F
Frost-free period: 120 to 160 days
Farmland classification: Not prime farmland

Map Unit Composition

Limon and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Limon

Setting

Landform: Flood plains, terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from shale

Typical profile

A - 0 to 12 inches: silty clay
C1 - 12 to 40 inches: silty clay
C2 - 40 to 68 inches: loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Gypsum, maximum content: 2 percent
Maximum salinity: Very slightly saline to moderately saline (2.0 to 8.0 mmhos/cm)
Sodium adsorption ratio, maximum: 10.0
Available water capacity: High (about 10.3 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: C
Ecological site: R069XY033CO - Salt Flat LRU's A & B
Other vegetative classification: Salt Flat (069AY033CO_1)
Hydric soil rating: No

Minor Components

Haverson
Percent of map unit: 1 percent
Hydric soil rating: No

Manzanola
Percent of map unit: 1 percent
Hydric soil rating: No

Rocky ford
Percent of map unit: 1 percent
Hydric soil rating: No

Mv—Minnequa-Manvel silt loams, 1 to 6 percent slopes, dry

Map Unit Setting
National map unit symbol: 2rgqm
Elevation: 4,000 to 6,000 feet
Mean annual precipitation: 10 to 12 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 130 to 170 days
Farmland classification: Not prime farmland

Map Unit Composition
Minnequa, dry, and similar soils: 55 percent
Manvel, dry, and similar soils: 30 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Minnequa, Dry

Setting
Landform: Pediments, ridges
Landform position (two-dimensional): Summit, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear, convex
Parent material: Slope alluvium and/or residuum weathered from limestone and shale

Typical profile
A - 0 to 6 inches: silt loam
Bw - 6 to 17 inches: silt loam
Bk - 17 to 35 inches: silty clay loam
Cr - 35 to 60 inches: bedrock

Properties and qualities
Slope: 1 to 6 percent
Depth to restrictive feature: 20 to 39 inches to paralithic bedrock
Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 45 percent
Gypsum, maximum content: 5 percent
Maximum salinity: Nonsaline to slightly saline (0.1 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum: 8.0
Available water capacity: Low (about 5.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Forage suitability group: Loamy (G069XW017CO)
Other vegetative classification: Loamy (G069XW017CO)
Hydric soil rating: No

Description of Manvel, Dry

Setting

Landform: Fans, interfluves
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Alluvium derived from limestone and shale

Typical profile

A - 0 to 7 inches: silt loam
Bk1 - 7 to 25 inches: silt loam
Bk2 - 25 to 49 inches: silt loam
Bk3 - 49 to 79 inches: silt loam

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Gypsum, maximum content: 3 percent
Maximum salinity: Nonsaline to moderately saline (1.0 to 8.0 mmhos/cm)
Sodium adsorption ratio, maximum: 5.0
Available water capacity: Moderate (about 8.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Forage suitability group: Loamy, Limy (G069XW022CO)

Other vegetative classification: Loamy Plains #6 (069XY006CO_2), Loamy, Limy (G069XW022CO)
Hydric soil rating: No

Minor Components

Manvel, deep, dry

Percent of map unit: 10 percent
Landform: Fans, interfluves
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Other vegetative classification: Loamy Plains #6 (069XY006CO_2), Loamy, Limy (G069XW022CO)
Hydric soil rating: No

Penrose

Percent of map unit: 5 percent
Landform: Hogbacks, hills, scarps
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Ecological site: R069XY058CO - Limestone Breaks LRU's A & B
Other vegetative classification: Limestone Breaks #58 (069XY058CO_2), Not Suited (G069XW000CO)
Hydric soil rating: No

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APPENDIX C AERIAL IMAGERY AND PHOTOS

APPENDIX C – AERIAL IMAGERY AND PHOTOS

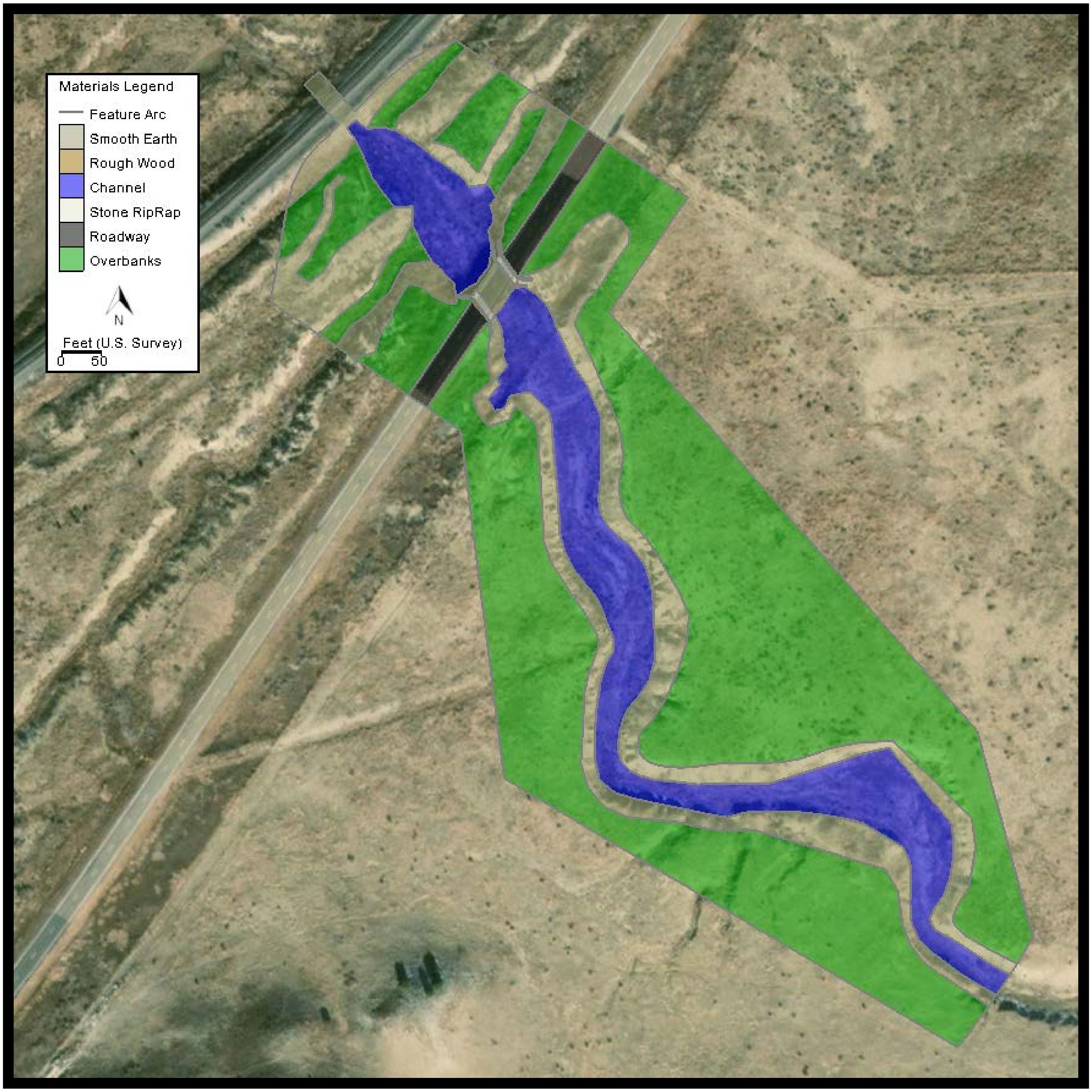
STRUCTURE N-21-C

FIGURE C1

Figure C2: Looking Downstream

Figure C3: Looking Upstream

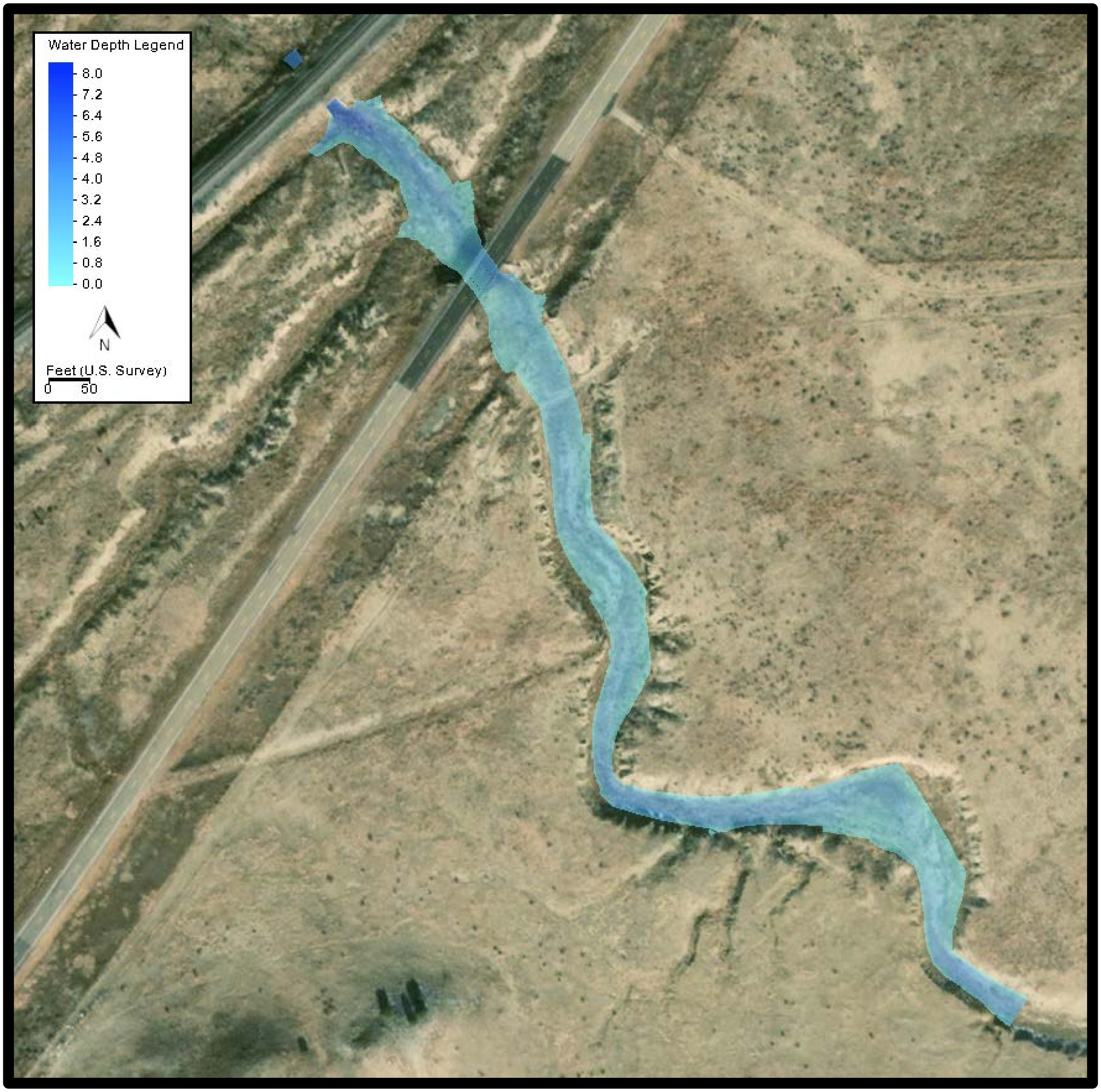
APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS



APPENDIX D – MATERIALS COVERAGE

STRUCTURE N-21-C

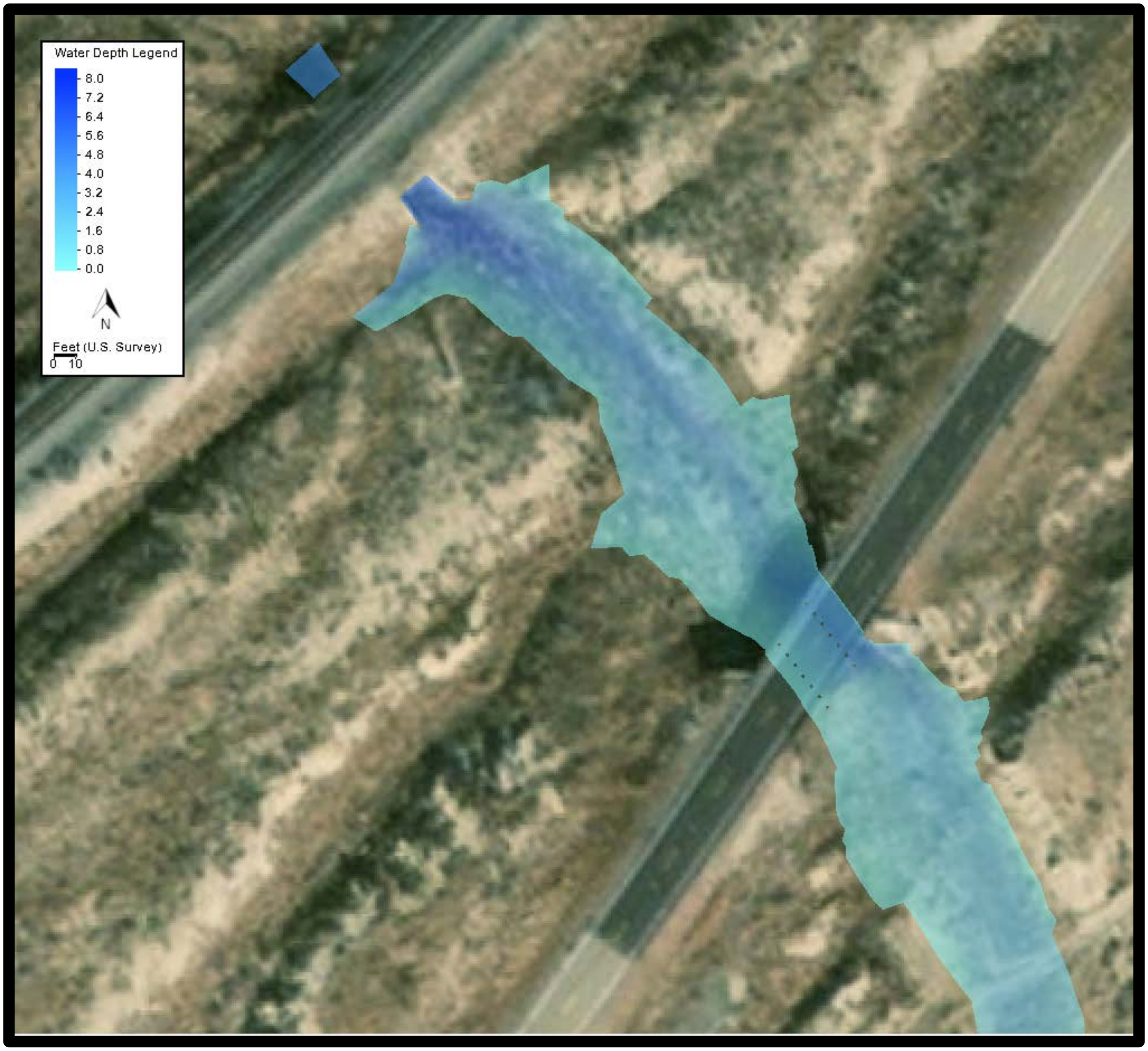
FIGURE D1



APPENDIX D – EXISTING CONDITIONS – WATER DEPTH

STRUCTURE N-21-C

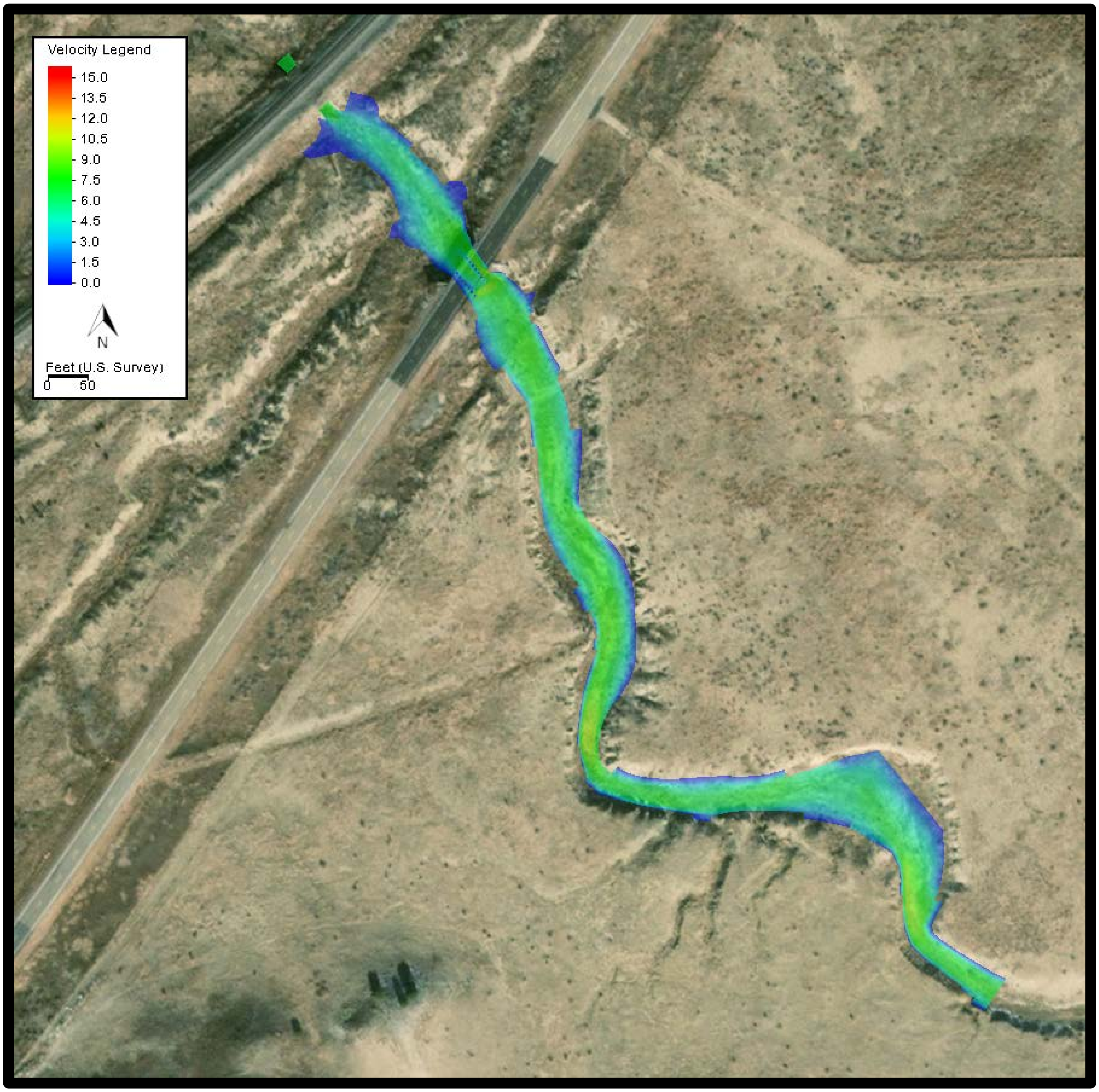
FIGURE D2



APPENDIX D – EXISTING CONDITIONS – WATER DEPTH

STRUCTURE N-21-C

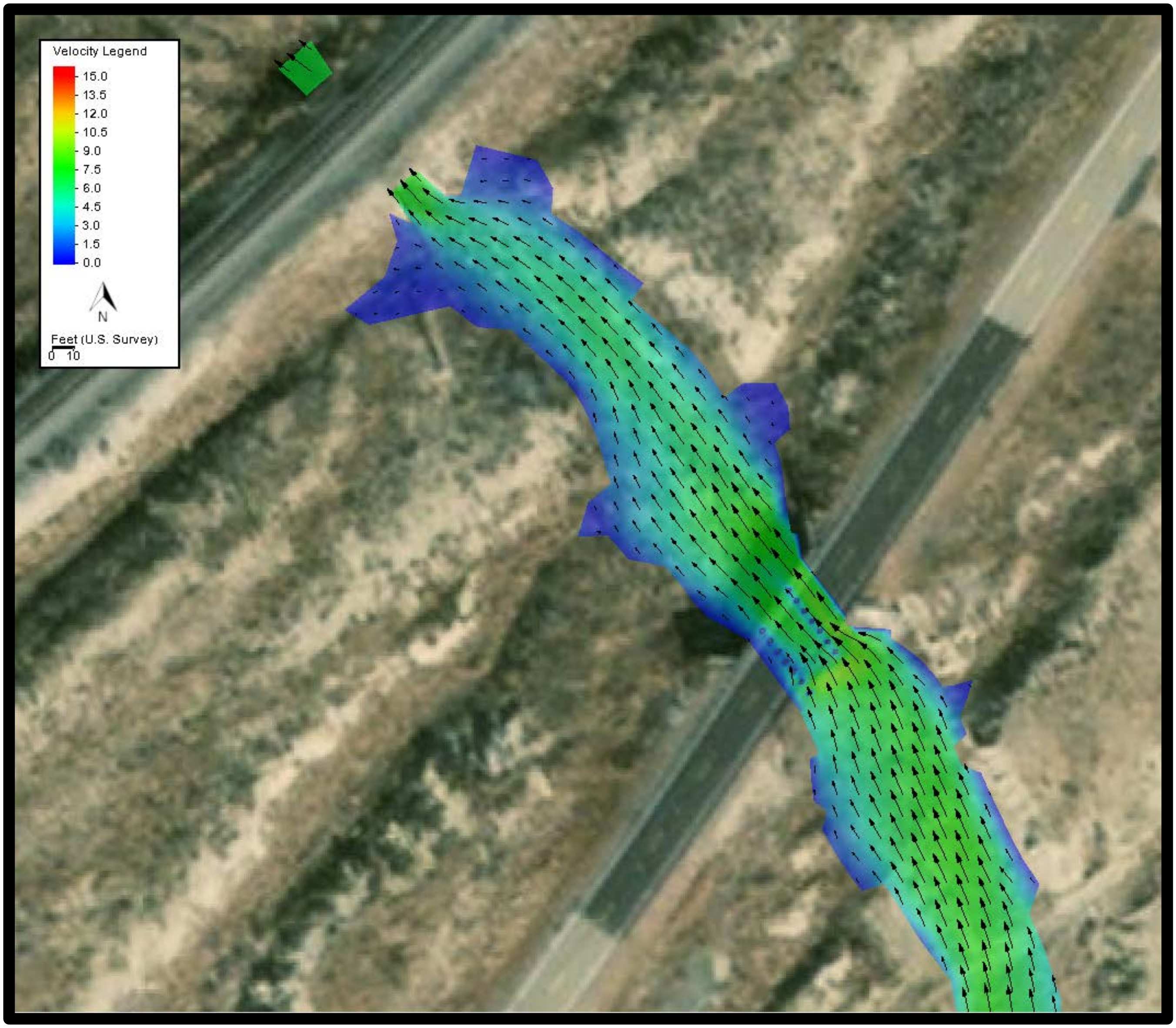
FIGURE D3



APPENDIX D – EXISTING CONDITIONS – VELOCITY

STRUCTURE N-21-C

FIGURE D4

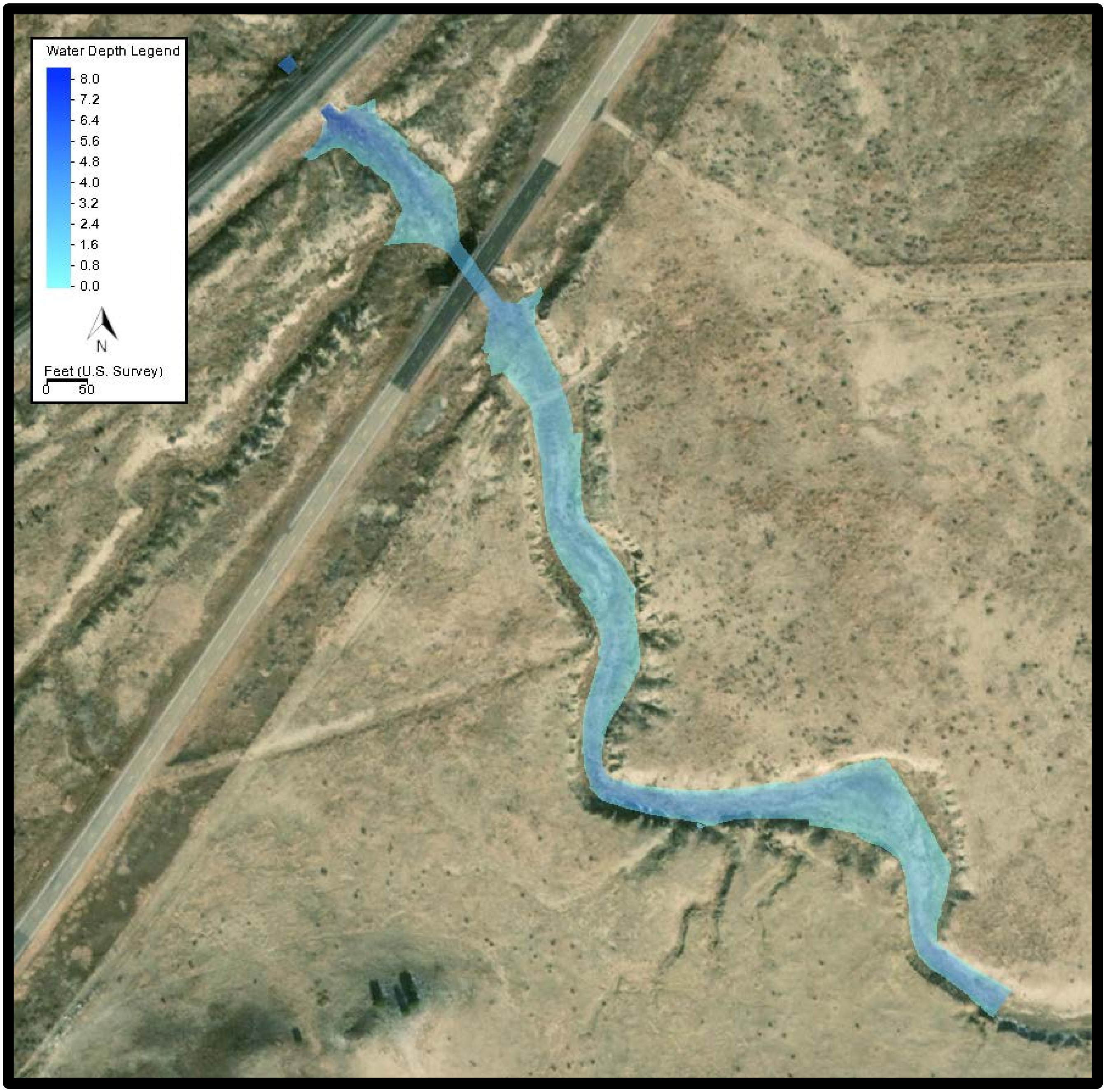


APPENDIX D – EXISTING CONDITIONS – VELOCITY

STRUCTURE N-21-C

FIGURE D5

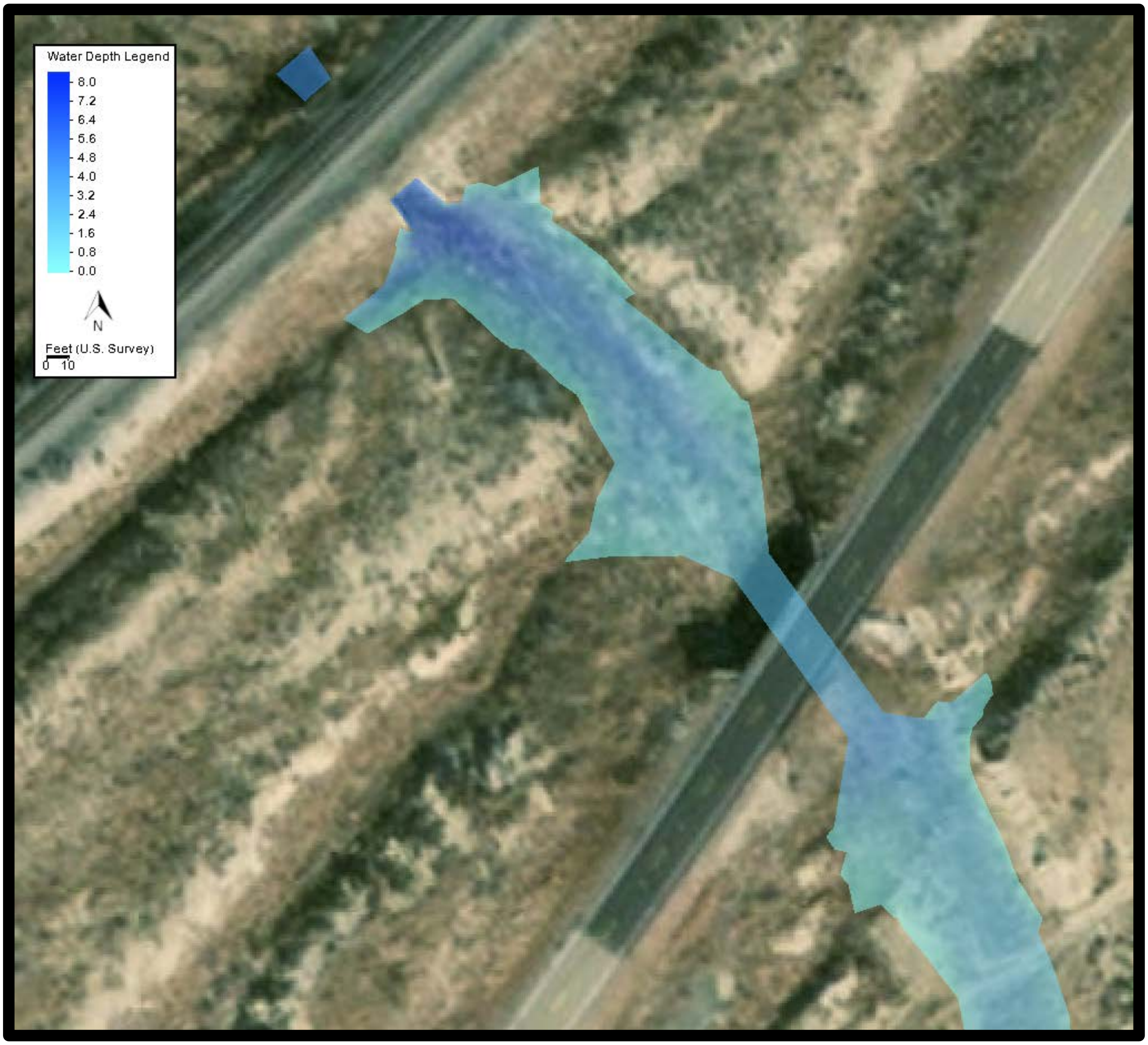
APPENDIX E EXISTING CONDITIONS MODEL GRAPHICS

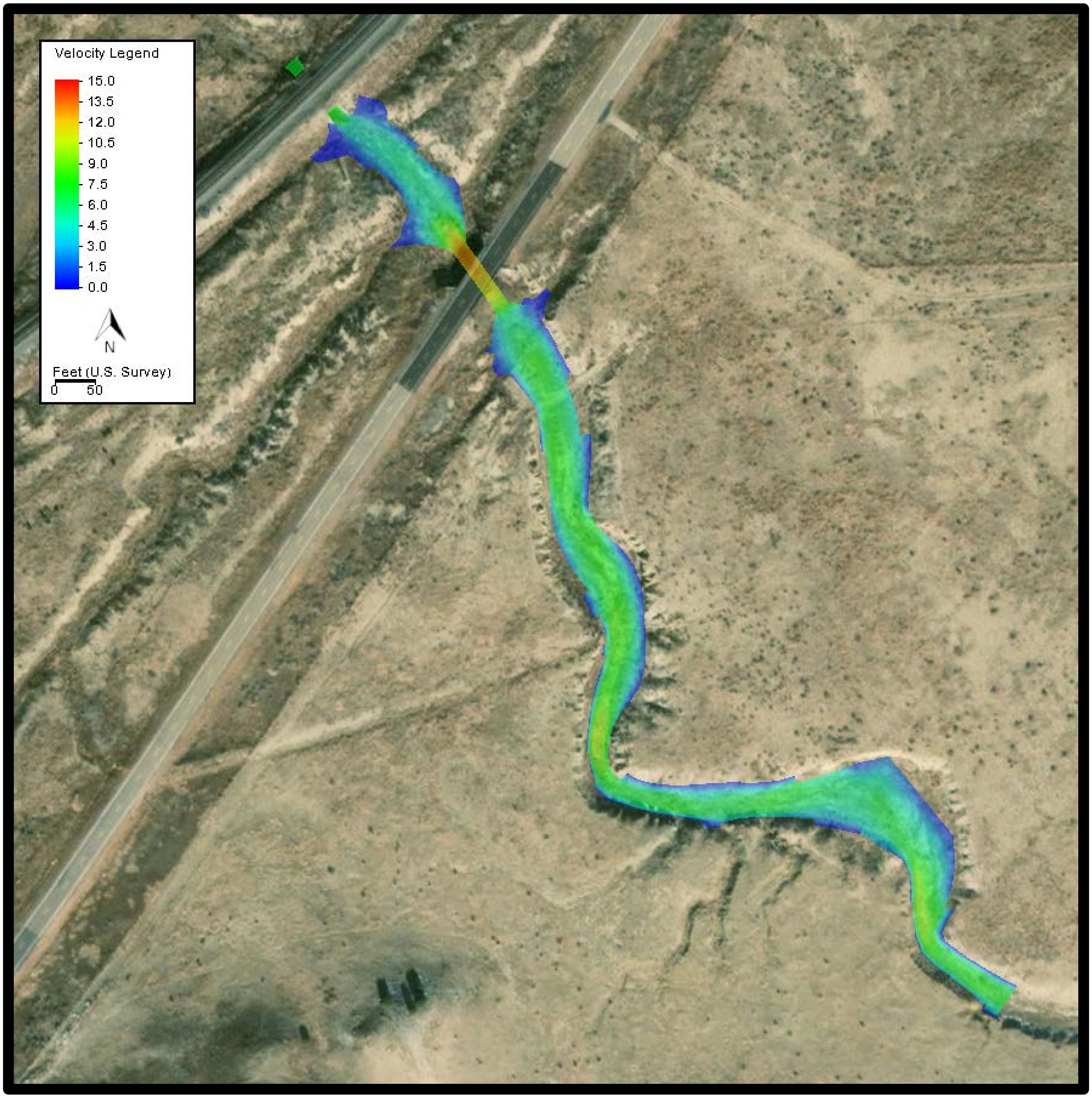


APPENDIX E – PROPOSED RCBC – WATER DEPTH

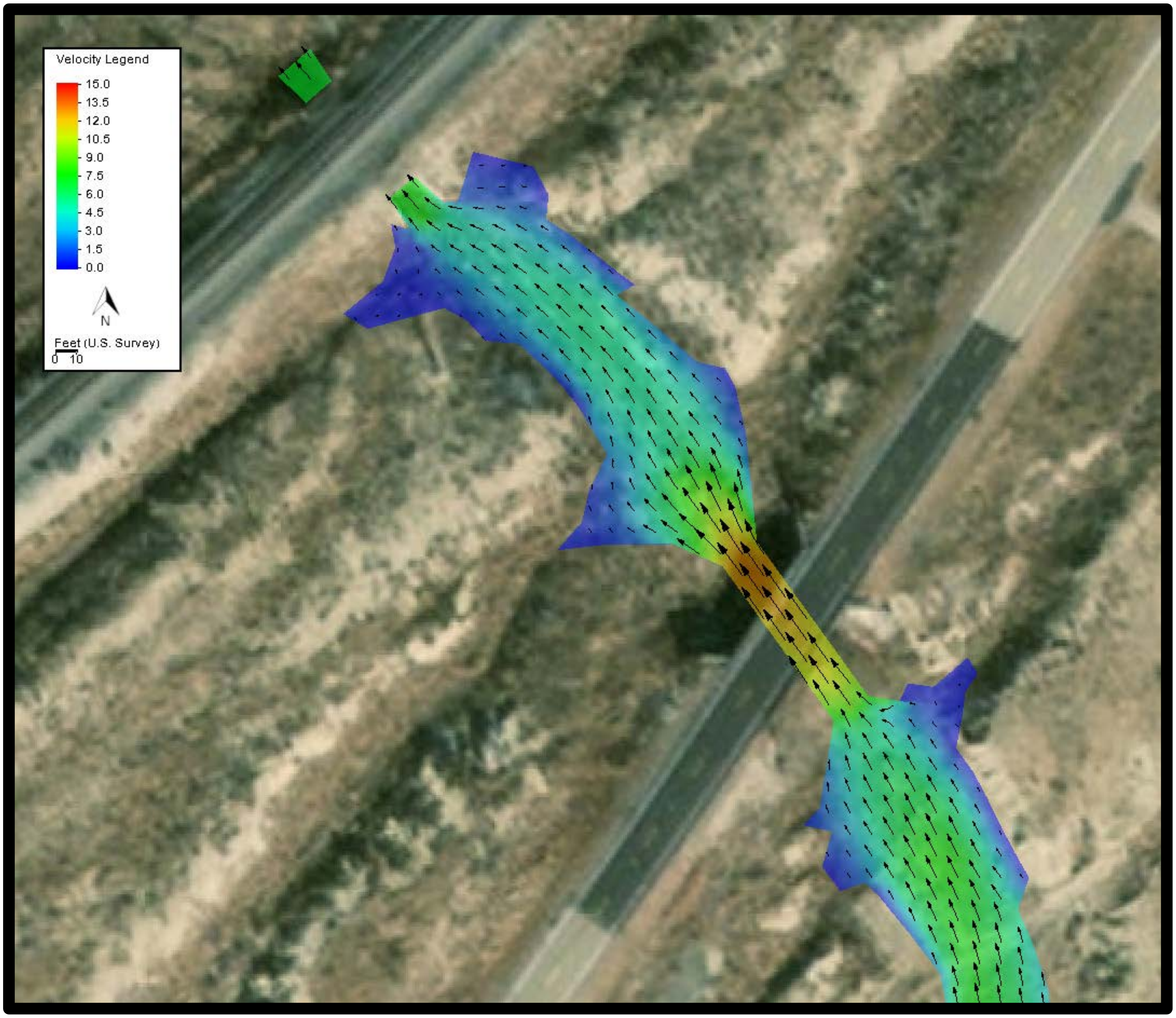
STRUCTURE N-21-C

FIGURE E1


Water Depth Legend
8.0
7.2
6.4
5.6
4.8
4.0
3.2
2.4
1.6
0.8
0.0
N
Feet (U.S. Survey)
0 10



APPENDIX E – PROPOSED RCBC – VELOCITY
STRUCTURE N-21-C
FIGURE E3

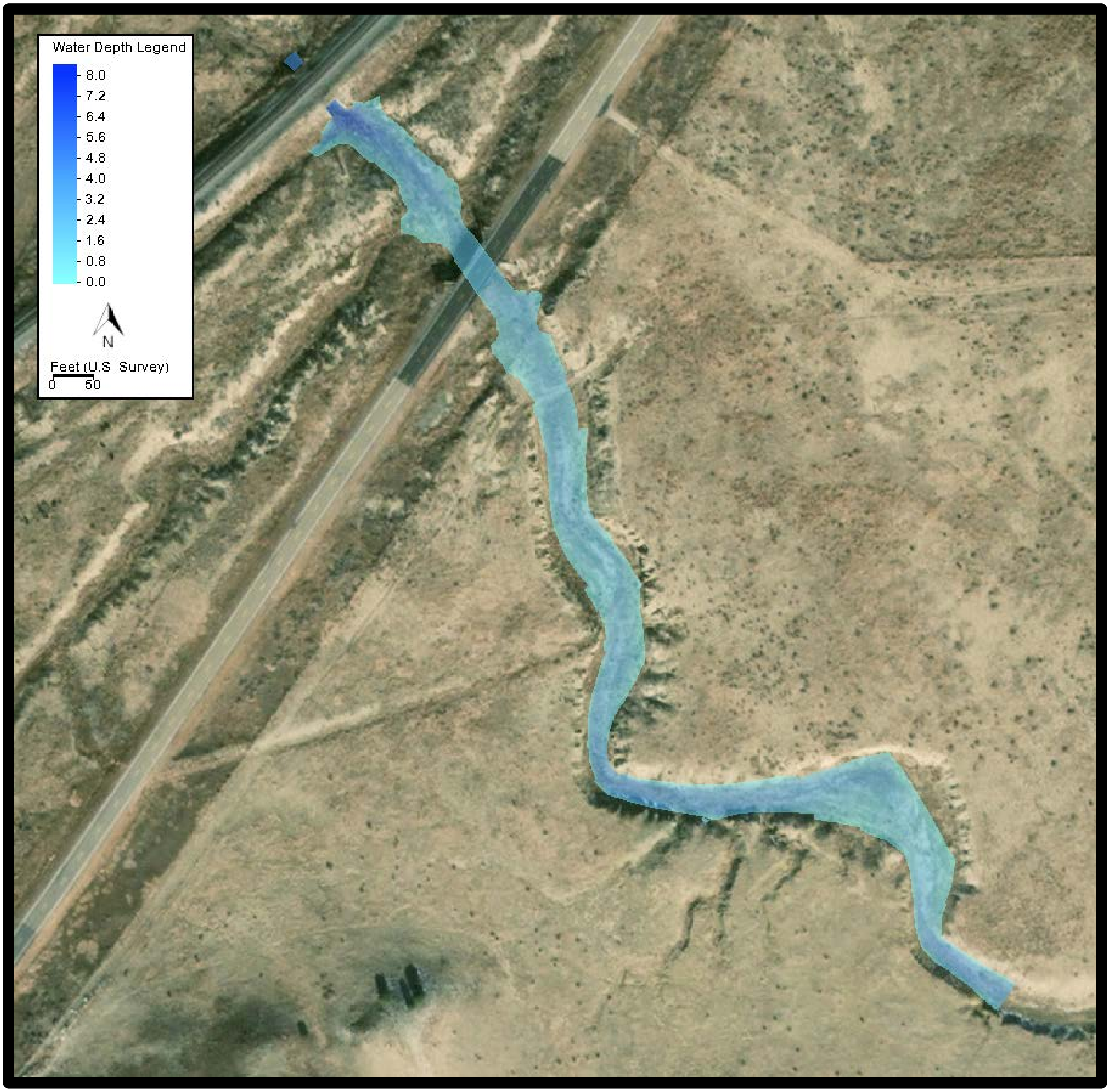


APPENDIX E – PROPOSED RCBC – VELOCITY

STRUCTURE N-21-C

FIGURE E4

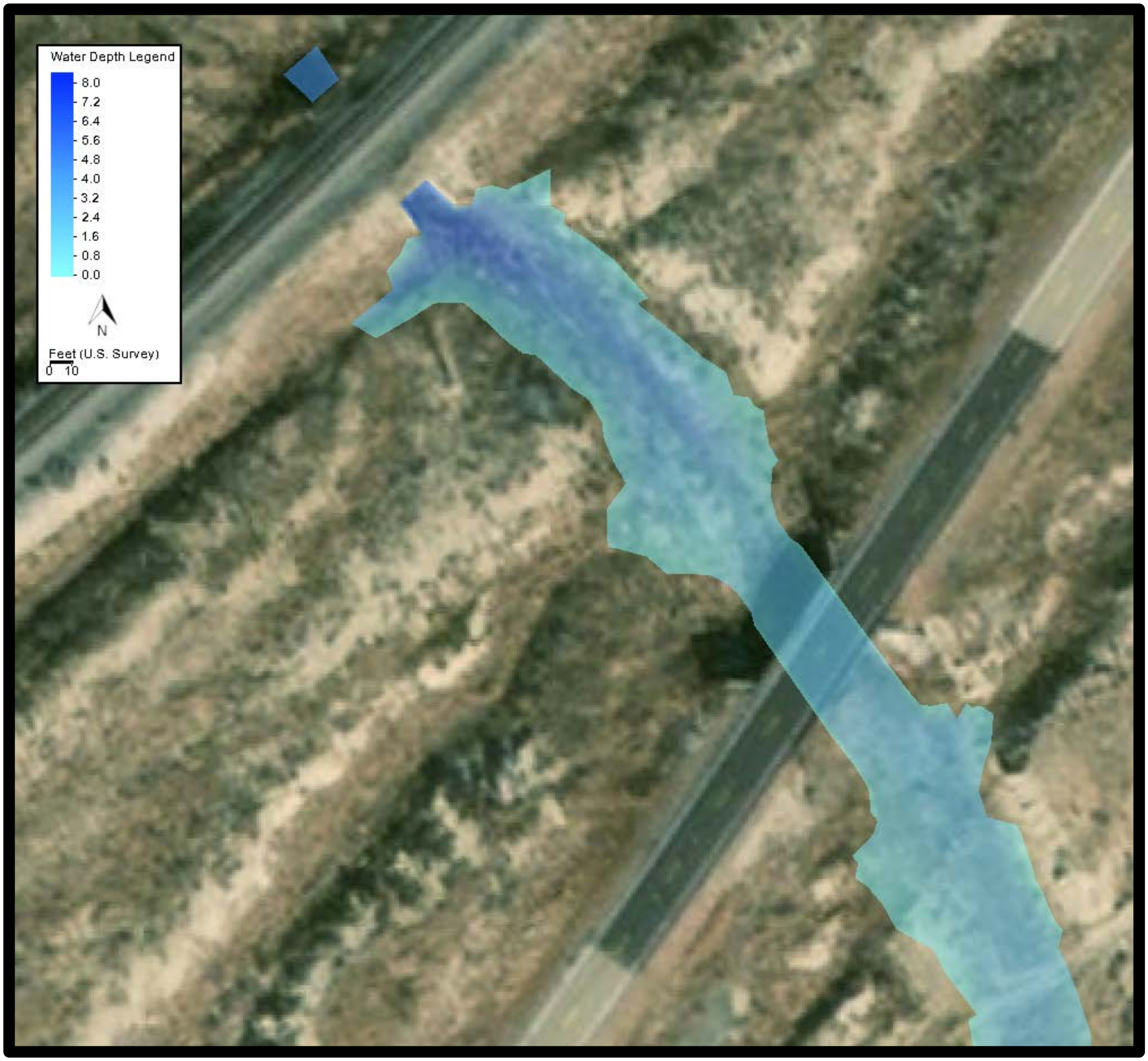
APPENDIX F PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS



APPENDIX F – PROPOSED BRIDGE – WATER DEPTH

STRUCTURE N-21-C

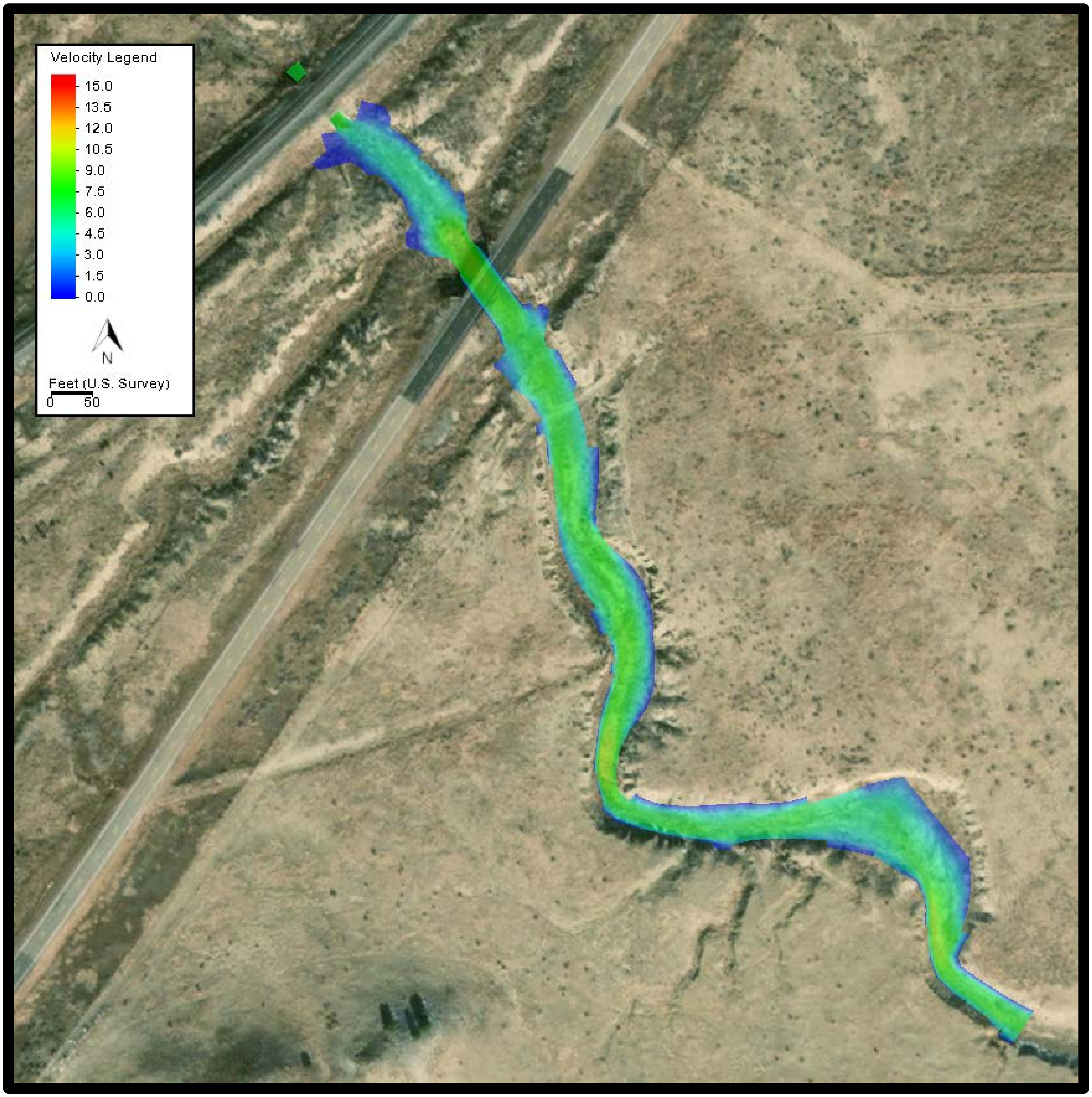
FIGURE F1



APPENDIX F – PROPOSED BRIDGE – WATER DEPTH

STRUCTURE N-21-C

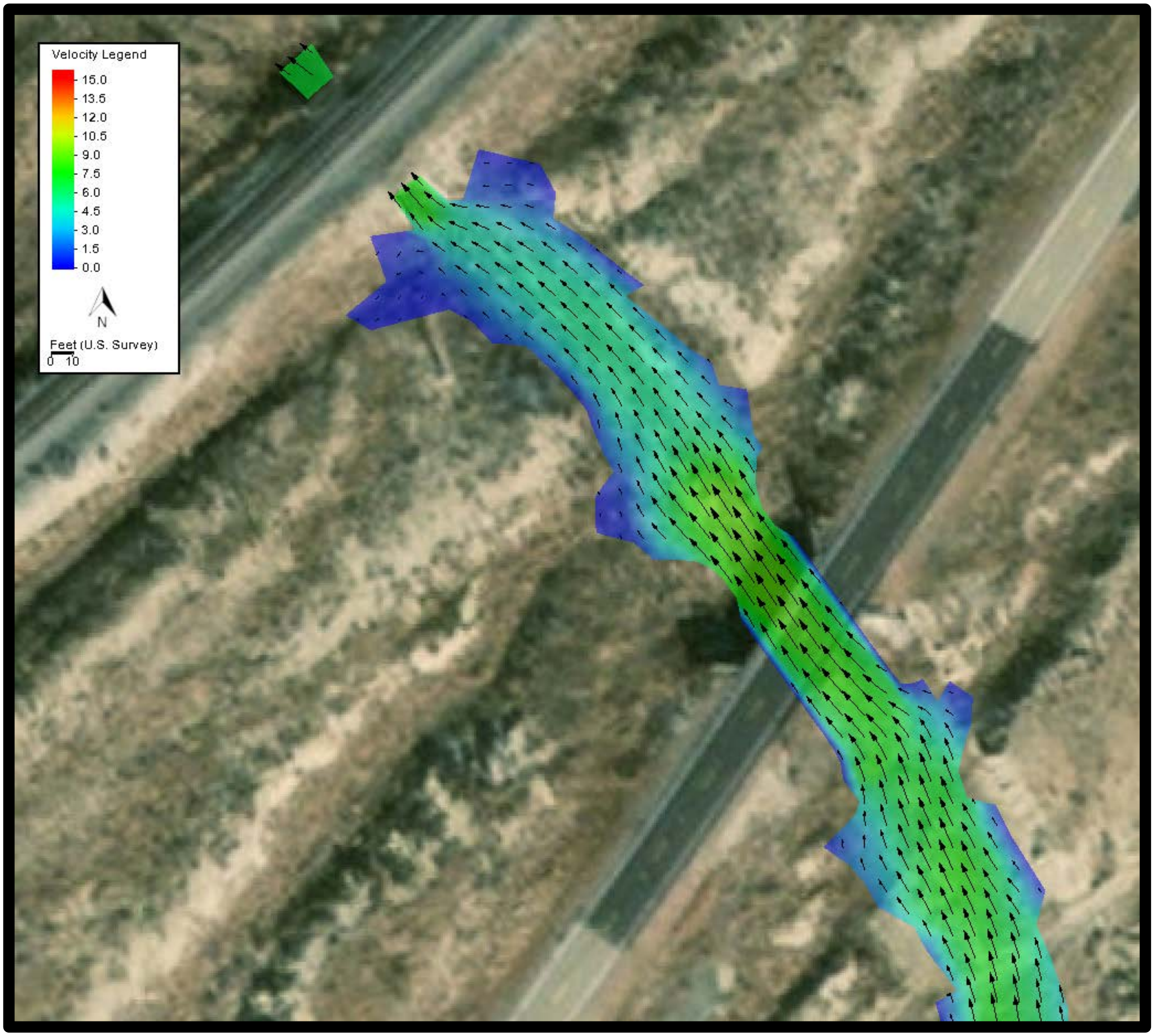
FIGURE F2



APPENDIX F – PROPOSED BRIDGE – VELOCITY

STRUCTURE N-21-C

FIGURE F3

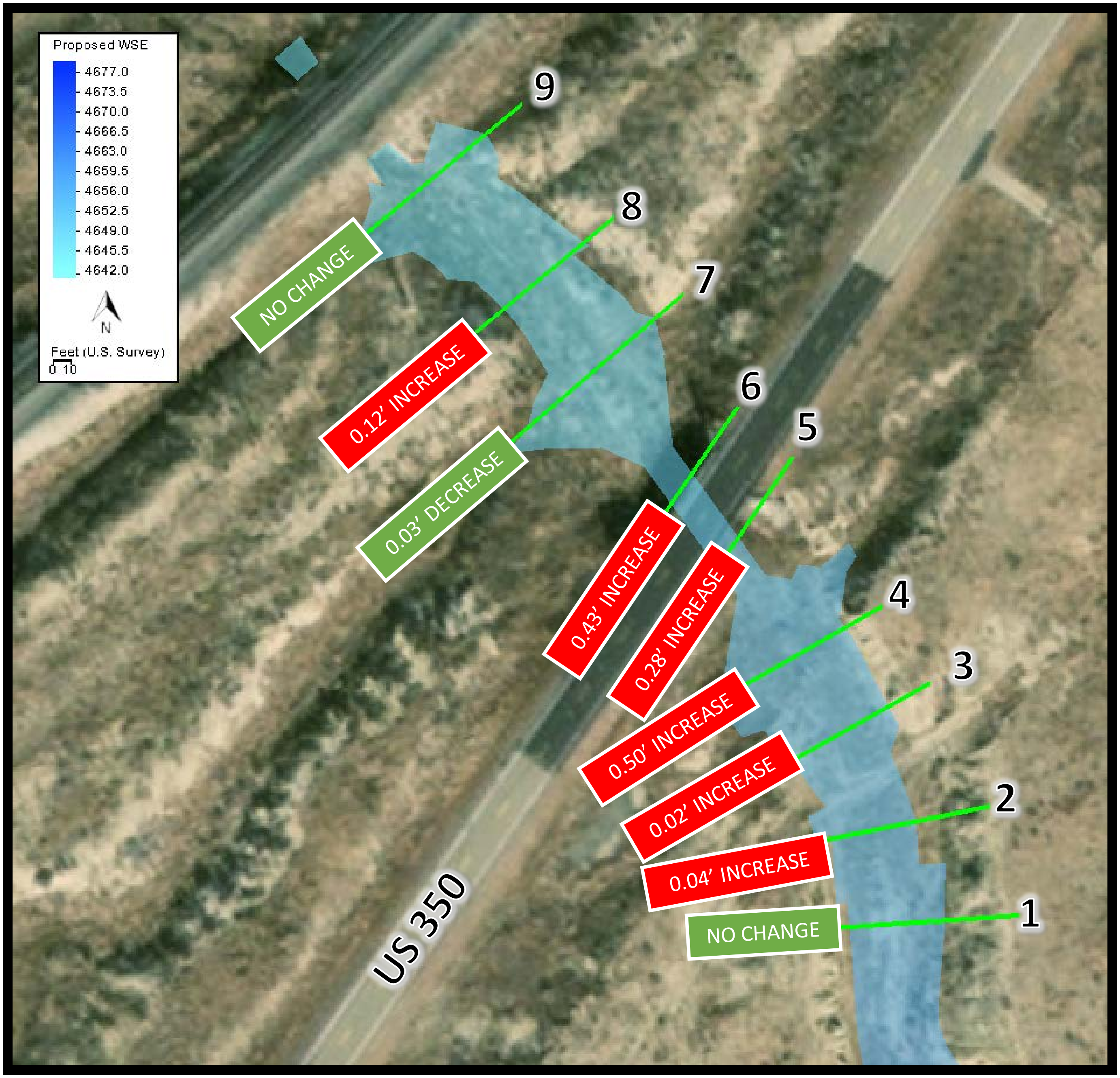


APPENDIX F – PROPOSED BRIDGE – VELOCITY

STRUCTURE N-21-C

FIGURE F4

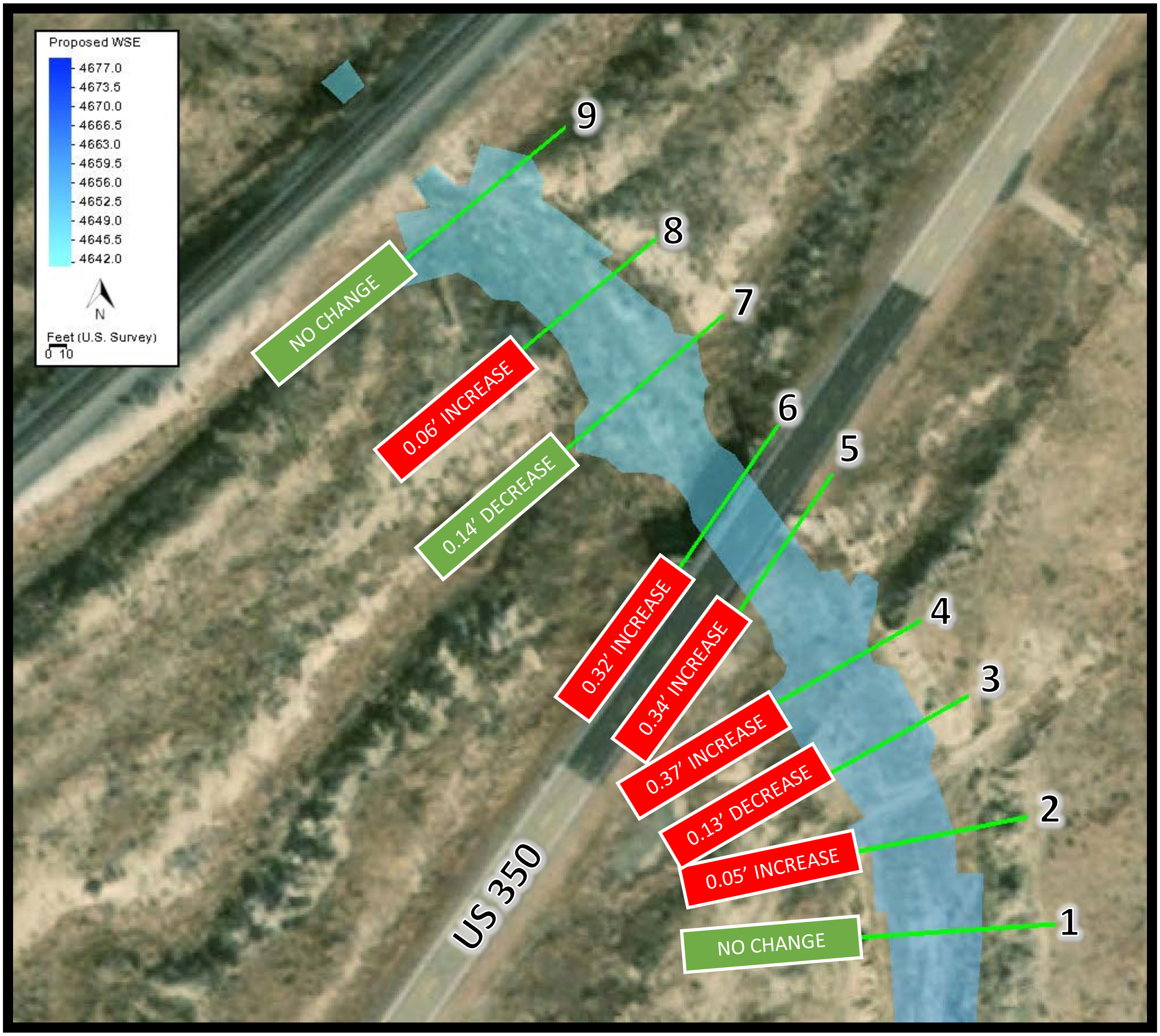
APPENDIX G WATER SURFACE ELEVATION COMPARISON GRAPHICS



APPENDIX G – RCBC – WSE COMPARISON

STRUCTURE N-21-C

FIGURE G1



Proposed WSE
4677.0
4673.5
4670.0
4666.5
4663.0
4659.5
4656.0
4652.5
4649.0
4645.5
4642.0
N
Feet (U.S. Survey)
0 10
9
NO CHANGE
8
0.06' INCREASE
7
0.14' DECREASE
6
0.32' INCREASE
5
0.34' INCREASE
4
0.37' INCREASE
3
0.13' DECREASE
2
0.05' INCREASE
1
NO CHANGE
US 350

APPENDIX H RCBC OUTLET ENERGY DISSIPATION CALCULATIONS

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	N-21-C	
Culvert	Culvert 1	
Flow	389.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	20.0	ft
Culvert Height	10.0	ft
Outlet Depth	1.64	ft
Outlet Velocity	11.88	ft/s
Froude Number	1.64	
Tailwater Depth	1.48	ft
Tailwater Velocity	6.77	ft/s
Tailwater Slope (SO)	0.0100	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.30	mm
D84 Value	25.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	9.13	
Scour Hole Dimensions		
Length	47.560	ft
Width	26.266	ft
Depth	4.898	ft
Volume	7562.488	ft^3
DS at .4(LS)	19.024	ft
Tailwater Depth (TW)	1.478	ft
Velocity with TW and WS	7.490	ft/s

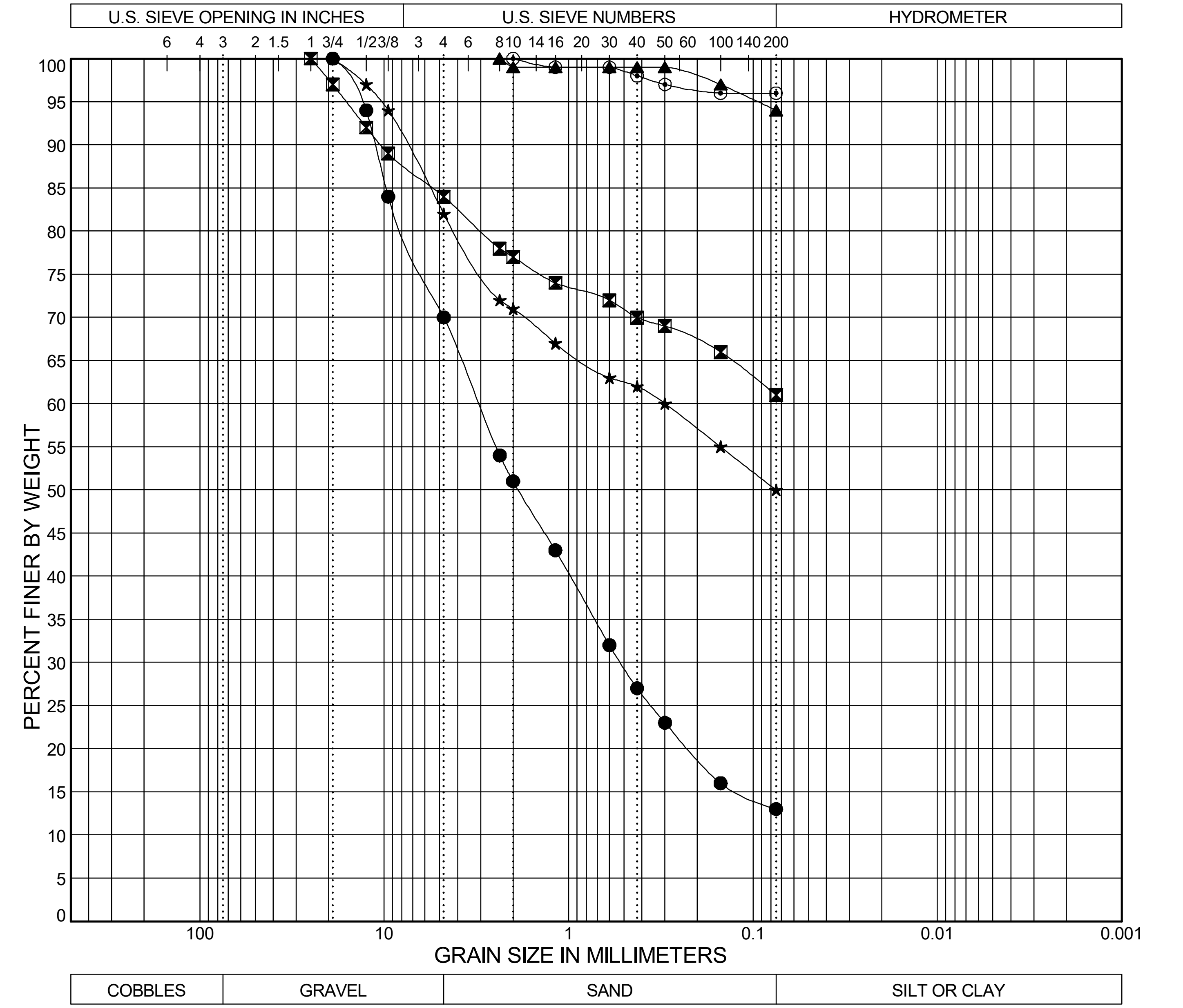
HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	N-21-C	
Culvert	Culvert 1	
Flow	389.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	20.0	ft
Culvert Height	10.0	ft
Outlet Depth	1.64	ft
Outlet Velocity	11.88	ft/s
Froude Number	1.64	
Tailwater Depth	1.48	ft
Tailwater Velocity	6.77	ft/s
Tailwater Slope (SO)	0.0100	
External Dissipator Data		
External Dissipator Category	Streambed Level Structures	
External Dissipator Type	Riprap Basin	
Restrictions		
Froude Number	<3	
Input Data		
Condition to be used to Compute Basin Outlet Velocity	Envelope Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.519 ft	
D50 of the Riprap Mixture	0.500	ft
DMax of the Riprap Mixture	1.000	ft
Results		
Brink Depth	1.638	ft
Brink Velocity	11.878	ft/s
Depth (YE)	1.638	ft
Riprap Thickness	1.500	ft
Riprap Foreslope	2.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.262	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.305	
D50/YE Check	D50/YE is OK	

Basin Length (LB)	80.000	ft
Basin Width	73.333	ft
Apron Length	20.000	ft
Pool Length	60.000	ft
Pool Depth (HS)	1.131	ft
TW/YE	0.903	
Tailwater Depth (TW)	1.478	ft
Average Velocity with TW	3.450	ft/s
Critical Depth (Yc)	0.948	ft
Average Velocity with Yc	5.453	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	5.819	ft/s
Size	0.221	ft
Distance: 2 LB		
Velocity	2.895	ft/s
Size	0.055	ft
Distance: 3 LB		
Velocity	1.924	ft/s
Size	0.024	ft
Distance: 4 LB		
Velocity	1.440	ft/s
Size	0.014	ft

APPENDIX I GEOTECHNICAL INFOMATION



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
●	**N-21-C-B-1**	**2.0**	**A-1-b (0)**	**SM**	**18**	**17**	**1**	**30.0**	**57.0**	**13.0**	
⧗	**N-21-C-B-1**	**10.0**	**A-6 (8)**	**CL**	**34**	**16**	**18**	**16.0**	**23.0**	**61.0**	
▲	**N-21-C-B-1**	**25.0**	**A-6 (20)**	**CL**	**38**	**17**	**21**	**0.0**	**6.0**	**94.0**	
★	**N-21-C-B-2**	**10.0**	**A-6 (6)**	**CL**	**32**	**13**	**19**	**18.0**	**32.0**	**50.0**	
⊙	**N-21-C-B-2**	**20.0**	**A-7-6 (29)**	**CL**	**46**	**17**	**29**	**0.0**	**4.0**	**96.0**	

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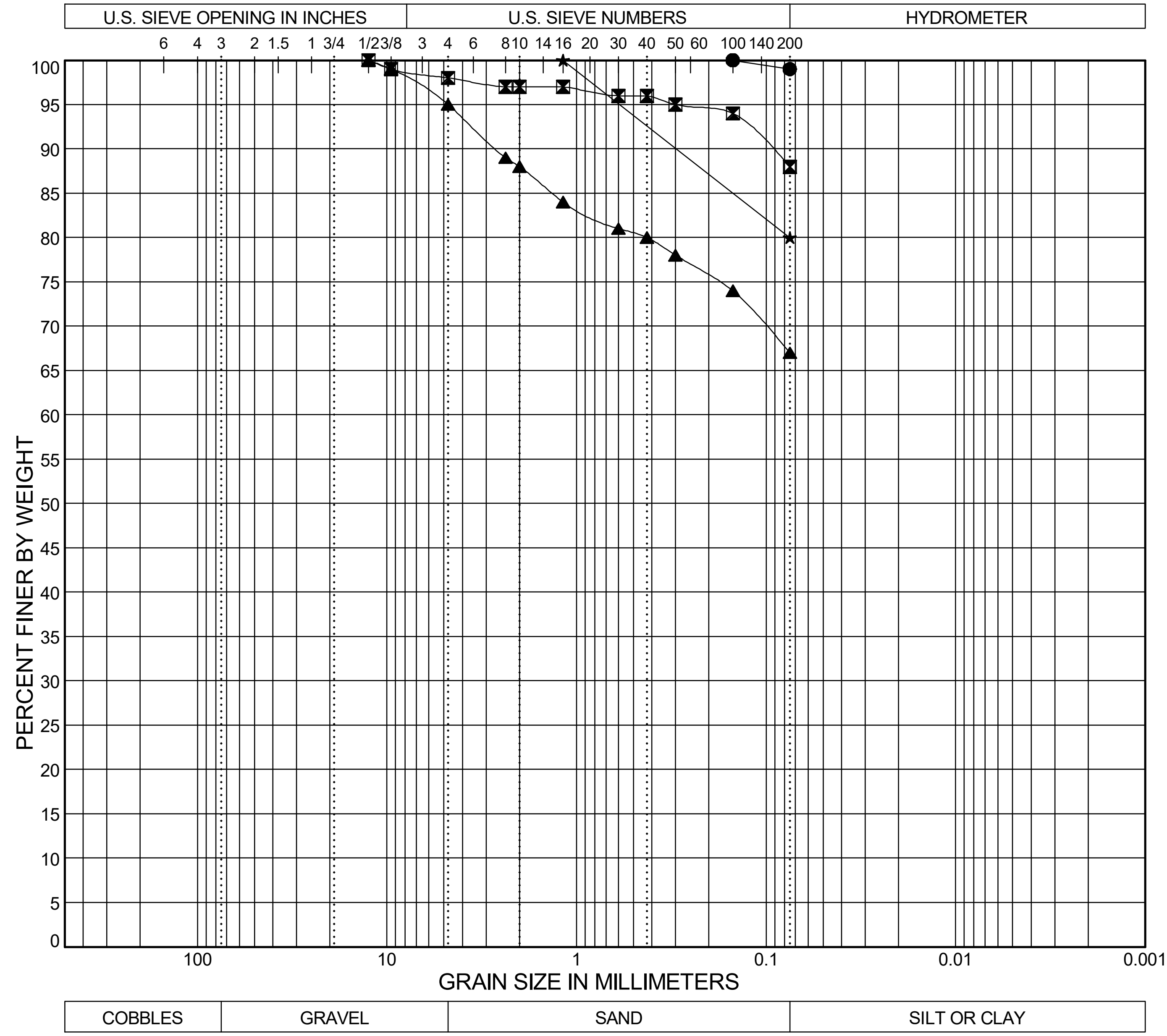
SIEVE ANALYSIS

FIGURE C- 1

Project No. 220-063 Date: 11-13-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure N-21-C



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**N-21-C-B-2**	**45.0**	**A-6 (12)**	**CL**	**31**	**19**	**12**	**0.0**	**1.0**	**99.0**	
⌧	**N-21-C-P-1**	**1.0**	**A-6 (12)**	**CL**	**32**	**17**	**15**	**2.0**	**10.0**	**88.0**	
▲	**N-21-C-P-1/P-2**	**2.5**	**A-6 (9)**	**CL**	**31**	**14**	**17**	**5.0**	**28.0**	**67.0**	
★	**N-21-C-P-2**	**4.0**	**A-6 (14)**	**CL**	**35**	**16**	**19**	**0.0**	**20.0**	**80.0**	

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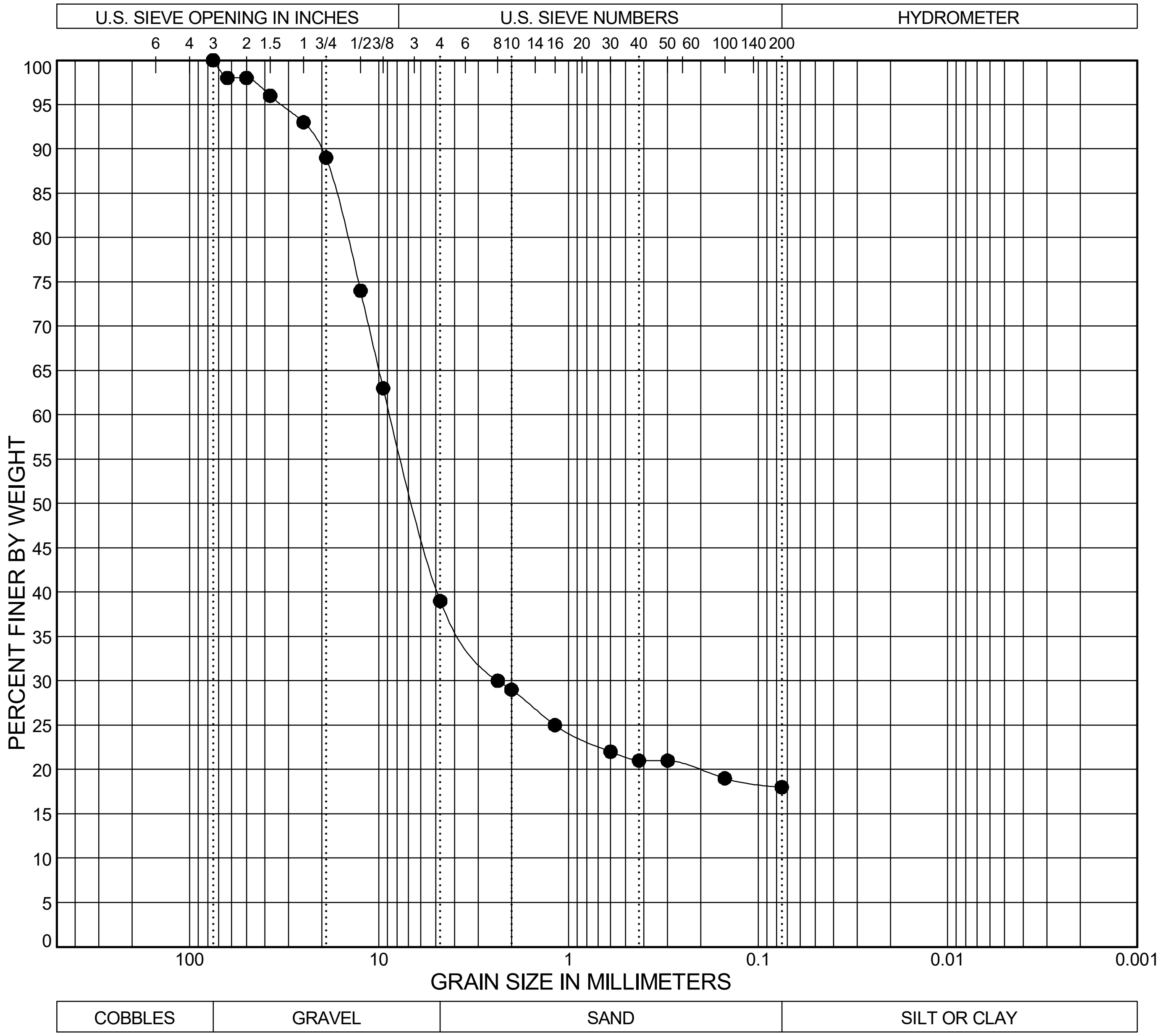
SIEVE ANALYSIS

FIGURE C- 2

Project No. 220-063 Date: 11-13-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure N-21-C



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**N-21-C Scour**	**0.0**						**61.0**	**21.0**	**18.0**	

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SIEVE ANALYSIS

FIGURE C- 3

Project No.	220-063	Date:	11-13-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

CDOT Region 2 Bridge Bundle
Structure N-21-C

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/13/20