PRELIMINARY HYDRAULICS REPORT
STRUCTURE I-15-T REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
TELLER COUNTY, COLORADO

A Part of Section 6, Township 13 South, Range 70 West of the 6th P.M.,
County of Teller, Colorado

February 12, 2021

Prepared for:

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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 I-15-T as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Teller County at Mile Post 271.691 along US 24 between Florissant and Divide. Structure I-15-T crosses over Twin Creek. Figure 1 below illustrates the project location. The project is located in Section 6, Township 13 South, Range 70 West of the 6th P.M., County of Teller, Colorado. Figure 1 shows the project limits.

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

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone X, as determined by the Flood Insurance Rate Maps (FIRM) #08119C0160D effective date September 25, 2009, as shown in **Appendix A**. FEMA Zone X is an area of minimal flood hazard risk. Since I-15-T 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 I-15-T falls into this category, but because the existing structure passes the 100-year flows, the proposed structures must be sized accordingly.

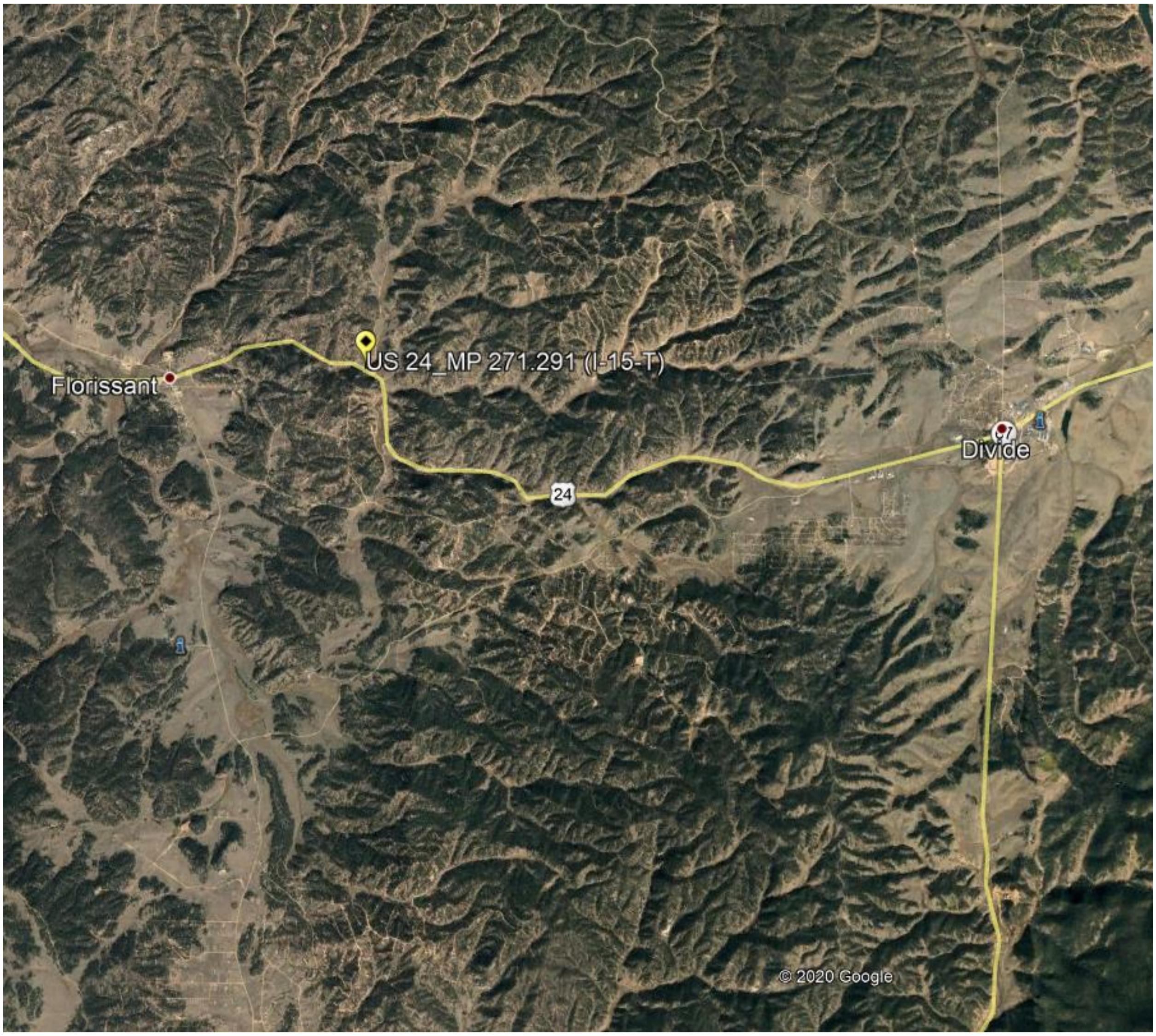


Figure 1: Vicinity Map

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 for structure I-15-T.

Twin Creek runs parallel to US 24 on the downstream side. Structure I-15-T flows combine with Twin Creek just downstream of the existing structure. Flows for Twin Creek were not provided by CDOT, and no published hydrology study was readily available. The drainage area of the Twin Creek basin is 18.1 square miles. A USGS StreamStats analysis was completed for Twin Creek. The flows produced by this analysis are much lower than the hydrology study for I-15-T produced. Further analysis will be required to more accurately depict the tailwater effect on structure I-15-T in the final design.

Table 1: Summary of Peak Discharge for Bridge I-15-T

River Location	Design Storm	25-year (cfs)	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	100-year	422	762	970	1294
Twin Creek	100-year	144	212	241	292

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing I-15-T structure is a two-cell 10 ft x 8 ft, concrete box culvert built in 1937 to allow for the seasonal wash to cross under State Highway (SH) 24. The structure has no skew and is 41.0 feet long. The existing culvert has four concrete wingwalls, one at each corner, which vary in length. The seasonal wash flows into Twin Creek which runs parallel to US 24 on the south side.

3.2 Watershed Overview

The unnamed seasonal wash is a dry tributary that flows from northeast to southwest under SH 24 and flows into Twin Creek. Twin Creek is a dry creek that flows from the southeast to the northwest and is south of SH 24. The seasonal wash watershed tributary to Twin Creek is approximately 3.75 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 approximate angle of attack of 90 degrees to the existing structure. The area surrounding the bridge is rural with undeveloped land to both upstream and downstream sides of the bridge. The upstream watershed included steep mountainous terrain, with areas of dense pine forest and areas of grass.

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 vertical cracking in the walls of the concrete culvert and stream abrasion and exposed rebar throughout. Heavy disintegration with loose coarse aggregate and exposed reinforcement was also observed in wing walls as well as degradation of the culvert headwalls. 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 high (significant) based on guidance from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 20. The flowchart for potential debris production is presented in Figure 2. The channel banks near the bridge are vegetated with tall grasses and shrubs, and several trees are present in the channel both upstream and downstream of the existing structure, as confirmed with the site visit in August, 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix C**.

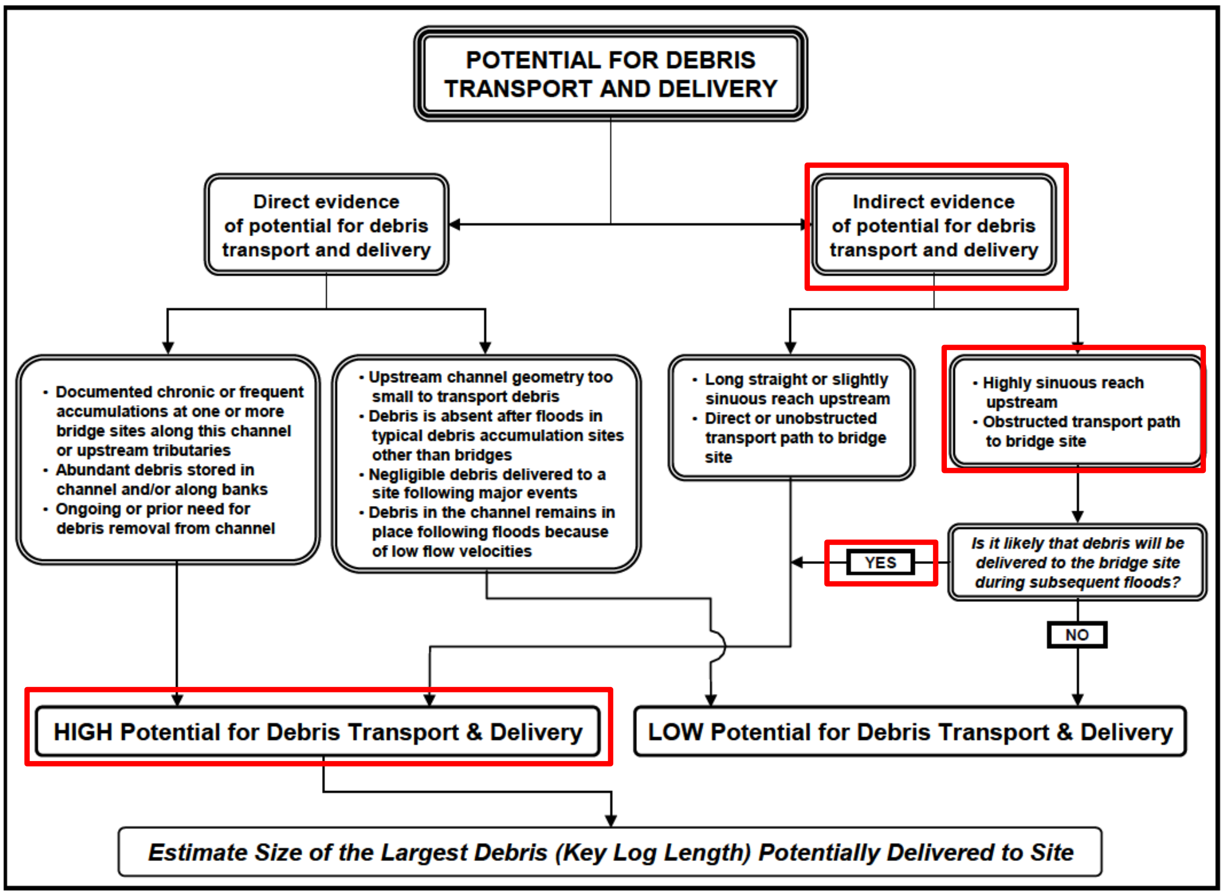


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

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 identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 4 feet of freeboard would typically be required. As discussed below, the existing water surface elevation at the bridge is 1.86 feet below the low chord of the bridge. The proposed bridge option preliminary design does not increase this condition, but still does not meet the 4' minimum. If a bridge is selected in the final phase of the design, freeboard requirements will need to be addressed with CDOT.

4.3 Modeling Parameters

4.3.1 Elevation Data

Existing conditions survey for the bridge and channel cross sections was performed by CDOT in June, 2020. LiDAR was acquired by CDOT in June, 2020. These two data sources were combined for the modeling elevation surface.

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 Central 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 floodplain. The total number of mesh elements is 5,199 and the mesh extends approximately 215 feet upstream of the structure and 175 feet downstream of the structure.

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	0.03
Over Bank	0.04
Open Space	0.05
Roadway	0.016
Heavy Vegetation	0.07
Dirt Road	0.02

4.3.4 Boundary Conditions

The boundary conditions include a steady state inflow and a normal depth calculated 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.

A second inflow boundary condition was included for Twin Creek, which runs north to south in this location parallel with US 24. The flows from I-15-T combine with flows from Twin Creek just downstream of the structure.

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 at Twin Creek (cfs)	Inflow at I-15-T (cfs)	Outflow Constant WSE (ft)
100-Year	212	762	8415.16

4.3.5 Hydraulic Structures

The modeled existing culvert geometry is based on the survey completed in August 2020. The survey data included shots detailing the structure. The inlet elevation of the culvert is 8416.10 and the outlet elevation of the culvert is 8414.90.

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.5 second time step for 2 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 range of depths experienced in the channel at the culvert during the 100-year event is from 0 feet to 10.30 feet. **Appendix D** presents the depth for the entire stream and the structure. The results also demonstrate that flows encroach on the dirt road located north of the channel upstream of the structure. 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.

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included removing the existing RCBC boundary conditions and replacing it with the proposed RCBC design option. The proposed model has 5,199 mesh elements. HY-8 was used to model the proposed box culvert due to the flow being perpendicular to the roadway.

A similar opening size was used for the RCBC to keep the WSEs the same or lower than existing conditions. The preliminary model shows the proposed culvert being 63.5 feet in length. The RCBC option for this structure required a 2 cell 10-foot wide by 8-foot tall structure. The inlet and outlet invert elevations of the RCBC are 8417.87 and 8414.45, respectively. This structure size was determined to allow no greater than 0.5 foot rise in the WSEs of the channel.

This RCBC size also meets maximum required headwater depth to structure depth ratio (HW/D) of 1.5. The headwater elevation at the culvert entrance is 8422.09 feet, which results is a headwater depth of 5.99 feet, producing a HW/D of 0.60.

Depths and velocity grids for the proposed RCBC show depths from 0 to 10.30 and velocities from 0 to 17.83. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Bridge

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included removing the existing RCBC structure boundary conditions and replacing it with the proposed bridge pressure boundary condition. The proposed model has 5,199 mesh elements. The proposed model has a 30-foot span width, no piers, the low chord of the bridge is at 8426.36 elevation, and the high chord didn't change from the existing condition.

Depths and velocity grids for the proposed RCBC show depths from 0 to 10.51 and velocities from 0 to 17.83. See **Appendix F** for 100-year depths and velocities graphics for this option.

5. WATER SURFACE ELEVATION ANALYSIS

FEMA has designated the project site as a Zone X, as determined by the FIRM #08119C0160D effective date September 25, 2009, as shown in **Appendix A**. FEMA Zone X is an area of minimal flood hazard risk. Since I-15-T 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, per the requirements of the CDOT DDM. 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 I-15-T falls into this category, but because the existing structure passes the 100-year flows, the proposed structures must be sized accordingly.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE by more than 0.5 feet. Because the opening of the proposed RCBC is the same as the existing opening, no change in WSE is expected.

In order to perform a comparison between the existing and proposed WSE, 11 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**. The WSE comparison at these sections is shown in Table 4.

For the proposed RCBC, upstream of structure I-15-T (Cross Sections 1-5), the WSE decreases between 0.00 feet and 0.02 feet between existing and proposed. Downstream of Bridge I-15-T (Cross Sections 6-11), the WSE increases a maximum of 0.12 feet between existing and proposed.

Table 4: Existing vs. Proposed Culvert WSE Table

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	PR vs EX*
1	Upstream	8429.07	8429.07	0.00
2	Upstream	8427.22	8427.22	0.00
3	Upstream	8425.43	8425.42	-0.01
4	Upstream	8422.83	8422.85	0.01
5	Upstream	8422.09	8422.17	0.08
6	Downstream	8424.42	8424.54	0.12
7	Downstream	8416.31	8416.29	-0.02
8	Downstream	8415.98	8415.98	0.00
9	Downstream	8415.39	8415.39	0.00
10	Downstream	8415.19	8415.19	0.00
11	Downstream	8415.20	8415.20	0.00

*Proposed-Existing

Proposed Bridge

Similarly, the model for the proposed bridge will not increase the WSE by more than 0.5 feet. The bridge opening for this option is very similar to the existing structure. Therefore, no significant change in WSE is expected.

For the proposed bridge option, upstream of structure I-15-T (Cross Sections 1-5), the WSE decreases between 0.00 feet and 1.86 feet between existing and proposed. Downstream of Bridge I-15-T (Cross Sections 6-11), the WSE increases a maximum of 0.20 feet between existing and proposed. **Appendix G** 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 Table

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	PR vs EX*
1	Upstream	8429.07	8429.07	0.00
2	Upstream	8427.22	8427.22	0.00
3	Upstream	8425.43	8425.42	-0.02
4	Upstream	8422.83	8422.27	-0.57
5	Upstream	8422.09	8420.23	-1.86
6	Downstream	8420.34	8418.78	-1.56
7	Downstream	8416.31	8415.94	-0.37
8	Downstream	8415.98	8415.98	0.00
9	Downstream	8415.39	8415.51	0.12
10	Downstream	8415.19	8415.39	0.20
11	Downstream	8415.20	8415.40	0.20

*Proposed-Existing

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, and outlet depth, velocity and Froude number was 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 1.63 which is less than 3. A 9-inch riprap basin is proposed following HEC-14 guidance for energy dissipation at the culvert outlet. 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 I-15-T. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary water surface elevation analysis and scour analysis.

A two-dimensional model was developed to analyze the flows through the existing RCBC 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 structure is a 2-cell 10-foot by 8-foot RCBC. Water surface elevation 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.

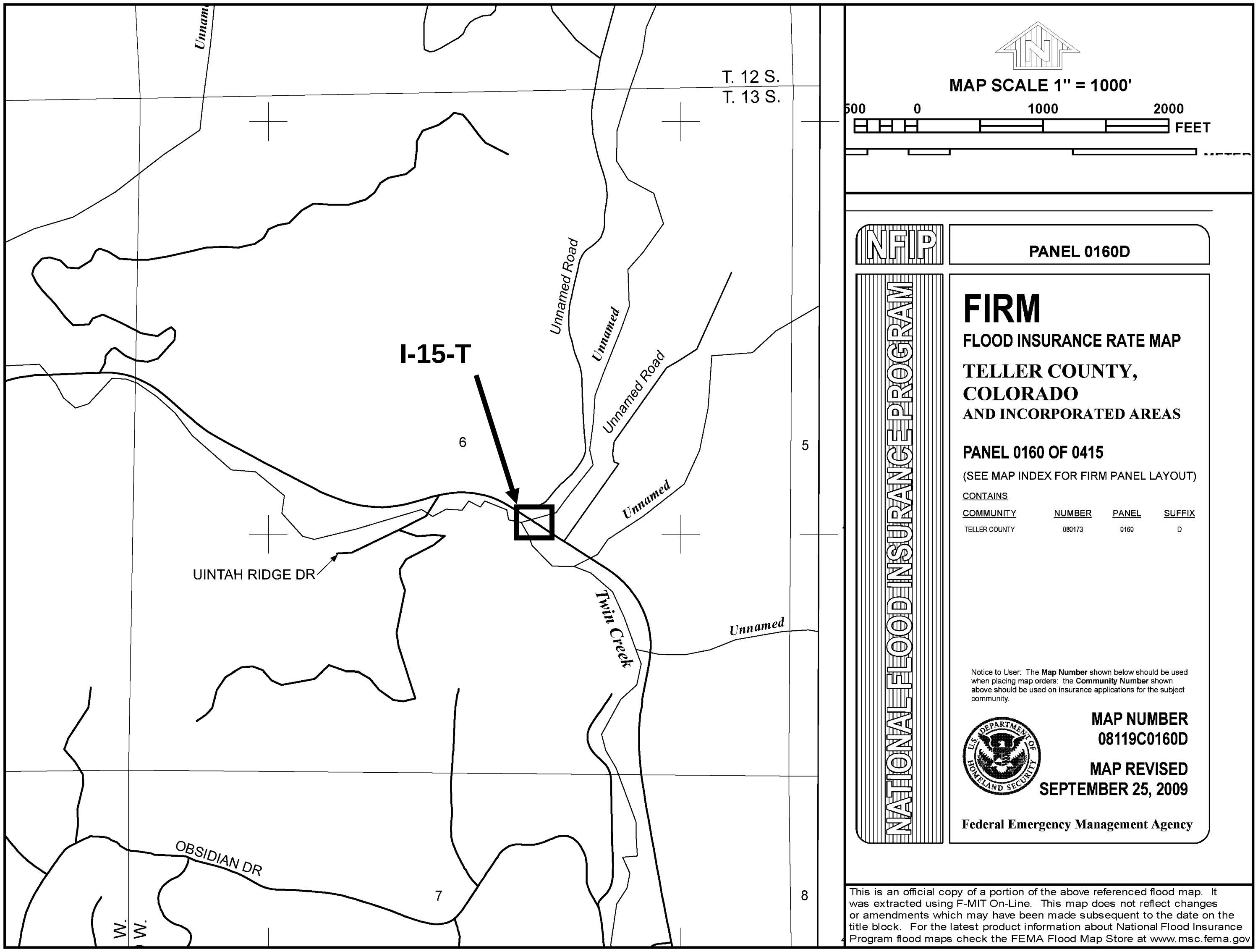
Water surface elevation analysis demonstrates that the proposed bridge opening will not cause significant rise in flood levels during the 100-year design event.

Because a bridge was not selected as the preferred alternative, a scour analysis was not completed for this structure. A riprap apron was designed in order to protect the proposed culvert outlet.

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



FEMA FIRM
STRUCTURE I-15-T
FIGURE 1

APPENDIX B NRCS SOIL SURVEY

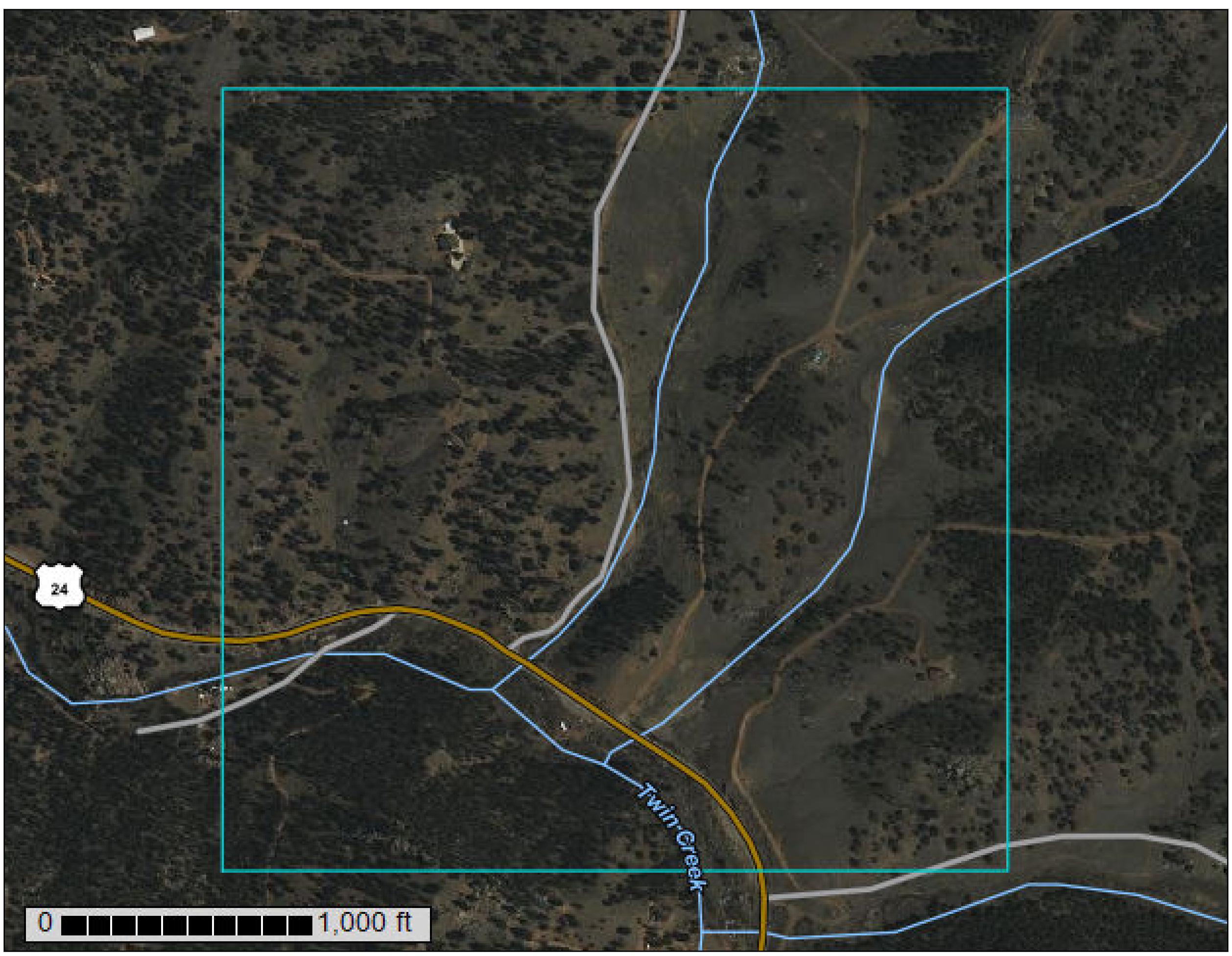
United States Department of Agriculture

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 Teller-Park Area, Colorado, Parts of Park and Teller Counties



December 10, 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.

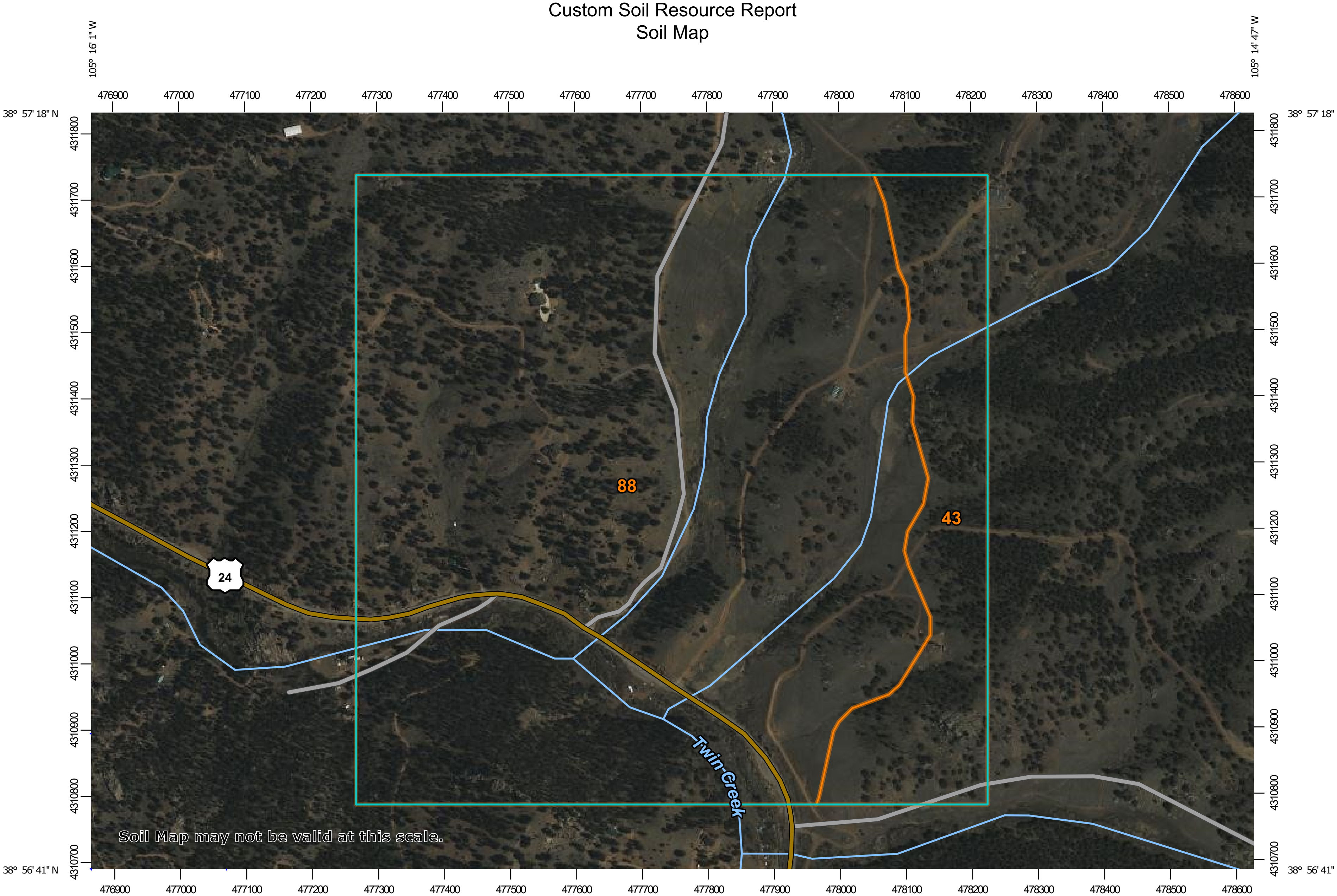
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree 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



Map Scale: 1:8,050 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 100, 200, 400, 600

Feet: 0, 350, 700, 1400, 2100

N

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 1:24,000.

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: Teller-Park Area, Colorado, Parts of Park and Teller Counties
Survey Area Data: Version 12, 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: May 18, 2020—May 21, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND	MAP INFORMATION
	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
43	Guffey-Rofork association, 5 to 50 percent slopes	32.7	14.5%
88	Rofork very gravelly sandy loam, 5 to 55 percent slopes	192.9	85.5%
Totals for Area of Interest		**225.6**	**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.

Teller-Park Area, Colorado, Parts of Park and Teller Counties

43—Guffey-Rofork association, 5 to 50 percent slopes

Map Unit Setting

National map unit symbol: 2n84h
Elevation: 8,300 to 9,500 feet
Mean annual precipitation: 14 to 20 inches
Mean annual air temperature: 38 to 40 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Guffey and similar soils: 50 percent
Rofork and similar soils: 25 percent
Minor components: 25 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Guffey

Setting

Landform: Mountains
Landform position (three-dimensional): Mountainflank
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Colluvium over residuum weathered from granite

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
E1 - 1 to 8 inches: very gravelly coarse sandy loam
E2 - 8 to 13 inches: very gravelly coarse sandy loam
Bt - 13 to 27 inches: very gravelly clay loam
Cr - 27 to 60 inches: bedrock

Properties and qualities

Slope: 5 to 50 percent
Depth to restrictive feature: 20 to 40 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: High
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.14 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 1.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C
Other vegetative classification: Douglas-fir/kinnikinnick-common juniper (PSME/ARUV-JUCO6) (C1219)
Hydric soil rating: No

Description of Rofork

Setting

Landform: Mountains
Landform position (three-dimensional): Mountaintop, mountainflank
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium derived from granite and gneiss over residuum weathered from granite and gneiss

Typical profile

A1 - 0 to 5 inches: very gravelly sandy loam
A2 - 5 to 9 inches: extremely gravelly sandy loam
AC - 9 to 14 inches: extremely gravelly coarse sand
Cr - 14 to 24 inches: bedrock

Properties and qualities

Slope: 5 to 50 percent
Depth to restrictive feature: 10 to 20 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.14 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Very low (about 0.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: D
Ecological site: R048AY240CO
Other vegetative classification: Ponderosa pine/Arizona fescue (PIPO/FEAR2) (C1109), Mountain muhly - Arizona fescue (MUMO-FEAR2) (G2602)
Hydric soil rating: No

Minor Components

Typic haplustolls

Percent of map unit: 10 percent
Landform: Mountains
Ecological site: R048AY222CO
Hydric soil rating: No

Rock outcrop

Percent of map unit: 5 percent
Landform: Knobs, hills
Landform position (three-dimensional): Crest, nose slope
Hydric soil rating: No

Adderton

Percent of map unit: 5 percent
Landform: Flood plains
Ecological site: R048AY222CO
Hydric soil rating: No

Catamount

Percent of map unit: 5 percent
Landform: Mountains
Hydric soil rating: No

88—Rofork very gravelly sandy loam, 5 to 55 percent slopes

Map Unit Setting

National map unit symbol: 2n84f
Elevation: 8,100 to 10,000 feet
Mean annual precipitation: 14 to 24 inches
Mean annual air temperature: 36 to 41 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Rofork and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rofork

Setting

Landform: Mountains
Landform position (three-dimensional): Mountaintop, mountainflank
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium derived from granite and gneiss over residuum weathered from granite and gneiss

Typical profile

A1 - 0 to 5 inches: very gravelly sandy loam
A2 - 5 to 9 inches: extremely gravelly sandy loam
AC - 9 to 14 inches: extremely gravelly coarse sand
Cr - 14 to 24 inches: bedrock

Properties and qualities

Slope: 5 to 55 percent
Depth to restrictive feature: 10 to 20 inches to paralithic bedrock
Drainage class: Well drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.14 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Very low (about 0.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: D
Ecological site: R048AY240CO
Other vegetative classification: Ponderosa pine/Arizona fescue (PIPO/FEAR2) (C1109), Mountain muhly - Arizona fescue (MUMO-FEAR2) (G2602)
Hydric soil rating: No

Minor Components

Typic haplustolls

Percent of map unit: 5 percent
Landform: Mountains
Ecological site: R048AY222CO
Hydric soil rating: No

Adderton

Percent of map unit: 3 percent
Landform: Flood plains
Ecological site: R048AY222CO
Hydric soil rating: No

Rock outcrop

Percent of map unit: 2 percent
Landform: Hills, knobs
Landform position (three-dimensional): Crest, nose slope
Hydric soil rating: No

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APPENDIX C AERIAL IMAGERY AND PHOTOS

EXISTING RCBC STRUCTURE STREAM ABRASION

STRUCTURE I-15-T

FIGURE 1

EXISTING RCBC STRUCTURE REBAR EXPOSURE AND DEGRADATION

STRUCTURE I-15-T

FIGURE 2

VEGETATION TYPICAL OF CHANNEL NEAR STRUCTURE

STRUCTURE I-15-T

FIGURE 3

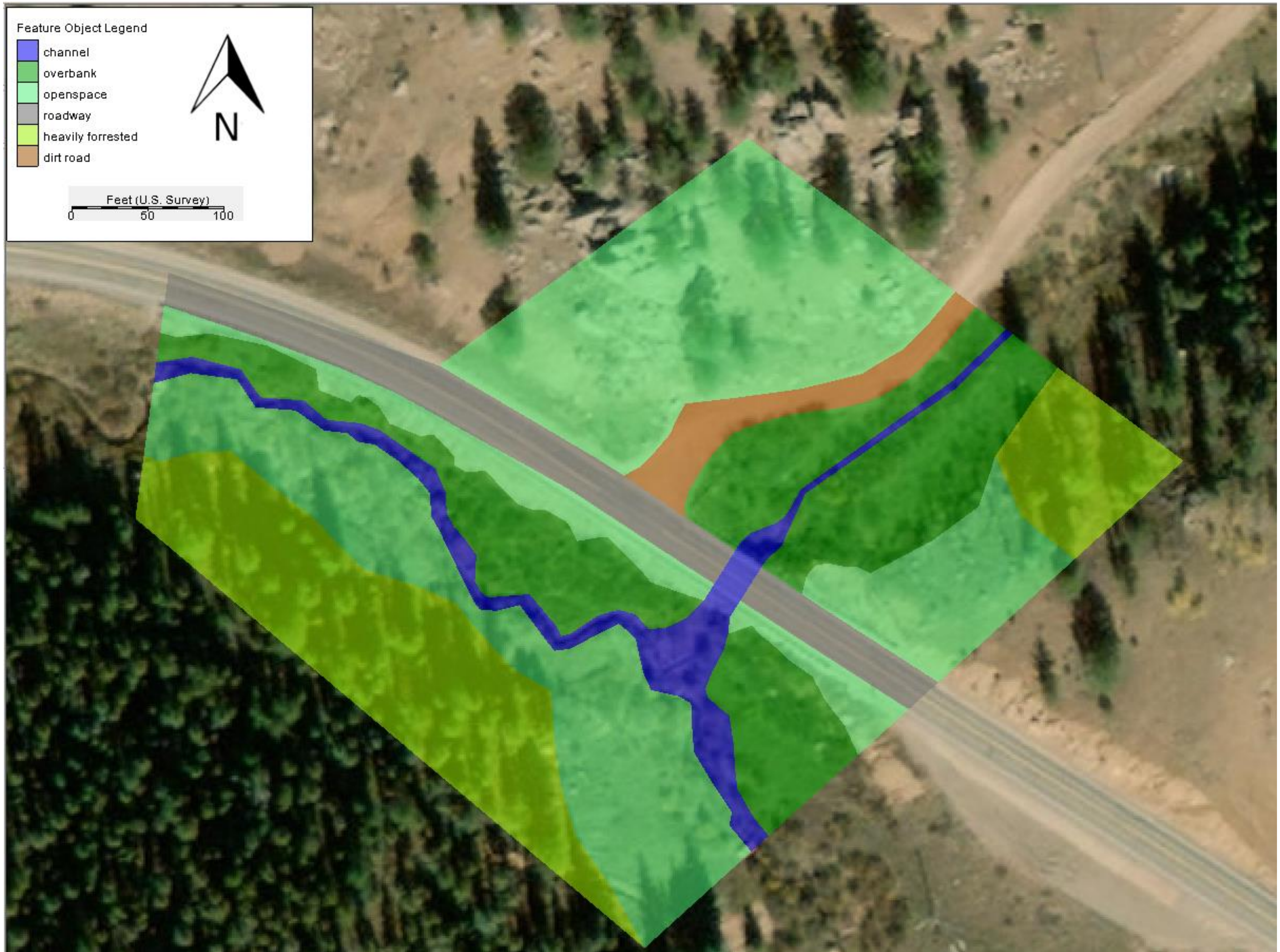
VEGETATION IN CHANNEL UPSTREAM OF STRUCTURE

STRUCTURE I-15-T

FIGURE 4

AERIAL IMAGERY NEAR STRUCTURE
STRUCTURE I-15-T
FIGURE 5

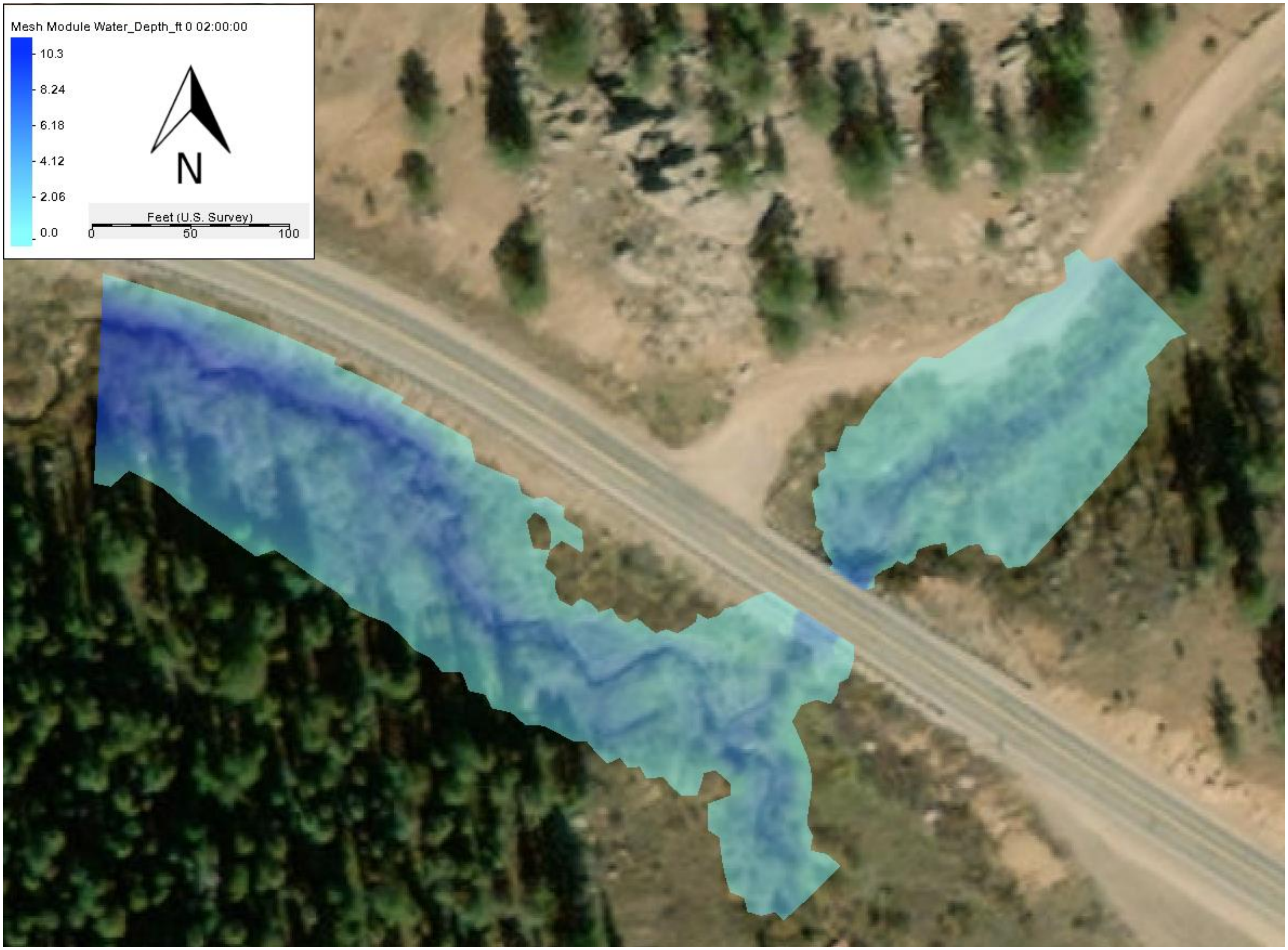
APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS



EXISTING CONDITIONS MATERIALS COVERAGES

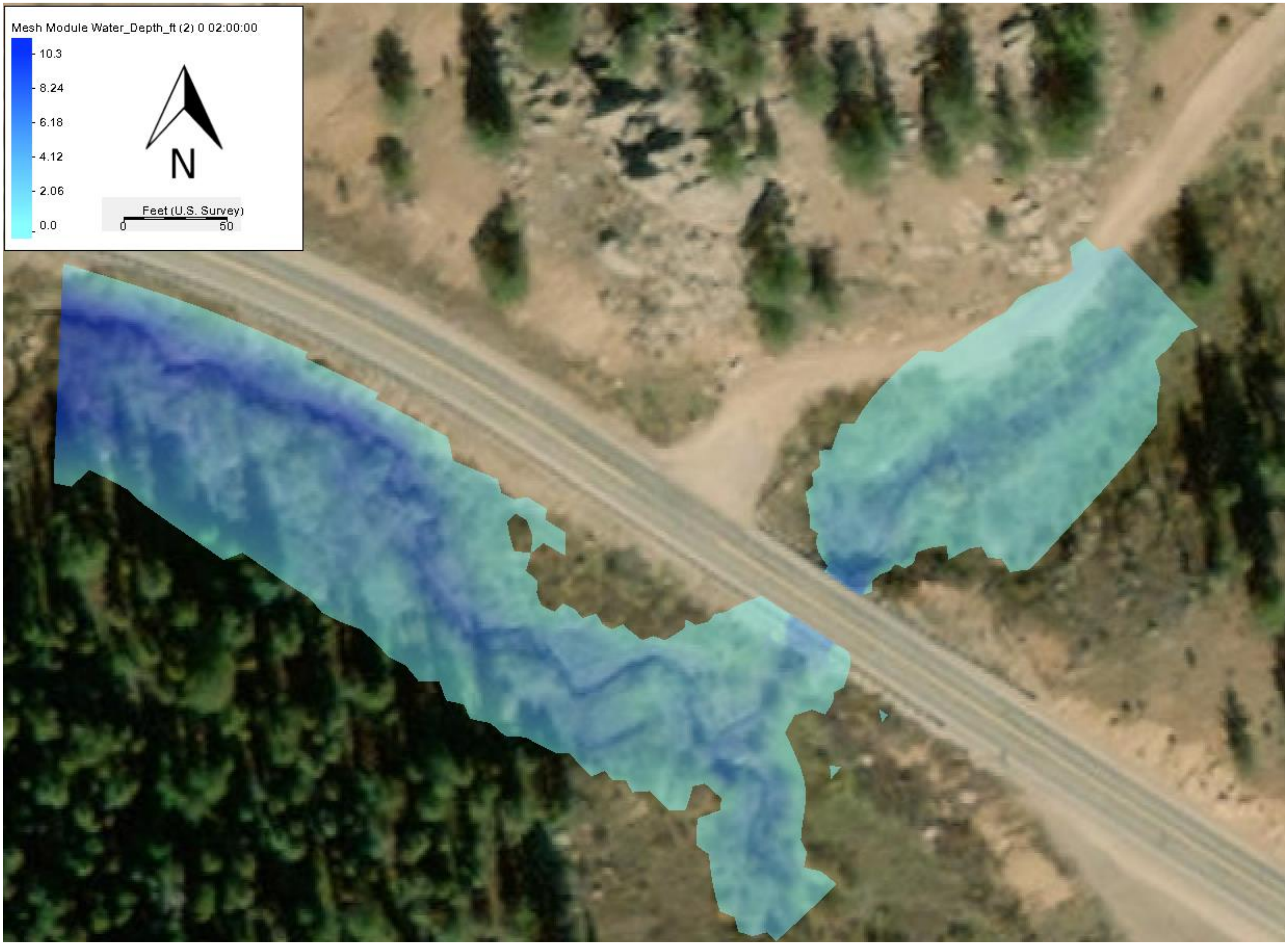
STRUCTURE I-15-T

FIGURE 1



EXISTING CONDITIONS 100-YEAR DEPTH RESULTS
STRUCTURE I-15-T
FIGURE 2

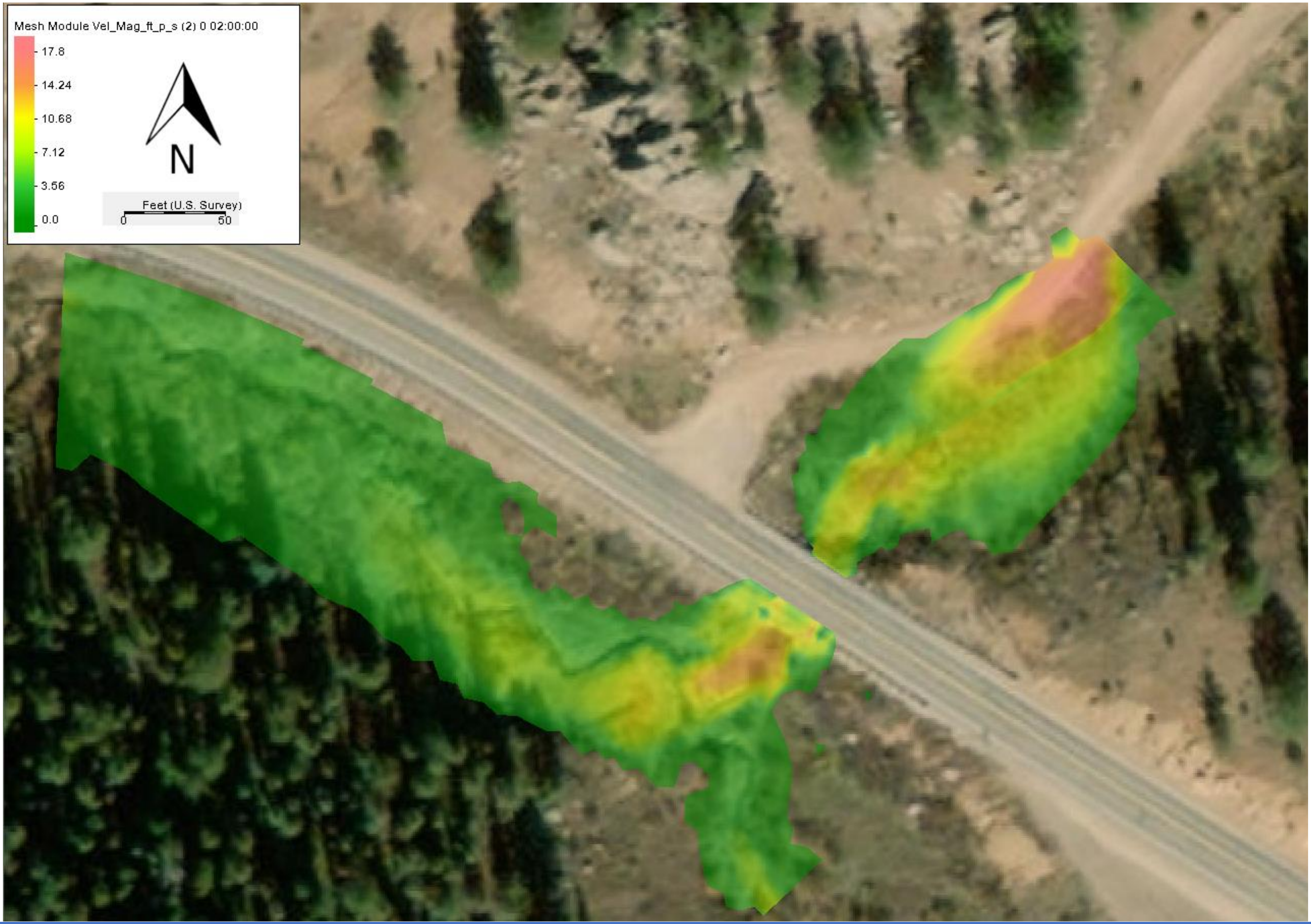
APPENDIX E PROPOSED RCBC ALTERNATIVE MODEL GRAPHICS



PROPOSED RCBC CONDITIONS 100-YEAR DEPTH RESULTS

STRUCTURE I-15-T

FIGURE 1

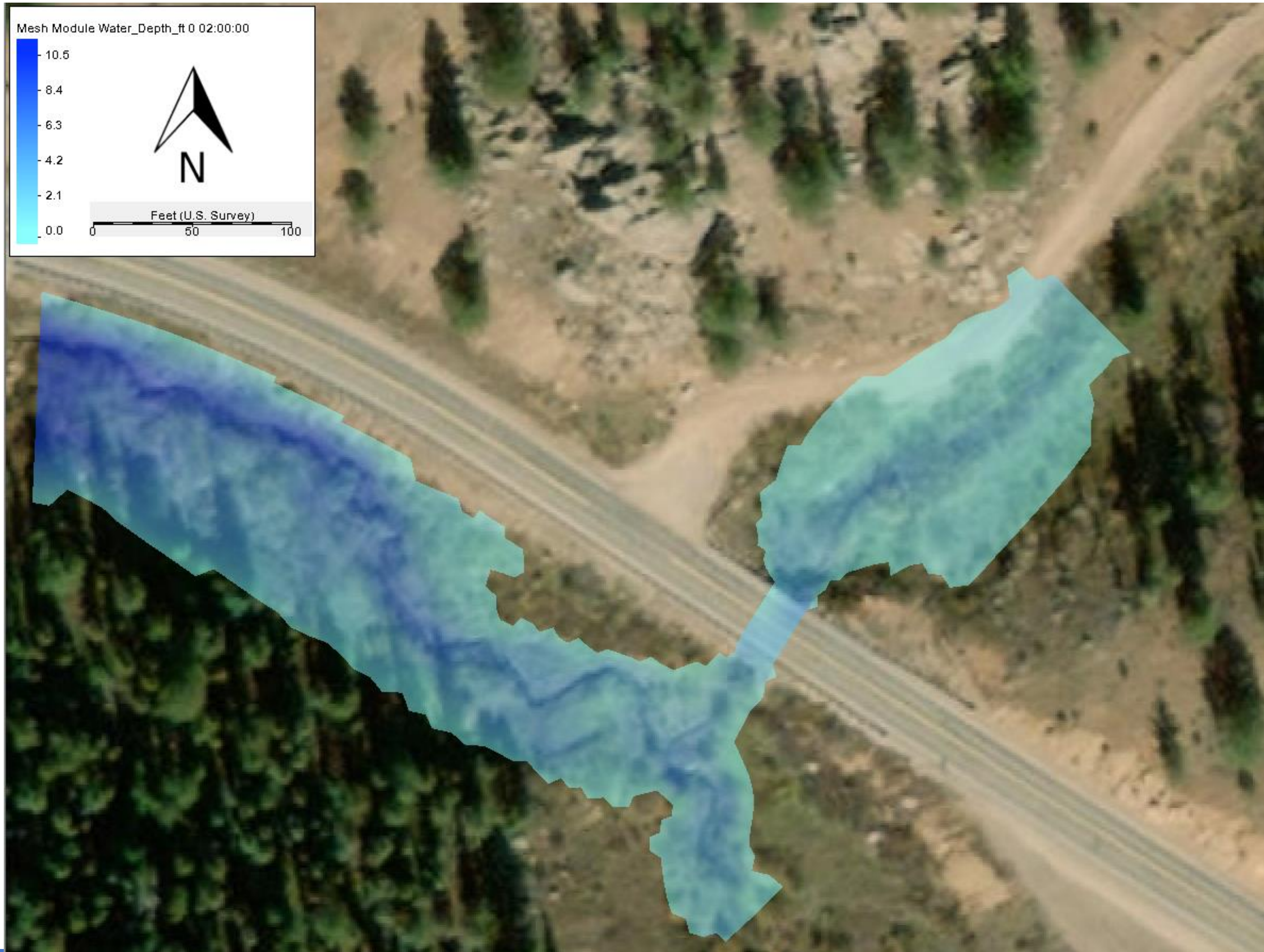


PROPOSED RCBC CONDITIONS 100-YEAR VELOCITY RESULTS

STRUCTURE I-15-T

FIGURE 2

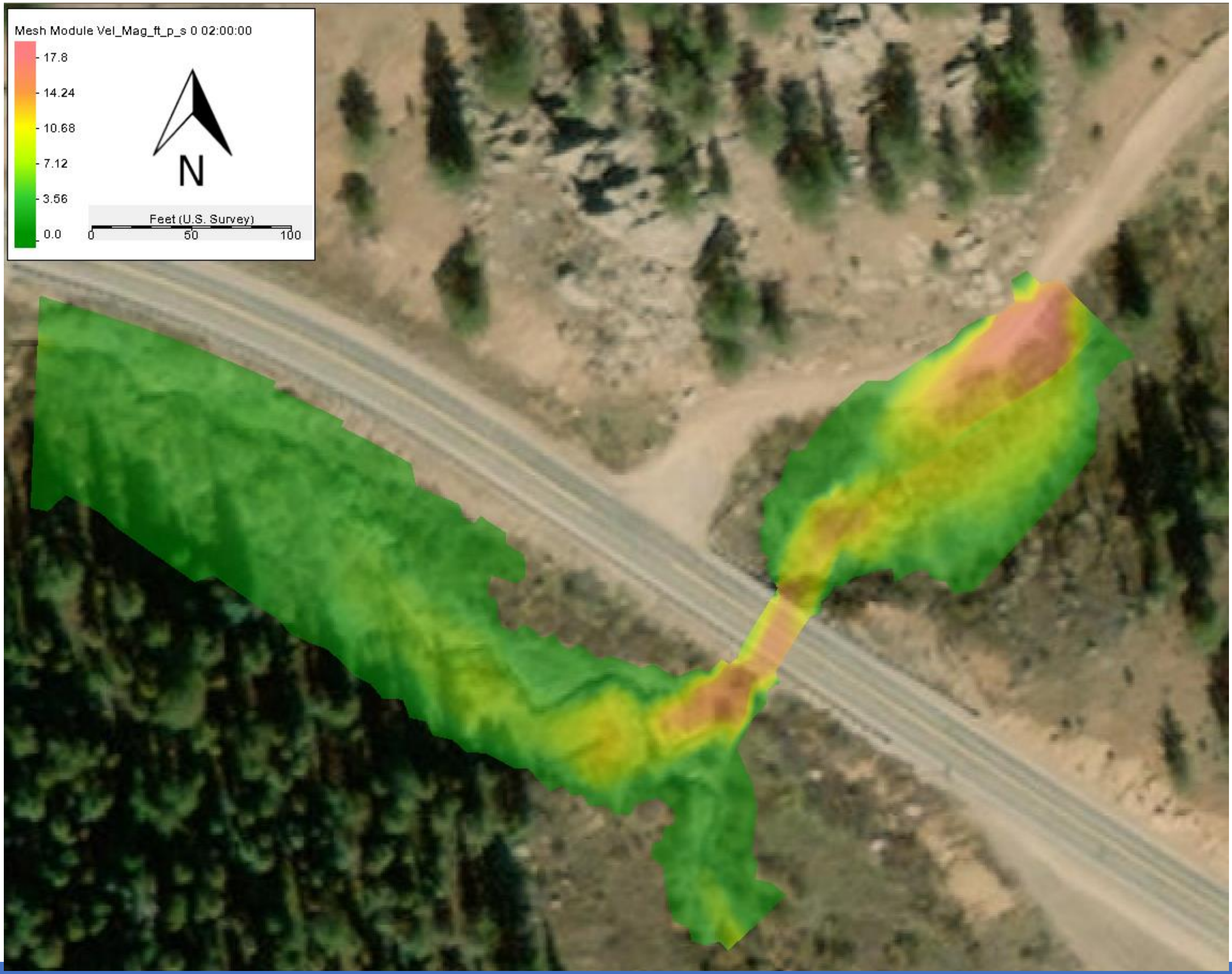
APPENDIX F PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS



PROPOSED BRIDGE CONDITIONS 100-YEAR DEPTH RESULTS

STRUCTURE I-15-T

FIGURE 1

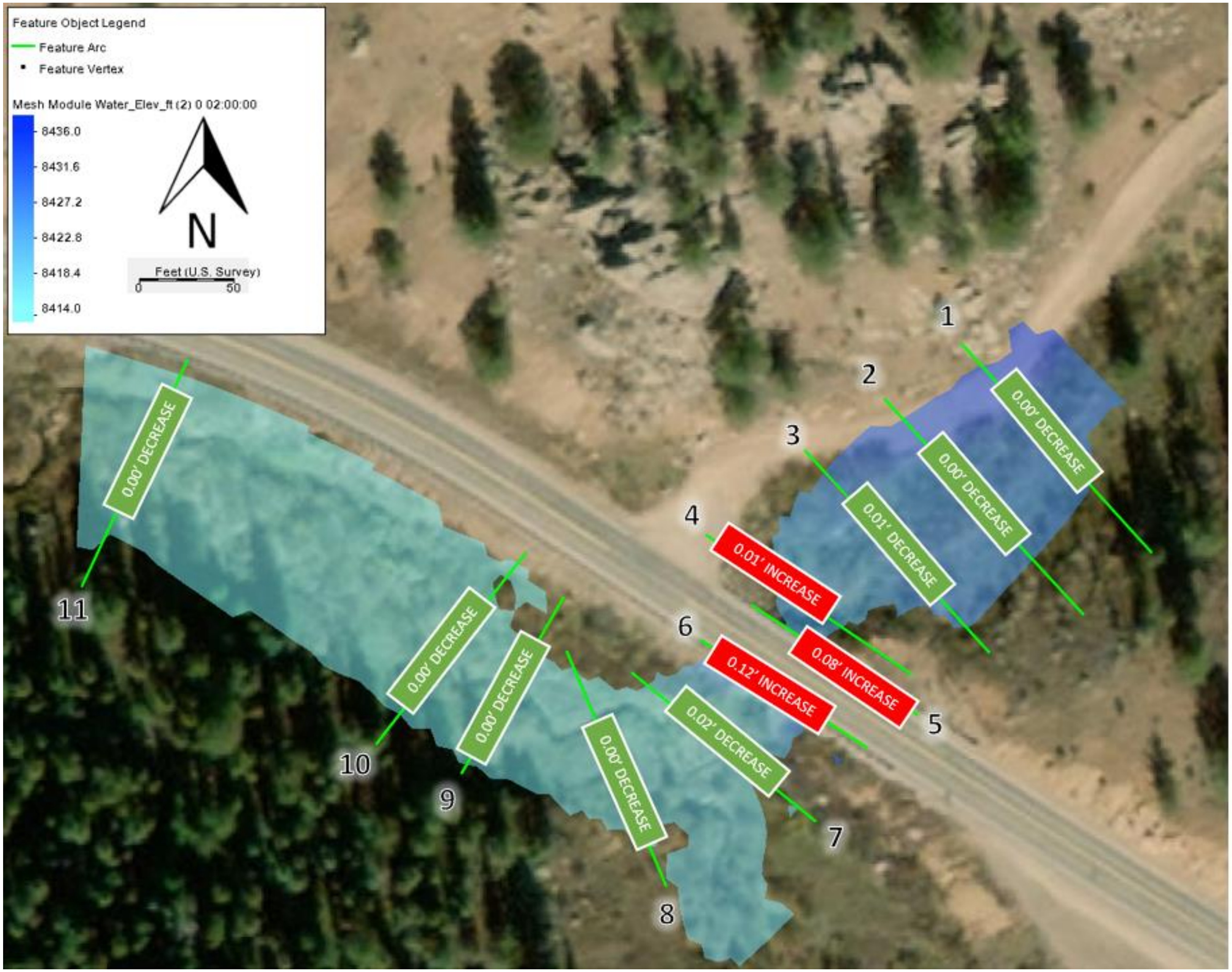


PROPOSED BRIDGE CONDITIONS 100-YEAR VELOCITY RESULTS

STRUCTURE I-15-T

FIGURE 2

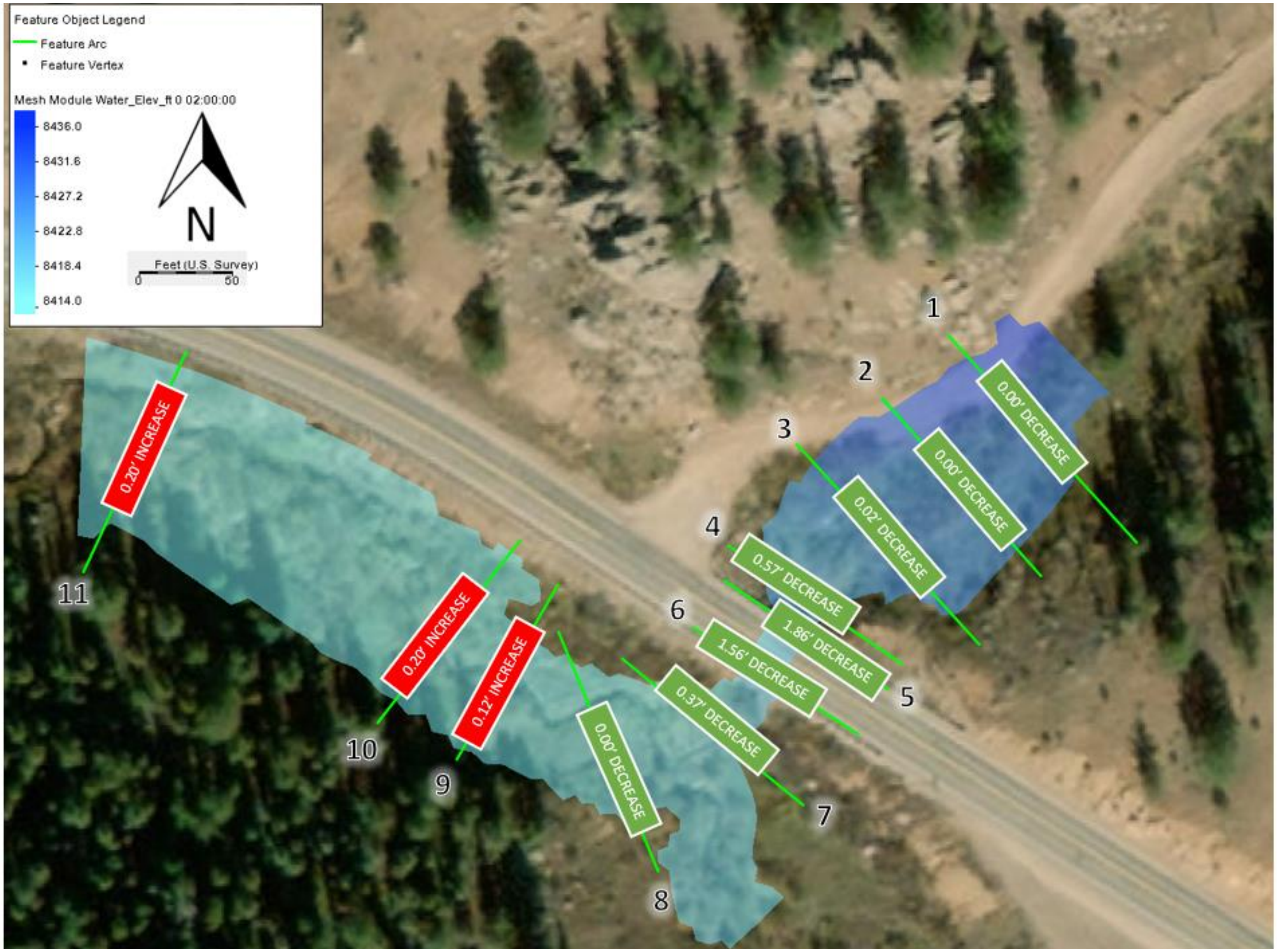
APPENDIX G WATER SURFACE ELEVATION COMPARISON GRAPHICS



RCBC CROSS SECTIONS USED TO COMPARE PROPOSED AND EXISTING RESULTS

STRUCTURE I-15-T

FIGURE 1



BRIDGE CROSS SECTIONS USED TO COMPARE PROPOSED AND EXISTING RESULTS

STRUCTURE I-15-T

FIGURE 2

APPENDIX H RCBC OUTLET ENERGY DISSIPATION

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Crossing 1	
Culvert	Culvert 1	
Flow	762.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	20.0	ft
Culvert Height	8.0	ft
Outlet Depth	2.57	ft
Outlet Velocity	14.84	ft/s
Froude Number	1.63	
Tailwater Depth	4.83	ft
Tailwater Velocity	3.82	ft/s
Tailwater Slope (SO)	0.0189	
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	Best Fit Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.513 ft	
D50 of the Riprap Mixture	0.500	ft
DMax of the Riprap Mixture	1.000	ft
Results		
Brink Depth	2.568	ft
Brink Velocity	14.836	ft/s
Depth (YE)	2.568	ft
Riprap Thickness	1.500	ft
Riprap Foreslope	2.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.316	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.195	
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)	1.158	ft
TW/YE	1.879	
Tailwater Depth (TW)	4.826	ft
Average Velocity with TW	1.903	ft/s

9-inch riprap stilling basin proposed at the CBC outfall. Dimensions listed here follow the Riprap Basin design as outlined in HEC-14 - "Hydraulic Design of Energy Dissipators for Culverts and Channels"

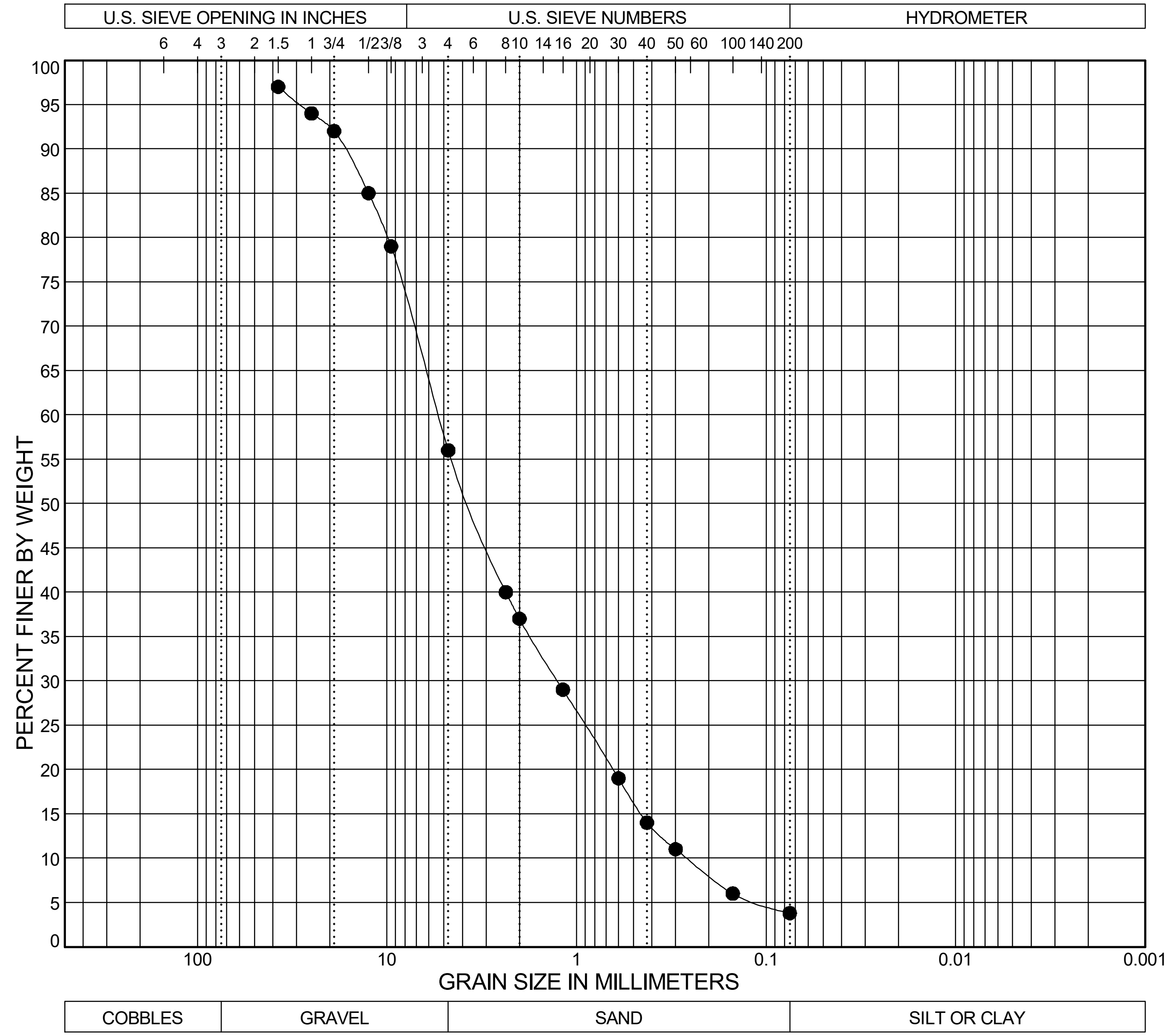
Critical Depth (Yc)	1.477	ft
Average Velocity with Yc	6.763	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	8.774	ft/s
Size	0.502	ft
Distance: 2 LB		
Velocity	4.536	ft/s
Size	0.134	ft
Distance: 3 LB		
Velocity	3.015	ft/s
Size	0.059	ft
Distance: 4 LB		
Velocity	2.257	ft/s
Size	0.033	ft

APPENDIX I GEOTECHNICAL INFORMATION

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 11-24-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
G-12-C Scour	0	BULK	0.4		83.0	16.6	0.4	NV	NP	NP								A-1-a (0)	GP
H-13-N Scour	0	BULK	5		0.0	60.0	40.0	NV	NP	NP								A-4 (0)	SM
I-13-G Scour	0	BULK	1.3		45.0	44.1	10.9	27	18	9								A-2-4 (0)	GW-GC
I-13-H Scour	0	BULK	12		9.0	24.1	66.9	46	31	15								A-7-5 (10)	ML
I-15-AO Scour	0	BULK	1.2		53.0	41.2	5.8	NV	NP	NP								A-1-a (0)	GW-GM
I-15-T Scour	0	BULK	1.4		41.0	55.2	3.8	NV	NP	NP								A-1-a (0)	SW
I-17-X Scour	0	BULK	0.4		55.0	44.3	0.7	NV	NP	NP								A-1-a (0)	GW
J-14-C Scour	0	BULK	1.9		48.0	46.7	5.3	NV	NP	NP								A-1-a (0)	GP-GM
J-15-G Scour	0	BULK	5.4		13.0	79.7	7.3	NV	NP	NP								A-1-b (0)	SP-SM



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
● **I-15-T Scour**	**0.0**	**A-1-a (0)**	**SW**	**NV**	**NP**	**NP**	**41.0**	**52.2**	**3.8**	

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

SIEVE ANALYSIS

Project No.	220-063	Date:	11-24-2020
Report By:	D. Gruenwald	Yeh Lab:	Colorado Springs
Checked By:	J. McCall		

CDOT Region 2 Bridge Bundle
Scour Test Results
Structure I-15-T

FIGURE

S- 5