PRELIMINARY HYDRAULICS REPORT
STRUCTURE I-13-G REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
PARK COUNTY, COLORADO

Section 13, Township 13 South, Range 77 West of the 6th P.M.,
County of Park, Colorado

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Prepared for:

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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 project area is located within Park County at Mile Post 227.095 along US 24 between Antero Junction and Hartsel. Two seasonal washes with deep channels converge just upstream of Structure I-13-G, with the combined flow continuing in a deep channel downstream. The project is located in Section 13, Township 13 South, Range 77 West of the 6th P.M. in Park County. **Figure 1** below 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. 08093C0925C, effective December 18, 2009. Since I-13-G 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-13-G falls into this category, but because the existing structure passes the 100-year flows, the proposed structures must be sized accordingly.

Figure 1: I-13-G Project Area

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 I-13-G.

Table 1: Summary of Peak Discharge for Bridge I-13-G

River Location	Design Storm	25-year (cfs)	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	25-year	360	679	967	1373

3. EXISTING CONDITIONS

3.1 Existing Structure

Existing structure is a three-span treated timber stringer bridge built in 1937 to span a seasonal wash. The bridge does not have skew and was based on a CDOT Standard P-117-B-H. The existing bridge consists of three 23.0 ft spans, has a curb-to-curb width of 29.0 ft, and out -to-out deck width of 30.0 ft. The existing vertical clearance varies from 8.0 ft to 9.0 ft. The existing bridge framing consists of 14 rows of 6 in x 20 in wood stringers, spaced at 2 ft 2 ¾ in. The bridge deck consists of 3 in x 6 in wood planks.

3.2 Watershed Overview

Two seasonal washes flow north from Kaufman Ridge, which forms the boundary between the South Platte and Arkansas River water sheds. These washes form stream beds that combine just upstream of I-13-G. The combined stream flows down to Antero Reservoir which dams the Middle Fork of the South Platte River. The stream beds do not have base flows.

The stream flows perpendicular to the current structure. The area surrounding the bridge is rural and undeveloped, composed of relatively flat grasslands and pasture lands for cattle on both the upstream and downstream sides of the bridge.

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 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**.

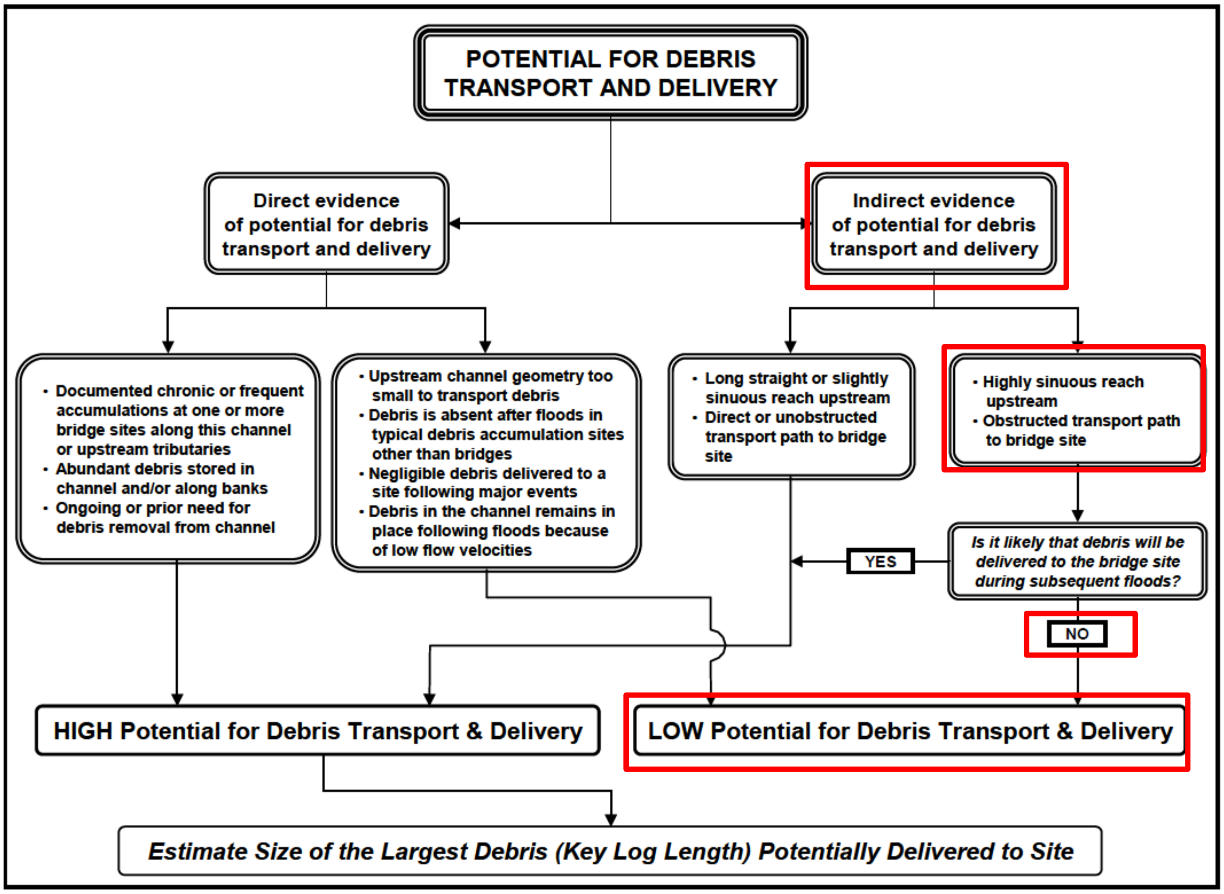

Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

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 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 Farnsworth Group in August 2020. Stanley Consultants performed a drone survey of the site in August 2020 which was used to add elevation detail. 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 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 overbanks. The total number of mesh elements is 4,254, and the mesh extends approximately 700 feet upstream of the bridge and 500 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 Vegetation	0.035
Smooth Earth	0.03
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 two steady-state inflows and one steady-state outflow.

The peak flows developed in Table 1 were used to develop the two steady-state inflow boundary conditions. The inflow boundary conditions extend 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	Inflows (cfs)	Outflow Constant WSE (ft)
100-Year	311 & 368	9108.30

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 9125.00 feet, not accounting for the railings, while the low chord is 9122.02 feet. The low chord of the bridge is over 5' above the highest water surface elevation during the 100-year event.

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

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.2 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 0.49 feet to 3.61 feet. Figure 5 presents the depth for the entire channel and the bridge. 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.

This project site is also a designated cattle crossing, which requires a structure height of at least 7 feet.

Proposed RCBC

This option was modeled using the SRH-2D model for the existing conditions as a base. Modifications included adding a single-cell 20’x7’ reinforced concrete box culvert where the existing roadway crosses over the stream bed. The RCBC was modeled as an open channel with the assumption that the water surface elevation would not approach the 7’ ceiling height of the culvert. The proposed model has 2,456 mesh elements. The inlet and outlet invert elevations of the culvert are 9113.82 and 9112.12, respectively.

The preliminary model shows the roadway embankment sloping at 3:1, with the proposed culvert being 60 feet in length. The single-cell 20-foot wide by 7-foot tall RCBC structure size causes a 0.75-foot rise just upstream in the 100-year event. Though this exceeds the state criteria of no more than 0.5 feet of rise, the existing channel is deep enough that this does not inundate much additional surface area, and that additional surface area is all contained to CDOT right-of-way. From a value standpoint, the single box option was determined to be the most effective size.

With a headwater elevation of 9116.81, the headwater depth of the structure is 3.51 feet. Therefore, the headwater depth to culvert height ratio (HW/D) is 0.50, which is less than the maximum 1.5 for this crossing, according to the CDOT Drainage Design Manual (DDM).

Depths and velocity grids for the proposed RCBC show depths from 1.69 feet to 4.78 feet and velocities from 4.57 fps to 14.04 fps. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Bridge

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. 4.5 feet below the low chord of the bridge, there are 2-foot embankment benches adjacent to the abutment, with 2:1 slopes covered in riprap from the embankment benches to a 29.5-foot-wide channel bottom. The proposed bridge has a 45-foot single span opening perpendicular to the roadway, with the low chord of the bridge at 9122.14 feet elevation, and the high chord at 9125.00 feet elevation. The proposed model has 2,596 mesh elements.

Depths and velocity grids for the channel bottom of the proposed bridge show depths from 2.22 feet to 2.91 feet and velocities from 5.27 fps to 9.45 fps. See **Appendix F** for 100-year depths and velocities graphics for this option.

Proposed Aluminum Arch

This option was modeled using the SRH-2D model for the existing conditions as a base. Modifications included adding a 23.33’ wide by 7.7’ tall aluminum arch culvert where the existing roadway crosses over the stream bed. The arch was modeled with a pressure boundary condition that calculates a parabolic-shaped ceiling. The proposed model has 3,442 mesh elements.

The preliminary model shows the roadway embankment sloping at 3:1, with the proposed arch being 60 feet in length. This project site is also a designated cattle crossing, which requires a structure height of at least 7 feet. The 23.33' wide by 7.7' tall aluminum box arch culvert structure was determined to allow a 0.74-foot of rise in the 100-year WSEs of the channel. Similar to the box culvert option, the additional land area inundated is small and within CDOT right-of-way, making this single arch the most cost-effective size.

Depths and velocities for the proposed aluminum arches show depths from 3.23 feet to 4.90 feet and velocities from 3.06 fps to 4.99 fps. See **Appendix G** 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 X, which is not a SFHA, as determined by the FIRM No. 08093C0925C effective December 18, 2009, 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. The channel walls are steep enough that raising the water surface elevation slightly beyond the recommended 0.5 feet does not result in much additional inundation, and that additional inundation is contained to CDOT right-of-way

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE by more than 0.75 feet. Because the culvert is narrower than the existing bridge opening, there is some concentration of flow, which results in a WSE rise of 0.75 feet at the convergence of the two channels. The flow becomes supercritical through the culvert; however, the proposed riprap at the culvert outlet causes a hydraulic jump that slows the velocity such that there is a slight WSE rise of 0.04 feet downstream of the structure.

In order to perform a comparison between the existing and proposed WSE, 9 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 H – Figure H1**. 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	9118.98	9118.98	0.00
2	Upstream	9117.47	9118.13	0.66
3	Upstream	9120.33	9120.33	0.00
4	Upstream	9117.34	9118.09	0.75
5	Upstream	9116.57	9116.81	0.24
6	Downstream	9115.68	9115.60	-0.08
7	Downstream	9114.31	9114.35	0.04
8	Downstream	9112.88	9112.90	0.02
9	Downstream	9109.34	9109.34	0.00

Proposed Bridge

The model for the proposed bridge raises the 100-year WSE 1.36 feet at the upstream end. 4.5 feet below the low chord of the bridge, there are 2-foot embankment benches adjacent to the abutment, with 2:1 slopes from the embankment benches to a 29.5-foot-wide channel bottom. The proposed bridge has a 42.5-foot single span opening perpendicular to the roadway.

For the proposed bridge option, upstream of Bridge I-13-G (Cross Sections 1-5), the WSE increases a maximum of 0.49 feet between existing and proposed. Downstream of Bridge I-13-G (Cross Sections 6-9), the WSE increases 0.29 feet and decreases up to 0.16 feet between existing and proposed. **Appendix H – Figure H2** shows the cross sections used for the proposed bridge option. **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	9118.98	9118.98	0.00
2	Upstream	9117.47	9117.44	-0.03
3	Upstream	9120.33	9120.33	0.00
4	Upstream	9117.34	9117.44	0.10
5	Upstream	9116.57	9117.07	0.50
6	Downstream	9115.68	9115.98	0.29
7	Downstream	9114.31	9114.16	-0.14
8	Downstream	9112.88	9112.91	0.03
9	Downstream	9109.34	9109.34	0.00

<u>Proposed Aluminum Arch</u>

Based on modeling results, the proposed aluminum arch culvert will not increase the WSE by more than 0.74 feet. Because the arch culvert is narrower than the existing bridge opening, there is some concentration of flow, which results in a WSE rise of 0.74 feet immediately upstream of the culvert wing walls.

In order to perform a comparison between the existing and proposed WSE, 9 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 arch option, as shown in **Appendix H – Figure H1**. The WSE comparison at these sections is shown in **Table 6.**

Table 6: Existing vs. Proposed Aluminum Arch WSE

Cross Section	Location Relative to Structure	Existing WSE (ft)	Proposed ALBC WSE (ft)	Difference (ft)
1	Upstream	9118.98	9118.98	0.00
2	Upstream	9117.47	9117.94	0.47
3	Upstream	9120.33	9120.33	0.00
4	Upstream	9117.34	9117.86	0.52
5	Upstream	9116.57	9116.53	-0.04
6	Downstream	9115.68	9115.96	0.27
7	Downstream	9114.31	9114.04	-0.27
8	Downstream	9112.88	9112.88	0.00
9	Downstream	9109.34	9109.34	0.00

6. BRIDGE SCOUR ANALYSIS

6.1 Scour Overview

For the proposed bridge option and proposed arch option as determined in the alternatives analysis, scour analyses were performed. The scour analyses are intended to inform the structural design of the crossing and countermeasure design. The FHWA recommends that bridges with complex flow characteristics use a 2D model to represent hydraulic conditions.

For the scour analyses, the FHWA Hydraulic Toolbox Version 4.4 software program was used. The Hydraulic Toolbox program uses equations presented in the FHWA Hydraulic Engineering Circular No. 18 Evaluation of Scour at Bridges (HEC-18) and the National Cooperative Highway Research Program (NCHRP) 24-20. SRH-2D was used as the hydraulic model platform for the bridge, and it has the capability to extract the data needed for these calculations directly from the model.

The proposed bridge foundations and aluminum arch footings will be designed to withstand the effects of scour up to and including the 500-year Scour Design Check Flood Frequency. Scour countermeasures will be designed to protect the approach roadway and bridge embankments from the effects of scour for the 25-year Hydraulic Design Flood Frequency. For both the bridge and aluminum arch options, a minimum toe-down depth of 4 feet was used in the analysis.

This reach of the wash has a notable flow contraction upstream of the bridge. Two of the wash’s tributaries form a confluence at the entrance of the bridge, exacerbating turbulence and contraction scour. These conditions indicate a significant scour potential at this bridge crossing. Vertical wall abutments with wing walls and riprap are recommended as scour countermeasures. The abutment and wing walls shall be designed with a toe wall extending down to the 25-yr scour depth. The FHWA Hydraulic Toolbox Version 4.4 (FHWA, 2018) was used to size riprap at the ends of the proposed wing walls and along the roadway embankment. The riprap was sized for the 25-year hydraulic design event. The Hydraulic Toolbox applies methodology outlined in the FHWA Hydraulic Engineering Circular No. 23 Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23) for sizing riprap at abutments based on abutment type, set-back ratio, Froude number, specific gravity of rock riprap, and a characteristic average velocity in the channel.

At the project site, the following scour components were calculated:

- Contraction Scour
- Abutment Scour
- Long-Term Degradation

All scour calculations can be found in **Appendix I**.

6.2 Site Geology/Geotechnical Information and Impact to Scour Depths

A geotechnical analysis was completed Yeh and Associates for the Project. Gradation of the stream bed was provided in this investigation and used for this preliminary scour analysis. Only one sample was taken from the channel, therefore this sample will be applied to abutment (local) scour, contraction scour and long-term degradation. Results from the geotechnical investigation is provided in **Appendix J**.

Borings at each abutment and one at each bridge approach, were also conducted as part of the field exploration. These were used to better understand subsurface conditions at the bridge crossing. Soils information from borings were not used in the scour analysis because boring samples at the abutments were assumed to not be as representative of channel bed conditions as the channel sample discussed above.

Because exact bedrock elevations are not known, no adjustment was made to the scour depths shown below.

6.3 Bridge Option Scour Results

Table 7 below summarizes the preliminary results for scour depth for the bridge option including contraction scour, abutment scour, and long-term scour at the bridge.

Table 7: Bridge Option NCHRP Scour Summary

Scour Component	25-Year	100-Year	500-Year
Long-Term Degradation	1.5	1.6	2.4
Contraction Scour	0.5	1.6	2.7
Local Abutment Scour	1.6	5.3	7.8
Total Scour*	3.1	6.9	10.2

* Contraction Scour is not included in the Total Scour when computing the NCHRP methodology.

Table 8 below summarizes the preliminary results for scour depth for the aluminum arch option including contraction scour, abutment scour, and long-term scour at the arch spread footing foundations.

Table 8: Aluminum Arch Option NCHRP Scour Summary

Scour Component	25-Year	100-Year	500-Year
Long-Term Degradation	1.1	1.7	4.6
Contraction Scour	0.1	3.1	4.0
Local Abutment Scour	1.5	4.5	8.6
Total Scour*	2.6	6.2	13.2

* Contraction Scour is not included in the Total Scour when computing the NCHRP methodology.

6.4 Riprap Scour Countermeasures

Proposed Bridge

Results of the Hydraulic Toolbox analysis are provided in **Appendix I**. A riprap with D50 of 12-inches (in) (Class 3 per HEC-23) is recommended. The resulting recommended thickness is 24-in based on HEC-23 for Class 3 riprap. Refer to Table 506-2 of CDOT's Division 500 Structures Specifications for the required gradation.

Riprap shall also be placed over a Class 1, non-woven geotextile filter material. According to CDOT's Division 700 Materials Details, geotextile materials should be selected from the New York Department of Transportation's Approved Products List of Geosynthetic materials that meet the National Transportation Product Evaluation Program (NTPEP) and AASHTO M-288 testing requirements. Class 1 geotextiles is the only class approved for applications related to slope protection.

The riprap slope protection at each wing wall should extend 25' from the end of the wing walls along the roadway embankment and configured with the data shown in Table 5. Riprap placed below existing grade shall be constructed with a maximum 2:1 side slope. Riprap above grade will be placed at the roadway embankment slope and no steeper than 2:1.

Table 9: Bridge Option Scour Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes (Max)	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap	12	24	2:1	4	9109.5	9118.5
Wing Walls	N/A	N/A	N/A	4	9109.5	9118.5

Proposed Arch

Results of the Hydraulic Toolbox analysis are provided in **Appendix I**. A riprap with D50 of 9-inches (in) (Class 3 per HEC-23) is recommended. The resulting recommended thickness is 18-in based on HEC-23 for Class 3 riprap. Refer to Table 506-2 of CDOT's Division 500 Structures Specifications for the required gradation.

7. 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 with D50 of 9 inches with a recommended thickness of 27 inches based on the Froude number of 1.21 which is less than 3. See results from HY-8 energy dissipation analysis in **Appendix I.**

8. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge I-13-G. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary floodplain analysis and scour analysis.

Two-dimensional models were developed to analyze the flows through the existing bridge and to compare the WSEs and velocities to proposed designs. These models were utilized to optimize the proposed solution to replacement of the existing bridge.

Based on the hydraulic analysis as well as longevity and maintenance concerns, the proposed replacement for this bridge is a single ached open bottom aluminum culvert (ALBC 71) which is approximately 23.33' x 7.7'. Floodplain analysis demonstrates that the proposed culvert opening will not cause a rise in flood levels of more than one foot during the 100-year design event and the design will not affect any upstream or downstream properties. The energy dissipation alternative selected for this culvert outlet is a riprap basin following HEC-14 guidelines. No floodplain development permit is required for this bridge replacement.

9. 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

National Flood Hazard Layer FIRMette

FEMA

105°57'43"W 38°55'43"N

105°57'6"W 38°55'15"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 12/3/2020 at 12:37 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

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

Structure I-13-G

December 7, 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: 1:2,130 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 30, 60, 120, 180

Feet: 0, 100, 200, 400, 600

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
39	Gebson-Glentivar complex, 3 to 15 percent slopes	5.3	37.2%
41	Girardot-Platdon complex, 0 to 1 percent slopes	6.3	44.4%
96	Sawfork very cobbly loam, 15 to 50 percent slopes	2.6	18.4%
Totals for Area of Interest		**14.1**	**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

39—Gebson-Glentivar complex, 3 to 15 percent slopes

Map Unit Setting

National map unit symbol: k10g
Elevation: 9,000 to 9,300 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Gebson and similar soils: 50 percent
Glentivar and similar soils: 40 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Gebson

Setting

Landform: Pediments
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium and/or slope alluvium

Typical profile

A - 0 to 6 inches: loam
Bt - 6 to 11 inches: clay loam
Bk1 - 11 to 19 inches: loam
Bk2 - 19 to 29 inches: loam
Bk3 - 29 to 60 inches: loam

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Moderate (about 8.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Description of Glentivar

Setting

Landform: Pediments
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium derived from limestone, sandstone, and shale

Typical profile

A - 0 to 6 inches: sandy loam
Bt - 6 to 12 inches: clay loam
Bk1 - 12 to 21 inches: gravelly loam
Bk2 - 21 to 24 inches: sandy loam
Bk3 - 24 to 36 inches: sandy loam
Bk4 - 36 to 40 inches: sandy loam
Cr - 40 to 50 inches: bedrock

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: 40 to 50 inches to paralithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.03 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: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Minor Components

Hodden

Percent of map unit: 5 percent
Landform: Hills
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Lanswick

Percent of map unit: 3 percent
Landform: Drainageways
Ecological site: R048BY280CO
Hydric soil rating: No

Newett

Percent of map unit: 2 percent
Landform: Ridges, knobs
Ecological site: R048BY232CO
Hydric soil rating: No

41—Girardot-Platdon complex, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: k122
Elevation: 8,500 to 9,300 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Girardot and similar soils: 70 percent
Platdon, frequently flooded, and similar soils: 20 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Girardot

Setting

Landform: Alluvial flats, drainageways
Down-slope shape: Linear
Across-slope shape: Linear, concave
Parent material: Alluvium

Typical profile

Ak - 0 to 4 inches: sandy clay loam
Bkg - 4 to 12 inches: sandy clay loam
Bg - 12 to 60 inches: stratified fine sandy loam to loam to sandy clay loam

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 0 to 10 inches
Frequency of flooding: NoneRare
Frequency of ponding: None
Calcium carbonate, maximum content: 60 percent
Maximum salinity: Very slightly saline to slightly saline (2.0 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Low (about 5.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C/D
Ecological site: R048AY241CO
Hydric soil rating: Yes

Description of Platdon, Frequently Flooded

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

A - 0 to 8 inches: loam
Ag - 8 to 18 inches: loam
Cg1 - 18 to 30 inches: very gravelly sandy clay loam
2Cg2 - 30 to 60 inches: extremely gravelly sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: 25 to 35 inches to strongly contrasting textural stratification
Drainage class: Very poorly 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: About 0 to 10 inches
Frequency of flooding: FrequentNone
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6w
Hydrologic Soil Group: B/D
Ecological site: R048AY241CO
Hydric soil rating: Yes

Minor Components

Gebson

Percent of map unit: 5 percent
Landform: Fan remnants
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Lanswick

Percent of map unit: 3 percent
Landform: Drainageways, hills
Landform position (three-dimensional): Base slope
Ecological site: R048BY280CO
Hydric soil rating: No

Platdon, poorly drained

Percent of map unit: 2 percent
Landform: Flood-plain steps
Landform position (three-dimensional): Tread
Ecological site: R048BY268CO
Hydric soil rating: No

96—Sawfork very cobbly loam, 15 to 50 percent slopes

Map Unit Setting

National map unit symbol: k0yz
Elevation: 8,900 to 9,800 feet
Mean annual precipitation: 10 to 16 inches
Mean annual air temperature: 35 to 39 degrees F
Frost-free period: 50 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

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

Description of Sawfork

Setting

Landform: Scarps on pediments
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Slope alluvium; slope alluvium derived from tuff

Typical profile

A - 0 to 4 inches: very cobbly loam
AB - 4 to 8 inches: very cobbly loam
Bt - 8 to 14 inches: very cobbly clay loam
Bw - 14 to 22 inches: sandy clay loam
2Bk1 - 22 to 30 inches: ashy sandy clay loam
2Bk2 - 30 to 39 inches: extremely paragravelly ashy sandy clay loam
2Bk3 - 39 to 48 inches: extremely paragravelly ashy sandy clay loam
2Cr - 48 to 52 inches: bedrock

Properties and qualities

Slope: 15 to 50 percent
Depth to restrictive feature: 40 to 52 inches to paralithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.03 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 5 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 2.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: C
Ecological site: R048BY227CO
Hydric soil rating: No

Minor Components

Newett

Percent of map unit: 3 percent
Landform: Knobs, ridges
Ecological site: R048BY232CO
Hydric soil rating: No

Rock outcrop

Percent of map unit: 3 percent
Landform: Knobs, hills
Landform position (three-dimensional): Crest, nose slope
Hydric soil rating: No

Lanswick

Percent of map unit: 2 percent
Landform: Drainageways, hills
Landform position (three-dimensional): Base slope
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

Glentivar

Percent of map unit: 2 percent
Landform: Ridges
Ecological site: R048BY225CO - Mountain Loam 10-16" South Park
Hydric soil rating: No

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APPENDIX C AERIAL IMAGERY AND PHOTOS

APPENDIX C – AERIAL IMAGERY AND PHOTOS

STRUCTURE I-13-G

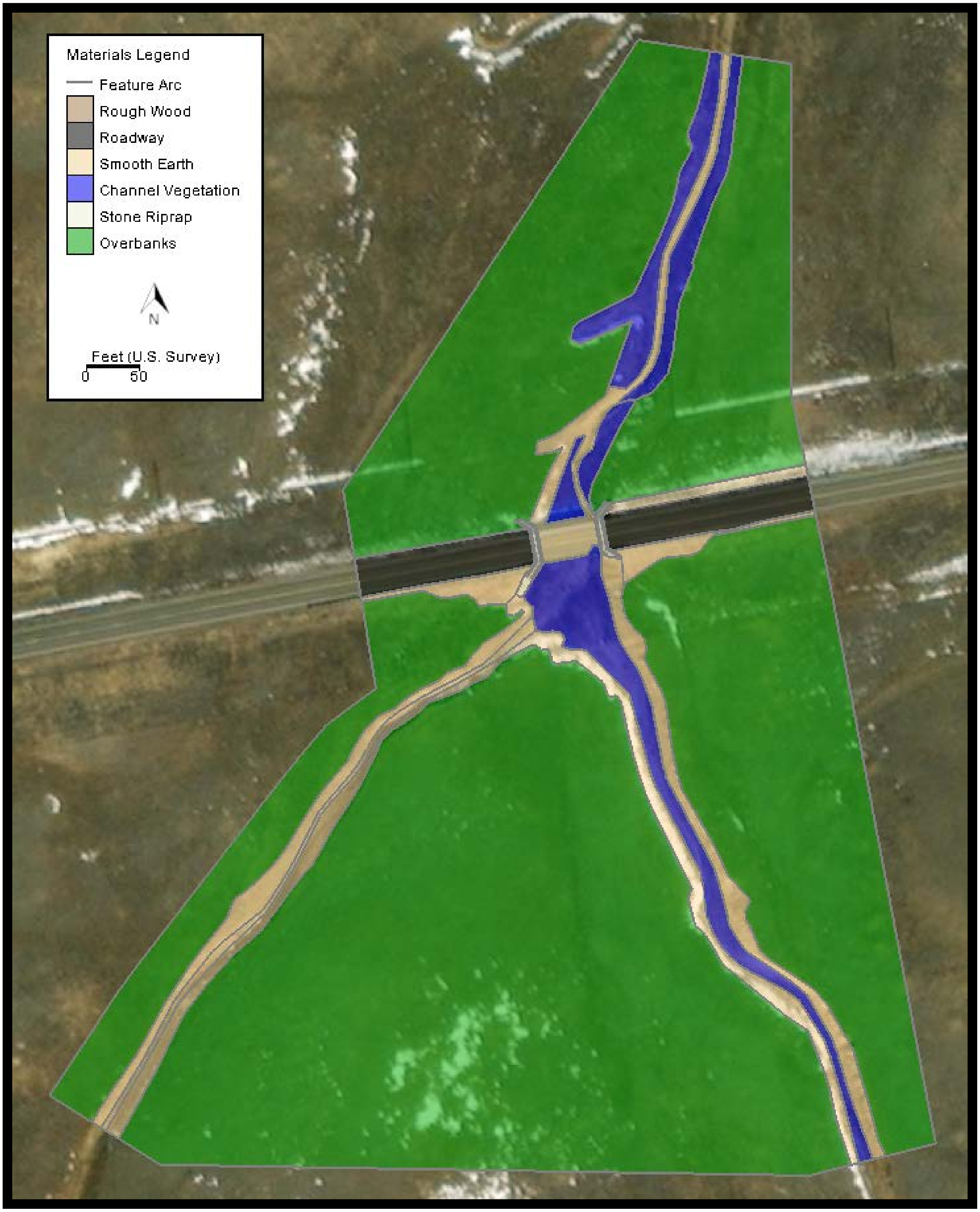
FIGURE C1

Figure C2: Aerial Looking Downstream

Figure C3: Aerial Looking Upstream

Figure C4: Ground Level Looking Downstream

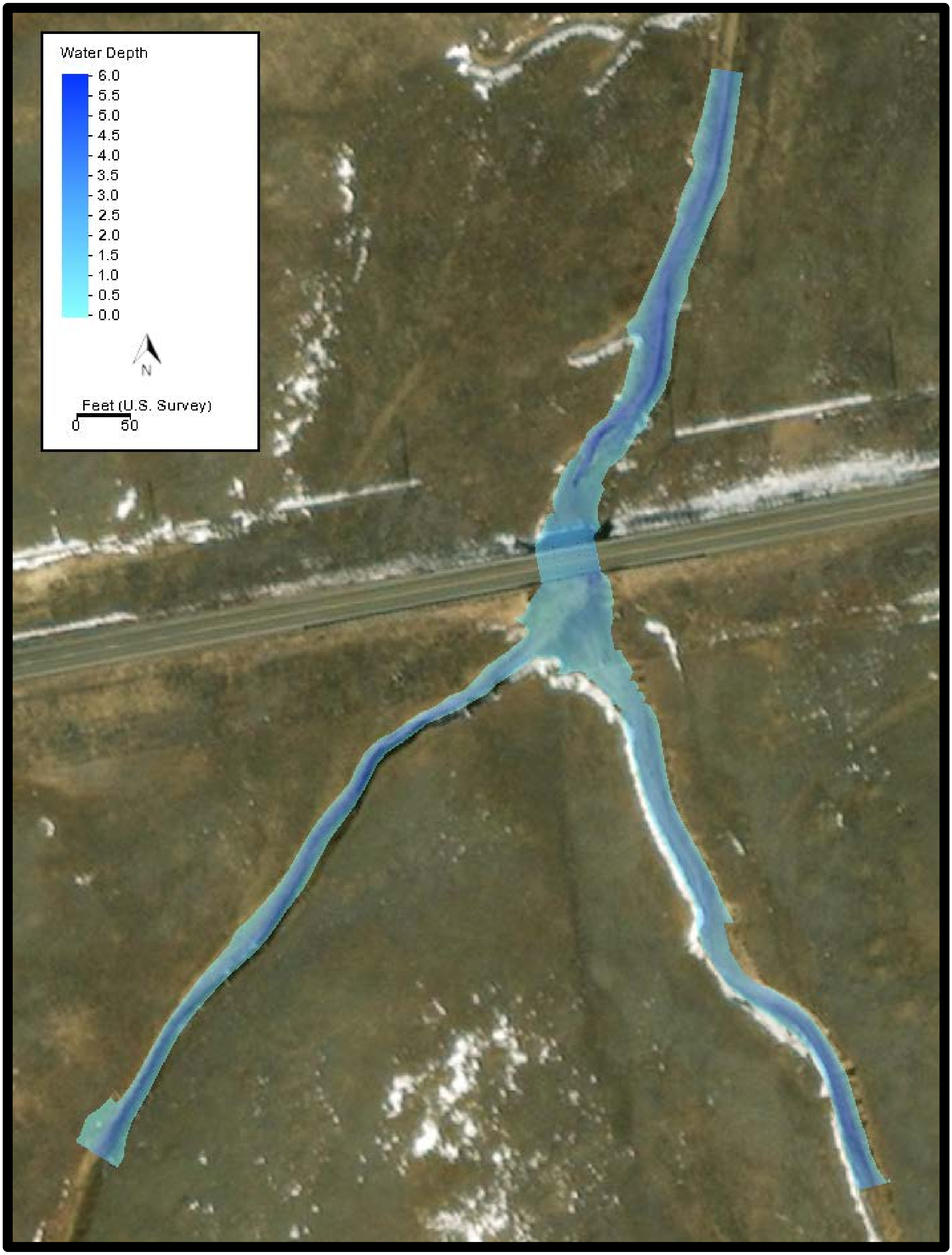
APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS



APPENDIX D – MATERIALS COVERAGE

STRUCTURE I-13-G

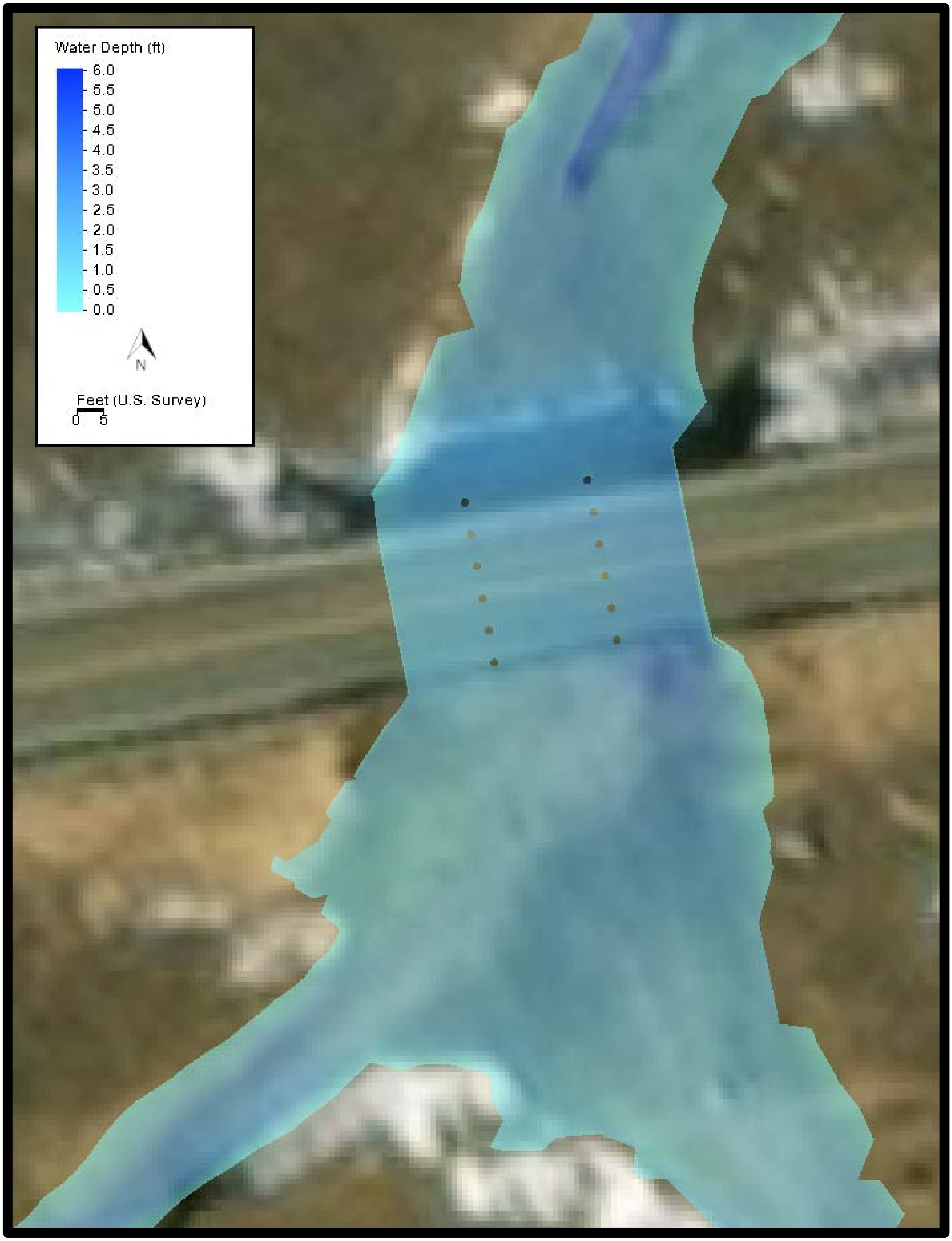
FIGURE D1



APPENDIX D – EXISTING CONDITIONS – WATER DEPTH

STRUCTURE I-13-G

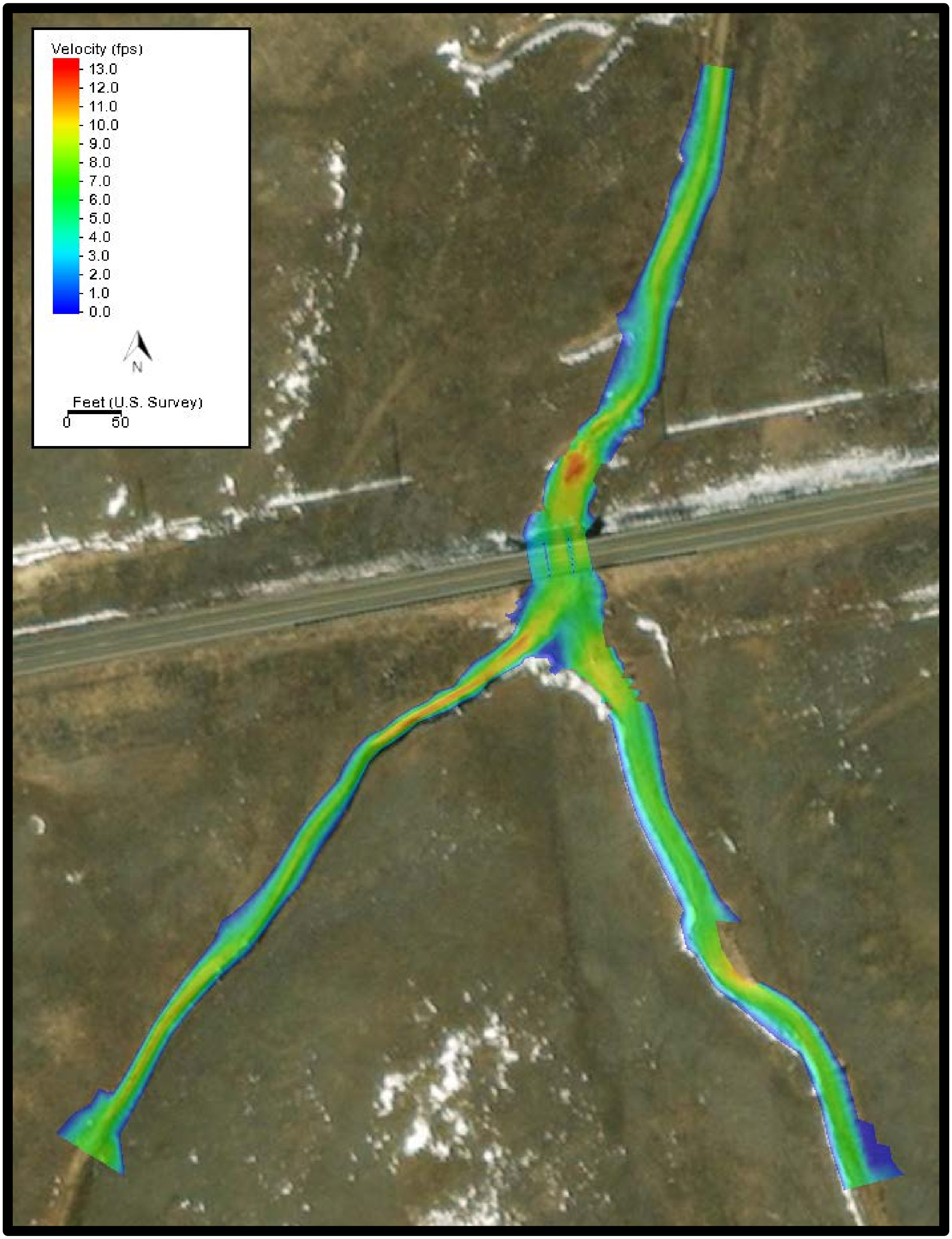
FIGURE D2



APPENDIX D – EXISTING CONDITIONS – WATER DEPTH

STRUCTURE I-13-G

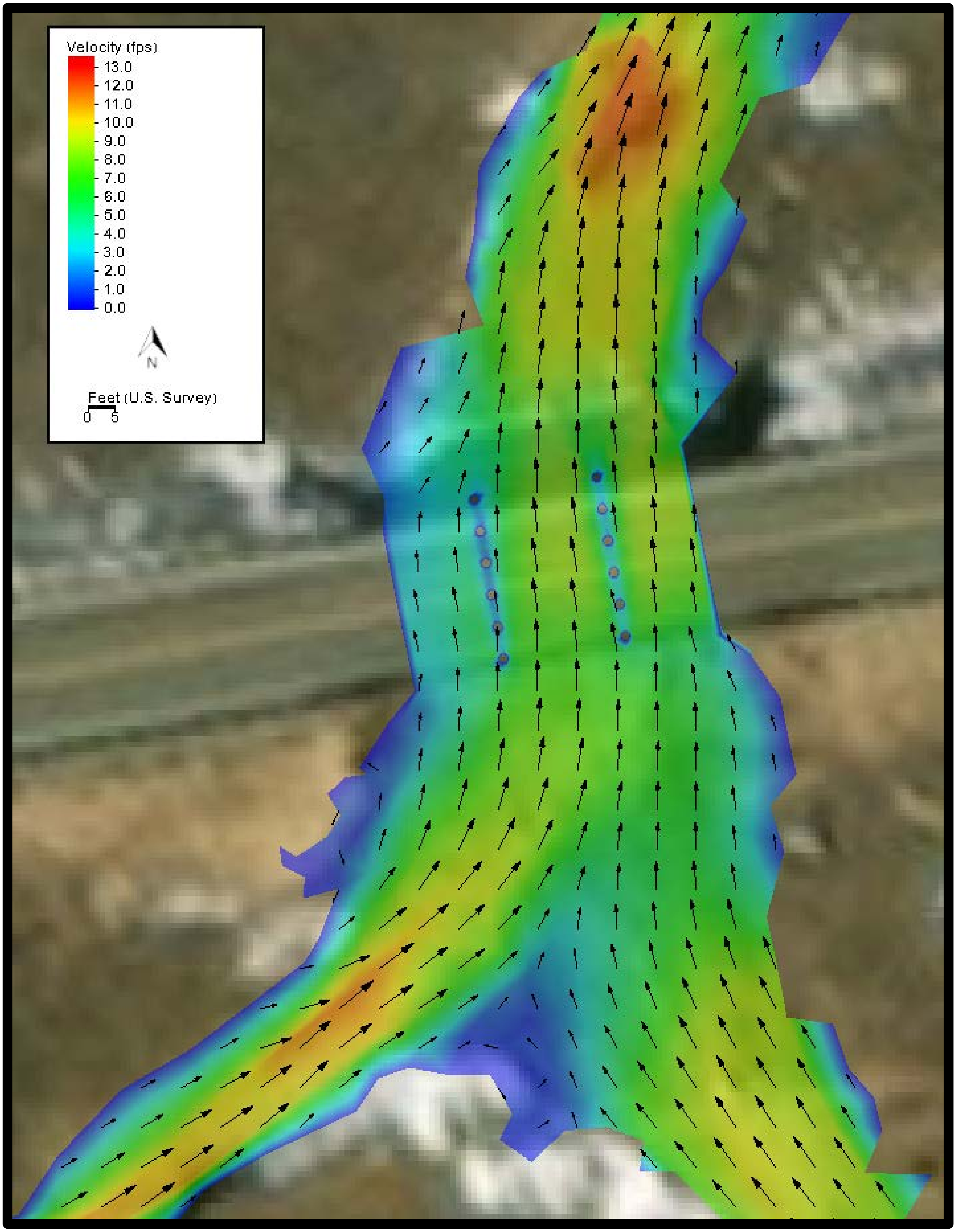
FIGURE D3



APPENDIX D – EXISTING CONDITIONS – VELOCITY

STRUCTURE I-13-G

FIGURE D4

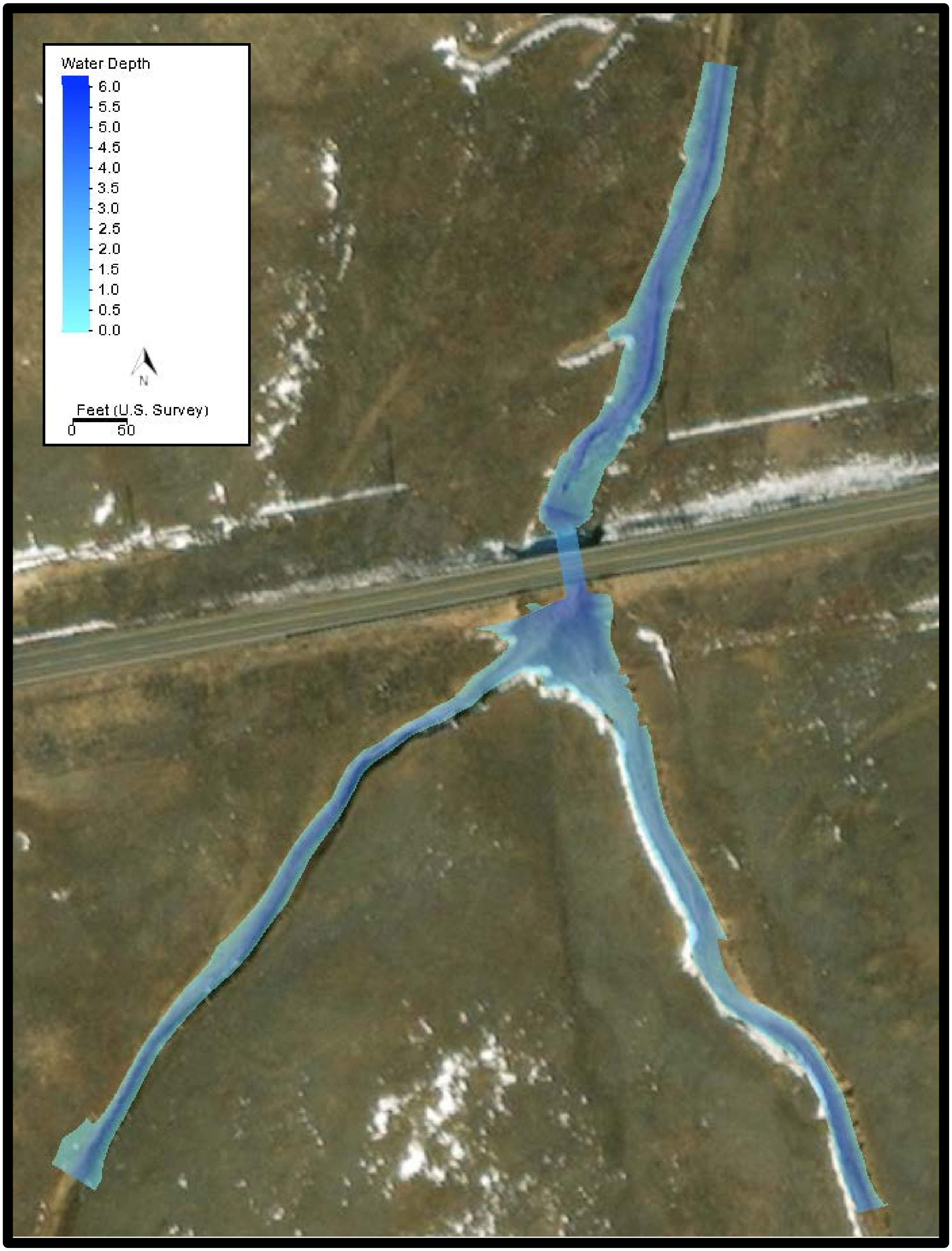


APPENDIX D – EXISTING CONDITIONS – VELOCITY

STRUCTURE I-13-G

FIGURE D5

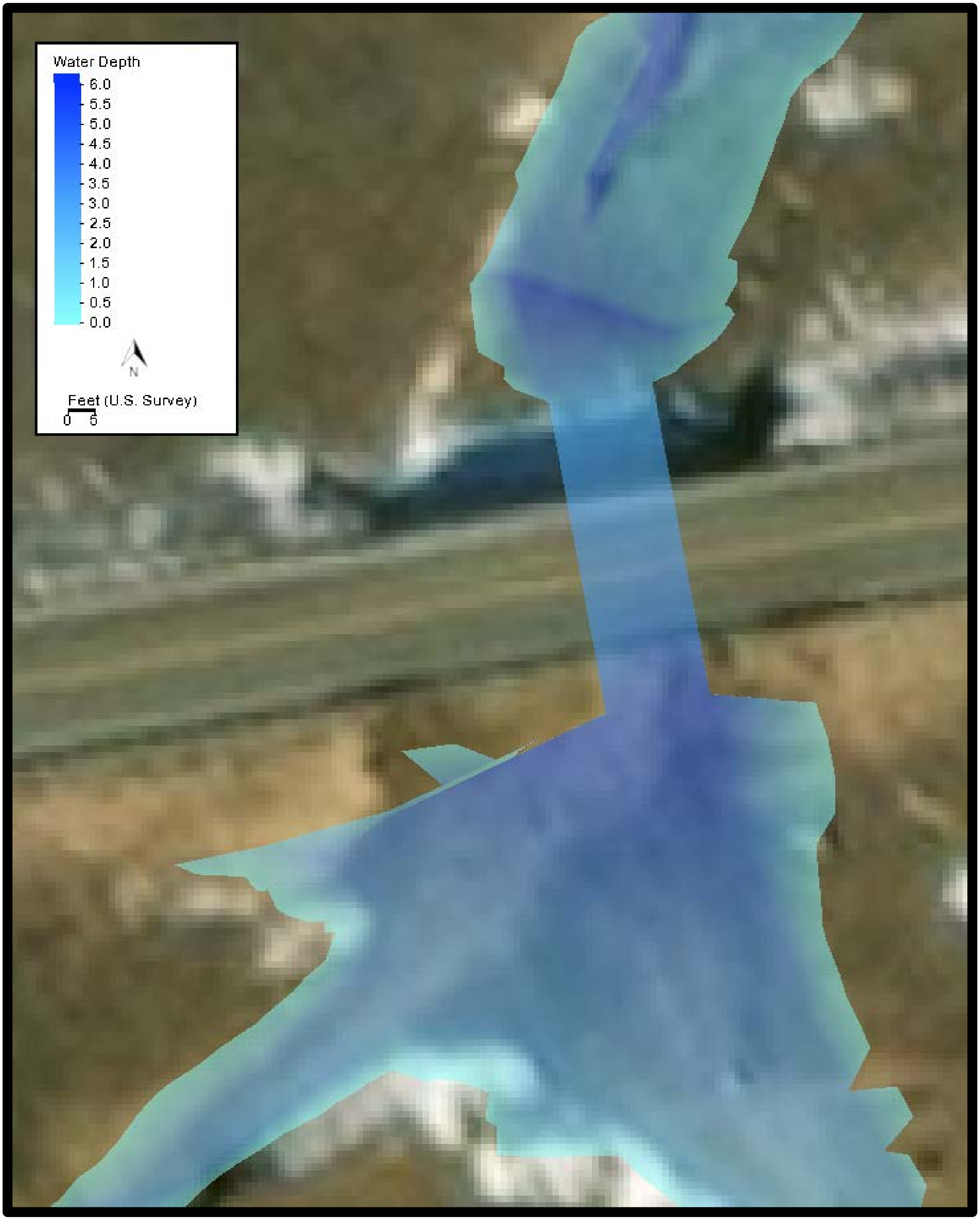
APPENDIX E PROPOSED RCBC MODEL GRAPHICS



APPENDIX E – PROPOSED RCBC – WATER DEPTH

STRUCTURE I-13-G

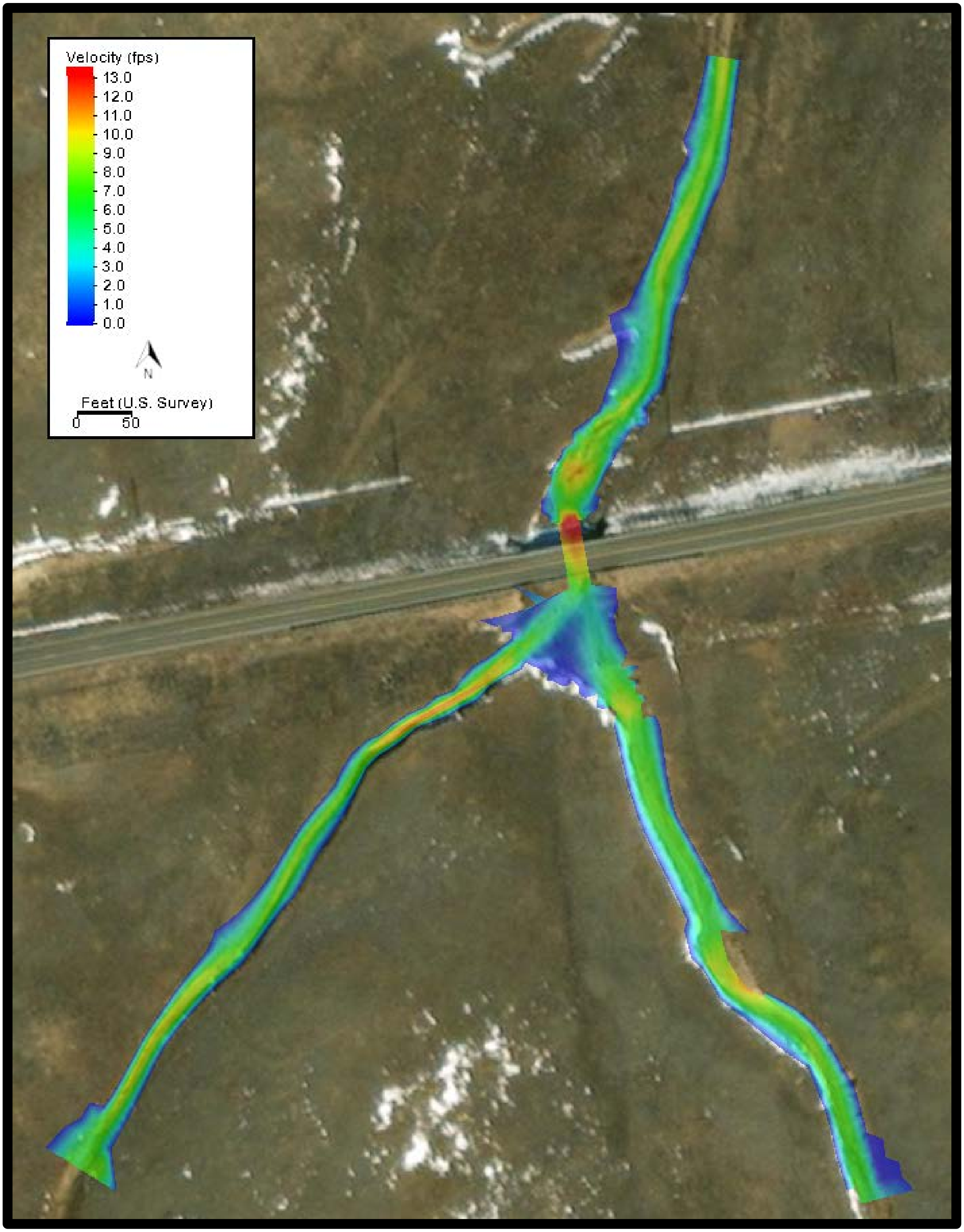
FIGURE E1



APPENDIX E – PROPOSED RCBC – WATER DEPTH

STRUCTURE I-13-G

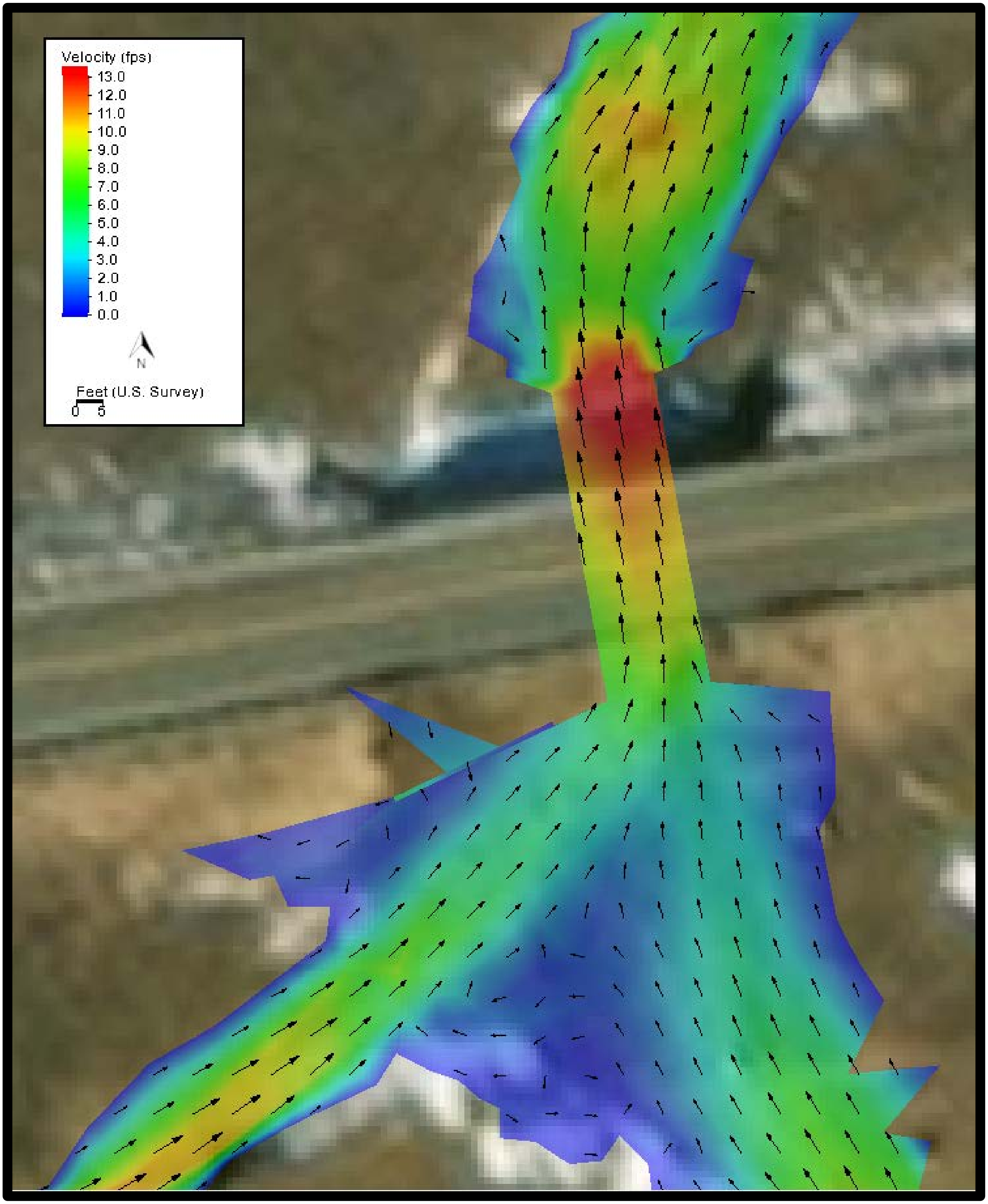
FIGURE E2



APPENDIX E – PROPOSED RCBC – VELOCITY

STRUCTURE I-13-G

FIGURE E3



APPENDIX E – PROPOSED RCBC – VELOCITY

STRUCTURE I-13-G

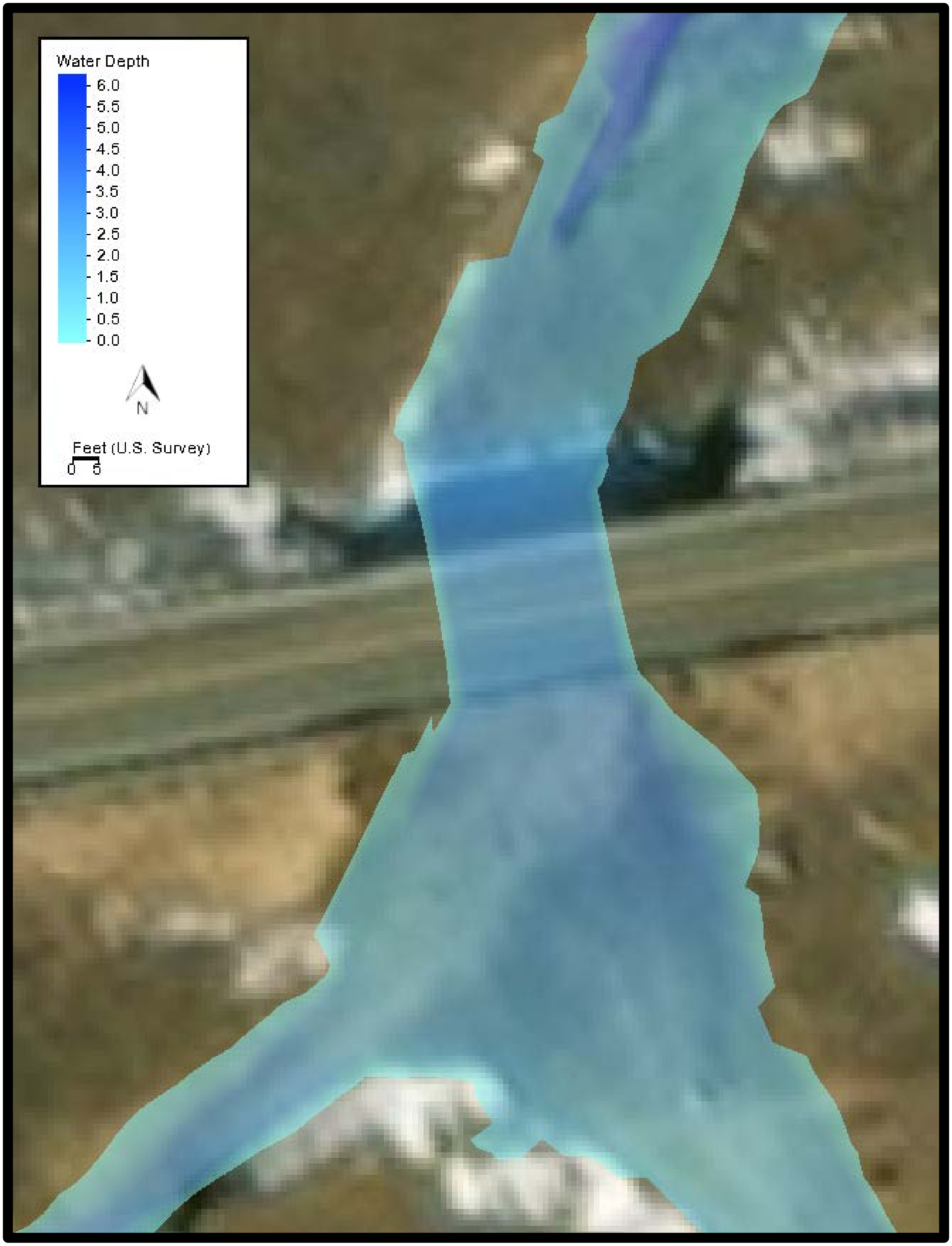
FIGURE E4

APPENDIX F PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS

APPENDIX F – PROPOSED BRIDGE – WATER DEPTH

STRUCTURE I-13-G

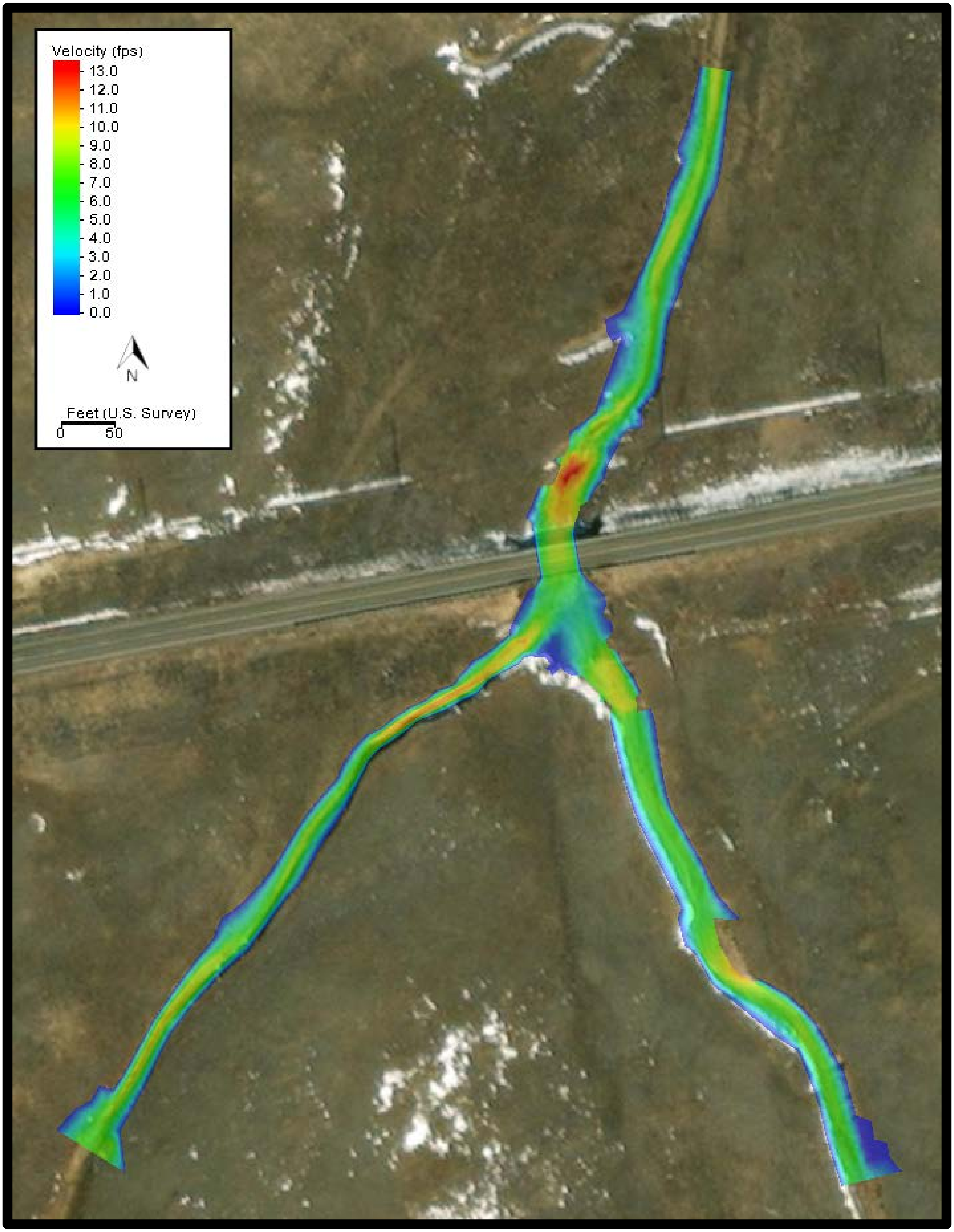
FIGURE F1



APPENDIX F – PROPOSED BRIDGE – WATER DEPTH

STRUCTURE I-13-G

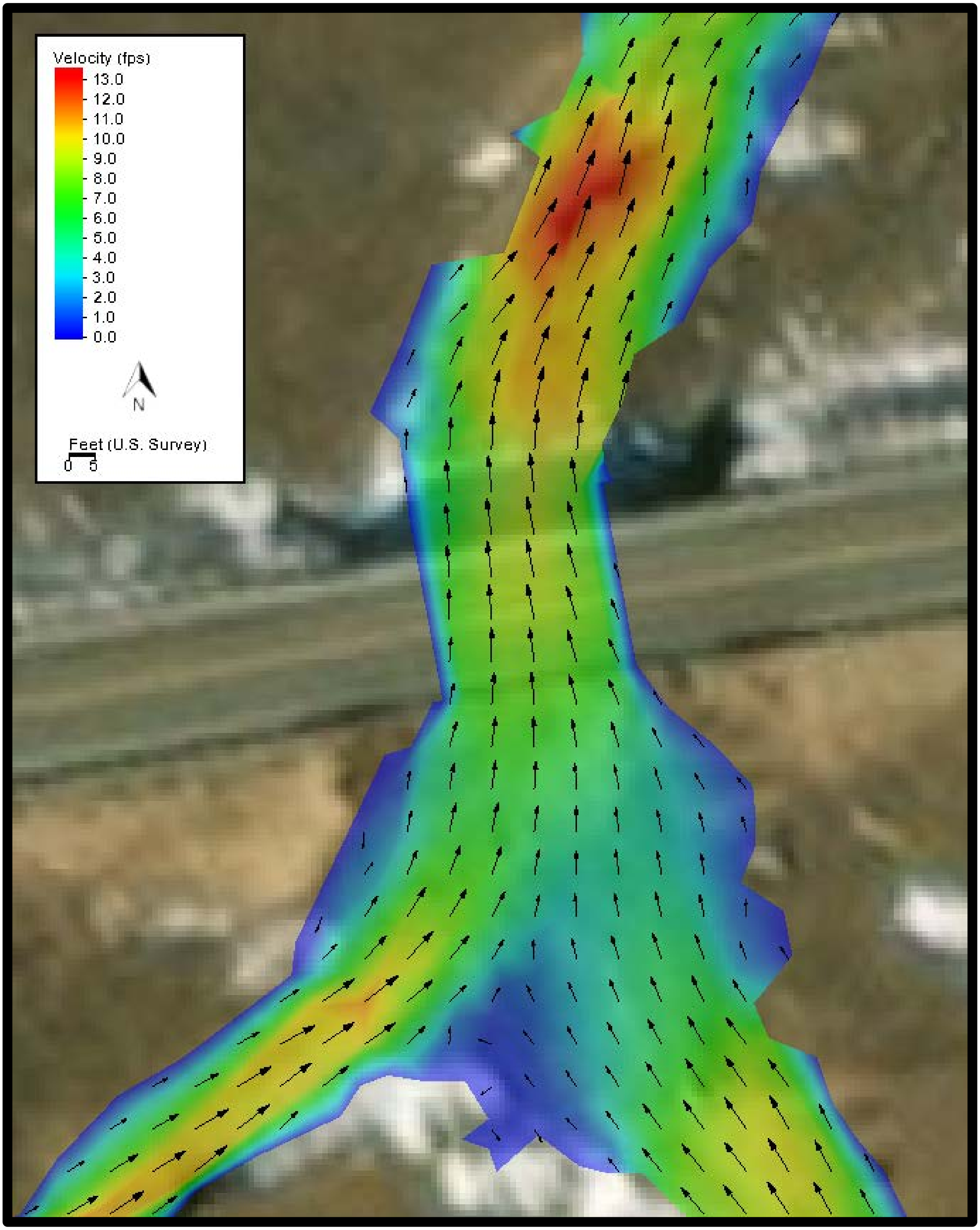
FIGURE F2



APPENDIX F – PROPOSED BRIDGE – VELOCITY

STRUCTURE I-13-G

FIGURE F3

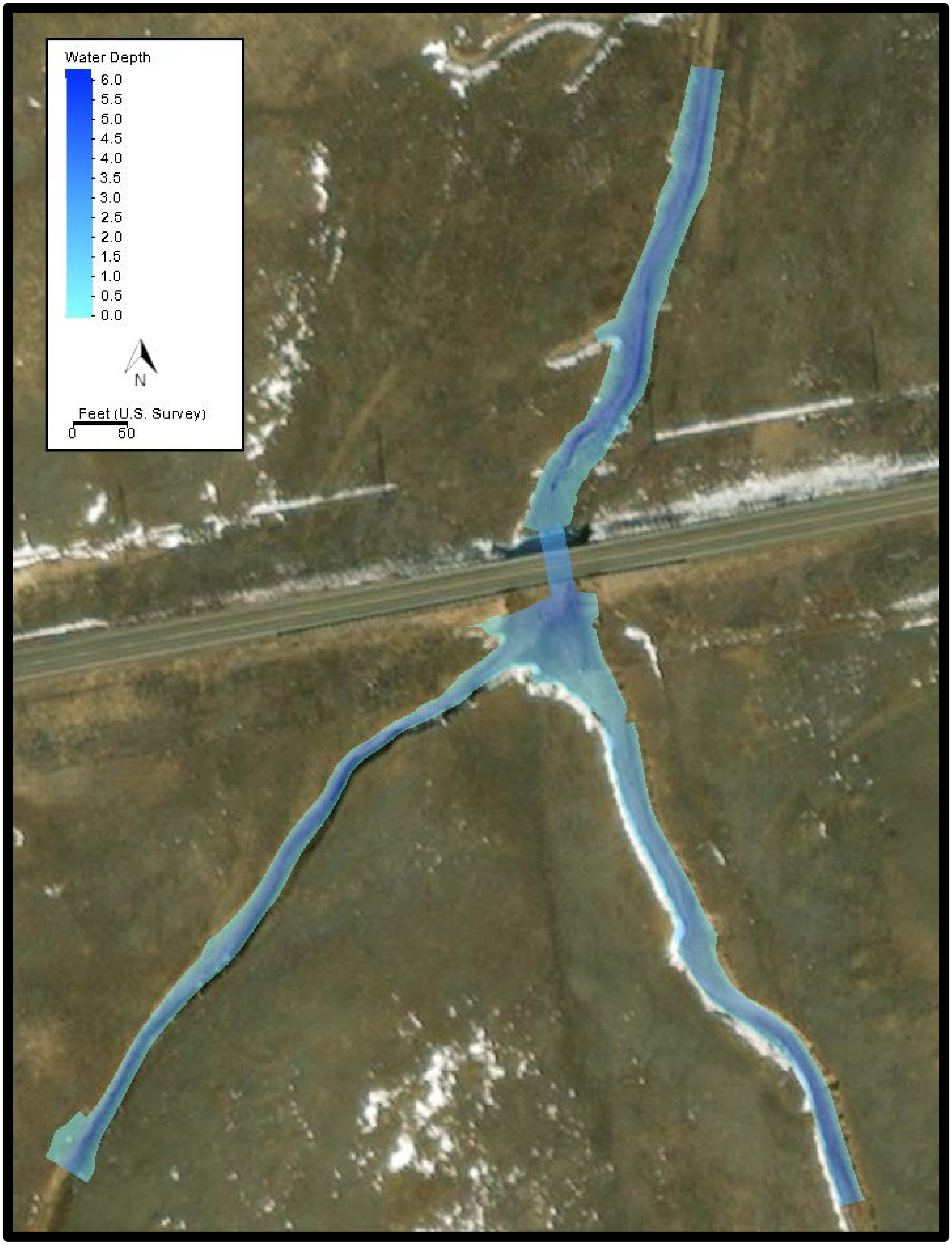


APPENDIX F – PROPOSED BRIDGE – VELOCITY

STRUCTURE I-13-G

FIGURE F4

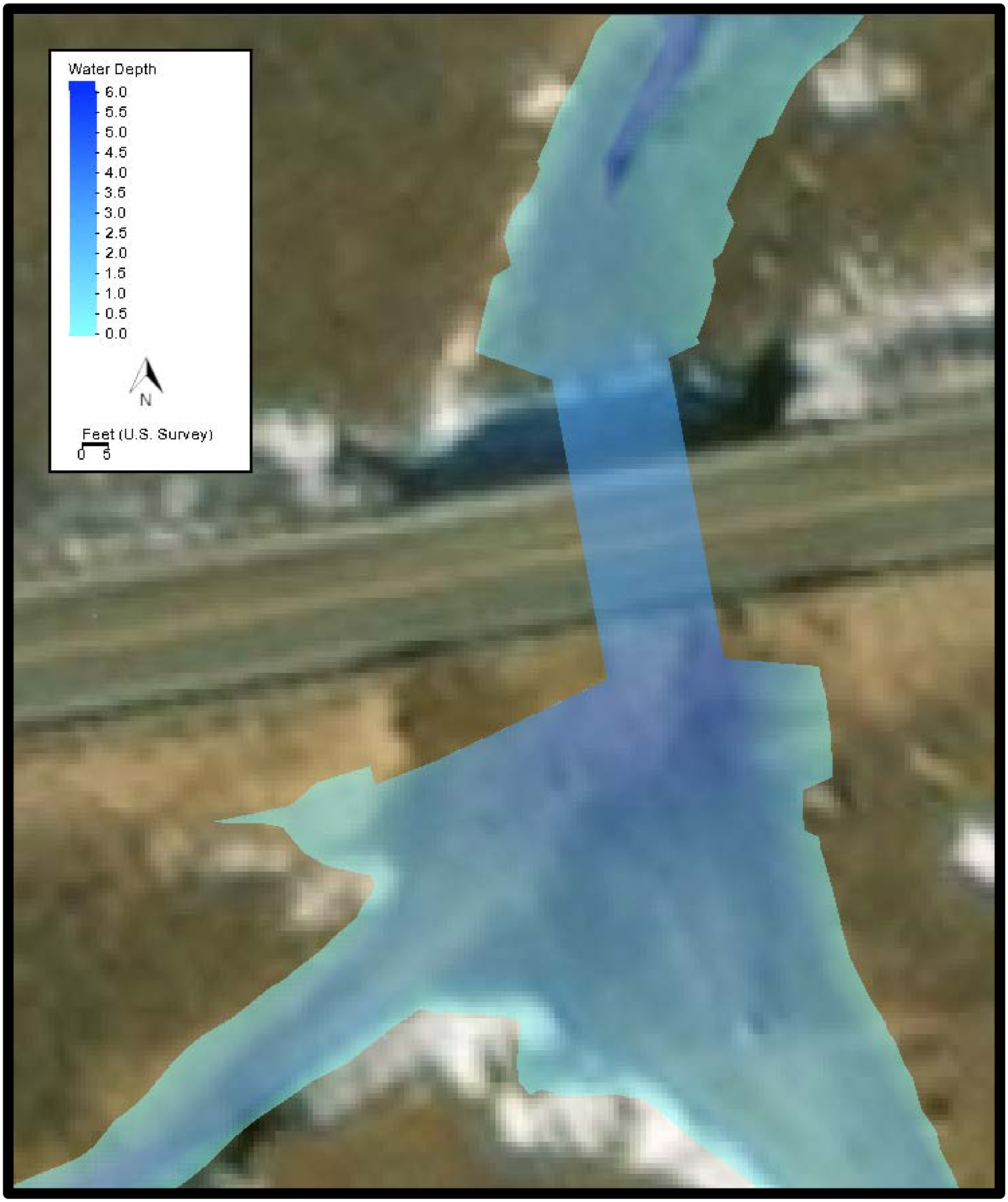
APPENDIX G PROPOSED ALUMINUM ARCHES ALTERNATIVE MODEL GRAPHICS



APPENDIX G – PROPOSED ALUMINUM ARCH – WATER DEPTH

STRUCTURE I-13-G

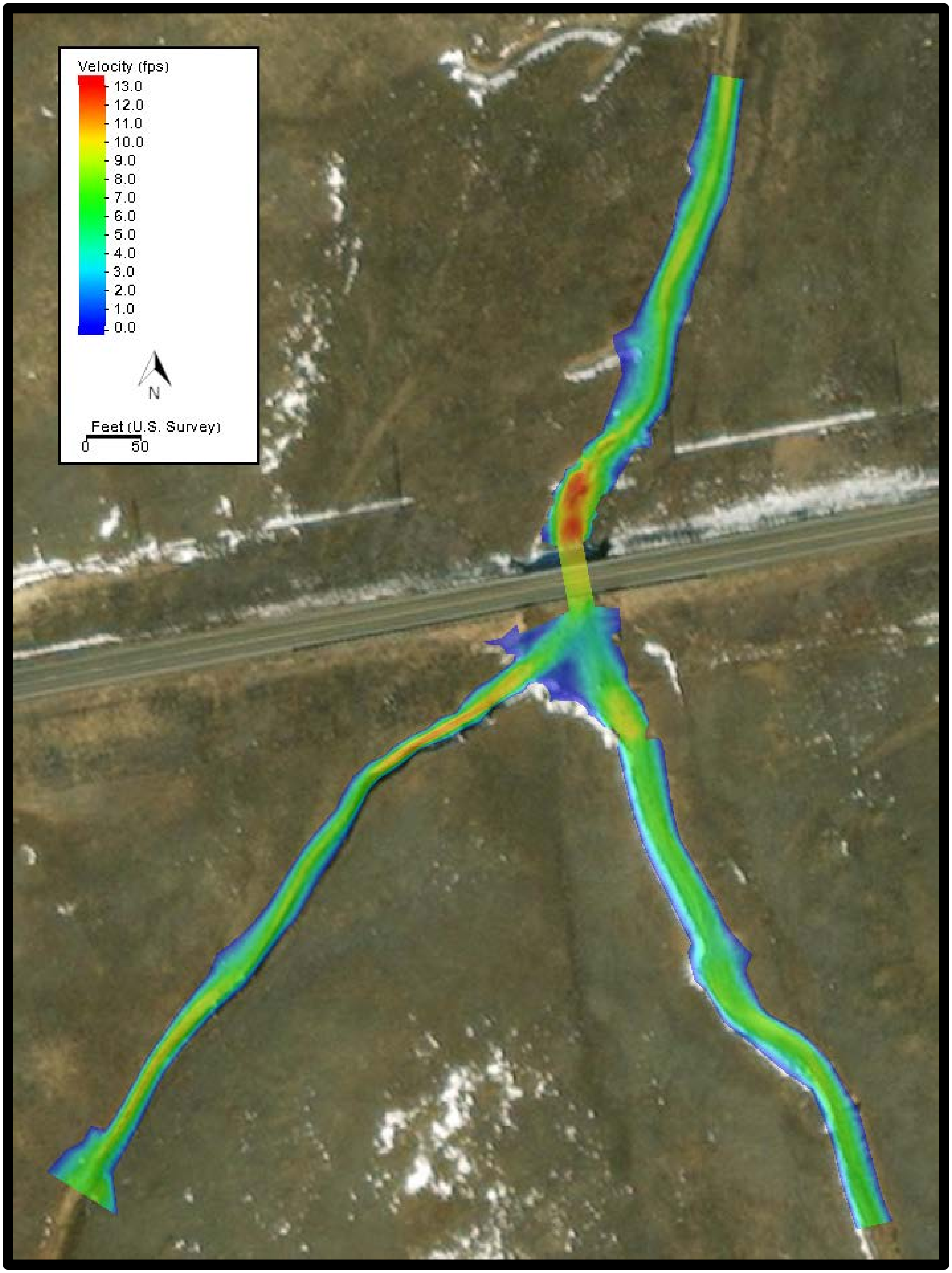
FIGURE G1



APPENDIX G – PROPOSED ALUMINUM ARCH – WATER DEPTH

STRUCTURE I-13-G

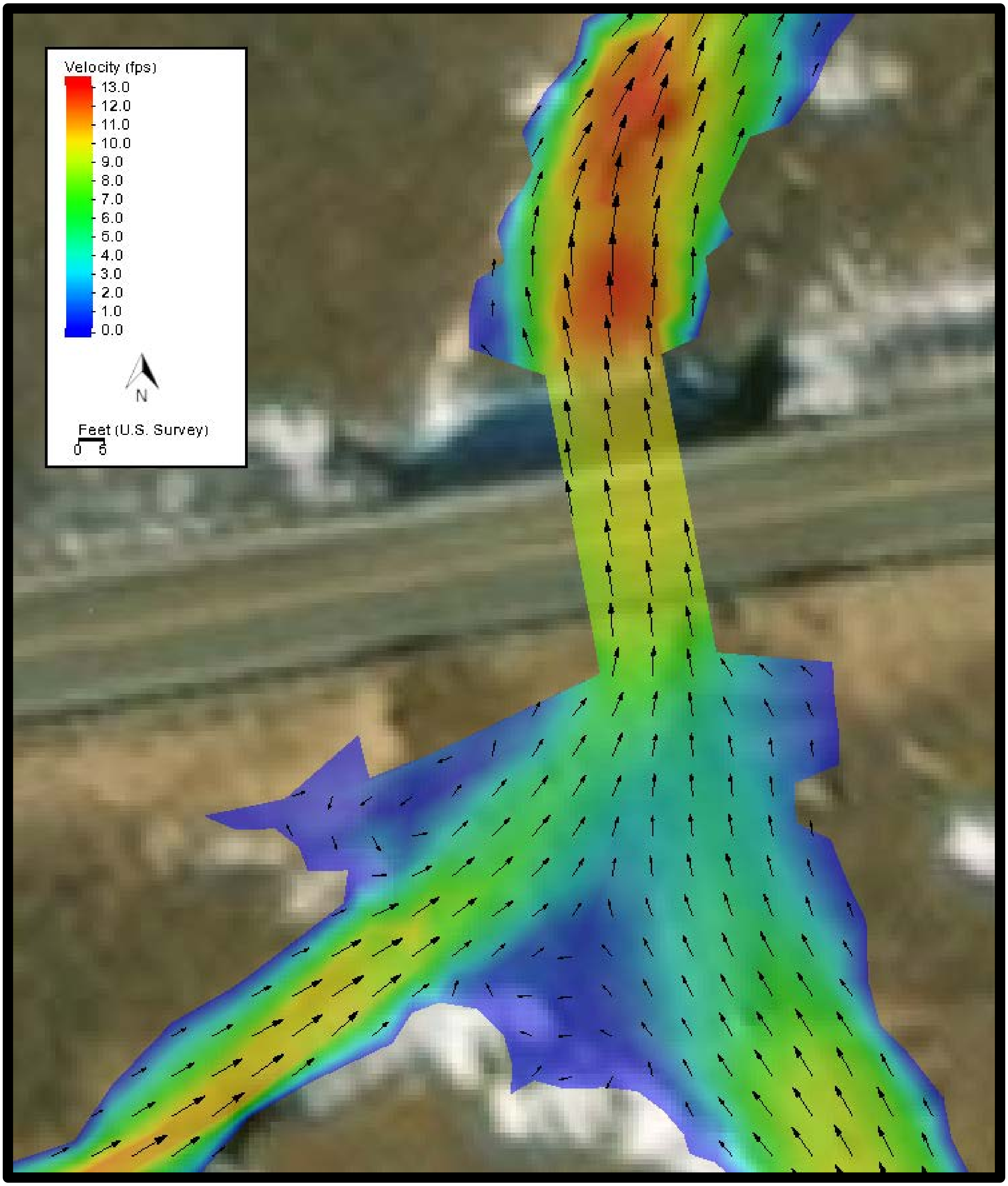
FIGURE G2



APPENDIX G – PROPOSED ALUMINUM ARCH – VELOCITY

STRUCTURE I-13-G

FIGURE G3

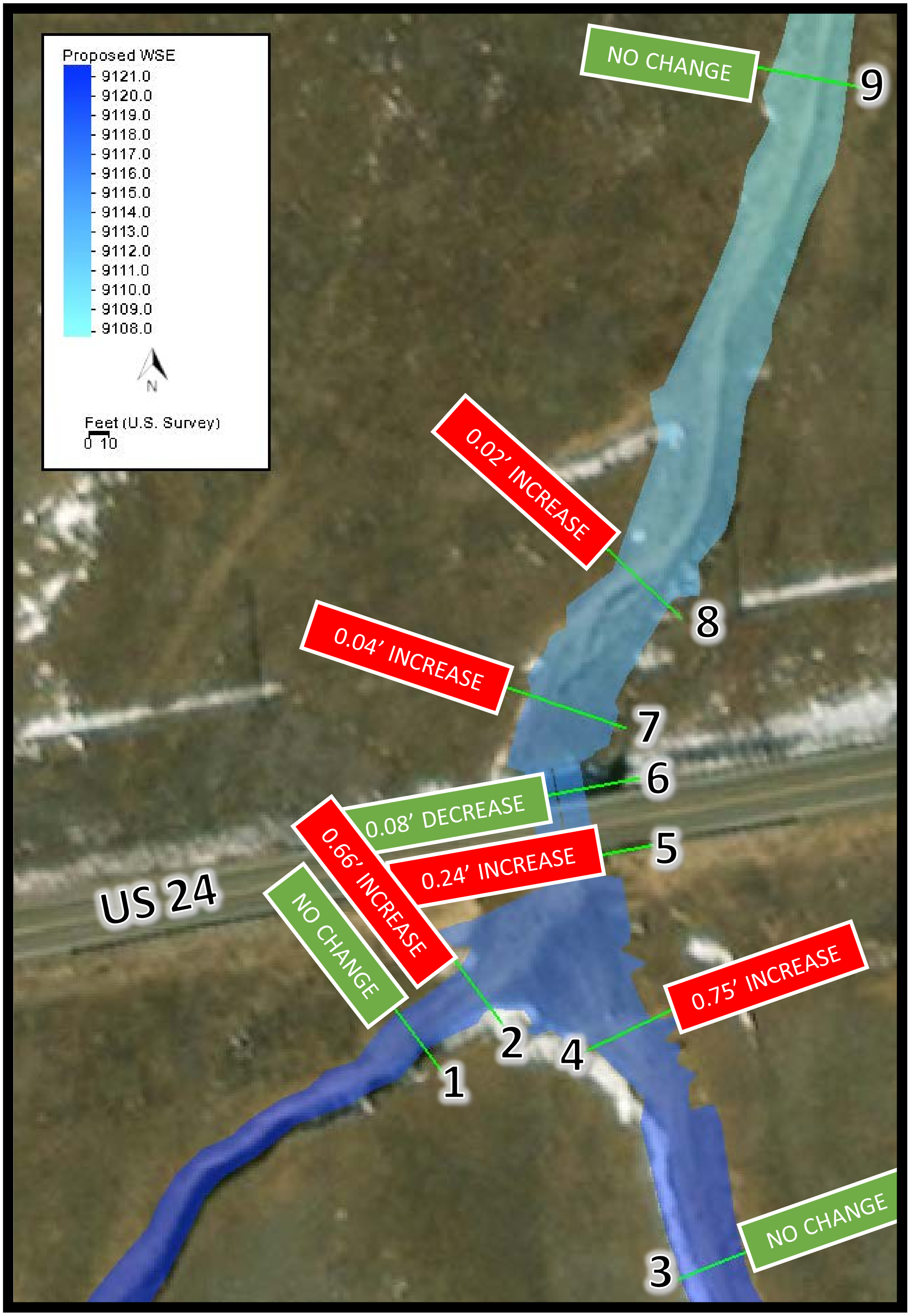


APPENDIX G – PROPOSED ALUMINUM ARCH – VELOCITY

STRUCTURE I-13-G

FIGURE G4

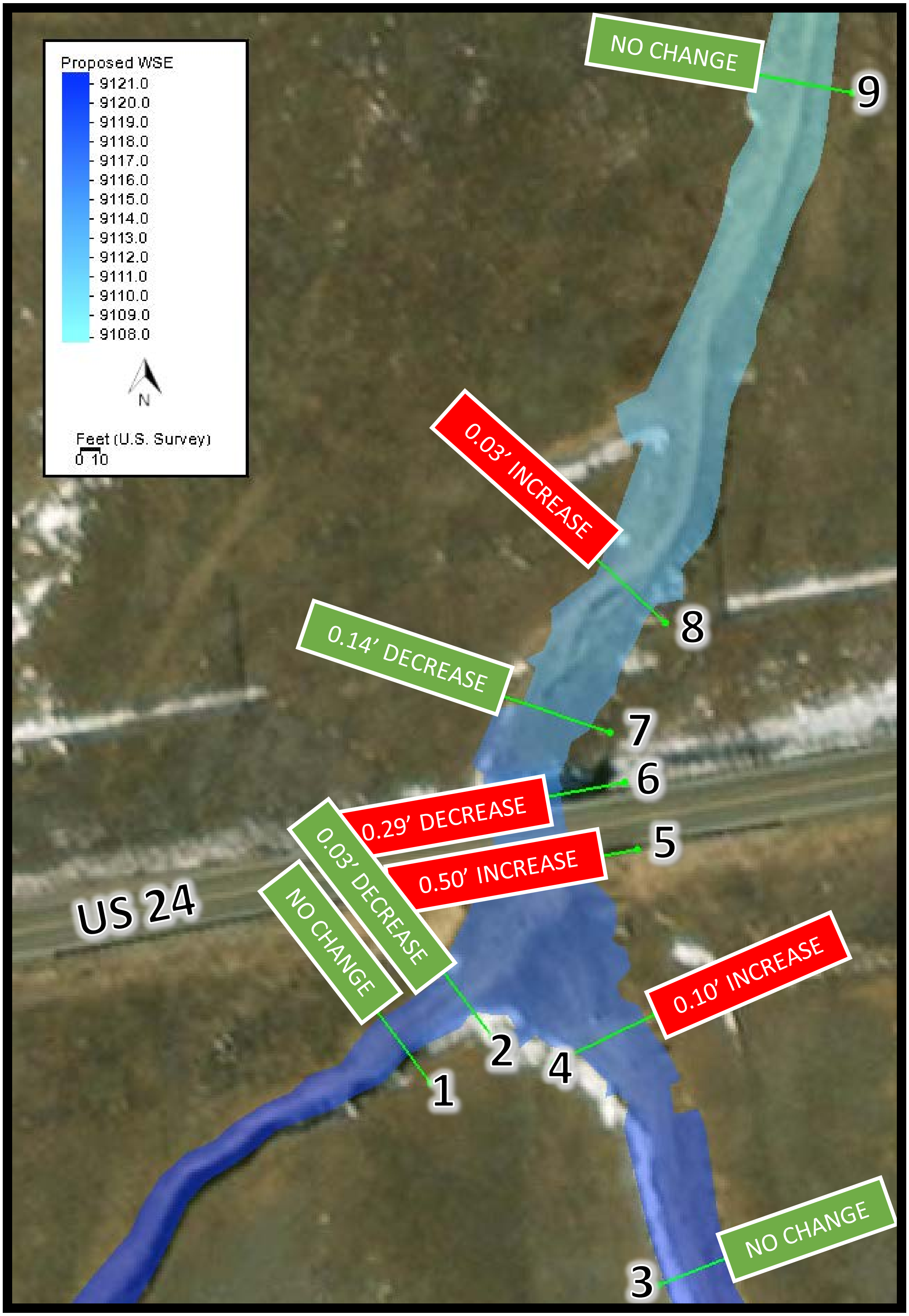
APPENDIX H WATER SURFACE ELEVATION COMPARISON GRAPHICS



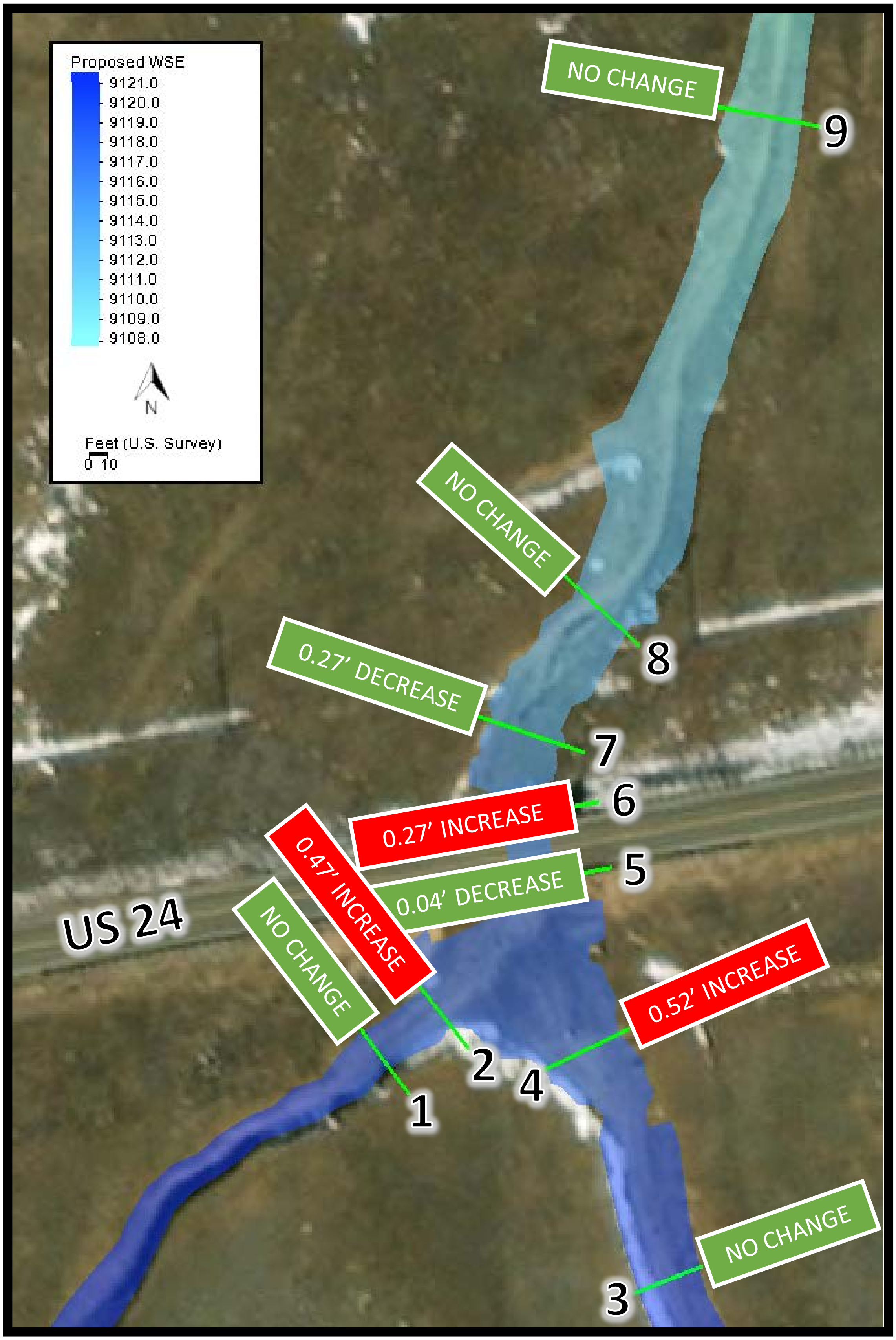
APPENDIX H – RCBC OPTION – WSE COMPARISON

STRUCTURE I-13-G

FIGURE H1



Proposed WSE
9121.0
9120.0
9119.0
9118.0
9117.0
9116.0
9115.0
9114.0
9113.0
9112.0
9111.0
9110.0
9109.0
9108.0
N
Feet (U.S. Survey)
0 10
NO CHANGE
9
0.03' INCREASE
8
0.14' DECREASE
7
6
0.29' DECREASE
0.03' DECREASE
0.50' INCREASE
5
US 24
NO CHANGE
0.10' INCREASE
2
4
1
NO CHANGE
3



APPENDIX H – ALUMINUM ARCH OPTION – WSE COMPARISON
STRUCTURE I-13-G
FIGURE H3

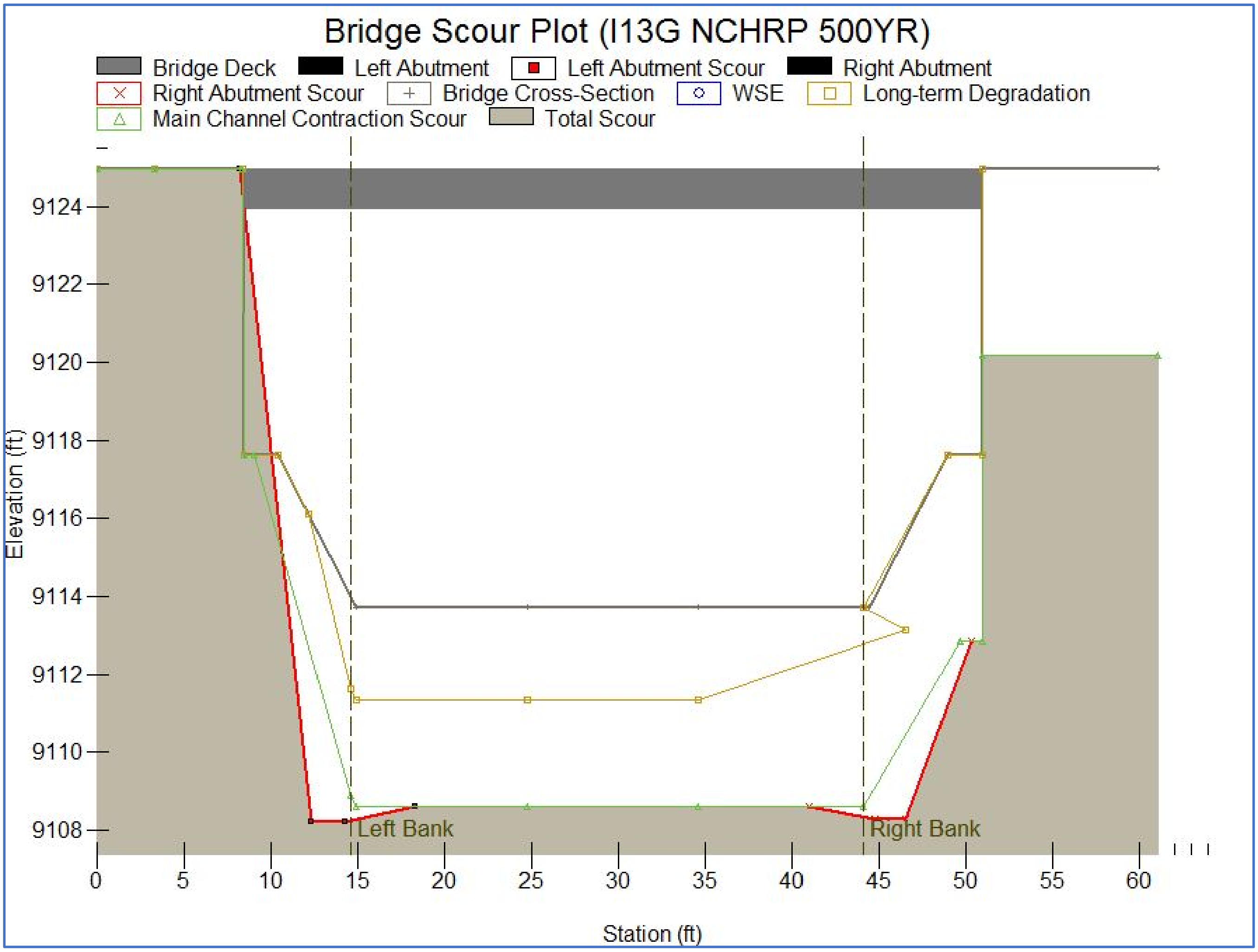
APPENDIX I ENERGY DISSIPATION AND SCOUR ANALYSIS

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	I-13-G	
Culvert	Culvert 1	
Flow	679.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	14.0	ft
Culvert Height	7.0	ft
Outlet Depth	3.67	ft
Outlet Velocity	13.20	ft/s
Froude Number	1.21	
Tailwater Depth	2.44	ft
Tailwater Velocity	5.07	ft/s
Tailwater Slope (SO)	0.0050	
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 = 0.790 ft	
D50 of the Riprap Mixture	0.750	ft
DMax of the Riprap Mixture	1.500	ft
Results		
Brink Depth	3.674	ft
Brink Velocity	13.201	ft/s
Depth (YE)	3.674	ft
Riprap Thickness	2.250	ft
Riprap Foreslope	3.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.456	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.204	
D50/YE Check	D50/YE is OK	
Basin Length (LB)	56.000	ft
Basin Width	51.333	ft
Apron Length	14.000	ft
Pool Length	42.000	ft
Pool Depth (HS)	1.842	ft
TW/YE	0.664	
Tailwater Depth (TW)	2.439	ft
Average Velocity with TW	4.953	ft/s

Critical Depth (Yc)	1.718	ft
Average Velocity with Yc	7.214	ft/s


Bridge Scour Plot (I13G NCHRP 500YR)
Bridge Deck
Left Abutment
Left Abutment Scour
Right Abutment
Right Abutment Scour
Bridge Cross-Section
WSE
Long-term Degradation
Main Channel Contraction Scour
Total Scour
Elevation (ft)
9124
9122
9120
9118
9116
9114
9112
9110
9108
Left Bank
Right Bank
0
5
10
15
20
25
30
35
40
45
50
55
60
Station (ft)

Hydraulic Analysis Report

Project Data

Project Title: I-13-G 100YR

Designer: Stanley Consultants

Project Date: Thursday, December 17, 2020

Project Units: U.S. Customary Units

Riprap Analysis: Bridge - Left Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the average velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 2.77 ft

Flow Depth at Toe of Abutment: 2.73 ft

Calculations will use either total or overbank discharges.

Total Discharge: 679 cfs

Overbank Discharge: 95.55 cfs

Total Bridge Area: 97 ft^2

Setback Area: 13.65 ft^2

Maximum Channel Velocity: 7 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.80505

Characteristic Velocity: 7 ft/s

Froude Number at the Abutment Toe: 0.746903

Abutment Coefficient: 1.02

Computed D50: 11.2977 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 11.2977 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

Minimum Riprap Thickness: 24 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 5.46 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

No channel used in calculations

Riprap Analysis: Bridge - Right Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the average velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 2.77 ft

Flow Depth at Toe of Abutment: 2.93 ft

Calculations will use either total or overbank discharges.

Total Discharge: 679 cfs

Overbank Discharge: 95.55 cfs

Total Bridge Area: 97 ft^2

Setback Area: 13.65 ft^2

Maximum Channel Velocity: 7 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.80505

Characteristic Velocity: 7 ft/s

Froude Number at the Abutment Toe: 0.720961

Abutment Coefficient: 1.02

Computed D50: 11.2977 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 11.2977 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

Minimum Riprap Thickness: 24 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 5.86 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

No channel used in calculations

Riprap Analysis: Arch Culvert - Left Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the maximum velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 4.87 ft

Flow Depth at Toe of Abutment: 4.95 ft

Calculations will use either total or overbank discharges.

Total Discharge: 679 cfs

Overbank Discharge: 123.5 cfs

Total Bridge Area: 136 ft^2

Setback Area: 24.75 ft^2

Maximum Channel Velocity: 4.99 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.02669

Characteristic Velocity: 4.99265 ft/s

Froude Number at the Abutment Toe: 0.395618

Abutment Coefficient: 1.02

Computed D50: 5.74717 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 5.74717 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS II

Riprap Class Order: 2

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 18 in

d85: 13 in

d50: 9.5 in

d15: 7 in

Layout Recommendations

Minimum Riprap Thickness: 18 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 9.9 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

No channel used in calculations

Riprap Analysis: Arch Culvert - Right Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the maximum velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 4.87 ft

Flow Depth at Toe of Abutment: 4.9 ft

Calculations will use either total or overbank discharges.

Total Discharge: 679 cfs

Overbank Discharge: 122.26 cfs

Total Bridge Area: 136 ft^2

Setback Area: 24.75 ft^2

Maximum Channel Velocity: 4.99 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.02669

Characteristic Velocity: 4.99265 ft/s

Froude Number at the Abutment Toe: 0.397631

Abutment Coefficient: 1.02

Computed D50: 5.74717 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 5.74717 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS II

Riprap Class Order: 2

The following values are an 'average' of the size fraction range for the selected riprap class.

d100: 18 in

d85: 13 in

d50: 9.5 in

d15: 7 in

Layout Recommendations

Minimum Riprap Thickness: 18 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 9.8 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

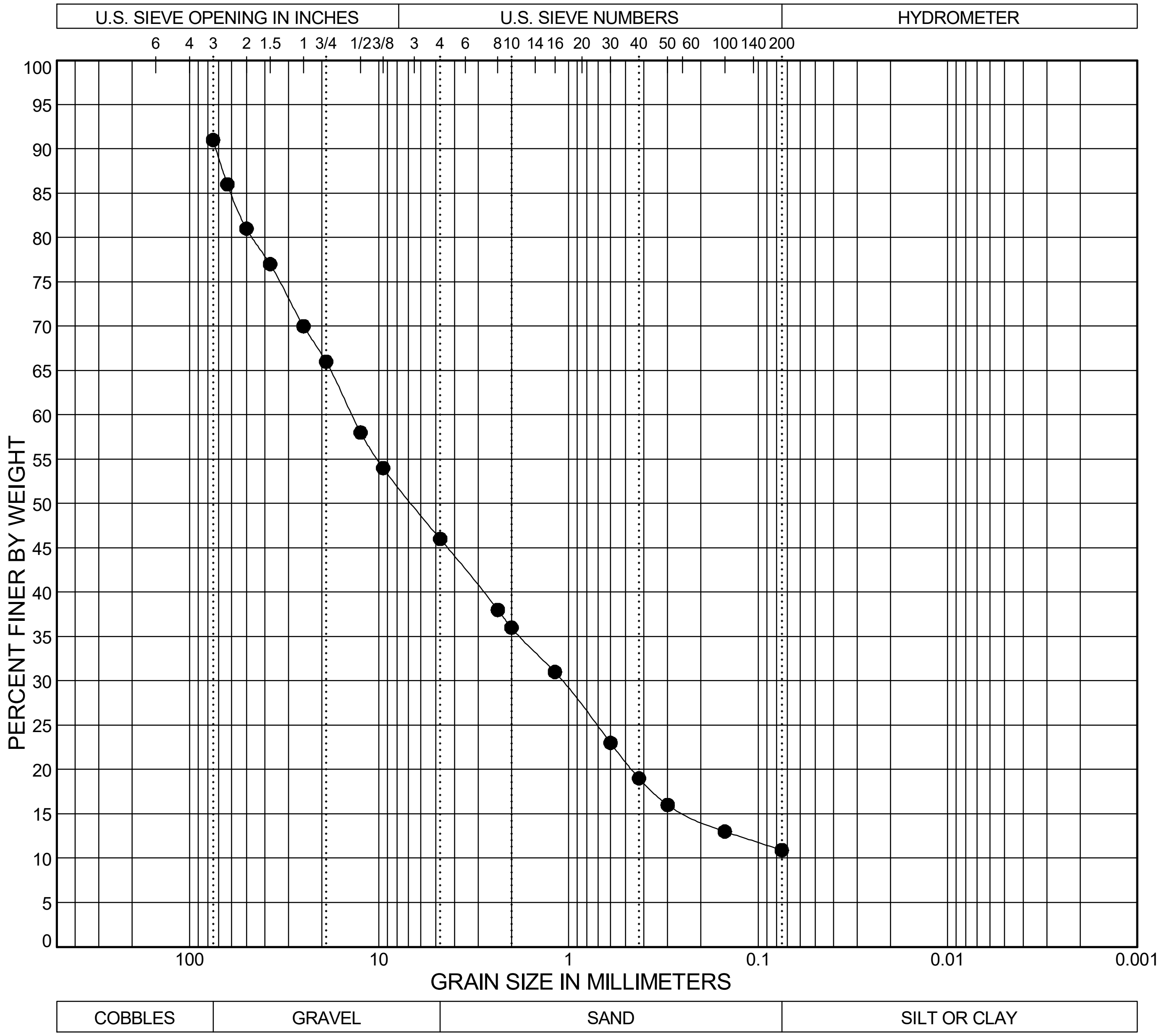
No channel used in calculations

APPENDIX J GEOTECHNICAL INFOMATION

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-13-G Scour**	**0.0**	**A-2-4 (0)**	**GW-GC**	**27**	**18**	**9**	**45.0**	**35.1**	**10.9**	

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SIEVE ANALYSIS

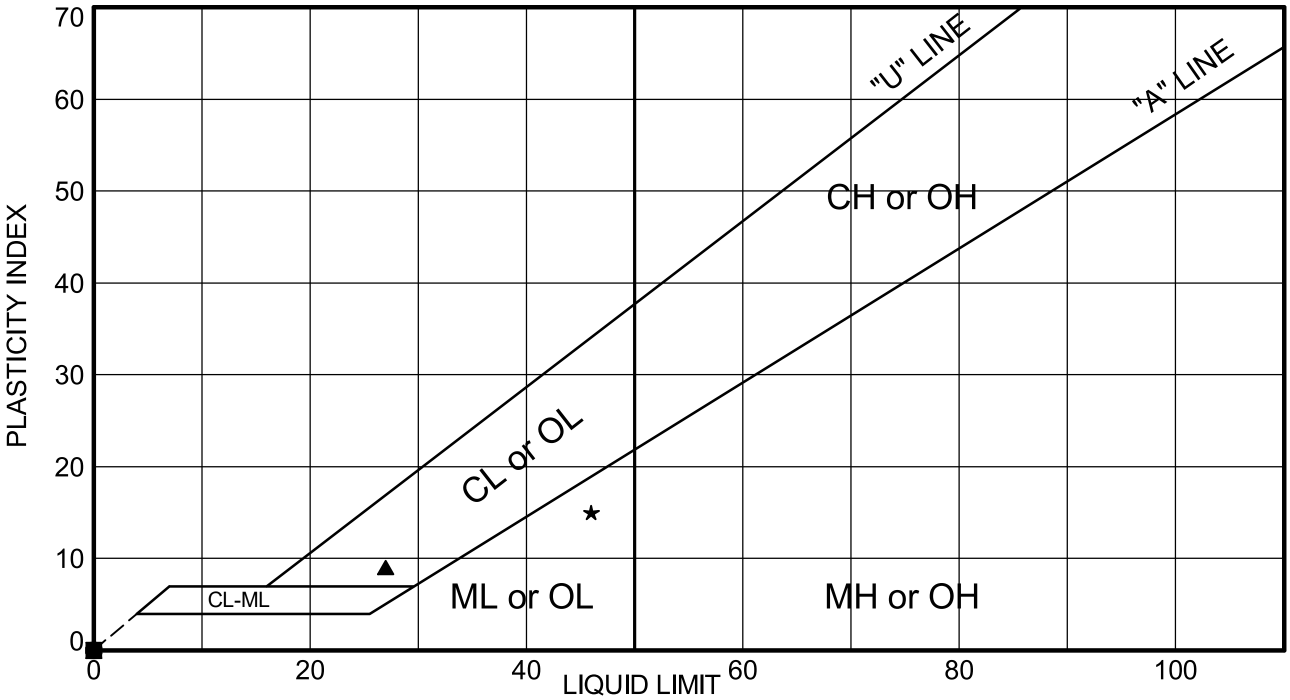
FIGURE

S- 3

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-13-G

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/24/20



	BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
●	**G-12-C Scour**	**0.0**	**NV**	**NP**	**NP**	**0.4**	**POORLY GRADED GRAVEL (GP)**	**A-1-a (0)**
⧗	**H-13-N Scour**	**0.0**	**NV**	**NP**	**NP**	**40.0**	**SILTY SAND (SM)**	**A-4 (0)**
▲	**I-13-G Scour**	**0.0**	**27**	**18**	**9**	**10.9**	**WELL-GRADED GRAVEL with CLAY and SAND (GW-GC)**	**A-2-4 (0)**
★	**I-13-H Scour**	**0.0**	**46**	**31**	**15**	**66.9**	**SANDY SILT (ML)**	**A-7-5 (10)**
⊙	**I-15-AO Scour**	**0.0**	**NV**	**NP**	**NP**	**5.8**	**WELL-GRADED GRAVEL with SILT and SAND (GW-GM)**	**A-1-a (0)**
✿	**I-15-T Scour**	**0.0**	**NV**	**NP**	**NP**	**3.8**	**WELL-GRADED SAND with GRAVEL (SW)**	**A-1-a (0)**
○	**I-17-X Scour**	**0.0**	**NV**	**NP**	**NP**	**0.7**	**WELL-GRADED GRAVEL with SAND (GW)**	**A-1-a (0)**
△	**J-14-C Scour**	**0.0**	**NV**	**NP**	**NP**	**5.3**	**POORLY GRADED GRAVEL with SILT and SAND (GP-GM)**	**A-1-a (0)**
⊗	**J-15-G Scour**	**0.0**	**NV**	**NP**	**NP**	**7.3**	**POORLY GRADED SAND with SILT (SP-SM)**	**A-1-b (0)**

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ATTERBERG LIMITS

FIGURE

S - 10

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
West Bridges

01 ATTERBERG LIMITS YEH - ALL BORINGS 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/24/20