PRELIMINARY HYDRAULICS REPORT
STRUCTURE J-15-G REPLACEMENT

As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
FREMONT COUNTY, COLORADO

A Part of Section 7, Township 16 South, Range 72 West of the 6^{th} P.M.,
County of Fremont, Colorado

February 12, 2021

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1. INTRODUCTION

1.1 Background and Purpose

The objective of Colorado Department of Transportation (CDOT) Region 2 Bridge Bundle Design Build project is to replace nineteen (19) rural structures spread across highway corridors in southern and western Colorado. The structures are located on US 350, US 24, CO 9, and CO 239. The role of Stanley Consultants is to assist CDOT in the design build procurement, geotechnical engineering, environmental clearances, survey, utility location and coordination, hydrology and hydraulics, preliminary structural design and roadway design.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, project number 23558) and funds from the Colorado Bridge Enterprise (5 additional structures, project number 23559). These projects are combined to form one design-build project.

The nineteen bridges identified to be included in the 'Region 2 Bridge Bundle' were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure J-15-G as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Fremont County at Mile Post 15.970 along SH 9 between Hartsel and US 50 junction. Structure J-15-G conveys flow from Mack Gulch under SH 9. Figure 1 below illustrates the project location. The project is located in Section 7, Township 16 South, Range 72 West of the 6th P.M., County of Fremont, 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) 08043C0125E effective date September 19, 2007, as shown in Appendix A. FEMA Zone X is an area of minimal flood hazard risk. Since J-15-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 outside a regulatory floodplain 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 J-15-G falls into the 25-year design category, but because the existing structure passes the 100-year flows, the proposed structures has been sized accordingly.

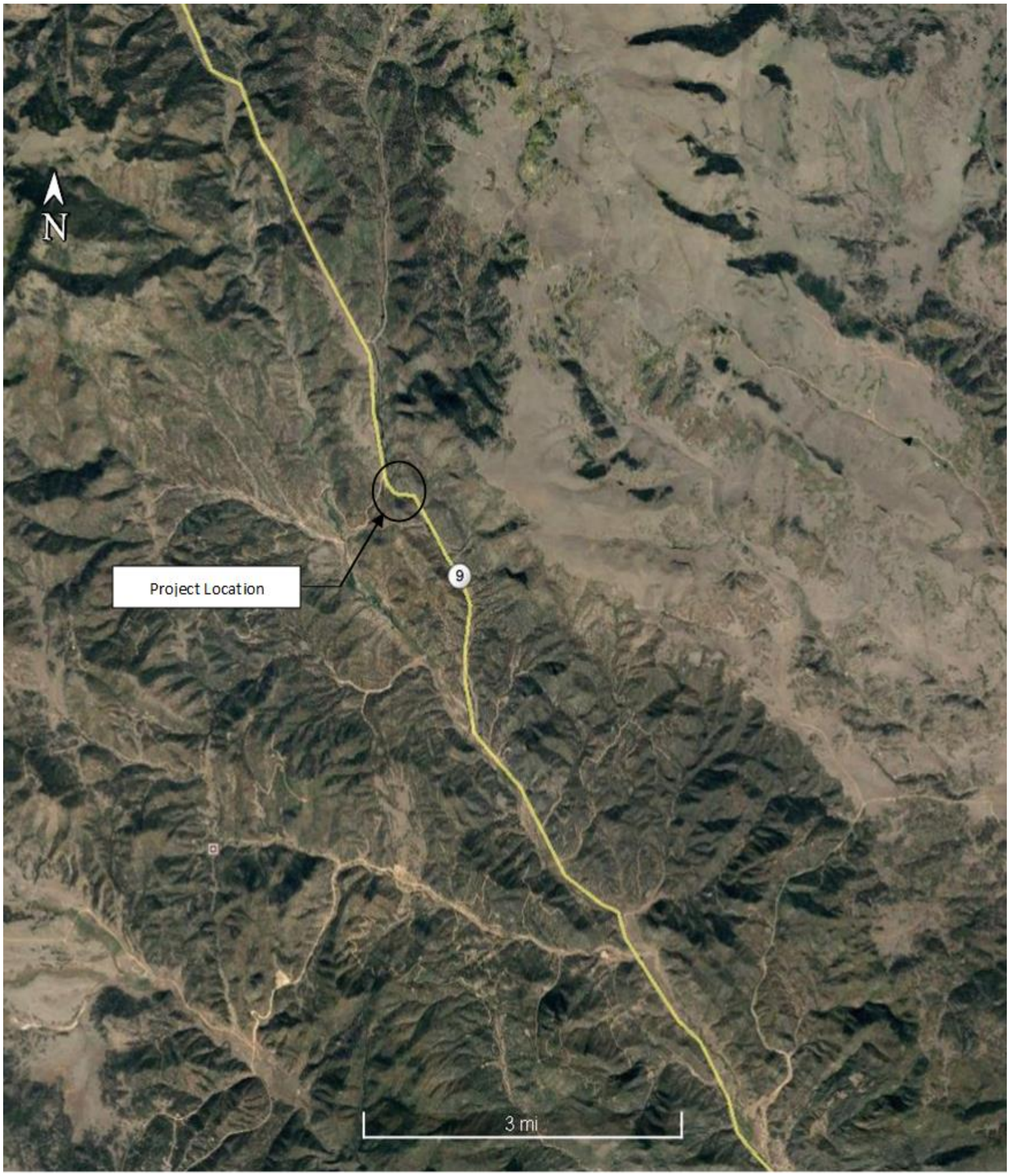


Figure 1: Vicinity Map

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. Structure J-15-G is located outside a FEMA 100-year floodplain, crosses a rural two-lane road, and conveys flows less than 4,000 cfs, therefore the models were developed using the 25-year storm. Table 1 is a summary of the approximate flowrates provided by CDOT of structure J-15-G.

Table 1: Summary of Peak Discharge for Bridge J-15-G

River Location	Design Storm	25-year (cfs)	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	25-year	1,341	2,402	3,054	4,019

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing structure consists of two (2) 84.0 inch galvanized CMP pipes built in 1971 to allow for the Mack Gulch to cross under State Highway (SH) 9. The structure has a 45-degree skew and are approximately 60.0 ft long. There are no special end treatments at either end of the structure. The pipes are on a 4.36% vertical slope with approximately 18.0 in of cover.

The structure is located on SH 9, 6.2 miles south of Guffey, Colorado, at MP 15.970, 14 miles north of junction of SH 9 and US 50.

3.2 Watershed Overview

Mack Gulch is a valley in Park County, Colorado that flows from the north along Glitter Gulch Ct towards the south crossing SH 9 to eventually meet with Currant Creek. The stream bed does not have a base flow.

The stream flows at an approximate angle of attack of 45 degrees to the roadway. The area surrounding the bridge is rural with undeveloped land to both upstream and downstream sides of the culvert.

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 severe corrosion and areas of section loss ranging from 25 to 100% are present along the length of the two 84” existing pipes. Site photos are included in Appendix B.

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: Pipe Culvert 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 2. 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 B.

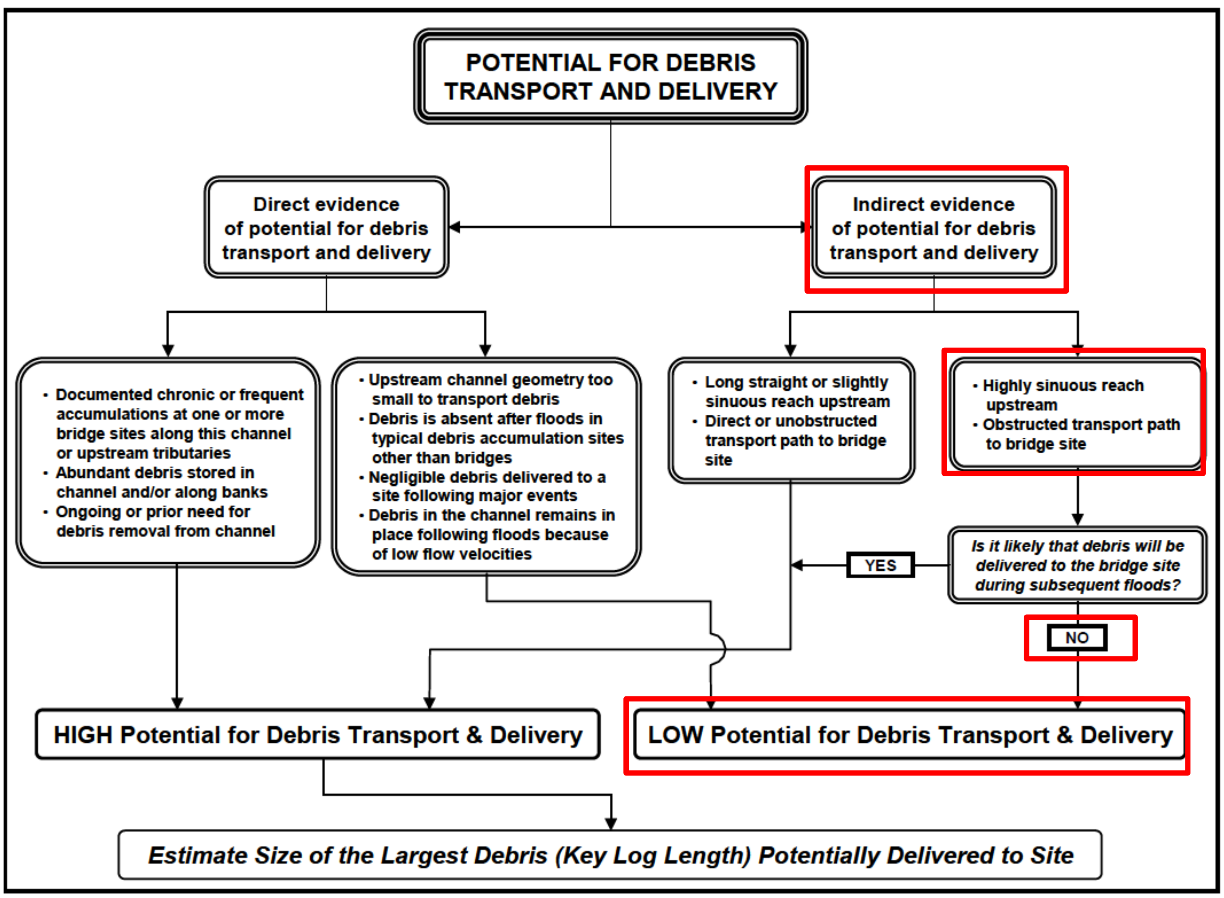


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

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. A bridge option is not considered for this crossing, therefore freeboard requirements are not applicable.

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 16,510 and the mesh extends approximately 973 feet upstream of the culvert and 805 feet downstream of the culvert.

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 B, and a map showing existing conditions materials coverages is shown in Appendix C.

Table 2: Manning's n-values

Land Use	n-value
Channel	0.045
Overbank	0.05
Paved Road	0.016
Open Space	0.035

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.

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

Table 3: Model Boundary Condition Inputs

Frequency Storm	Inflow (cfs)	Outflow Constant WSE (ft)
25-Year	1,341	7975.06

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 pipe culverts. The roadway elevation above the culvert is 8007.82 feet, while culvert inverts are 7999.97 feet, and 7997.35 feet, upstream and downstream, respectively. The existing culverts are 60 feet long. The culvert was modeled using HY-8.

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.5 seconds time step for 4 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 bridge during the 25-year event is from 1.0 feet to 7.0 feet. Figure 5 presents the depth for the entire flood limits and the structure. The results also demonstrate that the existing culvert overtops during the 25-year event. Existing conditions 25-year depths of flow are shown in Appendix C.

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. A pipe culvert and a 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 Pipe Culvert

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included adding a berm on the upstream channel overbank to contain flow into the existing channel. The proposed model has 16,510 mesh elements. HY-8 was used to model this proposed pipe culvert due to the limitations of modeling a pipe structure in SRH-2D.

Because the existing condition overtops the road, a larger opening size was used for the pipe culvert to keep the WSEs below the edge of roadway and meet Headwater Depth to Culvert Depth HW/D ratio as required by the CDOT DDM. The preliminary model shows the roadway embankment sloping at 4:1, and the proposed culvert being 76 feet in length. The pipe culvert option for this structure requires (4) 84" pipes. This structure size was determined to lower the WSEs of the channel. The headwater elevation at the culvert entrance is 8007.47 feet, which results in an HW/D of 1.08.

Depths and velocity grids for the proposed pipe culvert show depths from 1.8 to 7.8 feet and velocities from 1 to 6.5 ft/s. See Appendix D for 25-year depths and velocities graphics for this option.

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included adding a berm on the upstream channel overbank to contain flow into existing channel. The proposed model has 16,510 mesh elements. The preliminary model shows the roadway embankment sloping at 4:1, and the proposed culvert being 76 feet in length. The RCBC option for this structure involves a 2-cell structure with each cell opening size approximately 20-feet wide by 6-feet tall. This structure lowers the WSE of the channel and meets HW/D requirements for culverts. The headwater elevation at the culvert entrance is 8005.34, which results in an HW/D of 0.90.

Depths and velocity grids for the proposed RCBC show depths from 2.2 to 9.1 and velocities from 1 to 8.3 ft/s. See Appendix E for 25-year depths and velocities graphics for this option.

5. WATER SURFACE ELEVATION ANALYSIS FOR NON-FLOODPLAINS

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) 08043C0125E effective date September 19, 2007, as shown in Appendix A. FEMA Zone X are areas of minimal flood hazard located outside the special flood hazard area between the limits of the base flood and the 0.2% annual chance or 500-year flood. This report reviews changes to the WSE from the proposed culvert design options.

FEMA has designated the project site as a FEMA Zone X, as determined by the Flood Insurance Rate Maps (FIRM) 08043C0125E effective date September 19, 2007, as shown in Appendix A.

Proposed Pipe Culvert

Based on modeling results, the proposed pipe culvert will not increase the WSE. Because the proposed pipe quantity is about twice that of the existing structure, the WSE is expected to decrease and will no longer overtop the roadway with a decrease seen immediately upstream of the pipe culvert opening.

For the proposed pipe culvert, upstream of Structure J-15-G (Cross Sections 1-5), the WSE decreases between 0.02 feet and 2.30 feet between existing and proposed. Downstream of Structure J-15-G (Cross Sections 6-10), the WSE does not increase between existing and proposed.

In order to perform a comparison between the existing and proposed WSE, 10 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 pipe culvert option, as shown in Appendix F**.** The WSE comparison at these sections is shown in Table 4.

Table 4: WSE Comparison for Pipe Culvert Option (25-yr)

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Exposed vs Existing
1	Upstream	8018.73	8018.74	0.00
2	Upstream	8014.60	8014.60	0.01
3	Upstream	8012.06	8012.11	0.05
4	Upstream	8009.45	8009.47	0.02
5	Upstream	8008.46	8006.89	-1.57
6	Downstream	8004.03	8003.90	-0.13
7	Downstream	8000.90	7999.68	-1.22
8	Downstream	7998.72	7997.06	-1.67
9	Downstream	7994.91	7993.36	-1.56
10	Downstream	7990.18	7990.17	-0.01

As a check, the 100-year WSEs were also modeled against the existing condition. See Table 5 for a 100-year WSE comparison.

Table 5: WSE Comparison for Pipe Culvert Option (100-yr)

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Exposed vs Existing
1	Upstream	8021.36	8021.36	0.00
2	Upstream	8015.49	8015.48	-0.01
3	Upstream	8012.92	8012.92	-0.01
4	Upstream	8010.84	8010.90846	0.07
5	Upstream	8009.75	8010.13	0.38
6	Downstream	8005.00	8005.13	0.13
7	Downstream	8001.35	8001.35	0.00
8	Downstream	7999.11	7999.16	0.05
9	Downstream	7995.91	7995.95	0.04
10	Downstream	7991.22	7991.05	-0.17

<u>Proposed RCBC</u>

Similarly, the model for the proposed RCBC will not increase the WSE. The opening of the proposed RCBC is about twice that of the existing opening, the WSE is expected to decrease and will no longer overtop the roadway.

For the proposed RCBC, upstream of Structure J-15-G (Cross Sections 1-5), the WSE decreases between 0.02 feet and 2.61 feet between existing and proposed. Downstream of Structure J-15-G (Cross Sections 6-10), the WSE increases a maximum of 0.15 feet between existing and proposed. Appendix F shows the cross sections used for the proposed RCBC 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 RCBC option.

Table 6: WSE Comparison for RCBC Option (25-yr)

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Exposed vs Existing
1	Upstream	8018.73	8018.74	0.00
2	Upstream	8014.60	8014.60	0.01
3	Upstream	8012.06	8012.11	0.05
4	Upstream	8009.45	8009.47	0.02
5	Upstream	8008.46	8006.21	-2.25
6	Downstream	8004.03	8004.03	0.00
7	Downstream	8000.90	7999.77	-1.13
8	Downstream	7998.72	7997.16	-1.56
9	Downstream	7994.91	7993.50	-1.41
10	Downstream	7990.18	7990.30	0.12

As a check, the 100-year WSEs were also modeled against the existing condition. See Table 7 for a 100-year WSE comparison.

Table 7: WSE Comparison for RCBC Option (100-yr)

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Exposed vs Existing
1	Upstream	8021.36	8021.36	0.00
2	Upstream	8015.49	8015.49	0.00
3	Upstream	8012.92	8012.92	-0.01
4	Upstream	8010.84	8010.91	0.06
5	Upstream	8009.75	8010.28	0.53
6	Downstream	8005.00	8005.09	0.09
7	Downstream	8001.35	8001.36	0.01
8	Downstream	7999.11	7999.16	0.05
9	Downstream	7995.91	7995.94	0.03
10	Downstream	7991.22	7991.05	-0.17

6. 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 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 the proposed pipe culvert outlet is a riprap apron based on the Froude number of 2.5 which is less than 3. See results from HY-8 energy dissipation analysis in Appendix G.

The energy dissipation alternative selected for the RCBC outlet is a riprap apron based on the Froude number of 1.55 which is less than 3. See results from HY-8 energy dissipation analysis in Appendix G.

7. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Structure J-15-G. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary FEMA floodplain analysis and energy analysis.

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

Based on the hydraulic analysis and input from CDOT, the proposed replacement for this structure is a 2-cell 20-foot by 6-foot RCBC that has a length of 64-ft with a berm located on the right upstream channel overbank. The RCBC option is preferred because of long term maintenance concerns with pipe culverts. WSE analysis demonstrates that the proposed RCBC opening will not cause a rise in flood levels during the 25-year or 100-year design event.

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.
7. "Routine Inspection Colorado Department of Transportation: Structure Inspection and Inventory Report (J-15-G)." Colorado Department of Transportation, 2020.

APPENDIX A FEMA FIRM

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum.** For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242,** or visit its website at http://www.ngs.noaa.gov/.

Base map information shown on this FIRM was provided in digital format by Fremont County Regional GIS Authority.

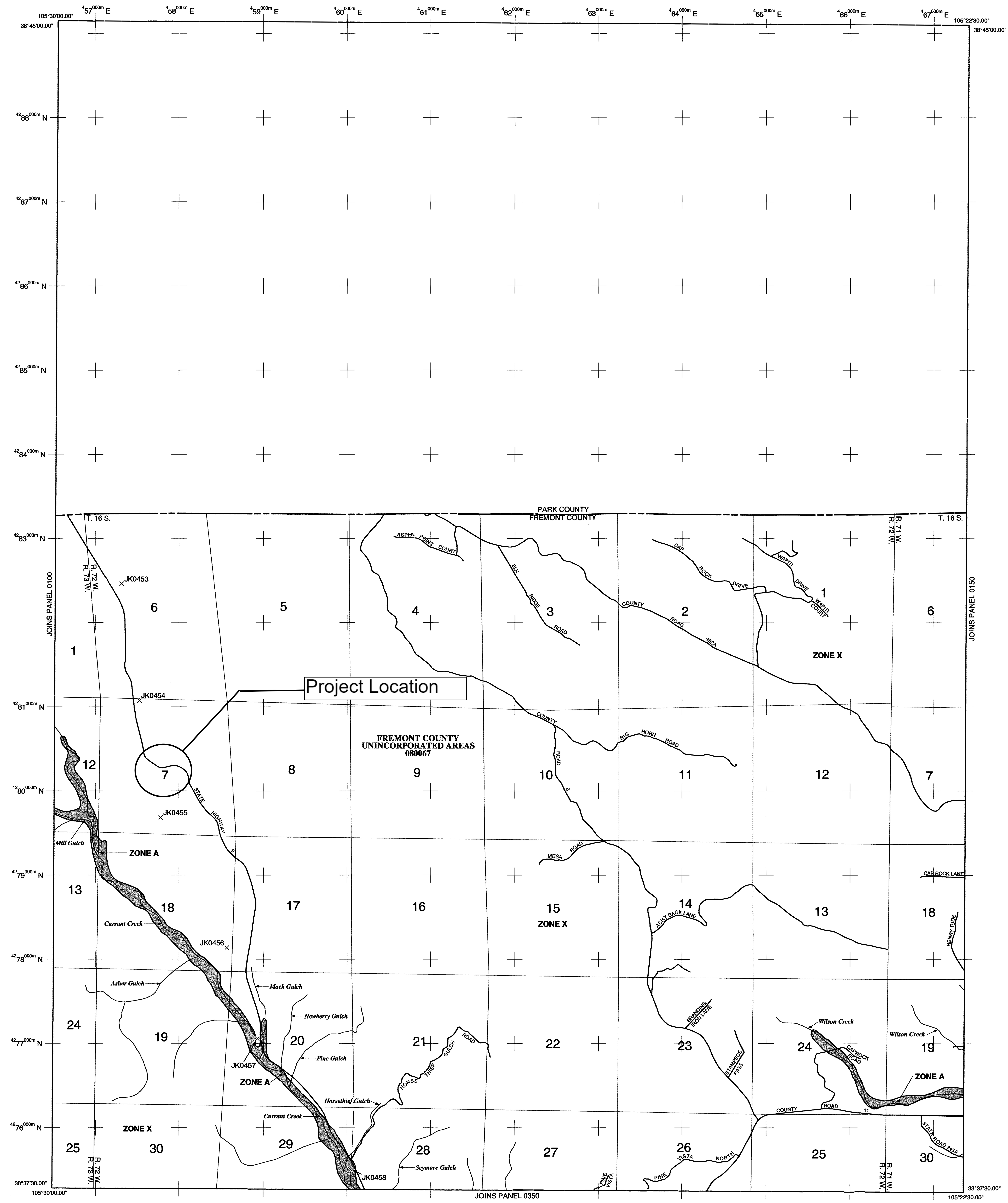
This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables *in the Flood Insurance Study report (which contains authoritative hydraulic data)* may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, *a Flood Insurance Study report,* and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

- **ZONE A** No Base Flood Elevations determined.
- **ZONE AE** Base Flood Elevations determined.
- **ZONE AH** Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
- **ZONE AO** Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
- **ZONE AR** Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
- **ZONE A99** Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
- **ZONE V** Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
- **ZONE VE** Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

- **ZONE X** Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

- **ZONE X** Areas determined to be outside the 0.2% annual chance floodplain.
- **ZONE D** Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513 — Base Flood Elevation line and value; elevation in feet*

(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

A — A Cross section line

23 — 23 Transect line

97°07'30", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)

$^{42}75^{000m}$N — 1000-meter Universal Transverse Mercator grid ticks, zone 13

6000000 M — 5000-foot grid ticks: Alabama State Plane coordinate system, east zone (FIPSZONE 0101), Transverse Mercator

DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)

• M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
September 19, 2007
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'
1000 0 2000 4000 FEET
600 0 600 1200 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0125E

FIRM
FLOOD INSURANCE RATE MAP
FREMONT COUNTY, COLORADO
AND INCORPORATED AREAS

PANEL 125 OF 925
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FREMONT COUNTY	080067	0125	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08043C0125E

EFFECTIVE DATE
SEPTEMBER 19, 2007

Federal Emergency Management Agency

APPENDIX B AERIAL IMAGERY AND PHOTOS

AERIAL IMAGERY
STRUCTURE J-15-G
FIGURE 3

PHOTO 1: EXISTING UPSTREAM CULVERT STRUCTURE
STRUCTURE J-15-G
APPENDIX B

PHOTO 2: EXISTING UPSTREAM CULVERT STRUCTURE

STRUCTURE J-15-G

APPENDIX B

PHOTO 3: LOOKING NORTH UPSTREAM OF CULVERT

STRUCTURE J-15-G

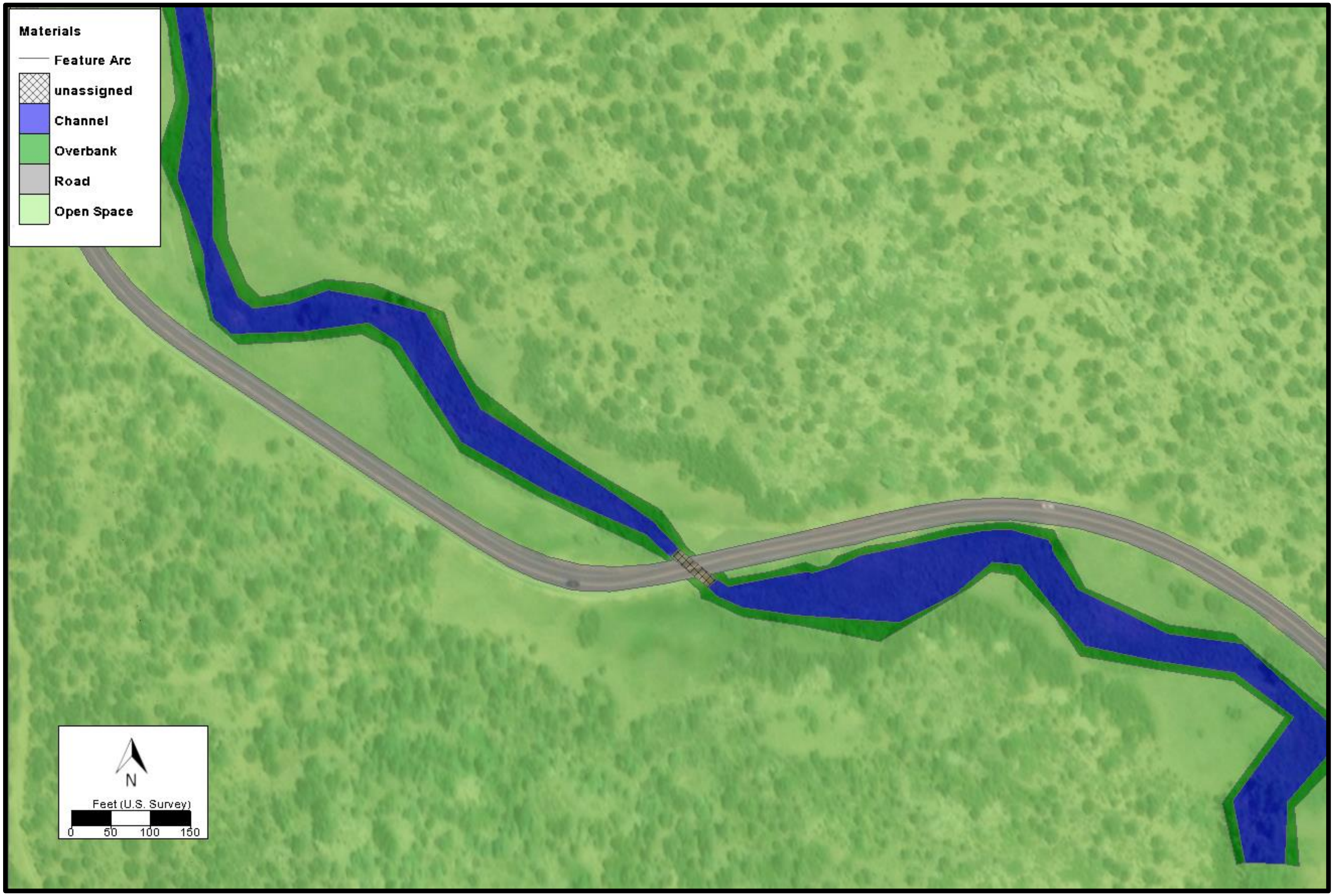
APPENDIX B

PHOTO 4: LOOKING SOUTH DOWNSTREAM OF CULVERT

STRUCTURE J-15-G

APPENDIX B

APPENDIX C EXISTING CONDITIONS MODEL GRAPHICS

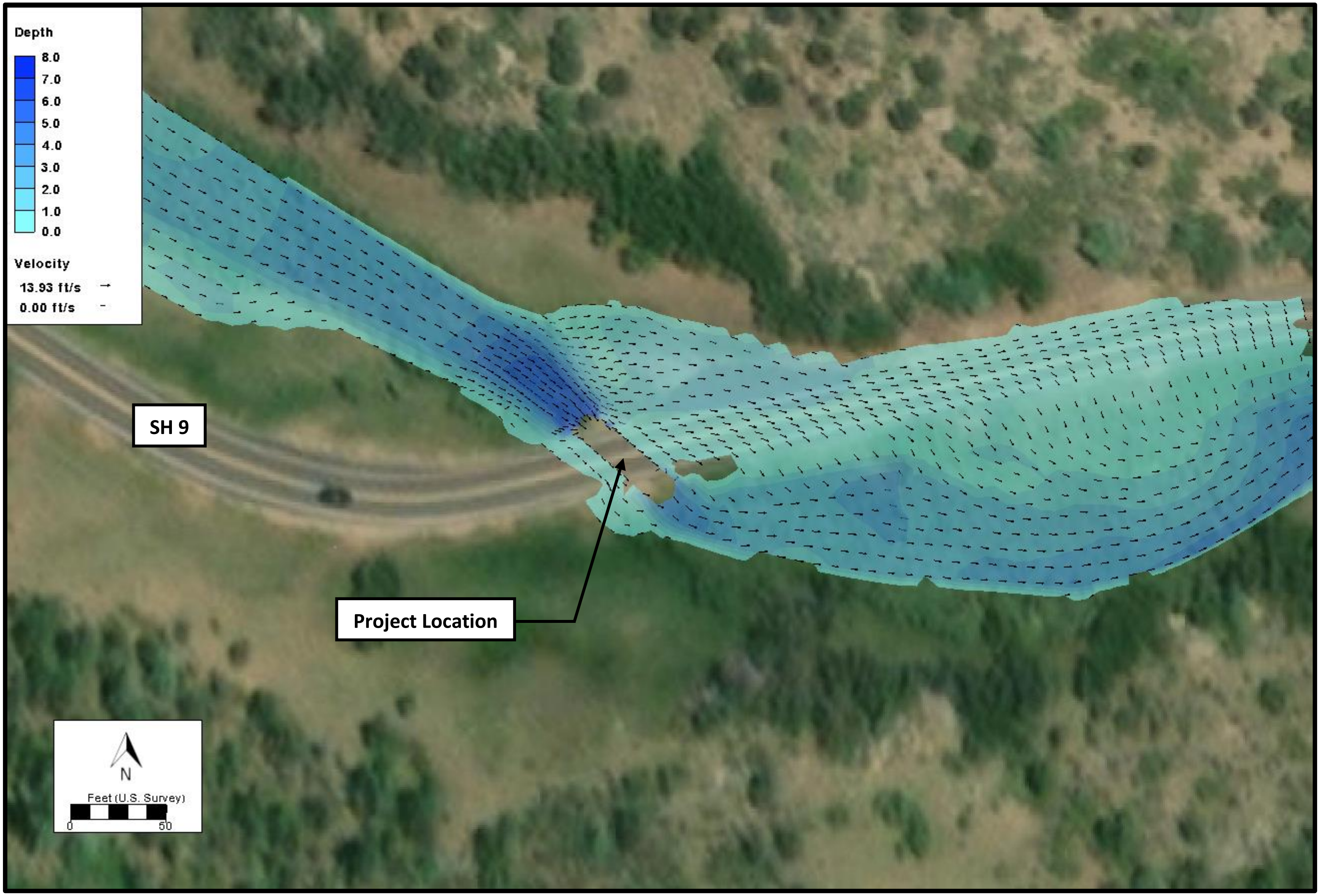


EXISTING CONDITIONS MODEL GRAPHICS

MATERIALS COVERAGE

STRUCTURE J-15-G

FIGURE 4



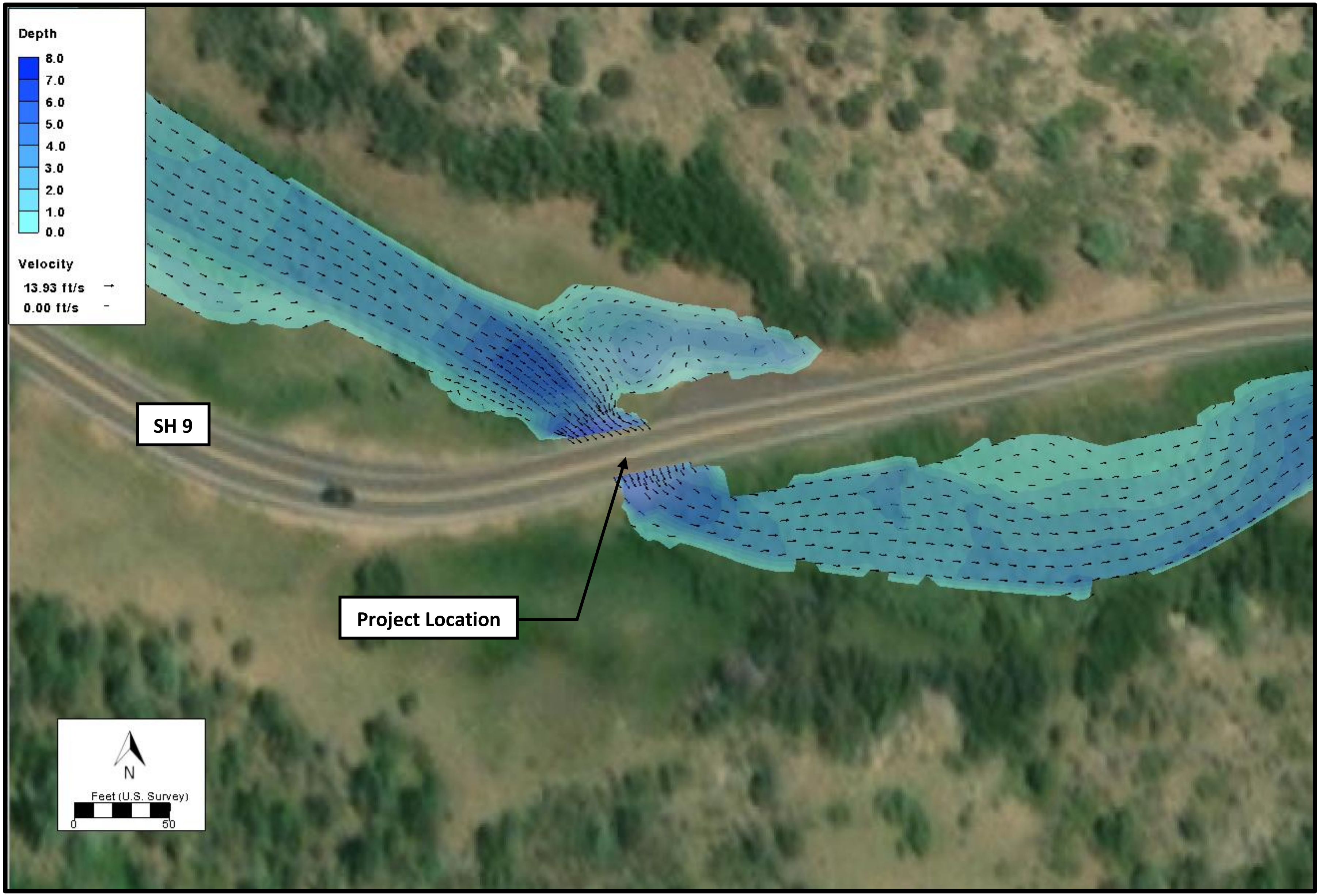
EXISTING CONDITIONS MODEL GRAPHICS

EXISTING CONDITIONS 25-YEAR DEPTH RESULTS

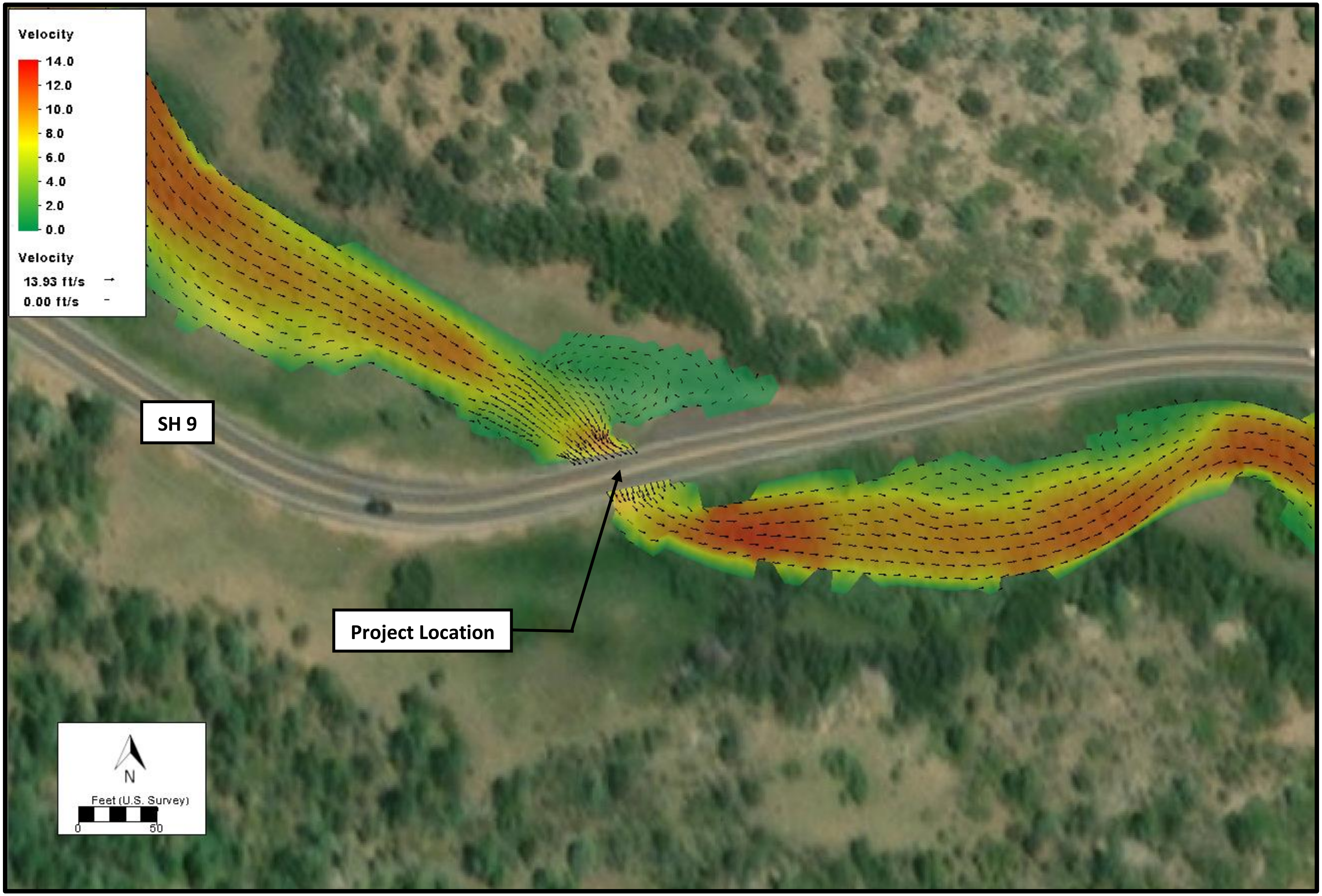
STRUCTURE J-15-G

FIGURE 5

APPENDIX D PROPOSED PIPE CULVERT ALTERNATIVE MODEL GRAPHICS



PROPOSED 25-YEAR DEPTH RESULTS – PIPE CULVERT OPTION
STRUCTURE J-15-G
FIGURE 6

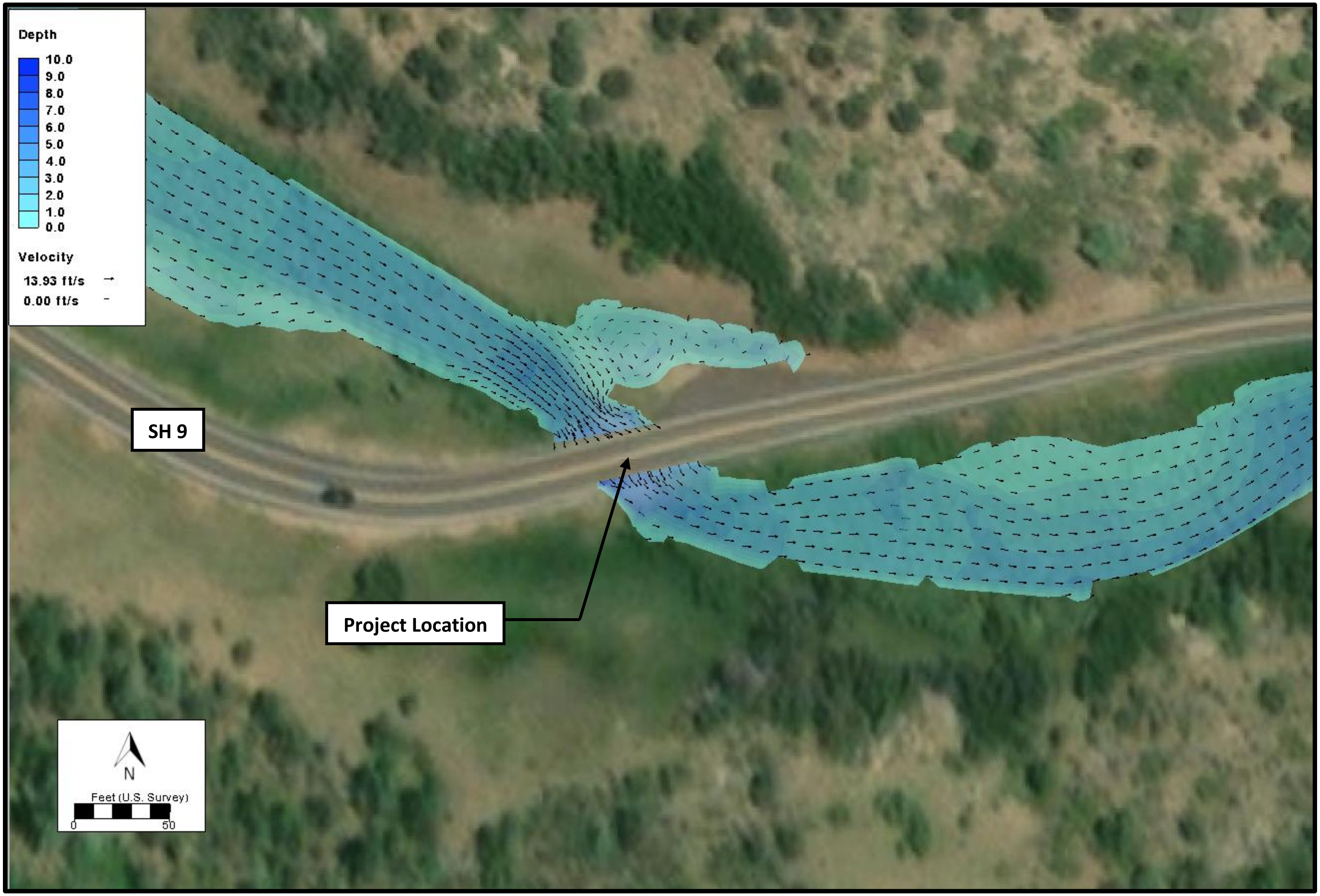


PROPOSED 25-YEAR VELOCITY RESULTS – PIPE CULVERT OPTION

STRUCTURE J-15-G

FIGURE 7

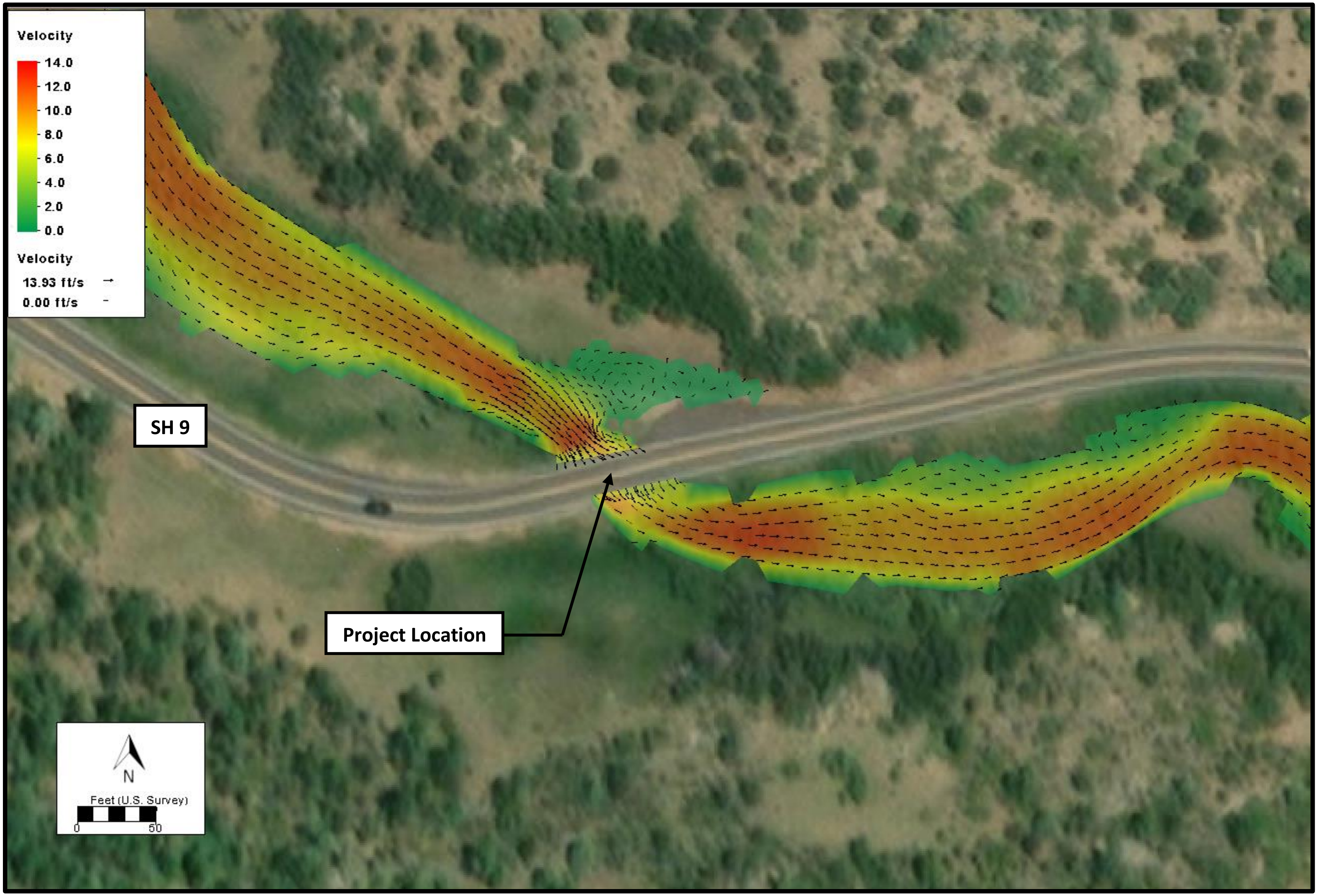
APPENDIX E PROPOSED RCBC ALTERNATIVE MODEL GRAPHICS



PROPOSED 25-YEAR DEPTH RESULTS – RCBC CULVERT OPTION

STRUCTURE J-15-G

FIGURE 8

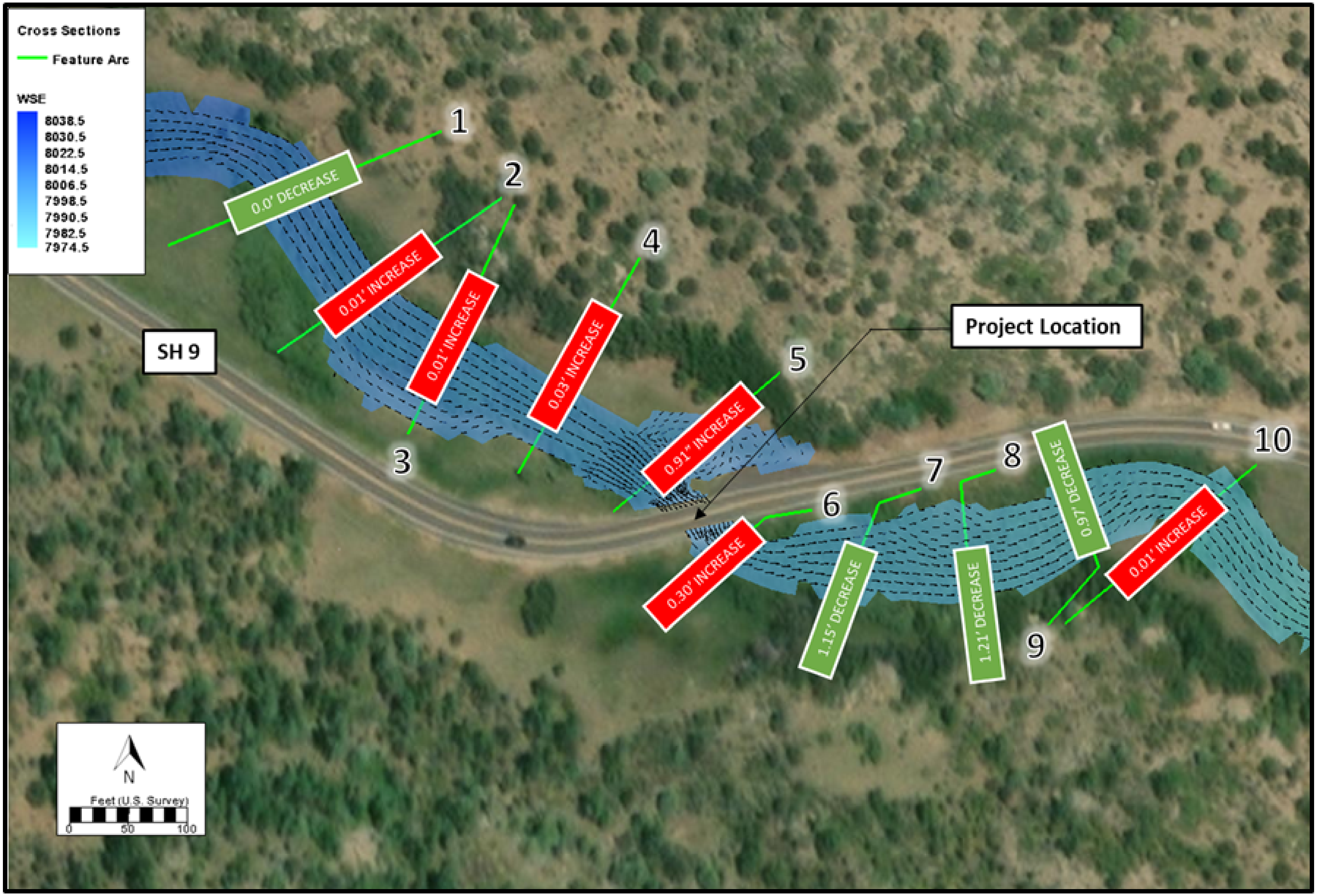


PROPOSED 25-YEAR VELOCITY RESULTS – RCBC CULVERT OPTION

STRUCTURE J-15-G

FIGURE 9

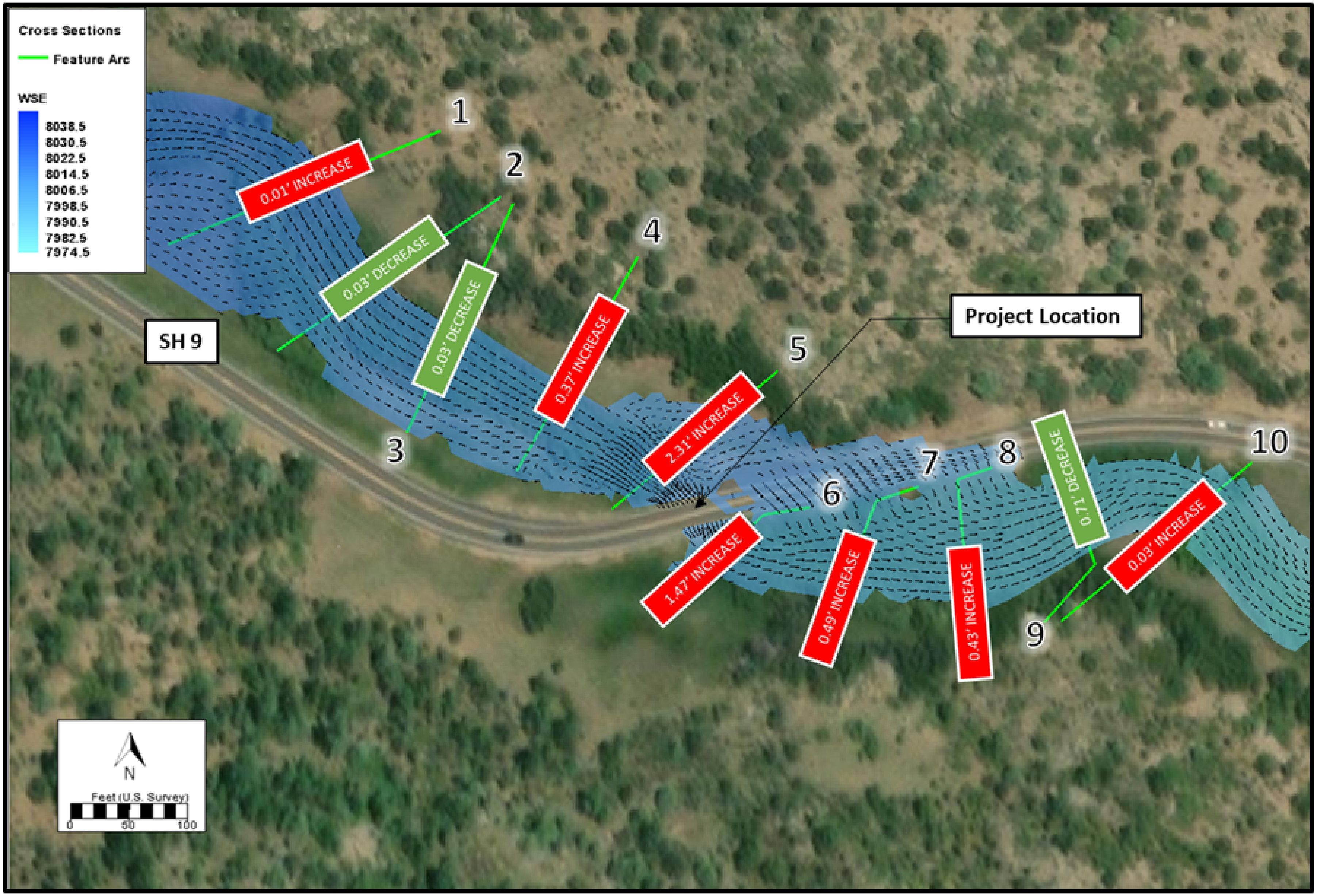
APPENDIX F WATER SURFACE ELEVATION COMPARISON GRAPHICS



25-YEAR WATER SURFACE ELEVATION CROSS SECTIONS – PIPE CULVERT OPTION

STRUCTURE J-15-G

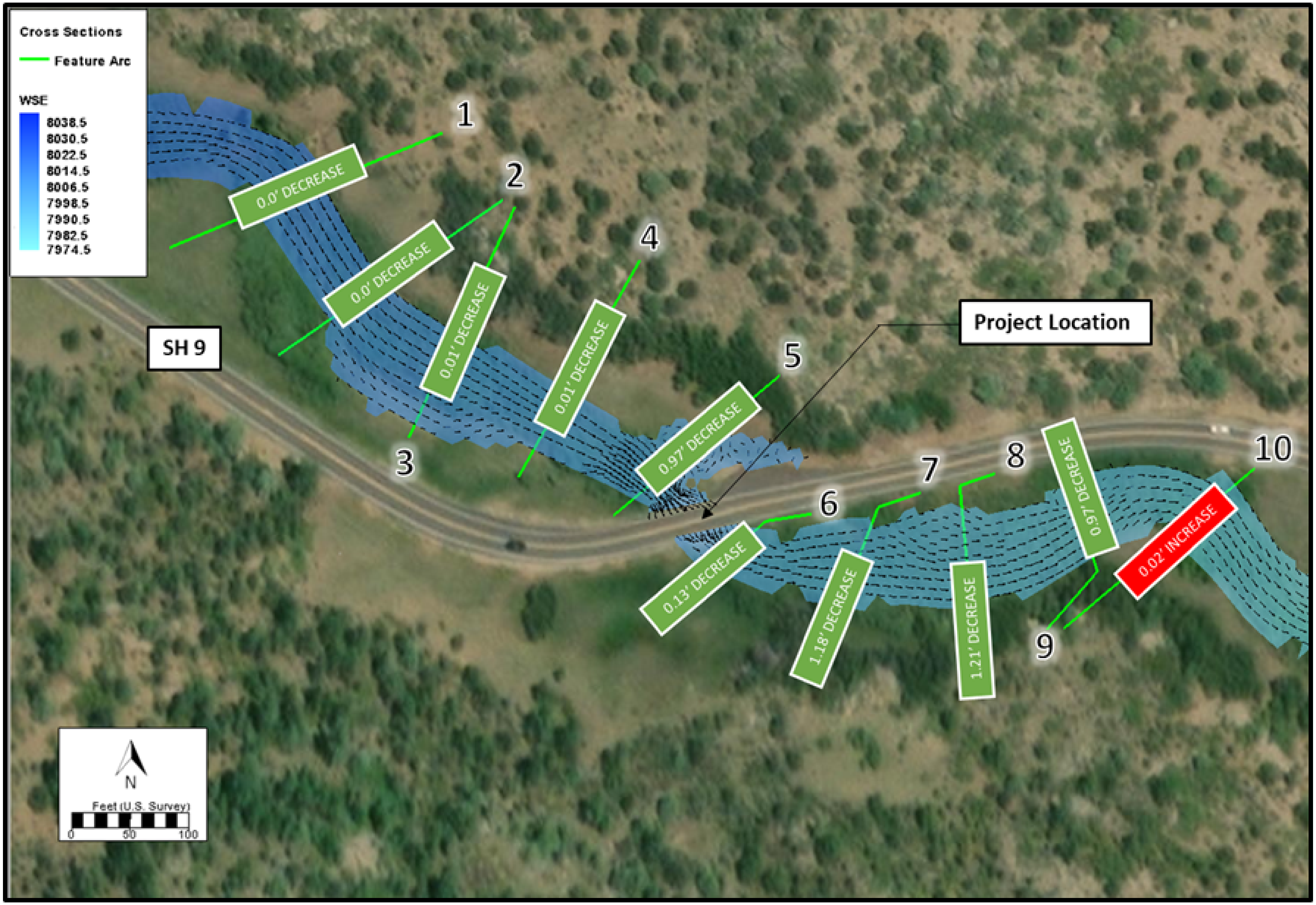
FIGURE 10



100-YEAR WATER SURFACE ELEVATION CROSS SECTIONS – PIPE CULVERT OPTION

STRUCTURE J-15-G

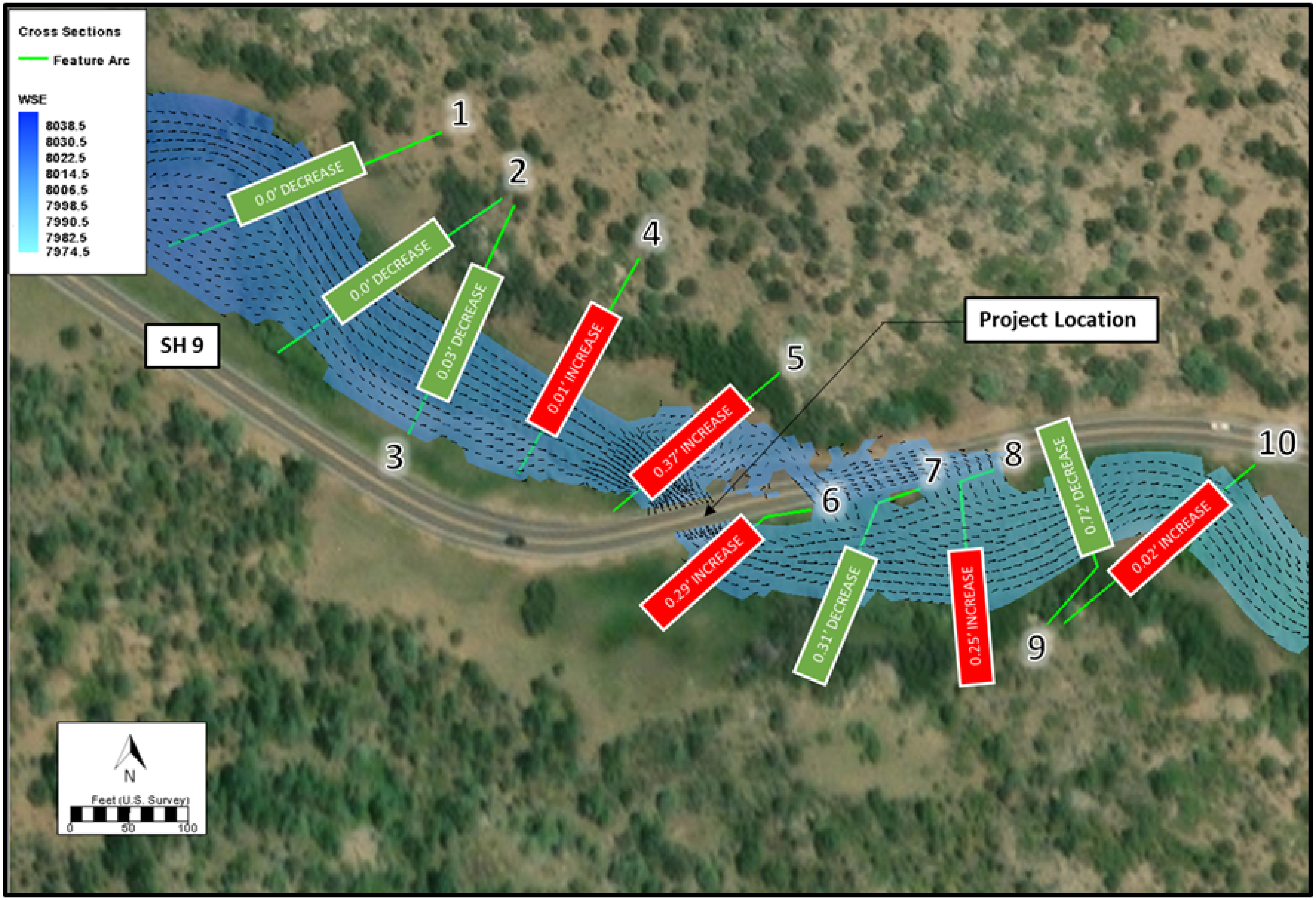
FIGURE 11



25-YEAR WATER SURFACE ELEVATION CROSS SECTIONS – RCBC CULVERT OPTION

STRUCTURE J-15-G

FIGURE 12

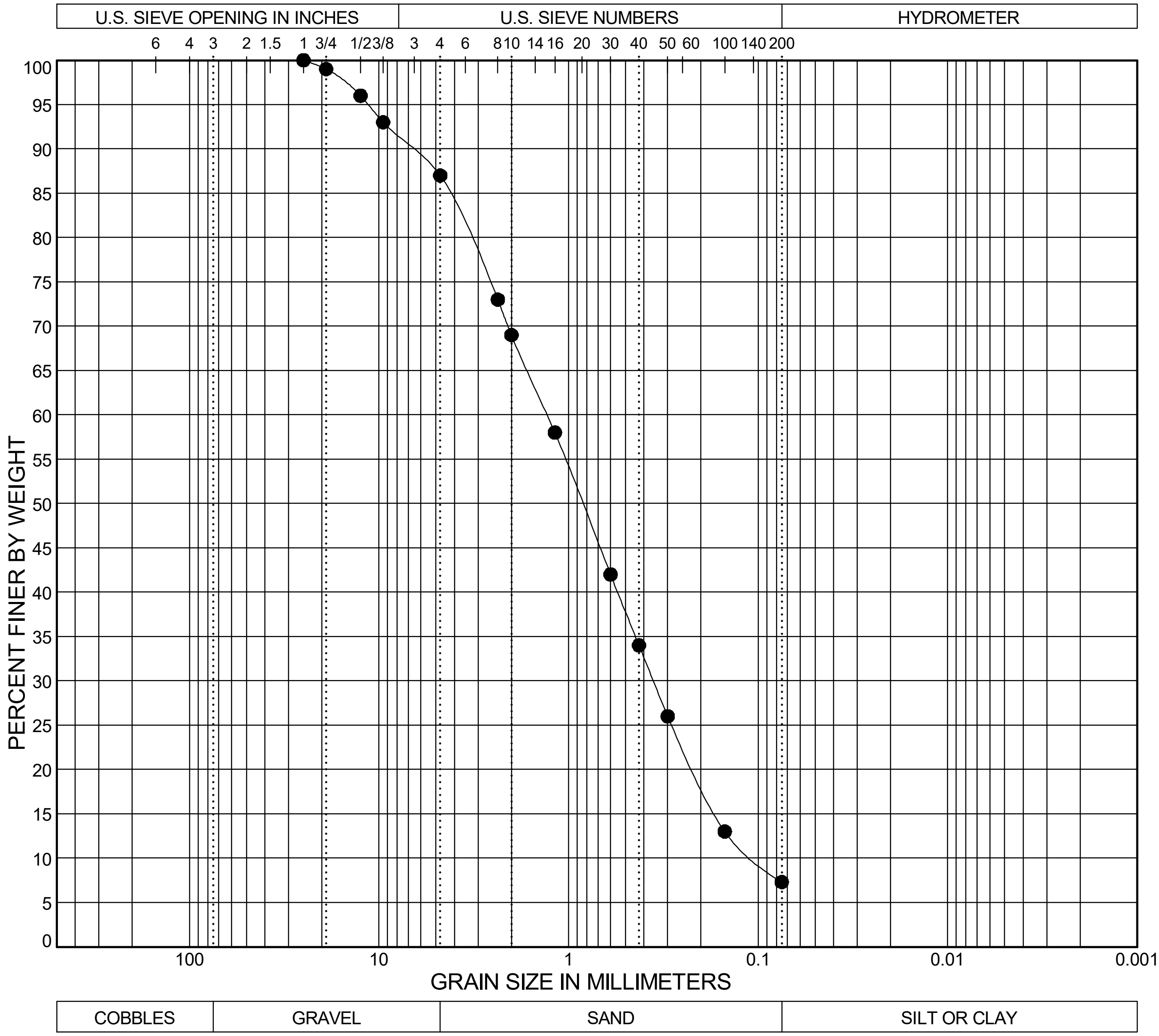


100-YEAR WATER SURFACE ELEVATION CROSS SECTIONS – RCBC CULVERT OPTION

STRUCTURE J-15-G

FIGURE 13

APPENDIX G ENERGY DISSIPATION



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
● **J-15-G Scour**	**0.0**	**A-1-b (0)**	**SP-SM**	**NV**	**NP**	**NP**	**13.0**	**79.7**	**7.3**	

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 J-15-G

FIGURE

S- 9

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed Pipe Culvert	
Culvert	4 - 84	
Flow	1341.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	28.0	ft
Culvert Height	7.0	ft
Outlet Depth	3.61	ft
Outlet Velocity	16.74	ft/s
Froude Number	1.55	
Tailwater Depth	2.95	ft
Tailwater Velocity	22.73	ft/s
Tailwater Slope (SO)	0.0402	
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 = 1.298 ft	
D50 of the Riprap Mixture	1.000	ft
DMax of the Riprap Mixture	2.000	ft
Results		
Brink Depth	3.612	ft
Brink Velocity	16.743	ft/s
Depth (YE)	6.328	ft
Riprap Thickness	3.000	ft
Riprap Foreslope	4.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	4.953	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.158	
D50/YE Check	D50/YE is OK	
Basin Length (LB)	74.302	ft
Basin Width	56.535	ft
Apron Length	24.767	ft
Pool Length	49.535	ft
Pool Depth (HS)	4.953	ft
TW/YE	0.466	
Tailwater Depth (TW)	2.950	ft
Average Velocity with TW	7.280	ft/s

12-inch riprap stilling basin proposed at the culvert 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)	2.517	ft
Average Velocity with Yc	8.654	ft/s

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed RCBC	
Culvert	2 - 20'x6'	
Flow	1341.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	40.0	ft
Culvert Height	6.0	ft
Outlet Depth	1.78	ft
Outlet Velocity	18.88	ft/s
Froude Number	2.50	
Tailwater Depth	2.95	ft
Tailwater Velocity	22.73	ft/s
Tailwater Slope (SO)	0.0402	
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 = 0.649 ft	
D50 of the Riprap Mixture	0.649	ft
DMax of the Riprap Mixture	1.500	ft
Results		
Brink Depth	1.776	ft
Brink Velocity	18.880	ft/s
Depth (YE)	1.776	ft
Riprap Thickness	2.250	ft
Riprap Foreslope	3.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.011	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.365	
D50/YE Check	D50/YE is OK	
Basin Length (LB)	160.000	ft
Basin Width	146.667	ft
Apron Length	40.000	ft
Pool Length	120.000	ft
Pool Depth (HS)	1.305	ft
TW/YE	1.662	
Tailwater Depth (TW)	2.950	ft
Average Velocity with TW	2.979	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)	1.366	ft
Average Velocity with Yc	6.570	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	6.796	ft/s
Size	0.301	ft
Distance: 2 LB		
Velocity	3.381	ft/s
Size	0.075	ft
Distance: 3 LB		
Velocity	2.247	ft/s
Size	0.033	ft
Distance: 4 LB		
Velocity	1.682	ft/s
Size	0.018	ft