US Army Corps of Engineers ®
Little Rock District
Hydrology and Hydraulics Section

Appendix A: Engineering

Continuing Authorities Program (CAP)
Section 14

Mortar Creek Emergency Streambank Erosion Protection and Prevention

Quitman, Faulkner County, AR

This page intentionally left blank.

Appendix A: Engineering

Table of Contents

Appendix A: Hydrology and Hydraulics Design

A.1. Introduction

The authority for this project is Section 14 of the Flood Control Act of 1946, as amended as administered under the U.S Army Corps of Engineers Continuing Authorities Program (CAP).

The natural stream alignment in conjunction with the west tributary appear to be causing the erosion behind the wingwalls of the existing bridge. The west tributary shown in Figure 1 runs parallel to the road from west to east before flowing into Mortar creek just upstream of the old bridge abutments with a drainage area of around 100 acres. When the water gets high, the west roadside ditch flow goes over the old west bridge abutment and directly attracts the existing bridge west wingwall. This flow causes and eddie behind the wingwall and corresponding erosion of the embankment. During this higher flows, the old bridge abutments are submerged, and their effects are proportionally drowned out, so the damaging erosion is caused by that west roadside ditch and would occur with or without the old bridge abutments.

There is erosion on the east abutment of the existing bridge as well; however, this erosion is developing slower due to the alignment of the channel and the flood plain flows on the east side. Even though this erosion is happening at a slower rate, it has propagated to a tipping point, that when exceeded, will result in bridge failure.

In the channel, the flow is being constricted to a small area directly upstream of the Mortar Creek Road Bridge due to the existing abutments from an old bridge over the creek. The deck of the old bridge was removed when the current bridge was built approximately 30 feet downstream; however, the old bridge abutments were left in place for reasons not recorded. The top of the old bridge concrete abutments are approximately 3-5 feet lower than the new bridge abutments and have an opening width about 10-15 less than the new bridge.

During low flows, the velocity through the bridge is increased due to the old abutment constriction. This can be simple shown by the equation Q=VA where Flow (Q) is equal to Velocity (V) times Area (A). The old bridge abutments decrease the area of flow and in turn increase the velocity. This increased velocity appears to be contributing to erosion downstream of the bridge along the banks. At this point, the erosion downstream of the bridge does not appear to be threatening to the bridge. There is some erosion around the downstream wingwalls that should be addressed as the material behind the wingwalls is crucial to bridge and roadway integrity.

During higher flows, the old bridge abutments are overtopped. Based on the erosion seen around the old bridge abutments, overtopping appears to occur often.

The watershed is a mix of pasture and woods. The channel appears to have a riparian buffer of at least 50-80 feet for most of its course. There appears to be two inline ponds on mortar creek upstream of the bridge about 2 miles and 3.5 miles respectively. The areas of creek bank with no trees consist of powerline/utilities crossings and the ponds mentioned above.

A.1.1. Location

Mortar Creek Bridge runs over Mortar Creek and is experiencing erosion around the upstream abutments and to a lesser extent around the downstream abutments. The bridge is location on Mortar Creek Road, also known as Old Springfield Road, which is a County Road off Arkansas State Highway 107 near Enders, AR. The project location is approximately 3.5 miles south of Quitman, AR and 7.5 miles west of Rose Bud, AR. The bridge is in a rural location and experiences mostly local vehicle and farm traffic. Mortar Creek eventually flows into the Cadron Creek and is Discharged into the Arkansas River around Navigation Mile 158.7 in Pool 8. A location map is shown in Figure 1.

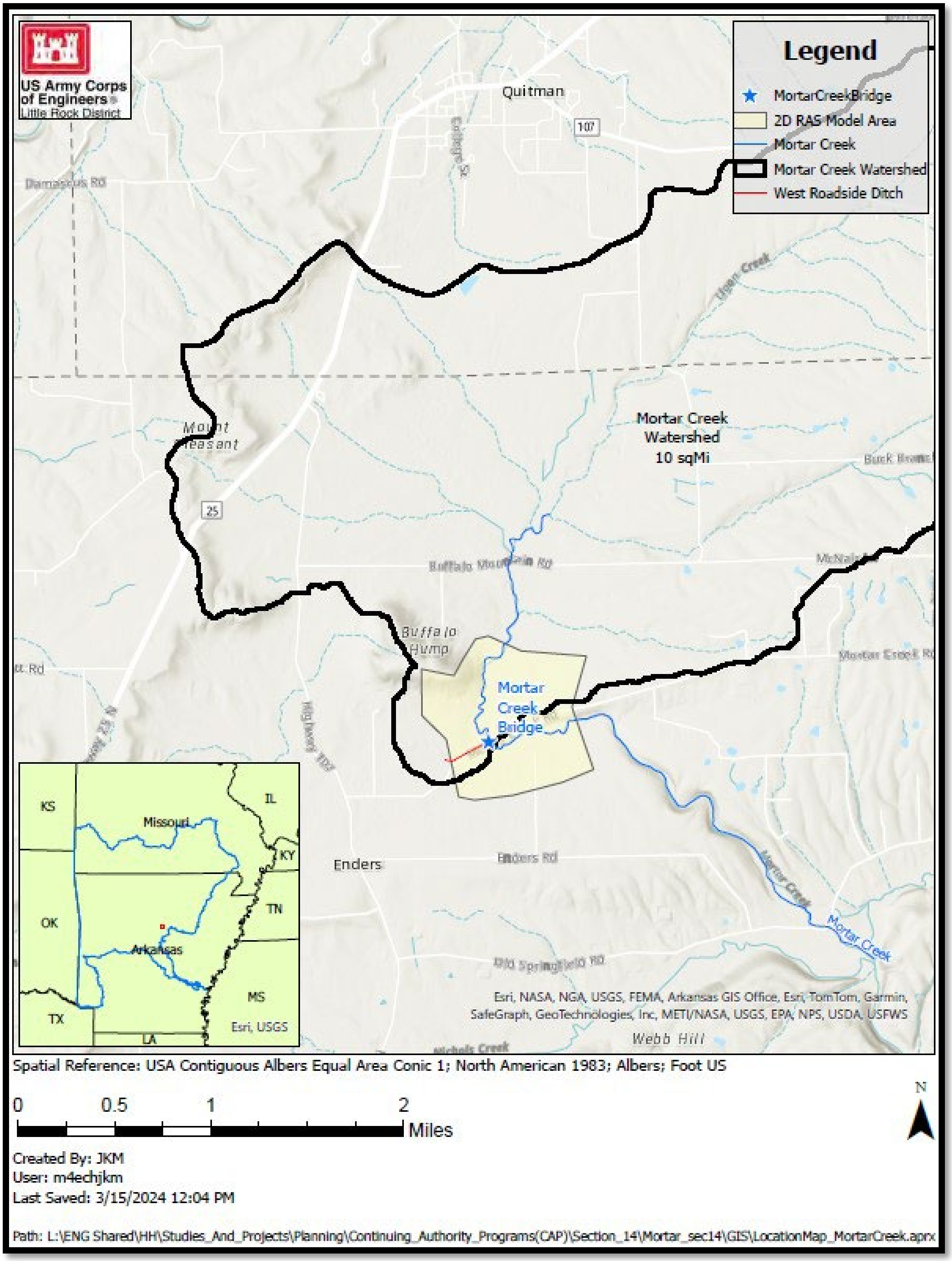

Figure 1. Mortar Creek Location Map

A.1.2. Design Guidance and Reference

This analysis considers the without-project and with-project conditions to determine whether flooding will be induced and to what degree per ER 1110-2-1150. All design, guidance, regulations, and project references are listed below:

US Army Corps of Engineers, Engineering Regulation 1110-2-1150, Engineering and Design for Civil Works Projects

US Army Corps of Engineers, Engineering Regulation 1110-2-1450, Hydraulic Design for Local Flood Protection Projects

US Army Corps of Engineers, Continuing Authorities Programs (CAP) Section 14, 33 U.S.C. §701r, Streambank erosion and shoreline protection of public works and nonprofit services

US Geological Survey, USGS StreamStats, https://streamstats.usgs.gov/

Multi-Resolution Land Characteristics Consortium, National Land Cover Database, https://www.mrlc.gov/data

National Oceanic and Atmospheric Administration's National Weather Service, Hydrometeorological Design Studies Center Precipitation Frequency Data Server (PFDS), Atlas 14-point precipitation frequency estimates, https://hdsc.nws.noaa.gov/pfds/

A.1.3. Description of Problem and Hydrology and Hydraulic Goals

Mortar Creek is funded under the Section 14 Continuing Authorities Programs streambank erosion and shoreline protection. The local sponsor, Faulkner County, provided a Letter of Interest to the Little Rock District Engineer on 14 Dec 2017 requesting a Section 14 study.

The new bridge at Mortar Creek was built between October 2010 and November 2012 according to google earth imagery shown in Figure 2. The problem that is happening today with the erosion around the abutments seems to be due to the alignment of Mortar creek and the roadside ditches. The new bridge is built with a hydraulic capacity that closer represents that of the channel at lower flows; therefore, the old bridge acts as a constriction in the channel. The goal of this section 14 project is to remove the old bridge abutments and place riprap on the approach of the existing bridge upstream where the old abutments are removed as well as overlay riprap around all four wingwalls of the current bridge. Doing this should help low flows not be as erosive downstream of the bridge and help pass high flows without causing turbulence and eddies on the upstream side of the bridge.

Figure 2. Original and Current Road Alignment

A.2. Background Information

Mortar Creek is a county road. The county government is able to approve closures and work within the right-of-way for the road.

A.3. Hydrology

An analysis was done on local rainfall and flow gages to determine what the precipitation trends are for the region. Based on the annual maximum 1, 2, 3, and 4-day precipitation data, the trends have been increasing slightly over the past 130 years.

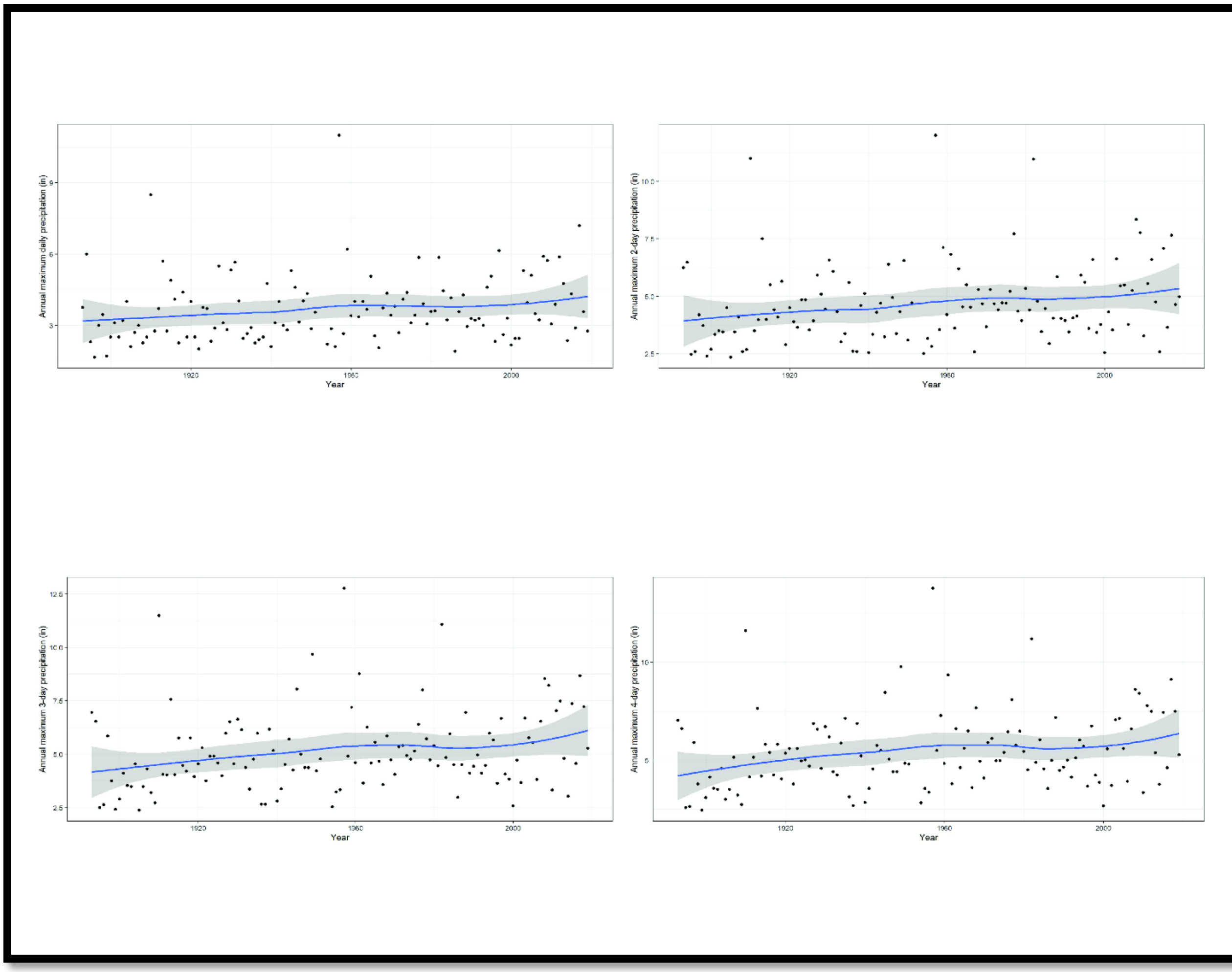

Figure 3. Co-Located Precipitation Gages at Damascus and Bee Branch, AR Analysis

The frequency flows used in the hydraulic modeling came from the USGS Stream Stats website. The StreamStats website can calculate a wide range of flow statistics for a given point of interest.

Frequency precipitation data was pulled from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14.

A.3.1. Methodology

In StreamStats, a point of interest is determined, and the contributing watershed is calculated with corresponding flow statistics. A report is generated and can be exported and printed to a PDF document. The frequency flows pulled from StreamStats for Mortar creek at the bridge site are shown in Table 1 in the hydrology results.

NOAA Atlas 14 has a website where a location can be pinpointed spatially on a map. Tables and statistics are then generated for the location of interest. The reoccurrence-duration table pulled from Atlas 14 can be found in Table 2 in the hydrology results.

A.3.2. Results

Below are the tables of hydrologic data used for the analysis of Mortar Creek erosion at the Mortar Creek bridge.

Table 1. Watershed Flows for Mortar Creek Bridge

	50% AEP	10% AEP	4% AEP	2% AEP	1% AEP
USGS Stream Stats	1180	2900	4000	4900	5840

Table 2. Example NOAA Atlas 14, Volume 9, Version 2-Point Precipitation Frequency Estimates

Duration	Average Reoccurrence Interval (years)				
	2	10	25	50	100
5-min	0.496	0.675	0.784	0.868	0.950
15-min	0.886	1.21	1.40	1.55	1.70
1-hr	1.69	2.30	2.69	3.00	3.31
2-hr	2.09	2.84	3.33	3.72	4.13
3-hr	2.34	3.18	3.75	4.22	4.70
6-hr	2.84	3.90	4.64	5.26	5.91
12-hr	3.47	4.85	5.81	6.59	7.42
1-day	4.16	5.88	7.05	8.00	8.99

A.4. Hydraulics

A two dimensional (2D) mathematical hydraulic model was developed for the Mortar Creek Analysis. A survey was conducted by the United States Army Corps of Engineers (USACE) Southwestern Division Little Rock (SWL) survey crew, obtaining accurate channel bathometry for Mortar Creek and area around the bridge to better inform the hydraulic modeling.

A.4.1. Methodology

The hydraulic modeling software used for the analysis, River Analysis System (RAS), was developed by the USACE Hydraulic Engineering Center (HEC). The version of software used was HEC-RAS 6.4.1.

The Li-DAR terrain used in the model was downloaded from the USGS servers and dated circa 2016. The grid cell sizes in the model are 25 feet for the overbank and 10 ft for the channel and around the structures.

A manning's n coefficient of 0.04 was used for the channel based on what was seen in the field and the National Land Cover Database (NLCD) 2019 was used for the overbank region.

Due to the lack of stream flow gages on Mortar Creek, the hydraulic model could not be calibrated to flow. It should be noted that this model should not be used to forecast or predict future flooding events or water surface elevations (WSE) for frequency events. The intent of this 2D hydraulic model was to get the best representation of flow in the channel and around the structure at various elevations. The results of the model were then compared to what was seen in the field before moving forward.

A.4.2. Results

The hydraulic model confirmed the suspicion that the flow from the west ditch was attacking the riprap behind the west wing wall. This is shown in Figure 4 below. The white lines are called particle tracers. The density and lengths of the lines help to show the velocity and flow paths. The colored in portion of the map shows the extent of the water surface and the color corresponds to a velocity.

This picture shows that with around a 50% Annual Exceedance Probability (AEP) flow, the west bank has flow parallel to it cutting in behind the west wingwall and the east wingwall has an eddie forming around it.

It should be noted that this hydraulic model has a flow input upstream where flow enters the model and is not a rain-on-grid model. This means that local runoff is not shown flowing over the surface. The flows and velocities around the wingwalls, while still accurate, are not fully representative of what is happening during a high-water event.

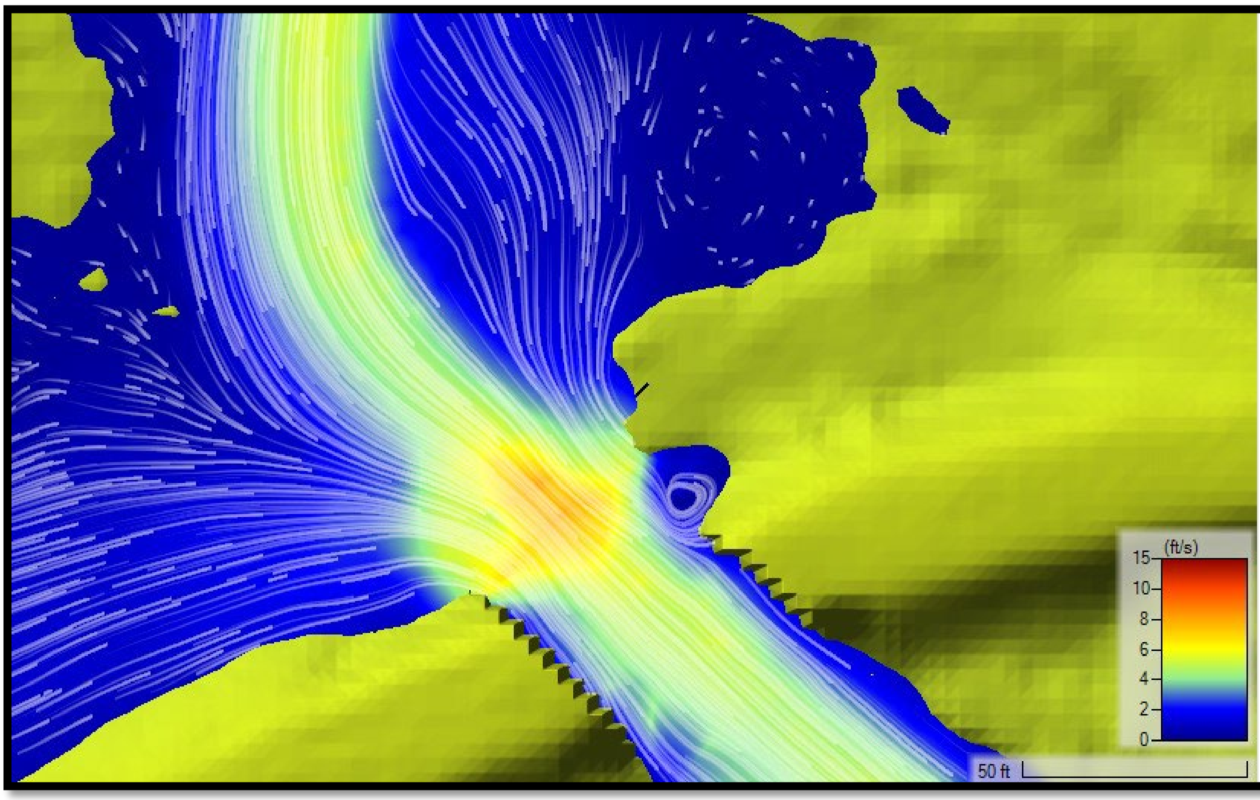

Figure 4. Screenshot from 2D RAS Model with Particle Tracers and Velocity Map for 50% AEP Flow

There is still some refinement that needs to be done around the bridge and the old abutments, but a screenshot of the initial model is shown in Figure 5. The entire 2D model domain can be seen in Figure 1.

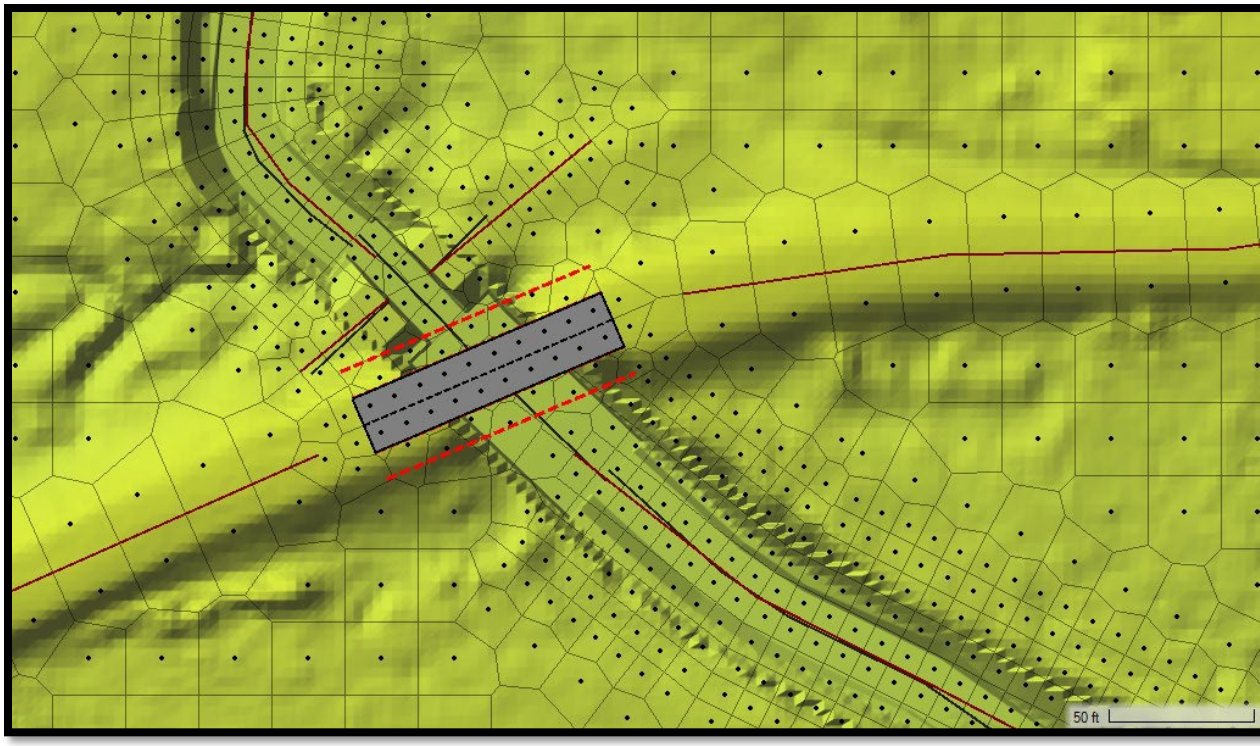

Figure 5. Hydraulic Model Mesh

A.5. Erosion Protection

Erosion protection was defined based on the velocities and elevations seen in the model runs as well as what was seen by the team during site visits. There were multiple conversations with hydraulic and civil engineers that went into developing the initial design.

A.5.1. Methodology

The hydraulic model was used to inform the erosion protection. Because this project is a section 14, the erosion protection that is designed needs to meet the goal of stabilizing the bridge and roadway in the wake of active erosion. That means that while there is erosion of the banks downstream of the bridge because it is not affecting the integrity of the structure or roadway, it is not included in this design.

The Isbash method was used to determine the stone size for the proposed riprap erosion protection. The Isbash recommendation for high turbulence flow was used for this design.

As far as the footprint of the erosion protection is concerned, as of now it was based off existing riprap and over the proposed removal of the old bridge abutments. The 30% design footprint of the Riprap can be found on Figure 6 in the Design Recommendations portion of the appendix.

A.5.2. Results

The velocities in the model appeared to be in the 8-10 ft/s range for the medium to higher flows. The Isbash equation was used to determine a riprap size of R400. A table for the gradation of R400 is given in Table 3.

Percent Lighter by Weight	Weight Range (lbs)
100	400-160
50	160-80
10	80-30

Table 3. R400 Gradation

A.6. Design Recommendations

The old bridge abutments upstream should be removed, and the bank restored to the natural channel. The area where the old abutments are removed shall receive a layer of R400. The four wingwalls of the existing bridge should receive an overlay or R400 riprap. All riprap should be a minimum of 30 inches thick and placed no steeper than a 2:1 (H:V) slope.

It is recommended to remove two trees. One tree is interlocked with the west abutment of the old bridge and has an exposed root system. The second tree is located around the southeast wingwall and could be a point of failure for the erosion protection due to it being in the middle of the embankment.

Figure 6 gives a rough overview of the 30% H&H design recommendations overlayed on a Civil Desing rendering of the site.

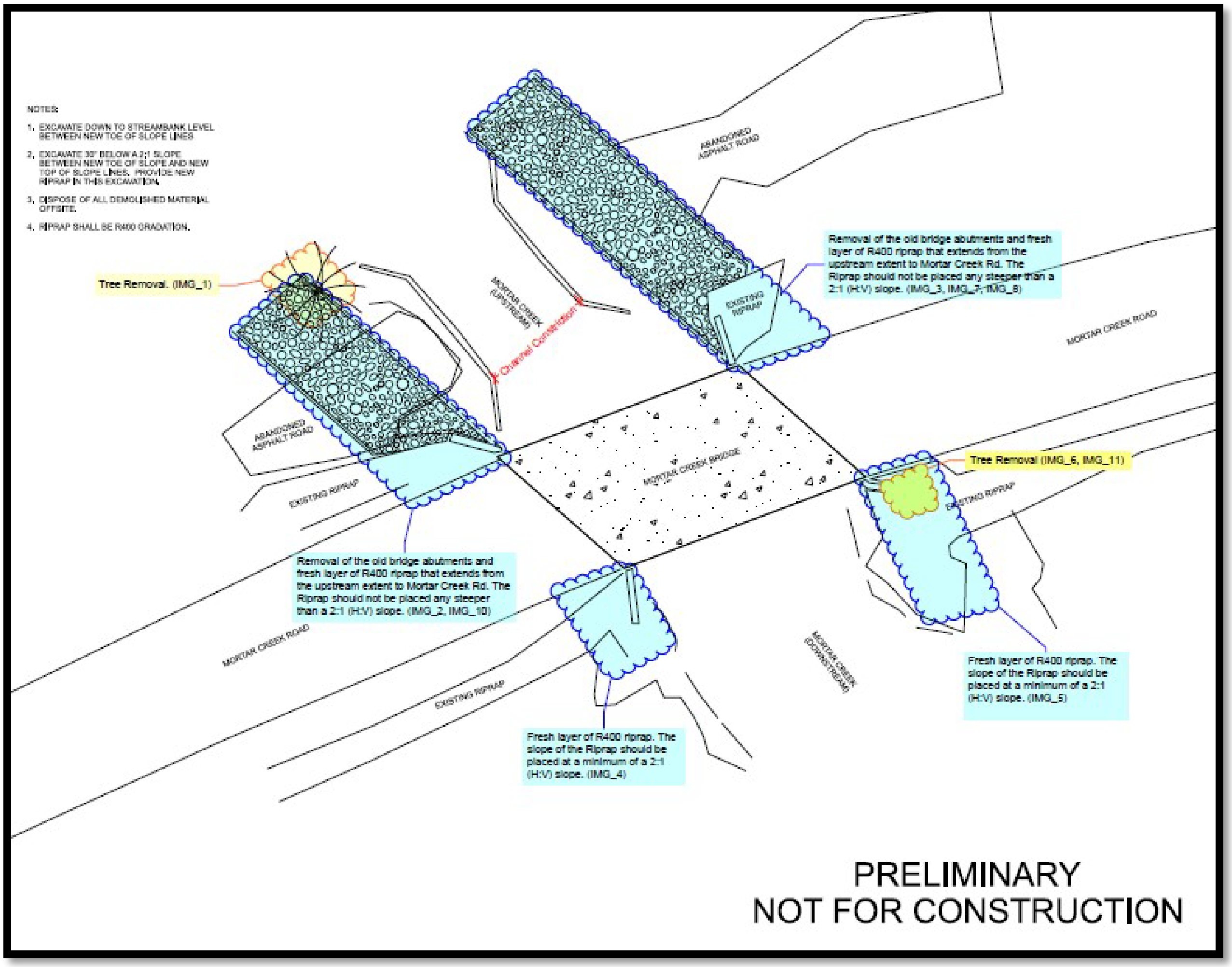

Figure 6. 30% H&H Recommendation

A.7. Calculations

A.7.1. Type of Calculation or Figures

- This section is for inputting important information that is too big or awkward for the report format
- Example include but are not limited to:
    - Scanned calculations
    - Drawings of design
    - Lists of coefficients such as manning's n used in model
    - Emails that had an impact on design or project schedule
    - Scans of design iterations

A.8. Civil Engineering

The determination of the TSP involved the following four activities:

1. Demolition of former bridge abutments
2. Widening of creek to match bridge opening
3. Excavation of upstream banks and riprap placement
4. Riprap placement on downstream banks

From the hydraulic engineering analysis, it became obvious that the former bridge abutments were a major cause of the erosion on the upstream abutment of the new bridge. This was due to the scour produced by the turbulence that the abutments caused since they constricted the channel prior to the new bridge opening. This erosion worked its way around the existing wingwalls and into the road embankment as shown in Figure 3. This condition required the demolition of the former bridge abutments.

The next step is to widen the creek section to where it matches the opening width of the bridge which will ensure a smoother transition for the creek flow into the bridge. There is significant material behind the former bridge abutments that needs to be removed. This material includes a portion of the old roadway. In addition, this material needs to be excavated back at a 2:1 (horizontal to vertical) slope as to ensure a future stable slope and as a viable foundation for the riprap.

Riprap placement on the upstream bank will require some excavation or a lower grade elevation for the previous step where the bank is being widened. This is due to the fact that the riprap depth is estimated to be 30 inches thick and the top of riprap will be near the natural top of bank. In other words, we just don't want to dump riprap without properly anchoring it into the bank. The details for this work will be further developed during the Design and Implementation phase (D&I).

The last step is to place riprap on the downstream bank adjacent to and in the vicinity of the wingwalls. As with the previous step, this will be further developed in the D&I phase.