APPENDIX R-1

Ohio River Modeling Potential Backwater Impacts – Indiana

Clarification Note for Central Alternative 1: Central Alternatives 1A and 1B as described in the DEIS/FEIS are physically the same alternative. The only difference between them is that Central Alternative 1A would include tolls on both the new I-69 bridge and on the US 41 bridge. Central Alternative 1B would only include tolls on the new I-69 bridge. Any reference in this document to Central Alternative 1 applies to both Central Alternative 1A and Central Alternative 1B.

This document was completed before the development of Central Alternative 1B Modified (Selected); therefore, the alternative is not included in the document. Applicable information regarding Central Alternative 1B Modified (Selected) is provided in the FEIS.

OHIO RIVER CROSSING

Ohio River Floodplain Modeling
Potential Backwater Impacts – Indiana

I-69 Ohio River Crossing Project
Evansville, IN and Henderson, KY

June 9, 2019

Prepared by:
Parsons Transportation Group, Inc.

INDIANA DEPARTMENT OF TRANSPORTATION

KENTUCKY TRANSPORTATION CABINET

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX A – SUPPORTING FIGURES

1 GENERAL

1.1 PURPOSE, PROJECT DESCRIPTION

The purpose of this hydraulic analysis is to determine requirements for bridges within the floodplain areas of the proposed I-69 Ohio River Crossing (ORX) project; to revise the regulatory floodway through the Letter of Map Revision (LOMR) process; and to determine the need for, and the extent of, flood easements associated with a floodway reduction.

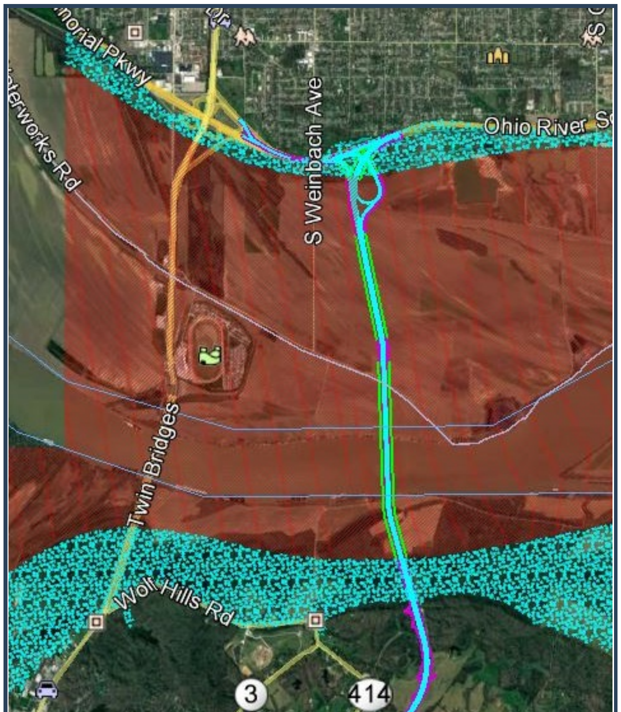

Figure 1-1. Study Area

1.2 STUDY AREA

The study area will extend from I-69 south of Evansville, IN (formerly I-164), across the Ohio River, to the Edward T. Breathitt Pennyrile Parkway (now designated as I-69 up to the KY 425 interchange) near Henderson, KY (Figure 1-1).

1.3 ANALYSIS DESCRIPTION

Advanced modeling that will meet the needs of the I-69 ORX project started with preparing a Data Terrain Model (DTM) that incorporated the I-69 ORX Bathymetric/Hydrographic Survey Data (XYZ data for 3 river miles of survey sections at 200 ft spacing); FEMA Flood Insurance Models (1D, steady-state) for Indiana and Kentucky Flood Hazard Determinations; and the U.S. Army Corps of Engineers' (USACE) Ohio River Community Model with time-variable (unsteady-state) flood flows.

Through the development of geometric files and flow data, the various bridge alternatives and flood easement options were modeled using both one-dimensional (1D) and two-dimensional (2D) analysis, which enabled a detailed evaluation of the results and the effects of the I-69 Ohio River Bridge Crossing on the Ohio River floodplain and floodway. This final hydraulic report documents the study conclusions and recommendations.

2 DESIGN CRITERIA / PROJECT LIMITATIONS AND GUIDELINES

2.1 FEDERAL EMERGENCY MANAGEMENT AGENCY

The Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security. Floodplain management regulations administered by FEMA are applicable to the I-69 ORX project. Both Vanderburgh County, IN and Henderson County, KY participate in the National Flood Insurance Program (NFIP). Both counties have Flood Insurance Studies (FIS) and multiple Flood Insurance Rate Maps (FIRM) which were created to document the regulatory base flood elevations within the counties and along the Ohio River. For a state to receive all the benefits of the NFIP, they must follow the regulations that FEMA has in place for each floodplain area. This also means that it is necessary to investigate the additional backwater and encroachment created by new structures placed in the floodway and floodplain.

FEMA requires that new structures placed in the floodway and floodplain create only a certain amount of backwater, determined by the states and the authority that the governor of each state has placed upon the state agency to enforce floodplain regulations. In Indiana, the maximum allowable backwater is less than 0.15 ft of rise above the base flood elevation; in Kentucky the allowable backwater is one foot above the base flood elevation. According to FEMA guidance (*Guidance for Flood Risk Analysis and Mapping*, FEMA 2016), if the state (or other jurisdiction) has established more stringent regulations, these regulations take precedence over the NFIP regulatory standard. Therefore, the development of a new Ohio River bridge between Evansville and Henderson would be restricted to less than 0.15 foot of rise. Figure 2-1 shows the floodplain and floodway limits in accordance with each state's regulations.

2.2 INDIANA DEPARTMENT OF NATURAL RESOURCES

In Indiana, the government agencies which have the authority to enforce FEMA regulations and the NFIP are the Indiana Department of Natural Resources (IDNR) along with the Local Floodplain Coordinators (LFCs) for counties and cities. The *Flood Insurance Study for Vanderburgh County, Indiana and Incorporated Areas (Study Number 18163CV000A, Effective March 17, 2011, FEMA)* is the document which IDNR and the LFCs use to enforce floodway and floodplain regulations in the county. IDNR is the agency which will ultimately review the 1D and 2D modeling created for the I-69 ORX project. With this modeling, one can determine the area of backwater (in acres) created by the existing US 41 bridges, the proposed area of backwater created by the new I-69 bridge, and the distance upstream that this backwater would travel. IDNR would oversee the acquisition of flowage easements required for any additional flooding potential/rise in backwater associated with the construction of a new Ohio River bridge. Prior to construction of the I-69 ORX project, a Construction in a Floodway Permit from IDNR and a Conditional Letter of Map Revision from FEMA will be required for the project.

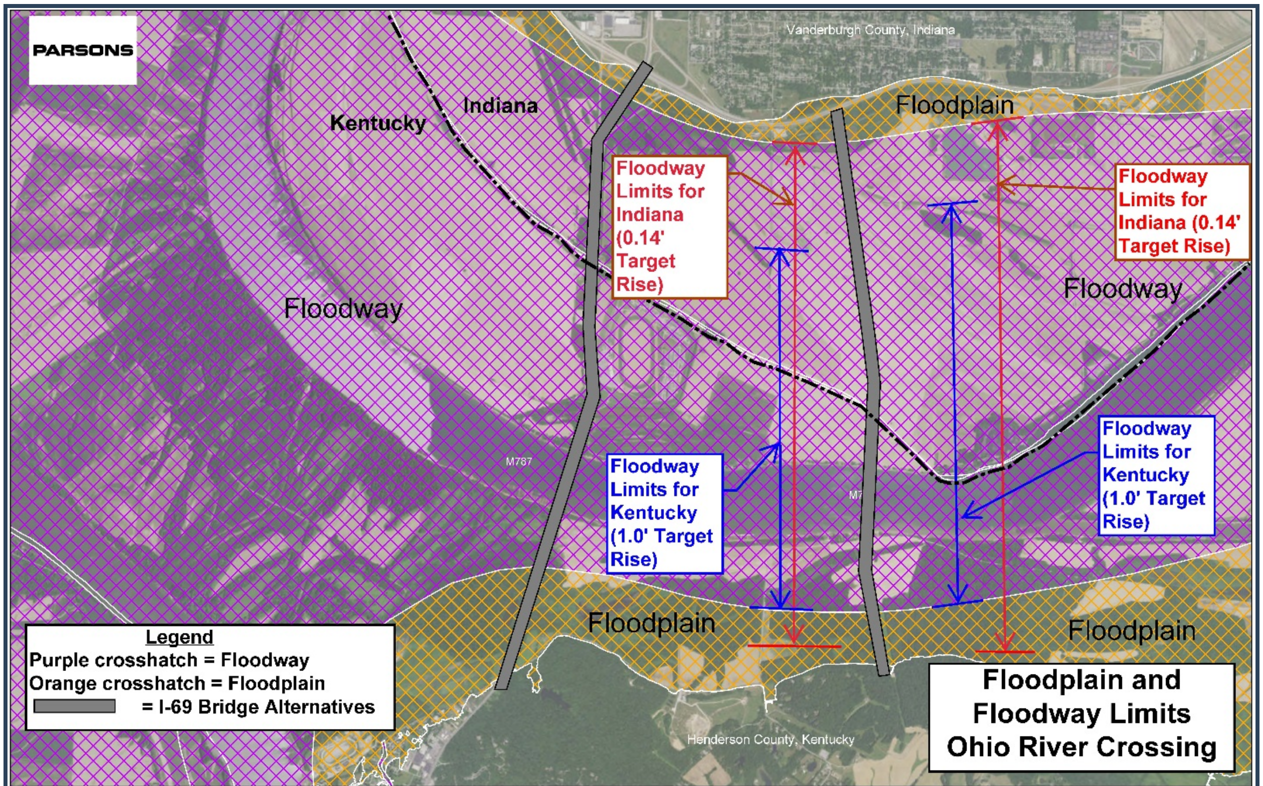

Figure 2-1. Floodway and Floodplain Limits

2.3 KENTUCKY DIVISION OF WATER

The Kentucky Division of Water (KDOW), along with LFCs, is the NFIP enforcing agency for Kentucky's floodplains and floodways. The *Flood Insurance Study, Henderson County, Kentucky and Incorporated Areas (Revised: September 29, 2017, Study Number 21101CV000B)* documents the regulatory flood elevations. According to the Henderson County Flood Insurance Study (FIS), the allowable backwater in Kentucky's waterways is 1 foot or less. A HEC-RAS model developed separately from the model used for Indiana floodways will be submitted to KDOW for their review and approval. KDOW is also the agency in Kentucky which is charged with approving and administering a Floodplain Construction Permit and, for FEMA, a Conditional Letter of Map Revision.

2.4 DESIGN FLOWS

The 100-year flood is the base flood that defines the floodplain and floodway in FEMA's floodplain regulations, and is the basis for IDNR and KDOW's flood permits. In highway design, KYTC and INDOT require use of the 100-year flood (the 1 percent event probability) (in this case, a major river crossing) to determine allowable backwater, roadway serviceability, and allowable velocity. The base flood as published in the FIS for Henderson County, KY is 920,000 cubic feet per second (cfs) at River Mile 784.5. The base flood as published in the Vanderburgh County, IN FIS is 555,000 cfs at the Evansville gage at River Mile 792.3. The discrepancy in these values can be attributed to the USACE's record model used for the Flood Insurance Studies. Both of these discharges were used in the record model and in the advanced floodplain modeling for the I-69 ORX project.

2.5 OHIO RIVER LOCKS AND DAMS OPERATIONS

The section of the Ohio River where the proposed I-69 ORX project would be constructed is bounded by the Newburgh Locks and Dam (8.5 miles upstream, and the John T. Myers Locks and Dam (59 miles downstream), of the project area. Both Locks and Dams are for navigational purposes and do not provide flood control. The John T. Myers Locks and Dam produces a normal pool that extends upstream to the project area at an elevation of 341.02 ft msl (Figure 2-2).

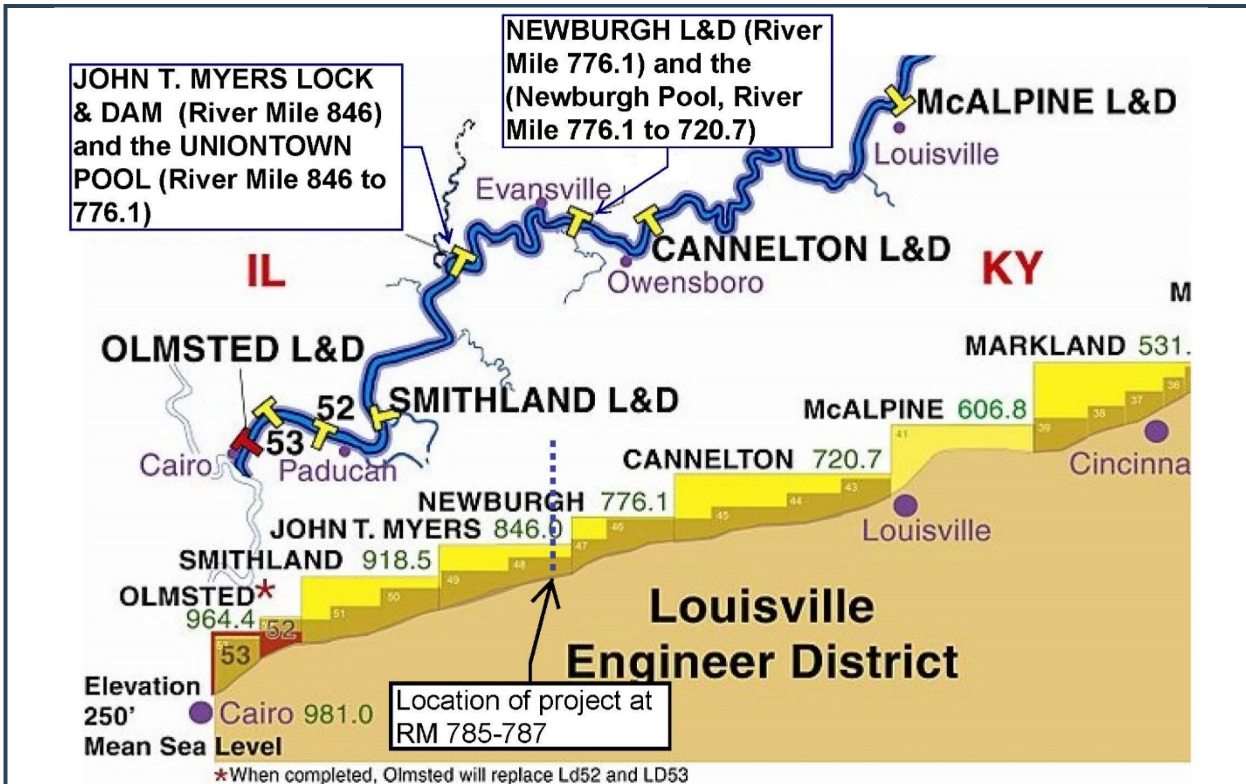

Figure 2-2. Ohio River Locks and Dams – Plan and Profile

2.6 ALTERNATIVES (CENTRAL VS. WESTERN ALIGNMENTS)

From the original five corridors considered, as described in the *Screening Report* (Indiana Department of Transportation [INDOT] and Kentucky Transportation Cabinet [KYTC] 2017) and *Screening Report Supplement* (INDOT and KYTC 2018), three build alternatives were evaluated in detail in the I-69 ORX Draft Environmental Impact Statement (DEIS). They are:

- West Alternative 1: Construct four lanes on I-69 and retain one of the existing US 41 bridges
- West Alternative 2: Construct six lanes on I-69 and take both existing US 41 bridges out of service

- Central Alternative 1: Construct four lanes on I-69 and retain one of the existing US 41 bridges

The West alternatives would be located at the existing US 41 river crossing, and Central Alternative 1 would be located approximately 2.0 miles upstream.

2.7 BRIDGE CONFIGURATIONS

The configurations for the I-69 ORX Ohio River bridge crossing must accommodate three basic criteria:

- a main span that accommodates commercial river traffic in accordance with U.S. Coast Guard (USCG) criteria,
- overflow spans that accommodate low water flow (sloughs) and provide additional capacity for flood flows, and
- additional spans that maintain access for existing local roads and provide for interchange movements.

For the main Ohio River span, USCG requires minimum horizontal and vertical clearances for navigational purposes. Vertical clearances are based on a 55 ft clearance above the flood flow of a 2 percent event probability (i.e., 50-year flood event) and 69 ft above the normal pool elevation.

Overflow spans are located to accommodate low flows for tributaries and sloughs and sized to provide additional conveyance capacity to the main spans to achieve the overall backwater criteria.

Spans that accommodate local access and interchange movements add little or no hydraulic capacity for flood flows.

3 HYDRAULIC MODELING

3.1 METHODOLOGY

The Ohio River floodplain within the project area is 15,000 to 25,000 ft wide. Its main flow channel is 2,000 to 2,500 ft wide and meanders within the floodplain.

Under the existing conditions at the US41 Ohio River bridge crossing, the main river span is accompanied by three approach spans that provide additional capacity for flood flows and through-access for a local road in the floodplain. Limitations in one-dimensional (1D) modeling can make it difficult to simulate the multiple flow paths through the separate bridge openings, around numerous piers, and around several abutments (Figure 3-1). The restrictions of 1D modeling for this condition include:

- results of the water surface elevation being averaged across a very wide cross-section,
- limits in the number of overflow structures allowed to be modeled, and
- difficult calibration efforts to balance flow paths.

Because of these limitations, the project also was analyzed with a two-dimensional (2D) hydraulic model. A 2D model better simulates the multiple flow paths that are occurring between the existing structures on US 41. The U.S. Bureau of Reclamation's SRH-2D (Sedimentation and River Hydraulics, Two-Dimensional model) program adopted by the Federal Highway Administration (FHWA) was used to simulate the 2D hydraulics models for this project. The SRH-2D model was developed using Aquaveo's SMS (Surface-water Modeling System) version 12.2.8 pre- and post-processor using the provided Light Detection and Ranging (LiDAR) data and bridge and roadway data developed for the project.

In addition to the 2D modeling of the existing condition, a 2D model was created of the various bridge types for the proposed alternatives.

After the existing and proposed alternative conditions were modeled in 2D, including determining the multiple flow paths, flow quantities, and locations, a modified 1D model was used to design the bridge opening lengths to meet project backwater requirements. The process of the 2D and 1D modeling was iterative and the following steps were processed until both models reflected similar hydraulic results for all conditions.

- Step 1: In the 2D model, proposed bridge lengths were analyzed until backwater averaged across the entire floodplain and met project requirements for allowable backwater.

- Step 2: In the 2D model, flow paths upstream of all the structures were drawn in, and flows passing through each bridge were calculated
- Step 3: In the 1D model, study reaches were set up for each bridge crossing to simulate the flow paths. This was done by setting boundaries for the ineffective areas, i.e. areas of stagnant flow, across the cross-section that matched the flow path locations within the 2D model (Figure 3-1). Each reach was modeled using the flow rates found in the 2D model.
- Step 4: In the 2D model, the bridge lengths were refined from the 1D model. Flow paths and flow rates were checked and modified if different than the first iteration. If significantly different, Steps 1 through 4 were repeated.

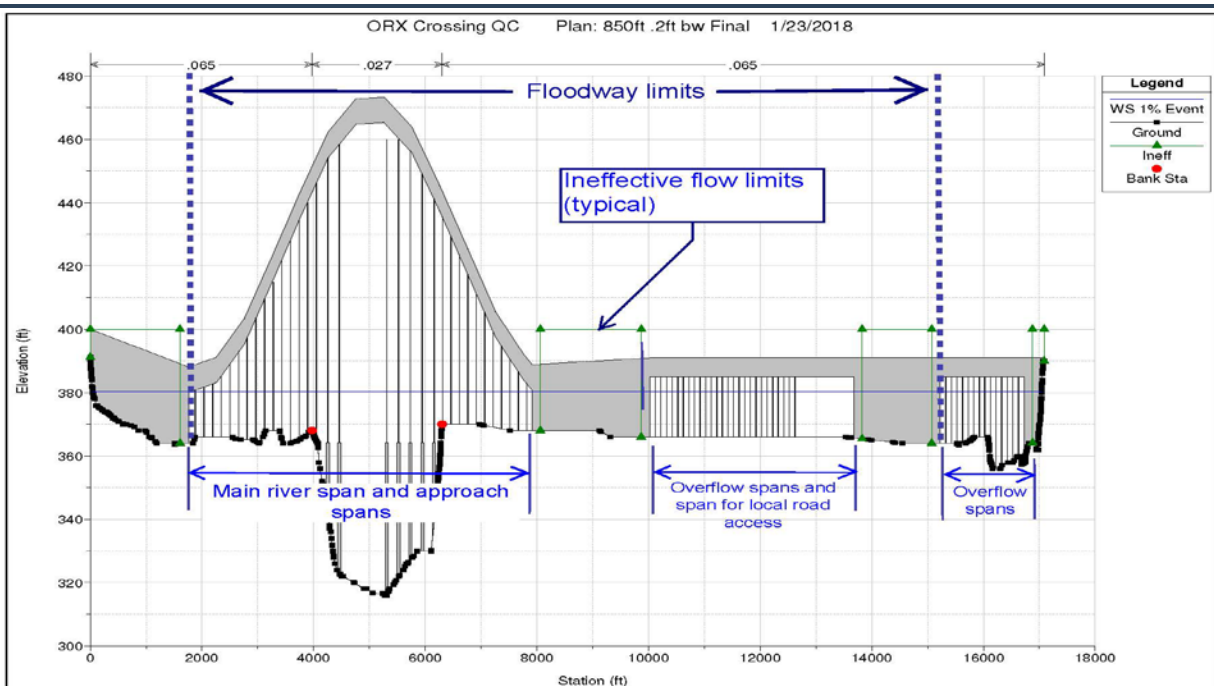

Figure 3-1. An Example Cross Section from the 1D Analysis showing Multiple Bridge Openings and Ineffective Flow Limits

3.2 SMS MODELING

3.2.1 MODEL DEVELOPMENT AND CALIBRATION

The 2D model, using the SMS Aquaveo SRH-2D software, was created using three main components. These components included the surface, the materials data, and the boundary conditions. The surface used was a combination of LiDAR data, 1D cross-section data, and survey data. The surface data were imported as a set of points and then redefined as a map layer for the 2D computations. The materials data was an additional map layer that defined Manning's n-values (ground roughness data), for the entire model coverage. The Manning's n-values were iteratively adjusted to match the calculated water surface elevations from the 1D analysis. Manning's n-values used the following table (Table 3-1).

Table 3-1. Manning's n-values for Ground Covers

MATERIALS DESCRIPTION	MANNING'S n-VALUE
Overbank	0.065
River	0.026
Woods-Urban	0.080

Bridges were modeled as elements with the approximate length of the span opening assigned with overbank, river or woods-urban Manning's n-values to allow flow passage through embankment, and piers were modeled with unassigned Manning's n-values.

The final component, the boundary condition, is a map coverage that contains the design flow for the project and a downstream boundary condition. The downstream boundary condition was based off of the FIRM's water surface elevation at the location where the 2D model terminates downstream of the project. See Table 3-2 for boundary conditions used.

Table 3-2. Boundary Conditions

BOUNDARY CONDITION	VALUE
Design Flow Rate (Upstream)	920,000 cubic feet per second
Water Surface Elevation (Downstream)	376.40 ft

Additional design items within the 2D models included monitor points to track the progress and model conversion, and monitor lines to obtain flow values at specific locations.

The 2D models encompassed an area of approximately 64.5 square miles, and contained just over 111,000 separate data points. The model area encompassed the total area affected by the alternatives. Upstream of the 2D model extent, a 1D model using HEC-RAS software was used to develop the impacts at various backwater conditions. Figure 3-2 shows the general topography used in the 2D model, the limits of which encapsulate the area analyzed.

3.2.2 Analysis Results

3.2.2.1 Existing

The existing condition 2D model was calibrated to both the FEMA floodplain maps and the existing HEC-RAS 1D model created for the project. To calibrate the 2D model, the materials data was adjusted until reasonable and calibrated water surfaces were obtained. Manning's n-values for the existing 2D model are similar to those in the 1D model. Figures 3-3 and 3-4 show the existing materials file used (Manning's n-values) and the SMS water surface elevation results of the existing condition.

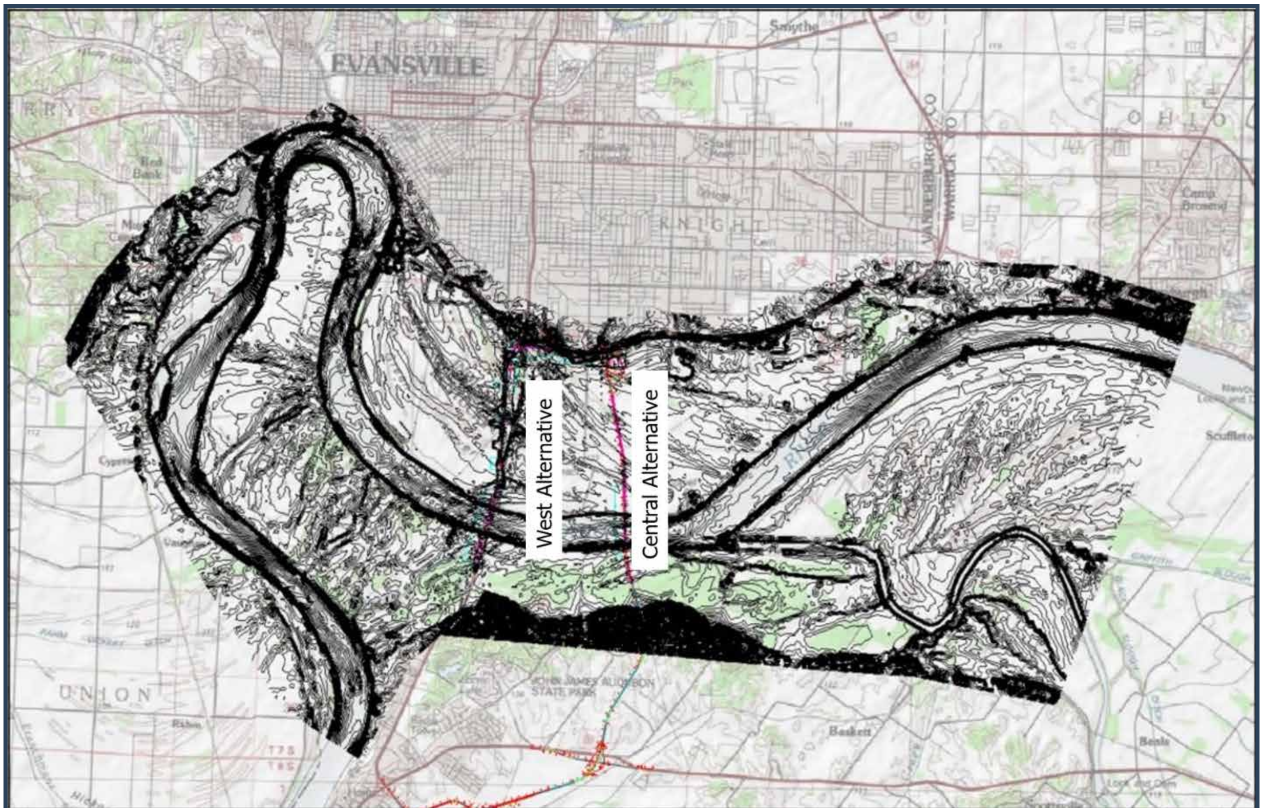

Figure 3-2. Limits and Topography of 2D Modeling

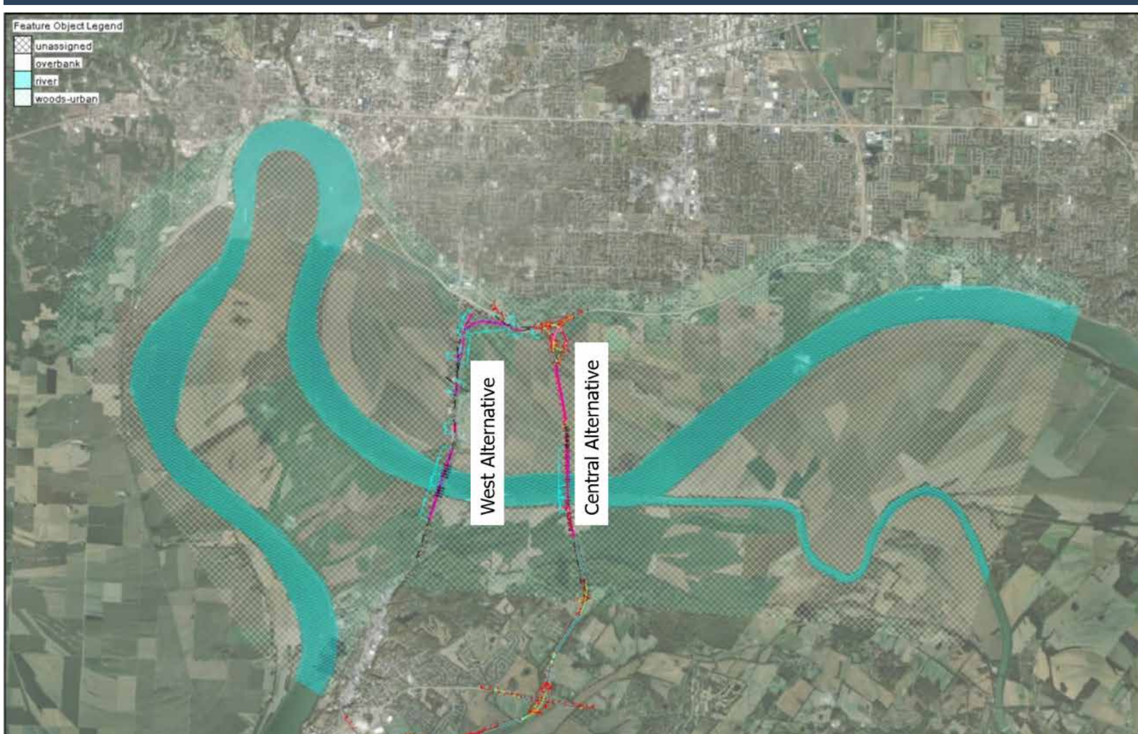

Figure 3-3. Existing Ground Cover

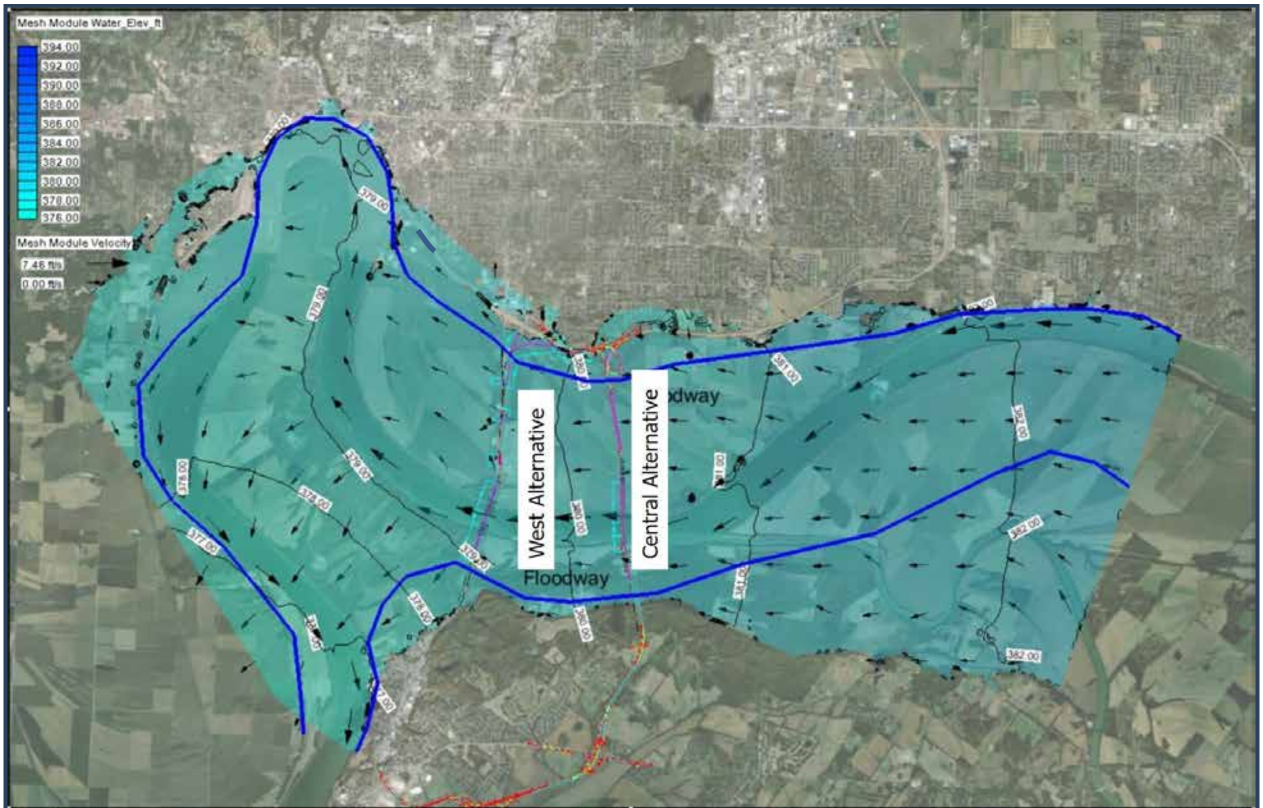

Figure 3-4. Existing Water Surface Elevations and Flow Vectors

3.2.3 Bridge Backwater Scenarios

Different scenarios for the West Alternatives and the Central Alternative were modeled in SMS. Two figures are provided for each scenario, a map of the resulting water surface elevations with flow vectors overlaid, and a map depicting the backwater (the proposed water surface elevations minus the existing water surface elevations). Only one scenario was modeled for the West Alternatives (Figures 3-5 and 3-6) while four scenarios were modeled for the Central Alternative based on backwaters of 0.14 ft, 0.20 ft, 0.40 ft, and 1.0 ft (Figures 3-8 through 3-15). Black hatch marks along the alignment represent pier and abutment limits inserted in the models.

3.2.3.1 West Alternatives

Parsons has assumed that all bridge openings for the West Alternatives (W1 and W2) will match the size and location of all bridge openings of the existing bridges (US 41). Figure 3-5 shows the water surface elevations and Figure 3-6 shows the backwater for the West Alternatives.

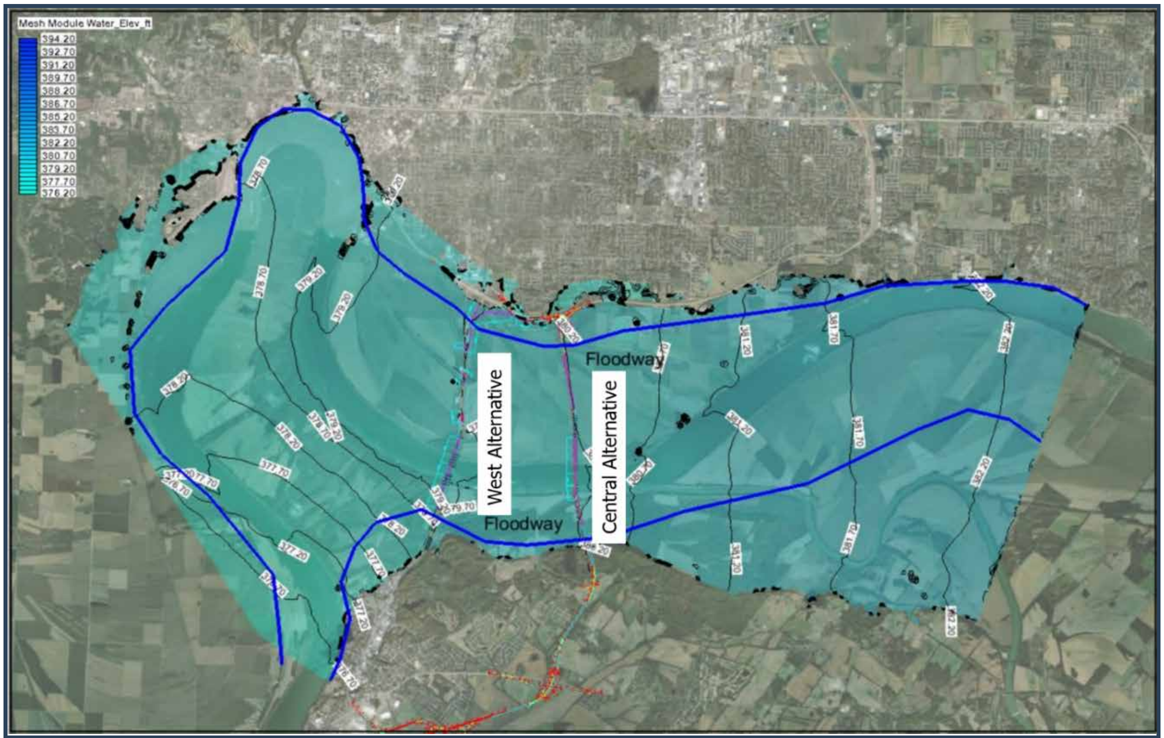

Figure 3-5. Proposed West Alternatives Water Surface Elevations

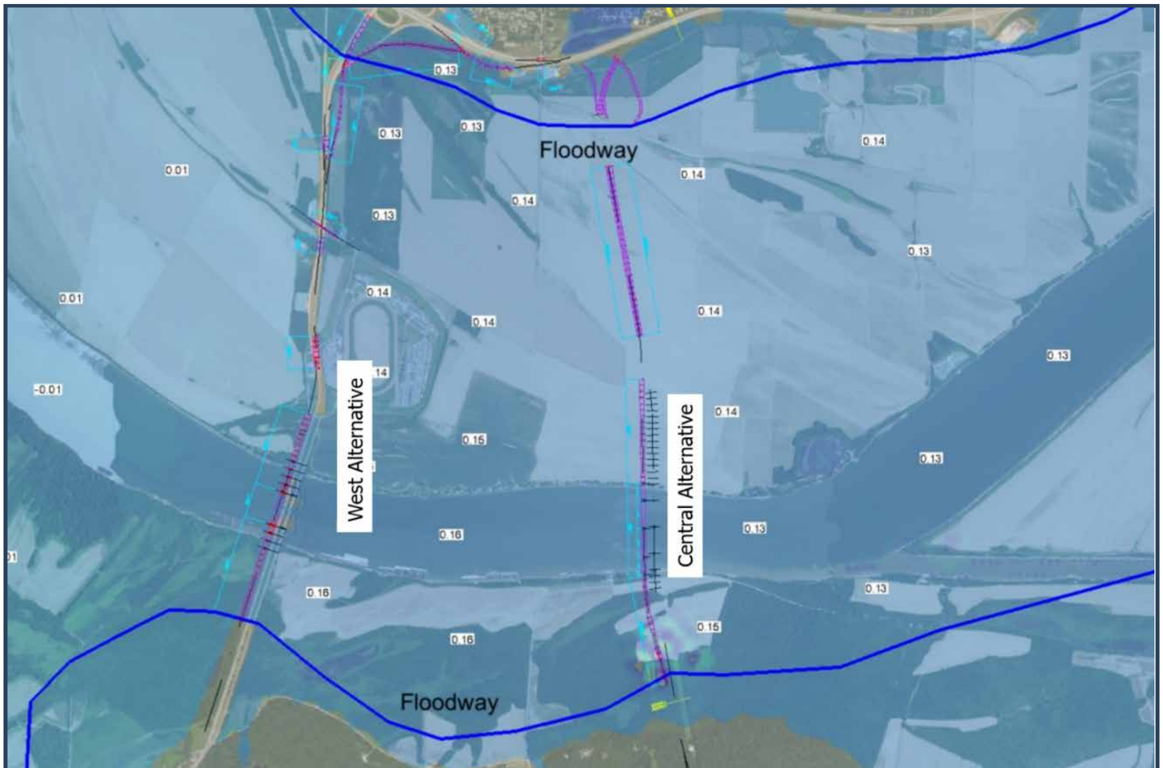

Figure 3-6. Proposed West Alternatives Backwater (feet)

3.2.3.2 CENTRAL ALTERNATIVE 1

In order to estimate the extent of flood easements over a range of backwaters, the bridge openings for the Central Alternative were adjusted to produce backwaters of 0.14 ft (the Indiana allowable maximum), and 0.20 ft, 0.40 ft, and 1.0 ft (the Kentucky allowable maximum) (Figure 3-7). Figures 3-8 through 3-15 show the water surface elevations and the backwater for these four different scenarios.

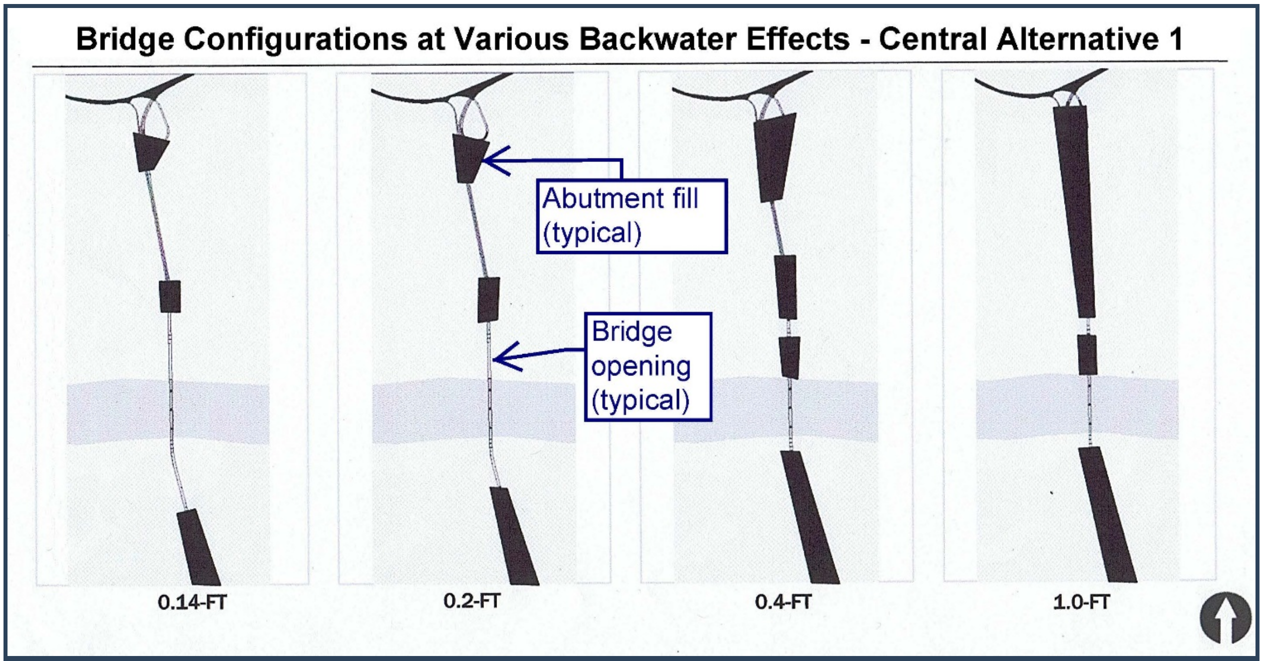

Figure 3-7 Bridge Configurations for Various Backwater Effects

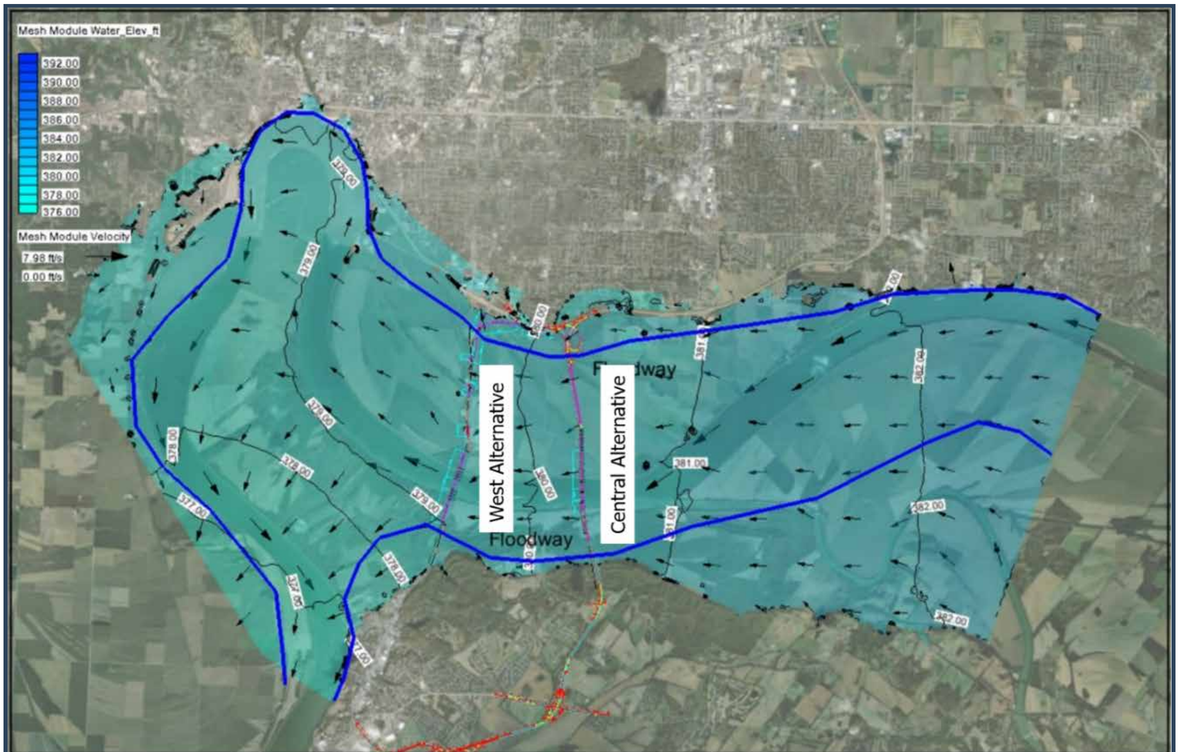

Figure 3-8. Proposed Central Alternative 1 Water Surface Elevations (0.14-ft Backwater)

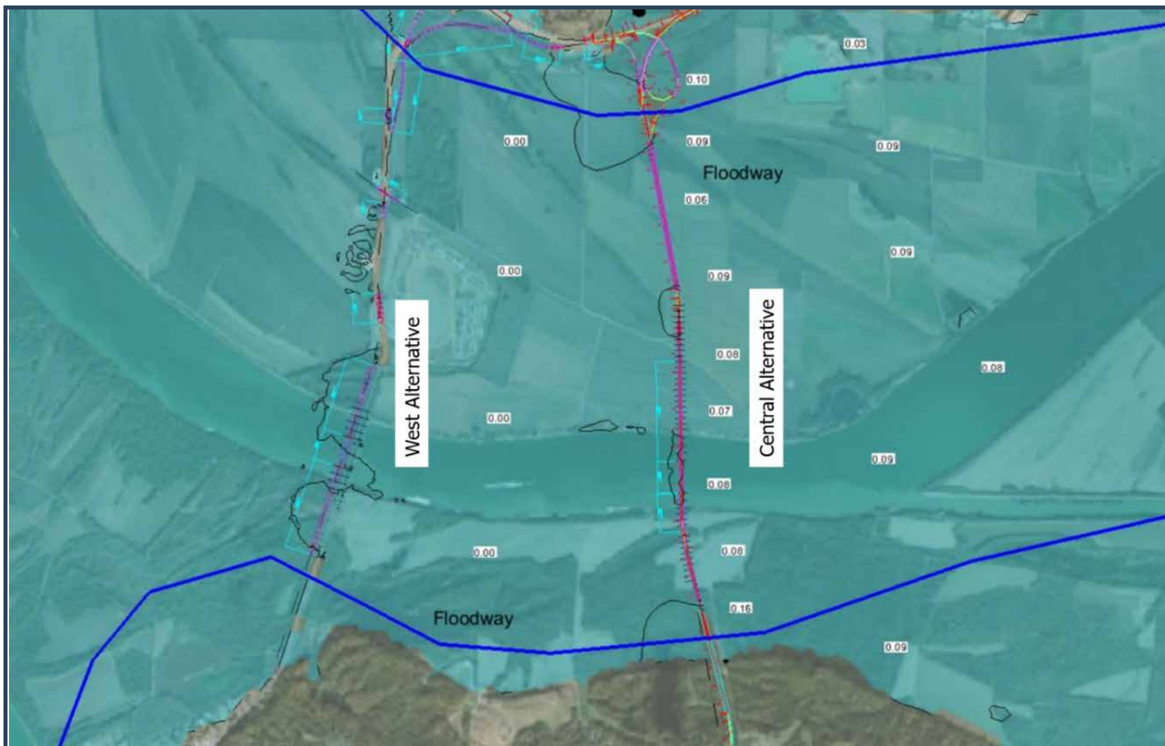

Figure 3-9. Proposed Central Alternative 1 – Maximum 0.14-ft Backwater

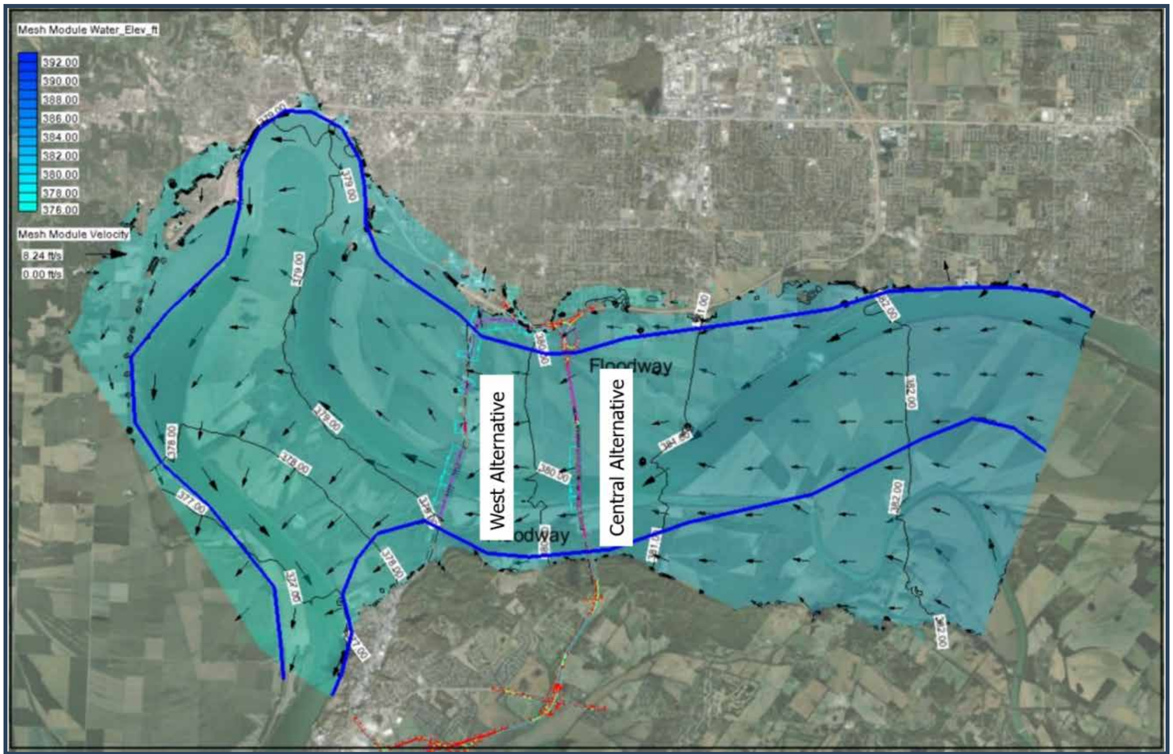

Figure 3-10. Proposed Central Alternative 1 – Water Surface Elevations at 0.20-ft Backwater

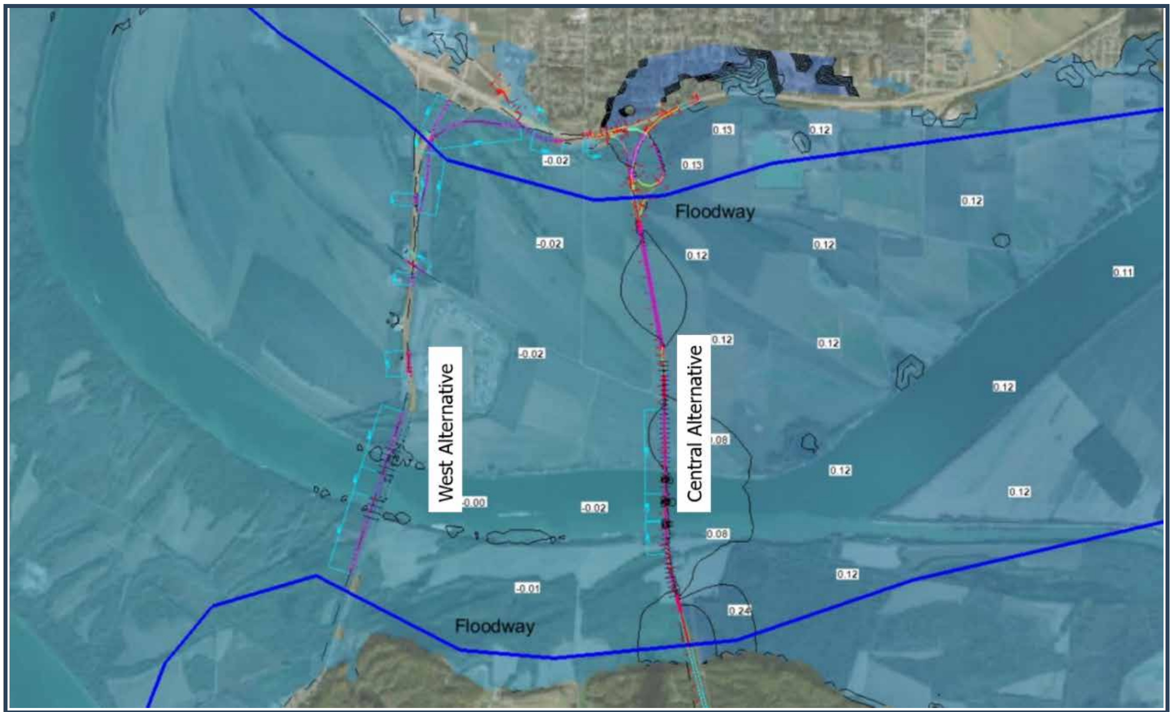

Figure 3-11. Proposed Central Alternative 1 – Maximum 0.20-ft Backwater

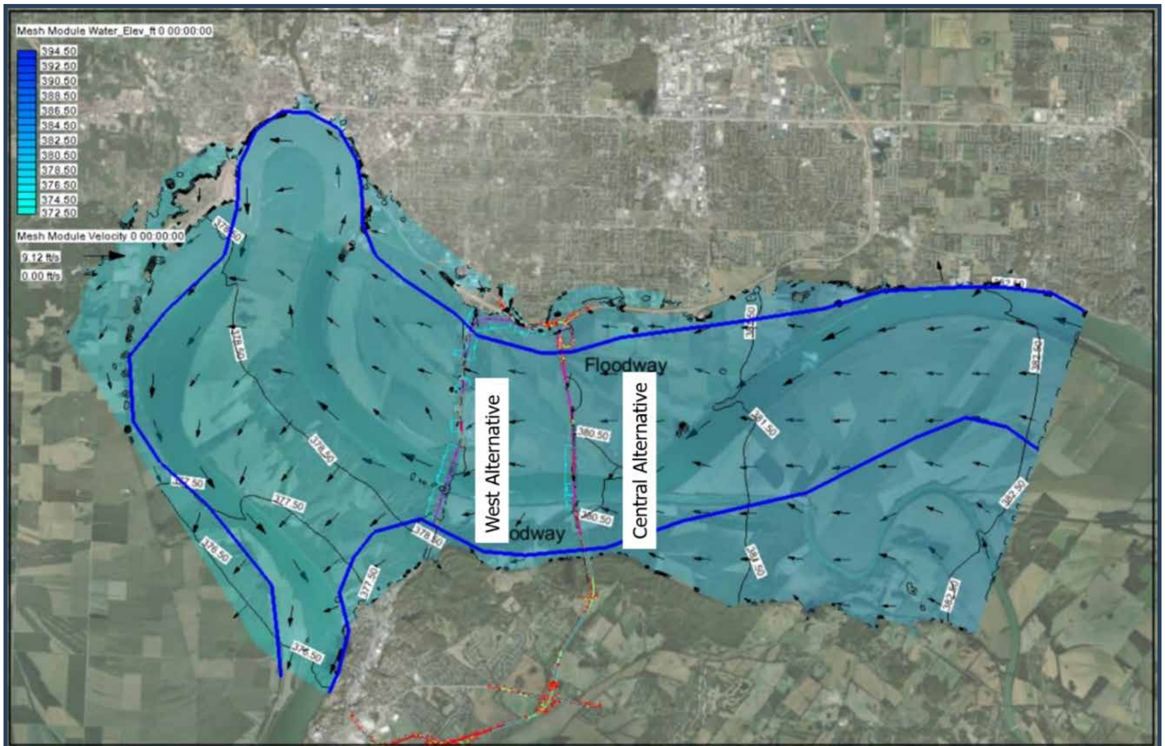

Figure 3-12. Proposed Central Alternative 1 Water Surface Elevations at 0.40-ft Backwater

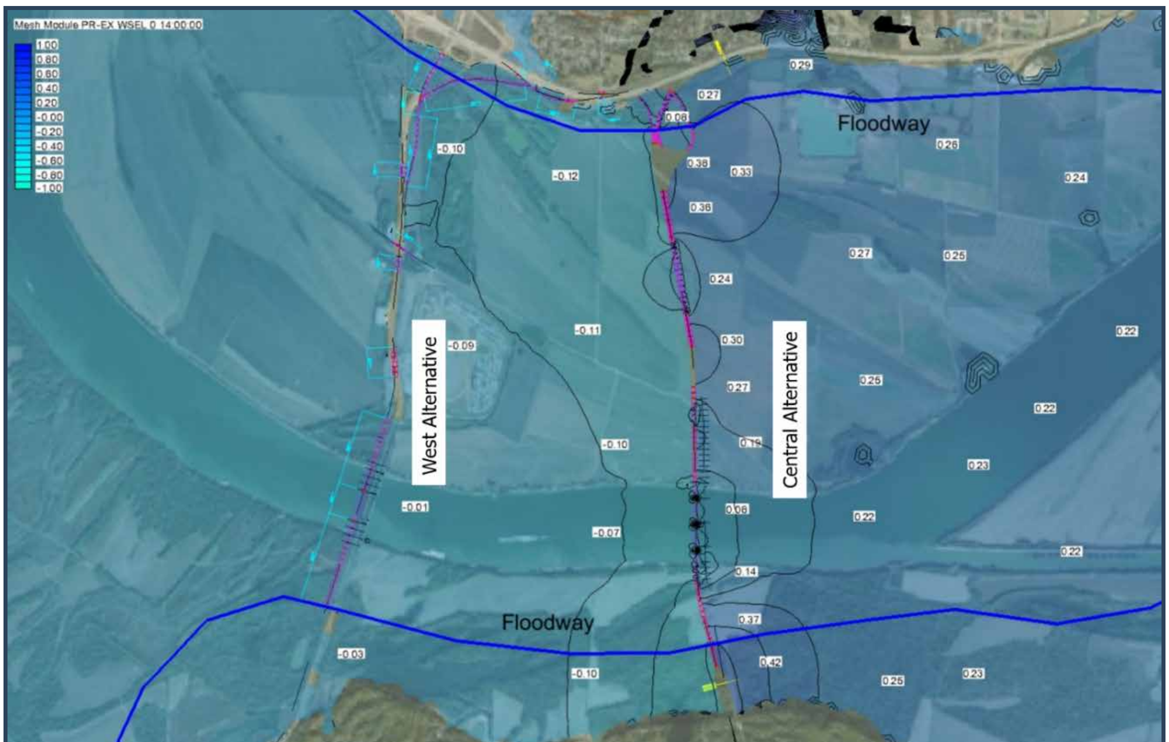

Figure 3-13. Proposed Central Alternative 1 – Maximum 0.40-ft Backwater

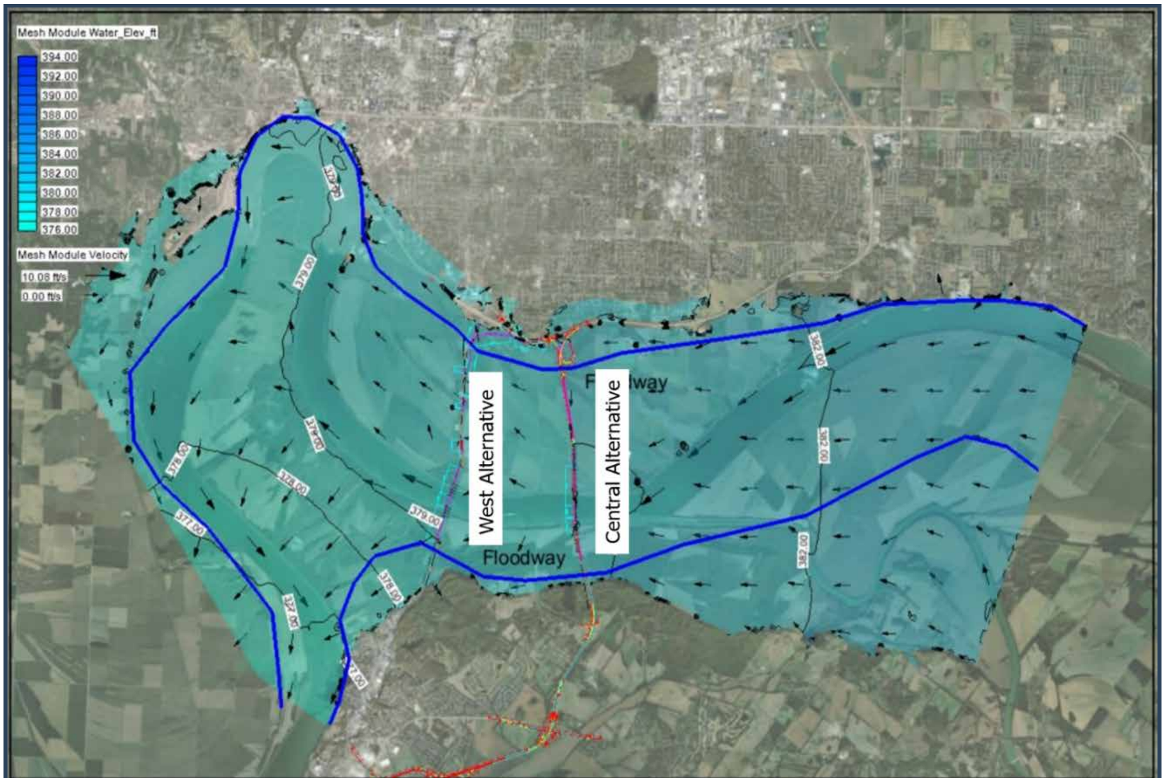

Figure 3-14. Proposed Central Alternative 1 – Water Surface Elevations at Maximum 1.0-ft Backwater

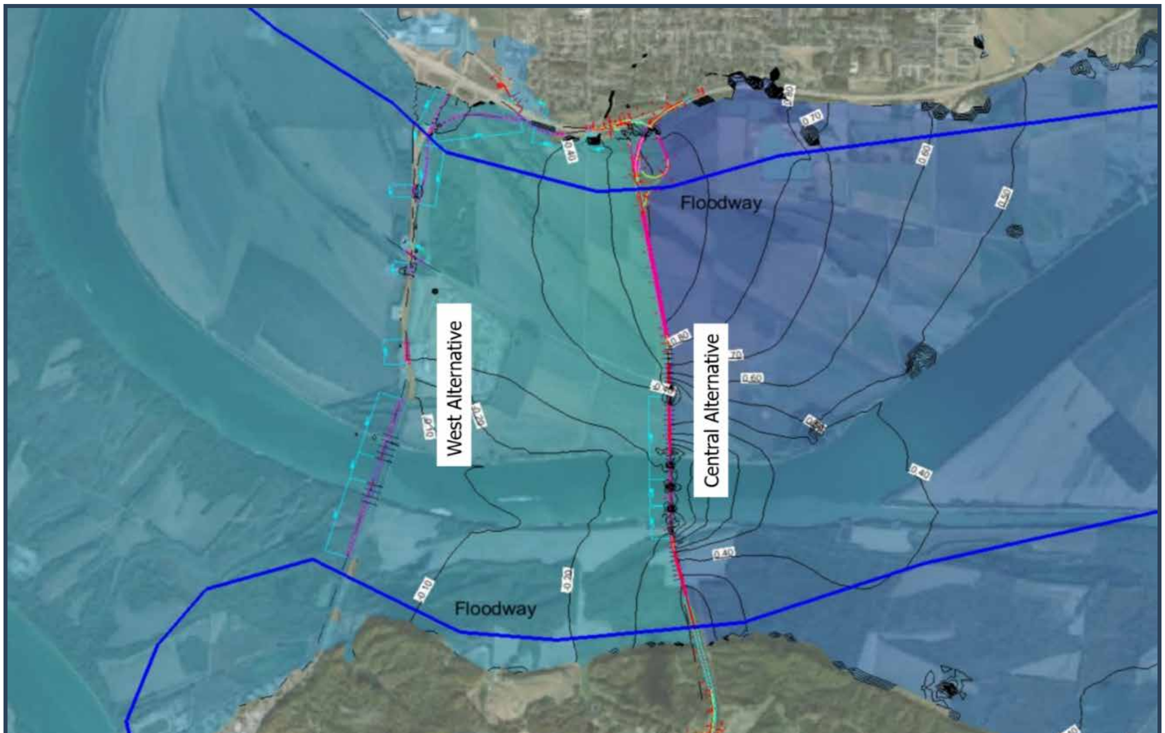

Figure 3-15. Proposed Central Alternative 1 – Maximum 1.0-ft Backwater

3.3 HEC-RAS MODELING

3.3.1 MODEL DEVELOPMENT AND CALIBRATION

HAC-RAS Version 5.03 was used for the 1D, gradually varied flow, hydraulic analysis. Parsons used the HAC-RAS model developed by the USACE for the Uniontown Pool and the Newburgh Pool. The two files in the model cover River Mile 846 (from the J.T Myers L & D) and upstream to River Mile 721.5 (upper end of Newburgh Pool, see Figure 2-2). The model was then truncated at River Mile 801.3 and used the corresponding starting water surface elevation of 376.82 NAVD 88. There were no bridges in either of the two USACE HAC-RAS record models. Omitting bridges from the models is standard practice for USACE and FEMA when generating floodway limits only. Parsons inserted both the existing and proposed bridges into the model for determining bridge backwater and flow characteristics.

Additional cross-sections for the HEC-RAS model in the vicinity of the project area were developed using field survey and LiDAR data in NAVD88. Cross-sections from the FIS were used outside of the project area. Existing plans were used to input the bridge geometry of the existing US 41 bridge into the model.

3.3.2 ANALYSIS RESULTS

3.3.2.1 EXISTING

The existing US 41 bridge crossing conveying the Ohio River consists of two bridges, a northbound bridge and a southbound bridge. Each has a main bridge span over the river channel and three overflow bridges in the floodplain. Bridge lengths, identical for the northbound bridge and the southbound bridge, are as follows:

Main bridge: 5,400 ft

Overflow 1: 383 ft

Overflow 2: 383 ft

Overflow 3: 1,200 ft (approximate, no existing plans available.)

These bridges cause a maximum of 0.38 ft of backwater (Backwater at a bridge is defined as the increase in water surface elevation at the bridge caused by the encroachment of the bridge into the stream of flow. Due to the characteristics of the stream (or, river), the backwater may dissipate immediately or dissipate miles upstream of the bridge). Because these bridges were built prior to 1973, the backwater is considered to be an existing condition and does not reduce the legal maximum of 0.14 ft of additional backwater for the proposed conditions.

For the purpose of considering cumulative effects in the project area, IDNR’s library of existing hydraulic models was searched. There exists one hydraulic model, FW-16556, that was developed for the permit of docking facilities for the riverboat casino. IDNR’s HEC-2 model was converted to HAC-RAS and was used to analyze existing and proposed conditions. It was found that the dock facilities resulted in no change over existing conditions. Therefore, nothing was changed in the Parsons models.

Sensitive

In summary, the Parsons' model for existing conditions was based on the current FIS model with no edits except adding in the US 41 bridges and substituting cross-sections where project survey data were available.

3.3.2.2 West Alternatives

Parsons has assumed that the bridge configurations for both West Alternatives would match the existing US 41 bridge lengths. Therefore, backwater would not exceed the allowable additional amount of 0.14 ft.

3.3.2.3 Central Alternative 1

Central Alternative 1 bridge configurations were developed to produce a range of backwaters. The results from the SMS analysis will be used to refine the preferred alternative for flood permits and a CLOMR.

4 MAP BOOK OF FLOOD EASEMENTS

4.1 BACKGROUND

The hydraulic analysis and modeling of the I-69 ORX alternatives produced estimates of upstream flooding for a variety of bridge configurations. For the West Alternatives located at the existing US 41 bridges, backwater was held at the existing condition. For Central Alternative 1, located upstream of US 41, backwater could range from 0.14 ft to a maximum of 1.0 ft. A backwater of 0.14 ft is the legal maximum in Indiana without flood easements. A backwater of 1 ft is the legal maximum for Kentucky. Backwater at the bridge crossings does not dissipate for several miles. Figure 4-1 depicts the extent of dissipation over a range of backwaters.

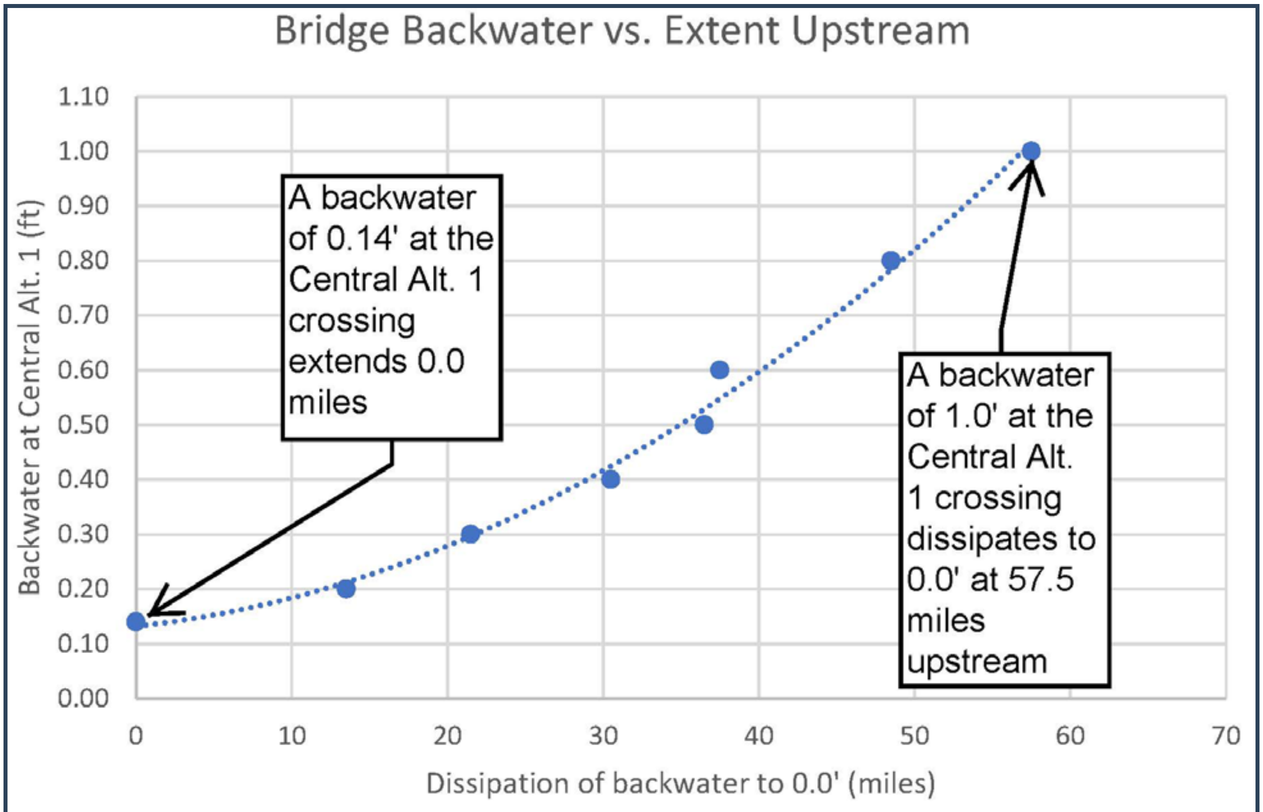

Figure 4-1. Bridge Backwater vs. Extent Upstream

4.2 PURPOSE

The purpose of the mapping is to document in detail the extent of the 1 ft maximum backwater, the impacted areas, and the required flood easements. The mapping scale should be sufficient to provide detail on the extent and size of the flood easement parcels.

4.3 SCOPE

The backwater and flood easement mapping cover the Indiana side where flood easements are required for backwater depths exceeding 0.14 ft. The *Indiana Mapbook (20180521 RPT Mapbook Potential Backwater Impacts – Indiana.pdf)* was developed to show the extent of flooding at a 1 ft backwater depth. The Mapbook consists of individual map panels suitable for printing on 11" x 17" sheets. An index map provides a key to the location and extent of the mapping and of each panel (See Figure A-3 in the Appendix). Each panel is developed at a scale of 1" = 2000' and has enough resolution for viewing small parcels and narrow floodplain fringe areas.

4.4 METHODOLOGY

The GIS mapping of the backwater area and the associated flood easement parcels from the Hydraulic Impacts Analysis is the basis of the detailed flood mapping. The selected layers include a topographic relief map with labeled streets and highways, the backwater area, and the required flood easements outlined on property parcels. The source of the parcel information is maintained by county agencies and is current to Dec 15, 2015. The Indiana Geographic Information Office claims a 100 percent participation rate from counties. The Indiana Map Data Sharing Initiative includes Vanderburgh and all other upstream counties except Warrick County, immediately upstream. The data for that county comes from the 2009 on-line edition of the *Indiana GIS News from the Indiana Geographic Information Council at* http://igic.org/news/.

The floodplain for Central Alternative 1 was modeled based on a 1' backwater condition for a 100-year flood event. This 1 ft backwater condition is the upper limit for planning purposes. It would require flood easements on the Indiana side but is the maximum allowable in Kentucky without easements. The resulting water surface profile for the Ohio River was used to map the floodplain in a GIS platform. The floodplain mapping for the Ohio River tributaries was limited to backwater directly caused by the Ohio River. LiDAR data from the *Indiana GIS News* was used to create a ground surface for Vanderburgh, Warrick, Spencer, and Perry counties. The water surface profile was compared with the ground surface to create a floodplain. The proposed floodplain represents the ground surface that is below the water surface. The area within the 100-year floodplain contained many fill encroachments from new development, documented by multiple Letter of Map Revisions (LOMR) to the FEMA flood maps. To get a more accurate representation of the existing area affected, a HEC-RAS analysis was created for the existing backwater conditions. Using the same method from above, the existing floodplain was recreated to compare the accuracy of the FEMA floodplain. The new base floodplain had less impacted area than the FEMA floodplain because the difference in the impacted area occurs where the LOMRs are located. The additional impacted area was found by comparing the new base floodplain and the proposed 1 ft backwater floodplain.

4.5 RESULT

For the *Indiana Map Book*, the extent of the 1 ft backwater, 57.5 miles upstream, falls between Troy, IN and Tell City, IN. As summarized in Table 4-1, without any backwater effect, the 100-year flood covers an area of 57,237 acres. Within that base flood area there are 6,056 parcels. A ft backwater encroaches on 2,427 parcels that are in the fringe area, i.e. an area already in the base floodplain. Additional parcels that were not previously in the floodplain but would be in a floodplain created by a 1 ft backwater total 4,516 parcels.

Table 4-1. Floodplain Areas and Parcel Quantities for 1 ft Backwater in Indiana

AREA OF BASE FLOOD (NO BACKWATER) (ACRES)	PARCELS IN BASE FLOOD AREA	FRINGE AREA CREATED BY 1 FT BACKWATER (ACRES)	ADDITIONAL PARCELS NEEDED FOR 1 FT BACKWATER
57,237	6,056	2,427	4,516

5 LITERATURE CITED

Guidance for Flood Risk Analysis and Mapping, General Hydraulics Considerations, November 2016, FEMA

Flood Insurance Study Vanderburgh County, Indiana and Incorporated Areas, Number 18163CV000A, Effective March 17, 2011, FEMA

Flood Insurance Study, Henderson County, Kentucky and Incorporated Areas, Number 18163CV000A, Revised September 29, 2017, FEMA

Screening Report, Indiana Department of Transportation (INDOT) and Kentucky Transportation Cabinet (KYTC), 2017

Screening Report Supplement, INDOT and KYTC, 2018

20180521 RPT Mapbook Potential Backwater Impacts – Indiana, Parsons, 2018

Indiana GIS News from the Indiana Geographic Information Council, 2009 on-line edition, http://igic.org/news/

APPENDIX A
SUPPORTING FIGURES

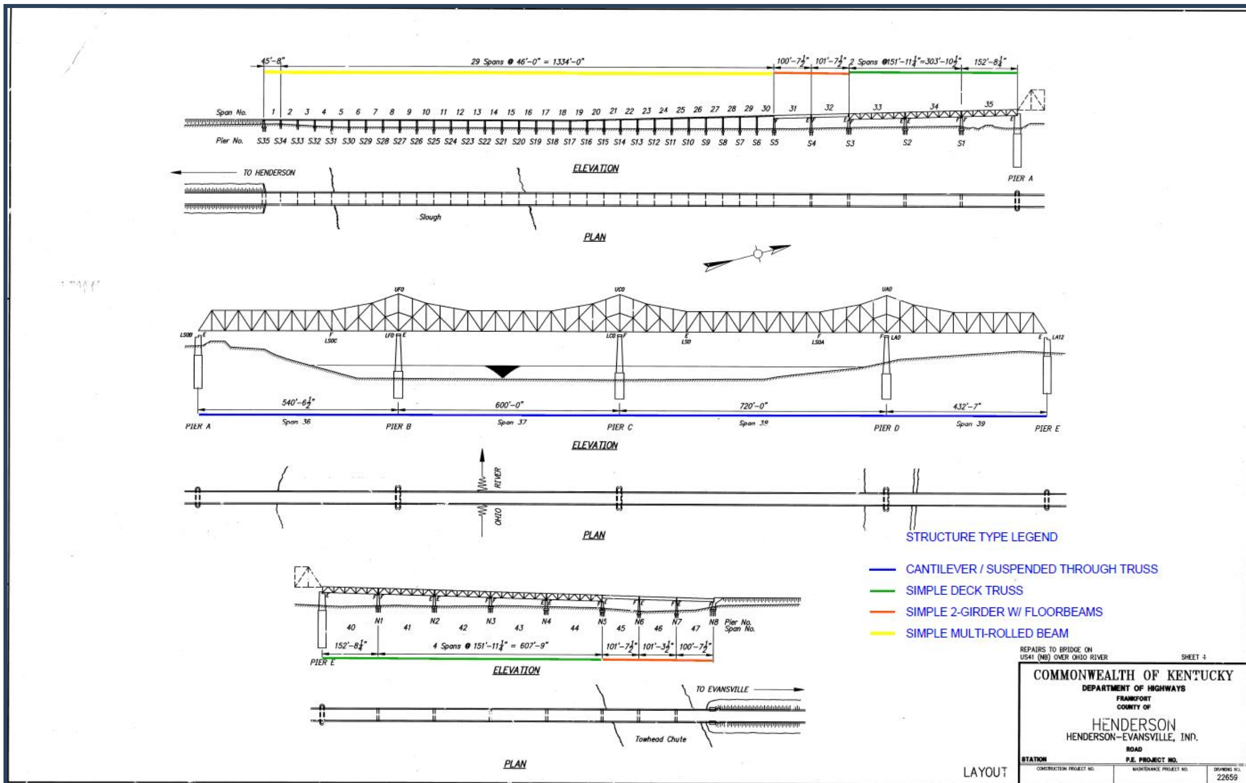

Figure A-1. Plan and Profile of the Existing US 41 Northbound Bridge

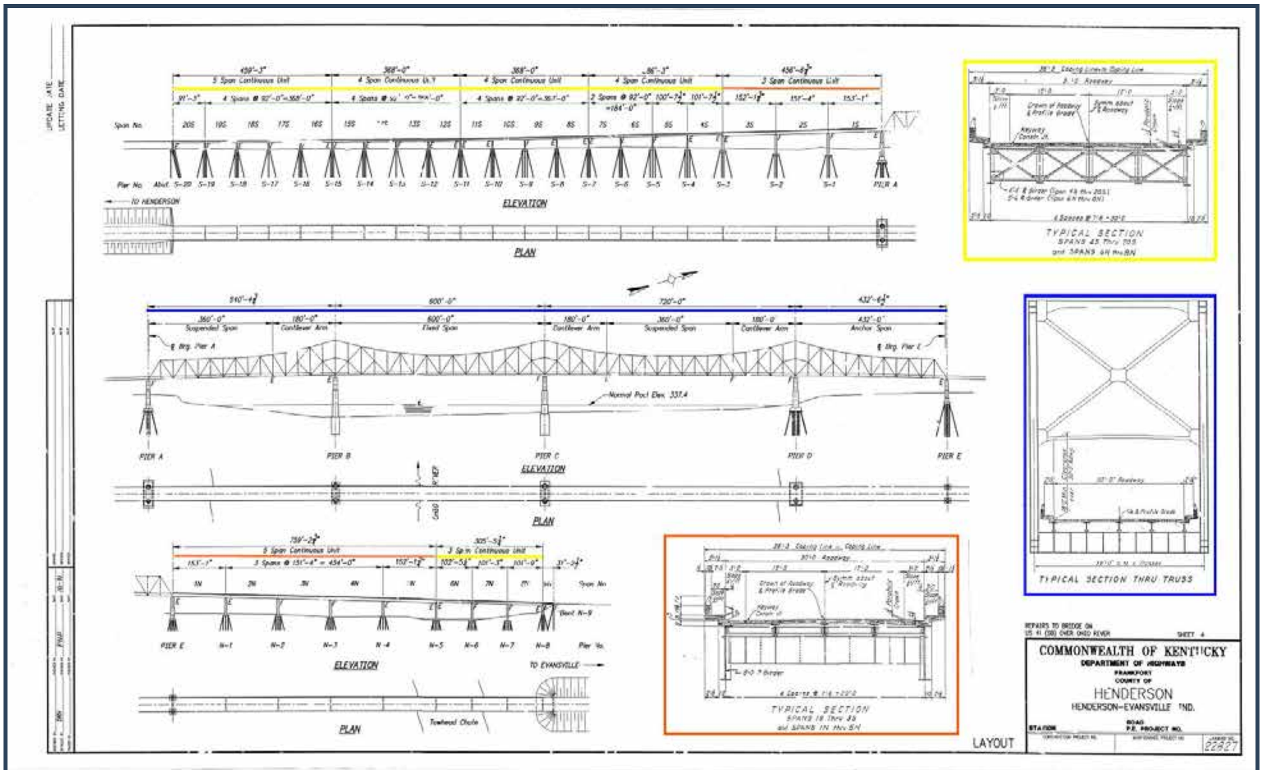

Figure A-2. Plan and Profile of the Existing US 41 Southbound Bridge

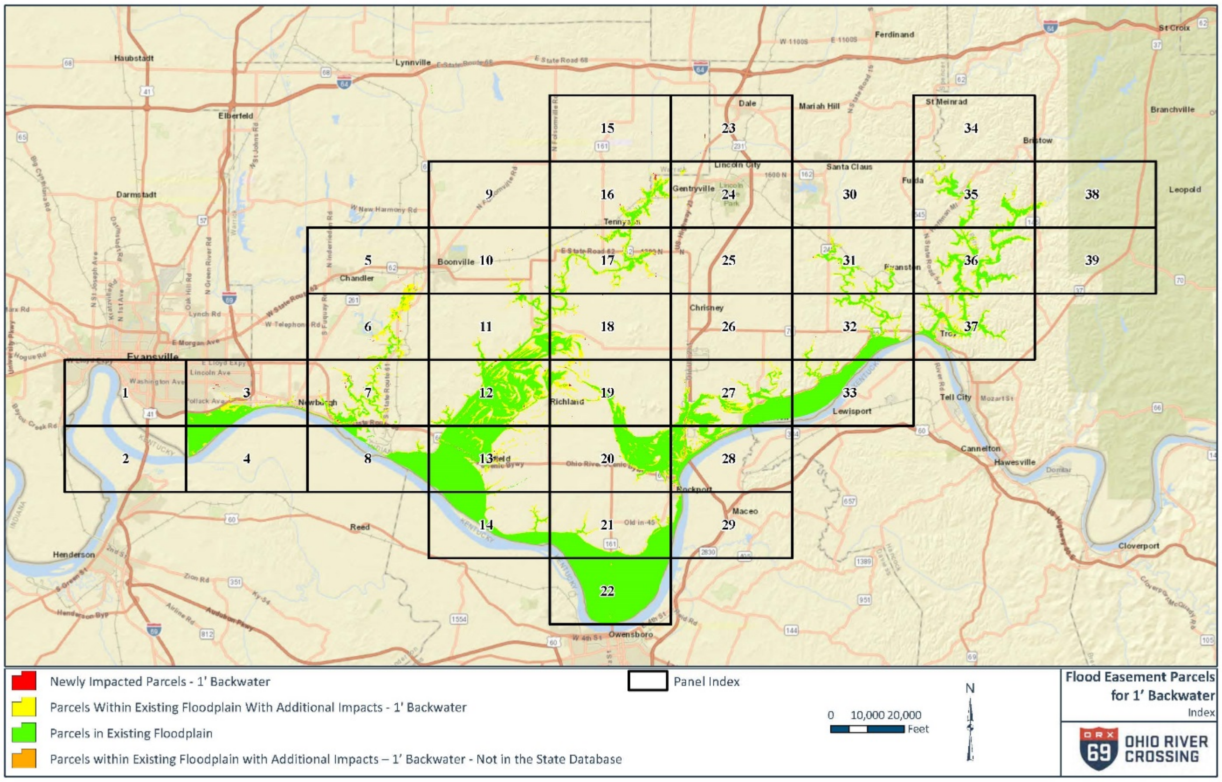

Figure A-3. Index of the Map Book of Potential 1' Backwater Impact in Indiana from Central Alternative A1

Figure A-4. Base Map – LiDAR and Bathymetric Surveys

Difference in WSEL
Floodway model minus Effective Model

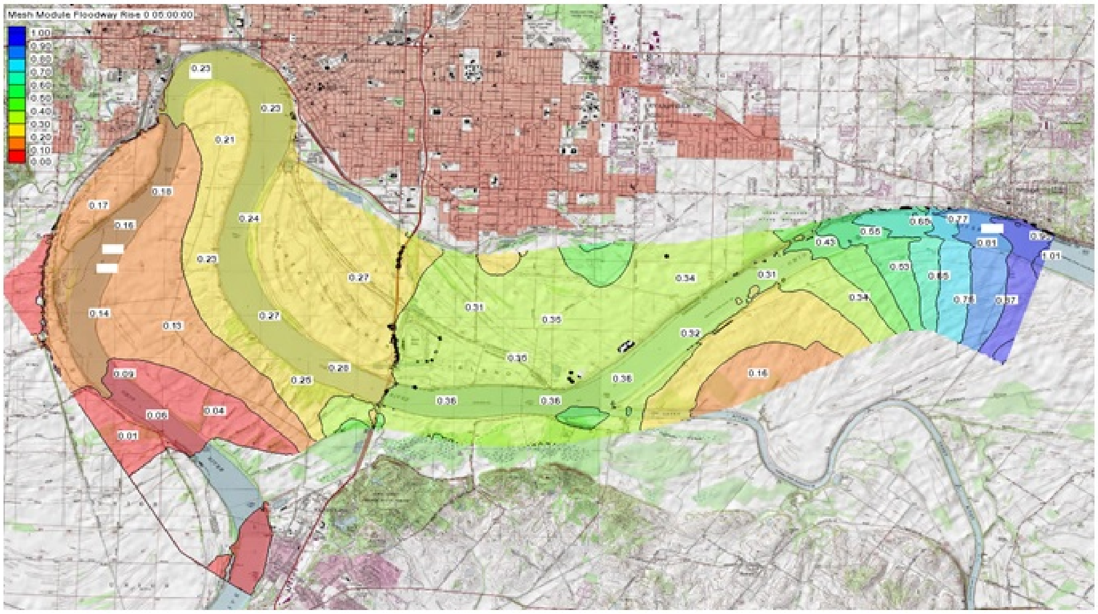

Figure A-5. 2D Modeling - Floodway Elevations minus Floodplain Elevations

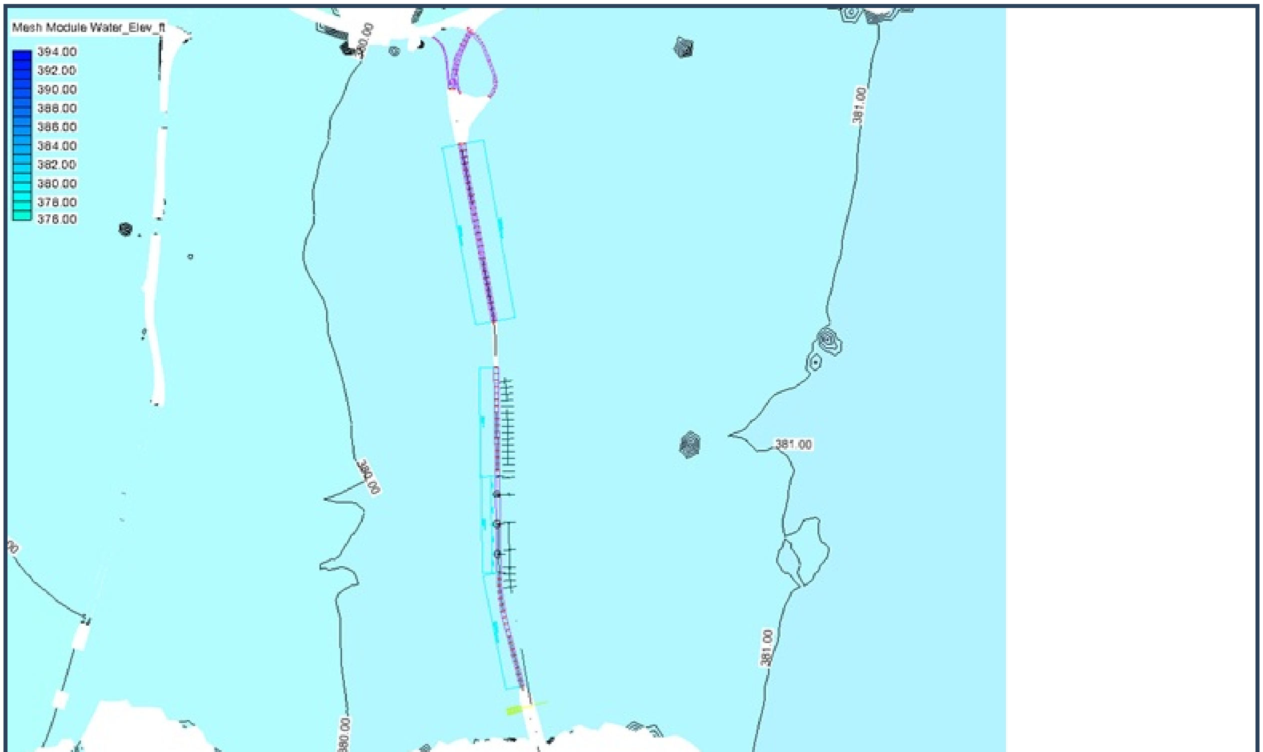

Figure A-6. 2D Modeling - Bridge Layout Plan – Central Alternative 1 – 0.14 ft Backwater

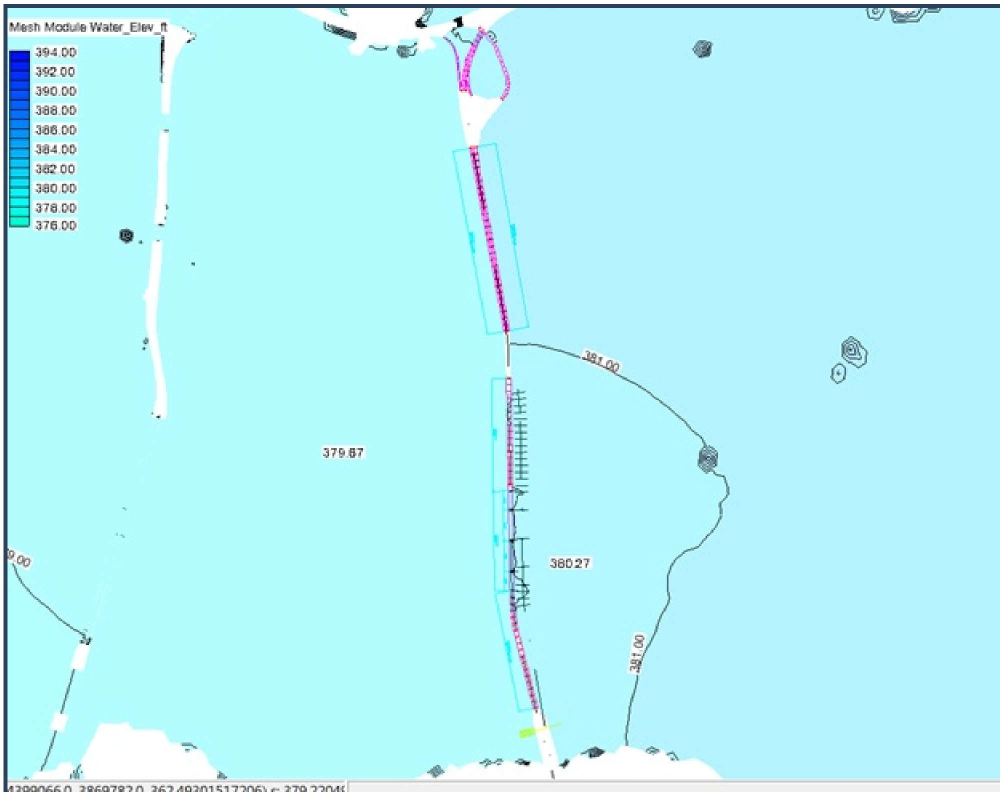

Figure A-7. 2D Modeling - Bridge Layout Plan – Central Alternative 1 – 1.0 ft Backwater

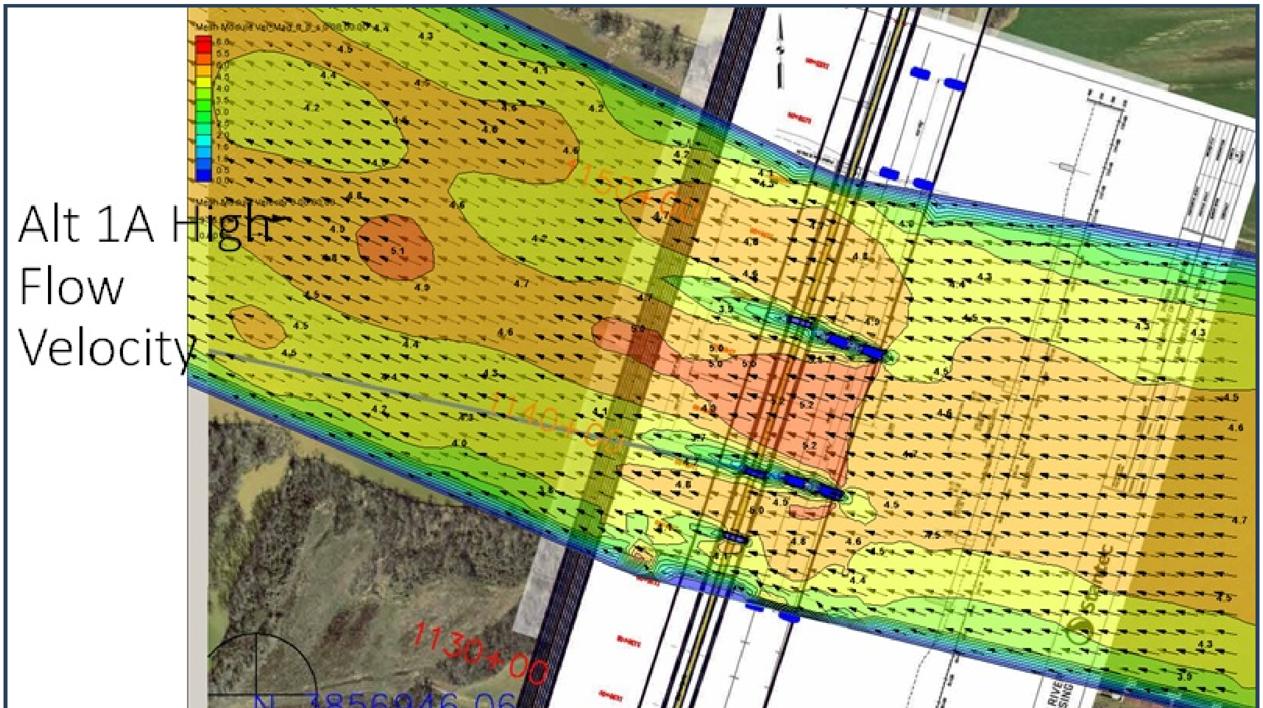

Figure A-8. 2D Modeling – Central Alternative 1 - Higher Flow Velocity Vectors