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Three Rivers, Southeast Arkansas Navigation Study

Ship Simulation Report

Morgan M. Johnston, Ronald E. Heath, and Mary Claire Allison

August 2020



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Morgan M. Johnston, Ronald E. Heath, and Mary Claire Allison

Coastal and Hydraulics Laboratory US Army Engineer Research and Development Center 3909 Hall Ferry Road Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for US Army Corps of Engineers, Little Rock District Little Rock, AR 72203

Under Work Unit 478043

Abstract

The McClellan-Kerr Arkansas River System (MKARNS) is a major inland waterway that begins at the Port of Catoosa in Tulsa, OK, and travels to the confluence of the White and Mississippi Rivers. Over the years, many structures have been built to help control overland flow between the White, Arkansas, and Mississippi Rivers. These structures have required a significant amount of rehabilitation, which has resulted in high maintenance costs. The US Army Corps of Engineers and the Arkansas Waterways Commission conducted the Three Rivers Southeast Arkansas Feasibility Study (also known as the Three Rivers Study). The Three Rivers Study focused on providing long-term dependable navigation in the MKARNS. From this study, a proposal was developed that included a 1,000 ft reopening of the Historic Cutoff and a reinforcement of several areas near the White River.

In 2019, the US Army Engineer Research and Development Center Ship/Tow Simulator was used to perform a navigation study to ensure the proposed modifications did not negatively impact navigation on the White River section of the MKARNS. Assessment of the proposed modifications was accomplished through analysis of ship simulations completed by experienced pilots, discussions, track plots, run sheets, and final pilot surveys.

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Preface

This study was conducted for the US Army Corps of Engineers, Little Rock District (SWL), under General Investigations, Work Unit 478043, "Three Rivers Study PED Statement of Work Modification." The technical lead at SWL was Ms. Catherine Funkhouser. The project manager was Ms. Dana Coburn.

The ship simulation portion of this project was completed by the US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Navigation Branch of the Navigation Division. The numerical modeling portion of this project was completed by the ERDC, CHL, River Engineering and Estuarine Branch of the Flood and Storm Protection Division. At the time of this study, Mr. Ben Burnham was Chief of the Navigation Branch, Mr. David May was Acting Chief of the River and Estuarine Engineering Branch, Dr. Jacqueline S. Pettway was Chief of the Navigation Division, and Dr. Cary Talbot was Chief of the Flood and Storm Protection Division.

At the time of publication of this report, the Deputy Director of CHL was Mr. Jeffrey R. Eckstein, and the Director was Dr. Ty V. Wamsley.

COL Theresa A. Schlosser was the Commander of ERDC, and the Director was Dr. David. W. Pittman.

1 Introduction

Background

The McClellan-Kerr Arkansas River System (MKARNS) is a major inland waterway that begins at the Port of Catoosa in Tulsa, OK, and terminates at the confluence of the White and Mississippi Rivers (Figure 1). The MKARNS contains 445 navigable miles and 18 locks and dams across Oklahoma and Arkansas. River traffic between the Arkansas and White Rivers is accomplished by transiting Montgomery Point Lock on the White River and Locks 1 and 2 on the Arkansas River. Approximately \$3.5 billion of commodity are transported across the MKARNS yearly.



Figure 1. MKARNS (USACE-SWL 2019).

The MKARNS terminates at the confluence of the White River with the Mississippi River (Figure 2 and Figure 3). The area between the White and Arkansas Rivers, the isthmus, has experienced many complications when river stages are high. When the water elevation exceeds the riverbank, the water will flow across the isthmus, often causing erosion along its path. The chance of this overland flow increases when the head differential between the two rivers is large and when one or more of the rivers has a water elevation above the riverbank. Eventually, the erosion caused by overland flow could result in a cutoff forming between the two rivers that would result in a redirection of river flow from the current path and a loss of ability to maintain minimum navigation pool elevations.







Figure 3. Project location focus (USACE-SWL 2019).

Prior to the construction of the MKARNS, there was a natural cutoff, known as the Historic Cutoff, which permitted flow between the White and Arkansas Rivers. However, the cutoff created dangerous crosscurrents and sediment concerns. The US Army Corps of Engineers (USACE) built the Historic Closure Structure in 1963 to close this natural cutoff. This structure prevented flows between the White and Arkansas Rivers, but a new cutoff, known as the Melinda Channel, was formed. Beginning in the late 1980s, several containment structures were built to help prevent the creation of cutoffs and overland flow. Figure 4 shows several structures that were previously constructed, in yellow and blue. These containment structures have required numerous repairs, which has resulted in high maintenance costs.



Figure 4. Containment structures between the White and Arkansas Rivers (USACE-SWL 2019).

Purpose

If the existing containment structures were to fail, or if a cutoff were to form, navigation would likely have to be closed due to the loss of the ability to maintain a minimum navigation pool elevation, strong crosscurrents, and sediment concerns. A navigation closure would be extremely expensive since a large amount of commerce is transported via the MKARNS. The USACE, along with the Arkansas Waterways Commission, conducted the Three Rivers Southeast Arkansas Feasibility Study (also known as the Three Rivers Study). This project focused on providing longterm dependable navigation in the MKARNS. From this study, a feasibility plan was developed. Part of this plan included a reopening of a portion of the Historic Cutoff. There were concerns that when water was diverted through the reopening, adverse navigation conditions might occur on the White River, likely due to crosscurrents. This study focused on determining the effects to navigation on the White River due to the implementation of the reopening.

Objective

The USACE, Little Rock District (CESWL), has proposed reopening a portion of the Historic Cutoff. This reopening would control flow when the water surface elevation at Navigation Mile 4 exceeds 145 ft (NAVD88). The ship/tow simulation study was conducted to ensure that the reopening would not cause adverse navigation conditions on the White River section of the MKARNS.

Approach

Simulations were conducted for the proposed reopening with four pilots over two testing weeks at the US Army Engineer Research and Development Center (ERDC) Ship/Tow Simulator (STS). Session one occurred from November 11–15, 2019, and session two occurred from December 16–20, 2019. Table 1 is a list of attendees for all testing sessions. The validity of the proposed opening was analyzed through a series of ship simulation exercises, track plots (Appendix A), discussions following simulations, written pilot comments (Appendix A), final wrap-up discussions, and final pilot questionnaires (Appendix B).

Name	Session: Dates Attended
Captain Rickey Davis, Jr.	One: November 11–15, 2019
Captain John Ward	One: November 11–15, 2019
Captain Manuel Salcido, Jr.	Two: December 16–20, 2019
Captain Kerry Miller	Two: December 16–20, 2019
Ms. Cathy Funkhouser – CESWL	One: November 13-15, 2019
Mr. Andrew Brown- CESWL	One: November 13–15, 2019
Ms. Mandy Edmondson – Arkansas Post Field Office	One: November 13, 2019
Mr. Chris Turner – Arkansas Post Field Office	One: November 13, 2019

Table 1. List of attendees for simulation testing.

Simulator description

Since the 1980s, the ERDC STS has served as a vital modeling tool for navigation projects for the USACE. The ERDC STS has three full mission bridges, each having a 270 deg¹ field of view. Each mission bridge can operate independently or can be linked together. Simulations occur in real time, which means transits take the same amount of time that they would in real life. Figure 5 shows a captain piloting the STS for the Three Rivers project. A virtual database is created for existing conditions and then proposed conditions for each unique project location. A virtual database includes input such as wind, waves, currents, bathymetry, navigational markers, and a visual scene.



Figure 5. Captain piloting the STS during testing.

¹ For a full list of the spelled-out forms of the units of measure used in this document, please refer to US Government Publishing Office Style Manual, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, <u>https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf</u>.

2 **Reconnaissance Trip**

A site visit to the White River was conducted on February 15, 2018. The site visit allowed ERDC personnel to observe navigation conditions along the White River, gain a more thorough knowledge of the project, and take digital images along the transit. ERDC and CESWL personnel and the current lockmaster met to discuss the project. ERDC and CESWL personnel boarded a USACE boat piloted by the current lockmaster. The transit began near Lock and Dam 1 and ended at Montgomery Point Lock and Dam. At the time of the transit, the tailwater stage was approximately 135.6 ft (NAVD88) at Lock and Dam 1 (also known as Norrell Lock and Dam) and 135.0 ft (NAVD88) at Montgomery Point Lock and Dam. Digital images were taken along the transit that were subsequently used to create the visual scene necessary for the STS.

3 Proposed Modifications

The USACE along with the Arkansas Waterways Commission conducted the Three Rivers Southeast Arkansas Feasibility Study. From this study, a plan was determined (Figure 6). The plan included reinforcing several areas between the White River and Arkansas River and reopening a portion of the Historic Cutoff structure (modifications are shown in purple in Figure 6). The reopening would be 1,000 ft wide and would control flow when the water surface elevation of the White River at Navigation Mile 4 exceeds 145 ft (NAVD88). If the White River stage is below 145 ft, no water will flow across the reopening. Therefore, ship simulations focused on vessel traffic on the White River transiting past the reopening when the stage was above the 145 ft threshold.



Figure 6. Selected plan (USACE-SWL 2018).

4 Numerical Hydraulic Model

Currents were developed for the study area. This section details the method used to create the currents that were utilized by the STS during simulations.

Modeling software

The numerical, hydraulic model study was conducted using the twodimensional (2D), depth-averaged, shallow water version of the Adaptive Hydraulics (AdH) finite-element code (Berger and Lee 2004). AdH provides an efficient computational framework for modeling a variety of fluid flow phenomena including three-dimensional (3D) unsaturated groundwater flow and 3D Navier Stokes flow, in addition to, 2D and 3D (hydrostatic) shallow water flow. An adaptive mesh refinement capability allows the insertion and subsequent removal of additional mesh nodes as necessary to resolve flow-field gradients to specified levels of computational accuracy. AdH can be operated on a variety of serial and parallel computer architectures including large-scale, parallel supercomputers located at the ERDC Department of Defense Supercomputing Resource Center in Vicksburg, MS.

In the 2D shallow water implementation of AdH, an unstructured, linear, triangular mesh defines the topography of the system. The free surface elevation (i.e., water depth) and a depth-averaged velocity vector are computed at each mesh node. The AdH 2D shallow water implementation can model unsteady subcritical, supercritical, and transcritical flow. Individual mesh elements may partially wet and dry during AdH simulations. The 2D implementation of AdH incorporates a vorticity transport algorithm to correct the lateral distribution of flow for helical flow in bends (Bernard 1992)

Model development

CESWL supplied an existing conditions AdH model, supporting topographic and bathymetric data and 2011 flood stages and flows ^{1,2}.

¹ Edmund M. Howe. CESWL. Personal communication. 24 March and 22 November 2017 and 22 May and 10 October 2019.

² Howe, E. M. In preparation. *Adaptive Hydraulics Modeling of the Arkansas, White, and Mississippi Rivers*. US Army Corps of Engineers, Little Rock District, Little Rock, AR.

These topographic and bathymetric datasets were also used to develop the district's HEC-RAS 2D model. The AdH model limits, presented in Figure 7, extended from approximately River Mile (RM) 565.5 on the Mississippi River near Arkansas City, AR, upstream to approximately RM 611.5 and extended approximately 29 miles up the Arkansas River and 25 miles up the White River and includes the adjacent floodplains. Mesh coordinates are mapped to the NAD83, Universal Transverse Mercator Zone 15, and the NAVD88 in feet.¹

¹ River mileage on the Lower Mississippi River is based on the 1962 alignment with distances measured from Head of Passes (RM 0).



Figure 7. Model limits.

Topographic data used included the most recent available floodplain elevations and channel bathymetry, described in Table 2, and three diversion alternatives with crest lengths (normal to flow) of 500, 750, and 1,000 ft.¹ The diversion alternatives include an updated cutoff containment levee system upstream of the diversion structures (Figure 6).

Category	Source	Year
Arkansas River	Little Rock District	2002
Arkansas River: From 2.8 miles downstream of Historic Cutoff to 3.8 miles upstream of the Historic Cutoff or just upstream of the Yancopin RR Bridge.	Little Rock District	2019
Mississippi River	Little Rock, Memphis, and Vicksburg Districts	2015
White River (upper)	Memphis District	2015
White River (lower)	Little Rock District	2015
White River: From the confluence with Mississippi River to NM 6.5 just upstream of the Owens Structure	Little Rock District	2019
Floodplain (primary)	LIDAR – FEMA, NRCS, USCOE	2011, 2012, 2009, 2010, 2005
Floodplain (secondary)	USGS 10-Meter DEM	N/A
Cutoff Containment Structures	Lidar	2010 - 2011
Proposed Diversion Structures	Georeferenced images (TIFF format) generated with ArcGIS: Little Rock District	N/A
Proposed Diversion Structures Approach Bathymetry	Little Rock District	2019

Table 2.	Topographic and	bathymetric	data sources.
	Topographic and	Sacilymouro	aata 00010001

For computation of currents for ship/tow simulations, the horizontal node spacing in the White River was decreased to 75 ft or less, and the mesh was refined locally as needed to resolve dikes in the White River upstream of Montgomery Point Lock and Dam. Other minor mesh modifications were made to improve computational stability and to resolve the existing soil cement levee upstream of the non-overtopping,

¹ Catherine S Funkhouser. CESWL. Personal communication. 5 and 9 September and 10 October 2019.

Historic Closure Structure and relief openings in the non-overtopping, abandoned railroad embankment. (The railroad embankment is displayed in Figure 7 as a discontinuous line inside the model limits. The closure structure is displayed in the figure as a chevron between the White and Arkansas Rivers.)

The revised existing conditions mesh contained 145,992 nodes and 290,324 elements, an increase of approximately 26% over the original mesh from the SWL AdH model. Node spacing ranged from approximately three-quarters of a mile in floodplain areas to 10 ft in the vicinity of hydraulic structures. These variations in mesh resolution represent a trade-off between topographic detail and computational performance. Automated mesh adaption during the simulation can further increase mesh resolution as needed to resolve gradients in the computed flow field.

For each of the proposed alternatives, the revised existing conditions mesh was modified to incorporate a diversion structure and realignment of the cutoff containment levee. The 1,000 ft diversion structure alternative is presented in Figure 8. The proposed diversion structure location is presented in relation to the location of Historic Cutoff channel and closure structure between the Arkansas and White Rivers.



Figure 8. Proposed 1000 ft diversion structure.

Model validation

Material type classifications, hydraulic roughness coefficients, and related model parameters used in the SWL AdH model were adopted for use in the revised model. Material type assignments are presented in Figure 9, and corresponding hydraulic roughness coefficients are presented in Table 3. The adaptive time-step was replaced with a 100 sec time-step due to limitations in the current release of the AdH program.



Figure 9. Material type assignments in the existing conditions mesh.

Material Type	Manning's <i>n</i> -value
Cleared overbank	0.0360
Dense vegetation in the overbank	0.0610
Moderate vegetation in the overbank	0.0540
Water body in the overbank	0.0405
Dense vegetation in the overbank (AOI)*	0.0630
Water body in the overbank (AOI)	0.0405
Relief opening in railroad embankment	0.0450

Material Type	Manning's <i>n</i> -value
Sandbar	0.0270
Vegetated sandbar	0.0324
Channel sandbar	0.0270
Channel vegetated sandbar	0.0285
Upper White River	0.0270
Mississippi River	0.0285
Protected bank	0.0270
Arkansas River	0.0260
Lower White River	0.0280
Containment structure slope	0.0600
Containment structure crown	0.0600
Containment approach	0.0600
Soil Cement Levee	0.0200

*AOI: area of interest

The SWL AdH model was validated to observed data from the 2008 and 2011 flood events.¹ The observed data sets included stage hydrographs at Wilbur D. Mills Dam (Dam 2) and Yancopin on the Arkansas River, Montgomery Point Lock and Dam on the White River, and high water marks. Computed stage hydrographs closely match the observed 2011 stage hydrographs with computed stages at the peak of the event slightly higher than observations at the two Arkansas River sites and slightly lower than observations at Montgomery Point Lock and Dam as presented for Yancopin in Figure 10 and for Montgomery Point in Figure 11. In simulations of the 2008 flood event, the model closely matched the peak stages at all three locations. However, the model overestimated stages on the rising limb of the 2008 hydrograph and underestimated stages during May 2008 portion of the receding limb.

¹ Howe, E. M. In preparation. *Adaptive Hydraulics Modeling of the Arkansas, White, and Mississippi Rivers*. US Army Corps of Engineers, Little Rock District, Little Rock, AR



Figure 10. Comparison of observed water surface elevations at Yancopin to SWL. AdH model computed values.¹

Figure 11. Comparison of observed water surface elevations at Montgomery Point Lock and Dam to SWL. AdH model computed values.²



¹ Adapted from Howe, E. M. In preparation. *Adaptive Hydraulics Modeling of the Arkansas, White, and Mississippi Rivers*. US Army Corps of Engineers, Little Rock District, Little Rock, AR

² Adapted from Howe, E. M. In preparation. Adaptive Hydraulics Modeling of the Arkansas, White, and Mississippi Rivers. US Army Corps of Engineers, Little Rock District, Little Rock, AR

1,000,000 800,000 600,000 400,000 200,000

3/1/2011

3/15/2011

3/29/2011

Additionally, the AdH model results were compared to results from a 2D HEC-RAS model developed by SWL. For both the 2008 and 2011 flood events, stages computed by the AdH model typically were higher than stages computed by the HEC-RAS model.

The 2011 flood event, Figure 12, was modeled in the revised AdH model to estimate currents in the White River for analysis of navigation conditions. The wetting and drying limits parameter in the AdH boundary condition input file specifies a depth threshold below which a dampening factor is applied to stabilize the computations. This factor was increased from 1.2 to 5.0 ft to allow the model to simulate the full range of flows specified in the simulation hydrograph. The increased dampening would be expected to result in a slightly greater head differential between the White and Arkansas Rivers and a corresponding increase in flows over both existing and proposed diversion structures.





As a check on model validation, computed stages generated with the revised AdH model were compared to values from the SWL AdH model with an emphasis on reproduction of White River stages. At Montgomery Point Lock and Dam and Benzal (approximately 7 miles upstream), the mean stage deviation was less than 0.25 ft as presented in Figure 13 and

4/26/2011

5/10/2011

5/24/2011

6/7/2011

6/21/2011

4/12/2011

Figure 14, respectively. At the peak of the 2011 flood, stages computed by the revised model were 0.4 ft lower at both locations.

Figure 13. Comparison of stages computed by the SWL AdH (initial) model and the revised AdH model at Montgomery Point Lock and Dam from 10 March to 20 June 2011.





Figure 14. Comparisons of stages computed by SWL AdH (initial) model and the revised AdH model at Benzal from 10 March to 20 June 2011.

At Yancopin on the Arkansas River, stages computed by the revised AdH model ranged from 0.6 ft lower to 1.6 ft higher than stages computed by the SWL model with a mean deviation of less than 0.1 ft, as presented in Figure 15. At the flood peak, stages computed by the revised model were 0.5 ft lower. In general, higher stages computed by the revised model are associated with periods when flow from the White River is being diverted into a relatively low Arkansas River. This behavior is most likely a response to mesh revisions intended to improve depiction of the existing cutoff containment structures and railroad relief openings. These revisions would be expected to slightly alter the timing and volume of computed diversion flows under existing conditions.



Figure 15. Comparisons of stages computed by SWL AdH (initial) model and the revised AdH model at Yancopin from 10 March to 20 June 2011.

Model simulations

Computed discharge hydrographs for each proposed alternative are presented in Figure 16. Peak discharges ranged from 120,000 cfs for the 1,000 ft alternative to 94,000 cfs for the 500 ft alternative. Corresponding peak unit discharges were greater for the smaller alternatives and ranged from 120 cfs/ft for the 1,000 ft alternative to 190 cfs/ft for the 500 ft alternative. The computed unit discharge was not uniform in the approach or over the crest of the weir. At times, the computed unit discharge in the Historic Cutoff channel downstream of the diversion was comparable to or greater than values in the White River upstream of the diversion as presented in Figure 17 for the 1,000 ft alternative and in Figure 18 for the 500 ft alternative. There are periods during both the existing and alternative simulations when flow in the lower reaches of the White River is upstream to the diversion(s).



Figure 16. Computed discharge hydrographs for each proposed diversion alternative.



Figure 17. Unit discharge (cfs/ft) contour map for a flow of 115,500 cfs through the 1,000 ft diversion structure on 2 June 2011.



Figure 18. Unit discharge (cfs/ft) contour map for a flow of 77,800 cfs through the 500 ft diversion structure on 2 June 2011.

Computed stage hydrographs from locations approximately 1,000 ft downstream (tailwater) and upstream (head-water) of the centerline of the diversion structure are presented in Figure 19 for the 1,000 and 500 ft diversion alternatives. The peak head-water stages were 167.5 and 167.6 ft, respectively. The peak tailwater stages were 167.0 and 166.9 ft, respectively. The corresponding head differentials are presented in Figure 20. In general, the maximum head differentials occurred near the beginning and termination of flow through the diversion structure. The larger structure produced smaller head differentials and significantly reduced the head differential during the March 2011 event and during the recession of the larger May–June 2011 event.

Figure 19. Computed stage hydrographs approximately 1,000 ft downstream and upstream of the centerline of the diversion structure.





Figure 20. Head differential across diversion structure determined from computed stages presented in Figure 13.

The computed stages along the Lower White River for all three alternatives averaged 0.3 ft higher than computed stages for existing conditions with peak stages approximately 0.7 ft higher, as presented in Figure 21 for Montgomery Point L and Dam and in Figure 22 for Benzal. Computed stages at Yancopin on the Arkansas River also were typically higher for the alternatives as presented in Figure 23. Peak computed stages for all three alternatives were approximately 0.8 ft higher than computed stages for existing conditions at the higher May 2011 peak. However, the alternatives exhibited slightly different behavior during the March 2011 flood peak with the 500 ft diversion structure tracking more closely to existing conditions stages than the larger diversion structures. The average increase in stage over the combined flood events for the 1,000 diversion structure was 0.3 ft as compared to an average increase of only 0.1 ft for the 500 ft structure.



Figure 21. Computed stage at Montgomery Point Lock and Dam.






Figure 23. Computed stage at at Yancopin. The 750 ft alternative would plot between the 500 ft and 1000 ft alternatives at the peak of the first flood event in March 2011.

5 Database Development

During a simulation, there are a variety of environmental factors that contribute to the forces that act upon the vessel during a transit. Some of these factors include wind, waves, currents, bathymetry, and ship-to-ship interaction. Virtual databases are developed as input into the ship simulator for the area of interest for existing conditions first. The existing conditions databases are validated with experienced mariners and then modified to replicate proposed future conditions. Testing of the proposed future conditions are referred to as production runs. A more thorough description of evaluating channel design through the use of the STS can be found in Webb (1994).

Design vessel

One design vessel was selected for use in STS testing: *Bruce Oakley* (Tugba60), an integrated 3×5 barge with 4,000 hp pusher tow. The integrated unit is 1,089 ft long, 105 ft wide, and drafts 9.5 ft.

A loaded unit was chosen as they are more susceptible to strong currents. Additional vessel information, in the form of a pilot card, can be found in Appendix C.

Visual database

A visual database was developed for the White River from the Benzal Bridge to Montgomery Point Lock and Dam. Figure 24 labels the bounds of the ship simulator visual database along with RM 4 and 6. Digital pictures taken of the area during the reconnaissance trip were used as a guideline to create the visual scene. Radar imagery was also created for the area. The radar is used by pilots to help navigate.



Figure 24. Extents of the ship simulation database.

Environmental database

An environmental database was created for the White River, which included current and bathymetric data. Bathymetric data were collected along the White River for incorporation into the ship simulator and the numerical model.

Wind

Wind has a minimal effect on loaded tow barge packages, so it was not included in any simulations.

Current development

Currents for the project were developed using the 2D, depth-average, shallow water version of the AdH code. Further description of the current development can be found in the Numerical Hydraulic Model (Chapter 4) section of this report.

Historic flow information was used to develop the AdH model for existing and proposed conditions. An extreme historic flooding event was selected for the proposed conditions, while more typical flow conditions were chosen for existing conditions. From the proposed condition AdH model, six hydrodynamic events were selected for testing in the STS based on navigational concerns. These events are described in the Results section (Chapter 7) of this report. The AdH model extents are shown in Figure 7. The elevation data and mesh of a portion of AdH model around the area of interest are shown in Figure 25 and Figure 26, respectively. The different material types are outlined in purple.





Figure 26. AdH mesh.



6 Validation

The first 2 days of the initial testing session were spent validating existing conditions (no reopening of the Historic Cutoff). First, pilots tested with no environmental conditions (slack water) in the White River. These simulations allowed pilots to familiarize themselves with the simulator and to assess the design vessel. After testing the design vessel, the pilots identified a slight modification that was required so that the virtual model could be as analogous to the prototype model as possible. This modification was implemented and then re-tested during the first testing session. Once the vessel was modified, pilots agreed it was a realistic representation of a 3×5 barge pushed by a 4,000 hp tow.

After initial simulations were completed in slack water, currents were added. Table 4 lists the six validation runs that were completed. Two validation currents were used for existing conditions testing. The first current set represented conditions that occurred in March 2010 on the White River with a stage of approximately 130.5 ft (NAVD88) and was considered a normal or everyday condition. The head differential between Lock and Dam 1 and Montgomery Point Lock and Dam computed in the numerical model was approximately 2.8 ft, which resulted in a strong current. The second current set represented a condition that would likely exhibit outdraft near the Owen's Lake Structure that used data from March 2011 on the White River with a stage of approximately 154.7 ft (NAVD88). *Outdraft* is when current pushes or pulls the vessel. This second current set had much weaker currents since the stage was high and there was essentially no head differential between the locks. During validation, pilots also noted any visual scene changes that needed to be adjusted.

Table 5 lists pilot scores for run difficulty and run safety for the validation simulations. Conditions for each simulation can be determined by comparing back to the run number listed in Table 4. Pilot scores are ranked from 1 to 5 with low scores indicating a safer and less difficult transit. Passing simulations are designated by a purple filled row in Table 5. Passing scenarios are accomplished by having two pilots occupy the same simulation database. One vessel transits upstream while the other vessel transits downstream. The pilots meet each other during the simulation run and *pass* each other. During this maneuver, they can communicate to each other by radio, see each other in the visuals, and feel the effect of each other's vessel as they pass. Passing simulations in week

#1 were completed by Pilot #1 and Pilot #2 while passing simulations in week #2 were completed by Pilot #3 and Pilot #4. After a passing simulation was completed, only one pilot scored the simulation for run difficulty and safety. Typically, the pilot who felt he had the more difficult transit scored the run. Average pilot scores for each run that were simulated by more than one pilot set are shown in Table 5.

Pilots agreed that the overall existing condition database was a good approximation of barge operations on the White River. Once the existing condition model was validated, production runs, or simulations of the proposed 1,000 ft reopening, could begin.

Run #	Channel	Direction	LD01 Stage ¹ (ft)	MPLD Stage ² (ft)	Hydro Name
1	Existing	Upbound	131.6	128.8	P0_12Mar10_everyday
2	Existing	Downbound	131.6	128.8	P0_12Mar10_everyday
3	Existing	Both - passing	131.6	128.8	P0_12Mar10_everyday
4	Existing	Upbound	154.8	154.8	P0_032411_outdraft
5	Existing	Downbound	154.8	154.8	P0_032411_outdraft
6	Existing	Both - passing	154.8	154.8	P0_032411_outdraft

Table 4. Validation runs completed.

_	Run Difficulty					Run Safety				
Run #	Pilot #1	Pilot #2	Pilot #3	Pilot #4	Average	Pilot #1	Pilot #2	Pilot #3	Pilot #4	Average
1	1	1	2	2	1.5	1	1	2	1	1.3
2	1	2	4	3	2.5	1	2	3	3	2.3
3				4	-				4	-
4	1	1	1	1	1.0	1	1	1	1	1.0
5	1	1	1	1	1.0	1	1	1	1	1.0
6	1		1		1.0	1		1		1.0

Table 5. Pilot scores for validation runs.³

¹ Approximate White River stage from numerical model near Lock and Dam 1 (Vertical Datum: NAVD88).

² Approximate White River stage from numerical model near Montgomery Point Lock and Dam (Vertical Datum: NAVD88).

³ Pilot scores are ranked from 1 to 5 with low scores indicating a safer and less difficult transit.

7 Results

This section presents results for the proposed condition simulations. Results are presented in the form of track plots (Appendix A), pilot comments filled out after each run (Appendix A), and final pilot questionnaires (Appendix B). Several pilot comments were summarized or paraphrased in each section, but the entirety of pilot comments can be found in Appendix A, following each track plot. For all track plots presented, the transiting vessel was the selected design vessel, a loaded 3×5 barge being pushed by a 4,000 hp towboat. Track plots in Appendix A show the vessel path for Pilot #1 in yellow, Pilot #2 in red, Pilot #3 in purple, and Pilot #4 in turquoise.

Production runs – initial testing

Six different current sets were tested during production runs. For each current set, a simulation was completed with the transiting vessel traveling upbound, downbound, and in both directions for a passing scenario. Results will be presented using this same convention for each current set tested. Passing simulations were split into individual plates if more than one simulation was completed to ensure passing can be better visualized. The plates that were split are designated with an "a" or "b" following the plate number.

Each plate shows the track plot for one or more simulations on top of an aerial view of the project area. The aerial imagery came from the National Agriculture Imagery Program (NAIP), which is managed by the US Department of Agriculture (USDA) Farm Service Agency (FSA). The imagery consists of two 3.75×3.75 min images that were combined to make a composite image that all tracks are overlaid on top of. At the time of the collection of the images, the river stage at Norrell Lock and Dam (Lock 1) was approximately 152 ft (NAVD88). In many simulations, vessels appear to be in the treeline based on the aerial image behind the tracks. Since many of the simulations occurred at a high water stage, the effective width of the White River may be greater than what is shown on the track plots. The basic depths from the hydrodynamic model are shown for each current set tested. The figures are contoured to show depths greater than 10 ft, which would be required for the design vessel to transit. Note that the elevations used in the model are for the ground and do not include trees or other vegetation. Therefore, while the depths may read greater than 10 ft, there could be

obstructions in the area that would not allow for the design vessel to transit through. These depth images should be used only to approximate the water line, not to infer an effective width of the channel. The 1,000 ft reopening is shown in orange in the plates in Appendix A.

Table 6 lists all of the initial production scenarios completed for the channel with the 1,000 ft reopening. The rightmost column contains the plate number in Appendix A that contains the corresponding track plot and run sheet for each simulation. The table lists the three simulations (upbound, downbound, passing) completed for a current set and then progresses to the next current set (signified by a change of the row fill color). All production simulations feature the 1,000 ft opening, the design vessel, and no wind. The current set name is listed in Table 6 for each simulation. In general, the naming convention is P1L (proposed large reopening), date simulated, and then a description word for the current set. Further description of each current set will be provided prior to discussion of results in the following sections.

Table 7 lists pilot scores for run difficulty and run safety for each proposed initial testing simulation along with averages (shown in burgundy) for each simulation if completed more than once. Pilot scores are ranked from 1 to 5 with low scores indicating a safer and less difficult transit. Conditions simulated for each run can be determined by comparing back to the run number listed in Table 6. Passing simulations for the proposed plan are designated by a purple-filled row in Table 7. Each passing simulation was completed by two pilots traveling in opposite transit directions in the same simulation. After a passing simulation was completed, only one of two transiting pilots scored the simulation for run difficulty and safety. Typically, the pilot who felt he had the more difficult transit scored the run. Average pilot scores for each run that were simulated by more than one pilot set are shown in Table 5. Note that some simulations have "NS" (not specified) listed instead of a score. This annotation represents that the simulation was completed, but the score was not specified by the completing pilot. This does not mean a failure or other issue occurred, only that the pilot forgot to include a score on their run sheet following the completed simulation. Also note that no NS is listed for a simulation that was scored higher than a 2 in run difficulty or safety by the other pilots who completed the same scenario and recorded a score.

Run #	Channel	Transit Direction	LD01 Stage ¹ (ft)	MPLD Stage ² (ft)	Current Set #: Hydro Name	Plate in Appendix A	
7	1,000 ft	Upbound	160 1	150 /	1. P11 052011 concentrated	1	
7	1,000 ft	Downbound	160.1	159.4	1: P1L_053011_concentrated	2	
9	1,000 ft Opening	Both - passing	160.1	159.4	1: P1L_053011_concentrated	3a, 3b	
10	1,000 ft Opening	Upbound	157.2	156.3	2: P1L_060411_strong	4	
11	1,000 ft Opening	Downbound	157.2	156.3	2: P1L_060411_strong	5	
12	1,000 ft Opening	Both - passing	157.2	156.3	2: P1L_060411_strong	6a, 6b	
13	1,000 ft Opening	Upbound	154.9	155.1	3: P1L_043011_reversal	7	
14	1,000 ft Opening	Downbound	154.9	155.1	3: P1L_043011_reversal	8	
15	1,000 ft Opening	Both - passing	154.9	155.1	3: P1L_043011_reversal	9a, 9b	
16	1,000 ft Opening	Upbound	154.9	153.7	4: P1L_060911_continuous	10	
17	1,000 ft Opening	Downbound	154.9	153.7	4: P1L_060911_continuous	11	
18	1,000 ft Opening	Both - passing	154.9	153.7	4: P1L_060911_continuous	12a, 12b	
19	1,000 ft Opening	Upbound	155.3	155.2	5: P1L_032511_similar	13	
20	1,000 ft Opening	Downbound	155.3	155.2	5: P1L_032511_similar	14	
21	1,000 ft Opening	Both - passing	155.3	155.2	5: P1L_032511_similar	15a, 15b	
22	1,000 ft Opening	Upbound	167.4	166.9	6: P1L_051211_peak	16	
23	1,000 ft Opening	Downbound	167.4	166.9	6: P1L_051211_peak	17	
24	1,000 ft Opening	Both - passing	167.4	166.9	6: P1L_051211_peak	18	
	1,000 ft Opening	All upbound tracks except passing and extreme scenarios.					
	1,000 ft Opening	All downbound tracks except passing and extreme scenarios.					

Table 6. Initial test matrix scenarios for the 1,000 ft opening.

¹ Approximate White River stage from numerical model near Lock and Dam 1 (Vertical Datum: NAVD88).

² Approximate White River stage from numerical model near Montgomery Point Lock and Dam (Vertical Datum: NAVD88).

	Run Difficulty						Run Safety			
Run #	Pilot #1	Pilot #2	Pilot #3	Pilot #4	Average	Pilot #1	Pilot #2	Pilot #3	Pilot #4	Average
7	1	1	1	1	1.0	1	1	1	1	1.0
8	1	1	1	1	1.0	1	1	1	2	1.3
9		1	2		1.5		1	2		1.5
10	1	1	1	1	1.0	1	1	1	1	1.0
11	1	NS ²	1	1	1.0	1	NS	1	2	1.3
12	1			1	1.0	1			2	1.5
13	1	2	2	1	1.5	1	1	2	1	1.3
14	2	1	2	1	1.5	2	1	2	1	1.5
15	1			1	1.0	1			2	1.5
16	2	1	2	1	1.5	2	1	2	1	1.5
17	1	1	2	1	1.3	1	1	2	2	1.5
18		NS		1	-		NS		2	-
19	1	NS	1	1	1.0	1	NS	1	1	1.0
20	1	1	1	1	1.0	1	1	1	1	1.0
21	1		1		1.0	1		1		1.0
22	1	NS	2	1	1.3	1	NS	2	1	1.3
23	1	NS	2	1	1.3	1	NS	2	1	1.3
24		1	2		1.5		1	2		1.5

Table 7. Pilot scores for proposed scenarios.¹

When vessels meet during normal operations, the upbound vessel will typically attempt to get out of the main channel by landing their tow partially on the bank. During the first week of testing, pilots identified three main areas where passing would likely occur along the White River (shown in Figure 27). Of the three locations identified, the area near the red star was selected to test the majority of the passing scenarios. This location was the closest to the reopening and the area most likely to be influenced by the proposed modifications. One simulation was completed that tested the lower meeting location identified (shown as the blue star in Figure 27).

¹ Pilot scores are ranked from 1 to 5 with low scores indicating a safer and less difficult transit.

² Simulation was completed, but a pilot score was not specified by the completing pilot.



Figure 27. Main passing locations identified by pilots. (USDA-FSA-APFO 20160107a and USDA-FSA-APFO 20160107b)

The track in its entirety is often not shown in the track plots in Appendix A. This study focused on the impact to navigation due to the reopening. Many transits were completed that started prior to the Benzal Bridge or ended past it, but no issues were found navigating through the bridge. Figure 28 shows two upbound transits that ended past Benzal Bridge, and Figure 29 shows 15 downbound transits that began prior to the Benzal Bridge. Pilots stated the transit through the bridge was unaffected by the inclusion of the reopening and the results supported the minimal difficulties conclusion. Therefore, all other tracks presented in this report are focused on the area near the reopening. This was done so that the impact of the diversion channel could be more thoroughly analyzed.



Figure 28. All upbound scenarios ending past Benzal Bridge. (USDA-FSA-APFO 20160107a)

Figure 29. All downbound scenarios starting prior to Benzal Bridge. (USDA FSA-APFO 20160107a)



Current set #1: Plates 1 – 3

Figure 30 shows the velocity magnitudes and vectors for the first current set. Different material types are outlined in purple. Based on the numerical model, the White River stage was approximately 159.4 ft near the reopening. In this current set, currents are strong and fairly concentrated flowing from Lock 1 to the reopening. Between the reopening and Montgomery Point Lock and Dam, the currents are very small. Depths from the AdH model are shown in Figure 31.

Plate 1 – Plate 3 show all the transits that were completed with the first current set. Plate 1 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended at least 0.75 mile past the reopening. Pilot #3 (shown in purple) continued the transit to just past the bridge. Tracks show small variations between pilots and no major impact to the vessel path when transiting past the reopening. Pilot comments for this scenario did not express any significant concerns. Pilot scores showed minimal issues with a maximum of 1 for run difficulty and safety. Plate 2 shows four downbound transits that began near the Benzal Bridge and ended at least 0.5 mile beyond the reopening. Pilot #4 (shown in turquoise) continued the transit until close to Montgomery Point Lock and Dam. Pilots show a slightly more varied transit path for this simulation, but this is likely due to pilot preference. Minimal influence to the transit path was observed near the reopening. Pilot comments included "no problems but could feel some current" and "current was fast but easy." Pilot scores averaged 1.0 for run difficulty and 1.3 for run safety. Plate 3 was separated into Plate 3a and Plate 3b to show a passing scenario for pilot 1/pilot 2 and pilot 3/pilot 4, respectively. Both of the plates show tracks of a successful passing. Pilot comments included "went well" and "normal meeting at this stage of water." The averaged pilot scores were 1.5 for both run difficulty and run safety.



Figure 30. Velocity magnitudes for current set #1.

Figure 31. Depths for current set #1.



Current set #2: Plates 4 - 6

Figure 32 and Figure 33 show the velocity magnitudes with vectors and the depths for the second current set, respectively. Based on the numerical model, the White River stage was approximately 156.4 ft near the reopening. In this current set, currents are strong but span most of the channel and flow from Lock 1 towards the reopening. Downstream of the reopening, the currents are significant but weaker than above the reopening. Flow goes from the reopening to Montgomery Point Lock and Dam.

Plate 4 – Plate 6 show all the transits that were completed with the second current set. Plate 4 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended at least 0.75 mile past the reopening. Tracks show small variations between pilots but no major impacts when transiting past the reopening. Some pilot comments expressed that small crosscurrents were noticeable at RM 4, but they were manageable. Pilot scores showed minimal concerns with a maximum score of one for run difficulty and run safety. Plate 5 shows four downbound transits that began near the Benzal Bridge and ended approximately 1 mile past the reopening. Tracks showed slightly different approaches around turns based on pilot preference, but no substantial pull is shown near the reopening. One pilot commented that he might have experienced less set or pull at RM 6 than he typically experiences. Pilot scores averaged 1.0 for run difficulty and 1.3 for run safety. Plate 6 was separated into Plate 6a and Plate 6b to show a passing scenario for pilot 1/pilot 2 and pilot 3/pilot4, respectively. Both plates show tracks of a successful passing. One pilot commented that the pass was fast due to the current but was not difficult. The averaged pilot scores were 1.0 and 1.5 for run difficulty and run safety, respectively.



Figure 32. Velocity magnitudes for current set #2.

Figure 33. Depths for current set #2.



Current set #3: Plates 7 - 9

The velocity magnitudes and vectors for the third current set are shown in Figure 34. In the third current set, currents reverse and flow from Montgomery Point Lock and Dam towards the reopening. Between the Benzal Bridge and the reopening, the currents are insignificant. The White River stage from the numerical model was approximately 154.9 ft near the reopening. Depths from the AdH model are shown in Figure 35.

Plate 7 – Plate 9 show all the transits that were completed with the third current set. Plate 7 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended approximately 1 mile past the reopening. Tracks do not show critical impacts to the vessel path when transiting past the reopening. The averaged pilot scores were 1.5 for run difficulty and 1.3 for run safety. Plate 8 shows four downbound transits that began near the Benzal Bridge and ended approximately 0.5 mile past the reopening. Pilot #1 (shown in yellow) and Pilot #3 (shown in purple) took a slightly different transit path that placed their vessel more in the center of the channel. Although both pilots were shifted towards the reopening, neither track showed a significant influence to its path when transiting past the reopening. Pilot comments included "easy and safe" and "absolutely no draft or current." The averaged pilot scores were 1.5 for both run difficulty and run safety. Plate 9 was separated into Plate 9a and Plate 9b to show the passing scenario for pilot 1/pilot 2 and pilot 3/pilot 4, respectively. Both plates show a successful passing. Due to the current, Pilot #3 and Pilot #4 did not think the typical passing location (red star shown in Figure 27) would be utilized for meeting in this current set. Therefore, they met above the reopening on the fly or with both vessels traveling at regular speed. Pilot scores averaged 1.0 for run difficulty and 1.5 for run safety. Pilot comments did not express any major concern for this scenario.



Figure 34. Velocity magnitudes for current set #3.

Figure 35. Depths for current set #3.



Current set #4: Plates 10 - 12

Figure 36 and Figure 37 show the velocity magnitudes with vectors and the depths for the fourth current set, respectively. The White River stage from the numerical model is the lowest for this current set of all the currents tested at approximately 153.9 ft near the reopening. Currents flow continuously from the Benzal Bridge to the Montgomery Point Lock and Dam with some flow diverted through the reopening.

Plate 10 – Plate 12 show all the transits that were completed with the fourth current set. Plate 10 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended at least 0.75 mile past the reopening. Pilot #1 (shown in yellow) and Pilot #2 (shown in red) took a transit path close to the center of the channel near the reopening. None of the tracks showed a significant impact when transiting by the reopening. Some pilot comments included "no problem" and "easy and safe." The averaged pilot scores were 1.5 for both run difficulty and run safety. Plate 11 shows four downbound transits that began near the Benzal Bridge and ended approximately 0.75 mile past the reopening. Tracks showed a varied approach for the pilots. This current set contained stronger currents, which likely contributed to the varying paths taken by the pilots. The vessel was also traveling with the currents, which makes the vessel harder to control than when going against the current. Pilot #2 (shown in red) and Pilot #3 (shown in purple) transited in close proximity to the reopening but did not experience extreme pull. All pilots were able to safely transit past the reopening. The averaged pilot scores were 1.3 for run difficulty and 1.5 for run safety. Pilot comments did not include any major concerns for this scenario. Plate 12 was separated into Plate 12a and Plate 12b to show a passing scenario for pilot 1/pilot 2 and pilot 3/pilot 4, respectively. Both of the plates show a successful passing. One pilot commented that currents were faster, which made the transit more dangerous, but the outflow near RM 4 was not a factor. Pilot scores were not averaged for this passing scenario as only one score was specified.



Figure 36. Velocity magnitudes for current set #4.

Figure 37. Depths for current set #4.



Current set #5: Plates 13 - 15

The velocity magnitudes and vectors for the fifth current set are shown in Figure 38. The White River stage was approximately 155.1 ft near the reopening. Currents are approximately the same magnitude above and below the reopening. Current flows from the Benzal Bridge to the reopening and from Montgomery Point Lock and Dam to the reopening. Depths from the AdH model are shown in Figure 39.

Plate 13 – Plate 15 show all the transits that were completed with the fifth current set. Pilot scores conveyed minimal issues with a maximum of one for run difficulty and safety for all simulations completed on this current set (excluding extreme scenarios). Plate 13 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended at least 0.75 mile past the reopening. Pilot #4 (shown in turquoise) continued the transit slightly past the bridge. Pilot #1 (shown in yellow) intentionally slowed his vessel and traveled close by the reopening to feel more of the effect from the opening. Pilot #1 experienced more of the current, but it was not detrimental to his approach. All vessels were able to successful transit by the reopening. Some pilot comments included "no problem at all" and "the cross current at turn 4 was barely noticeable." Plate 14 shows four downbound transits that began near the Benzal Bridge and ended approximately 0.75 mile past the reopening. Pilot #1 (shown in yellow) intentionally stopped his tow near the reopening to test its maximum effect. Overall, pilots did not experience a large impact on their transits due to the reopening for this current set. Pilot comments did not indicate any critical concerns for this scenario. Plate 15 was separated into Plate 15a and Plate 15b to show two passing scenarios that were both completed by pilot 1/pilot 2. While a passing scenario was performed by the second pilot set (pilot 3/pilot4), this data set was corrupted, and track plots could not be generated. However, pilot comments and pilot scores expressed this scenario was not difficult for either pilot set. Pilot 1/pilot 2 completed this scenario again (shown in Plate 15b) at the lower meeting place (shown as the blue star in Figure 27).



Figure 38. Velocity magnitudes for current set #5.

Figure 39. Depths for current set #5.



Current set #6: Plates 16 - 18

The White River stage from the numerical model is the highest for this current set of all the currents tested at approximately 166.9 ft near the reopening. Figure 41 shows the depths from the AdH solution for this current set. This high stage resulted in a significant amount of overland flow with minor velocity magnitudes. Figure 40 shows the velocity magnitudes and vectors for the sixth current set. Currents flow from Lock 1 to the reopening. Downstream of the reopening, the currents are minimal except in close proximity to Montgomery Point Lock and Dam.

Plate 16 – Plate 18 show all the transits that were completed with the sixth current set. Plate 16 shows four upbound transits that began approximately a mile upstream of Montgomery Lock and Dam and ended at least 0.75 mile past the reopening. Tracks show some variations between pilots, but no major concerns when transiting past the reopening. Pilot comments for this scenario included "no problems" and "minimal draft towards Historic Closure [at] mile 4." The averaged pilot scores were 1.3 for both run difficulty and run safety. Plate 17 shows four downbound transits that began near the Benzal Bridge and ended at least 0.5 mile past the reopening. Pilots show a more varied transit path for this simulation near RM 6. Minimal impact to the tracks near the reopening can be observed. Pilot comments did not express any significant concerns for this scenario. The averaged pilot scores were 1.3 for both run difficulty and run safety. Plate 18 shows a passing scenario for pilot 1/pilot 2. While a passing scenario was performed by the second pilot set (pilot 3/pilot 4), this data set was corrupted, and track plots could not be generated. However, pilot comments and pilot scores expressed this scenario was not difficult for either pilot set. Averaged pilot scores was 1.5 for both run difficulty and run safety. Pilot comments included "easy run, no drafts or pulls" and "not a problem meeting."



Figure 40. Velocity magnitudes for current set #6.

Figure 41. Depths for current set #6.



Plate 19 and Plate 20

Plate 19 and Plate 20 shows a composite of all initial testing upbound and downbound simulations, respectively. Neither composite includes transits for any passing or extreme scenarios.

Production runs – extreme scenarios

Following the results from the first testing session, some extreme scenarios were added after the initial testing matrix was completed in the second testing session. Table 8 lists the extreme scenarios that were completed at the end of testing. Two types of extreme scenarios were simulated: failure of one engine near the reopening and a worst-case meeting location near the reopening. Since these scenarios were completed at the end of testing, time did not allow for all currents and scenarios to be tested. Table 9 lists the pilot scores for run difficulty and run safety for the extreme scenarios tested. Averages were not calculated for these simulations as testing was limited.

Run #1	Description	Direction	White River Stage (ft) ²	Hydro	Plate in Appendix A
8E	Failure of one engine	Downbound	159.4	P1L_053011_concentrated	21
17E	Failure of one engine	Downbound	153.9	P1L_060911_continuous	22
9P	Worst-case meeting	Both	159.4	P1L_053011_concen	23
12P	Worst-case meeting	Both	156.4	P1L_060411_strong	24
15P	Worst-case meeting	Both	154.9	P1L_043011_reversal	25a, 25b
18P	Worst-case meeting	Both	153.9	P1L_060911_continuous	26
21P	Worst-case meeting	Both	155.1	P1L_032511_similar	27

Table 8. Extreme scenarios completed in second testing session.

Table 9. Pilot scores for extreme scenarios.

		Run Di	fficulty	Run	Safety
Run #	Description	Pilot #3	Pilot #4	Pilot #3	Pilot #4
8E	Failure of one engine	3	1	4	2
17E	Failure of one engine	3	3	4	3
17E	Failure of one engine	3	3	4	4
9P	Worst-case meeting		4		5
12P	Worst-case meeting	2		3	
15P	Worst-case meeting	4		5	
15P	Worst-case meeting		3		4
18P	Worst-case meeting	3		3	
21P	Worst-case meeting		3		4

¹ E: Engine failure simulation; P: worst passing location simulation.

² White River stage near reopening.

Engine failure simulations: Plate 21 and Plate 22

When a vessel experiences an engine failure, the pilot will attempt to safely land the vessel on the riverbank as quickly as possible. Once on the riverbank, repairs to the vessel occur until the engine is fixed. In these scenarios, a port or starboard engine experienced failure very close to the reopening to test if an engine failure in this location would be detrimental. The engine that fails (port or starboard) influences how the pilot would attempt to land the vessel. For this reason, the engine failure side was varied for these simulations. Downbound transits were considered worse for engine failure as the vessel would be carried by the current and it would be harder to stop than in an upbound transit. Therefore, all engine failure simulations were completed with the vessel heading downbound.

Plate 21 and Plate 22 in Appendix A, show engine failure scenarios completed during testing. In Plate 21, the track plots are shown for a simulation that utilized the first current set. The transit began approximately 1.25 miles above the reopening. Pilot #3 (shown in purple) experienced a starboard engine failure and Pilot #4 (shown in turquoise) experienced a port engine failure near the reopening. Both pilots were able to land their tow on the bank line following engine failure. One pilot comment included "able to navigate with loss of engine. Cross current was not a factor." Plate 22 shows a track of a simulation that used the fourth current set. Pilot #3 and Pilot #4 each completed this simulation twice. During the initial simulation, the engine failure occurred too far away from the reopening, and one of the pilots was able to land their vessel prior to reaching the reopening. Since this transit did not show interaction with the reopening, both initial tracks are not shown. The transit began approximately 1.25 miles prior to the reopening. Pilot #3 (shown in purple) experienced a port engine failure and Pilot #4 (shown in turquoise) experienced a starboard engine failure near the reopening. Both pilots were able to land their tow on the bank line following engine failure.

Worst meeting location simulations: Plates 23 – 27

During the second week of testing, a few worst-case meeting location simulations were tested. For these simulations, the vessels started approximately 1 mile upstream or downstream from the reopening. Figure 42 shows the approximate starting positions for the extreme passing scenarios. For these simulations, the pilots steered as if they believed there were no other traffic on the White River. Communication was not shared between the pilots until the vessels came into view of one another. Once the downbound pilot saw the other vessel, he would call over and begin giving instructions to the upbound pilot on how to pass (port side to or starboard side to). At this point, both pilots would attempt to get out of the way of the other vessel keeping speed. The eventual pass was expected to happen near the reopening, but due to variations of pilot speeds, the meeting location varied for each run. This type of meeting is rare and would only occur if communication failed between pilots.





Plate 23 – Plate 27 show all of the worst meeting location scenarios simulated. The first current set was used to create the track plots shown in Plate 23. Pilots were able to pass in this on-the-fly location (starboard side to) but did not consider it safe. However, the major factor that made this scenario dangerous was not the pull from the reopening. A pilot comment for this simulation was "Very dangerous place to pass. The crosscurrent was a factor but a very high chance of grounding is present regardless of its

presence." The second current set was used to create the track plots shown in Plate 24. Pilots had less trouble with this simulation as they met at a slightly different location and passed port-side-to. A pilot comment for this simulation was "meeting went well without much problem." The third current set was used to create the track plots shown in Plate 25. Plate 25 was separated into Plate 25a and Plate 25b to show two different passing scenarios both completed by pilot 3/pilot 4. In the initial simulation (Plate 25a), the vessels attempted to pass port-side-to, but this attempt proved difficult and resulted in a head-on collision of the vessels. During the second attempt (Plate 25b), vessels attempted to pass starboard-sideto and were successful. The fourth current set was used to create the track plots shown in Plate 26. Pilots passed port-side-to for this current set and were able to successfully pass. A pilot comment for this simulation was "didn't have too much trouble." The sixth and final current set was used to create the track plots shown in Plate 27. Pilots were able to pass starboardside-to in this current set but found the maneuver difficult. In general, pilots were primarily able to pass in these worst-meeting-location scenarios but considered the passing maneuver dangerous and not ideal.

8 **Production Runs Summary**

The 1,000 ft reopening had minimal influence on all initial testing simulations. Pilots experienced little difficulty navigating by the reopening on upbound, downbound, or passing scenarios. The minor influences can be recognized in the track plots and in pilot comments on the run sheets in Appendix A. Furthermore, pilot scores reinforce this minimal impact as both run difficulty and run safety scores were equal to or less than 2 for any initial testing scenarios.

Pilots were able to manage transiting past the reopening for two different current sets with one engine experiencing failure. Pilots experienced difficulties navigating during the extreme worst meeting location scenarios. While several of these scenarios resulted in failures, note that these scenarios represented an extreme worst-case scenario that is unlikely. In general, the results of these scenarios may have been worsened due to the effects of the reopening but were likely not caused by the reopening. Pilots expressed that these scenarios would likely have resulted in failure with or without the reopening.

9 Conclusions and Recommendations

Overall conclusions and recommendations are based on track plots (Appendix A), run sheets (Appendix A), final pilot surveys (Appendix B), discussions after each simulation, and final wrap-up meetings completed at the end of each testing week.

While the reopening may divert a significant amount of current through it, the river stage must be high (above 145 ft) for this to occur. In general, this high river stage often results in less extreme currents. Pilots showed little difficulty navigating by the slight draw to the reopening. Typically, pilots attempt to navigate on the insides of the turns along the White River (see Figure 43 and Figure 44 for a typical upbound and downbound transit, respectively). Following this preferred path, vessels will not typically transit close to the proposed reopening, which lessens its effect. The numerical model currents located on the inside of this turn across from the reopening are typically not extreme. In Figure 45, the velocity magnitudes in knots are shown for all the current sets tested with the 1,000 ft opening (velocity magnitudes below 0.25 knot are blanked). Additionally, a black polygon has been placed in each current set image to represent where the vessel would typically travel when transiting by this bend. In general, the currents are reduced in this preferred transit path. Furthermore, vessels travel at a moderate speed when transiting by the reopening (approximately 5–6 knots over the ground in the ship simulations). Since the transiting vessel is often on the inside of the bend across from the reopening and going a moderate speed, the vessel speed dictates the vessel trajectory much more than the currents from the reopening. Therefore, while the reopening may influence the vessel path, it does not dominate it.



Figure 43. Example of a typical upbound transit. (USDA-FSA-APFO 20160107a and USDA-FSA-APFO 20160107b)

Figure 44. Example of a typical downbound transit. (USDA-FSA-APFO 20160107a and USDA-FSA-APFO 20160107b)





Figure 45. Velocity magnitudes of all current sets with black polygon representing typical vessel path (velocity magnitudes below 0.25 knot are blanked).

While many current sets were tested over the course of the ship simulation project, the modifications exist in an area that includes a highly dynamic system. It is possible that certain conditions were not tested that could result in adverse navigation conditions due to the proposed 1,000 ft reopening. However, based on the trends noticed through ship simulations, experience of the pilots and the STS team, and engineering judgment, it is concluded that the proposed reopening will not result in adverse crosscurrents on the White River.

ERDC recommends the 1,000 ft reopening be constructed as proposed. No simulations showed concerns for adverse navigation impacts on the White River due to the implementation of the reopening. While some of the extreme scenarios resulted in run failures, these scenarios represented an

extreme worst-case that is unlikely. Furthermore, the reopening may have made the extreme scenarios worse. However, after discussion with the pilots, it was concluded that these scenarios would have resulted in a failure with or without the proposed reopening. The implementation of these modifications appear to have lessened the difficulty of the turn at RM 6, so it is possible the modifications would actually improve navigable conditions along the White River.

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Appendix A: Track Plots and Pilot Comments

Initial testing track plots and pilot comments

Each plate shows the track plot for one or more simulations on top of an aerial view of the project area. The aerial imagery came from the NAI), which is managed by the USDA FSA. The imagery consists of two 3.75×3.75 minute images that were combined to make a composite image on which all tracks are overlaid. The plates in this appendix are referenced to USDA-FSA-APFO (20160107a) and USDA-FSA-APFO (20160107b).

The following section presents first the track plot and then a consolidated sheet of pilot comments for each track plot. Each track plot is presented with its paired pilot comment sheet except for Plate 19 and Plate 20, which show all of the upbound and downbound transits on a single plot. Track plots show the vessel path for Pilot #1 in yellow, Pilot #2 in red, Pilot #3 in purple, and Pilot #4 in turquoise.

Six different current sets were tested during production runs. For each current set, a simulation was completed with the transiting vessel traveling upbound, downbound, and then in both directions for a passing scenario. Results will be presented using this same convention for each current set tested. Passing simulations were split into individual plates if more than one simulation was completed so that passing can be better visualized. The plates that were split are designated with an "a" or "b" following the plate number. Each plate shows the track plot for one or more simulations on top of an aerial view of the project area. In many simulations, vessels appear to be in the treeline based on the aerial image behind the tracks. Due to the high water stages at which many simulations took place, the effective width of the White River may be greater than what is shown on the track plots.

1,000 ft reopening initial testing matrix


Pilot comments for plate 1. Plate 1 Pilot Comments

Channel: 1000-ft opening Transit direction: Upbound Current set #1: P1L_053011_concentrated

Test matrix number: 7 Vessel: Tugba60 White River stage: 159.4 ft.

Pilot 1 comments (1 run completed):

NOTHING BUT CRUZIN

Pilot 2 comments (1 run completed):

No different then wormed at this stage.

Pilot 3 comments (1 run completed):

Pilot 4 comments (1 run completed):



Plate 2.

Pilot comments for plate 2.

Plate 2 Pilot Comments

Channel: 1000-ft opening Transit direction: Downbound Current set #1: P1L_053011_concentrated

Pilot 1 comments (2 runs completed): Repetition 1 comment: Test matrix number: 8 Vessel: Tugba60 White River stage: 159.4 ft.

Repetition 2 comment (began prior to bridge to just past it): Track not shown on plate

GREAT RYN

GOOD RUN

Pilot 2 comments (1 run completed):

Misjudged Mi 6 oner chuld up in the bend. Other they that Was Normal nun at this stage of the river.

Pilot 3 comments (1 run completed):

Noproblems but could feel some current

Pilot 4 comments (1 run completed):

CURPENT was fast but easy.



Plate 3a.



Plate 3b.

Pilot comments for plate 3a and 3b.

Plate 3 Pilot Comments

Channel: 1000-ft opening Transit direction: Both - passing Current set #1: P1L_053011_concentrated Test matrix number: 9 Vessel: Tugba60 White River stage: 159.4 ft.

Pilot 1/Pilot 2 comments(1 run completed): Upbound: Pilot 1

Downbound: Pilot 2

Normal meeting @this stage of water.

Pilot 3/Pilot 4 comments (1 run completed): Upbound: Pilot 4

Downbound: Pilot 3

Went well



Plate 4.

Pilot comments for plate 4.

Plate 4 Pilot Comments		
Channel: 1000-ft opening Transit direction: Upbound Current set #2: P1L_060411_strong	Test matrix number: 10 Vessel: Tugba60 White River stage: 156.4 ft.	
Pilot 1 comments (1 run completed):		
GOOD AS THOUGH I WAS	AT WORK	
Pilot 2 comments (1 run completed):		
Small doot a round top side mile 4.	Nothing extreme.	
Pilot 3 comments (1 run completed):		
It slowed down after gettin Very 1.412 draft	g above cutoff	
Pilot 4 comments (1 run completed):		
minimal cross current o	it turn 4	



Plate 5.

Pilot comments for plate 5.

Plate 5 Pilot Comments

Channel: 1000-ft opening Transit direction: Downbound Current set #2: P1L_060411_strong Test matrix number: 11 Vessel: Tugba60 White River stage: 156.4 ft.

Pilot 1 comments (1 run completed):

GOOD RUN

Pilot 2 comments (1 run completed):

Normal no change. May be loss set / Pull @ mi. 6 Han NOIMA)

Pilot 3 comments (1 run completed):

Pilot 4 comments (1 run completed):

The increased current made it a little more dangerous and the outdraft stronger. Still pretty easy.



Plate 6a.



Plate 6b.

Pilot comments for plate 6a and Gb.

Plate 6 Pilot Comments Channel: 1000-ft opening Test matrix number: 12 Transit direction: Both - passing Vessel: Tugba60 Current set #2: P1L_060411_strong White River stage: 156.4 ft. Pilot 1/Pilot 2 comments(1 run completed): Downbound: Pilot 2 Upbound: Pilot 1 GOOD RUN NO PROBLEMS Pilot 3/Pilot 4 comments (1 run completed): Upbound: Pilot 3 Downbound: Pilot 4 Fasy pass but fast



Plate 7.

Pilot comments for plate 7.

Plate 7 Pilot Comments Channel: 1000-ft opening Transit direction: Upbound Current set #3: PiL_043011_reversal Pilot 1 comments (1 run completed): ABGOLUTE GOOD MODEL & GOOD CURRENTS Pilot 2 comments (1 run completed): Strong Wpbound eddy @M:3, other than that no chave, Pilot 3 comments (1 run completed): hist area tooches. Did wative speed picked up

Not any topole Did votice speed picked up below diversion and slow down above diversion

Pilot 4 comments (1 run completed):

Easy to run. The outdraft at Turn 4 is noticeable but easy to manage.



Plate 8.

Pilot comments for plate 8. Plate 8 Pilot Comments

Channel: 1000-ft opening Transit direction: Downbound Current set #3: P1L_043011_reversal Pilot 1 comments (1 run completed): I THOUGHT THE CURRENTS WOULD HAVE AFFECTED BOAT SPEED MORE AT MILE 3 Pilot 2 comments (1 run completed): Abschuirty ND draft or current.

Pilot 3 comments (1 run completed):

Pilot 4 comments (1 run completed):



Plate 9a.



Plate 9b.

Pilot comments for plate 9.

Plate 9 Pilot Comments Channel: 1000-ft opening Test matrix number: 15 Transit direction: Both - passing Vessel: Tugba60 Current set #3: P1L_043011_reversal White River stage: 154.9 ft. Pilot 1/Pilot 2 comments(1 run completed): Downbound: Pilot 2 Upbound: Pilot 1 DEFINITELY FEEL A LITTLE ORAFT WHEN NORTH AT OPENING Pilot 3/Pilot 4 comments (1 run completed): Upbound: Pilot 3 Downbound: Pilot 4 Corrent dictated that we move meeting location for a sofer pass, tasy and pretty safe. we passed on The fly (both vessels moving full speed.) this is slightly less safe because of combined speed during Pa95.



Plate 10.

Pilot comments for plate 10.

Plate 10 Pilot Comments Channel: 1000-ft opening Transit direction: Upbound Current set #4: PIL_060911_continuous Pilot 1 comments (1 run completed): CURRENTS ARE A GOOD REPRESENTATION BUT EXPECTED THE CROSS CHARENTS TO AFFECT THE TOW SOONER WAY, Pilot 2 comments (1 run completed): Easy N/S Raw. Mas slight put/l towards approving. Pilot 3 comments (1 run completed): No problem

Pilot 4 comments (1 run completed):

Easy + Safe

ш Pilot #2 Pilot #3 3,000 Feet 2,000 1,000 Track plot legend: 0 Channel: 1,000 ft. opening Transit direction: Downbound Current set #4: P1L_060911_continuous Approximate White River stage: 153.9 ft.

Plate 11.

Pilot comments for plate 11.

Plate 11 Pilot Comments Channel: 1000-ft opening Test matrix number: 17 Transit direction: Downbound Vessel: Tugba60 Current set #4: P1L_060911_continuous White River stage: 153.9 ft. Pilot 1 comments (1 run completed): ABSOLUTE PERFECT FEELING OF CURRENTS AROUND INLET Pilot 2 comments (1 run completed): Repetition 1 comment: Was a big pull to right decouding bank above mile 5. Then to left bank below S. Other than that was normal around mi. 4. Repetition 2 comment (ran from prior to bridge to just past it): Track not shown on plate No pull whatsoever. Pilot 3 comments (1 run completed): Went good Pilot 4 comments (1 run completed): fast averent but manageoble



Plate 12a.

2,550 Feet **Frack plot legend:** Pilot #3 1,700 850 Ŧ 0 Channel: 1,000 ft. opening Transit direction: Both - passing Current set #4: P1L_060911_continuous Approximate White River stage: 153.9 ft.

Plate12b.

Pilot comments for plate 12a and 12b.

Plate 12 Pilot Comments		
Channel: 1000-ft opening Transit direction: Both - passing Current set #4: P1L_060911_continuous	Test matrix number: 18 Vessel: Tugba60 White River stage: 153.9 ft.	
Pilot 1/Pilot 2 comments(1 run completed): Upbound: Pilot 1	Downbound: Pilot 2	
Grant run, No noticiable different	ence with path open while 5/B	
Pilot 3/Pilot 4 comments (1 run completed):		
faster current mac	le the danger greater	
but the outflow at 7	ivrn 4 was not a factor	

ш Pilot #2 Pilot #3 3,000 Feet 2,000 1,000 Track plot legend: 0 Channel: 1,000 ft. opening Transit direction: Upbound Current set #5: P1L_032511_similar Approximate White River stage: 155.1 ft. D

Plate 13.

Pilot comments for plate 13.

Plate 13 Pilot Comments		
Channel: 1000-ft opening Transit direction: Upbound Current set #5: P1L_032511_similar	Test matrix number: 19 Vessel: Tugba60 White River stage: 155.1 ft.	
Pilot 1 comments (1 run completed):		
Pilot 2 comments (1 run completed):		
No eddy around mile 3. Other than geel.	that was normal	
Pilot 3 comments (1 run completed):		
No pooblem at ell		
Pilot 4 comments (1 run completed):		
The cross current at turn 4 Noticeable,	was Borely	

Plate 14.



Pilot comments for plate 14.

Plate 14 Pilot Comments Channel: 1000-ft opening Test matrix number: 20 Transit direction: Downbound Vessel: Tugba60 Current set #5: P1L_032511_similar White River stage: 155.1 ft. Pilot 1 comments (1 run completed): STOPPED TOW INTENTIONALLY TO TRY AND SEE ANY CURRENT EFFECT BUT FELT NONE. THEN BACK UP CLOSE TO OPENING AND WHEN I GUT STUPPED AND STARTED TAKING OFF AGAIN INSTICED A DRAFT PULLING ON TOW TOWARD OPENING. Pilot 2 comments (1 run completed): Slight pull to right bank @ mil. But Normal feel at this stage. Pilot 3 comments (1 run completed): Didn't fiel a pull at mile 6 Pilot 4 comments (1 run completed): No noticable outdraft currenTS



Plate 15a.



Plate 15b.

Pilot comments for plate 15.

Plate 15 Pilot Comments Channel: 1000-ft opening Test matrix number: 21 Transit direction: Both - passing Vessel: Tugba60 Current set #5: P1L_032511_similar White River stage: 155.1 ft. Pilot 1/Pilot 2 comments(2 run completed): Repetition 1 comment: Downbound: Pilot 1 Upbound: Pilot 2 Same thing. No ditterence. Repetition 2 comment (lower meeting place): Downbound: Pilot 1 Upbound: Pilot 2 DIDN'T FEEL ANY EFFECTS OF AN EDDY OR DRAFTS Pilot 3/Pilot 4 comments (1 run completed): Tracks not shown on plate Upbound: Pilot 4 Downbound: Pilot 3 Want good om neeting N/B tow

ш Pilot #2 Pilot #3 3,000 Feet 2,000 1,000 Track plot legend: 0 Channel: 1,000 ft. opening Transit direction: Upbound Current set #6: P1L_051211_peak Approximate White River stage: 166.9 ft.

Plate 16.

Pilot comments for plate 16.

Plate 16 Pilot Comments

Channel: 1000-ft opening Transit direction: Upbound Current set #6: P1L_051211_peak Test matrix number: 22 Vessel: Tugba60 White River stage: 166.9 ft.

Pilot 1 comments (1 run completed):

No comment listed.

Pilot 2 comments (1 run completed):

Minimal drath towageds Historic Closhre M: 4.

Pilot 3 comments (1 run completed):

Pilot 4 comments (1 run completed):
ш Pilot #2 Pilot #3 3,000 Feet 2,000 1,000 Track plot legend: 0 Channel: 1,000 ft. opening Transit direction: Downbound Current set #6: P1L_051211_peak Approximate White River stage: 166.9 ft.

Plate 17.

Pilot comments for plate 17.

Plate 17 Pilot Comments Channel: 1000-ft opening Test matrix number: 23 Transit direction: Downbound Vessel: Tugba60 Current set #6: P1L_051211_peak White River stage: 166.9 ft. Pilot 1 comments (1 run completed): REALLY GOOD RUN OF CURRENTS Pilot 2 comments (1 run completed): Fert no pull any where Pilot 3 comments (1 run completed): No comment listed. Pilot 4 comments (1 run completed): Very easy and safe to run

2,550 Feet Pilot #: 1,700 **Frack plot legend:** 850 Ŧ 0 Channel: 1,000 ft. opening Transit direction: Both - passing Current set #6: P1L_051211_peak Approximate White River stage: 166.9 ft.

Plate 18.

Pilot comments for plate 18.

Plate 18 Pilot Comments

Channel: 1000-ft opening Transit direction: Both - passing Current set #6: P1L_051211_peak Test matrix number: 24 Vessel: Tugba60 White River stage: 166.9 ft.

Pilot 1/Pilot 2 comments (1 run completed): Upbound: Pilot 1

Downbound: Pilot 2

Easy run, No draths or pulli.

Pilot 3/Pilot 4 comments (1 run completed): Tracks not shown on plate Upbound: Pilot 4

Downbound: Pilot 3

Not a pashler meeting



Plate 19.



Plate 20.

Extreme scenarios track plots and pilot comments

The following section presents the track plots and pilot comments for the extreme scenarios. The track plot is first presented and then followed by the subsequent sheet of pilot comments. The extreme scenarios were completed by Pilot #3 (show in purple) and Pilot #4 (shown in turquoise). Engine failure scenarios are shown first followed by worst-meeting-location scenarios. Passing simulations were split into individual plates if more than one simulation was completed so that passing can be better visualized. The plates that were split are designated with an "a" or "b" following the plate number. Each plate shows the track plot for one or more simulations on top of an aerial view of the project area. In many simulations, vessels appear to be in the treeline based on the aerial image behind the tracks. Due to the high water stages at which many simulations took place, the effective width of the White River may be greater than what is shown on the track plots.



Extreme scenarios – engine failure simulations

Plate 21.

Pilot comments for plate 21.

Plate 21 Pilot Comments Channel: 1000-ft opening Test matrix number: 8E Transit direction: Downbound Vessel: Tugba60 Current set #1: P1L_053011_concentrated White River stage: 159.4 ft. Pilot 3 comments (1 run completed): Starboard engine failure Made it that the bend and able to stop and land tow on Right descending bank Pilot 4 comments (1 run completed): Port engine failure way still able to navigate with Loss or engine. Cruck corrent was not a factor.



Plate 22.

Pilot comments for plate 22.

Plate 22 Pilot Comments	
Channel: 1000-ft opening Transit direction: Downbound Current set #4: P1L_060911_continuous	Test matrix number: 17E Vessel: Tugba60 White River stage: 153.9 ft.
Pilot 3 comments (2 runs completed): Repetition 1: Starboard engine failure – Track not shown on plat	e
Was in straight away and able to stip - Poet engine	tow with
Repetition 2: Port engine failure	
Made : Larsond beard with one eng. to steaight away and stopped to w	in- and steerad
Pilot 4 comments (2 runs completed): Repetition 1: Port engine failure – Track not shown on plate	
Whs still able to navigate on one	ongine.
The (1055 current was more of a factor manageoble.	r but
Repetition 2: Starboard engine failure	
was able to navigate on one engine The crosscorrent was most noticeable but I was still able to get past it	in this generic relatively gately



Extreme scenarios – worst-meeting-location simulations

Pilot comments for plate 23.

Plate 23 Pilo	ot Comments
Channel: 1000-ft opening Transit direction: Both - passing Current set #1: P1L_053011_concentrated	Test matrix number: 9P Vessel: Tugba60 White River stage: 159.4 ft.
Pilot 3/4 comments (1 run completed): Worst case meeting spot	
Upbound: Pilot 4	Downbound: Pilot 3
Very dangerous place The cross corrent was high chance of grounding of its presence.	70 pugs. a factor but a very is present reguardless



Plate 24.

Pilot comments for plate 24.

Plate 24 P	ilot Comments				
Channel: 1000-ft opening Transit direction: Both - passing Current set #2: P1L_060411_strong	Test matrix number: 12P Vessel: Tugba60 White River stage: 156.4 ft.				
Pilot 3/4 comments (1 run completed): Worst case meeting spot					
Upbound: Pilot 4	Downbound: Pilot 3				
Meeting went well	without much problem.				



Plate 25a.



Plate 25b.

Pilot comments for plate 25a and 25b.

ments
Test matrix number: 15P Vessel: Tugba60 White River stage: 154.9 ft.
vnbound: Pilot 4
dat dat me hug laft
vnbound: Pilot 4
k pass > a foctor but rcone it.

ш 2,550 Feet Track plot legend: Pilot #3 1,700 850 + 0 Extreme Scenarios - Worst Meeting Location Channel: 1,000 ft. opening Transit direction: Both - passing Current set #4: P1L_060911_continuous Approximate White River stage: 153.9 ft.

Plate 26.

Pilot comments for plate 26.

Plate 26 Pilot	Comments					
Channel: 1000-ft opening Transit direction: Both - passing Current set #4: P1L_060911_continuous	Test matrix number: 18P Vessel: Tugba60 White River stage: 153.9 ft.					
Pilot 3/4 comments (1 run completed): Worst case meeting spot						
Upbound: Pilot 3	Downbound: Pilot 4					
Didn't have too much	terrble					



Plate 27.

Pilot Comments for plate 27.

Plate 27 Pilot	Comments
Channel: 1000-ft opening Transit direction: Both - passing Current set #5: P1L_032511_similar	Test matrix number: 21P Vessel: Tugba60 White River stage: 155.1 ft.
Pilot 3/4 comments (1 run completed): Worst case meeting spot	
Upbound: Pilot 4	Downbound: Pilot 3
Was a very bud spot to m high rish of colligion, the effect but was not the major present	eet and hud a outdruft had some Factor in The danger

Appendix B: Final Pilot Questionnaires

Captain Ward, page 1.

Three Rivers Ship Simulation Study - Final Questionnaire Name: JOHN WARD A reopening of the Historic Cutoff has been suggested to control overtopping flow location when elevation at Navigation Mile 4 exceeds 145 ft. to prevent uncontrolled cutoffs from forming. Testing for this project occurred during two testing weeks: November 11-15, 2019 and December 16-20, 2019. 1. Please comment on your experience of using the ERDC ship tow simulator this week for testing. VERY EXCITING AND VERY INFORMATIVE OF HOW CURRENTS WOULD EFFECT THE AREA AND TOW 2. Do you feel the environmental conditions and visuals provided a reasonable representation of the White River? VERY GOOD REPRESENTATION 3. Would the addition of wind have impacted navigation for the loaded barge/tow package (15-pack barge with 4,000 HP tow) that was used for testing? REALLY WOULD NOT AFFETT TOW AT ALL UNLESS TOWAND BOAT HAD TO GTOP AT THE OPENINGS

Captain Ward, page 2.

4. Please comment on the behavior of the design vessel (15-pack barge with 4,000 HP pusher tow). Do you feel the design vessel was adequate representation of a real life vessel? THE SECOND MODEL OF VESSEL SEEMED TO BE SPOT ON GREAT JOB 5. Do you have any concerns that the proposed opening will impact empty barges? NO CONCERNS 6. Do you feel that the proposed opening was feasible for the current sets tested for the chosen design vessel (15-pack barge with 4,000 HP tow) for the following situations? a. Upbound vessel traffic b. Downbound vessel traffic c. Passing situations 1 DO NOT THINK IT WILL HENDER NAVIGATIONS AT ALL

Captain Ward, page 3.

7. Overall, do you think the addition of the opening would have a negative impact on navigation on the White River? I THINK IT WILL BE A POSITIVE IMPACT DUE TO CHANGING FLOW SET AT MILE 6 8. Do you think any additional testing runs ("what if" scenarios) should have been completed that were not tested this week? I THINK ALL SCENARIOS WERE COVERED VERY WELL 9. Any additional comments? VERY WELL THOUGHT OUT PLANNING THANK YOU FOR THE OPPORTUNITY TO BE PART OF THE TESTING OF THESE SCENARIOS

Captain Davis, page 1.

Three Rivers Ship Simulation Study – Final Questionnaire Name: Ridsey Davis Jr. A reopening of the Historic Cutoff has been suggested to control overtopping flow location when elevation at Navigation Mile 4 exceeds 145 ft. to prevent uncontrolled cutoffs from forming. Testing for this project occurred during two testing weeks: November 11-15, 2019 and December 16-20, 2019. 1. Please comment on your experience of using the ERDC ship tow simulator this week for testing. Very tim and interesting. 2. Do you feel the environmental conditions and visuals provided a reasonable representation of the White River? I think so. Was very Ralistic. 3. Would the addition of wind have impacted navigation for the loaded barge/tow package (15-pack barge with 4,000 HP tow) that was used for testing? No, Was a loaded 15 barges, wind does doesn't Impact at all.

Captain Davis, page 2.

4. Please comment on the behavior of the design vessel (15-pack barge with 4,000 HP pusher tow). Do you Please comment on the benavior of the design reaction of a real life vessel? The second model they SPNA was better than the first. 5. Do you have any concerns that the proposed opening will impact **empty** barges? Not $\alpha I = \alpha I$. 6. Do you feel that the proposed opening was feasible for the current sets tested for the chosen design vessel (15-pack barge with 4,000 HP tow) for the following situations? a. Upbound vessel traffic Ves b. Downbound vessel traffic 1/03 c. Passing situations

Captain Davis, page 3.

7. Overall, do you think the addition of the opening would have a negative impact on navigation on the White River? None at all. Would have positive impact @ mi. 6. 8. Do you think any additional testing runs ("what if" scenarios) should have been completed that were not tested this week? No. 9. Any additional comments? I'm truly blessed for hoving spent time with such an awarone group of people. They were Nothing short of again amazing the entire time. I'm truly improssed.

Captain Salcido, page 1.

Three Rivers Ship Simulation Study – Final Questionnaire Name: Manny Salcido A reopening of the Historic Cutoff has been suggested to control overtopping flow location when elevation at Navigation Mile 4 exceeds 145 ft. to prevent uncontrolled cutoffs from forming. Testing for this project occurred during two testing weeks: November 11-15, 2019 and December 16-20, 2019. 1. Please comment on your experience of using the ERDC ship tow simulator this week for testing. It was AN experience. Glad to have such a tool to test and learn 2. Do you feel the environmental conditions and visuals provided a reasonable representation of the White River? It was a good Representation of conditions 3. Would the addition of wind have impacted navigation for the loaded barge/tow package (15-pack barge with 4,000 HP tow) that was used for testing? Wind would not have an impact.

Captain Salcido, page 2.

4. Please comment on the behavior of the design vessel (15-pack barge with 4,000 HP pusher tow). Do you feel the design vessel was adequate representation of a real life vessel? Very adequate. Felt like the real thing. 5. Do you have any concerns that the proposed opening will impact empty barges? No CONCORN on an empty tow. Emptires are easier to control. 6. Do you feel that the proposed opening was feasible for the current sets tested for the chosen design vessel (15-pack barge with 4,000 HP tow) for the following situations? a. Upbound vessel traffic b. Downbound vessel traffic c. Passing situations A. Upbound toattic wouldn't be much tareble B. Would have adequate house power to contart downbourd C. No a perblam

Captain Salcido, page 3.

7. Overall, do you think the addition of the opening would have a negative impact on navigation on the White River? No, Not a negative impact. I think it would be bene ficial 8. Do you think any additional testing runs ("what if" scenarios) should have been completed that were not tested this week? We tried just about all what it scenorion 9. Any additional comments? I hope # was useful in this study

Captain Miller, page 1.

Three Rivers Ship Simulation Study - Final Questionnaire Name: Kerry Miller A reopening of the Historic Cutoff has been suggested to control overtopping flow location when elevation at Navigation Mile 4 exceeds 145 ft. to prevent uncontrolled cutoffs from forming. Testing for this project occurred during two testing weeks: November 11-15, 2019 and December 16-20, 2019. 1. Please comment on your experience of using the ERDC ship tow simulator this week for testing. I found it to be pretty accurate to handling and conditions of Tow boat operation. Helpful to Learn the different currents at different gtagos. 2. Do you feel the environmental conditions and visuals provided a reasonable representation of the White River? Yes. They seemed pretly close to reality. 3. Would the addition of wind have impacted navigation for the loaded barge/tow package (15-pack barge with 4,000 HP tow) that was used for testing? No, wind would be a non-factor with Loads

4. Please comment on the behavior of the design vessel (15-pack barge with 4,000 HP pusher tow). Do you feel the design vessel was adequate representation of a real life vessel? Yes, The bruee oakley was my boat and it Behaved very gimilar to the simulator. there is only one difference. On the real boat you cannot "twist" due to wort nozzels. I tried it on The computer and it seened to work 1942 5. Do you have any concerns that the proposed opening will impact empty barges? None at all 6. Do you feel that the proposed opening was feasible for the current sets tested for the chosen design vessel (15-pack barge with 4,000 HP tow) for the following situations? (a. Upbound vessel traffic (A. Downbound vessel traffic Q. Passing situations Yes I have ran 15 with that boat in those situations on the white river SUCESSFULLY

Captain Miller, page 3.

7. Overall, do you think the addition of the opening would have a negative impact on navigation on the White River? NO, I gaw no situation where the proposed opening would endanger a vessel significantly It would be benifical to remove outdraft from Turn 6 and open turn 4 8. Do you think any additional testing runs ("what if" scenarios) should have been completed that were not tested this week? No, we addressed all feasible scenarios. 9. Any additional comments? Thank you for having me and I hope you got good information

Appendix C: Pilot Card

PILOT CARD TUGBA60V2 Version 2 Bruce Oakley Ship's name ____ WDG3843 Deadweight 0_____tonnes Yearbuilt _____ Call Sign ____ 2012 Draught aft ______2.895 ____ m / _9__ft _6_ in Forward _____ 2.895 m / 9 ft 6 in Displacement 27318 tonnes SHIP'S PARTICULARS Length overall 331.9 _ m Anchor chain: Port ______ shackles Starboard _ shackles 32 Breadth ____ m Bulbous bow No (1 shackle = 27.432 m = 15 fathoms) Air draught 303.24 m 28.66 m 17.46 m 32 m 297.19 m PROPULSION PARTICULARS Diesel Maximum power 2942 Type of engine _ kW (_ 4000 hp) Manoeuvring engine RPM Pitch Speed (knots) Loaded Ballast order Full sea speed 1 225.0 N/A 7.0 N/A Full Ahead 0.8 200.0 N/A N/A 6.2 Half Ahead 0.5 160.0 N/A 4.9 N/A Slow Ahead 0.25 102.0 N/A 3.1 N/A 1.7 Dead Slow Ahead 0.125 N/A N/A 57.0 Dead Slow Astern -0.125 -57.0 N/A -0.25 -102.0 N/A Slow Astern -0.5 -160.0 N/A Half Astern Full Astern -1 -225.0 N/A

Pilot card – 3 x 5 barge.

Pilot card – 3 x 5 barge.

	Type of rudder Normal/Normal/Flanking/Flanking						angle		45	
Hard-over to I	hard-over		9		s					
Rudder angle	for neutral e	ffect	0							
Thruster:	Bow	N/A	_ KW (N/A	hp)	Stern	N/A	_ KW (N/A	hp)
			c	HECKED	IF ABO	ARDAND	READY			
Anchors						In	dicators:			
Whistle							Rudde	r		
Radar		3 cm			10 cm		Rpm/p	itch		
ARPA							Rate of	fturn		
Speed log		Dopple	r:	Yes / No		C	ompass syste	m		
Water	speed					C	onstant gyro	error ±		
Grour	nd speed					vi	łF			
Dual-	axis					EI	ec. pos. fix. s	ystem		
Engine telegra	aphs						Туре			
Steering gear							-			
Numb	er of power i	inite operatio								
Num		units operatin	9							
THER INFO	RMATION:									
Unit Conversion Factors

Multiply	Ву	To Obtain
cubic feet	0.02831685	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
horsepower (550 foot-pounds force per second)	745.6999	watts
knots	0.5144444	meters per second
miles (US statute)	1,609.347	meters

Abbreviations and Acronyms

2D	two-dimensional
3D	three-dimensional
AdH	Adaptive Hydraulics
CESWL	USACE, Little Rock District
ERDC	US Army Engineer Research and Development Center
FSA	Farm Service Agency
MKARNS	McClellan-Kerr Arkansas River System
NAIP	National Agriculture Imagery Program
NS	not specified
RM	River Mile
STS	Ship/Tow Simulator
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture

Form Approved REPORT DOCUMENTATION PAGE OMB No. 0704-0188 The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS. 1. REPORT DATE 2. REPORT TYPE 3. DATES COVERED (From - To) August 2020 **Final Report** 4. TITLE AND SUBTITLE 5a. CONTRACT NUMBER Three Rivers, Southeast Arkansas Navigation Study: Ship Simulation Report 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER 6. AUTHOR(S) 5d. PROJECT NUMBER Morgan M. Johnston, Ronald E. Heath, and Mary Claire Allison 5e. TASK NUMBER 5f. WORK UNIT NUMBER 478043 8. PERFORMING 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ORGANIZATION REPORT** Coastal and Hydraulics Laboratory NUMBER US Army Engineer Research and Development Center ERDC/CHL TR-20-16 3909 Hall Ferry Road Vicksburg, MS 39180-6199 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) 10. SPONSOR/MONITOR'S ACRONYM(S) US Army Corps of Engineers, Little Rock District USACE SWL 700 W Capitol Ave 7th FL Little Rock, AR 72203 **11. SPONSOR/MONITOR'S** REPORT NUMBER(S) 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 13. SUPPLEMENTARY NOTES 14. ABSTRACT The McClellan-Kerr Arkansas River System (MKARNS) is a major inland waterway that begins at the Port of Catoosa in Tulsa, OK, and travels to the confluence of the White and Mississippi Rivers. Over the years, many structures have been built to help control overland flow between the White, Arkansas, and Mississippi Rivers. These structures have required a significant amount of rehabilitation, which has resulted in high maintenance costs. The US Army Corps of Engineers and the Arkansas Waterways Commission conducted the Three Rivers Southeast Arkansas Feasibility Study (also known as the Three Rivers Study). The Three Rivers Study focused on providing longterm dependable navigation in the MKARNS. From this study, a proposal was developed that included a 1,000 ft reopening of the Historic Cutoff and a reinforcement of several areas near the White River. In 2019, the US Army Engineer Research and Development Center Ship/Tow Simulator was used to perform a navigation study to ensure the proposed modifications did not negatively impact navigation on the White River section of the MKARNS. Assessment of the proposed modifications was accomplished through analysis of ship simulations completed by experienced pilots, discussions, track plots, run sheets, and final pilot surveys.

15. SUBJECT TERMS

Arkansas River, Hydrodynamics, Inland navigation, Mississippi River, Ships—Maneuverability—Simulation methods, Water currents, White River (Ark. And Mo.)

16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF	18. NUMBER	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	c. THIS PAGE	ABSTRACT	OF PAGES	Morgan M. Johnston
Unclassified	Unclassified	Unclassified	SAR	147	19b. TELEPHONE NUMBER (Include area code) 601-634-2365