US Army Corps of Engineers®
St. Louis District

UMR 104.0 – 101.5 Hydraulic Sediment Response (HSR) Model Study

Technical Report M73

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Executive Summary

The U.S. Army Corps of Engineers, St. Louis District, is responsible for providing a navigation channel on 195 miles of the Middle Mississippi River (MMR) between the confluences of the Missouri River near St. Louis, MO and the Ohio River near Cairo, IL. District personnel have relied upon the construction of river training structures to minimize the need for repetitive channel maintenance dredging in order to accomplish this task.

From 2000 to 2015, approximately 5.8 million cubic yards of material was dredged between UMR 104.0 and 101.5 at a cost of approximately $12.7M (see Figures 3 and 4, below). The dredging in this location has equated to roughly 8% of the Middle Mississippi dredging material and expenditure over this timeframe.

In December, 2015, the U.S. Army Corps of Engineers, St. Louis District began conducting a physical hydraulic sediment response (HSR) model at the Applied River Engineering Center (AREC) in St. Louis, Missouri. Alternative testing involved testing 28 different potential solutions to the dredging issues in the UMR 104.0 – 101.5 reach. Of the 28 alternatives tested, it was determined that Alternative 25 was the most effective in reducing or eliminating the need for repetitive channel maintenance dredging in the future while avoiding and minimizing adverse effects to fish and wildlife. River training structure construction associated with Alternative 25 is shown on Plate 45 and also detailed in the table below.

Type of Structure	Location (River Mile)	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.80	LDB	350
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Degrade Riverward Section of Existing Dike	103.10	LDB	425
Install Rootless MRS Dike	102.30	LDB	550
Install Rootless MRS Dike	102.00	LDB	550

Model bathymetry for Alternative 25 clearly demonstrated improved navigation channel depths and widths between UMR 102.5 and 101.5 when compared to the model base test. Model testing results for Alternative 25 demonstrated no significant negative environmental impacts.

1 Introduction

The U.S. Army Corps of Engineers, St. Louis District, conducted a study of the flow and sediment transport response conditions of the Upper Mississippi River (UMR) between River Miles (RM) 104.0 and 101.5 near Rockwood, Illinois. This study was funded by the U.S. Army Corps of Engineers, St. Louis District's Regulating Works Project. The objective of the model study was to provide a recommended course of action based upon an analysis of the effectiveness of various river engineering measures intended to reduce or eliminate the need for repetitive channel maintenance dredging. The recommended alternative should avoid and minimize negative environmental impacts whenever reasonably possible.

The study was conducted between December, 2015 and January, 2017 using a physical hydraulic sediment response (HSR) model at the St. Louis District Applied River Engineering Center in St. Louis, Missouri. The model study was conducted by Jasen Brown, P.E., Hydraulic Engineer, with model operation performed by Cory Tabbert, Engineering Co-Op student. Robert D. Davinroy, P.E., Chief, River Engineering (retired) and David Gordon, P.E., Chief, Hydraulic Design provided direct supervision of the effort. Other personnel involved in this study are shown in Table 1, below.

Table 1: Other Personnel Involved in the Study.

Name	Position	District / Company
Leonard Hopkins, P.E.	Chief of Hydrologic and Hydraulic Branch	St. Louis District
Brian Johnson	Chief of Environmental Compliance Section	St. Louis District
Tim Lauth, P.E.	Regulating Works Project Technical Lead	St. Louis District
Mike Rodgers, P.E.	Regulating Works Project Project Manager	St. Louis District
Lance Engle	Dredge Project Manager	St. Louis District
Butch Atwood	Mississippi River Fishery Biologist	Illinois Department of Natural Resource (IDNR)
Matthew Mangan	Biologist	U.S. Fish and Wildlife Service(FWS)
Bernie Heroff	Port Captain	ARTCO
Janet Sternburg	Fishery Biologist	Missouri Department of Conservation (MDC)

2 Background

2.1 Problem Description

The authorized minimum channel dimensions for ensuring the safe passage of commercial vessels on the UMR are 9 feet of depth and 300 feet of width with additional width in bends at low water. For practical considerations, the Corps has established a Low Water Reference Plane (LWRP) to use for measuring relative river depths.

River training structures and revetments have previously been utilized in the reach between UMR river miles 104.0 and 101.5 to reduce the need for repetitive channel maintenance dredging. The most recent Regulating Works Project construction in this reach was completed in 2000. However, the reach still requires a substantial amount of dredging to maintain a safe and dependable navigation channel. The reach between UMR river miles 104.0 and 102.5 is a river bend where the sediment deposition along the right descending bank (RDB) sandbar will, without dredging, encroach upon the navigation channel enough to make navigation through the bend unsafe due to insufficient navigation channel width. See Figure 1, below.

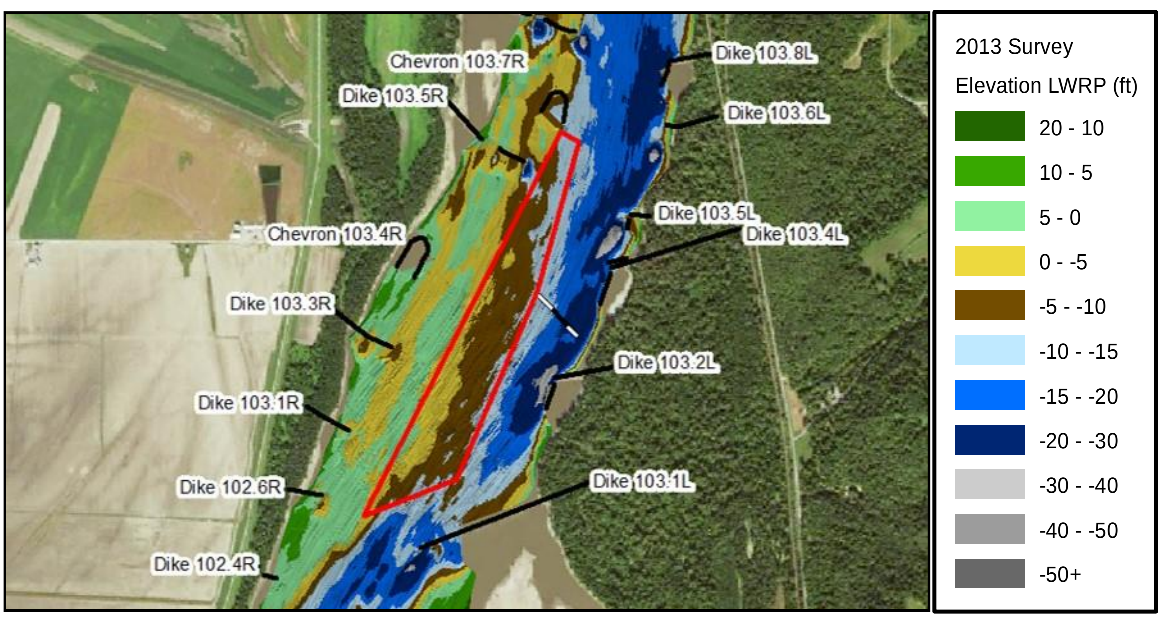

Figure 1: 2013 Bathymetry Survey. Representative dredge box outlined in red.

Additionally, the crossing from UMR 102.5 to 101.5 has required dredging to maintain sufficient navigation channel depth. See Figure 2, below.

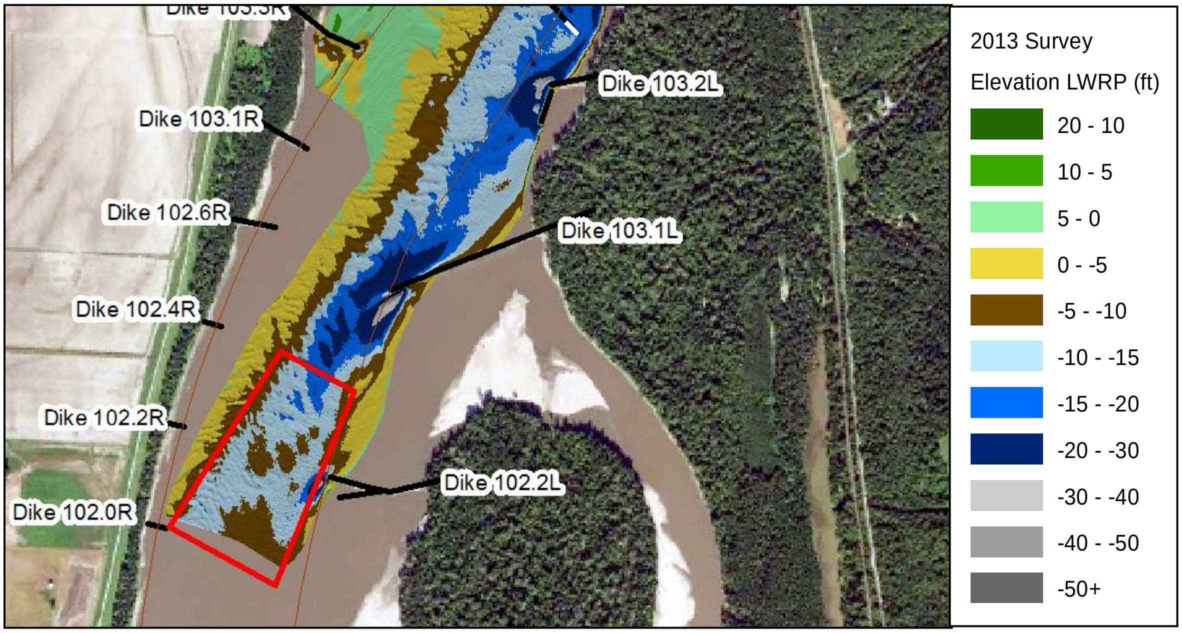

Figure 2: 2011 Bathymetry Survey. Representative dredge box outlined in red.

From 2000 to 2015, approximately 5.8 million cubic yards of material was dredged between UMR 104.0 and 101.5 at a cost of approximately $12.7M. See Figures 3 and 4, below. Also reference Plate 3.

2.2 Environmental Features

USACE biologists and partnering natural resource agency representatives pointed out that there are two important areas of habitat along the LDB between UMR 104.0 and 101.5. Alternatives in this model study were

a. Rockwood Chute – The entrance to Rockwood Chute is at UMR 102.7. Side channels are important for overwintering and low velocity habitats for various fish species prevalent on the MMR.

b. Rockwood Island Sandbar – The sandbar located at the upstream end and river side of Rockwood Island serves as important shallow water habitat for various fish species prevalent on the MMR. Sandbars on the MMR are also potential nesting areas for local birds (including the Least Tern).

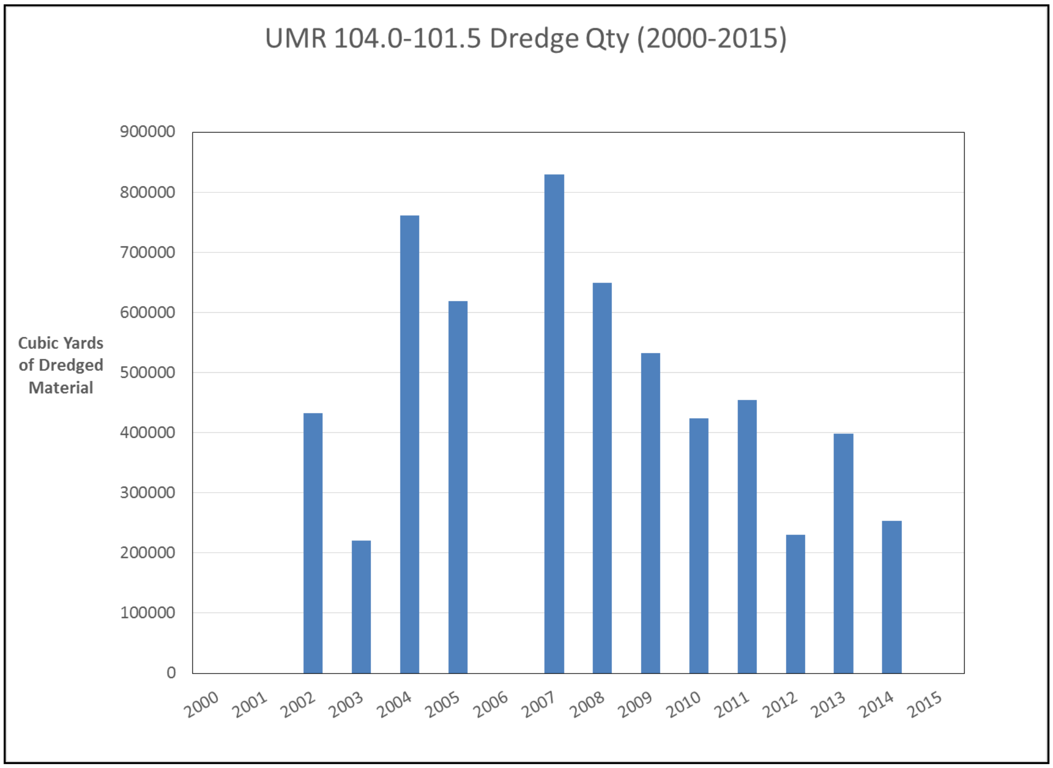

Figure 3: Dredge quantities over time for UMR 104.0-101.5.

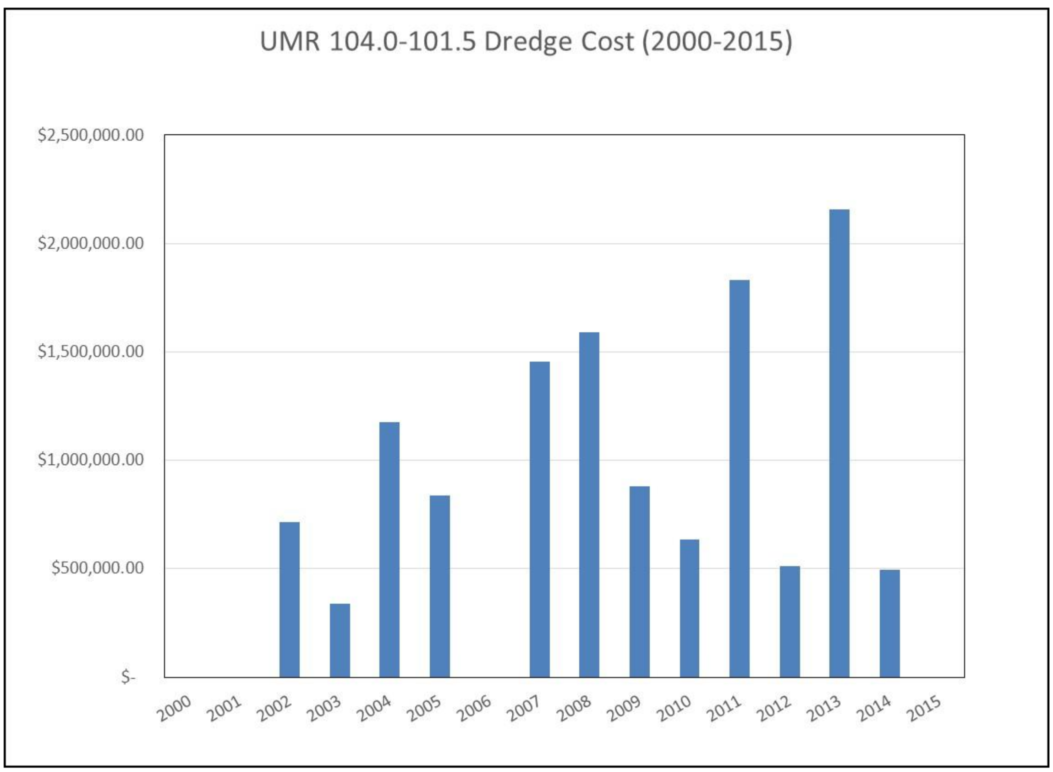

Figure 4: Dredge costs over time for UMR 104.0-101.5.

2.3 Study Purpose and Goals

The purpose of this study was to evaluate various design alternatives intended to reduce or eliminate repetitive dredging between UMR river miles 104.0 and 101.5. HSR modeling technology was used to test the changes in flow patterns and sediment transport.

The goals of this study were to:

i. Investigate and provide analysis on the existing flow mechanics.

ii. Evaluate a variety of remedial measures utilizing an HSR model with the objective of identifying the most effective and economical plan to reduce or eliminate the need for dredging between RM 104.0 to RM 101.5 while avoiding and minimizing adverse effects to fish and wildlife. In order to determine the best alternative, the following criteria below were used to evaluate each alternative:

   a. The alternative should reduce or eliminate the need for dredging along the RDB sandbar between RM 104.0 and RM 102.5.

   b. The alternative should reduce or eliminate the need for dredging in the channel crossing between RM 102.5 and RM 101.5.

   c. The alternative should have a minimal impact, if possible, on the flows entering Rockwood Chute.

   d. The alternative should have a minimal impact, if possible, on the sandbar along the river side of Rockwood Island.

2.4 Study Reach

The study comprises a 2.5 mile stretch of the UMR between RM 104.0 and RM 101.5 near Rockwood, Illinois. Additional river length both upstream and downstream of the study area was modeled to allow for adequate entrance and exit conditions. Plate 1 is a location and vicinity map of the study reach. Plate 2 is a planform and nomenclature map of the study reach. Plate 4 illustrates geomorphological changes to the river banklines in the study reach over the time period from 1968 to 2011. Counties located around the study reach are Randolph and Jackson in Illinois and Perry in Missouri.

Present and historic hydrographic surveys of the Mississippi River, in the HSR model study area, are shown on Plates 5-9. The plates show bathymetric surveys from 1986-1987, 2005, 2007, 2010, and 2013.

The following bathymetric trends have remained relatively constant after comparison of the above mentioned hydrographic surveys:

Table 2: Study Reach Characteristics

River Miles	Description
105.0 – 104.5	The thalweg was located along the LDB throughout this 0.5 mile reach. Depths along the LDB increased to up to 30' below LWRP from UMR 106.0 – 105.0 as the flow was concentrated along the LDB. Between RM 104.7 and 104.5, flows tended to spread out as the thalweg moved slightly away from the LDB. There was a dike field extending from the RDB with a spacing of 900' and an average effective length of 300'.
104.5 – 103.0	The thalweg at UMR 104.5 was located slightly off the LDB, as the river planform turned south between RM 104.0 and RM 103.0. Flows were concentrated along the LDB and scour down to depths approaching 40' below LWRP were observed. Between RM 103.7 and RM 103.0 there were structures located along both banklines. The RDB had a mix of chevrons and notched river training structures that were constructed on a large sandbar. The average spacing of these structures was approximately 800'. The LDB had a series of trail dikes with an effective length of approximately 250' on average with approximately 400' trail sections on average. There was also a single weir with a degraded cross section at RM 103.2 extending from the LDB approximately 400' and angled upstream at approximately 25 degrees.
103.0 – 102.0	The thalweg crossed from the LDB to the RDB in this reach. There were structures on both sides of the channel, but Dike 103.1L just upstream of the entrance to Rockwood Chute was shown to have a substantial impact on the bathymetry in the crossing. The structure is angled downstream at approximately 40 degrees downstream from the primary direction of flow and extends out from the bank approximately 1700'. The top of the dike was approximately 10' above LWRP. Just upstream of this structure, the sandbar along the RDB tended to encroach upon the navigation channel. However, there was

	significant scour off the end of this structure and as a result the RDB sandbar was cut back downstream of the structure. The average channel width from dike tip to dike tip through this reach was approximately 1600'.
102.0 – 100.4	The thalweg was concentrated along the RDB from RM 102.0 through RM 100.0. The planform bent toward the LDB in a gentle curve. There were structures on both sides of the river. The structures along the outside of the bend along the RDB that were spaced approximately 1100' apart. The average effective length of these structures was approximately 200'. The structures along the sandbar on the inside of the bend are spaced approximately 1700' apart. These structures had little to no effective length as they were completely covered in sand. Liberty Chute reconnects to the main channel at RM 100.7 and RM 100.0.
100.4 - 99.0	The thalweg crossed from the RDB to the LDB in this reach. There was a set of chevrons along the LDB at the downstream end of Liberty Chute near RM 100.0. Along the RDB, there was a series of notched dikes where the Mile 100 islands formed. These structures were spaced approximately 800' – 2000' apart with effective lengths of approximately 900' – 1300'. The average width from the dike tips to the LDB in this reach was approximately 1500'.

3 HSR Modeling

3.1 Model Calibration and Replication

The HSR model was calibrated to replicate the general conditions of the river at the time of the model study. This involved a 3 step process.

First, planform "fixed" boundary conditions of the study reach, i.e. banklines, islands, side channels, tributaries and other features were established according to recent available high resolution aerial photographs. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries. These boundaries were based off of documentation (such as plans and specifications) as well as hydrographic surveys.

Second, "loose" boundary conditions of the model were replicated. Bed material was introduced into the channel throughout the model to an approximate level plane. The combination of the fixed and loose boundaries served as the starting condition of the model.

Third, model tests were run using steady state discharge. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The bed progressed from a static, flat, arbitrary bed into a fully-formed, dynamic, and three dimensional (3D) mobile bed. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bathymetry were similar to observed recent river bathymetry and the tests were repeatable, the model was considered calibrated and alternative testing began.

An overhead view of the HSR model is shown in Plate 16.

See Appendix 2: HSR Modeling Theory for more details on the use of HSR Models.

3.2 Scales and Bed Materials

The model employed a horizontal scale of 1 inch = 500 feet, or 1:6000, and a vertical scale of 1 inch = 68 feet, or 1:816, for a 7.4 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those observed in the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.40. Some areas of the model bed were determined to consist of non-erodible materials. These areas were modeled using heavy steel pellets that would not translate downstream during model calibration and testing.

3.3 Appurtenances

The HSR model insert was constructed according to the 2012 high-resolution aerial photography of the study reach. The insert was then mounted in a hydraulic flume that recirculates water and sediment in a closed, steady state loop. The riverbanks of the model were constructed from dense polystyrene foam, and modified during calibration with clay (banklines). Steel pellets were utilized in the model as non-erodible material. River training structures in the model were made of galvanized steel mesh. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.01 inch/inch.

3.4 Flow Control

In all model tests, a steady state flow was simulated in the channel. This served as the average design energy response of the river. Because of the constant variation experienced in the prototype, this steady state flow was used to theoretically analyze the ultimate expected sediment response. The flow was held steady at a constant flow rate of 1.45 Gallons per Minute (GPM) during model calibration and for all design alternative tests.

3.5 Data Collection

The river bed in the model was surveyed with a high definition, 3D laser scanner that collects a dense cloud of xyz data points. These xyz data points were then geo-referenced to real world coordinates and triangulated to create a 3D surface. The surface was then color coded by elevation using standard color tables that were also used in color coding prototype surveys. This process allowed a direct visual comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

Flow visualization was used for the recommended alternative to provide a better understanding of the changes to the flow distribution in the model as a result of the changes. The water surface was seeded with dry sediment and the area of interest was recorded with a high definition camera as the sediment passed by. The analysis allowed the observation of surface flow patterns in addition to qualitative information such as flow distribution and direction.

4 HSR model tests

4.1 Replication Test

Once the model adequately replicated general prototype trends, the resultant bathymetry served as a benchmark for the comparison of all future model alternative tests. In this manner, the actions of any alternative, such as new channel improvement structures, realignments, etc., were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative test and the replication test by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place. The resultant bathymetry of this bed response served as the base test of the HSR model. Plate 17 shows the bed configuration of the HSR Model Replication.

Results of the HSR model base test bathymetry and a qualitative comparison to the aforementioned prototype surveys between Mile 106.0 and Mile 99.0 indicated the following trends:

Table 3: Comparison of Model and Prototype bathymetric trends.

River Mile	Comparison
106.0 – 104.5	Both the model and the prototype surveys showed the thalweg located along the LDB. The prototype's thalweg was deeper. Along the RDB a large depositional bar was apparent in both the model and prototype.
104.5 – 102.0	The depositional bar grew from the RDB towards the LDB in both the prototype and model. The thalweg became shallower, but small scour holes appeared around the ends of the river training structures. The scour holes were slightly more defined in the model.
102.5 – 101.5	The transition of the thalweg from the LDB to the RDB was observed in both the model and the prototype. The crossing was moderately deeper in the prototype than in the model.
101.5 – 99.0	The thalweg was located along the RDB in both the model and in the prototype. Depths in the model were greater than those in the prototype surveys.

4.2 Design Alternative Tests

The testing process consisted of installing alternative structure configurations in the model in an attempt to alter the model bathymetry and velocity distribution in a manner intended to alleviate the repetitive dredging in the UMR 104.0 – 101.5 reach of the Mississippi River. Alternative designs began with an evaluation of concept level river engineering solutions based on the judgment of the design engineer and other engineers consulted. These concept level designs were generally evaluated in the model via high impact / high cost designs to progressively less impact / lower cost designs before reaching an optimized design for a given concept. Evaluation of each alternative was accomplished through a qualitative comparison to the model base test bathymetry.

Alternative 1: (Plate 18)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.50	RDB	1,140
Install Trail Dike	103.30	RDB	4,640

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
Structures tested were designed to terminate at a point along a 1500' navigation channel stabilization line. It was shown that there was likely insufficient energy along the RDB (inside of a bend) to deepen the channel and prevent the RDB sandbar from encroaching on the navigation channel.

Alternative 2: (Plate 19)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	104.3	LDB	8,810

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	No

Additional Comments
This alternative utilizes the energy along the LDB on the outside of the bend. However, because this alternative involves a structure that extends downstream of the opening to Rockwood Chute, this alternative would likely reduce the flows within Rockwood Chute.

Alternative 3: (Plate 20)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.40	LDB	4,290

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	No

Additional Comments
This alternative is similar to Alternative 2, but with less upstream construction. It utilizes the energy along the LDB on the outside of the bend. However, because this alternative involves a structure that extends downstream of the opening to Rockwood Chute, this alternative would likely reduce the flows within Rockwood Chute.

Alternative 4: (Plate 21)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.20	LDB	850
Repair Dike	103.10	LDB	600
Install Dike	102.30	LDB	680

Bathymetry

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative had generally positive results, but raising the 600' section of Dike 103.1 could significantly impact the flows going into Rockwood Chute. Existing scour at the upstream end of Rockwood Island would likely be exacerbated by this alternative.

Alternative 5: (Plate 22)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Repair Dike	103.10	LDB	600

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	No

Additional Comments
This alternative could significantly impact the flows entering Rockwood Chute. It also would likely increase the scour at the upstream end of Rockwood Island.

Alternative 6: (Plate 23)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Remove Dike	102.20	LDB	1,475

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
This alternative was done to investigate the effect of Dike 102.2L on the current bathymetry.

Alternative 7: (Plate 24)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Repair Dike	103.10	LDB	700
Remove Dike	102.20	LDB	1,475

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	No

Additional Comments
This alternative was done to investigate the possibility of establishing a secondary channel behind the sandbar along the LDB at RM 102.

Alternative 8: (Plate 25)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Weir	103.40	LDB	200
Install Weir	103.20	LDB	250

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was intended to begin understanding how additional bendway weirs would impact the bathymetry through the bend.

Alternative 9: (Plate 26)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.60	LDB	890
Install Trail Dike	103.40	LDB	1,470
Install Dike	102.30	LDB	1,140

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
While this alternative showed some positive results, the thalweg alignment near RM 103.5 would likely be problematic for navigation. It's also likely that the sandbar along the RDB would still encroach on the navigation channel periodically.

Alternative 10: (Plate 27)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.60	LDB	890
Install Trail Dike	103.40	LDB	1,470
Install Dike	102.30	LDB	1,030

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
This alternative was meant to build off of Alternative 9, evaluating what impact a shorter dike at RM 102.3L would have.

Alternative 11: (Plate 28)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	104.40	LDB	5,560

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
This alternative was tested to evaluate the impact of working farther upstream with a trail dike with tiebacks along the LDB.

Alternative 12: (Plate 29)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	470
Install Rootless Dike	103.30	RDB	365
Install Rootless Dike	103.10	RDB	215
Install Rootless Dike	102.60	RDB	110
Install Rootless Dike	103.50	RDB	140
Install Dike	104.10	LDB	265
Install Dike	103.90	LDB	370
Install Weir	103.40	LDB	310
Install Weir	103.20	LDB	510
Install Dike	102.30	LDB	850

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
This alternative was an attempt to evaluate a 1200' channel constriction through the UMR 104.0 – 102.5 reach.

Alternative 12A: (Plate 30)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	575
Install Rootless Dike	103.30	RDB	370
Install Rootless Dike	103.10	RDB	280
Install Rootless Dike	103.60	RDB	230
Install Rootless Dike	102.40	RDB	180
Install Rootless Dike	102.20	RDB	200
Install Rootless Dike	102.00	RDB	200
Install Dike	104.10	LDB	265
Install Dike	103.90	LDB	370
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Trail Dike	103.15	LDB	1,020
Install Dike	102.30	LDB	850
Extend Dike	101.80	LDB	310

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was similar to Alternative 12, with the addition of more structures including two additional rootless dike extensions at the downstream end of the bend (Dike 102.0R and Dike 102.2R). Also, the addition of Trail Dike 103.15L provided additional navigation channel depth, but would likely impact flows in Rockwood Chute.

Alternative 12B: (Plate 31)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	575
Install Rootless Dike	103.30	RDB	370
Install Rootless Dike	103.10	RDB	280
Install Rootless Dike	103.60	RDB	230
Install Rootless Dike	102.40	RDB	180
Install Rootless Dike	102.20	RDB	200
Install Rootless Dike	102.00	RDB	200
Install Dike	104.10	LDB	265
Install Dike	103.90	LDB	370
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Trail Dike	103.15	LDB	1,020
Restore Dike	103.10	LDB	1,400
Install Dike	102.30	LDB	850
Extend Dike	102.20	LDB	165
Extend Dike	101.80	LDB	310

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was similar to Alternative 12A, with the addition of the restoration of Dike 103.1L, at the entrance to Rockwood Chute. This change is likely to negatively impact the flows entering Rockwood Chute.

Alternative 12C: (Plate 32)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	575
Install Rootless Dike	103.30	RDB	370
Install Rootless Dike	103.10	RDB	280
Install Rootless Dike	103.60	RDB	230
Install Rootless Dike	102.40	RDB	180
Install Rootless Dike	102.20	RDB	200
Install Rootless Dike	102.00	RDB	200
Install Dike	104.10	LDB	265
Install Dike	103.90	LDB	370
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Dike	102.30	LDB	850
Extend Dike	102.20	LDB	165
Extend Dike	101.80	LDB	310

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was similar to Alternative 12B, but without the trail dike structure at RM 103.15L, which would likely impact the flows entering Rockwood Chute. This was done to evaluate the need for this structure.

Alternative 13: (Plate 33)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install BEDS	103.40	LDB	1,350
Install BEDS	103.20	LDB	1,350
Install BEDS	103.10	LDB	2,300
Install BEDS	102.60	LDB	1,600
Install BEDS	102.30	LDB	2,400
Install BEDS	102.20	LDB	2,200
Install BEDS	102.00	LDB	2,250

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	No

Additional Comments
This alternative was done to evaluate the use of a new and innovative type of structure constructed below average bed elevations intended to utilize the energy associated with bedload transport to deepen the navigation channel. These structures are tentatively referred to as Bedload Energy Distribution Structures (BEDS).

Alternative 14: (Plate 34)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	575
Install Rootless Dike	103.30	RDB	370
Install Rootless Dike	103.10	RDB	280
Install Rootless Dike	103.60	RDB	230
Install Rootless Dike	102.40	RDB	180
Install Dike	103.90	LDB	370
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Trail Dike	103.15	LDB	1,020
Repair Dike	103.10	LDB	1,400
Install Dike	102.30	LDB	850

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was similar to Alternative 12B, but with one less structure along the LDB at the upstream end of the UMR 104.0 to 102.5 reach.

Alternative 15: (Plate 35)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	345
Install Rootless Dike	103.30	RDB	250
Restore Existing Dike	103.10	RDB	210
Install Rootless Dike	103.60	RDB	120
Install Rootless Dike	102.40	RDB	175
Install Dike	103.90	LDB	165
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Trail Dike	103.15	LDB	850
Repair Dike	103.10	LDB	1,400

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was similar to Alternative 13, but without a structure at RM 102.1L. This was done to evaluate the need for this structure in the design.

Alternative 16: (Plate 36)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	345
Install Rootless Dike	103.30	RDB	250
Install Rootless Dike	103.10	RDB	210
Install Rootless Dike	103.60	RDB	120
Install Rootless Dike	102.40	RDB	175
Install Dike	103.90	LDB	165
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Repair Dike	103.10	LDB	1,400
Install Dike	102.30	LDB	1,215

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was similar to Alternative 12C, but with less structure along the LDB at the downstream end of the UMR 102.5 – 101.5 reach.

Alternative 17: (Plate 37)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	345
Install Rootless Dike	103.30	RDB	250
Install Rootless Dike	103.10	RDB	210
Install Rootless Dike	103.60	RDB	120
Install Rootless Dike	102.40	RDB	175
Install Dike	103.90	LDB	165
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Dike	103.15	LDB	520
Repair Dike	103.10	LDB	1,400

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was very similar to Alternative 15, but without the trail on the end of Dike 103.15L. This was done to evaluate the need for the trail on this structure.

Alternative 18: (Plate 38)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	345
Install Rootless Dike	103.30	RDB	250
Install Rootless Dike	103.10	RDB	210
Install Rootless Dike	103.60	RDB	120
Install Dike	103.90	LDB	165
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Dike	103.15	LDB	520
Repair Dike	103.10	LDB	1,400

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
No	Yes

Additional Comments
This alternative was very similar to Alternative 17, but without the Rootless Dike Extension at RM 102.4R. This was done to evaluate the need for this structure.

Alternative 19: (Plate 39)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Rootless Dike	103.50	RDB	345
Install Rootless Dike	103.30	RDB	250
Install Rootless Dike	103.10	RDB	210
Install Rootless Dike	103.60	RDB	120
Install Dike	103.90	LDB	165
Install Weir	103.40	LDB	725
Install Weir	103.20	LDB	900
Install Dike	103.15	LDB	520

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was very similar to Alternative 18, but without the restoration of Dike 103.1L. This was done to evaluate the need for restoring this structure.

Alternative 20: (Plate 40)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Trail Dike	103.20	LDB	860

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was done to evaluate a minimalist approach to construction in this reach to reduce the need for dredging.

Alternative 21: (Plate 41)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.60	LDB	800
Install Trail Dike	103.40	LDB	700
Install Trail Dike	103.20	LDB	860
Install Dike	102.30	LDB	1,300

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was done to evaluate an approach involving aligning the structures along the outside of a bend to establish a more hydraulically efficient navigation channel through the UMR 104.0 to 101.5 reach.

Alternative 22: (Plate 42)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Remove Partial Dike	103.10	LDB	425
Install Dike	102.30	LDB	1,300

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was similar to Alternative 21, but with a shortening of Dike 103.1L. This was done in recognition that Dike 103.1L extended further into the navigation channel than any other structure along the LDB.

Alternative 23: (Plate 43)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Dredge Disposal Island Capped With "A" Size Rock	103.50	RDB	2100 x 650

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was done to test out another innovative idea involving covering the area typically used for dredge disposal near RM 103.0 along the RDB sandbar with a layer of A-Stone.

Alternative 24: (Plate 44)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Remove Partial Dike	103.10	LDB	425
Install Chevron	102.30	LDB	300 x 300
Install Dike	102.00	LDB	1,150

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
After further review of the Alternative 22 test results, AREC engineers decided that additional testing of an alternative similar to Alternative 22 was warranted. Alternative 24 was similar to Alternative 22, but with a chevron at RM 102.3L (as opposed to the 1,300 ft dike at 102.3L) and a new dike at RM 102.0L. This change was made to evaluate the performance of the chevron and downstream dike in creating additional depth at the UMR 102.5 – 101.5 channel crossing. Alternative 24 was marginally more effective in creating depth through this crossing when compared to Alternative 22.

Alternative 25: (Plate 45)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.80	LDB	350
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Remove Partial Dike	103.10	LDB	425
Install Rootless Dike	102.30	LDB	550
Install Rootless Dike	102.00	LDB	550

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
Alternative 25 was similar to Alternative 24, but with different structure configurations at the downstream end of UMR 104.0-101.5 along the LDB. Flow visualization testing on Alternative 25 was also performed to demonstrate how this alternative may affect the flows entering Rockwood Chute and / or the sandbar adjacent to Rockwood Island. The flow visualization test results confirmed the bathymetry analysis that no significant impact is expected. Flow visualization test results are shown on Plate 49.

Alternative 26: (Plate 46)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	450
Remove Partial Dike	103.10	LDB	425
Install Rootless Dike	102.30	LDB	550
Install Rootless Dike	102.00	LDB	550

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
Alternative 26 was similar to Alternative 25, but without any changes to Dike 103.8L at the upstream end of the UMR 104.0 to 101.5 reach.

Alternative 27: (Plate 47)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Remove Partial Dike	103.10	LDB	425

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
No	Yes

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was done to evaluate the effectiveness of making changes only to Dike 103.1L.

Alternative 28: (Plate 48)

Type of Structure	Miles	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.80	LDB	350
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Remove Partial Dike	103.10	LDB	425

Bathymetry Analysis

Likely to Reduce Dredging Along UMR 104.0-102.5 RDB Sandbar?	Likely to Reduce Dredging at UMR 102.5-101.5 Channel Crossing?
Yes	No

Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Yes	Yes

Additional Comments
This alternative was done to evaluate the necessity of the two MRS Dikes at UMR 102.3L and 102.0L.

5 Conclusions

5.1 Evaluation and Summary of the Model Tests

Table 4: Summary of Model Test Results

Test	Reduce Dredging Along RDB Sandbar (UMR 104.0-102.5)	Reduce Dredging / Deepen the Channel Crossing (UMR 102.5-101.5)	Minimal Impact on Flow into Rockwood Chute?	Minimal Impact on LDB Sandbar adjacent to Rockwood Island?
Alternative 1	No	No	Yes	Yes
Alternative 2	Yes	Yes	No	No
Alternative 3	Yes	Yes	No	No
Alternative 4	Yes	Yes	No	Yes
Alternative 5	No	Yes	No	No
Alternative 6	No	No	Yes	No
Alternative 7	No	No	No	No
Alternative 8	No	No	Yes	Yes
Alternative 9	Yes	Yes	Yes	No
Alternative 10	No	No	Yes	No
Alternative 11	No	No	Yes	No
Alternative 12	No	No	Yes	No
Alternative 12A	Yes	Yes	No	Yes
Alternative 12B	Yes	Yes	No	Yes
Alternative 12C	No	Yes	Yes	Yes
Alternative 13	No	No	Yes	No
Alternative 14	Yes	Yes	No	Yes
Alternative 15	Yes	Yes	No	Yes
Alternative 16	No	Yes	No	Yes

Alternative 17	No	Yes	No	Yes
Alternative 18	No	Yes	No	Yes
Alternative 19	Yes	No	Yes	Yes
Alternative 20	Yes	No	Yes	Yes
Alternative 21	No	Yes	Yes	Yes
Alternative 22	Yes	Yes	Yes	Yes
Alternative 23	No	No	Yes	Yes
Alternative 24	Yes	Yes	Yes	Yes
Alternative 25	Yes	Yes	Yes	Yes
Alternative 26	Yes	Yes	Yes	Yes
Alternative 27	Yes	No	Yes	Yes
Alternative 28	Yes	No	Yes	Yes

Most alternatives were implemented in the model to encourage the navigation channel to follow a path closer to the Right Descending Bank (RDB) than the river has shown a tendency to take in recent years. This was done with the goal of utilizing the river's energy to prevent or reduce problem sandbar encroachment on the navigation channel from the RDB side of the river. Overall, this approach was shown to be less effective than an approach taken in the 4 most successful alternatives. These were Alternatives 22, 24, 25, and 26. These alternatives focused on working within the existing river trends in this reach and reworking existing structures to be more effective in establishing a dependable navigation channel. Of these alternatives, it was determined that Alternative 25 was the most effective in reducing or eliminating the need for repetitive channel maintenance dredging in the future. Alternative 25 was more effective than Alternative 22, 24, and 26 at reducing the need for dredging along the RDB sandbar between RM 104.0 and 102.5. Alternative 25 included an adjustment to the length and trail dike configuration of Dike 103.8L (which Alternatives 22, 24, and 26 did not) that allows a wider navigation channel through this reach. Additionally, comparison of the bathymetry results of these alternatives showed that the utilization of new MRS Dikes at RM 102.3 and 102.0 along with an 860 ft trail dike off the end of Dike 103.2L (along with the removal of 425 ft of Dike 103.1L, which is included in Alternatives 22, 24, 25, and 26) was necessary to minimize the potential for future repetitive channel maintenance dredging in the channel crossing between RM 102.5 and RM 101.5. During the alternative development process, natural resource agency partners expressed concern about flow impacts into Rockwood Chute and along the sandbar adjacent to Rockwood Island. Therefore, alternatives were developed to avoid and/or minimize these impacts. Flow

Visualization test results on Alternative 25 (see Plate 49) indicated that there will be no significant impacts to the flows entering Rockwood Chute and the model bathymetry for Alternative 25 demonstrated no significant change to the sandbar along the river side of Rockwood Island, avoiding any impact to the sandbar habitat.

5.2 Recommendations

Based on the analysis discussed above, Alternative 25 is the recommended alternative.

Construction of Alternative 25 will involve reconfiguring the planform layout of Dike 103.8L, Dike 103.6L, Dike 103.4L, and Dike 103.2L. Each of these structures should be restored to a height equal to the height of the newly configured dike trail in order to prevent river flows from flanking the structure.

The elevation of the remaining section of Dike 103.1 (after degradation of the riverward 425') should remain unchanged. The elevation of this structure is likely an integral component in maintaining the flows entering Rockwood Chute.

Funding limitations could result in a need to construct Alternative 25 in phases. Based on modeling results, it is not anticipated that there would be a significant benefit to any particular order of construction (i.e., upstream to downstream or vice versa).

Table 5: Recommended Alternative.

Type of Structure	Location (River Mile)	LDB or RDB	Dimensions in Feet (Plan View)
Install Dike	103.90	LDB	165
Install Trail Dike	103.80	LDB	350
Install Trail Dike	103.60	LDB	410
Install Trail Dike	103.40	LDB	500
Install Trail Dike	103.20	LDB	860
Degrade Riverward Section of Existing Dike	103.10	LDB	425
Install Rootless MRS Dike	102.30	LDB	550
Install Rootless MRS Dike	102.00	LDB	550

5.3 Interpretation of Model Test Results

In the interpretation and evaluation of the model test results, it should be remembered that these results are qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodible variables. Flood flows were not simulated in this study.

This model study was intended to serve as a tool for the river engineer to guide in assessing the general trends that could be expected to occur in the actual river from a variety of imposed design alternatives. Measures for the final design may be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirements.

6 For more information

For more information about micro modeling or the Applied River Engineering Center, please contact Jasen Brown or David Gordon at:

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8 APPENDIX 2: HSR MODELING THEORY

The principle behind the use of a hydraulic sediment response model is similitude, the linking of parameters between a model and prototype so that behavior in one can predict behavior in the other.

There are two different types of similitude; mathematical similitude and empirical similitude. Mathematical similitude is founded on the scale relationship between all linear dimensions (geometric similarity), a scale relationship between all components of velocity (kinematic), or both geometric and kinematic similarity with the ratio of all common point forces equal (dynamic similarity).

In contrast to mathematical similitude, empirical similitude is based on the belief that the laws of mathematical similitude can be relaxed as long as other more fundamental relationships are preserved between the model and the prototype. All physical models used in the past by USACE employed, to some degree, empirical similitude. Numerous definitions of what relationships must be preserved have been put forward concerning physical sediment models. These relationships often deal with the scalability of elements of sediment transport processes or surface or structure roughness. Hydraulic sediment response models depend on similitude in the morphologic response, i.e. the ability of the model to replicate known prototype parameters associated with the bed response in the river under study. Bed response includes thalweg location, scour and deposition within the channel and at various river structures, and the overall resultant bed configuration. These parameters are directly compared to what is observed from prototype surveys.

Detailed cross-sectional analysis of prototype and model surveys defining bed response and bed configuration have shown that HSR model variation from the prototype is often approximately that of the natural variation observed in the prototype. This correspondence allows hydraulic engineers to use the HSR model with confidence and introduce alternatives in the model to approximate the bed response that can be expected to occur in the prototype.

HSR models were developed from empirical large scale coal bed models utilized by the USACE Waterways Experiment Station (now named the Environmental Research and Development Center, or ERDC). These models were used by MVS from 1940 to the mid-1990s. For a more thorough explanation of the early ERDC model development, please refer to the following link:

http://www.erdc.usace.army.mil/