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St. Louis District

UPPER MISSISSIPPI RIVER
BOSTON BAR BI-OP 2011
HYDRAULIC SEDIMENT RESPONSE MODEL STUDY

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation improvement study of the Mississippi River at Boston Bar from RM 10.2 to RM 7.6. Approximately 3.4 miles of Boston Chute was also studied. As part of the pilot project portion of the Biological Opinion (Bi-Op) program, this study was funded by the U.S. Army Corps of Engineers, St. Louis District.

The study was conducted between May 2011 and October 2011 at the Applied River Engineering Center (AREC), U.S. Army Corps of Engineers, St. Louis District. The study was performed by Mr. Ivan H. Nguyen, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, P.E., Chief of River Engineering Section for the St. Louis District. Additional personnel from the St. Louis District included: Mr. Leonard Hopkins, P.E., Chief of Hydrologic and Hydraulic Branch, Ms. Ashley N. Cox, Hydraulic Engineer, Mr. Jason Floyd, Engineering Technician, Mr. Jasen L. Brown, P.E., Hydraulic Engineer, Ms. Emily Rivera, Student Co-Op, and Ms. Dana Fischer, Student Co-Op.

Personnel involved in overseeing this study and supplying knowledge and critical river data included: Mr. Brian L. Johnson, Chief of Environmental Planning Section, Mr. Lance Engle, Dredge Manager, Mr. Shawn Kempshall, River Surveyor, and Mr. Michael T. Rodgers, Project Manager. Personnel from other agencies involved in the study included: Mr. Atwood Butch from the Illinois Department of Natural Resource, Mr. Matthew Mangan from the U.S. Fish and Wildlife, Mr. Dave Knuth from the Missouri Department of Conservation, and Mr. Bernard Heroff from the Archer Daniels Midland Company (Industry Barges).

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BACKGROUND

1. Problem Description

Side channels are a critical biological component of the Mississippi River. Most side channels within the Middle Mississippi River (MMR) lack bathymetric diversity. They contained relatively few scour holes and had uniform bed response at high elevation. Boston Chute, located along the left descending bank (LDB) of the Mississippi River between River Miles (RM) 10.2 and RM 7.6, experienced similar problems. The chute was very shallow and connected to the Mississippi River only during high flows. Sedimentation is a problem in Boston Chute mainly due to closure structures and the back flooding of the Ohio River. There is a critical need to rehabilitate and conserve these critical aquatic habitats.

2. Study Purpose and Goals

The purpose of this study was to address the need for additional biologic habitat inside Boston Chute as well as adjacent to Boston Bar, and communicate the results of the analysis of various river engineering measures.

The goals of the study were to:

i. Investigate and provide analysis on the existing flow mechanics of the Mississippi River near Boston Bar.
ii. Calibrate a Hydraulic Sediment Response (HSR) model to replicate prototype bathymetry and velocity distribution of the Mississippi River near Boston Bar.
iii. Evaluate a variety of remedial measures utilizing the HSR model with the objective of identifying the most effective and economical plan to enhance biologic diversity within Boston Chute as well as adjacent to Boston Bar.
iv. Communicate to environmental agencies, other Corps personnel, and river industry personnel the results of the HSR model tests and the plans for improvements.

3. Study Reach

The study reach was located between Scott County in Missouri and Alexander County in Illinois. Boston Bar, located along the LDB of the Mississippi River, between RM 10.2 and RM 7.6, covers an area of approximately 2860 acres. Plate (1) is a location and vicinity map of the study reach.

A. Structures

Plate (2) is a 2010 aerial photograph illustrating the planform and nomenclature of the Lower Mississippi River between RM 12.0 and 6.0. At the time of this study, the study reach had a total of 43 structures: 2 closure structures within Boston Chute, 2 L-dikes, 4 notched dikes, 26 longitudinal dikes, and 9 weirs. The right descending bank (RDB) was completely revetted except at the dike field between RM 10.10 and 9.40.

There was a pile dike (Dike 10.30L) located across the upstream end of Boston Chute and a rock closing structure (Dike 7.90L) located across the lower end of Boston Chute. These structures acted as closure structures. However, Dike 7.90L appeared to control the flow through Boston Chute because it was constructed of rock, while Dike 10.30L was constructed of wood piles and allowed more flow to pass through it.

B. Average Annual Hydrograph

Plate (5) shows the monthly average annual hydrograph (data from entire period of record) from four nearby gage locations compared to height of Dike 7.90L (+11 feet LWRP). Graphs of these average annual hydrographs indicated that during the period from August 1 to November 30, the water level was typically below the closure structure height. This likely contributed significantly to the shallow depths within Boston Chute. Plate (6) shows 2006 helicopter photographs of Boston Bar and Boston Chute closure structures where the river stage was below +11 feet LWRP.

C. Boston Chute

Boston Chute had an average width of approximately 250 feet, ranging from 125 to 550 feet. There were two secondary channels just upstream on the island; however these have been filled with sediment. According to a 2010 & 2011 hydrographic surveys of Boston Chute, the average bottom elevation was about +5 feet LWRP. See Plate (4)

D. Real Estate

In this reach, most land is agricultural. However, the island is considered non-farmland. Boston Bar was mainly used for paper production and cottonwood or sycamore planting on an 8-10 year rotation. It was owned by Christine Chambliss. The area upstream of Boston Bar between RM 10.6 and 11.2 along the Illinois side was owned by John Waggener and Christine Wolford. Along the Missouri bank, RM 10.0 to 9.4 was owned by Norbert Rowling, RM 10.3 to RM 10.1 was owned by Margaret Stricker, and RM 10.3 and up is owned by Stallings Farms.

E. Geomorphology

To understand the planform of the river near Boston Bar, an investigation was conducted on the historical changes, both manmade and natural, those lead up to the present day condition. Plate (7) shows geomorphic planform changes between RM 12.0 and 4.0 encompassing the years from 1917 to 2003, and was sourced from "Geomorphology of the Middle Mississippi River" produced by the St. Louis District (2005). Historic aerial photographs revealed that the Mississippi River channel in the area of Boston Bar had changed significantly over time. Numerous dike and weir fields were built along both descending banks. These river training structures caused the study reach to change. Plate (2) shows all existing structures within the reach and the condition as of 2010.

The 1928 aerial photo Plate (8) of the project area showed Boston Bar smaller and Boston Chute wider than its 2010 dimensions. The I-57 Bridge was not constructed until 1978. Between 1928 and 1978, there were two islands in the middle of the Mississippi channel. The difference between 1928 and 2010 aerial photos can be seen on Plates (9).

The 1968 Aerial photograph (Plate 10) showed most of the structures in the reach were in place and the river planform was very similar to that of the 2010 aerial photograph. The difference between the 1968 and 2010 aerial photos was that Boston Bar had two separate inflow channels that combined into one outflow channel. However, the upstream inflow channel slowly filled in while the downstream channel remained open. The difference between 1968 and 2010 aerial photos can be seen on Plates (11). Plate (12) through (15) shows historic aerial photographs taken in 1942, 1956, 1976, and 1982 of Boston Bar and Boston Chute.

F. Recent Construction

There were three recent construction efforts near Boston Bar reach. In FY09, Dikes 9.40L and 9.20L were notched. In FY10 Dike 8.3L was notched. In FY11, Dike 8.7L was notched. Surveys in the immediate area of the dike notches indicated that the notches created scour holes and bathymetric diversity. Plate (4) shows a post construction hydrographic survey.

G. Environmental Features

According to biologists in the Environmental Branch of the Corps of Engineers, St. Louis District, only one mussel bed existed within the study reach, around I-57 bridge pier. See Plate (2).

H. Study Reach Channel Characteristics and General Trends

i. Mississippi River

The thalweg entered the study reach along the RDB between RM 12.0 – 11.2, and transitioned to the LDB between RM 11.2-10.7, where it remained until RM 7.5. Shoaling occurred along the LDB between RM 10.0 and 9.0 with depths ranged from -15 feet and -5 feet LWRP. At the I-57 Bridge crossing, the thalweg shifted back to the LDB. At this location (RM 7.5-6.8), depths between -35 feet and -15 feet LWRP were observed. The survey showed adequate navigation depths, however, in reality many areas of the channel shoal considerably, and the survey reflects the channel is being artificially maintained by dredging. An example where the bar between RM 10.2 and 7.6

has shoaled prior to the dredge cut is shown on Plate (20) in the 2008 hydrographic survey. The 2010 and 2011 combined hydrographic surveys (Plate 4) showed post dredge conditions.

Hydrographic surveys from the last 10 years showed periodic shoaling occurred in the navigation channel between RM 11.65 and RM 10.80, RM 9.6 and RM 8.5, as well as between RM 7.40 and RM 6.35. This aggradation has created dredging issues at three locations. Plate (16) shows three main dredging locations located within the study reach. Also, Plate (17) through (22) shows hydrographic surveys taken in 1998, 2005, 2006, 2008 and 2009. Boston Chute was not included in these surveys.

ii. Boston Chute

The 2010 and 2011 combined hydrographic survey, Plate (4), showed significant sediment deposition within Boston Chute at the entrance and exit. This aggradation has limited the flow coming into the chute, which makes the chute limited in providing adequate aquatic habitat. A meander pattern was observed at the entrance of Boston Chute with depths between -10 feet to +5 feet LWRP. The thalweg within this meandering side channel entrance crossed from bank to bank three times before the bathymetry flattened out at +10 ft LWRP thru RM 7.8. A scour hole caused by Closure Dike 7.90L had depths that were up to -20 feet LWRP.

I. Field Observation

Personnel from the Applied River Engineering Center inspected the study reach on August 1, 2011. This visit allowed the site to be photographed and studied. Sediment samples were taken in three locations inside Boston Chute. It was found that the materials inside Boston Chute were primarily clay with some mixed sand. The area along Boston Bar in the main channel between RM 9.0 and 8.0 yielded the same result. However, two sediment samples taken at the dredge area in the main channel at RM 8.5 were found to have mostly sand. Photographs from the site visit can be seen on Plate (23).

HSR MODELING

An HSR model study was conducted for the purpose trying to increase flow through Boston Chute and also creating sustainable islands or isolated band bars along the main channel. All of these measures were studied so as not to increase repetitive dredging in the main channel.

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the conditions in the river at the time of the model study. Replication of the model was achieved during calibration and involved a three 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 the 2010 high resolution aerial photography. Various other fixed boundaries were also introduced into the model including any channel improvement structures, underwater rock, clay and other non-mobile boundaries.

Second, “loose” boundary conditions of the model were developed. 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, steady state discharge simulation tests were run through the model. Adjustment of the discharge, sediment volume, model slope, fixed boundaries, and entrance conditions were refined during these tests as part of calibration. The mobile bed developed from a static, flat, arbitrary bed into a fully-formed, dynamic, and three dimensional bed responses. The resulting bed configuration was surveyed numerous times during the calibration tests and compared to recent river bathymetry. Repeated tests were simulated for the assurance of model stability and repeatability. When the general trends of the model bed bathymetry were similar to observed recent river bathymetry, and the tests were repeatable, the model was considered replicated and alternative testing then began.

2. Scale and Bed Materials

The HSR model employed a horizontal scale of 1 inch = 500 feet, or 1:6,000, and a vertical scale of 1 inch = 58 feet, or 1:696, for an 8.6 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. Plate (24) is a photograph of the Boston Bar HSR model used in this study.

3. Appurtenances

The HSR model insert planform was constructed according to the 2010 high-resolution aerial photography of the study reach. The insert was then mounted in a standard HSR model flume. The riverbanks of the model were constructed from dense polystyrene foam, clay, and polymesh to develop proper bendway mechanics. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.008 inch/inch. River training structures in the model were constructed of galvanized steel mesh to generate appropriate scaled roughness.

4. Flow Control

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to control the flow of water and sediment into the model. For all model tests, flow entering the model was held steady at 3.0 Gallon per Minutes (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the actual river, this steady state flow was used to replicate existing conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. Data Collection

Data from the HSR model was collected with a three dimensional (3D) laser scanner and flow visualization.

A. 3-D Laser Scanner

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 georeferenced to real world coordinates and triangulated to create a 3D surface. The surface was then color coded by elevation using standard color tables that are also used in color coding prototype surveys. This process allowed a direct comparison between HSR model bathymetry surveys and prototype bathymetry surveys.

B. Flow Visualization

Flow visualization is a tool used to monitor the flow patterns in a HSR model. The preferred method at the Applied River Engineering Center is to dye the water black and seed the water surface with dry white sediment (Poly-Urea-grit) at the model entrance. The dry sediment floats on the top of the water surface and provides a visual representation of surface flow patterns in the model. A high definition video camera is used to record approximately 30 seconds of the sediment floating through the study area. The recording is processed with software that reduces the original recording to approximately 20% of the original speed. The video speed reduction allows viewer to more easily track the flow patterns.

6. Replication Test

Once model replication was achieved through the calibration process, 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, side channel modifications, etc, were compared directly to the replicated condition. General trends were evaluated for any major differences positive or negative between the alternative and the replication by comparing the surveys of the two and also carefully observing the model while the actual testing was taking place.

Plate (25) shows the results of the replication test. Plate (26) is a detailed comparison between the 2010 & 2011 combined hydrographic survey of Boston Bar and the model replication. The 1998 survey of the Mississippi River was also used when comparing the model to prototype. As observed in both prototype surveys and the model, the thalweg was located along the LDB before crossing to the RDB between RM 12.0 and 11.0, where it remained until RM 8.0. Sediment deposition was observed in the dike fields along the LDB from the model entrance to RM 7.0 and had depths that ranged between +10 feet to -5 feet LWRP. Between RM 10.2 and 7.6, the main channel experienced excessive sediment deposition with depths approximately +5 feet LWRP.

A scour hole was observed at RM 10.8 as the thalweg crossed from the LDB to the RDB with depths of approximately -30 feet LWRP. The thalweg then passed through a dike field and descended through a sharp bend before it crossed over to the LDB at RM 7.0 with depths ranged between -40 feet and -25 feet LWRP. Adjacent to the dike field, two scour holes were observed from two notched dikes (Dike 9.40L and 9.20L) had depths as low as -20 feet LWRP. Both the model and prototype showed similar trends

Similar to the prototype, Boston Chute had depths that ranged between +10 feet and 0 feet LWRP. Approximately one mile down the chute, depths decreased to +10 feet LWRP and remained constant to RM 7.8. The scour hole caused by closure structure 7.9L had depths that were as low as -10 feet LWRP. However, the scour hole did not extend further downstream in the chute as it entered the Mississippi. Deposition occurred at both the entrance and exit condition of Boston Chute in both the model and prototype with depths up to +10 feet LWRP.

The trends in the crossing of the main channel between RM 7.5 and 7.0 and the deposition that occurred along the bar along the RDB were very similar in both the model and the prototype. The crossing in the model had depths that ranged between -20 feet and -10 feet LWRP while the prototype had greater depths that were as deep as

-30 feet LWRP. The thalweg crossed over a weir field from RM 7.0 to end of study reach with depths between -40 feet and -30 feet LWRP in both the model and prototype.

7. Design Alternative Testing

Design alternative testing involved two phases of study. Phase 1 involved the testing of disposable locations for dredge material for the creation of island or shallow sandbar adjacent to Boston Bar. Phase 2 involved the testing of various structural alternatives intended to increase flow in Boston Chute.

A. Phase I: Island Creation

U.S. Army Corps of Engineers (USACE) personnel and agency partners have desired for a number of years to use dredge material as sandbar and island habitat because of its potential to increase the populations of endangered bird species such as the Least Tern and American Avocet. The HSR Model was used with the purpose of determining the best location for dredge disposal area adjacent Boston Bar.

In all alternatives, dredge disposal areas were studied under dominant, steady state energy conditions. This was accomplished in order to simplify testing and observe general long term trends at the tested disposable location. Tests were conducted to examine whether the dredge disposal area would erode due to the flow of the river. The design height for the dredge disposal area was set to +30 ft LWRP. This was accomplished by placing a scoop of sediment, roughly 1.5 inches in diameter in the model (or 450,000 sq. ft scaled to real world size), at the proposed locations while the model was still running. This was to simulate actual dredging events. Each test was run for 30 minutes to allow the model bed time to sufficiently respond to changes. The resultant dredge disposal area was closely analyzed for any changes in size and depth.

Alternative 1: Dredge Disposal Area 8.4L

Plate (27) shows the bathymetry of Alternative 1. The dredge disposal area was located 500 feet off the LDB at RM 8.4 between two notched dikes, Dike 8.70L and Dike 8.30L. The goal of this alternative was to utilize Dike 8.70L to protect the dredge disposal area.

Table1: Alternative 1 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.4	500	30	30	500,000	350,000

Test results indicated that the dredge disposal area did not scour away due to the flow of the river. The resultant dredge disposal area measured approximately 350,000 sq. ft in area and had depths at roughly +30 feet LWRP. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 2: Dredge Disposal Area 8.1L

Plate (28) shows the bathymetry of Alternative 2. The dredge disposal area was placed 500 feet off the LDB at RM 8.1 between three notched dikes, Dike 8.30L, 8.25L and 8.0L. The goal of this alternative was to utilize Dike 8.30L and Dike 8.70L to protect the dredge disposal area.

Table 2: Alternative 2 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	280,000

Test results indicated that the dredge disposal area did not scour away due to the flow of the river. The resultant dredge disposal area measured approximately 280,000 sq. ft in area and had depths at roughly +30 feet LWRP. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal area. Based on observations, the proposed area had the lowest energy. This made sense because it is inside of a bend and there are two structures, one upstream and one downstream, to help protect the dredge disposal area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 3: Dredge Disposal Area 8.9L

Plate (29) shows the bathymetry of Alternative 3. The dredge disposal area was placed 300 feet off the LDB of Boston Bar at RM 8.9 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to utilize Dike 9.20L to redirect protect the dredge disposal area.

Table 3: Alternative 3 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.9	300	30	16	450,000	125,000

Test results indicated that the dredge disposal area scoured significantly due to the flow of the river. Observations showed that the flow coming off notched Dike 9.20L was causing the scour. The dredge disposal area depths decreased from +30 feet LWRP to +16 feet LWRP while surface area reduced in half to approximately 125,000 sq. ft in area. The dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 4: Dredge Disposal Area 8.8L

Plate (30) shows the bathymetry of Alternative 4. The dredge disposal area was placed 300 feet off the LDB of Boston Bar at RM 8.8 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to utilize Dike 9.20L to redirect protect the dredge disposal area.

Table 4: Alternative 4 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.8	300	30	22	450,000	200,000

Test results indicated that the dredge disposal area was scoured significantly due to the flow of the river. Similar to alternative 3, the flow coming off Dike 9.20L was causing the scour. However, the scour was far less. The resultant dredge disposal area measured approximately 200,000 sq. ft in area and had depths at roughly +22 ft LWRP. Overall, the dredge disposal area did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 5: Dredge Disposal Area 8.7L

Plate (31) shows the bathymetry of Alternative 5. The dredge disposal area was placed 200 feet off the LDB of Boston Bar at RM 8.8 between two notched dikes, Dike 9.20L and Dike 8.70L. The goal of this alternative was to move even further away from notch Dike 9.20L.

Table 5: Alternative 5 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.7	200	30	28	450,000	300,000

Test results indicated that the dredge disposal area was far enough that flow coming off Notch Dike 9.20L had insignificant effects. The resultant dredge disposal area was measured at approximately 300,000 sq. ft in area and had depths at roughly +28 ft

LWRP. Most of the available energy for sediment transport was observed along the RDB. Observations and bathymetric surveys showed that the dredge disposal area was stable. Overall, the dredge disposal area also did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 6: Dredge Disposal Area 8.7L

Plate (32) shows the bathymetry of Alternative 6. This alternative placed the dredge disposal area against Boston Bar and Dike 8.70L at RM 8.7. The dredge disposal area would then become an extension of Boston Bar or a shallow sandbar. The goal of this alternative was to utilize both Boston Bar and Dike 8.70L to help protect the dredge disposal area.

Table 6: Alternative 6 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (sq. ft) Before	Area (sq. ft) After
8.7	0	30	24	450,000	200,000

Test results indicated that the dredge disposal area was scoured away due to the flow of the river. The resultant sand bar measured approximately 200,000 sq. ft in area and had depths of roughly +24 ft LWRP. Most of the available energy available for sediment transport was observed along the RDB. Overall, the sand bar did not cause any unwanted problems to the main channel, Boston Bar and Chute.

Alternative 7: Dredge Disposal Areas 8.7L, 8.4L and 8.0L

Plate (33) shows the bathymetry of Alternative 7. This alternative consisted of the combination of Alternatives 1, 2 and 6. The goal of this alternative was to determine the effects of the combining Alternatives 1, 2, and 6, as these 3 alternatives had individually produced favorable resultant bathymetries.

Table 7: Alternative 7 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	300,000
8.4	500	30	30	450,000	400,000
8.7	0	30	24	450,000	350,000

Test results indicated that all three dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas measured approximately 300,000 sq. ft, 450,000 sq. ft, and 350,000 sq. ft in area and had depths at roughly +30 ft, +30 ft, and +24 ft LWRP respectively. Most of the energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 8: Dredge Disposal Areas 8.7L & 8.4L

Plate (34) shows the bathymetry of Alternative 8. This alternative consisted of the combination of Alternative 1 and Alternative 6. The goal of this alternative was to determine the effects of the combining Alternatives 1 and 6, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 8: Alternative 8 Summary

RM	Distance (ft)	Elevation Before	Elevation After	Area (ft^2) Before	Area (ft^2) After

		LWRP (ft)	LWRP (ft)		
8.4	500	30	30	450,000	350,000
8.7	0	30	24	450,000	350,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.7L and 8.4L measured approximately 450,000 sq. ft and 450,000 sq. ft in area and had depths at roughly +30 ft and +24 LWRP respectively. Most of the energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 9: Dredge Disposal Areas 8.7L & 8.0L

Plate (35) shows the bathymetry of alternative 9. This alternative is a combination of alternative 6 and alternative 2. The goal of this alternative was to determine the effects of the combining Alternatives 2 and 6, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 9: Alternative 9 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	375,000
8.7	0	30	24	450,000	300,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.7L and 8.1L measured approximately 375,000 sq. ft, and 300,000 sq. ft in area and had depths at roughly +30 ft and +24 LWRP respectively. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 10: Dredge Disposal Areas 8.4L & 8.0L

Plate (36) shows the bathymetry of Alternative 10. This alternative consisted of the combination of Alternative 1 and Alternative 2. The goal of this alternative was to determine the effects of the combining Alternatives 1 and 2, as these 2 alternatives had individually produced favorable resultant bathymetries.

Table 10: Alternative 10 Summary

RM	Distance (ft)	Elevation Before LWRP (ft)	Elevation After LWRP (ft)	Area (ft^2) Before	Area (ft^2) After
8.1	500	30	30	450,000	380,000
8.4	500	30	30	450,000	380,000

Test results indicated that both dredge disposal areas did not scour away due to the flow of the river. The resultant dredge disposal areas 8.4L and 8.1L measured approximately 380,000 sq. ft, and 380,000 sq. ft in area and had depths at roughly +30 ft and +30 ft LWRP respectively. Most of the available energy available for sediment transport was observed along the RDB. Model bathymetry did not show any significant changes upstream or downstream of the dredge disposal areas. The dredge disposal areas did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

B. Phase II: Structure Tests

The goal of phase II was to analyze various alternatives with the intent of increasing flow and enhancing aquatic habitat diversity inside Boston Chute. This was accomplished by placing, removing and notching river training structures in the model. Similar to Phase I testing, the model was operated for at least 30 minutes to allow the model bed time to sufficiently respond to changes.

Alternative 11: Closure Dike 7.90L

Plate (37) shows the resultant bathymetry of Alternative 11. Closure Structure 7.90L was removed to depth of -10 ft LWRP for the purpose of increasing flow through Boston Chute.

Table 11: Alternative 11 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	7.9	Remove	All	Chute	-10

Test results indicated that model bathymetry did not cause any significant changes when compared to the replication test. However, the scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 12: Dike 10.05L

Plate (38) shows the resultant bathymetry of Alternative 12. This alternative consisted of constructing a new dike located at the tip of Boston Bar at RM 10.05. The new dike measured 500 ft in length, +2 ft LWRP in height, and angled upstream. Dike 10.1L, Dike

10.30L, Dike 7.90L, and Pile Dike 10.10L were removed to a depth of -10 ft LWRP. The goal was to increase flow inside Boston Chute.

Table 12: Alternative 12 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.05	New	500	LDB	+2
Pile	10.10	Remove	All	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated the chute experienced degradation between RM 10.6 and 10.0 with depths ranged between -5ft and 0ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 12B: Dike 10.05L Test 2

Plate (39) shows the resultant bathymetry of Alternative 12B. This alternative had the same setup as Alternative 12. However, Pile Dike 10.10L was notched instead of removed.

Table 12B: Alternative 12B Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)

Dike	10.05	New	500	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that the chute experienced degradation between RM 10.6 and 10.0 with depths that ranged between -5ft and 0ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. The scour hole downstream of Dike 7.90L filled in with sediment. No sediment movement but higher flow was observed inside of Boston Chute. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar and Chute.

Alternative 13: Dike Removal

Plate (40) shows the resultant bathymetry of Alternative 13. Pile Dike 10.1L and Dike 7.90L in Boston Chute were removed to depth of -10ft LWRP. The goal was to increase flow in Boston Chute.

Table 13: Alternative 13 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.10	Remove	All	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated no significant changes in the bathymetry. The scour hole downstream of Dike 7.90L filled in with sediment. Higher flows were observed inside

Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 13B: Dike Removal

Plate (41) shows the resultant bathymetry of Alternative 13B. Pile Dike 10.1L was notched while Dike 7.90L was removed in Boston Chute to depth of -10ft LWRP. The goal was to increase flow in Boston Chute.

Table 13 B: Alternative 13B Summary

Structure	RM	Type	Length(ft)	Bank	LWRP(ft)
Pile Dike	10.10	Notch	250	Chute	-10
Dike	7.9	Remove	All	Chute	-10

Test results indicated no significant changes in the bathymetry. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 14: Chevrons

Plate (42) shows the resultant bathymetry of Alternative 14. This alternative consisted of removing Dike 10.10L and 10.30L to depths of -10 ft LWRP. Two chevrons, located 300 ft off the bank line, were tested along the LDB of where the existing dikes were located. The goal of this alternative was to test whether the flow split from the chevrons could increase flow in Boston Chute.

Table 14: Alternative 14 Summary

Structure	RM	Type	Dimension (ft)	Bank	LWRP (ft)
Chevron	10.3	New	500x500	LDB	+2
Chevron	10.2	New	500x500	LDB	+2
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10

Test results indicated that the main channel between RM 10.0 and 9.0 experienced degradation and had depths -10 feet LWRP and deeper. However, shoaling occurred between RM 10.2 and 9.8 along the LDB which limits the amount of flow coming through Boston Chute. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 15: Master Plan Proposal

Plate (43) shows the resultant bathymetry of Alternative 15. This proposed alternative involved 21 hard points along both banks between RM 10.1 and 8.0 that were presented in the 2011 Master plan. Each hard point was placed in 500 foot increments from each other. They were all perpendicular to the bank line with depths of +2 feet LWRP. The goal of these hard points was to create scour holes in the hopes of adding more aquatic diversity within the Chute.

Table 15: Alternative 15 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.1	New	80	LDB	+2
Hard Point	10.0	New	50	RDB	+2

Hard Point	9.9	New	80	LDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	LDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	LDB	+2
Hard Point	9.4	New	80	LDB	+2
Hard Point	9.3	New	80	RDB	+2
Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	RDB	+2
Hard Point	9.0	New	80	LDB	+2
Hard Point	8.9	New	80	RDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	RDB	+2
Hard Point	8.3	New	80	LDB	+2
Hard Point	8.2	New	80	RDB	+2
Hard Point	8.1	New	80	LDB	+2

Test results indicated no significant changes in the bathymetry between Alternative 15 and the replication test. The twenty one hard points inside Boston Chute caused the velocities to decrease considerably. No sediment movement was observed.

Alternative 16: Boston Chute 18 Hard Points

Plate (44) shows the resultant bathymetry of Alternative 16. 18 hard points, each measuring 50 feet in length, were placed in 500 foot increments inside of Boston Chute. They were aligned perpendicular from the bank line and had depth of +2 feet LWRP. Dike 10.1L and 10.3L in the main channel and Dike 7.90L in Boston Chute were removed to depth of -10 ft LWRP. The goal was to increase flow and habitat diversity in Boston Chute.

Table 16: Alternative 16 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.3	New	80	LDB	+2
Hard Point	10.2	New	80	LDB	+2
Hard Point	10.1	New	80	LDB	+2
Hard Point	9.9	New	80	RDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	RDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	RDB	+2
Hard Point	9.4	New	80	RDB	+2
Hard Point	9.3	New	80	RDB	+2

Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	LDB	+2
Hard Point	8.9	New	80	LDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	LDB	+2

Table 16-2: Alternative 16 Summary 2

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated no significant changes to model bathymetry. However, the Boston Chute entrance between RM 10.2 and 9.8 experienced sediment deposition due to the removal of Dike 10.30L and Dike 10.10L. Depths were between of -5 ft and 0 ft LWRP. Approximately one mile down the chute, depths decreased to +10 ft LWRP and remained constant through RM 7.8. Observations showed no sediment movement and decrease in velocities in Boston Chute.

Alternative 17: Remove and Notch

Plate (45) shows the bathymetry of Alternative 17. This Alternative consisted of notching Pile Dike 10.10L and removing Dike 10.30L, Dike 10.10L, and Dike 7.90L to depth of -10 ft LWRP. The goal was to increase flow inside Boston Chute.

Table 17: Alternative 17 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile Dike	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that Boston Chute inflow channel experienced sediment deposition with depths ranging between +10 and -5 ft LWRP. The scour hole downstream of Closure Structure 7.90L filled in with sediment. Higher flows were observed inside Boston Chute, but the increased flow was insufficient to mobilize model sediment. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

Alternative 18: Master Plan Proposal with Modifications

Plate (46) shows the resultant bathymetry of Alternative 18. This alternative was involved testing the proposed construction found in the 2011 Master Plan (21 hard points in Boston Chute). However, this alternative also consisted of notching Pile Dike 10.10L to depth of -10ft LWRP and removing Dike 10.30L, Dike 10.10L and Dike 7.90L to depths of -10 ft LWRP. The goal was to increase flow and habitat diversity within Boston Chute.

Table 18: Alternative 18 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Hard Point	10.1	New	80	LDB	+2
Hard Point	10.0	New	50	RDB	+2
Hard Point	9.9	New	80	LDB	+2
Hard Point	9.8	New	80	RDB	+2
Hard Point	9.7	New	80	LDB	+2
Hard Point	9.6	New	80	RDB	+2
Hard Point	9.5	New	80	LDB	+2
Hard Point	9.4	New	80	LDB	+2
Hard Point	9.3	New	80	RDB	+2
Hard Point	9.2	New	80	LDB	+2
Hard Point	9.1	New	80	RDB	+2
Hard Point	9.0	New	80	LDB	+2
Hard Point	8.9	New	80	RDB	+2
Hard Point	8.8	New	80	LDB	+2
Hard Point	8.7	New	80	LDB	+2
Hard Point	8.6	New	80	LDB	+2
Hard Point	8.5	New	80	LDB	+2
Hard Point	8.4	New	80	RDB	+2
Hard Point	8.3	New	80	LDB	+2

Hard Point	8.2	New	80	RDB	+2
Hard Point	8.1	New	80	LDB	+2

Table 18-2: Alternative 18 Summary 2

Structure	RM	Type	Length (ft)	Bank	LWRP (ft)
Dike	10.30	Remove	All	LDB	-10
Dike	10.10	Remove	All	LDB	-10
Pile Dike	10.10	Notch	200	Chute	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that RDB between RM 10.30 and 10.10 experienced less depth because Dike 10.30L and Dike 10.10L were not in place to constrict the main channel. However, immediately outside of Boston Chute entrance, the river bed eroded uniformly with depths approximately -5 ft LWRP. For Boston Chute, minor scour was observed at Boston Chute entrance with depths between -5 ft and +5 feet LWRP. The scour hole downstream of Dike 7.90L was filled in with sediment.

Alternative 18B: Dike Structure 10.05

Plate (47) shows the resultant bathymetry of Alternative 18B. This alternative consisted of constructing a new dike structure located at the tip of Boston Bar, RM 10.05. The new dike measured 1200 ft in length, +2ft LWRP in height, and perpendicular to the flow. Dike 10.1L, Dike 10.30L, and Dike 7.90L were removed while Pile Dike 10.10L was notched to depth of -10 ft LWRP. The goal was to increase depths inside Boston Chute.

Table 19: Alternative 19 Summary

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)

Dike	10.05	New	1200	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

Test results indicated that the main channel experienced aggradation along the LDB between RM 10.6 and 10.0 with depths ranging between -5 feet and -10 feet LWRP. Boston Chute entrance also experienced similar problems with depths ranged from +10 feet and +15 feet LWRP. For the rest of the chute, depths decreased to +10 feet LWRP and remained constant through RM 7.8. The scour hole downstream of Dike 7.90L filled in with sediment. No sediment movement was observed inside of Boston Chute. The proposed alternative did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

CONCLUSION

1. Evaluation and Summary of Test Results

For Phase I, in order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The most important consideration was whether the dredge disposal area maintained its area and depth. There were several alternatives that met this requirement, including Alternatives 7 through 10, which were combinations of other alternatives. If more than one dredge disposal area were to be built at Boston Bar, they should be considered. However, for the purposes of the conclusions of this report, only alternatives involving one dredge disposal location were considered for recommendation.

Table 19: Phase I Test Summary

Alternative	Dredge Disposal Area(s)	Distance From Boston Bar (ft)	No Significant Erosion	Maintained Design Height (ft)
1	8.4L	500	X	X
2	8.1L	500	X	X
3	8.9L	300		
4	8.8L	300		
5	8.7L	200	X	X
6	8.7L	0		
7	8.1L, 8.4L & 8.7L	500, 500 & 0	X	X
8	8.4L & 8.7L	500 & 0	X	X
9	8.1L & 8.7L	500 & 0	X	X
10	8.4L & 8.1L	500 & 500	X	X

For Phase II, in order to determine the best alternative, certain considerations, based on the study purpose and goals were used to evaluate each alternative. The first consideration was that the alternative had to increase flow through Boston Chute. The second consideration was that the alternative must not introduce additional sediment in Boston Chute. The third consideration was that the alternative would not negatively impact the navigation channel. Finally, the fourth consideration was that the alternative should preserve all if not part of Pile Dike 10.10L and 8.20L inside Boston Chute. The ideal alternative would have been able to meet all four conditions; however, no alternatives met all four conditions. There were quite a few alternatives that met three of the four conditions. Some alternatives that met most of the criterion were not recommended due to the necessity of pile dike removal inside Boston Chute. These were Alternatives 11, 12, 13 and 16.

Table 20: Phase II Test Summary

Alternative	Increase Flow In Boston Chute	No Sediment Increase In Boston Chute	Maintain Navigation Channel	Preserved Pile Dikes	Improve Navigation Channel
Alternative 11	X	X	X		
Alternative 12	X	X	X		
Alternative 12B	X	X	X	X	
Alternative 13	X	X	X		
Alternative 13B	X	X	X	X	
Alternative 14			X	X	X
Alternative 15		X	X	X	
Alternative 16		X	X		

Alternative 17	X	X		X	
Alternative 18		X	X	X	
Alternative 18		X		X	

2. Recommendations

Alternative 2 (Plate 28) was recommended as the most desirable alternative for dredge disposal placement because the area did not experience significant erosion and maintained the design height. This alternative could considerably reduce the lack of habitat diversity within the reach by providing more nesting locations for Least Terns. The recommended design for Alternative 2 included the following.

Table 21: Recommended Alternative from Phase I

RM	Distance Away From Boston Bar (ft)	LWRP (ft)	Area (sq. ft)
8.1	500	30	280,000

Alternative 12B, Plate (39), was recommended as the most desirable alternative because of its observed ability to increase flow and keep sediment away from Boston Chute while having no significant impacts on the navigation channel. The alternative consisted of notching Pile Dike 10.10L; removing Dike 7.90L, Dike 10.10L and Dike 10.30L; and constructing Dike 10.05L at the tip of Boston Bar. Testing showed this alternative would increase flow into Boston Chute. According to flow visualization test results (Appendix B), this alternative significantly increased flow within Boston Chute. The recommended design for Alternative 12B included the following:

Table 23: Recommended Alternative from Phase II

Structure	RM	Type	Length (ft)	Bank	LWRP(ft)
Dike	10.05	New	500	LDB	+2
Pile	10.10	Notch	250	Chute	-10
Dike	10.10	Remove	All	LDB	-10
Dike	10.30	Remove	All	LDB	-10
Dike	7.90	Remove	All	Chute	-10

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 error as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high and 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 simulates in this study.

This model study was intended to serve as a tool for the river engineer as a guide in the assessing the general trends that could be expected to occur in the Mississippi River from a variety in 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 requirement.

EXTENDED STUDY

1. New Side Channel

At the July 22, 2011, Boston Bar calibration meeting, there were many suggestions and opinions made to help guide the testing process. One of those suggestions involved excavating the secondary inflow channels located upstream of Boston Bar to increase flow in Boston Chute. During the testing process, these channels were not taken into consideration because they were not connected to the main channel or Boston Chute.

There were two secondary side channels located upstream of Boston Bar. However, only one was excavated in this extended study because one of them was too narrow. The new side channel could potentially provide more flow and environmental diversity to the reach by connecting the main channel with Boston Chute. The goal of this extended study was to determine what would happen inside Boston Chute if a side channel was opened.

Table 24: New Side Channel Summary

Type	RM	Depth LWRP (ft)	Channel Width (ft)	Bank	Length (ft)
Side Channel	10.6 – 10.3	-5	80	LDB	1000

Note: Part of Dike 10.30L and Dike 10.10L were removed in the process.

New Side Channel on Existing Planform

Plate (48) shows the bathymetry of Alternative (19). The test showed that when opening another side channel entrance, insignificant amount of flow was introduced through Boston Chute. Model bathymetry of Boston Chute was similar to the replication test with depths ranging from -5ft and +10ft LWRP. No sediment movement was observed inside of Boston Chute. The new side channel did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute.

New Side Channel on Phase II Recommended Alternatives

Plate (49) shows the bathymetry of Alternative 20. Test results indicated that the chute experienced higher flow due to the new inflow channel and the removal of Dike 10.30L and 10.10L. While higher flows were observed inside Boston Chute, the increased flow was insufficient to mobilize model sediment. The new side channel did not cause any unwanted problems to the main channel, Boston Bar, or Boston Chute. See flow visualization test results, Appendix B.

FOR MORE INFORMATION

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APPENDIX A: PLATES

APPENDIX B: FLOW VISUALIZATION RESULTS

The first condition recorded was the replication test, or existing conditions as seen in Figure 1 below. Remember that dry sediment was introduced along the LDB for all videos, not uniformly across the channel. (Please note that there is a DVD available with this report to view the videos.)

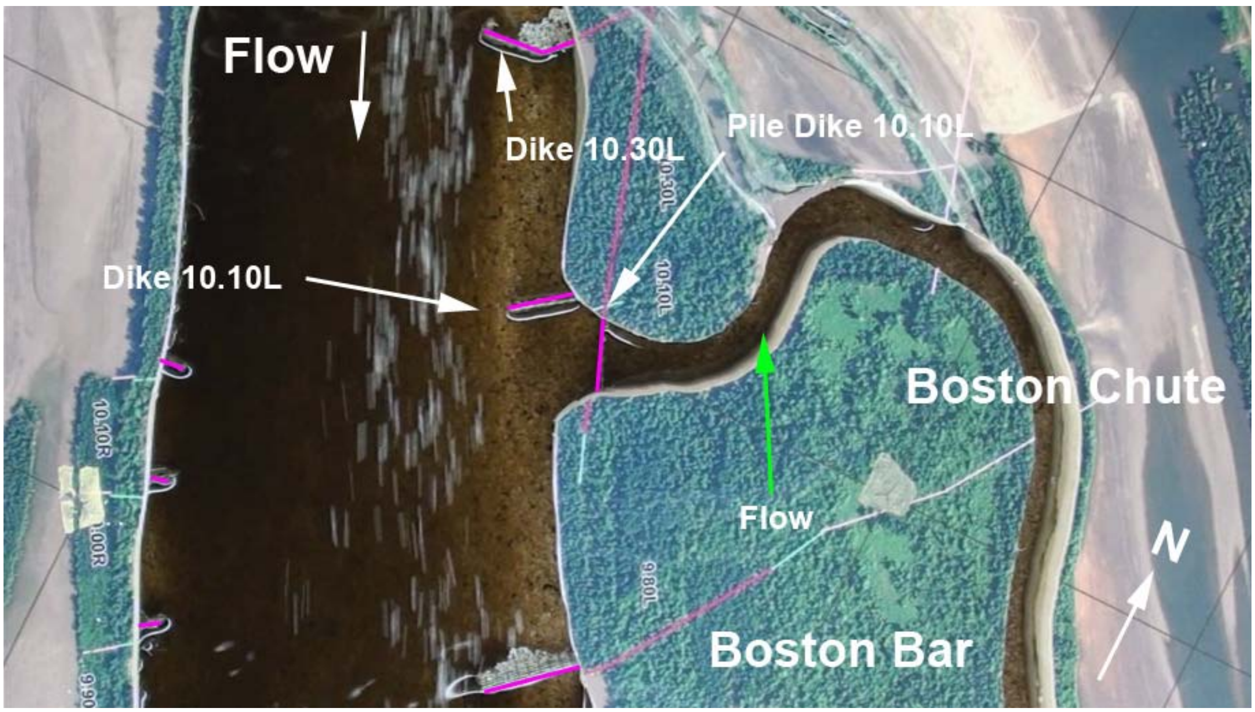

Figure 1: Flow Visualization - Replication Test

The flow exited the sharp bend at RM 14.0 and maintained a straight path just upstream of Figure 1's extents. As seen in the snapshot of the existing conditions, the resultant flow was concentrated in the center of the main channel of Figure 1. Immediately downstream, the flow kept the same path. There was minimum flow observed inside Boston Chute. All structures are highlighted in pink for increased visibility.

The next condition recorded was post construction with the recommended alternative (Alternative 12B) of removing Dike 10.30L, 10.10L and 7.90L; notching Pile Dike

10.10L; and constructing Dike 10.05L as seen in Figure 2 below. All structures were highlighted in pink for increase visibility.

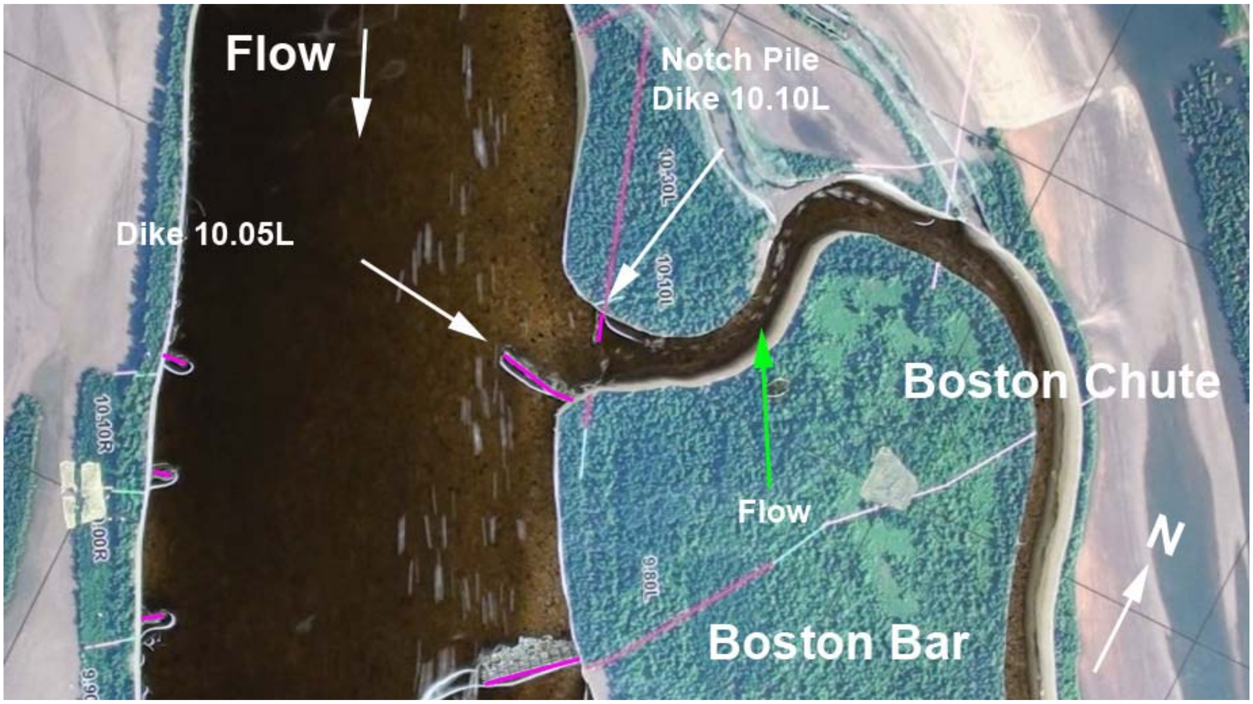

Figure 2: Alternative 12B Flow Visualization

Again, the flow exited the sharp bend at RM 14.0 and maintained a straight path just upstream of Figure 2’s extents. As seen in the snapshot of the post construction conditions, the resultant flow was dispersed into two directions along the LDB. Dike 10.05L split the concentrated flow, sending the majority of the flow down the main channel and the rest towards Boston Chute. Compared to the existing conditions, there was increased in flow in Boston Chute.