Technical Report M67

MORO CHUTE HSR MODEL
RIVER MILES 125.00 – 117.00

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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Sponsored by and Prepared for:
U.S. ARMY CORPS OF ENGINEERS – ST.LOUIS DISTRICT
AVOID & MINIMIZE PROGRAM

In Cooperation With:
ILLINOIS DEPARTMENT OF NATURAL RESOURCES
UNITED STATES FISH & WILDLIFE SERVICE
MISSOURI DEPARTMENT OF CONSERVATION
RIVER INDUSTRY ACTION COMMITTEE

Final Report – March, 2013

INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation improvement study of the Mississippi River at Moro Chute from River Mile (RM) 125.00 to RM 117.00. This study was funded by the Avoid and Minimize (A&M) Program. The objective of the model study was to produce a report that outlined the results of an analysis of various river engineering measures, intended for the development of side channel habitat and to enhance the environmental diversity along the left descending bank (LDB) of Moro Island without negatively affecting the navigation channel.

The study was conducted between October 2012 and February 2014 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 D. Davinroy, P.E., Chief of River Engineering Section for the St. Louis District. See Table 1 for other personnel involved in the study.

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
Ashley Cox	Hydraulic Engineer	St. Louis District
Jasen Brown, P.E.	Acting Project Manager	St. Louis District
Edward Brauer, P.E.	Hydraulic Engineer	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Sarah Markenson	Real Estate	St. Louis District
Adam Rockwell	Cartographic Technician	St. Louis District
Shawn Kempshall	River Surveyor	St. Louis District
Lance Engle	Dredge Project Manager	St. Louis District
Charles Wardle	Student Co-Op	St. Louis District
Brian Johnson	Chief of Environmental Planning Section	St. Louis District
David Gordon, P.E.	Chief of Hydraulic Design	St. Louis District
Mike Rodgers, P.E.	Project Manager	St. Louis District
Dawn Lamm	Hydraulic Design	St. Louis District
Peter Russell, P.E.	Hydraulic Design	St. Louis District
Romanda Walker	Public Affairs	St. Louis District
Kathryn Mccain	Ecologist	St. Louis District
Butch Atwood	Mississippi River Fishery Biologist	Illinois Department of Natural Resource (IDNR)
Matthew Mangan	Biologist	U.S. Fish and Wildlife (FWS)
Donovan Henry	Biologist	U.S. Fish and Wildlife (FWS)
Bernie Heroff	Port Captain	ARTCO
Ed Henleben	Senior Operations Manager	River Industry Action Committee (RIAC)
Dave Ostendorf	Fishery Biologist	Missouri Department of

		Conservation (MDC)
Mark Boone	Program Advisor	Missouri Department of Conservation (MDC)
Dave Knuth	Fisheries Management Biologist	Missouri Department of Conservation (MDC)
Ryan Christensen	Waterways Assistant Chief	U.S. Coast Guard
Shannon Hughes	Port Captain	Kirby Inland Marine
Terry Hoover	Safety Manager	Ingram Barge Company
Michael Canada	Operator	Ingram Barge Company

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BACKGROUND

1. Problem Description

The main channel near Moro Chute has been sufficient for navigation with depths that were at least -10 feet Low Water Reference Plane (LWRP). However, the dike field along the LDB at Moro Island has caused a lack of bathymetric diversity. The sandbar located along the LDB against Moro Island, from RM 122.50 to RM 119.50, had an average width of 400 feet and an average elevation of +5 feet LWRP. The side channels experienced deposition, which provided limited connectivity to the main channel and very little bathymetric diversity. However, there was a plunge pool with depths greater than -30 feet LWRP in the main side channel caused by Dike 121.10L.

At low water there were many structures that prevented flow from passing through Moro Chute. However, if water levels were greater than +15 feet LWRP flow was able to pass through Moro Chute. Approximately 7 months of the year the side channel was dry, leaving exposed sandbars. See Figure 1 for a generalized schematic of the existing flow mechanics in the study reach.

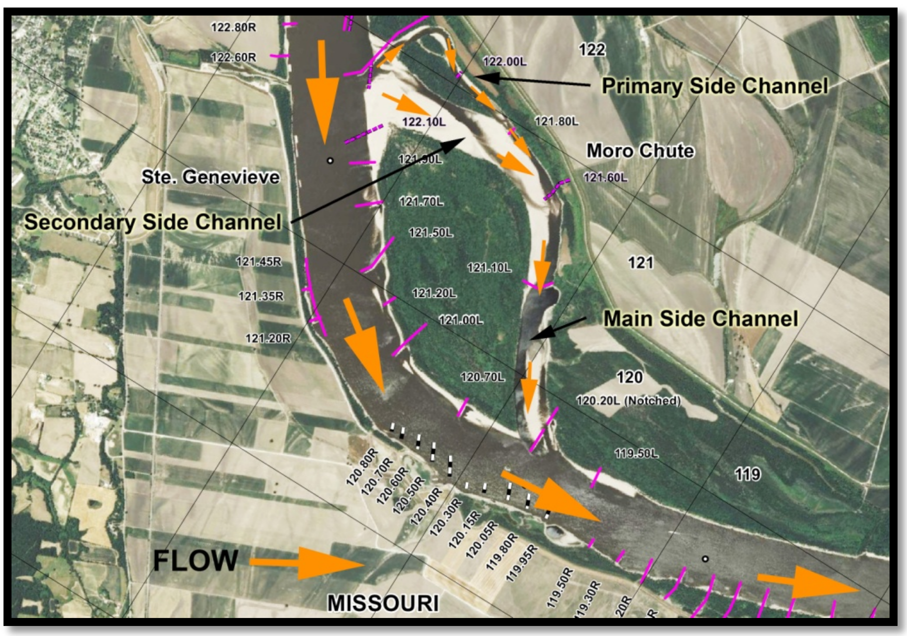

Figure 1: Moro Chute Reach with Flow Trends

2. <u>Study Purpose and Goals</u>

The purpose of this study was to find a solution to enhance the environmental diversity in the Moro Island Complex and produce a report that communicated the results of the Hydraulic Sediment Response (HSR) model study.

The goals of this study were to:

i. Investigate and provide analysis on the existing flow mechanics causing the lack of diversity.
ii. Evaluate a variety of remedial measures utilizing an HSR model with the objective of identifying the most effective and economical plan to create a more diverse habitat in and around Moro Chute. The following 3 criteria were used to evaluate each alternative.
   a. The alternative should enhance the environmental diversity of Moro Chute and the sandbar on the southwestern side of Moro Island.
   b. The alternative should maintain the navigation channel requirements of at least 9 foot depth and 300 foot of width.
   c. Maintain a side channel that can provide longer durations of connectivity between RM 122.70 and RM 120.00. (Below +10 feet LWRP)
iii. Communicate to other engineers, river industry personnel, and environmental agency personnel the results of the HSR model tests and the plans for improvement.

3. <u>Study Reach</u>

The study comprised an 8 mile stretch of the Mississippi River, between RM 125.00 – 117.00 in Randolph County, IL just east of St. Genevieve, MO. The mouth of the Kaskaskia River was approximately 2.5 miles downstream from the exit of Moro Chute. An overview of the vicinity where Moro Chute is located can be seen in Plate 1.

The Moro Chute reach can be categorized as a series of 2 side channels and 2 islands. The primary side channel into Moro Chute was much deeper and narrower than the secondary side channel. The secondary side channel was located downstream of the primary side channel. It was wider and shallower than the primary side channel. A small island was located between the primary and secondary channels of Moro Chute. The primary side channel and secondary side channel then combined at RM 122.00 to create the main side channel of Moro Chute. Between the main side channel and the Mississippi River, there was a large island called Moro Island.

A. Features and Structures

Plate 2 is a 2012 aerial photograph illustrating the planform and nomenclature of the Middle Mississippi River between RM 125.00 and RM 117.00. The city of Ste. Genevieve, MO is located along the RDB between RM 125.00 and RM 122.00. The Ste. Genevieve C&L Levee system was located along the RDB to protect the city during floods and high water events. Another levee system, Ste. Genevieve Co. L.D., begins at RM 122.00 and continues to RM 117.00. The Prairie Du Rocher D&L Levee system was located along the LDB between RM 125.00 and the Kaskaskia River (RM 3.00). The bluff line was located along the LDB downstream from the mouth of the Kaskaskia River.

At the time of this study, the reach had a total of 85 structures: 66 rock dikes, 11 weirs, 5 pile dikes, 2 notched dikes and 1 L-dike. There were two dike fields along the RDB: dike field 1 was located between RM 125.00 and RM 122.50 and dike field 2 was located between RM 119.00 and RM 116.00. Between RM 121.45 and RM 121.20, the RDB was re-aligned with stone to an elevation of +18 feet LWRP. Immediately downstream of the realignment stone, between RM 120.80 and RM 119.95, there was a weir field with the weirs having an average length of 400 feet. There was 1 dike field and 1 weir field located along the LDB. The dike field was located between RM 125.00 and RM 119.00, and the weir field was located between RM 117.50 and RM 116.00. There were three locations, each approximately 1,000 feet long, inside Moro Chute where revetment was constructed to protect the banklines from erosion. Five pile dikes were identified in the study reach, 4 were located along the LDB and 1 was located along the RDB. For the main channel, revetment was placed on banks where dikes were absent. There was revetment along the RDB between RM 122.50 and RM 119.20 and along the LDB between RM 119.20 and RM 116.00. Refer to Table 2 for a more detailed history of the river training structures.

Table 2: Study Reach River Structure History

River Training Structures	Length (feet)	Description
Dike 125.40L	120	Stone dike. Constructed before 1928. (Photograph 1, Plate 3)
Dike 125.30L	150	Stone dike. Constructed before 1928. (Photograph 2, Plate 3)
Dike 125.30R	500	Pile dike. Structure not shown on the master plan. Constructed before 1928. (Photograph 3, Plate 3)
Dike 124.90L	560	Stone dike. Constructed between 1928 and 1939. (Photograph 4, Plate 3)
Dike 124.90R	675	Stone dike. Constructed in 1985. (Photograph 5, Plate 3)
Dike 124.70L	430	Stone dike. Constructed between 1928 and 1939. (Photograph 1, Plate 4)
Dike 124.70R	500	Stone dike. Constructed in 1993 to elevation of 365.80 feet. (Photograph 2, Plate 4)
Dike 124.50L	760	Stone dike. Constructed between 1968 and 1976. (Photograph 3, Plate 4)
Dike 124.50R	500	Stone dike. Constructed in 1900. Original dike was 300 feet. Maintenance in 1993. Extended 200 feet. Raised to elevation of 364.7 feet (11,142 tons was placed). (Photograph 4, Plate 4)
Dike 124.20L	680	Stone dike. Constructed before 1928. (Photograph 1, Plate 5)

Dike 124.20R	1,000	Stone dike. Dike constructed between 1928 and 1939. (Photograph 2, Plate 5)
Dike 124.00L	480	Stone dike. Constructed between 1928 and 1939. (Photograph 3, Plate 5)
Dike 123.90L	700	Stone dike. Constructed before 1928. (Photograph 4, Plate 5)
Dike 123.90R	575	Stone dike. Constructed in 1993. Originally a pile dike. Offset centerline of old pile dike 20 feet downstream. Construct 200 feet x 80 feet x 2 feet apron downstream. Key into high bank. Raise 250 feet of existing pile dike (degraded) then extend dike 100 feet to elevation of 364.4 feet. (Photograph 1, Plate 6)
Dike 123.70R	475	Stone dike. Constructed between 1968 and 1976. (Photograph 2, Plate 6)
Dike 123.60L	700	Stone dike. Constructed before 1928. Extended 300 feet between 1939 and 1942. (Photograph 4, Plate 6)
Dike 123.50R	400	Stone dike. Constructed between 1939 and 1942. Extended 200 feet to elevation of 364.1 feet between 1982 and 1986. (8,840 tons was placed). (Photograph 4, Plate 6)
Dike 123.40L	830	Stone dike. Dike constructed before 1928. (Photograph 1, Plate 7)
Dike 123.40R	500	Stone dike. Constructed in 1993 to elevation of 364.1 feet. (Photograph 2, Plate 7)
Dike 123.20L	1,260	Stone dike. Constructed between 1928 and 1939. (Photograph 3, Plate 7)
Dike 123.20R	500	Stone dike. Constructed between 1968 and 1976. (Photograph 4, Plate 7)

Dike 123.00L	2,830	Stone dike. Constructed between 1928 and 1939. Repaired in 1989 to elevation of +10 feet LWRP. Original 1,350 feet long pile structure still visible. (Photograph 1, Plate 8)
Dike 122.90R	330	Stone dike. Constructed between 1942 and 1939. (Photograph 2, Plate 8)
Dike 122.80R	350	Stone dike. Constructed in 1993. Originally a pile dike. Offset centerline of old pile dike 20 feet downstream. Construct 200 feet x 80 feet x 2 feet apron downstream. Key into high bank. Raise 200 feet of existing pile dike (degraded) then extend dike 150 feet to elevation of 363.7 feet. (Photograph 3, Plate 8)
LPSTP 122.70L	50	Longitudinal Peaked Stone Toe Protection (LPSTP). There are five structures total. Constructed in 2008. (Photograph 1, Plate 9)
Dike 122.60R	500	Stone dike. Constructed before 1928. (Photograph 4, Plate 8)
Dike 122.60L	3,000	Stone dike. Dike constructed before 1928. Dike extended 2,000 feet between 1928 and 1939. (Photograph 1-4 on Plate 10)
Dike 122.10L	1,000	Pile Dike. Constructed between 1928 and 1939. (Photograph 1, Plate 11)
Dike 122.00L	200	Pile Dike. Dike constructed between 1928 and 1939 (1,000 feet). Dike shortened between 1942 and 1968 (800 feet). (Photograph 2, Plate 9)
Dike 121.90L	900	Stone Dike. Dike constructed between 1968 and 1976. (Photograph 2, Plate 11)
Dike 121.80L	200	Stone Dike. Dike constructed between 1939 and

		1942. (Photograph 1, Plate 12)
Dike 121.70L	860	Stone Dike. Dike constructed in 1968 and 1976. (Photograph 3, Plate 11)
Dike 121.60L	300	Pile Dike. Dike constructed between 1939 and 1942. (Photograph 4, Plate 12)
Dike 121.50L	1,300	Dike constructed between 1928 and 1939. Repair dike-line, dike-head, and round-out on (May 1985). (Photograph 4, Plate 11)
Dike 121.45R	800	Constructed in 1989 elevation of 10 feet LWRP. (Photograph 1, Plate 13)
Dike 121.35R	1,030	Constructed in 1989 elev. 10 feet STL. (Photograph 1, Plate 13)
Dike 121.20R	300	Constructed in 1989 elev. +10 feet STL. 06-C-0406, Restore trail dike to uniform height, 2,713 tons, Patton-Tully, 1/30/07. (Photograph 1, Plate 13)
Dike 121.20L	Buried	Buried under sediment. Dike constructed between 1928 and 1939. (Picture not available)
Dike 121.10L	800	Stone Dike. Dike constructed between 1928 and 1939. Dike extended 400 feet and removed 550 feet between 1942 and 1968. (Photograph 1, Plate 11)
Dike 121.00L	1,250	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 3, Plate 13)
Weir 120.80R	300	Weir constructed in September 1997.
Dike 120.70L	530	Stone Dike. Dike constructed between 1968 and 1976. (Photograph 4, Plate 13)
Weir 120.70R	310	Weir constructed in September 1997.
Weir 120.60R	476	Weir constructed in September 1997.

Weir 120.50R	559	Weir constructed in September 1997.
Dike 120.50R	-	(Photograph 2, Plate 13)
Weir 120.40R	580	Weir constructed in September 1997.
Weir 120.30R	159	Weir constructed in September 1997.
Dike 120.20L	1,450	Stone Dike. Dike constructed between 1928 and 1939. Notched 200 feet wide at 500 feet from the bankline in 2011. (Photograph 1 & 2, Plate 14)
Weir 120.15R	285	Weir constructed in September 1997.
Weir 120.05R	480	Weir constructed in September 1997.
Weir 119.95R	430	Weir constructed in September 1997.
Weir 119.80R	470	Weir constructed in September 1997.
Dike 119.50L	550	Stone Dike. Dike constructed between 1968 and 1976. (Photograph 3, Plate 14)
Dike 119.50R	200	Dike constructed between 1968 and 1976. Repair dike-head, round-out, and breach in 1985. (Photograph 4, Plate 14)
Dike 119.30R	330	Stone Dike. Dike constructed before 1928. (Photograph 1, Plate 15)
Dike 119.20R	725	Stone Dike. Dike constructed before 1928. Dike extended 300 feet between 1928 and 1939. (Photograph 2, Plate 15)
Dike 119.00R	1,000	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 3, Plate 15)
Dike 118.80R	1,375	Stone Dike. Dike constructed before 1928. Dike was extended 200 feet between 1939 and 1968. (Photograph 4, Plate 15)
Dike 118.70R	1,450	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 1, Plate 16)
Dike 118.60R	1,640	Stone Dike. Dike constructed between 1928 and

		1939. (Photograph 2, Plate 16)
Dike 118.40R	1,500	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 3, Plate 16)
Dike 118.30R	2,100	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 4, Plate 16)
Dike 118.10R	1,700	Stone Dike. Dike constructed between 1928 and 1939. (Photograph 1, Plate 17)
Dike 117.90R	2,750	Constructed in 1990. (Photograph 2, Plate 17)
Dike 117.60R	580	Constructed in 1990. (Photograph 3, Plate 17)
Dike 117.60R	260	Constructed in 1985. (Photograph 3, Plate 18)
L-Dike 117.50R	2,350	Dike constructed between 1976 and 1982. In 1990 dike extended for 700 feet from the tip, facing downstream. A 32 feet wide notch located 1,000 feet from the bank-line. (Photograph 4, Plate 17)
Weir 117.20L	600	Weir constructed in January 2002.
Weir 117.10L	310	Constructed in February 1993. Extended by 350 feet in January 2002.
Dike 117.10R	740	Constructed in 1990. (Photograph 2, Plate 18)
Weir 117.00L	460	Constructed in February 1993. Extended by 300 feet in January 2002.
Weir 116.90L	400	Weir constructed in February 1993.
Weir 116.80L	485	Weir constructed in February 1993.
Weir 116.70L	325	Weir constructed in February 1993.
Weir 116.60L	190	Weir constructed in February 1993.
Dike 116.60R	3,900	Stone Dike. Dike constructed before 1928. Dike extended 1,000 feet between 1928 and 1939. (Photograph 4, Plate 18)
Weir 116.50L	360	Weir constructed in February 1993.
Weir 116.30L	355	Weir constructed in February 1993.

Dike 116.30R	1,700	Dike constructed before 1928. Dike repaired in 1990. (Photograph 4, Plate 18)
Weir 116.20L	370	Weir constructed in February 1993.
Weir 116.10L	440	Weir constructed in February 1993.
Weir 116.00L	465	Weir constructed in February 1993.

B. Primary Side Channel

The entrance to the primary side channel was located downstream of Dike 122.60L. The width of the primary side channel varied between 300 and 225 feet with an average width of 250 feet. The distance from the entrance of the primary side channel to the confluence of the primary side channel and the secondary side channel was approximately 4,500 feet. During low water, a deteriorated wooden pile dike that extended off of Dike 122.60L could be seen. See Photograph 4 on Plate 10. A small island with an area of approximately 5 acres existed between the primary side channel and the secondary side channels. Approximately 800 feet from the primary side channel entrance, a side channel bisected the northern point of the island. The small side channel was approximately 1,000 feet long with an entrance width of 100 feet and an exit width of 50 feet. See photograph 1 on Plate 20. At the outside bend of the primary side channel, there was a series of Longitudinal Peaked Stone Toe Protection (LPSTP) structures constructed in 2008. LPSTP incorporated hard points with toe revetment as shown in Photograph 1 on Plate 9. See Plate 20 for photographs that show the bankline before the LPSTP was constructed.

C. Secondary Side Channel

The entrance to the secondary side channel was located downstream from the entrance to the primary side channel. The secondary side channel had an average width of 1,200 feet and was approximately 3,500 feet long from the entrance at RM 122.40 to the confluence of the primary and secondary side channel at RM 122.00. Moro Island had an area of approximately 600 acres. Flow through the secondary side channel was restricted most of the year because of sediment deposition and wide channel width. See Plate 21.

D. Main Side Channel

The main side channel began at the confluence of the primary side channel and secondary side channel at Dike 121.80L. The main side channel had a length of approximately 9,000 feet long with a width that ranges between 700 feet and 1,000 feet wide. The main side channel connected to the Mississippi River immediately downstream at Dike 120.20L. There was a large plunge pool downstream of Dike 121.10L. The main side channel was the widest at 1,100 feet at the plunge pool. See Plates 22 and 23.

E. Main Channel

There were many sandbars located along the LDB between the dike fields. Dikes 124.45R, 121.35R, and 121.20R, located along the RDB, were constructed to align the bankline and to protect against erosion. See photograph 1 on Plate 13. To maintain the navigation channel from 2000 to 2010 between RM 123.00 and RM 120.00, approximately 600,000 cubic yards was dredged at a cost of $1.4 million. Figure 2 shows the dredge material removed per year and Plate 24 displays the dredge areas and dredge disposal locations.

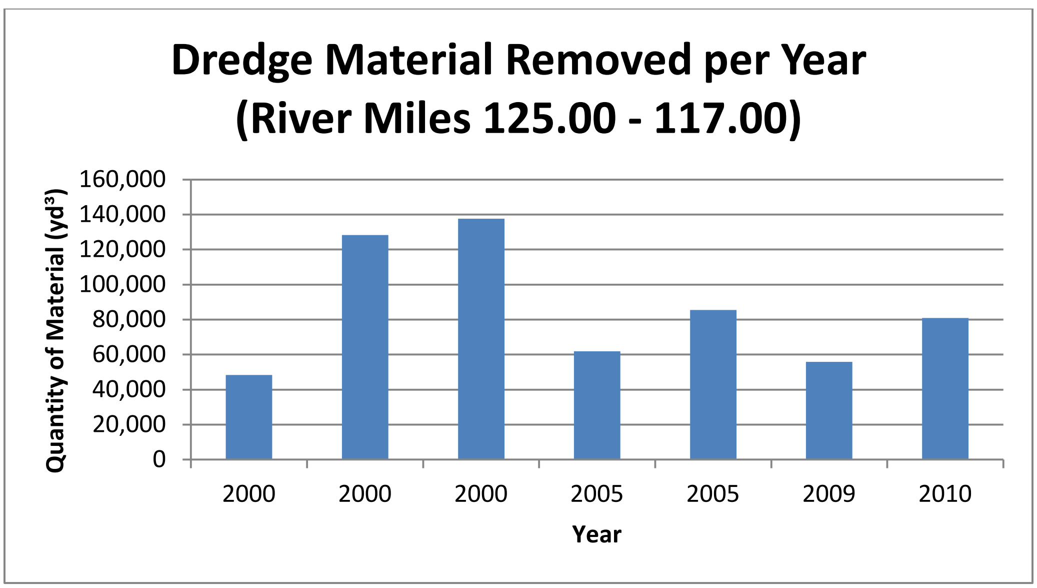

Figure 2: Study Reach Dredge Removal Data

F. <u>Real Estate</u>

The following table shows all the property owners located along both the Illinois and Missouri sides of the study reach.

Table 3: Property Owners along the Illinois and Missouri Banklines

State	**RM**	**Owner**
Missouri	126.00 - 124.90	Mississippi Lime Co.
	124.90 – 122.00	Ste. Genevieve Levee District
	121.90	JKB LLC
	121.80	Eric and Jody Lurk
	121.70	Janet and Henry Linderer
	121.60	Beulah Loida Trust
	121.50	Roman Catholic Congregation
	121.50	Southern IL Sand Co.
	121.50 - 121.36	Janet and Brown Govreau
	121.35 - 121.20	Basler
	120.80	Church of Ste. Genevieve
	120.70 - 120.20	Herman and Margaret Baechle
	120.30	Wayne/Kenneth Hoog
	120.20 – 120.00	New Bourbon Regional Port Authority
	119.00	Loida Land Company
	118.00	Howard Klepzig
	117.00	Clarence T. Kertz Vol. Trust
	117.80	Paul G. Roth
Illinois	125.00	M&M Kertz Farms
	124.00	Robert and Linda Yagge
	123.00 - 120.50 & Small island N of Moro	Whitetail Way LLC.
	Moro Island	Range Land Company

	(122.00 – 120.00)	
	120.50	Alvin Yard
	120.40 – 118.00	Glenda Zanders
	South of Kaskaskia	State of Illinois

G. <u>Geomorphology</u>

To understand the planform of the river near Moro Chute, an investigation was conducted on the historical changes, both man-made and natural, that lead to the present day condition. Plate 25 shows geomorphic planform changes between RM 129.00 and RM 117.00, encompassing the years from 1817 to 2011. Based on this planform comparison, in addition to historic aerial photographs and maps, it was estimated that Moro Chute did not exist until sometime between 1928 and 1939, after the sandbar in the middle of the channel meandered eastward along the LDB.

From 1817 to 1866, the average river width increased from 8,500 feet to 12,000 feet. There were 2 islands in 1817 and 4 islands in 1866 as shown on Plate 26. The island from RM 124.00 to RM 121.00 eroded considerably in size. The bankline from RM 126.00 to RM 122.00 along the Missouri side meandered westward approximately 3,000 feet. These changes occurred naturally, predating the use of river training structures in this river reach.

The river continued to undergo major changes from 1866 to 1881, as shown on Plate 27. The river widened throughout the study reach creating additional islands. The study reach went from having 4 to 10 islands. The most significant changes occurred along the RDB from RM 122.00 to RM 120.00 and along the LDB from RM 120.00 to RM 117.00. In these areas, the channel widths doubled to approximately 15,000 feet and 27,000 feet, respectively. These changes occurred naturally, predating the use of river training structures in this river reach.

From 1881 to 1908 the river continued to transform, as seen on Plate 28. The LDB between RM 124.00 and 120.00 meandered eastward approximately 9,000 feet. At this location, Moro Island was developed, and the width of its side channel was roughly 200 feet. Moro Island was roughly 1,700 acres at that time. Along the RDB between RM 119.00 and RM 116.00, the channel meandered eastward roughly 20,000 feet.

The river continued to transition from 1908 to 1928, shown on Plate 29. The Missouri bankline remained the same, but the Illinois bankline meandered westward from RM 124.00 to RM 119.00. As the channel constricted, Moro Island disappeared along with its side channel. However, there was a large sandbar located in the middle of the channel between RM 122.50 and RM 121.50 with an area of 137 acres. Along the RDB, between RM 125.00 and RM 117.00, there were 5 islands instead of 8. There were 36 river training structures built during this time.

From 1928 to 1956 the river still experienced changes to the planform, most likely due to the 40 river training structures constructed at that time. The Illinois bankline remained constant from RM 126.00 to RM 123.00. However, the bankline meandered eastward an average of 800 feet from RM 123.00 to RM 120.00 and westward an average of 500 feet from RM 123.00 to RM 117.00. The Missouri bankline remained constant from RM 121.50 to RM 119.00. However, the bankline meandered eastward an average of 2,500 feet and 3,000 feet from RM 126.00 to RM 121.50 and from RM 119.00 to RM 116.00, respectively. The number of island decreased from 5 to 3. See Plate 30. Structures built during this time included dikes and dike extensions.

There were no significant changes to the banklines throughout the study reach from 1956 to 1968, as seen on Plate 31. This was due to construction of the river training structures in previous years which locked in the basic planform of the reach. However, Moro Island was bigger but had a smaller side channel. There was a narrow side channel along the Missouri side from RM 125.00 to RM 123.00. The side channel was very narrow. In 1956, there were two Beaver Islands along the RDB between RM

119.00 and RM 116.00. In 1968, the upper Beaver Island meandered eastward and separated into 4 islands.

From 1968 to 1976 there were no major changes to the banklines throughout the study reach, as shown on Plate 32. Moro Island was broken into three separate islands, which introduced new side channels. The Kaskaskia River connected to the Mississippi at RM 117.50. There were 7 islands in 1968 and 6 islands in 1976.

There were no significant changes to the banklines throughout the study reach from 1976 to 1986, as seen on Plate 33. However along the Missouri side from RM 125.00 to RM 123.00, the side channel connected back to the main channel as seen in 1968 on Plate 31 and 32. There was an island developed along the Illinois side at RM 122.50. There were a total of two small islands located just upstream of Moro Island in 1976. Structures built during this time included dike and dike extensions. There were 6 islands in 1976 and 9 islands in 1986.

From 1986 to 2003 there were no major changes to the banklines throughout the study reach, as shown on Plate 34. There were 9 islands in 1986 and 4 islands in 2003. The side channel along the Missouri side from RM 125.00 and 123.00 was no longer connected to the main channel. All three islands located just upstream of Moro Island disappeared, thus creating a 3,000 foot wide Moro Chute. A majority of the existing revetment was placed during this time. Structures built during this time included dikes, dike extensions and weirs.

There were no significant changes or transformations of the planform from 2003 to 2011, as shown on Plate 35. There were 4 islands in 2003 and 5 islands in 2011. An island was developed at the entrance of Moro Chute, thus splitting the flow into two directions. The two secondary channels combined into one and connected back to the Mississippi River. They are called Primary Side Channel, Secondary Side Channel and Main Side Channel as mentioned above in Section 3 Part B, C and D. Plate 36-42 showed aerial maps between 1928 to 1986 overlay. These maps were overlayed on top of the 2012 aerial photograph.

A side channel analysis based on historical and recent aerial photographs and hydrographic surveys was lead by Tom Keevin and conducted by Erin Guntren (MVS personnel) in FY 2012. Their analysis looked at the area changes of side channels based on aerial photographs and the volume changes based on cross sections taken from hydrographic surveys. The results (including primary side channel, secondary side channel, and main side channel) showed that the side channels increased in size and depths while decreased in sedimentation. See Table 4 for more details. (Controlling height for connectively)

Table 4: Side Channel Analysis

	Months	**1986**	**2001**	**Percent Change**
Area (Ac)	January	76.28	63.24	-17%
	April	207.91	300.45	+44%
	July	200.11	261.01	+30%
	October	98.60	96.63	+2%
Volume (YD^3)	January	825,964	318,615	-61%
	April	3,877,536	4,319,468	+11%
	July	2,446,646	2,328,210	-4%
	October	1,055,970	528,932	-49%
Mean Depth (Feet)	January	6.71	3.12	-53%
	April	11.56	8.91	+22%
	July	7.58	5.53	-27%
	October	6.64	3.39	-48%

H. Channel Characteristics and General Trends

Range line and multi-beam hydrographic surveys of the Mississippi River from 2005 to 2012 within the HSR Model extents, are shown on Plates 43-50. For this study, the bathymetric data was referenced to the Low Water Reference Plane (LWRP).

Recent surveys were used to determine general trends because they showed the most recent construction and the resultant river bed changes. The following bathymetric trends remained relatively constant from 2005 - 2012 after comparison of the above mentioned hydrographic surveys:

i. Bathymetry

Table 5: Study Reach Bathymetry Trends

River Miles	**Description**
125.00 – 123.00	Scour occurred off the tip of dikes along the LDB with depths as low as -40 feet LWRP. The thalweg was located along the LDB with depths between -40 feet LWRP to -15 feet LWRP. Sandbars extended out along the RDB an average of 400 feet within the dike fields.
123.00 – 122.00	**Main Channel:** The thalweg crossed from the LDB to the RDB with depths of approximately -8 feet LWRP. This crossing was shallow and dredging has occasionally occurred to maintain the navigational depths. A plunge pool was located behind Pile Dike 123.00L with depths as low as -15 feet LWRP.

	Side Channel: The primary and secondary side channel entrances were located along the LDB of the side channel with depths as high as +10 feet LWRP. Scour occurred along the outside bend of the primary side channel with depths of approximately -5 feet LWRP.
122.00 – 120.00	**Main Channel:** The thalweg was located along the RDB with depths between -30 feet LWRP to -10 feet LWRP. Sandbars along the LDB extended past Moro Island with an average elevation of +7 feet LWRP.
	Side Channel: The main side channel had elevations as high as +10 feet LWRP. Scour occurred roughly 1,000 feet upstream of Dike 121.10L along the LDB in the main side channel, with average elevation of -10 feet LWRP. Downstream from Dike 121.10L, there was a 500 foot wide plunge pool with depths as low as -40 feet LWRP.
120.00 – 118.00	**Main Channel:** The thalweg crossed from the RDB to the LDB with depths of approximately -12 feet LWRP. Sediment deposition occurred along the LDB to RM 119.25 with elevation of +10 feet LWRP.
	Side Channel: At RM 120.00 along the LDB, the main side channel connected to the main channel. Sediment deposition occurred along the LDB with elevation of +10 feet LWRP.

118.00 – 117.00	The thalweg was located along the LDB through the bend to RM 117.00, with depths as low as -45 feet LWRP. Beaver Island was located along the RDB along with a side channel complex. There was no bathymetry data for this part of the river.

ii. Site Data

On September 19, 2012, personnel from AREC visited Moro Chute reach to examine bank lines, structures and any data that could not otherwise be gathered in the office. At the Chester, IL gage, the river stage was 1.40 feet LWRP (341.78 feet in elevation). The following observations were made:

- Primary Side Channel: Scouring occurred along the outside bend where LPSTP was constructed.
- Secondary Side Channel: There was no major erosion along either bank. The entire bed was exposed.
- Main Side Channel: The entire bed of the side channel was exposed. However, there was water in a large scour hole downstream of Dike 121.10L.
- Main Channel: Many sandbars were located along the LDB.
- Pile Dike 125.30R was visible but is not included on any hydrographic surveys. (Photograph 3, Plate 3)
- Dike 122.00L (Photograph 2, Plate 9), 122.10L (Photograph 1, Plate 11), and 121.60L (Photograph 4, Plate 12) were pile dikes.
- Dike 123.00 includes two sections. Section 1 consisted of a rock structure while part 2 consisted of a pile structure. (Photograph 1, Plate 8)

HSR MODELING

A discussion of Hydraulic Sediment Response (HSR) modeling theory is included in Appendix C.

1. Model Calibration and Replication

The HSR modeling methodology employed a calibration process designed to replicate the general 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 most 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) provided by the Little Rock District.

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, three dimensional mobile bed response. 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 replicated and alternative testing began.

2. Scales and Bed Materials

The HSR model employed a horizontal scale of 1 inch = 800 feet, or 1: 9,600, and a vertical scale of 1 inch = 52 feet, or 1:624, for 15.4 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.

3. Appurtenances

The HSR model insert planform was constructed according to the 2012 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. Leveling feet in four corners of the 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. Plate 51 is a photograph of the Moro Chute HSR model used in this study.

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 1.15 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 (3-D) laser scanner, Laser Doppler Velocimeter (LDV) and flow visualization. The operation of this equipment is described below.

A. 3D 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 were 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 (AREC) is to dye the water a dark color 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 30 seconds clips of the sediment floating throughout the study area. The recording is processed with software that reduces the original recording speed by 20%. The video speed reduction allows the 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 testing was taking place.

Bathymetric trends were recorded from the model using a 3-D laser scanner. Calibration was achieved after numerous favorable bathymetric comparisons of the prototype surveys were made to several of the model. The resultant bathymetry served as the bathymetry replication test for the model and is shown on Plate 52. Results of the HSR model replication test bathymetry and a comparison to the 2005 through 2012 prototype surveys indicated the following trends:

Table 6: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
125.00 – 123.00	The model and the prototype surveys showed scour occurred off of the tips of dikes located along the LDB with depths as low as -40 feet LWRP. The thalweg was located along the LDB with depths between -15 feet LWRP and -30 feet LWRP. A sandbar extended out into the main channel along the RDB.
123.00 – 122.00	**Main Channel:** The thalweg crossed from the LDB to the RDB with depths of approximately -10 feet LWRP in the model and prototype surveys. **Side Channel:** Sedimentation occurred at the primary and secondary side channel entrances with depths as high as -5 feet LWRP in both the model and prototype survey. Further downstream along the side channels, depths of at least +10 feet LWRP were observed. Scour did not occur along the outside bend of the primary side channel as seen on the prototype because the channel was too narrow.

122.00 – 120.00	**Main Channel:** The thalweg was located along the RDB with depths between -30 feet LWRP and -10 feet LWRP in both the model and prototype surveys. Sandbars along the LDB extended past Moro Island with average elevation of +7 feet LWRP and scour occurred off the tips of dikes. **Side Channel:** The main side channel had elevations as high as +10 feet LWRP. Scour occurred along the LDB approximately 1,000 feet upstream from Dike 121.10L, with depths as low as -10 feet LWRP in the prototype. However, the model showed very minimal scour at the same location. The plunge pool downstream of Dike 121.10L, with depths as low as -15 feet LWRP, was observed in both the model and prototype surveys.
120.00 – 118.00	**Main Channel:** The thalweg crossed from the RDB to the LDB with depths approximately -15 feet LWRP in both the model and prototype surveys. **Side Channel:** At RM 120.00, along the LDB, the main side channel connected to the main channel. Sediment deposition occurred along the LDB to RM 119.25 with elevations of +10 feet LWRP.

7. Design Alternative Tests

The testing process consisted of modeling alternative measures in the HSR model followed by analyses of the bathymetry results. The goal was to enhance habitat diversity in the side channels and along the LDB of Moro Island. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry (deposition and scouring). Only the most promising alternatives were then evaluated against model replication flow visualization.

Alternative 1:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	123.00	LDB	1,200	Existing Bed
Remove Dike	122.60	LDB	1,200	Existing Bed
Remove Pile Dike	123.00	LDB	1,700	Existing Bed
Remove Pile Dike	122.60	LDB	750	Existing Bed
Construct New Dike	122.65	LDB	1,200	+18.5
Construct New Dike	122.15	LDB	1,200	+18.5

Results: Bathymetry Analysis (Plate 53)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The new dikes directed a small amount of flow to the secondary side channel and caused scouring at the crossing between RM 122.50 and 121.50, while maintaining a relatively deep navigation channel. No sediment transport was observed. The primary side channel remained the same and no sediment transport was observed.

Alternative 2:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	123.00	LDB	1,200	Existing Bed
Remove Dike	122.60	LDB	1,700	Existing Bed
Remove Pile Dike	123.00	LDB	1,200	Existing Bed
Remove Pile Dike	122.60	LDB	750	Existing Bed
Construct New Dike	122.15	LDB	1,100	+18.5

Results: Bathymetry Analysis (Plate 54)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Minimal	No	No	No	The thalweg remained along the LDB between RM 123.0 and 122.0 before crossing over to the RDB. Pile Dike 122.10L caused a deep scour hole adjacent to Moro Island. As a result, sedimentation occurred in the navigation channel at RM 122.2. Dike 122.10L directed very little flow to the secondary side channel. No sediment transport was observed in the side channels.

Alternative 3:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	123.00	LDB	1,200	Existing Bed
Remove Pile Dike	123.00	LDB	1,200	Existing Bed

Results: Bathymetry Analysis (Plate 55)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Scour occurred off the tip of Dike 122.60L. The crossing between RM 122.50 and 121.50 experienced degradation with elevation as low as -20 feet LWRP. No sediment transport was observed in the side channels.

Alternative 4:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Pile Dike	122.10	LDB	300	Existing Bed
Shorten Dike	121.90	LDB	300	Existing Bed
Shorten Dike	121.70	LDB	300	Existing Bed
Construct Rootless Dike	122.10	LDB	200	+18.5
Construct Rootless Dike	121.90	LDB	200	+18.5
Construct Rootless Dike	121.70	LDB	200	+18.5

Results: Bathymetry Analysis (Plate 55)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	Scour occurred between notches adjacent to Moro Island. All side channels remained the same and no sediment transport was observed.

Alternative 5:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	122.60	LDB	900	Existing Bed
Shorten Dike	121.90	LDB	300	Existing Bed
Shorten Dike	121.70	LDB	300	Existing Bed
Shorten Dike	121.50	LDB	300	Existing Bed
Construct Rootless Dike	121.90	LDB	200	+18.5
Construct Rootless Dike	121.70	LDB	200	+18.5
Construct Rootless Dike	121.50	LDB	200	+18.5
Extend Dike	122.80	RDB	200	+18.5
Extend Dike	122.60	RDB	320	+18.5

Results: Bathymetry Analysis (Plate 57)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	Scour occurred between notches adjacent to Moro Island. All side channels remained the same and no sediment transport was observed.

Alternative 6:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Extend Dike	122.80	RDB	250	+18.5
Extend Dike	122.60	RDB	300	+18.5
Construct Rootless Dike	121.90	LDB	175	+18.5
Construct Rootless Dike	121.70	LDB	300	+18.5
Construct Rootless Dike	121.50	LDB	150	+18.5
Shorten Dike	122.60	LDB	400	Existing Bed
Shorten Dike	122.10	LDB	200	Existing Bed
Shorten Dike	121.90	LDB	400	Existing Bed
Shorten Dike	121.70	LDB	250	Existing Bed
Shorten Dike	121.50	LDB	225	Existing Bed

Results: Bathymetry Analysis (Plate 58)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	Scour occurred between notches and adjacent to Moro Island. All side channels remained the same and no sediment transport was observed.

Alternative 7:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Extend Dike	122.80	RDB	100	+18.5
Extend Dike	122.60	RDB	250	+18.5
Construct Rootless Dike	121.90	LDB	250	+18.5
Construct Rootless Dike	121.70	LDB	200	+18.5
Construct Rootless Dike	121.50	LDB	150	+18.5
Construct Rootless Dike	121.00	LDB	150	+18.5
Shorten Dike	122.60	LDB	250	Existing Bed
Shorten Dike	122.10	LDB	200	Existing Bed
Shorten Dike	121.90	LDB	220	Existing Bed
Shorten Dike	121.70	LDB	230	Existing Bed
Shorten Dike	121.50	LDB	330	Existing Bed
Shorten Dike	121.00	LDB	220	Existing Bed

Results: Bathymetry Analysis (Plate 59)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Minimal	No	No	No	Minimal scour occurred between notches and adjacent to Moro Island. The main channel at RM 122.00 was shallower. All side channels remained the same and no sediment transport was observed.

Alternative 8:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	300	Existing Bed
Notch Dike	122.60	LDB	800	Existing Bed
Shorten Pile Dike	123.00	LDB	250	Existing Bed

Results: Bathymetry Analysis (Plate 60)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The notches directed a small amount of flow to the primary and secondary side channels entrances, while maintaining a relatively deep navigation channel. No sediment was transport was observed. All side channels remained the same and no sediment transport was observed.

Alternative 9:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	122.60	LDB	200	Existing Bed
Shorten Pile Dike	123.00	LDB	300	Existing Bed
Shorten Dike	122.60	LDB	1,600	Existing Bed
Construct SCED*	122.60	LDB	1,800	+18.5

Results: Bathymetry Analysis (Plate 61)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The SCED directed a small amount of flow to the primary side channel entrance, while maintaining a relatively deep navigation channel. No sediment was transport was observed. Scour occurred off the tip of pile Dike 122.10L but has no negative impacts. All side channels remained the same and no sediment transport was observed.

*Side Channel Enhancement Dike

Alternative 10:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notched Dike	123.00	LDB	340	Existing Bed
Notch Dike	122.60	LDB	425	Existing Bed
Shorten Pile Dike	123.00	LDB	300	Existing Bed
Extend Dike	122.60L	LDB	650	+18.5

Results: Bathymetry Analysis (Plate 62)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The notches directed a small amount of flow to the secondary side channel entrances, while maintaining a relatively deep navigation channel. No sediment was transport was observed. All side channels remained the same and no sediment transport were observed.

Alternative 11:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	300	Existing Bed
Notch Dike	122.60	LDB	800	Existing Bed
Shorten Pile Dike	123.00	LDB	250	Existing Bed
Shorten Dike	122.60	LDB	300	Existing Bed

Results: Bathymetry Analysis (Plate 63)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The notches directed a small amount of flow to the secondary side channel entrance. No sediment was transport was observed. Degradation was observed at the crossing in the navigation channel between RM 122.5 and 121.5 and at the sandbar adjacent to Moro Island between RM 122.00 and 120.00. The sandbar along the RDB at RM 122.50 grew wider into the main channel. All side channels remained the same and no sediment transport were observed.

Alternative 12:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	200	Existing Bed
Shorten Pile Dike	123.00	LDB	200	Existing Bed
Shorten Dike	122.60	LDB	900	Existing Bed

Results: Bathymetry Analysis (Plate 64)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Scours occurred off the tip of Dike 121.90L. There were no negative impacts to the navigation channel. All side channels remained the same and no sediment transport was observed.

Alternative 13:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	210	Existing Bed
Notch Dike	122.60	LDB	520	Existing Bed
Shorten Pile Dike	123.00	LDB	300	Existing Bed
Construct Dike	123.00	LDB	250	+18.5
Construct Dike	121.00	LDB	450	+18.5
Construct Dike	121.80	LDB	450	+18.5
Construct Dike	121.60	LDB	450	+18.5

Results: Bathymetry Analysis (Plate 65)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Minimal	No	No	No	The notches directed a small amount of flow to the primary and secondary side channels. Degradation occurred at the sandbar adjacent to Moro Island between RM 122.00 and 120.00. No negative impacts on the navigation channel. All side channels remained the same and no sediment transport was observed.

Alternative 14:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	123.00	LDB	1,400	Existing Bed
Shorten Dike	122.60	LDB	900	Existing Bed
Shorten Pile Dike	122.10	LDB	220	Existing Bed
Remove Pile Dike	123.00	LDB	1,350	Existing Bed
Construct SCED	122.10	LDB	1,550	+18.5

Results: Bathymetry Analysis (Plate 66)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The SCED directed nimimal flow to the secondary side channel and caused a huge scour hole along the LDB between RM 122.4 and 122.0. The sandbar along the RDB at RM 121.80 was increase in size. Degradation occurred along the LDB at Moro Island between RM 122.00 and 120.00. No bathymetric change to all of the side channels and no sediment transport was observed.

*Side Channel Enhancement Dike

Alternative 15:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Remove Pile Dike	123.00	LDB	1,350	Existing Bed
Shorten Dike	123.00	LDB	1,400	Existing Bed
Shorten Dike	122.60	LDB	900	Existing Bed
Shorten Pile Dike	122.10	LDB	175	Existing Bed
Construct SCED	122.10	LDB	1,850	+18.5
Construct Dike	122.50	LDB	720	+18.5
Construct Dike	122.20	LDB	540	+18.5
Construct Dike	121.90	LDB	430	+18.5

Results: Bathymetry Analysis (Plate 67)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	This alternative shares similar results to Alternative 14.

*Side Channel Enhancement Dike

Alternative 16:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Remove Pile Dike	123.00	LDB	1,350	Existing Bed
Remove Dike	122.60	LDB	1,800	Existing Bed
Shorten Dike	123.00	LDB	1,400	Existing Bed
Construct SCED	122.10	LDB	1,850	+18.5
Construct Dike	122.50	LDB	720	+18.5
Construct Dike	122.20	LDB	540	+18.5
Construct Dike	121.90	LDB	430	+18.5

Results: Bathymetry Analysis (Plate 68)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	This alternative shares similar results to Alternative 14.

*Side Channel Enhancement Dike

Alternative 17:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	400	Existing Bed
Shorten Pile Dike	123.00	LDB	350	Existing Bed
Construct Diverter Dike	122.60	LDB	1,450	+18
Remove Dike	122.60	LDB	1,800	Existing Bed
Extend Dike	123.00	LDB	200	+18

Results: Bathymetry Analysis (Plate 69)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The diverter dike directed a small amount of flow to the primary and secondary side channels. No sediment was transport was observed. Degradation occurred at the sandbar located along the LDB between RM 122.00 and 120.00. There are no negative impacts to the navigation channel, no bathymetric changes to all side channels, and no sediment transport was observed.

Alternative 18:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	300	Existing Bed
Remove Pile Dike	123.00	LDB	1350	Existing Bed
Remove Pile Dike	122.60	LDB	800	Existing Bed
Remove Dike	122.60	LDB	1800	Existing Bed
Extend Dike	123.00	LDB	250	+18.5
Extend Dike	121.80	LDB (SSC)	1,450	+18.5
Construct Diverter Dike	122.60	LDB	1,100	+18.5
Construct Dike	122.10	LDB	700	+18.5
Construct Dike	121.90	LDB (SSC)	575	+18.5
Construct Dike	121.70	LDB (SSC)	550	+18.5
Construct Dike	121.35	RDB (MSC)	250	+18.5
Construct Dike	120.80	RDB (MSC)	150	+18.5
Construct Dike	120.80	LDB (MSC)	300	+18.5
Construct Dike	120.60	Moro Chute	440	+18.5
Construct Dike	120.20	Moro Chute	440	+18.5
Construct Rootless Dike	122.05	LDB (SSC)	325	+18.5
Construct Rootless Dike	121.95	LDB (SSC)	325	+18.5

SSC: Secondary Side Channel

MSC: Main Side Channnel

Results: Bathymetry Analysis (Plate 70)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Results similar to Alternative 17.

Alternative 19:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	300	Existing Bed
Remove Pile Dike	123.00	LDB	1,350	Existing Bed
Remove Pile Dike	122.60	LDB	800	Existing Bed
Remove Dike	122.60	LDB	1800	Existing Bed
Extend Dike	123.00	LDB	250	+18.5
Extend Dike	121.80	LDB (SSC)	450	+18.5
Construct Dike	122.10	LDB	1,150	+18.5
Construct Dike	122.40	LDB (SSC)	1,100	+18.5
Construct Dike	121.90	LDB	575	+18.5
Construct Dike	121.70	LDB (SSC)	550	+18.5
Construct Dike	121.35	RDB (MSC)	250	+18.5
Construct Dike	120.80	RDB (MSC)	150	+18.5
Construct Dike	120.80	LDB (MSC)	300	+18.5
Construct Dike	120.60	LDB (MSC)	440	+18.5
Construct Dike	120.20	LDB (MSC)	440	+18.5
Construct Rootless Dike	121.20	LDB (SSC)	325	+18.5
Construct Rootless Dike	121.00	LDB (SSC)	325	+18.5

SSC: Secondary Side Channel

MSC: Main Side Channnel

Results: Bathymetry Analysis (Plate 71)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Dike 122.10L directed a small amount of flow to the secondary side channel. No sediment transport was observed. Degradation occurred at the sandbar located along the LDB between RM 122.00 and 120.00. There are no negative impacts to the navigation channel, no bathymetric changes to all side channels, and no sediment transport was observed.

Alternative 20:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.00	LDB	300	Existing Bed
Remove Pile Dike	123.00	LDB	1,350	Existing Bed
Remove Dike	122.60	LDB	1,800	Existing Bed
Extend Dike	123.00	LDB	300	+18.5
Construct SCED*	122.50	LDB	1,160	+18.5

Results: Bathymetry Analysis (Plate 72)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The SCED directed a small amount of flow in the primary side channel. No sediment transport was observed. Degradation occurred at the sandbar located along the LDB between RM 122.00 and 120.00. There are no negative impacts to the navigation channel, no bathymetric changes to all of the side channels, and no sediment transport was observed.

*SCED: Side Channel Enhancement Dike

Alternative 21:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	123.0	LDB	300	Existing Bed
Remove Pile Dike	123.0	LDB	1,350	Existing Bed
Remove Dike	122.6	LDB	1,800	Existing Bed
Extend Dike	123.0	LDB	300	+18.5
Construct SCED*	122.5	LDB	1,160	+18.5

Results: Bathymetry Analysis (Plate 73)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Results similar to Alternative 20.

*SCED: Side Channel Enhancement Dike

Alternative 22:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Pile Dike	122.10	LDB	300	Existing Bed
Shorten Dike	121.90	LDB	200	Existing Bed
Shorten Dike	121.70	LDB	120	Existing Bed
Shorten Dike	121.50	LDB	225	Existing Bed
Shorten Dike	121.20	LDB	150	Existing Bed
Construct Rootless Dike	121.90	LDB	250	+18.5
Construct Rootless Dike	121.70	LDB	250	+18.5
Construct Rootless Dike	121.50	LDB	250	+18.5
Construct Rootless Dike	121.20	LDB	250	+18.5
Construct Rootless Dike	121.00	LDB	250	+18.5

Results: Bathymetry Analysis (Plate 74)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	The notches created scour and diversity at the sandbar adjacent to Moro Chute between RM 122.00 and RM 121.00. The sandbar along the RDB developed further downstream to RM 121.80 thus constriction the navigation channel around RM 122.00.

Alternative 23:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Pile Dike	122.10	LDB	625	Existing Bed
Shorten Dike	121.90	LDB	220	Existing Bed
Shorten Dike	121.70	LDB	120	Existing Bed
Shorten Dike	121.50	LDB	300	Existing Bed
Shorten Dike	121.20	LDB	140	Existing Bed
Shorten Dike	121.00	LDB	300	Existing Bed
Construct Rootless Dike	121.90	LDB	250	+18.5
Construct Rootless Dike	121.70	LDB	250	+18.5
Construct Rootless Dike	121.50	LDB	250	+18.5
Construct Rootless Dike	121.20	LDB	250	+18.5
Construct Rootless Dike	121.00	LDB	250	+18.5

Results: Bathymetry Analysis (Plate 75)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	The notches created scours and diversity at the sandbar adjacent to Moro Chute between RM 122.00 and RM 121.00. The sandbar along the RDB at RM 121.80 was increase in size. There are no bathymetric changes to all of the side channels and no sediment transport was observed.

Alternative 24:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Pile Dike	122.10	LDB	400	Existing Bed
Shorten Dike	121.90	LDB	250	Existing Bed
Shorten Dike	121.70	LDB	240	Existing Bed
Shorten Dike	121.50	LDB	200	Existing Bed
Shorten Dike	121.00	LDB	200	Existing Bed
Construct Rootless Dike	121.90	LDB	175	+18.5
Construct Rootless Dike	121.70	LDB	175	+18.5
Construct Rootless Dike	121.50	LDB	175	+18.5
Construct Rootless Dike	121.20	LDB	175	+18.5
Construct Rootless Dike	121.00	LDB	175	+18.5

Results: Bathymetry Analysis (Plate 76)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Minimal	No	No	No	Results similar to Alternative 23.

Alternative 25:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	122.10	LDB	600	Existing Bed
Notch Dike	121.90	LDB	300	Existing Bed
Notch Dike	121.70	LDB	275	Existing Bed
Notch Dike	121.50	LDB	425	Existing Bed

Results: Bathymetry Analysis (Plate 77)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Results similar to replication test.

Alternative 26:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	122.10	LDB	530	Existing Bed
Notch Dike	121.90	LDB	220	Existing Bed
Notch Dike	121.70	LDB	380	Existing Bed
Notch Dike	121.50	LDB	450	Existing Bed
Notch Dike	123.00	LDB	280	Existing Bed
Shorten Pile	123.00	LDB	300	Existing Bed
Shorten Dike	122.60	LDB	800	Existing Bed

Results: Bathymetry Analysis (Plate 78)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	Degradation occurred at the primary and secondary side channel entrances and Moro Island along the LDB between RM 123.00 and 121.00. Scour occurred off the tip of Notched Dike 121.90L. There are no negative impacts to the navigation channel, no bathymetric changes to all of the side channels, and no sediment transport was observed.

Alternative 27:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Notch Dike	122.10	LDB	530	Existing Bed
Notch Dike	121.90	LDB	220	Existing Bed
Notch Dike	121.70	LDB	380	Existing Bed
Notch Dike	121.50	LDB	450	Existing Bed
Notch Dike	123.00	LDB	280	Existing Bed
Shorten Pile	123.00	LDB	300	Existing Bed
Shorten Dike	122.60	LDB	1600	Existing Bed
Remove Pile Dike	122.60	LDB	800	Existing Bed

Results: Bathymetry Analysis (Plate 79)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
No	No	No	No	The sandbar along the LDB experience degradation between RM 123.00 and RM 121.00. There are no negative impacts to the navigation channel, no bathymetric changes to all of the side channels, and no sediment transport was observed.

Alternative 28:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Construct Rootless Dike	122.10	LDB	200	+18.5
Construct Rootless Dike	121.90	LDB	200	+18.5
Construct Rootless Dike	121.70	LDB	200	+18.5
Construct Rootless Dike	121.50	LDB	200	+18.5
Shorten Pile Dike	123.00	LDB	300	Existing Bed
Shorten Dike	122.60	LDB	900	Existing Bed
Shorten Dike	122.10	LDB	350	Existing Bed
Shorten Dike	121.90	LDB	200	Existing Bed
Shorten Dike	121.70	LDB	100	Existing Bed
Shorten Dike	121.50	LDB	220	Existing Bed
Notch Dike	123.00	LDB	280	Existing Bed

Results: Bathymetry Analysis (Plate 80)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	Degradation occurred at the primary and secondary side channel entrances and Moro Island along the LDB between RM 123.00 and 121.00. The notches created scours and diversity along the LDB between RM 122.00 and 121.00. Degradation occurred along the LDB between Dike 123.00L and 122.10L.

Alternative 29:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	122.10	LDB	350	Existing Bed
Shorten Dike	121.90	LDB	200	Existing Bed
Shorten Dike	121.70	LDB	100	Existing Bed
Shorten Dike	121.50	LDB	220	Existing Bed
Construct Rootless	121.10	LDB	200	+18.5
Construct Rootless	121.90	LDB	200	+18.5
Construct Rootless	121.70	LDB	200	+18.5
Construct Rootless	121.50	LDB	200	+18.5
Notch Dike	123.00	LDB	280	Existing Bed
Notch Dike	122.60	LDB	280	Existing Bed
Shorten Pile	123.00	LDB	300	Existing Bed

Results: Bathymetry Analysis (Plate 81)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	The notches created scour and diversity along the LDB between RM 123.00 and 121.00. Degradation occurred along the LDB between Dike 123.00L and 122.10L.

Alternative 30:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
Shorten Dike	122.10	LDB	350	Existing Bed
Shorten Dike	121.90	LDB	200	Existing Bed
Shorten Dike	121.70	LDB	100	Existing Bed
Shorten Dike	121.50	LDB	220	Existing Bed
Notch Dike	122.60	LDB	250	Existing Bed
Construct Rootless	121.10	LDB	200	+18
Construct Rootless	121.90	LDB	200	+18
Construct Rootless	121.70	LDB	200	+18
Construct Rootless	121.50	LDB	200	+18

Results: Bathymetry Analysis (Plate 82)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Additional Comments
Yes	No	No	No	The notches created scour and diversity along the LDB between RM 122.50 and 121.00. Degradation occurred along the LDB between Dike 123.00L and 122.10L.

Alternative 31:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
New Side Channel	123.00	LDB	3,200 by 150	Existing Bed

Results: Bathymetry Analysis (Plate 83)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Enhanced Environmental Diversity in the New Side Channel	Additional Comments
No	No	No	No	No	A small amount of flow was directed to the new side channel. Scour occurred at the entrance and continued downstream for 100 feet.

Alternative 32:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
New Side Channel	123.00	LDB	3,200 by 150	Existing Bed
Shorten Dike	123.20	LDB	300	Existing Bed

Results: Bathymetry Analysis (Plate 84)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Enhanced Environmental Diversity in the New Side Channel	Additional Comments
No	No	No	No	No	A small amount of flow was directed to the new side channel. Scour occurred at the entrance and continued downstream for 100 feet.

Alternative 33:

Type of Structure	River Mile	LDB / RDB	Dimensions (Feet)	Elevation (Feet LWRP)
New Side Channel	123.00	LDB	3200 by 150	-10
Shorten Dike	123.20	LDB	300	-10
Construct Dike	123.10	LDB	450	+18

Results: Bathymetry Analysis (Plate 85)

Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel	Enhanced Environmental Diversity in the New Side Channel	Additional Comments
No	No	No	No	No	A small amount of flow was directed to the new side channel. Scour occurred at the entrance and continued downstream for 100 feet.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

In order to determine the best alternative, certain criteria, based on the study purpose and goals, were used to evaluate each alternative. The first and most important consideration was that the alternative had to enhance habitat diversity in the side channels and along the LDB of Moro Island. The second condition was that the alternative had to maintain the navigation channel requirements of at least 12 foot of depth and 300 foot of width. The third condition was that the alternative should avoid and minimize negative impacts to environmental features within the reach. Although there were a number of alternatives that showed minimal improvements in enhancing the LDB of Moro Island while maintaining the navigation channel requirements, they were not recommended. These alternatives were not recommended primarily because they caused deposition in the navigation channel. Some of the alternatives that met the criterion but were not chosen were alternatives 6, 7 and 22.

Table 7: Summary of Test Results

Alternative	Enhanced Environmental Diversity Adjacent to Moro Chute	Enhanced Environmental Diversity in the Primary Side Channel	Enhanced Environmental Diversity in the Secondary Side Channel	Enhanced Environmental Diversity in the Main Side Channel
1	No	No	No	No
2	Minimal	No	No	No
3	No	No	No	No
4	Yes	No	No	No
5	Yes	No	No	No
6	Yes	No	No	No
7	Minimal	No	No	No
8	No	No	No	No
9	No	No	No	No

10	No	No	No	No
11	No	No	No	No
12	No	No	No	No
13	Minimal	No	No	No
14	No	No	No	No
15	No	No	No	No
16	No	No	No	No
17	No	No	No	No
18	No	No	No	No
19	No	No	No	No
20	No	No	No	No
21	No	No	No	No
22	Yes	No	No	No
23	Yes	No	No	No
24	Minimal	No	No	No
25	No	No	No	No
26	No	No	No	No
27	No	No	No	No
28	Yes	No	No	No
29	Yes	No	No	No
30	Yes	No	No	No
31	No	No	No	No
32	No	No	No	No
33	No	No	No	No

2. <u>Recommendations</u>

Alternative 29, Plate 81, was recommended as the most desirable alternative because of its ability to enhance the habitat diversity at and around Moro Island, while having no significant impacts on the navigation channel. Bathymetry results showed that along the

LDB, between RM 122.0 and 121.0, scour occurred at the notches. As a result, a secondary channel was created.

The goal to enhance the habitat diversity at Moro Island Complex involved increasing the flow and sediment transport through the side channels. However, the location of the primary side channel entrance being blocked by structures and the natural planform of the river made the task nearly impossible. The width of the secondary side channel was also a problem. Therefore, the approach taken in the recommended alternative was to create a secondary channel on the western side of Moro Island with river training structures. Overall, this alternative would enhance the habitat diversity and maintain the navigation channel near Moro Island.

The recommended design included the following:

- Shorten Pile Dike 123.00L
    - Shorten pile dike 300 feet
    - Shorten pile dike will be to existing bed elevation
- Shorten Dike 122.10L
    - Shorten dike 350 feet long
    - Shorten pile dike will be to existing bed elevation
- Shorten Dike 121.90L
    - Shorten dike 200 feet long
    - Shorten pile dike will be to existing bed elevation
- Shorten Dike 121.70L
    - Shorten dike 100 feet long
    - Shorten pile dike will be to existing bed elevation
- Shorten Dike 121.50L
    - Shorten dike 220 feet long
    - Shorten pile dike will be to existing bed elevation
- Construct Rootless Dike 121.10L
    - Construct rootless dike 200 feet long

    - Construct rootless dike to elevation of +18.5 feet LWRP
- Construct Rootless Dike 121.90L
    - Construct rootless dike 200 feet long
    - Construct rootless dike to elevation of +18.5 feet LWRP
- Construct Rootless Dike 121.70L
    - Construct rootless dike 200 feet long
    - Construct rootless dike to elevation of +18.5 feet LWRP
- Construct Rootless Dike 121.50L
    - Construct rootless dike 200 feet long
    - Construct rootless dike to elevation of +18.5 feet LWRP
- Notch Dike 123.00L
    - Notch dike 280 feet long
    - Notch dike will be to existing bed elevation
- Notch Dike 122.60L
    - Notch dike 280 feet long
    - Notch dike will be to existing bed elevation

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. Water surfaces were not analyzed and 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 Mississippi 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.

FOR MORE INFORMATION

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APPENDIX

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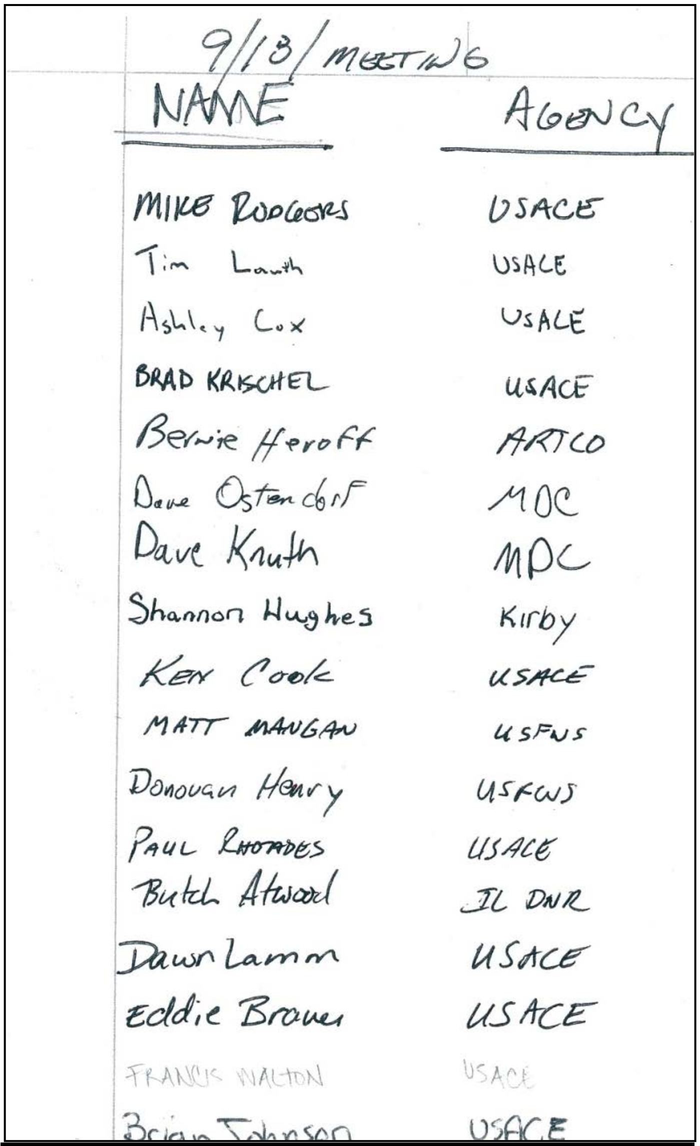
2. Meeting Minutes



9/18/ MEETING

NAME	AGENCY
MIKE RODGERS	USACE
Tim Lauth	USACE
Ashley Cox	USACE
BRAD KRISCHEL	USACE
Bernie Heroff	ARTCO
Dave Ostendorf	MDC
Dave Knuth	MDC
Shannon Hughes	Kirby
KEN Cook	USACE
MATT MANGAN	USFWS
Donovan Henry	USFWS
PAUL RHOADES	USACE
Butch Atwood	IL DNR
Dawn Lamm	USACE
Eddie Brauer	USACE
FRANCIS WALTON	USACE
Brian Johnson	USACE

Figure 3: September 18, 2013 Model Meeting Sign-in Sheet

3. Cross Section Comparison

To verify the predictive capabilities of the HSR model used for this study, cross sections were developed for the replication model condition and three prototype bathymetries, the 2007, 2010 and 2012 river surveys.

Table 8: Cross Section Comparison Model Replication Scan and 2007 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2007 Survey (feet²)	True Model Replication (feet²)	True 2007 Survey (feet²)	
40+00	630,652	623,707	42,043	41,580	1.11%
60+00	627,436	616,407	41,829	41,094	1.77%
80+00	609,142	677,425	40,609	45,162	10.61%
100+00	647,001	732,863	43,133	48,858	12.45%
120+00	612,911	632,241	40,861	42,149	3.10%
140+00	689,317	702,288	45,954	46,819	1.86%
160+00	586,390	563,642	39,093	37,576	3.96%
180+00	626,411	517,701	41,761	34,513	19.00%
200+00	624,400	513,723	41,627	34,248	19.45%
220+00	571,740	547,984	38,116	36,532	4.24%
240+00	590,877	571,783	39,392	38,119	3.28%
260+00	535,836	519,404	35,722	34,627	3.11%
280+00	523,525	519,448	34,902	34,630	0.78%
360+00	616,080	637,179	41,072	42,479	3.37%
380+00	650,314	633,093	43,354	42,206	2.68%
400+00	685,703	681,567	45,714	45,438	0.60%
				Average	**5.7**

Table 9: Cross Section Comparison Model Replication Scan and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2010 Survey (feet²)	True Model Replication (feet²)	True 2010 Survey (feet²)	
40+00	630,652	698,522	42,043	46,568	10.2%
60+00	627,436	704,917	41,829	46,994	11.6%
80+00	609,142	757,907	40,609	50,527	21.8%
100+00	647,001	880,713	43,133	58,714	30.6%
120+00	612,911	690,397	40,861	46,026	11.9%
140+00	689,317	623,423	45,954	41,562	10.0%
160+00	586,390	474,225	39,093	31,615	21.2%
180+00	626,411	491,225	41,761	32,748	24.2%
200+00	624,400	494,295	41,627	32,953	23.3%
220+00	571,740	508,160	38,116	33,877	11.8%
240+00	590,877	545,843	39,392	36,390	7.9%
260+00	535,836	491,836	35,722	32,789	8.6%
280+00	523,525	473,799	34,902	31,587	10.0%
360+00	616,080	667,313	41,072	44,488	8.0%
380+00	650,314	649,997	43,354	43,333	0.0%
400+00	685,703	668,595	45,714	44,573	2.5%
				Average	**13.3**

Table 10: Cross Section Comparison Model Replication Scan and 2012 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	Model Replication (feet²)	2012Survey (feet²)	True Model Replication (feet²)	True 2012 Survey (feet²)	
40+00	630,652	673,201	42,043	44,880	6.5%
60+00	627,436	705,123	41,829	47,008	11.7%
80+00	609,142	717,098	40,609	47,807	16.3%
100+00	647,001	809,092	43,133	53,939	22.3%
120+00	612,911	651,182	40,861	43,412	6.1%
140+00	689,317	654,808	45,954	43,654	5.1%
160+00	586,390	570,900	39,093	38,060	2.7%
180+00	626,411	571,943	41,761	38,130	9.1%
200+00	624,400	567,785	41,627	37,852	9.5%
220+00	571,740	564,749	38,116	37,650	1.2%
240+00	590,877	527,643	39,392	35,176	11.3%
260+00	535,836	501,700	35,722	33,447	6.6%
280+00	523,525	502,045	34,902	33,470	4.2%
360+00	616,080	570,757	41,072	38,050	7.6%
380+00	650,314	597,286	43,354	39,819	8.5%
400+00	685,703	644,669	45,714	42,978	6.2%
				Average	**8.4**

Table 11: Cross Section Comparison between 2007 and 2010 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2007 Survey (feet²)	2010 Survey (feet²)	True 2007 Survey (feet²)	True 2010 Survey (feet²)	
40+00	623,707	698,522	41,580	46,568	11.3%
60+00	616,407	704,917	41,094	46,994	13.4%
80+00	677,425	757,907	45,162	50,527	11.2%
100+00	732,863	880,713	48,858	58,714	18.3%
120+00	632,241	690,397	42,149	46,026	8.8%
140+00	702,288	623,423	46,819	41,562	11.9%
160+00	563,642	474,225	37,576	31,615	17.2%
180+00	517,701	491,225	34,513	32,748	5.2%
200+00	513,723	494,295	34,248	32,953	3.9%
220+00	547,984	508,160	36,532	33,877	7.5%
240+00	571,783	545,843	38,119	36,390	4.6%
260+00	519,404	491,836	34,627	32,789	5.5%
280+00	519,448	473,799	34,630	31,587	9.2%
360+00	637,179	667,313	42,479	44,488	4.6%
380+00	633,093	649,997	42,206	43,333	2.6%
400+00	681,567	668,595	45,438	44,573	1.9%
				Average	**8.6**

Table 12: Cross Section Comparison between 2007 and 2012 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2007 Survey (feet²)	2012 Survey (feet²)	True 2007 Survey (feet²)	True 2012 Survey (feet²)	
40+00	623,707	673,201	41,580	44,880	7.6%
60+00	616,407	705,123	41,094	47,008	13.4%
80+00	677,425	717,098	45,162	47,807	5.7%
100+00	732,863	809,092	48,858	53,939	9.9%
120+00	632,241	651,182	42,149	43,412	3.0%
140+00	702,288	654,808	46,819	43,654	7.0%
160+00	563,642	570,900	37,576	38,060	1.3%
180+00	517,701	571,943	34,513	38,130	10.0%
200+00	513,723	567,785	34,248	37,852	10.0%
220+00	547,984	564,749	36,532	37,650	3.0%
240+00	571,783	527,643	38,119	35,176	8.0%
260+00	519,404	501,700	34,627	33,447	3.5%
280+00	519,448	502,045	34,630	33,470	3.4%
360+00	637,179	570,757	42,479	38,050	11.0%
380+00	633,093	597,286	42,206	39,819	5.8%
400+00	681,567	644,669	45,438	42,978	5.6%
				Average	**6.8**

Table 13: Cross Section Comparison between 2010 and 2012 Bathymetry

Cross Section Station	Area Without Correction		Corrected Area		Percent Difference
	2010 Survey (feet²)	2012 Survey (feet²)	True 2010 Survey (feet²)	True 2012 Survey (feet²)	
40+00	698,522	673,201	46,568	44,880	3.7%
60+00	704,917	705,123	46,994	47,008	0.0%
80+00	757,907	717,098	50,527	47,807	5.5%
100+00	880,713	809,092	58,714	53,939	8.5%
120+00	690,397	651,182	46,026	43,412	5.8%
140+00	623,423	654808	41,562	43,654	4.9%
160+00	474,225	570,900	31,615	38,060	18.5%
180+00	491,225	571,943	32,748	38,130	15.2%
200+00	494,295	567,785	32,953	37,852	13.8%
220+00	508,160	564,749	33,877	37,650	10.5%
240+00	545,843	527,643	36,390	35,176	3.4%
260+00	491,836	501,700	32,789	33,447	2.0%
280+00	473,799	502,045	31,587	33,470	5.8%
360+00	667,313	570,757	44,488	38,050	15.6%
380+00	649,997	597,286	43,333	39,819	8.5%
400+00	668,595	644,669	44,573	42,978	3.6%
				Average	**7.8**

Table 14: Average Percent Difference Between Model Replication and Prototype Surveys

Model Replication & 2007 Survey	Model Replication & 2010 Survey	Model Replication & 2012 Survey	Average Percent Difference
5.70	13.30	8.40	9.20

Table 15: Average Percent Difference Between Prototype Surveys

2007 Survey & 2010 Survey	2007 Survey & 2012 Survey	2010 Survey & 2012 Survey	Average Percent Difference
8.60	6.80	7.80	7.70

4. **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 (Environmental Research and Development Center). These models were used by MVS from 1940 to the mid 1990s. For a more thorough explanation of the HSR model development, please refer to the following link: http://www.wes.army.mil/Welcome.html

5. Flow Visualization Results

Flow visualization is a tool used to monitor the flow patterns in an HSR model. The preferred method at the Applied River Engineering Center is to dye the water 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 60 seconds of the sediment floating through the study area. The recording is processed with software that reduces the recording to approximately 20% of the original speed. The video speed reduction allows viewers to more easily track the flow patterns.

The first condition recorded was the replication test, or existing conditions as seen in Figure 4 below.

(Please note that there is a DVD available with this report to view the video). (Please note that there is a DVD available with this report in order to view the described videos. Furthermore, Youtube hyperlinks will be provided in the online version of the report. To access the Youtube videos simply click on the still image of the video, and it will direct you to the associated Youtube video.)

The flow exited a bend at RM 122.00 and about to cross over to the RDB just upstream of Figure 4’s extents. As seen in the snapshot of the existing conditions, the resultant flow was concentrated along the LDB in Figure 4. Immediately downstream, flow crossed over to the RDB and began to disperse across the channel. No sediment movement as observed in the side channels. All structures are highlighted in pink for increased visibility.

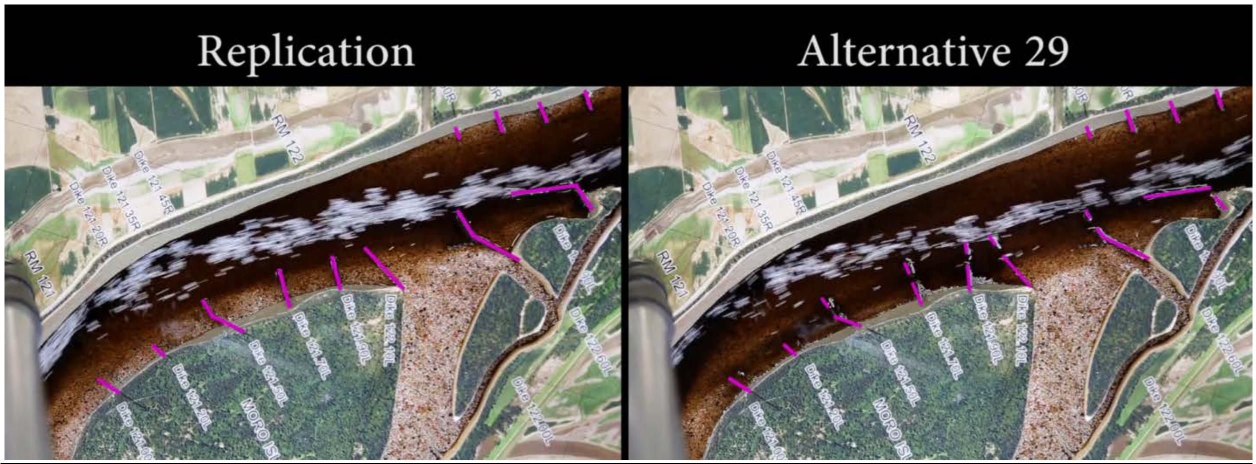


Figure 4: Flow Visualization

The next condition recorded was post construction with the recommended alternative (Alternative 29) for constructing rootless dike extensions and shortened dikes that would create a secondary channel and provide habitat diversity adjacent to Moro Island.

Again, the flow exited a bend at RM 122.00 and about to cross over to the RDB just upstream of Figure 4’s extents. As seen in the snapshot of the post construction conditions, the flow split sending the majority of the flow through the main channel. A secondary side channel was created between the notch structures. Compared to the existing conditions, there was increased flow and sediment transport along the LDB.