US Army Corps of Engineers
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Technical Report M39

SEDIMENTATION STUDY OF THE UPPER MISSISSIPPI RIVER AT IOWA ISLAND, RIVER MILES 230 TO 219

HSR MODEL INVESTIGATION

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Prepared for
U.S. Army Corps of Engineers, St. Louis District
Avoid and Minimize Program

In cooperation with:
ILLINOIS DEPARTMENT OF NATURAL RESOURCES
MISSOURI DEPARTMENT OF CONSERVATION
U.S. FISH AND WILDLIFE SERVICE
RIVER INDUSTRY ACTION COMMITTEE
Final Report - June 2006

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District initiated a sedimentation improvement study of the Iowa-Squaw Island reach of the Upper Mississippi River between Miles 230.0 and 219.0 near Grafton, Illinois. The purpose of the study was to evaluate design alternatives to alleviate repetitive channel maintenance dredging associated with continual sediment deposition in the navigation channel while maintaining or improving existing environmental conditions. This study will utilize and/or modify the existing dike fields and incorporate new construction to optimize the energies associated with sediment transport in an attempt to reduce chronic dredging concerns.

Mr. Michael T. Rodgers, hydraulic engineer and Mr. Edward H. Riiff, engineering technician, under direct supervision of Mr. David C. Gordon, hydraulic engineer, and Mr. Robert D. Davinroy, Chief of River Engineering, conducted the study between March 2005 and February 2006. Other personnel also involved with the study included: Mr. Leonard Hopkins, Project Manager, Avoid and Minimize Program; Ms. Teri Allen TOC and Mr. Kip Runyon from the Environmental Branch of the Planning, Programs, and Project Management Division. Personnel from other agencies involved in the study included: Mr. Butch Atwood from the Illinois Department of Natural Resources, and Ms. Karen Westfall from the U.S. Fish and Wildlife Service; Mr. Danny Brown from the Missouri Department of Conservation; Mr. Samuel Dickey and Mr. Ray Hopkins from River Industry Action Committee (RIAC); Mr. Milton Ohlsen and Mr. Holaus from the Duck Club Marina; Mr. Scott Bachman from Wahoo Marine; Mr. George Wendel, Mr. Doug Smith and Mr. Don Woebling from Anchor Yankers Yacht Club.

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BACKGROUND

Hydraulic Sediment Response (HSR) modeling methodology was used to evaluate the present sediment transport conditions as well as the impact associated with the incorporation of future design alternatives along the Iowa Island Reach of the Upper Mississippi River. This study was funded as part of the Avoid and Minimize Program of the Upper Mississippi River. The primary goal of this study was to alleviate chronic dredging in the main channel adjacent to Iowa Island, Enterprise Island, and Island 521.

1. Study Reach

The Iowa-Squaw Island reach is located 18 miles upstream of Mel Price Locks and Dam near Grafton, Illinois. The study is comprised of an 11-mile stretch of the Upper Mississippi River, between Miles 230.0 and 219.0. Plate 1 is a location and vicinity map of the study reach. The study area was located in St. Charles County in Missouri, and Calhoun County in Illinois.

Plate 2 is the 2004 aerial photograph illustrating the geomorphology and nomenclature of the Upper Mississippi River between Miles 230.0 and 219.0. This reach of river contains several islands and side channels. Exposed bedrock (non-erodable) is located along the Left Descending Bank (LDB). The majority of the LDB consists of Karst Topography (exposed limestone and dolomite) which act as a natural revetment, inhibiting the action of channel meandering (Plate 3). The Right Descending Bank (RDB) is typical flood plain alluvium and the majority of the river bank was revetted or had some other form of bank protection (Plate 4). River training structures also have a major impact on the location of the channel. Structure placement is necessary to maintain the 9 foot navigation channel.

2. Dredging and Alignment Analysis

This reach of the Mississippi River is one of the most heavily dredged reaches in the entire St. Louis District. In the last 50 years, dredging has occurred on a yearly

basis in this reach. Plate 5 shows the locations of both the dredge cuts and disposal sites in this reach for the dredging that occurred between 1979 and 2004. Plate 6 is a graph that illustrates the yearly dredging totals from 1994 to 2004 between Miles 230.0 and 219.0. Within this eleven mile reach, over 5.25 million cubic yards of material was dredged at a cost of nearly $10.5M over these 10 years. That translated into a yearly average of over 500,000 cubic yards of material at a cost of over $1.0M per year. The area between Miles 222.0 and 224.0 accounted for 40% of the total volume of material dredged. Over the last 10 years this eleven mile reach is responsible for 8.5% (by volume) of dredging that occurred in the St. Louis District.

In 2001, the Bolter Bar HSR Model Study was completed and design alternatives were tested to reduce dredging from mile 226.0 to 225.0. A solution was identified and in 2002 a longitudinal dike and four chevrons were constructed along the RDB at this location. Since the installation of these structures, repetitive dredging at this location has not been required (approximately 4 years). Dredging was also eliminated at Mile to 227 by extending the trail on Dike 227.5 R and by rebuilding closure structure 226.3 R in Bolter Chute. Shoaling continues to take place through the remainder of this river reach and repetitive dredging remains necessary to maintain the navigation channel.

Dredging in this area has not only been repetitive and costly, but also troublesome. The Corps has had difficultly locating viable dredge spoil placement areas that will not negatively affect recreation, homeowners, or the environment. The normal disposal method of dredge material is open water placement without confinement. Areas to place this material within the reach are very limited. Therefore, in 1996, under the Avoid and Minimize Environmental Impacts Program, placement of this material in deep portions of the channel thalweg was initiated. Physical and biological monitoring showed no adverse effects to the environment but the deep portion of channel can only handle a small portion of the overall volume dredged from the reach. Furthermore, this material eventually will be naturally transported from these deep areas and may be deposited in other problem areas downstream

that already experience repetitive channel maintenance dredging. Therefore, a means must be found to reduce the shoaling problem and then utilize the remaining dredge material in a beneficial manner.

3. Flow Split Analysis

Flow split analysis is a tool used to determine what portion of main channel flow is "lost" to side channels, thereby not contributing to the maintenance of the navigation channel. Closure Structure 226.3 R was designed to increase flow in the main channel by reducing flow in the Bolter Chute. The Bolters Bar Chevrons were designed to constrict the navigation channel, while not eliminating flow entering Iowa Chute. By constricting the flow in the navigation channel, the channel increases its ability to transport sediment and its ability to maintain the navigation channel.

The main need for repetitive dredging through this reach is the loss of flow from the main channel to the side channels. Discharge measurements identify the amount of flow that is lost to a particular side channel. Plate 7 displays flow split measurements collected at Miles 227.3 and 224.6 between 1988 and 2004. Each colored bar shows the percent of the total discharge handled by each channel throughout the years.

At Mile 227.3, the data shows that the main channel typically carried more than 60% of the total flow from 1988 to 1995. By 1996 and 1997 the flow in the main channel had dropped to below 50% of the total. The decrease in flow in the main channel correlates with increased flow in both Bolter and Dardenne Chutes. The cause of increase flow to the side channel was the degradation of closure structure 226.3 R. This structure was rebuilt in early 2000 and the resulting flow splits from 2000, 2002, and 2004 showed increase flow in the main channel. Repairing the closure structure brought the flow splits back to pre 1996 levels, sustaining on average of 65% of flow in the main channel.

At Mile 224.6, the data shows the main channel carried nearly 50% of the total flow from 1988 to 1994. From 1995 to 1997, the flow in the main channel dropped to

about 40% of the total flow. From 2000 to present the flow in the main channel continues to be around 45%. Due to the impact of the Bolter Bar structures constricting the channel, dredging has not been needed and the navigation channel has been able to maintain itself even with the loss of flow to the side channels.

The overall trend in the reduction of flow in the main channel (due to the increase of flow in the side channels) has caused the continual need for repetitive dredging through this reach. Due to environmental factors and recreational use, flow to the side channels can not be completely restricted. Therefore, any viable solution needs to consider the affect it has on flow to the side channels.

4. Study Purpose and Goals

The purpose of this study was to assess the sediment transport conditions of the Mississippi River and to examine the interaction between the main channel and the side channel complex.

The primary goal of this study was to evaluate design alternatives that would reduce the need for repetitive dredging and maintain necessary depths in the navigation channel while not negatively affecting the side channel complex for environmental and recreational purposes. Design alternatives included examining methods of increasing velocities in the main channel and improving the navigation channel alignment without closing off the chutes. The use of dikes, chevrons, and other structures in the main channel were considered. Assessments of these alternatives included the examination of the ultimate effects to sedimentation patterns within the main channel, at the entrances to the side channels, and within each side channel.

HSR MODEL DESCRIPTION

1. Scales and Bed Materials

In order to investigate the sediment transport conditions described previously, a physical HSR model was designed and constructed. Plate 8 is a photograph of the HSR model used in this study. The zero reference plane of the prototype was assumed to be the MP (Minimum Pool) condition. The model employed a horizontal scale of 1 inch = 800 feet, or 1:9600, and a vertical scale of 1 inch = 50 feet, or 1:600, for a 16 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those of the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.40.

2. Appurtenances

The HSR model insert was constructed according to the 2004 high-resolution aerial photograph of the study reach. The insert was then mounted in a standard HSR flume. The riverbanks of the model were constructed from dense polystyrene foam, and modified during calibration with galvanized steel mesh. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.007 inch/inch. River training structures in the model were made of galvanized steel mesh.

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 automatically control the flow of water and sediment into the model. Discharge was monitored by a magnetic flow meter interfaced with the customized computer software. Water stages were manually checked with a mechanical three-dimensional point digitizer. Resultant bed configurations were measured and recorded with a three-dimensional laser digitizer.

HSR MODEL TESTS

1. Model Calibration

The calibration of the HSR model involved the adjustment of water discharge, sediment volume, model slope, and entrance conditions of the model. These parameters were refined until the measured bed response of the model was similar to that of the prototype.

A. HSR Model Operation

In all model tests, a steady state flow was simulated in the Upper Mississippi River channel. This served as the average design energy response of the river. Because of the constant variation experienced in the prototype, this steady state flow was used to theoretically analyze the ultimate expected sediment response. The flow was held steady at a constant flow rate of 2.05 gallons per minute (GPM) during model calibration and for all design alternative tests. The most important factor during the modeling process is the establishment of an equilibrium condition of sediment transport. The high steady flow in the model simulated an average energy condition representative of the river's channel forming flow and sediment transport potential at bankfull stage.

B. Prototype Data

Several prototype hydrographic surveys were used to determine the general bed characteristics and sediment transport trends that have existed in the prototype. Plate 9 is a 1881 hydrographic survey of the study reach. Minimal changes in bankline location and island configuration have occurred within the last 125 years. This can be attributed to the advent of river training structures and exposed outcrops of limestone located along the LDB. Hydrographic surveys of the Mississippi River main channel from 1998, 2001 and 2004 are shown on Plates 10, 11, and 12 respectively. Upon comparing these surveys it was evident that all of the recent surveys showed similar bathymetric trends. In the HSR model calibration process

more emphasis was placed on the 2004 hydrographic survey (Plate 12) because it was the only survey that incorporated the addition of the Bolter Bar structures which were constructed in 2002.

The general trends of the prototype as observed in the hydrographic surveys are described as follows:

- The thalweg entered the study reach along the RDB near Mile 229.0. A scour hole pattern with depths below –30 feet MP was located within the dike field downstream of the entrance to Dardenne Chute.
- The navigation channel narrowed near the head of Bolter Island at Mile 227.3. A point bar extended from the LDB near Mile 227.0.
- A narrow but deep channel with depths below –20 feet MP was located on the RDB between Miles 227.2 and 226.0.
- The main channel between Miles 226.0 and 225.0 has depths ranging from -20 feet MP to -10 MP. Historically, through this stretch, the main channel was artificially maintained by repetitive dredging. After the completion of the Bolters Bar structures the navigation channel has maintained itself.
- A small area of scour with depths below –20 feet MP was located near the head of Iowa Island on the RDB near Mile 225.0.
- The main channel then made a quick, shallow crossing to the LDB between Miles 225.0 and 224.3. A small scour hole with depths below –20 feet MP was located on the LDB near Mile 224.3. A bar was located on the RDB directly across from the scour hole. This was probably a result of the repetitive dredging and the placement of disposal material.
- The main channel then began another crossing back to the RDB between Miles 224.0 and 223.5 and crossed back to LDB at Mile 223.3.
- Another channel crossing began from the LDB at Mile 223.0 to the RDB at Mile 222.7. Shoaling was located on the LDB from Mile 222.8 to 222.0 and the channel contracted considerably. A scour hole was located off of Dike 222.4R with depths below -30 feet MP. Repetitive dredging is used to maintain the

channel through Miles 223.0 to 221.4. Without the use of dredging depths of 0 feet MP to -10 feet MP could be expected at some locations through this stretch.

- The main channel remained on the RDB until Mile 222.3 and proceeded to cross to the LDB at Mile 222.0R. Depths were -20 feet MP along the LDB and -10 MP through the crossing. A large point bar was located on the right descending bank from Mile 222.3 to 221.5. This deposition could be attributed to the repetitive placement of dredge spoil material at this location.
- The main channel made a final crossing from the LDB at Mile 221.5 to the center of the river and remained there for the rest of the study reach. Depths through the crossing were at -10 feet MP and once the channel stabilized in the center of the channel depths were -20 feet MP. A large shoaling area was located at the confluence of the side channel and main channel.

Plate 12 also shows prototype survey of the 2004 Dardenne, Iowa, and Squaw Chute side channel complex. Once again, in the micro model calibration process more emphasis was placed on the 2004 survey. The prototype surveys showed the following trends:

- Depths at the entrance to Dardenne Chute were above -10 feet MP.
- Depths in the remaining portions of Dardenne Chute were variable between 0 and –20 feet MP.
- A deep thalweg was located at the entrance to Bolter Chute with depths near –30 feet MP.
- A scour hole was located downstream of closure structure 226.3R which had depths that exceeded -40 feet MP. This was due to the notch that was placed in the closure structure.
- Deep water, depths exceeding -20 feet MP was located on the RDB at Mile 223.5 after the convergence of Dardenne and Bolter Chutes. The depth remains consistent through the remainder of the side channel as it crosses from the RDB to the LDB at Mile 224.5.

- Depths at the entrance to Iowa Chute and throughout the channel were generally between 0 and –10 feet MP. Depths through the small chute between Iowa and Enterprise Islands were also between 0 and –10 feet MP.

Depths within Bolter Chute and the main side channel appeared to have average depths comparable to, or deeper than those within the main navigation channel.

2. Base Test

Model calibration was achieved once a favorable qualitative comparison of the prototype surveys was made to several surveys of the model. The resultant bathymetry of this bed response served as the base test of the micro model. Plate 13 shows the resultant bed configuration of the micro model base test. The base test was developed from the simulation of successive repeatable design hydrographs until bed stability was reached and a similar bed response was achieved as compared with prototype surveys. This survey then served as the comparative bathymetry for all design alternative tests.

Results of the HSR base test bathymetry and a comparison to the prototype surveys indicated the following trends:

- The thalweg of the main channel entered the study reach on the RDB with depths approaching –30 feet MP. The thalweg maintained its depth past the entrance to Dardenne Chute. Scour holes with depths over –30 feet MP were formed off the ends of Dikes 228.8R and 228.4R.
- The thalweg became shallow between Miles 227.9 and 227.4. Depths along the in the center exceeded –10 feet MP through this reach. These trends resembled those of the prototype surveys.
- A thalweg with depths that exceeded –30 feet MP was located on the RDB, beginning at the head of Bolter Island at Mile 227.3 and extending to Mile 226.0. A point bar with depths between 0 and –10 feet MP was formed on the LDB near Mile 227.0. These trends also resembled those of the prototype surveys.

- Mile 226.0 is the beginning of the Bolter Bar structures. Depths through this stretch exceed -15 feet MP which is also similar to the prototype. Prior to the construction of the Bolter Bar structures, this was a location of shoaling and repetitive dredging. Upon completion of the structures the channel has maintained or exceeded depths of -15 feet MP.
- A scour hole with a depth of –30 feet MP was formed near the head of Iowa Island on the RDB. The channel made a short, shallow crossing to the LDB where another scour hole formed with depths below –30 feet near Mile 224.2. The channel again became shallow before another area of scour was formed on the LDB. There are signs of deposition in the main channel from Miles 224.5 to 223.5. This is a location of past dredging in the prototype and the deposition is most likely dredge material. These trends resembled those of the prototype surveys.
- A large point bar was located on the RDB from Mile 223.4 to 222.5. The location of this bar on the prototype is upstream. The differences between the base test and the prototype can be attributed to the years of repetitive dredging and disposal placement through this section of the reach.
- The main channel from Miles 223.0 to 221.8 completes a series of crossings. Beginning at Mile 223.0 on LDB, with depths exceeding -30 feet MP the main channel crossed to the RDB at Mile 222.5. The depth at this crossing was -10 feet MP. A second crossing occurred from Miles 222.4 to 221.9. The depths along the crossing were -10 feet MP. A bar formed on the LDB from Miles 222.4 to 222.0. These trends are similar to the prototype with the only variation being the depths of the main channel and size and location of the bars. These variations can be due to extensive dredging and disposal placement through this stretch over the years.
- A large bar formed on the RDB from Miles 221.8 to 221.3 off of the tip of Island Number 521 and extends across the majority of the channel. The prototype has a bar that is similar in size and location but does not extend across the channel. The differences between the base test and prototype can once again be attributed to the dredge and placement of disposal material.

Results of the base test within the side channel complex showed slight differences as compared to the prototype. Overall elevations were slightly higher in the base test as compared to the prototype. The base test indicated the following bathymetric trends in the side channels.

- Dardenne Chute had depths mainly between 0 and –10 feet MP. These elevations were slightly higher in some areas than shown in prototype surveys.
- The upper end of Bolter Chute to Closure Dike 226.3R had depths below –10 feet MP. Depths downstream of the dike to Mile 225.2 were generally between 0 and –10 feet MP. A scour hole with depths below –30 feet MP was formed on the RDB between Miles 225.2 and 224.7. A crossing was then located just downstream of this area. Although the trends were consistent with the prototype surveys, the elevations were slightly higher.
- Iowa Chute had depths between 0 and –10 feet MP before its confluence with Bolter Chute. Downstream of this area, depths were below –20 feet MP while depths further downstream were between –10 and –20 feet MP.

In general, the overall bathymetric trends established in the micro model base test were similar to those trends observed in the prototype surveys.

3. Design Alternative Tests

Ten design alternative plans were model tested to examine methods of modifying the sediment transport response trends that would help alleviate the need for repetitive dredging within the navigation channel. The effectiveness of each design was evaluated by comparing the resultant bed configuration to that of the base condition. Impacts or changes induced by each alternative were evaluated by observing the sediment response of the model. A qualitative evaluation of the ramifications to the main channel and the side channel was made during team participation meetings at the Applied River Engineering Center in St. Louis, Missouri. Personnel from the St. Louis District Corps of Engineers, Missouri Department of Conservation, Illinois Department of Natural Resources, U.S. Fish and Wildlife Service, River Industry Action Committee and local recreational users carefully examined and discussed each alternative.

Alternative Number	Structure	Type of Structure	Dimension/Height (ft)	Alternative Successful	Comments
1 - Main Channel (Plate 14)	224.6 R	Chevron	300x300/+2 MP	No	This alternative was successful in the immediate area of the proposed structures but not through the entire study reach. More emphasis must be made on the lower portion of the reach.
	224.4 R	Dike	400/+2 MP		
	224.2 R	Chevron	300x300/+2 MP		
	223.9 R	Dike	400/+2 MP		
	223.7 R	Chevron	300x300/+2 MP		
2 - Main Channel (Plate 15)	224.5 L	Chevron	300x300/+2 MP	No	This alternative was successful in the immediate area of the proposed structures but not through the entire study reach. More emphasis must be made on the lower portion of the reach.
	224.2 L	Dike	350/+2 MP		
	223.8 L	Chevron	300x300/+2 MP		
	223.3 L	Chevron	300x300/+2 MP		
3 - Main Channel (Plate 16)	224.5 L	Chevron	300x300/+2 MP	No	This alternative was successful in the immediate area of the proposed structures but not through the entire study reach. More emphasis must be made on the lower portion of the reach.
	224.1 L	Dike	350/+2 MP		
	223.8 L	Chevron	300x300/+2 MP		
	223.3 L	Chevron	300x300/+2 MP		
	223.0 L	Chevron	300x300/+2 MP		
4 - Main Channel (Plate 17)	224.5 L	Chevron	300x300/+2 MP	No	Dike 222.8 R is an existing dike that was raised with a trail added to it. This alternative was successful in the immediate area of the proposed structures but not through the entire study reach. More emphasis must be made on the lower portion of the reach.
	224.2 L	Longitudinal Dike	1000/+2 MP		
	223.8 L	Chevron	300x300/+2 MP		
	223.3 R	Longitudinal Dike	900/+2 MP		
	223.3 L	Chevron	300x300/+2 MP		
	222.8 R	Existing Dike w/trail added	900/+2 MP		
5 - Main Channel (Plate 18)	225.3R	Remove Existing Dike		Not Completely	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4 R and 222.0 R were removed to realign the navigation channel. This alternative did very well at increasing sediment transport through the majority of the reach. The end of the reach still had deposition.
	225.1R	Remove Existing Dike			
	224.5 L	Chevron	300x300/+2 MP		
	224.2 L	Longitudinal Dike	1000/+2 MP		
	223.8 L	Chevron	300x300/+2 MP		
	223.3 R	Longitudinal Dike	900/+2 MP		
	223.3 L	Chevron	300x300/+2 MP		
	222.8 R	Existing Dike w/trail added	900/+2 MP		
	222.4 L	Dike w/ trail added	1200/+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			

Alternative Number	Structure	Type of Structure	Size/Height (ft)	Alternative Successful	Comments
6 - Main Channel (Plate 19)	225.3R	Remove Existing Dike		Yes in Main Channel, Side Channel Displays Connectivity	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4R and 222.0 R were removed to realign the navigation channel. This alternative did very well at increasing sediment transport through the majority of the reach. More emphasis needs to be placed on side channel
	225.1R	Remove Existing Dike			
	224.2 L	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	223.5 L	Chevron	300x300/+2 MP		
	223.3 R	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	222.8 R	Existing Dike w/trail added	900/+2 MP		
	222.4 L	Dike w/ trail added	250 dike w/1200/+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			
	221.8 L	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	221.7 R	Existing Dike Raised	Raise to +2 MP		
6 - Side Channel	223.2 R	Chevron	300x300/+2 MP		
	222.3 L	Dike w/ trail added	300 dike w/700 trail/+2 MP		
	222.0 R	Chevron	300x300/+2 MP		
7 - Main Channel (Plate 20)	225.3R	Remove Existing Dike		Yes in Main Channel, Side Channel Displays Connectivity	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4R and 222.0 R were removed to realign the navigation channel. This alternative did very well at increasing sediment transport through the majority of the reach.
	225.1R	Remove Existing Dike			
	224.2 L	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	223.5 L	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	223.3 R	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	222.8 R	Existing Dike w/trail added	1200/+2 MP		
	222.4 L	Dike w/ trail added	1200/+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			
	221.8 L	Dike w/ trail added	350 dike w/1200 trail /+2 MP		
	221.7 R	Existing Dike Raised	Raise to +2 MP		
	221.3 L	Existing Dike Raised	Raise to +2 MP		
	221.0 L	Existing Dike Raised	Raise to +2 MP		
7 - Side Channel	223.2 L	Dike w/ trail added	300 dike w/700 trail /+2 MP		
	222.5R	Raise & Remove portion of Dike	Raise Portion to +2 MP		

Alternative Number	Structure	Type of Structure	Size/Elevation (ft)	Alternative Successful	Comments
8 - Main Channel (Plate 21)	225.3R	Remove Existing Dike		Yes in Main Channel, Side Channel Displays Connectivity	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4R and 222.0 R were removed to realign the navigation channel. This alternative did very well at increasing sediment transport through the majority of the reach.
	225.1R	Remove Existing Dike			
	224.2 L	Dike w/ trail added	250 dike w/1200 trail /+2 MP		
	223.5 L	Dike w/ trail added	250 dike w/900 trail /+2 MP		
	223.3 R	Dike w/ trail added	250 dike w/900 trail /+2 MP		
	222.8 R	Existing Dike w/trail added	900/+2 MP		
	222.4 L	Dike w/ trail added	250 dike w/900 trail /+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			
	221.8 L	Dike w/ trail added	350 dike w/1200 trail /+2 MP		
	221.7 R	Existing Dike Raised	Raise to +2 MP		
	221.3 L	Existing Dike Raised	Raise to +2 MP		
	221.0 L	Existing Dike Raised	Raise to +2 MP		
8 - Side Channel	223.2 L	Dike w/ trail added	300 dike w/700 trail /+2 MP		
	222.5 R	Raise & Lower portions of Dike	Raise to +2 MP		
9 - Main Channel (Plate 22)	225.3 R	Remove Existing Dike		Yes in Main Channel, Side Channel Displays Connectivity	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4R and 222.0 R were removed to realign the navigation channel. This alternative did very well at reducing sediment transport through the majority of the reach. Connectivity between the side channel and main channel is improving with increased sediment transport through the side channel.
	225.1 R	Remove Existing Dike			
	223.9 L	Dike	300/+2 MP		
	223.7 L	Dike	400/+2 MP		
	223.5 L	Dike	400/+2 MP		
	223.3 L	Dike	300/+2 MP		
	223.4 R	Longitudinal Dike	800 /+2 MP		
	222.8 R	Existing Dike w/trail added	900/+2 MP		
	222.4 L	Dike w/ trail added	250 dike w/900 trail /+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			
	221.8 L	Dike w/ trail added	350 dike w/1200 trail /+2 MP		
	221.7 R	Existing Dike Raised	Raise to +2 MP		
	221.3 L	Existing Dike Raised	Raise to +2 MP		
	221.0 L	Existing Dike Raised	Raise to +2 MP		
9 - Side Channel	223.2 L	Dike w/ trail added	300 dike w/700 trail /+2 MP		
	222.5 R	Raise & Lower portions of Dike	Raise to +2 MP		

Alternative Number	Structure	Type of Structure	Size/Elevation (ft)	Alternative Successful	Comments
* 10 - Main Channel (Plate 23)	225.3R	Remove Existing Dike		Yes in Main Channel, Side Channel Displays Connectivit y	Dikes 225.3 R and 225.1 R were removed to allow access to the main channel from the side channel. Dike 222.8 R is an existing structure that was raised and a trail added to it. Dikes 222.4R and 222.0 R were removed to realign the navigation channel. This alternative did very well at increasing sediment transport through the majority of the reach.
	225.1R	Remove Existing Dike			
	224.2 L	Longitudinal Dike	1400/+2 MP		
	223.4 L	Dike w/ trail added	400 dike w/1200 trail /+2 MP		
	223.4 R	Longitudinal Dike	800/+2 MP		
	222.8 R	Existing Dike w/trail added	800/+2 MP		
	222.4 L	Dike w/ trail added	300 dike w/800 trail /+2 MP		
	222.4R	Remove Existing Dike			
	222.0R	Remove Existing Dike			
	221.7 R	Existing Dike Raised	Raise to +2 MP		
	221.3 L	Existing Dike Raised	Raise to +2 MP		
	221.0 L	Existing Dike Raised	Raise to +2 MP		
* 10 - Side Channel	223.2 L	Dike w/ trail added	300 dike w/700 trail /+2 MP		
	222.5 R	Raise & Lower portions of Dike	Raise to +2 MP/ Lower to -10 MP		

* Identifies Recommended Alternative

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Several alternative design tests were conducted in the HSR model. Each alternative was evaluated using the following three objectives:

1. The reduction in the need for repetitive dredging between Mile 224.5 and Mile 222.0
2. The reduction in the need for repetitive dredging between Mile 222.0 and Mile 220.5
3. Affect on flow through the Iowa Island Cutes

Test	Increased Depth at Upper Dredging Section (Miles 224.5-222.0)	Increased Depth at Lower Dredging Section (Miles 222.0-220.5)	Minimal Affect on Iowa Island Side-channel Complex
Alternative 1	X		X
Alternative 2	X		X
Alternative 3	X		X
Alternative 4	X		X
Alternative 5	X		X
Alternative 6	X	X	X
Alternative 7	X		X
Alternative 8	X	X	X
Alternative 9	X	X	X
Alternative 10	X	X	X

Additional objectives evaluated during the modeling process were the following:

1. Improve the alignment of the navigation channel
2. Identify a location for dredge spoil material off of the main channel
3. Improve access from the side channels to the main channel

Test	Better Alignment of the Navigation Channel	New Dredge Disposal Location Identified Off of Main Channel	Improve Access from Side Channels to Main Channel
Alternative 1			
Alternative 2			
Alternative 3			
Alternative 4			
Alternative 5			
Alternative 6		X	X
Alternative 7		X	X
Alternative 8	X	X	X
Alternative 9	X	X	X
Alternative 10	X	X	X

Alternatives 6, and 7 – 10, (Plates 19 through 23, respectively) were successful in meeting the original design parameters. All ten alternatives were successful in increasing sediment transport through the navigation while not negatively affecting the side channel complex. Alternative 10 is the recommended design due to its ability to maintain the sufficient contraction width for navigation purposes and because it was the most economically feasible alternative that satisfied all of the identified requirements.

2. Recommendations

Alternative 10 is the recommended plan to solve the dredging problems of the Iowa Island Reach. In Alternative 10, 5 dikes were added, 4 dikes were removed, 1 existing dike was raised and had a trail added to it, 3 existing dike were raised and 1 dike had 2/3 of it lowered and the remainder raised. The structures are configured as follows:

MAIN CHANNEL

The work proposed is needed to alleviate dredging and alignment problems in this reach as well as improve recreational access from side channels to main channels.

- Within this six mile reach (226.0 to 220.0), over 5.28 million cubic yards of material was dredged at a cost of nearly $10.6 million over the last 15 years. However, dredging has not occurred in Mile 226.0 to 225.0 since the construction of the Bolters Bar structures in 2001.
- That works out to a yearly average of over 350,000 cubic yards of material at a cost of over $700,000.00 per year.
- The area between Miles 224.0 and 222.0 accounted for 40% of the total volume dredged in this reach.
- Dredge disposal areas that would not negatively affect recreation, homeowners or the environment have been difficult to locate in this reach.

The recommended design includes the following:

a. Remove existing Dikes 225.3 (R) & 225.1 (R)
   - These structures are redundant and impede recreational craft from entering main channel.
   - Needed to reuse material for new structures
b. Construct Longitudinal Dike 224.2 (L) 1400 feet parallel to flow from outer bank at River Mile 224.2 at +2 MP.
   - Needed for channel contraction to increase sediment transport

- Needed to better align the navigation channel for tow industry

c. Construct Dikes with Trails 223.4 (L) & 222.4 (L), construct Longitudinal Dike 223.4 (R), add trail to Dike 222.8 (R) and remove Dikes 222.4 (R) & 222.0 (R).
   - Construct Dike 223.4 (L) out 400 feet from bank at +2 MP, with a 1200 foot trail attached, running parallel with flow at +2 MP.
   - Extend dike parallel to flow 800 feet from outer bank at River Mile 223.4 (R) (+2 MP)
   - Construct a Trail Dike off the tip of Dike 222.8 (R) 800 feet long running parallel to flow at +2 MP, raise Dike 222.8 (R) to +2 MP if needed.
   - Construct Dike 222.4 (L) out 300 feet from bank at +2 MP, with an 800 foot trail attached, running parallel with flow at +2 MP.
   - Remove Dikes 222.4 (R) & 222.0 (R)

d. Raise existing Dikes 221.7 (R), 221.3 (L) and 221.0 (L)
   - Raise existing Dikes 221.7 (R), 221.3 (L) and 221.0 (L) to + 2MP.

<u>SIDE CHANNEL</u>

The following is recommended to increase sediment transport through the side channel complex

- The HSR study includes the Dardenne Side Channel Complex, which is an intricate system of side channels.
- Several private marinas are located of off Dardenne Slough, whose patrons need access to the main channel.
- Portions of the slough are degrading causing problems for recreational boaters.

a. Construct Dike with Trail 223.2 (L) and raise and lower portions of Dike 222.5 (R)

- Construct Dike 223.2 (L) out 300 feet from bank at +2 MP, with a 700 foot trail attached, running parallel with flow at +2MP.
- Raise a portion of Dike 222.5 (R), 300 feet from LDB to +2 MP and lower the remaining portion of the dike to -10 MP. Downstream of the structure is good fish habitat, precautions must be made not to remove the structure entirely but simply lower it.

It is recommended that in implementing these structures into the Iowa/Squaw Island Reach, a phased construction approach should be followed. Caution should be taken when working on Dike 222.5 in the side channel. This structure has been identified as creating excellent aquatic habitat. In addition, a close monitoring program of navigation channel conditions both before and after construction should be incorporated.

3. Cost and Benefits of Recommended Design

Estimates indicate that the total cost for implementing the recommended design alternative, (Alternative 10) is in the range of $2.4m. This cost includes the Service & Administration as well as the Plans & Specifications portion of the project. Based on historical dredging data through this reach, in excess of $500,000 per year (on average) is spent on mechanical dredging to maintain the navigation channel. Assuming Alternative 10 alleviates all dredging through this reach, all design and construction costs could be recouped by the fourth quarter of the fourth year. Along with the economic benefits, Alternative 10 would create a safer channel by realigning the navigation channel and optimizing its alignment.

4. Interpretation of Model Test Results

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

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

FOR MORE INFORMATION

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APPENDIX OF PLATES

Plate #'s 1 through 24 follow:

1. Location and Vicinity Map of the Study Reach
2. 2004 Aerial Photography
3. Photographs of Karst Topography on LDB
4. Photographs of Alluvium on RDB
5. Dredge Cut and Disposal Locations
6. Graphs of Yearly Dredging Totals
7. Flow Split Measurements
8. Iowa-Squaw Island Micro Model
9. 1881 Hydrographic Survey
10. 1997 Hydrographic Survey
11. 2001 Hydrographic Survey
12. 2004 Hydrographic Survey
13. Base Test
14. Alternative 1
15. Alternative 2
16. Alternative 3
17. Alternative 4
18. Alternative 5
19. Alternative 6
20. Alternative 7
21. Alternative 8
22. Alternative 9
23. Alternative 10
24. Zoomed in Plate of Alternative 10