Technical Report M65

Bumgard Island HSR MODEL
River Miles 36.0 – 25.0

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a study of the flow and sediment transport response on the Mississippi River between River Miles (RM) 36.00 and 25.00, approximately 3.5 miles downstream of Commerce, Missouri. This study was funded by the Regulating Works Project. The objective of the model study was to produce a report that outlined the results of an analysis of various river engineering measures intended to reduce or eliminate the need for repetitive channel maintenance dredging between RM 34.50 to 27.20.

The study was conducted between April, 2012 and September, 2013 using a physical Hydraulic Sediment Response (HSR) model at the Applied River Engineering Center, St. Louis District in St. Louis, Missouri. The model study was performed by Katherine Clancey, Hydraulic Engineer, under direct supervision of Mr. Robert 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.	Hydrologic and Hydraulic Branch Chief	St. Louis District
Robert Davinroy, P.E	Chief of River Engineering Section	St. Louis District
Jasen Brown, P.E.	Hydraulic Engineer	St. Louis District
Dave Gordon, P.E.	Chief of Hydraulic Design Section	St. Louis District
Adam Rockwell	Cartographic Technician	St. Louis District
Jason Floyd	Engineering Technician	St. Louis District
Michael Rodgers, P.E.	Project Manager for River Works Projects	St. Louis District
Lance Engle	Dredging Project Manager	St. Louis District
Dawn Lamm	Hydraulic Engineer	St. Louis District
Ashley Cox	Hydraulic Engineer	St. Louis District
Ivan Nguyen	Hydraulic Engineer	St. Louis District
Eddie Brauer, P.E.	Hydraulic Engineer	St. Louis District
Charles Frerker	Biologist	St. Louis District
Brandon Schneider	Biologist	St. Louis District
Zachary Ryals	Hydraulic Engineer	St. Louis District
Timothy Lauth, P.E.	Hydraulic Engineer	St. Louis District
Sarah Markenson	Real Estate	St. Louis District
Scott Flash	Student Trainee	Omaha District
Butch Atwood	Mississippi River Fisheries Biologist	Illinois Dept. of Natural Resources
Matt Mangan	Biologist	U.S. Fish & Wildlife Service
Robert Cail	Refuge Manager	U.S. Fish & Wildlife Service
David Ostendorf	Resource Staff Scientist	Missouri Dept. of Conservation
Dave Knuth	Fishery Biologist	Missouri Dept. of Conservation
Joe McMullen	Biologist	Missouri Dept. of Conservation
Danny Brown	Resource Staff Scientist	Missouri Dept. of Conservation
Shannon Hughes	River Field Port Captain	Kirby Inland Marine

TABLE OF CONTENTS

BACKGROUND

1. Problem Description

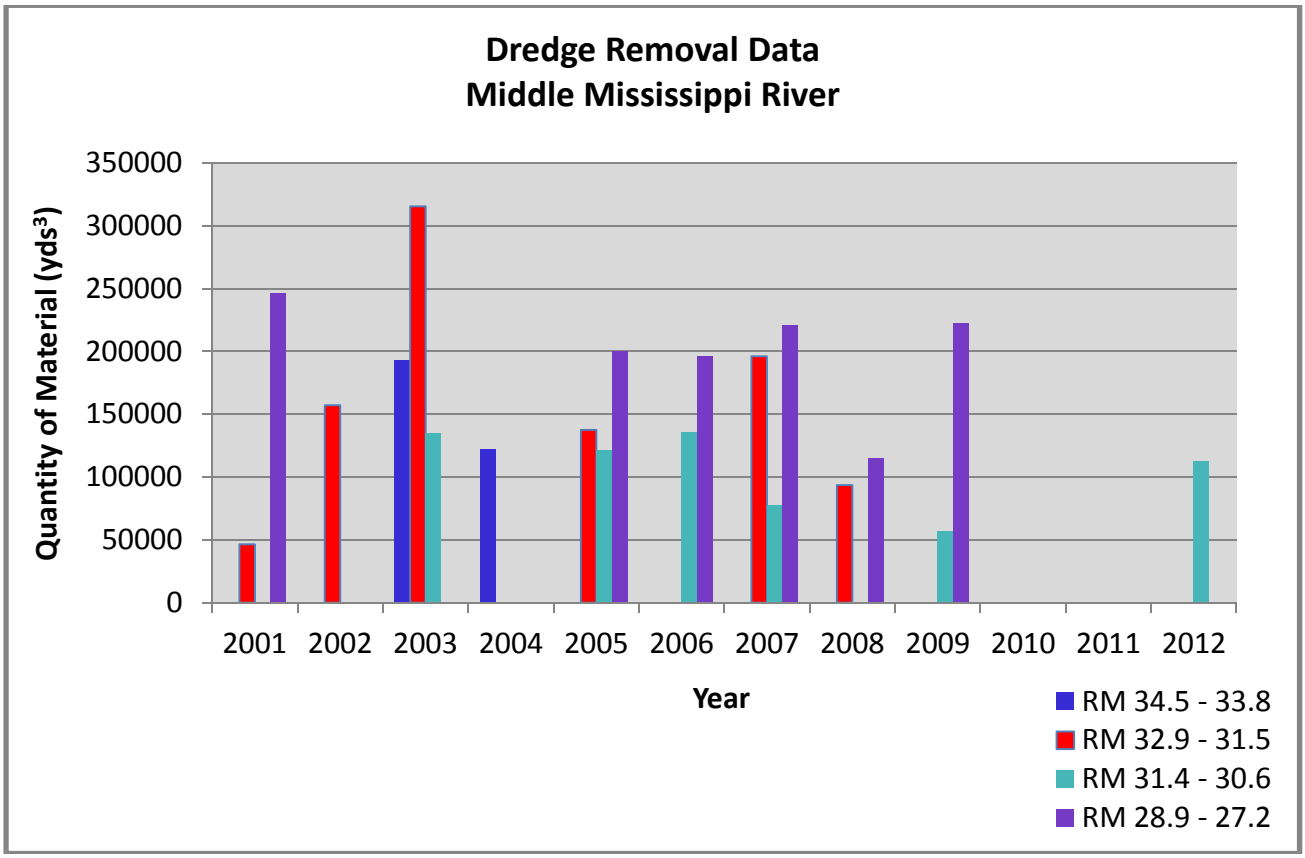
A. Dredging

Dredging in the Mississippi River is commonly used to provide required navigation dimensions of depth, width, alignment, or a combination thereof. In the case of this study, repetitive channel maintenance dredging was required in four different areas along the reach (see Plate 1). The sandbar located along the Right Descending Bank (RDB) near River Mile (RM) 35.00 to 31.80 has grown in size between RM 34.50 to 33.80 and RM 32.90 to 31.50. Bumgard Island, located along the Left Descending Bank (LDB) between RM 31.00 to 29.00, has also grown causing shoaling between RM 31.40 to 30.60. Downstream of Bumgard Island on the LDB, shoaling has occurred between RM 28.90 to 27.20. On average, dredging in this reach has been required nearly every year from 2001 to 2012. During this twelve year period, the following total estimates of dredge material quantities in cubic yards (cy) and costs were calculated:

- RM 34.50 to 33.80: 315,516 cy at a cost of $408,414
- RM 32.90 to 31.50: 946,670 cy at a cost of $2,328,255
- RM 31.40 to 30.60: 639,035 cy at a cost of $973,146
- RM 28.90 to 27.20: 1,201,738 cy at a cost of $1,930,945

See Graph 1 for a comparative analysis of the dredge material removed annually and its cost.

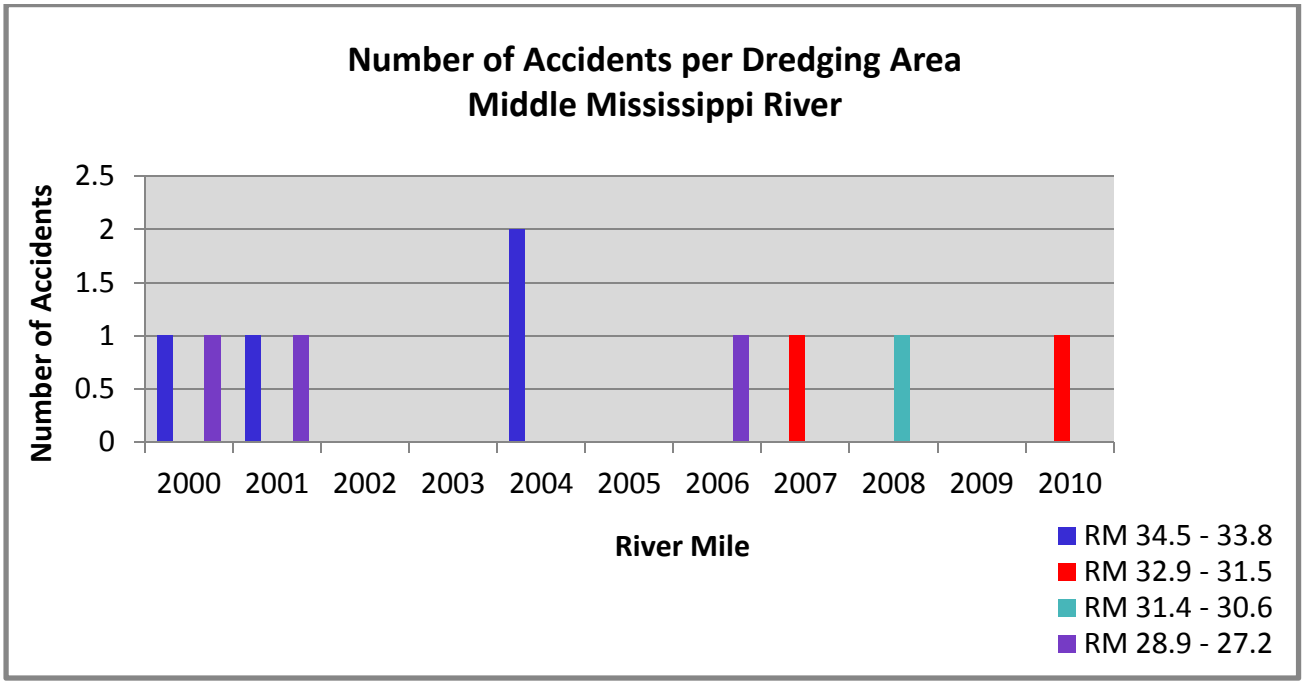
Graph 1: Study Reach Dredge Removal Data



B. Accident Data

There have been several accidents reported for this study reach, all of which have occurred within the four dredging areas. The available accident data for RM 34.50 to 27.20, provided by Coast Guard District 8, reveals that between 2000 and 2010 there has been one collision and nine groundings. However, seven of those groundings occurred outside of the marked channel. See Graph 2 for the number of accidents in Bumgard's Island reach.

Graph 2: Study Reach Accident Data



2. Study Purpose and Goals

The purpose of this study was to find a river engineering solution to reduce or eliminate dredging at RM 34.50 to 27.20 and produce a report that communicates 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 sedimentation problems.

ii. Evaluate a variety of remedial measures utilizing an HSR model with the objective of identifying the most effective and economical plan to reduce or eliminate sedimentation at RM 34.50 to 27.20. In order to determine the best alternative, three criteria were used to evaluate each alternative.

    a. The alternative should reduce or eliminate sedimentation from RM 34.50 to 27.20.
    b. The alternative should maintain the navigation channel requirements of at least 9 foot of depth and 300 foot of width.
    c. The alternative should avoid and minimize negative impacts to environmental features within the reach.

iii. Communicate to other engineers, river industry personnel, and environmental agency personnel the results of the HSR model tests and the plans for improvements.

3. Study Reach

The study comprised an 11 mile stretch of the Mississippi River, between RM 36.00 to 25.00 passing through Scott County, Missouri and Alexander County, Illinois. Most of the properties on the Missouri and Illinois side are used for agricultural purposes. There is also a levee system on the Missouri side within the reach of this study. Plate 2 is a location and vicinity map of the study reach.

Plate 3 is a 2007 aerial photograph illustrating the planform and nomenclature of the Lower Mississippi River between RM 36.00 to 25.00. There are a total of 57 Dikes, 9 Weirs and 7 Chevrons. See Table 2 for the river training structures' history and existing conditions. Within the study, revetments are located between RM 36.00 to 35.00 on the (RDB), RM 35.00 to 32.00 on the (LDB), RM 32.00 to 27.50 on the (RDB), RM 29.50 to 28.00 on the (LDB), and RM 26.80 to 25.00 on the (LDB).

Table 2: Study Reach River Structure History

River Training Structure	Material	Length (ft)	Description
Spur Dike 37.20L	Combination of stone and piles	2075	Constructed prior to 1942
Hardpoint 37.15L	Stone	300	Constructed in May 1999. Repairs were performed in May 2003
Spur Dike 37.10L	Combination of stone and piles	1400	Constructed prior to 1942
Hardpoint 37.05L	Stone	250	Hardpoint is located in Santa Fe Chute and was constructed in May 1999. Repairs were performed in May 2003
Dike 37.00L	Stone	275	Constructed in May 1999
Chevron 36.70L	Stone	490	Constructed in February 2010

Spur Dike 36.70L	Stone	1640	Constructed prior to 1942 and shortened in February 2010
Chevron 36.50L	Stone	490	Constructed in March 2010
Spur Dike 36.50L	Stone	310	Constructed prior to 1942 and shortened in February 2010
Chevron 36.20L	Stone	490	Constructed with four leg extensions in March 2010
Chevron 36.20L (Leg Extensions)	Stone	150	Four leg extensions were constructed in March 2010
Spur Dike 36.20L	Stone	350	Constructed prior to 1942 and shortened in January 2010
Chevron 35.90L	Stone	490	Chevron was constructed in January 2010
Spur Dike 35.90L	Stone	315	Constructed prior to 1942 and shortened in January 2010
Spur Dike 35.70L	Piles	1230	Constructed prior to 1942
Spur Dike 35.50L	Stone	840	Constructed prior to 1942
Spur Dike 35.20L	Stone	210	Constructed prior to 1942
L- Head Dike 35.10R	Stone	1150	Constructed prior to 1942. Repairs were performed in October 1979 and February 1991
Pile Dike 35.00R	Piles	715	Constructed prior to 1942
Closure Dike 35.00L	Stone	1000	Constructed between 1942 and 1956

L-Head Dike 34.8R	Stone	1700	Constructed prior to 1942. Repairs were performed in October 1979
Spur Dike 34.60L	Stone	250	Constructed prior to 1942
Trail Dike 34.20L	Stone	750	Constructed prior to1942
Trail Dike 34.10L	Stone	630	Constructed prior to1942
Dike 34.1R	Combination of stone and piles	900	Constructed prior to 1942. Dike was extended in September 1979
Spur Dike 33.30R	Stone	540	Constructed prior to 1942
Chevron 32.80R	Stone	731	Constructed in December 2009
Chevron 32.60R	Stone	730	Constructed in December 2009
Chevron 32.40R	Stone	730	Constructed in February 2010
Spur Dike 32.60R	Combination of stone and piles	1150	Constructed prior to 1942 and extended in October 1979
Spur Dike 32.20R	Stone	470	Constructed in September 1979
Trail Dike 32.20L	Stone	350	Constructed prior to 1942. Repairs were performed in June 1989
Spur Dike 32.00R	Stone	400	Constructed prior to 1942
Spur Dike 32.00L	Stone	550	Constructed prior to 1942. Repairs were performed in April 1989
Spur Dike 31.90L	Stone	890	Constructed prior to 1942
Spur Dike 31.80L	Stone	450	Constructed prior to 1942. Repairs were performed in June 1989
Spur Dike 31.60L	Stone	1325	Constructed prior to 1942. Repairs were performed in April 1989

Spur Dike 31.40L	Stone	380	Constructed prior to 1942
Spur Dike 31.20L	Stone	650	Constructed prior to 1942
Spur Dike 31.10L	Stone	1000	Constructed prior to 1942
Weir 30.55R-29.60R	Stone	Between 370 - 800 ft long	Constructed in November 1991
Hardpoint 30.50L-29.50L	Stone	Between 100 - 210 ft long	Hardpoints were constructed between 1976 and 1987
Spur Dike 28.00L	Stone	420	Constructed in October 1978
Spur Dike 27.60R	Stone	300	Constructed prior to 1942
Spur Dike 27.50L	Stone	550	Constructed prior to 1942 and extended in October 1979
Spur Dike 27.30R	Stone	270	Constructed prior to 1942
Spur Dike 27.20L	Stone	370	Constructed in August 1979
Spur Dike 27.00R	Stone	915	Constructed prior to 1942. Repairs were performed in April 1989
Dike 26.90R	Stone	1320	Constructed prior to 1942. Repairs were performed in 1979
Spur Dike 26.80L	Stone	250	Constructed October 1979
L-Head Dike 26.70R	Stone	2400	Constructed prior to 1942 and extended in October 1979
Spur Dike 26.40R	Stone	630	Constructed prior to 1942. Repairs were performed in August 1979

Spur Dike 26.10R	Combination of stone and piles	1280	Constructed prior to 1942. Repairs were performed in October 1979 and April 1989
Spur Dike 25.50R	Stone	500	Constructed in December 1978. Repairs were performed in April 1989
Spur Dike 25.40L	Stone	170	Constructed prior to 1942
Spur Dike 25.30R	Stone	350	Constructed in July 1979
Spur Dike 25.30L	Stone	220	Constructed prior to 1942
Spur Dike 25.20L	Stone	380	Constructed prior to 1942
Trail Dike 25.00L	Stone	670	Constructed prior to 1942. Repairs were performed in May 1988
Trail Dike 24.90L	Stone	1250	Constructed prior to 1942. Repairs were performed in November 1979
Closure Dike 24.80R	Stone	920	Constructed in August 1979. Repairs were performed in April 1989
L-Head Dike 24.50L	Stone	1840	Constructed prior to 1942. Repairs were performed in November 1979

A. Geomorphology

To understand the planform of the river near the Bumgard Island reach, an investigation was conducted into the historical changes, both natural and manmade, that lead up to the present day condition. Plate 4 - 9 shows geomorphic planform changes from RM 42.00 to 27.00, encompassing the years from 1817 to 2003, and was sourced from “Geomorphology of the Middle Mississippi River”, produced by the St. Louis District (2005). Based on this planform comparison, the meander migration between RM 36.00 and 27.00 displays significant changes with an increase in the degree of curvature of the river from RM 36.00 to 32.00 and RM 32.00 to 27.00.

Between 1881 and 2003 there was a significant reduction in the width of the river between RM 38.00 and 33.00, approximately 7,000 ft, which dramatically changed the location of the RDB. Revetment was constructed between RM 35.00 to 32.00 on the LDB, prior to the 1942 planform map (Plate 12), which prevented any meandering or erosion of the bankline.

Between 1817 and 1928 there was a general widening of roughly 3,000 ft due to erosion of the RDB between RM 31.50 to 29.50. Between 1928 and 2003 there was a reduction in width of roughly 4,000 ft, which dramatically changed the location of the LDB. This was the result of Dikes 32.20 L to 31.10 L which were constructed prior to 1942. The 1942 planform map displays that revetment had been placed between RM 32.00 to 27.50 on the RDB which prevented any more erosion from occurring on the RDB.

Between 1881 and 2003 there was a reduction in the width of the river of approximately 5,000 ft between RM 29.00 and 27.00. Dikes were constructed on both descending banks which narrowed the river in this area.

Plates 10 - 16 show the study reach through aerial photographs from 1925 to 1987. These plates show four main islands within the reach of this study: Burnham, Billings, Bumgard and Buffalo Island.

The aerial photographs show that Burnham Island increased in size while its side channel (Santa Fe Chute) did not experience significant changes.

Billings Island, on the Missouri side of the reach, was observed to have decreased in size. As shown on the 1925 aerial photograph (Plate 10), Billings Island and Chute extended from RM 34.00 to 32.00. The 1942 planform map displays that Dikes 34.80, 34.10 and 33.30, located on the RDB, were constructed prior to this. The 1987 aerial photograph (Plate 16) shows that the island significantly changed after the structures were constructed, thus, reducing the size of the island and side channel.

The aerial photographs show that Bumgard Island, on the Illinois side of the reach, has also changed significantly. The 1925 aerial photograph shows that Bumgard Island had a much wider side channel than what currently exists. The 1935 aerial photograph (Plate 11) shows that Dikes 32.20 to 31.10, located on the LDB, were constructed prior to this date which led to a much narrower side channel. Aerial photographs from 1935 to the present do not show any other significant changes.

On the Missouri side of the reach, Buffalo Island, much like Bumgard Island, had a wider side channel which became narrower with the construction of Dikes 27.60 to 26.10, located on the RDB, as shown on aerial photographs from 1925 and 1935.

B. Channel Characteristics and General Trends

i. Bathymetry

Range line and multi-beam hydrographic surveys of the Mississippi River from 1956 to 2012 within the HSR Model extents, are shown on Plates 17 - 25. Plates 26 - 32 show pre-dredge conditions from 2005 to 2012. For this study, the bathymetric data was referenced to the Low Water Reference Plane (LWRP).

Recent surveys (2001 - 2012) were used to determine general trends because they showed the most recent construction and the resultant river bed changes. The bathymetric trends remained relatively constant from 2001 - 2012 after comparison of the hydrographic surveys:

Table 3: Study Reach Bathymetry Trends

River Miles	Description
36.00 to 35.00	The thalweg was located along the RDB with depths between -20 ft to -30 ft LWRP. Santa Fe Chute was very shallow with depths between 10 ft to -2 ft LWRP.
35.00 to 31.60	The thalweg crossed and was located along the LDB. Deposition occurred along Billings Island on the RDB and extended into the main channel. Pre-dredge surveys showed depths between 10 ft to -10 ft LWRP. Along the LDB scour extended from RM 34.60 to 33.00 and RM 32.50 to 32.00 with depths between -15 ft to -50 ft LWRP.
31.60 to 29.00	At RM 31.60 the thalweg crossed from the LDB to the RDB. Deposition extended into the main channel from sand bars located on both banks, thus requiring annual dredging. Pre-dredge surveys showed depths between -4 ft to -10 ft LWRP. There were significant depths around the weirs located on the RDB near RM 30.55 to 29.60, with depths between -20 ft to -50 ft LWRP. The side channel along Bumgard Island was very shallow with depths between +10 ft to 0 ft LWRP.
29.00 to 27.00	Deposition also occured downstream of Bumgard Island. It extended from the LDB to the main channel between RM 29.00 and 27.00. Pre-dredge surveys showed depths between -4 ft to -10 ft LWRP.
27.00 to 25.00	The thalweg was located along the LDB with depths between -10 ft to -30 ft LWRP. Due to scour around Dikes 25.40 to 24.50, located on the LDB, the channel reached depths up to -40 ft LWRP.

ii. Site Data

The authors of this report and other personnel from the Applied River Engineering Center (AREC) visited the Bumgard Island reach on two occasions to examine banklines and structures. The first trip took place on April 18, 2012, and the gage at Commerce (RM 39.50) was 20.50 ft (322.33 ft in elevation based on NGVD 29). The second field visit took place on May 24, 2012 with the river stage at 17.80 ft (319.63 ft in elevation based on NGVD 29). Because of the low stage during both trips, many hydraulic structures were visible. The following observations were made:

- Dike 26.40 R - Structure had a low top elevation which was almost at the same height as the water surface level and seemed to be notched or degraded towards the center of the structure.
- Dikes 31.10L, 31.2L and 31.4L - Structures had a low top elevation.
- Dike 31.8L - Structure had a low top elevation.
- Chevron 32.60R and 32.80R - Structures were degraded on the left leg, however the right leg was in good conditions.
- Dike 34.80L - The dike was visible and in good conditions but the trail dike was not visible.
- Dike 34.60L - Structure was not visible.
- Dike 35.20L, 35.70L and 37.10L - Only a couple of wood piles were visible.
- Chevron 36.50L - Structure was slightly degraded on the right leg.
- Dike 39.60L - This was a closing structure at the entrance of Santa Fe Chute. At the time of the visit there was just a little water entering the side channel at a low spot on the structure.

Pictures from the site visit can be seen on Plates 33 - 36.

HSR MODELING

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.

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 calibrated and alternative testing began.

2. Scales and Bed Materials

The model employed a horizontal scale of 1 inch = 800 feet, or 1:9,600, and a vertical scale of 1 inch = 85 feet, or 1:1,020, for a 9.4 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 planform insert was constructed according to the 2007 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 routed into dense polystyrene foam and modified during calibration with clay and polymesh. The measured slope of the insert and flume was approximately 0.018 inch/inch. River training structures in the model were made of galvanized steel mesh to generate appropriate scaled roughness. A picture of the HSR model can be seen on Plate 37.

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 0.80 Gallons per Minute (GPM). This served as the average expected energy response of the river. Because of the constant variation experienced in the river, this steady state flow was used to replicate existing general conditions and empirically analyze the ultimate expected sediment response that could occur from future alternative actions.

5. Data Collection

Data from the HSR model was collected with a three dimensional (3D) laser scanner. 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 the coordinate system of the prototype data 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.

6. Replication Test

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

A. Bathymetry

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 (2001 to 2012) were made to several surveys of the model. The resultant bathymetry is shown on Plate 38.

Results of the HSR model base test bathymetry and a comparison to the 2001 through 2012 prototype surveys indicated the following trends:

Table 4: Study Reach and Prototype Bathymetry Trend Comparison

River Miles	Description
36.00 to 35.00	In both the model and prototype: The thalweg was located along the RDB with depths between -20 ft to -30 ft LWRP. Santa Fe Chute was shallow with depths between 10 ft to +2 ft LWRP.
35.00 to 31.60	In both the model and prototype: A sand bar extended from RM 35.00 to 31.8 on the RDB with depths between 10 to -10 ft LWRP. The thalweg was located along the LDB with scour extending from RM 34.6 to 33.0 and from RM 32.50 to 32.00. The main channel showed depths between -15 ft to -50 ft LWRP. In both the model and pre dredge surveys: Sedimentation extended from RM 32.90 to 31.60.
31.60 to 29.00	In both the model and prototype: At RM 31.60 the thalweg crossed from the LDB to the RDB. There were significant depths near weirs located on the RDB between RM 30.55 and 29.60, with depths between -20 ft to -50 ft LWRP. The side channel by Bumgard Island was very shallow with depths between +10 ft to 0 ft LWRP. In both the model and pre-dredge surveys: Sedimentation extended from RM 31.60 to 30.60.
29.00 to 27.00	In both the model and pre dredge surveys: Sedimentation extended from RM 29.00 to 27.00.
27.00 to 25.00	In both the model and prototype: The thalweg was located along the LDB with depths between -10 ft to -30 ft LWRP. Due to scour around Dikes 25.40 to 24.50, located on the LDB, the channel reached depths up to -40 ft LWRP.

7. Design Alternative Tests

The testing process consisted of modeling alternative measures in the HSR model. The goal was to reduce or eliminate the need for repetitive channel maintenance dredging between RM 34.50 - 27.20. Evaluation of each alternative was accomplished through a qualitative comparison to the model replication test bathymetry.

A total of 85 alternatives were tested in this study. Near the completion of testing (Alternative 71 - 85), a second replication test was established to better define detailed high water trends occurring in the Bumgard Island side channel (Plates 109 -123). This test showed the trends in the side channel as compared to the 2013 prototype survey (Plate 25). After re-evaluating several alternative tests (prior to Alternative 71), results indicated that all previous tests were still valid. The energy in the Bumgard Side channel was minimal, as the existing channel condition in 2013 was extremely shallow. The only observed energy in the model was associated with small localized scour at the location of some of the dike hardpoints. The majority of energy and flow was located in the main channel. These trend observations were also verified in the field during high water while collecting the 2013 side channel bathymetry.

Alternative 1:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	33.10	LDB	600	-15
Weir	33.00	LDB	600	-15
Weir	32.80	LDB	600	-15
Weir	32.70	LDB	600	-15
Weir	32.60	LDB	600	-15
Weir	32.50	LDB	600	-15
Weir	32.40	LDB	600	-15
Weir	32.30	LDB	600	-15
Weir	32.30	LDB	600	-15

Results: *Bathymetry (Plate 40)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	The proposed weirs eliminated scouring between RM 32.70 - 32.00. The channel significantly deepened between RM 31.90 - 31.40 and improved between RM 31.40 - 30.55 but remained slightly shallow. There were no significant changes downstream of RM 29.00.

Alternative 2:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Dike Extension	34.60	LDB	310	+15
Trail Dike	34.60	LDB	550	+15
Weir	33.10	LDB	900	-15
Weir	32.80	LDB	900	-15
Weir	32.60	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15

Results: *Bathymetry (Plate 41)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	The proposed dike extension and trail dike did not provide significant bathymetric changes. The weirs eliminated scouring between RM 32.70 - 32.00, but created sedimentation along Chevrons 32.8R & 32.60R. The channel slightly improved between RM 31.90 - 31.00, however was at approximately -8 ft LWRP which is still too shallow. There were no significant changes downstream of RM 29.00.

Alternative 3:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	900	-15
Weir	34.10	LDB	900	-15
Weir	33.90	LDB	900	-15
Weir	33.70	LDB	900	-15
Weir	33.60	LDB	900	-15
Weir	33.40	LDB	900	-15
Weir	33.30	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15

Results: *Bathymetry (Plate 42)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	The proposed weirs eliminated scouring between RM 34.50 - 33.30 and RM 32.70 - 32.00. Sedimentation extended into the main channel along Chevrons 32.80R and 32.60R. The channel deepened between RM 31.90 - 31.60 but still remained shallow between RM 31.60 - 30.60. There were no significant changes downstream of RM 29.00.

Alternative 4:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	900	-15
Weir	34.10	LDB	900	-15
Weir	33.90	LDB	900	-15
Weir	33.80	LDB	900	-15
Weir	32.60	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15

Results: *Bathymetry (Plate 43)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 34.50 - 33.30 and RM 32.70 - 32.00. They also increased the width of the channel, between RM 32.70 - 31.90, approximately 200 ft. The channel improved between RM 31.90 - 30.60 but was still too shallow for the minimum required depth needed. There were no significant changes downstream of RM 29.00.

Alternative 5:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.40	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	33.90	LDB	600	-15
Weir	33.70	LDB	600	-15
Weir	32.60	LDB	900	-15
Weir	32.50	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike	31.80	RDB	500	+15
Trail Dike	31.80	RDB	440	+15

Results: *Bathymetry (Plate 44)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	This alternative is very similar to Alternative 4 but has a trail dike located at RM 31.80. The bathymetric results therefore look very similar but the trail dike in this alternative helped reduce sedimentation on the RDB between RM 31.80 - 31.00.

Alternative 6:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.40	LDB	900	-15
Weir	34.10	LDB	900	-15
Weir	33.90	LDB	900	-15
Weir	33.70	LDB	900	-15
Weir	32.60	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike	31.80	RDB	500	+15
Trail Dike	31.80	RDB	440	+15

Results: *Bathymetry (Plate 45)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	This alternative is very similar to Alternative 5 but Weir 32.30L was set at another angle. The bathymetric results therefore look very similar but the angle of the weir further improved he deepness of the channel between 31.90 - 30.60. However, it was still slightly shallow along Dikes 31.40L - 31.10L.

Alternative 7:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.70	LDB	900	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.00	LDB	600	-15
Weir	31.90	LDB	600	-15
Weir	31.80	LDB	600	-15
Weir	31.60	LDB	600	-15

Results: *Bathymetry (Plate 46)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	No	The proposed weirs eliminated scouring between RM 33.80 - 32.00 and increased the width of the channel, between RM 32.60 - 31.90, approximately 200 ft. The channel significantly deepened between RM 31.90 - 31.40 but the weirs did not have much effect further downstream. The channel remained shallow between RM 31.40 - 30.60 and slightly deepened along Bumgard Island between RM 31.00 - 30.00. There were no significant changes downstream of RM 29.00.

Alternative 8:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.40	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.00	RDB	440	+15
Trail Dike	32.00	RDB	500	+15
Weir	32.00	LDB	600	-15
Weir	31.90	LDB	600	-15
Weir	31.80	LDB	600	-15
Weir	31.60	LDB	600	-15

Results: *Bathymetry (Plate 47)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	This alternative is very similar to Alternative 7 but has additional weirs and a trail dike. The weirs at RM 34.60 - 34.10 helped maintain the channel width and eliminate scouring in that section. The trail dike did not have much effect on the channel. The channel deepened between RM 31.90 - 31.00 but was still very shallow between RM 31.60 - 31.00. There were no significant changes downstream of RM 29.00.

Alternative 9:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.40	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.00	RDB	440	+15
Trail Dike	32.00	RDB	500	+15
Weir	32.00	LDB	600	-15
Weir	31.90	LDB	600	-15
Weir	31.80	LDB	600	-15
Weir	31.60	LDB	600	-15
Weir	31.40	LDB	600	-15
Weir	31.20	LDB	600	-15
Weir	31.10	LDB	600	-15

Results: *Bathymetry (Plate 48)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	This alternative is very similar to Alternative 8 but has more weirs located between RM 31.40 - 31.10. Since the weirs are located in a very shallow section they did not have any effect on the channel and so the bathymetric results were very similar to that of Alternative 8. The channel deepened between RM 31.90 - 31.60 but remained very shallow between RM 31.60 - 30.60. There were no significant changes downstream of RM 29.00.

Alternative 10:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.40	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.00	LDB	900	-15
Weir	31.90	LDB	900	-15
Weir	31.80	LDB	900	-15
Weir	31.60	LDB	900	-15
Weir	31.40	LDB	900	-15
Weir	31.20	LDB	900	-15
Weir	31.10	LDB	900	-15

Results: *Bathymetry (Plate 49)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	This alternative is similar to Alternative 9 but all the weirs are 900 ft long instead of 600 ft between RM 32.00 - 31.10 and the trail dike was removed. The proposed weirs eliminated scouring between RM 34.50 - 33.30 and RM 32.70 - 32.00. They increased the width of the channel, between RM 34.50 - 31.90, approximately 200 ft. However some sedimentation extended into the main channel along Chevrons 32.80R and 32.60R. Although the channel started deepening downstream of RM 31.90, it did not deepen enough between RM 31.60 - 30.60. There were no significant changes downstream of RM 29.00.

Alternative 11:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.40	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.20	RDB	325	+.5
Dike Extension	32.00	RDB	240	+15
Trail Dike	32.00	RDB	500	+15
Dike	31.80	RDB	400	+15
Weir	32.00	LDB	900	-15
Weir	31.90	LDB	900	-15
Weir	31.80	LDB	900	-15
Weir	31.60	LDB	900	-15
Weir	31.40	LDB	900	-15
Weir	31.20	LDB	900	-15
Weir	31.10	LDB	900	-15

Results: *Bathymetry (Plate 50)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	The proposed weirs eliminated scouring between RM 34.50 - 33.30 and RM 32.70 - 32.00. They increased the width of the channel between RM 34.50 - 31.90, approximately 200 ft. The channel improved and deepened significantly between RM 31.90 - 31.60. It also deepened significantly between RM 31.60 - 30.70. There were no significant changes downstream of RM 29.00.

Alternative 12:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.20	RDB	325	+15
Dike Extension	32.00	RDB	240	+15
Trail Dike	32.00	RDB	500	+15
Weir	32.00	LDB	900	-15
Weir	31.90	LDB	900	-15
Dike	31.80	RDB	400	+15
Weir	31.80	LDB	900	-15
Weir	31.60	LDB	900	-15

Results: *Bathymetry (Plate 51)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	This alternative is very similar to Alternative 11 but Weirs 31.40L - 31.10L were removed since they provided little effect to improve the channel. Therefore, the bathymetric results between both alternatives were very similar.

Alternative 13:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.60	LDB	600	-15
Weir	34.30	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.20	RDB	325	+15
Dike Extension	32.00	RDB	240	+15
Weir	32.00	LDB	900	-15
Weir	31.90	LDB	900	-15
Dike	31.80	RDB	400	+15
Weir	31.60	LDB	900	-15

Results: *Bathymetry (Plate 52)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	No	This alternative is very similar to Alternative 12 but the trail dike was removed. The bathymetric results were therefore very similar but it was slightly shallower between 31.60 - 31.00.

Alternative 14:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.10	LDB	900	-15
Dike Extension	32.00	LDB	145	+15
Dike Extension	31.90	LDB	150	+15
Dike Extension	31.80	LDB	250	+15
Dike Extension	31.60	LDB	95	+15
Dike Extension	31.40	LDB	375	+15
Dike Extension	31.20	LDB	255	+15

Results: *Bathymetry (Plate 53)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	No	The proposed weirs eliminated scouring between RM 33.50 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.80R and 32.60R. The channel deepened between RM 31.90 - 31.70 but there were no significant changes downstream of RM 31.70.

Alternative 15:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Dike Extension	32.00	LDB	145	+15
Dike	31.90	RDB	400	+1.5
Trail Dike	31.90	RDB	1100	+15
Dike Extension	31.90	LDB	150	+15
Dike Extension	31.80	LDB	250	+15
Dike Extension	31.60	LDB	95	+15
Dike Extension	31.40	LDB	375	+15
Dike Extension	31.20	LDB	255	+15

Results: *Bathymetry (Plate 54)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	No	The channel slightly deepened between RM 31.90 - 31.40 but it got shallower between RM 31.40 - 31.00. There were no significant changes downstream of RM 31.00.

Alternative 16:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Dike Extension	31.90	LDB	150	+15
Dike	31.90	RDB	400	+15
Trail Dike	31.90	RDB	1100	+15
Dike Extension	31.80	LDB	250	+15
Dike Extension	31.60	LDB	95	+15
Dike Extension	31.40	LDB	375	+15
Dike Extension	31.20	LDB	255	+15

Results: *Bathymetry (Plate 55)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	No	No	The channel slightly deepened between RM 31.90 - 31.80 but it got shallower between RM 31.80 - 31.00 and RM 29.00 - 27.20.

Alternative 17:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Trail Dike	32.20	LDB	415	+15
Trail Dike	32.00	LDB	600	+15
Trail Dike	31.90	LDB	400	+15

Results: *Bathymetry (Plate 56)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	No	The proposed structures significantly improved and deepened the channel between RM 31.90 - 31.40. However, the width of the channel remained very narrow between RM 31.40 - 30.60. There were no significant changes downstream of RM 31.40.

Alternative 18:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Trail Dike	32.20	LDB	600	+15
Trail Dike	32.00	LDB	600	+15
Trail Dike	31.90	LDB	400	+15

Results: *Bathymetry (Plate 57)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	Yes	The proposed structures significantly improved and deepened the channel between RM 31.90 - 31.40. However, the width of the channel remained very narrow between RM 31.70 - 30.60. The channel slightly deepened between RM 29.00 - 27.20.

Alternative 19:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Trail Dike	32.20	LDB	600	+15
Trail Dike	32.00	LDB	600	+15
Trail Dike	31.90	LDB	400	+15
Trail Dike	31.80	LDB	515	+15
Trail Dike	31.60	LDB	445	+15
Trail Dike	31.40	LDB	510	+15
Trail Dike	31.20	LDB	560	+15

Results: *Bathymetry (Plate 58)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	Yes	The proposed structures significantly improved and deepened the channel between RM 31.90 - 31.40. However, the width of the channel remained very narrow along the RDB between RM 31.60 - 30.60 and was shallower along the LDB. The channel slightly deepened between RM 29.00 - 27.20.

Alternative 20:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Dike Removal	32.60	RDB	1000	+15
Dike Removal	32.20	RDB	500	+15
Trail Dike	32.20	LDB	600	+15
Trail Dike	32.00	LDB	600	+15
Trail Dike	31.90	LDB	400	+15
Trail Dike	31.80	LDB	515	+15
Trail Dike	31.60	LDB	445	+15
Trail Dike	31.40	LDB	510	+15
Trail Dike	31.20	LDB	560	+15
Trail Dike	32.20	LDB	600	+15

Results: *Bathymetry (Plate 59)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	No	Yes	The removed structures allowed more flow on the right side of Chevrons 32.80R, 32.60R and 32.40R. The trail dikes significantly improved and deepened the channel between RM 31.90 - 31.00. However, the width of the channel remained very narrow along the RDB between RM 31.60 - 30.60. The channel slightly deepened between RM 29.00 - 27.20.

Alternative 21:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.20	RDB	325	+15
Trail Dike	32.20	LDB	600	
Trail Dike	32.00	LDB	500	+15
Dike Extension	32.00	RDB	260	+15
Trail Dike	32.00	RDB	500	
Dike	31.90	RDB	400	+15
Trail Dike	31.90	LDB	300	+15
Trail Dike	31.80	LDB	400	+15
Trail Dike	31.60	LDB	350	+15
Trail Dike	31.40	LDB	400	+15
Trail Dike	31.20	LDB	450	+15

Results: *Bathymetry (Plate 60)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. The structures significantly deepened the channel between RM 31.90 - 31.20 and improved depths between RM 31.20 - 30.50 although it was still too shallow. The channel was also improved and deepened between RM 28.90 - 27.20.

Alternative 22:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike Extension	32.20	RDB	325	+15
Trail Dike	32.20	LDB	300	
Dike (Shorten Existing)	32.20	LDB	105	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	145	+15
Dike Extension	32.00	RDB	260	+15
Trail Dike	32.00	RDB	500	
Dike	31.90	RDB	400	+15
Trail Dike	31.90	LDB	300	+15
Dike (Shorten Existing)	31.90	LDB	100	+15
Trail Dike	31.80	LDB	400	+15
Dike (Shorten Existing)	31.80	LDB	125	+15
Trail Dike	31.60	LDB	400	+15
Dike (Shorten Existing)	31.60	LDB	140	+15
Trail Dike	31.40	LDB	400	+15
Trail Dike	31.20	LDB	450	+15

Results: *Bathymetry (Plate 61)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is very similar to Alternative 21 and so the bathymetric results were similar as well. This alternative involved shortening existing dikes between RM 32.20 - 31.60 which made the channel shallower between RM 31.40 - 30.60 than seen for Alternative 21.

Alternative 23:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Trail Dike	32.20	LDB	300	+15
Dike (Shorten Existing)	32.20	LDB	105	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	145	+15
Trail Dike	31.90	LDB	300	+15
Dike (Shorten Existing)	31.90	LDB	100	+15
Trail Dike	31.80	LDB	400	+15
Dike (Shorten Existing)	31.80	LDB	125	+15
Trail Dike	31.60	LDB	400	+15
Dike (Shorten Existing)	31.60	LDB	140	+15
Trail Dike	31.40	LDB	400	+15
Trail Dike	31.20	LDB	450	+15

Results: *Bathymetry (Plate 62)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The structures significantly deepened the channel between RM 31.90 - 31.40 and slightly deepened it between RM 31.40 - 30.50. It also deepened between RM 29.00 - 27.20.

Alternative 24:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Trail Dike	32.20	LDB	625	+15
Dike (Shorten Existing)	32.20	LDB	100	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Trail Dike	31.90	LDB	300	+15
Trail Dike	31.80	LDB	400	+15
Trail Dike	31.60	LDB	400	+15
Dike Extension	31.60	LDB	70	+15
Trail Dike	31.40	LDB	400	+15
Dike Extension	31.40	LDB	250	+15
Trail Dike	31.20	LDB	450	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15

Results: *Bathymetry (Plate 63)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The structures significantly improved and deepened the channel between RM 31.90 - 30.30 and increased the width to approximately 800 ft. Between RM 30.50 - 29.15, sediment eroded from Bumagrd Island resulting in some land loss. The structures improved the channel depth between RM 29.00 - 27.20.

Alternative 25:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Trail Dike	32.20	LDB	625	+15
Dike (Shorten Existing)	32.20	LDB	100	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Trail Dike	31.90	LDB	300	+15
Trail Dike	31.80	LDB	400	+15
Trail Dike	31.60	LDB	400	+15
Dike Extension	31.60	LDB	70	+15
Trail Dike	31.40	LDB	400	+15
Dike Extension	31.40	LDB	250	+15
Trail Dike	31.20	LDB	450	+15
Dike Extension	31.20	LDB	310	+15

Results: *Bathymetry (Plate 64)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 24 but Dike Extension 31.10L was removed to try to help smooth the transition of the flow through the bend when entering the weir field so it wouldn't erode as much sediment from Bumgard Island. This helped but Bumgard Island still had a lot of land loss.

Alternative 26:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Trail Dike	32.20	LDB	625	+15
Dike (Shorten Existing)	32.20	LDB	100	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Trail Dike	31.90	LDB	300	+15
Trail Dike	31.80	LDB	400	+15
Trail Dike	31.60	LDB	400	+15
Dike Extension	31.60	LDB	70	+15
Trail Dike	31.40	LDB	400	+15
Dike Extension	31.40	LDB	250	+15
Trail Dike	31.20	LDB	450	+15
Dike Extension	31.20	LDB	310	+15

Results: *Bathymetry (Plate 65)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The trail dikes significantly deepened the channel between RM 31.90 - 31.20 and between RM 31.20 - 30.50 ft. However, it did not provide much width between RM 31.30 - 30.50. The channel also deepened between RM 29.00 - 27.20.

Alternative 27:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Trail Dike	32.20	LDB	625	+15
Dike (Shorten Existing)	32.20	LDB	100	+15
Trail Dike	32.00	LDB	500	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Trail Dike	31.90	LDB	300	+15
Trail Dike	31.80	LDB	400	+15
Trail Dike	31.60	LDB	400	+15
Dike Extension	31.60	LDB	70	+15
Trail Dike	31.40	LDB	400	+15
Dike Extension	31.40	LDB	250	+15
Trail Dike	31.20	LDB	450	+15
Dike Extension	31.20	LDB	310	+15
Weir Removal	30.55	RDB	375	+15
Weir Removal	30.50	RDB	540	+15

Results: *Bathymetry (Plate 66)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The channel improved and deepened significantly between RM 31.90 - 30.50 and the width increased approximately 400 ft. The channel also deepened between RM 29.00 - 27.20.

Alternative 28:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir Removal	30.55	RDB	375	-15

Results: *Bathymetry (Plate 67)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The channel significantly deepened between RM 31.90 - 31.40 but only slightly deepened between RM 31.40 - 30.50. The channel also deepened significantly between RM 29.00 - 27.20.

Alternative 29:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir (Shorten Existing)	30.55	RDB	160	-15

Results: *Bathymetry (Plate 68)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is very similar to Alternative 28 but instead of removing Weir 30.55R it was shortened. This change had minimal effects on the channel and therefore the bathymetric results were very similar.

Alternative 30:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike	31.70	RDB	185	+15
Dike	31.30	RDB	195	+15
Weir (Shorten Existing)	30.55	RDB	160	-15

Results: *Bathymetry (Plate 69)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is very similar to Alternative 29 but includes two other dikes on the RDB between RM 31.70 - 31.30. The channel didn't improve with these structures and became shallower than seen with Alternative 29.

Alternative 31:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike (Shorten Existing)	31.90	LDB	120	+15
Trail Dike	31.90	LDB	360	+15
Dike	31.80	RDB	200	+15
Dike	31.50	RDB	110	+15
Trail Dike	31.50	RDB	580	+15
Dike	31.30	RDB	135	+15
Dike (Shorten Existing)	31.20	LDB	50	+15
Trail Dike	31.20	LDB	580	+15
Weir Removal	30.55	RDB	375	-15

Results: *Bathymetry (Plate 70)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The channel significantly deepened between RM 31.90 - 31.40 and slightly deepened between RM 31.40 - 30.50. However, sediment eroded from Bumagrd Island. The channel also deepened significantly between RM 29.00 - 27.20.

Alternative 32:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike (Shorten Existing)	31.90	LDB	120	+15
Trail Dike	31.90	LDB	360	+15
Dike	31.80	RDB	200	+15
Dike	31.50	RDB	110	+15
Trail Dike	31.50	RDB	580	+15
Dike	31.30	RDB	135	+15
Dike (Shorten Existing)	31.20	LDB	50	+15
Trail Dike	31.20	LDB	580	+15
Weir Removal	30.55	RDB	375	-15

Results: *Bathymetry (Plate 71)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 31 but it has another weir at RM 32.20. The weir allowed more improvement to the channel between RM 31.40 - 30.50 than seen on Alternative 31.

Alternative 33:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Weir Removal	30.55	RDB	375	-15
Weir	30.55	RDB	240	-15
Weir Removal	30.50	RDB	540	-15
Weir	30.50	RDB	675	-15

Results: *Bathymetry (Plate 72)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The channel significantly deepened between RM 31.90 - 31.40 and slightly deepened between RM 31.40 - 30.50. However, sediment eroded from Bumgard Island. The channel also deepened significantly between RM 29.00 - 27.20.

Alternative 34:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Weir Removal	30.55	RDB	375	-15
Weir Removal	30.50	RDB	540	-15

Results: *Bathymetry (Plate 73)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and increased the width of the channel approximately 300 ft. The channel significantly deepened between RM 31.90 - 31.40 and slightly deepened between RM 31.40 - 30.50. Bumgard didn't face as much erosion by removing Weirs 30.55R & 30.50R. The channel also deepened between RM 29.00 - 27.20.

Alternative 35:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike	31.70	LDB	190	+15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15
Dike	31.40	RDB	120	+15
Trail Dike	31.40	RDB	380	+15
Dike	31.10	RDB	164	+15
Weir (Shorten Existing)	30.55	RDB	140	-15
Weir (Shorten Existing)	30.50	RDB	110	-15

Results: *Bathymetry (Plate 74)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 31.40 and between RM 31.40 - 30.50. However it was not as wide as needed between RM 31.00 - 30.60 and sediment eroded in Bumgard Island leading to some land loss. The channel significantly deepened between RM 29.00 - 27.20.

Alternative 36:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike (Shorten Existing)	32.20	LDB	77	+15
Dike (Shorten Existing)	32.00	LDB	145	+15
Dike	31.70	RDB	190	+15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15
Dike	31.40	RDB	120	+15
Trail Dike	31.40	RDB	380	+15
Dike	31.10	RDB	164	+15

Results: *Bathymetry (Plate 75)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is very similar to Alternative 35 but Weirs 30.55R & 30.50R were not shortened. The change did not have much effect on the channel and provided similar bathymetric results as seen with Alternative 35.

Alternative 37:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Notched Dike[1]	31.80	LDB	65	+15
Dike Extension	31.80	LDB	90	+15
Dike	31.70	RDB	190	+15
Notched Dike[2]	31.60	LDB	100	+15
Dike Extension	31.60	LDB	145	+15
Dike (Shorten Existing)	31.40	LDB	85	+15
Dike Extension[3]	31.40	LDB	190	+15
Dike	31.40	RDB	120	+15
Trail Dike	31.40	RDB	380	+15
Dike Extension[4]	31.20	LDB	225	+15
Dike	31.10	RDB	164	+15

Results: *Bathymetry (Plate 76)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 36 but Dikes 31.80L - 31.20L were all extended. This did not improve the depths of the channel between RM 31.00 - 30.60 and eroded even more sediment from Bumgard Island.

[1] Notch should start 300 ft from dike endpoint on the LDB.
[2] Notch should start 300 ft from dike endpoint on the LDB
[3] Dike extension should start 85 ft from shortened dike
[4] Dike extension should start 65 ft from existing dike

Alternative 38:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike (Shorten Existing)	32.20	LDB	77	+15
Dike (Shorten Existing)	32.00	LDB	145	+15
Notched Dike[5]	31.80	LDB	65	+15
Dike Extension	31.80	LDB	90	+15
Dike	31.70	RDB	190	+15
Notched Dike[6]	31.60	LDB	100	+15
Dike Extension	31.60	LDB	145	+15
Dike (Shorten Existing)	31.40	LDB	100	+15
Dike Extension[7]	31.40	LDB	190	+15
Dike	31.40	RDB	120	+15
Trail Dike	31.40	RDB	380	+15
Notched Dike[8]	31.20	LDB	100	+15
Dike Extension	31.20	LDB	280	+15
Dike	31.10	RDB	164	+15
Notched Dike[9]	31.10	LDB	100	+15

[5] Notch should start 300 ft from dike endpoint on the LDB
[6] Notch should start 250 ft from LDB
[7] Dike extension should start 100 ft from shortened dike
[8] Notch should start 300 ft from LDB
[9] Notch should start 480 ft from LDB

Results: *Bathymetry (Plate 77)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 30.60. Although the channel deepened, it did not widen enough between RM 31.00 - 30.50. Bumgard Island lost even more sediment with the notched dikes as flow passed through the middle of the island. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 39:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike (Shorten Existing)[10]	31.80	LDB	70	+15
Dike Extension[11]	31.80	LDB	70	+15
Dike	31.70	RDB	190	+15
Notched Dike[12]	31.60	LDB	85	+15
Dike Extension	31.60	LDB	80	+15
Dike (Shorten Existing)	31.40	LDB	85	+15
Dike Extension[13]	31.40	LDB	240	+15
Dike	31.40	RDB	120	+15
Trail Dike	31.40	RDB	380	+15
Notched Dike[14]	31.20	LDB	100	+15
Dike Extension	31.20	LDB	230	+15
Dike	31.10	RDB	164	+15
Notched Dike[15]	31.10	LDB	100	+15

[10] Notch should start 370 ft from dike endpoint on the LDB
[11] Dike extension should start 70 ft from shortened dike
[12] Notch should start 250 ft from LDB
[13] Dike extension should start 85 ft from shortened dike
[14] Notch should start 180 ft from LDB
[15] Notch should start 480 ft from LDB

Results: *Bathymetry (Plate 78)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 30.80 but sedimentation extended along the new dikes on the RDB. Although the channel deepened, it did not widen enough between RM 31.00 - 30.50. Due to the notched dikes, flow crossed through Bumgard Island. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 40:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	32.70	RDB	190	+15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15

Results: *Bathymetry (Plate 79)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.60, 32.40R and 32.20R. The channel significantly improved and deepened between RM 31.90 - 31.40 but only slightly deepened between RM 31.40 - 30.50. The channel also deepened significantly between RM 29.00 - 27.20.

Alternative 41:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	32.70	RDB	190	+15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15
Weir	30.70	RDB	390	-15
Weir	30.60	RDB	420	-15

Results: *Bathymetry (Plate 80)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 40 but it includes two more weirs at RM 30.70R & 30.60R. This made it shallower in the channel between RM 31.40 - 30.70 but it was helping with the transition of the flow into the weir field at the bend.

Alternative 42:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15
Weir	30.70	RDB	390	-15
Weir	30.60	RDB	420	-15

Results: *Bathymetry (Plate 81)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 41 but Weir 32.20L is set at another angle. This change did not help improve the depth of the channel between RM 31.40 - 30.60. It got shallower than seen with Alternative 41.

Alternative 43:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike Extension	31.60	LDB	50	+15
Dike Extension	31.40	LDB	108	+15
Weir	30.80	RDB	340	-15
Weir	30.70	RDB	390	-15
Weir	30.60	RDB	420	-15

Results: *Bathymetry (Plate 82)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 42 but includes a weir at RM 30.80R. This weir helped improve the shallowness seen on Alternative 42 between RM 31.40 - 30.60 but it still wasn't deep enough.

Alternative 44:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike Extension	31.60	LDB	165	+15
Dike Extension	31.40	LDB	275	+15
Weir	30.80	RDB	340	-15
Weir	30.70	RDB	390	-15
Weir	30.60	RDB	420	-15

Results: *Bathymetry (Plate 83)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	This alternative is similar to Alternative 43 but the length used for the extended Dikes was changed. The bathymetric results between both alternatives do not differ much.

Alternative 45:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 84)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.60, 32.40R and 32.20R. The channel deepened between RM 31.90 - 31.60 and although it also improved between RM 31.60 - 30.50, it was still very shallow towards the RDB. The dike at RM 31.10L along with the weirs at RM 30.90R & 30.70R facilitated flow to enter the side channel along Bumgard Island which had not been achieved during the replication test or with any other alternative. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 46:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	47	+15
Dike Extension	31.90	LDB	52	
Dike Extension	31.80	LDB	67	+15
Dike Extension	31.60	LDB	97	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15

Results: *Bathymetry (Plate 85)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.60, 32.40R and 32.20R. The channel significantly deepened between RM 31.90 - 30.60 although it remained slightly shallow along dikes at RM 31.60 - 31.10. There was an increase in the width of the channel along Bumgard Island between RM 30.60 - 29.15 and a significant improvement in the depth of the channel between RM 29.00 - 27.20.

Alternative 47:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.30	LDB	900	-15
Weir	32.20	LDB	900	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.90	LDB	26	+15
Dike Extension	31.80	LDB	74	+15
Dike Extension	31.60	LDB	150	+15
Dike Extension	31.40	LDB	364	+15
Dike Extension	31.20	LDB	464	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 86)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.30L - 32.20L eliminated scouring between RM 32.70 - 32.00. However, sedimentation extended into the main channel along Chevrons 32.60, 32.40R and 32.20R. The channel deepened between RM 31.90 - 31.60 but did not provide much width and remained shallow between RM 31.60 - 30.60. The dike at RM 31.10L along with the weirs at RM 30.90R & 30.70R facilitated flow to enter the side channel along Bumgard Island. The channel significantly deepened between RM 29.00 - 27.20.

Alternative 48:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15

Results: *Bathymetry (Plate 87)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and in conjunction with the extended dikes, improved the channel significantly. The channel deepened between RM 31.90 - 30.60. Much more flow was directed at weir 30.55 which caused it to jump over to Bumgard Island instead of maintaining on the weir field. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 49:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	900	-15
Weir	32.40	LDB	900	-15
Weir	32.30	LDB	900	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 88)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The weirs at RM 32.50L - 32.30L eliminated scouring along the LDB and provided more width to the main channel between RM 32.40 - 32.00. The channel significantly deepened between RM 31.90 - 30.60. Weir 30.70R allowed a smoother transition of the flow into the weir field but would still cross over to Bumgard Island. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 50:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 89)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.60, 32.40R and 32.20R. The channel deepened between RM 31.90 - 30.60 but remained slightly shallow towards the RDB between RM 31.60 - 30.60. The dike at RM 31.10L along with the weirs at RM 30.90R & 30.70R facilitated flow to enter the side channel along Bumgard Island The channel widened between RM 30.60 - 29.15 and significantly deepened between RM 29.00 - 27.20.

Alternative 51:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	47	+15
Dike Extension	31.90	LDB	52	+15
Dike Extension	31.80	LDB	67	+15
Dike Extension	31.60	LDB	97	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15

Results: *Bathymetry (Plate 90)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 and in conjunction with the extended dikes on the LDB and the new dike on the RDB, improved the channel significantly. The channel deepened between RM 31.90 - 30.60 but remained very narrow at RM 30.60. Much more flow was directed at Weir 30.55R which caused it to cross over to Bumgard Island instead of maintaining on the weir field. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 52:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	258	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15

Results: *Bathymetry (Plate 91)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50L - 32.20L eliminated scouring along the LDB. However, there was sedimentation along Chevrons 32.80 & 32.60. The channel improved significantly and was deepened between RM 31.90 - 30.60. Weir 30.90R did not ease the transition of the flow into the weir field and there was much more flow against Bumgard Island. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 53:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 92)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50L - 32.20L eliminated scouring between RM 32.70 - 32.00. However, some sedimentation extended into the main channel along Chevrons 32.80, 32.60R and 32.40R. The channel significantly deepened between RM 31.90 - 31.40 but remained slightly shallow along Dikes 31.20L & 31.10L. The channel widened between RM 30.50 - 29.15 and also significantly deepened between RM 29.00 - 27.20.

Alternative 54:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 93)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs between RM 32.50L - 32.20L eliminated scouring along the LDB. However, sedimentation extended into the main channel along Chevrons 32.80, 32.60R and 32.40R. The channel significantly deepened between RM 31.90 - 31.60 but remained slightly shallow between RM 31.60 - 30.50. The channel widened between RM 30.50 - 29.15 and also significantly deepened the channel between RM 29.00 - 27.20.

Alternative 55:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.90	RDB	350	-20
Weir	30.70	RDB	400	-20

Results: *Bathymetry (Plate 94)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50L - 32.20L eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 30.60 although it was slightly shallow between RM 31.40 - 31.10. The channel widened between RM 30.60 - 29.15 and also significantly deepened between RM 29.00 - 27.20.

Alternative 56:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15

Results: *Bathymetry (Plate 95)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The proposed weirs eliminated scouring between RM 32.70 - 32.00 along the LDB. The channel significantly deepened between RM 31.90 - 30.60 but remained very narrow between RM 31.00 - 30.60. Some flow was directed into Bumgard Island as it reached the first few weirs on the RDB between RM 30.60 - 30.30. The channel also significantly deepened between RM 29.00 - 27.20.

Alternative 57:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 96)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel deepened between RM 31.90 - 31.40 but only slightly deepened between RM 31.40 - 30.60. The channel was widened along the weir field between RM 30.60 - 29.15 and significantly deepened between RM 29.00 - 27.20.

Alternative 58:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 97)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel deepened between RM 31.90 - 31.40 but only slightly deepened between RM 31.40 - 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deepened between RM 29.00 - 27.20.

Alternative 59:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 98)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel deepened between RM 31.90 - 31.40 but only slightly deepened between RM 31.40 - 30.90. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deepened between RM 29.00 - 27.20.

Alternative 60:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	89	-15
Weir	30.60	RDB	166	-15

Results: *Bathymetry (Plate 99)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 30.60 with just a few shallow spots between RM 31.40 - 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 61:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	89	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 100)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. However, some sedimentation extended into the main channel along Chevrons 32.80R, 32.60R and 32.40R. The channel significantly improved and deepened between RM 31.90 - 30.60 with just a few shallow spots between RM 31.20 - 30.60. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 62:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	89	-15

Results: *Bathymetry (Plate 101)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	Yes	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. The channel significantly improved and deepened between RM 31.90 - 30.60 but had a few shallow spots along Dike 31.20L & 31.10L. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 63:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 102)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
No	No	Yes	Yes	The weirs at RM 32.50 - 32.20 eliminated scouring along the LDB. There was significant improvement between RM 31.90 - 30.60 providing a much deeper and wider channel. The channel was also wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 64:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 103)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. There was significant improvement between RM 31.90 - 30.60 providing a much deeper and wider channel. The channel was also wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 65:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	300	-15
Weir	32.40	LDB	300	-15
Weir	32.30	LDB	500	-15
Weir	32.20	LDB	300	-15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 104)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. The channel was deepened between RM 31.90 - 30.60 but did not deepen along dikes 31.20L & 31.10L. The channel was wider along the weir field between RM 30.60 - 29.15 with some flow getting into Bumgard Island and significantly deeper between RM 29.00 - 27.20.

Alternative 66:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	300	-15
Weir	32.40	LDB	300	-15
Weir	32.30	LDB	500	-15
Weir	32.20	LDB	300	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 105)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The proposed structures allowed sufficient width and depth where needed throughout the whole reach of the study. There was just one small shallow spot at RM 30.90.

Alternative 67:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	300	-15
Weir	32.40	LDB	300	-15
Weir	32.30	LDB	500	-15
Weir	32.20	LDB	300	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 106)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. The channel deepened between RM 31.90 - 31.60 and was improved between RM 31.60 - 30.60 but still remained too shallow. The weirs at RM 30.90R & 30.70R allowed some flow to enter the side channel along Bumgard Island. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 68:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	300	-15
Weir	32.40	LDB	300	-15
Weir	32.30	LDB	500	-15
Weir	32.20	LDB	300	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	350	-15
Weir	30.70	RDB	400	-15

Results: *Bathymetry (Plate 107)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. The channel deepened between RM 31.90 - 31.40 and improved between RM 31.40 - 30.60 but still remained too shallow. The weirs at RM 30.90R & 30.70R allowed some flow to enter the side channel along Bumgard Island. The channel was wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 69:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir (Degrade)	30.55	RDB	375	-15
Weir (Degrade)	30.50	RDB	542	-18
Weir (Degrade)	30.30	RDB	759	-18

Results: *Bathymetry (Plate 108)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. There was significant improvement between RM 31.90 - 30.60 providing a much deeper channel and about 800 ft in width. The channel was also wider along the weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20. This alternative helped clear all four dredging spots.

Alternative 70:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.20	LDB	102	+15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike	31.60	RDB	300	+15
Weir (Degrade)	30.55	RDB	375	-15
Weir (Degrade)	30.50	RDB	542	-18
Weir (Degrade)	30.30	RDB	759	-18

Results: *Bathymetry (Plate 109)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This alternative is similar to Alternative 69 but without the extended dikes between RM 31.80 - 31.10. The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. The channel deepened between RM 31.90 - 31.50 and although it improved between RM 31.50 - 30.60 it still remained shallow. The channel was wider along the Weir field between RM 30.60 - 29.15 and significantly deeper between RM 29.00 - 27.20.

Alternative 71:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 109)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel at RM 34.00 and in conjunction with weirs at RM 32.50 - 32.20 it eliminated scouring along the LDB and also widened the channel. There was significant improvement between RM 31.90 - 30.60 providing a much deeper channel and about 800 ft in width. Contrary to Alternative 69, this alternative did not require the need to degrade Weirs 30.55 - 30.30R. The proposed Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was also wider along the weir field between RM 30.60 - 29.15 without affecting Bumgard Island or its Side Channel. Between RM 29.00 - 27.20, the main channel significantly deepened. As a result, this alternative helped clear all four dredging spots.

Alternative 72:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 110)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 71 but without the extension of Dike 31.10L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also deepened the channel significantly between RM 31.90 - 30.60 and provided about 800 ft in width. However, without the extension of Dike 31.10L there was slightly some sedimentation between RM 31.40 to 31.00. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was also great improvement between RM 29.00 - 27.20 with a much deeper channel.

Alternative 73:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 111)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 72 but without the extension of Dike 31.20L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also deepened the channel significantly between RM 31.90 - 30.60 and provided about 800 ft in width. However, without the extension of Dike 31.20L there was slightly some sedimentation between RM 31.40 to 31.00. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was also great improvement between RM 29.00 - 27.20 with a much deeper channel.

Alternative 74:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 112)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 73 but without the extension of Dike 31.40L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without the extension of Dike 31.40L there was much more sedimentation between RM 31.60 to 30.50. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was still great improvement between RM 29.00 - 27.20 with a much deeper channel compared to the replication although there was some slight sedimentation.

Alternative 75:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 113)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 74 but without any dike alterations between RM 31.60 to 32.00. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without any dike extension between RM 31.80 to 31.10 there was much more sedimentation between RM 31.60 to 30.50. It is noticeable that even the small extensions at RM 31.80 & 31.60, as shown in Alternative 74, had some effect reducing the sedimentation and improving the channel alignment. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was still great improvement between RM 29.00 - 27.20 with a much deeper channel compared to the replication although there was some slight sedimentation.

Alternative 76:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Offset Dike	31.45	LDB	250	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 114)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 75 but with an offset dike slightly above Dike 31.40L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. The goal with the offset dike was to continue to allow some flow along the existing dikes while also providing some constriction to the main channel but sedimentation built up between RM 31.60 to 31.00. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was still great improvement between RM 29.00 - 27.20 with a much deeper channel compared to the replication although there was some slight sedimentation.

Alternative 77:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Offset Dike	31.35	LDB	250	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 115)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 76 but with an offset dike slightly below Dike 31.40L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. The goal with the offset dike was to continue to allow some flow along the existing dikes while also providing some constriction to the main channel but sedimentation built up between RM 31.60 to 31.00. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was great improvement between RM 29.00 - 27.20 with a much deeper channel.

Alternative 78:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Offset Dike	31.45	LDB	215	+15
Offset Dike	31.25	LDB	215	+15
Offset Dike	31.15	LDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 116)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 76 but with three offset dikes slightly above Dike 31.40L, 31.20L and 31.10L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. The goal with the offset dikes was to continue to allow some flow along the existing dikes while also providing some constriction to the main channel. Even with the constriction some sedimentation built up between RM 31.60 to 30.55 and the flow in between the offset dikes and the existing dikes cut through Bumgard Island. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was great improvement between RM 29.00 - 27.20 with a much deeper channel.

Alternative 79:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Offset Dike	31.35	LDB	215	+15
Offset Dike	31.15	LDB	235	+15
Offset Dike	31.05	LDB	325	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 117)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	This Alternative is similar to 77 but with three offset dikes slightly below Dike 31.40L, 31.20L and 31.10L. The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. The goal with the offset dikes was to continue to allow some flow along the existing dikes while also providing some constriction to the main channel. Even with the constriction some sedimentation built up between RM 31.60 to 30.55 and the flow in between the offset dikes and the existing dikes cut through Bumgard Island. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was great improvement between RM 29.00 - 27.20 with a much deeper channel.

Alternative 80:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 118)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. This test was to see the effect one single extension located at Dike 31.40L would have on constriction of the channel to reduce sedimentation between 31.60 – 30.50. As shown with Alternative 74, it was after this extension was eliminated that the sedimentation worsened but this test showed that the extension alone is not enough to clear up the channel. The short extensions at Dike 31.80L and 31.60L are also needed to improve the channel alignment and provide more effective results as shown with Alternative 73. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The channel was wider along the weir field between RM 30.60 - 29.15 and there was great improvement between RM 29.00 - 27.20 with a much deeper channel compared to the replication although there was some slight sedimentation.

Alternative 81:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15
Chevron	28.90	LDB	300 x 300	+15

Results: *Bathymetry (Plate 119)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without any dike extension between RM 31.80 to 31.10 there was much more sedimentation between RM 31.60 to 30.50. A chevron was placed at RM 28.90 which provided some constriction to the channel and deepened the channel further more than shown with Alternative 75.

Alternative 82:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15
Chevron	28.90	LDB	300 x 300	+15
Chevron	28.60	LDB	300 x 300	+15
Chevron	28.40	LDB	300 x 300	+15

Results: *Bathymetry (Plate 120)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without any dike extension between RM 31.80 to 31.10 there was much more sedimentation between RM 31.60 to 30.50. Three chevrons were placed between RM 29.00 to 28.00 which provided constriction to the channel and deepened the channel further more than shown with Alternative 81.

Alternative 83:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15
Rootless Dike	28.80	LDB	400	+15
Rootless Dike	28.50	LDB	370	+15
Rootless Dike	28.30	LDB	390	+15
Dike Extension	28.00	LDB	172	+15
Dike Extension	27.20	LDB	177	+15

Results: *Bathymetry (Plate 121)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without any dike extension between RM 31.80 to 31.10 there was much more sedimentation between RM 31.60 to 30.50. Three rootless dikes were placed between RM 29.00 to 28.00 which provided constriction to the channel and deepened the channel further more than shown with Alternative 82.

Alternative 84:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike	31.60	RDB	300	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15
W Dike	28.80	LDB	350 x 350	+15
Rootless Dike	28.50	LDB	350	+15
W Dike	28.30	LDB	350 x 350	+15
Dike Extension	28.00	LDB	184	+15
Dike Extension	27.20	LDB	146	+15

Results: *Bathymetry (Plate 122)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also reduced the sedimentation in the channel between RM 31.90 - 30.60. However, without any dike extension between RM 31.80 to 31.10 there was much more sedimentation between RM 31.60 to 30.50. Two W dikes and a rootless dike were placed between RM 29.00 to 28.00 along with two dike extensions at Dike 28.00L and 27.20L which provided constriction to the channel and deepened the channel further more than shown with Alternative 82.

Alternative 85:

Type of Structure	River Mile	LDB or RDB	Dimensions (Feet)	Structure Top Elevation (ft in LWRP)
Weir	34.20	LDB	600	-15
Weir	34.10	LDB	600	-15
Weir	32.50	LDB	400	-15
Weir	32.40	LDB	500	-15
Weir	32.30	LDB	650	-15
Weir	32.20	LDB	500	-15
Dike (Shorten Existing)	32.00	LDB	105	+15
Dike Extension	31.80	LDB	27	+15
Dike Extension	31.60	LDB	69	+15
Dike	31.60	RDB	300	+15
Dike Extension	31.40	LDB	248	+15
Dike Extension	31.20	LDB	310	+15
Dike Extension	31.10	LDB	385	+15
Notch Dike	31.10	LDB	185	+15
Weir	30.80	RDB	160	-15
Weir	30.70	RDB	162	-15

Results: *Bathymetry (Plate 123)*

Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Additional Comments
Yes	Yes	Yes	Yes	The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 which also significantly reduced the sedimentation in the channel between RM 31.90 - 30.60. However, some of the flow concentrated in the main channel was diverted to the side channel through the notch at Dike 31.10L. This prevented a deeper main channel between RM 31.40 to 31.00 and caused some erosion to Bumgard Island. The flow that entered the side channel tried to cut across the island and re connect with the main channel. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00 and the channel was wider along the weir field between RM 30.60 - 29.15. The alternative also showed significant improvement between RM 29.00 to 27.00 with a much deeper channel.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Alternatives	Reduced Deposition at RM 34.50 to 33.80	Reduced Deposition at RM 32.90 to 31.50	Reduced Deposition at RM 31.40 to 30.60	Reduced Deposition at RM 28.90 to 27.20	Positive Overall Impact on Study Reach
Alternative 1	No	Yes	Yes	No	No
Alternative 2	No	Yes	Yes	No	No
Alternative 3	No	Yes	Yes	No	No
Alternative 4	No	Yes	Yes	Yes	No
Alternative 5	No	Yes	Yes	No	No
Alternative 6	No	Yes	Yes	No	No
Alternative 7	No	Yes	Yes	No	No
Alternative 8	Yes	Yes	Yes	No	No
Alternative 9	Yes	Yes	Yes	No	No
Alternative 10	Yes	Yes	Yes	No	No
Alternative 11	Yes	Yes	Yes	No	No
Alternative 12	Yes	Yes	Yes	No	No
Alternative 13	Yes	Yes	Yes	No	No
Alternative 14	No	Yes	No	No	No
Alternative 15	No	Yes	No	No	No
Alternative 16	Yes	Yes	No	No	No
Alternative 17	No	Yes	No	No	No
Alternative 18	No	Yes	No	Yes	No
Alternative 19	No	Yes	No	Yes	No
Alternative 20	No	Yes	No	Yes	No
Alternative 21	No	Yes	Yes	Yes	No
Alternative 22	No	Yes	Yes	Yes	No
Alternative 23	No	Yes	Yes	Yes	No
Alternative 24	No	Yes	Yes	Yes	No
Alternative 25	No	Yes	Yes	Yes	No
Alternative 26	No	Yes	Yes	Yes	No
Alternative 27	No	Yes	Yes	Yes	No
Alternative 28	No	Yes	Yes	Yes	No
Alternative 29	No	Yes	Yes	Yes	No
Alternative 30	No	Yes	Yes	Yes	No
Alternative 31	No	Yes	Yes	Yes	No
Alternative 32	No	Yes	Yes	Yes	No
Alternative 33	No	Yes	Yes	Yes	No
Alternative 34	No	Yes	Yes	Yes	No
Alternative 35	No	Yes	Yes	Yes	No
Alternative 36	No	Yes	Yes	Yes	No

Alternative 37	No	Yes	Yes	Yes	No
Alternative 38	No	Yes	Yes	Yes	No
Alternative 39	No	Yes	Yes	Yes	No
Alternative 40	No	Yes	Yes	Yes	No
Alternative 41	No	Yes	Yes	Yes	No
Alternative 42	No	Yes	Yes	Yes	No
Alternative 43	No	Yes	Yes	Yes	No
Alternative 44	No	Yes	Yes	Yes	No
Alternative 45	No	No	Yes	Yes	No
Alternative 46	No	No	Yes	Yes	No
Alternative 47	No	No	Yes	Yes	No
Alternative 48	No	Yes	Yes	Yes	No
Alternative 49	No	Yes	Yes	Yes	No
Alternative 50	No	No	Yes	Yes	No
Alternative 51	No	No	Yes	Yes	No
Alternative 52	No	No	Yes	Yes	No
Alternative 53	No	No	Yes	Yes	No
Alternative 54	No	No	Yes	Yes	No
Alternative 55	No	No	Yes	Yes	No
Alternative 56	No	No	Yes	Yes	No
Alternative 57	No	No	Yes	Yes	No
Alternative 58	No	No	Yes	Yes	No
Alternative 59	No	No	Yes	Yes	No
Alternative 60	No	No	Yes	Yes	No
Alternative 61	No	No	Yes	Yes	No
Alternative 62	No	Yes	Yes	Yes	No
Alternative 63	No	No	Yes	Yes	No
Alternative 64	Yes	Yes	Yes	Yes	Yes
Alternative 65	Yes	Yes	Yes	Yes	No
Alternative 66	Yes	Yes	Yes	Yes	Yes
Alternative 67	Yes	Yes	Yes	Yes	No
Alternative 68	Yes	Yes	Yes	Yes	No
Alternative 69	Yes	Yes	Yes	Yes	Yes
Alternative 70	Yes	Yes	Yes	Yes	No
Alternative 71	Yes	Yes	Yes	Yes	Yes
Alternative 72	Yes	Yes	Yes	Yes	Yes
Alternative 73	Yes	Yes	Yes	Yes	Yes
Alternative 74	Yes	Yes	Yes	Yes	Yes
Alternative 75	Yes	Yes	Yes	Yes	Yes
Alternative 76	Yes	Yes	Yes	Yes	Yes
Alternative 77	Yes	Yes	Yes	Yes	Yes
Alternative 78	Yes	Yes	Yes	Yes	Yes
Alternative 79	Yes	Yes	Yes	Yes	Yes
Alternative 80	Yes	Yes	Yes	Yes	Yes
Alternative 81	Yes	Yes	Yes	Yes	Yes

Alternative 82	Yes	Yes	Yes	Yes	Yes
Alternative 83	Yes	Yes	Yes	Yes	Yes
Alternative 84	Yes	Yes	Yes	Yes	Yes
Alternative 85	Yes	Yes	Yes	Yes	Yes

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 reduce or eliminate the dredging at RM 34.50 – 27.20. The second condition was that the alternative had to maintain the navigation channel requirements of at least 9 foot of depth and 300 foot of width. While accomplishing these criteria, it is also essential to avoid impacts to the environmental features of the reach such as Bumgard Island and its side channel.

2. Recommendations

Alternative 75 (Plate 113) was recommended as the most desirable alternative because of its observed ability to significantly reduce dredging between RM 34.50 – 27.20 while avoiding impacts to Bumgard Island and its side channel. Note that while there was a reduction in sedimentation, the weirs will not completely eliminate the need to dredge near RM 31.00 or RM 28.00.

The recommended design included the following:

- Construct Weir at RM 34.20 (L)
  - Construct Weir 600 feet long
  - Top elevation of the Weir will be -20 feet (LWRP)
- Construct Weir at RM 34.10 (L)
  - Construct Weir 600 feet long
  - Top elevation of the Weir will be -20 feet (LWRP)
- Construct Weir at RM 32.50 (L)
  - Construct Weir 400 feet long
  - Top elevation of the Weir will be -15 feet (LWRP)
- Construct Weir at RM 32.40 (L)
  - Construct Weir 500 feet long
  - Top elevation of the Weir will be -15 feet (LWRP)
- Construct Weir at RM 32.30 (L)
  - Construct Weir 650 feet long
  - Top elevation of the Weir will be -15 feet (LWRP)
- Construct Weir at RM 32.20 (L)
  - Construct Weir 500 feet long
  - Top elevation of the Weir will be -15 feet (LWRP)

- Construct Dike at RM 31.60 (R)

    - Construct Dike 300 ft long
    - Top elevation of the Trail Dike will be +15 feet (LWRP)
- Construct Weir at RM 30.80 (R)
    - Weir is 160 ft long
    - Top elevation of the Weir will be -20 feet (LWRP)
- Construct Weir at RM 30.70 (R)
    - Weir is 162 ft long
    - Top elevation of the Weir will be -20 feet (LWRP)

The weirs at RM 34.20 & 34.10 improved the width of the channel as well as the weirs at RM 32.50 - 32.20 and reduced the sedimentation in the channel between RM 31.90 - 30.60. Dike 31.60 provided more constriction to the channel, thus, contributing to the sediment reduction. Weirs 30.80 & 30.70R helped the flow transition from the crossing into the bend at RM 31.00. The design alternative also showed great improvement in the channel depth between RM 29.00 - 27.20 although there was some slight sedimentation.

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

A. Report Plates

1. Dredging Locations – 1:49,000
2. Location and Vicinity Map
3. Nomenclature and Dike Locations – 1:49,000
4. 1817 Geomorphology
5. 1866 Geomorphology
6. 1881 Geomorphology
7. 1928 Geomorphology
8. 2003 Geomorphology
9. Blueprint for Restoration
10. 1925 Aerial Photograph Overlay
11. 1935 Aerial Photograph Overlay
12. 1942 Planform Map
13. 1956 Planform Map
14. 1968 Aerial Photograph Overlay
15. 1977 Aerial Photograph Overlay
16. 1987 Aerial Photograph Overlay
17. 1935 - 1956 Hydrographic Survey Overlay – 1:49,000
18. 1968 - 1971 Hydrographic Survey Overlay – 1:49,000
19. 1976 – 1977 Hydrographic Survey Overlay – 1:49,000
20. 1986 - 1987 Hydrographic Survey Overlay – 1:49,000
21. April 2001 Hydrographic Survey Overlay – 1:49,000
22. February 2005 Hydrographic Survey Overlay – 1:49,000
23. September 2007 Hydrographic Survey Overlay – 1:49,000
24. August 2010 Hydrographic Survey Overlay – 1:49,000
25. July 2011 Hydrographic Survey Overlay – 1:49,000
26. September 2005 Pre-Dredge Hydrographic Survey – 1:49,000
27. November 2006 Pre-Dredge Hydrographic Survey – 1:49,000
28. September 2007 Pre-Dredge Hydrographic Survey – 1:49,000
29. August 2008 Pre-Dredge Hydrographic Survey – 1:49,000
30. September 2009 Pre-Dredge Hydrographic Survey – 1:49,000

31. September 2011 Pre-Dredge Hydrographic Survey – 1:49,000
32. November 2012 Pre-Dredge Hydrographic Survey – 1:49,00
33. Bumgard Island Field Photographs
34. Bumgard Island Field Photographs
35. Bumgard Island Field Photographs
36. Bumgard Island Field Photographs
37. Bumgard Island HSR Model
38. Replication Test: Bathymetry Results – 1:49,000
39. Alternative 1: Bathymetry Results – 1:49,000
40. Alternative 2: Bathymetry Results – 1:49,000
41. Alternative 3: Bathymetry Results – 1:49,000
42. Alternative 4: Bathymetry Results – 1:49,000
43. Alternative 5: Bathymetry Results – 1:49,000
44. Alternative 6: Bathymetry Results – 1:49,000
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72. Alternative 34: Bathymetry Results – 1:49,000
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74. Alternative 36: Bathymetry Results – 1:49,000
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79. Alternative 41: Bathymetry Results – 1:49,000
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81. Alternative 43: Bathymetry Results – 1:49,000
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92. Alternative 54: Bathymetry Results – 1:49,000
93. Alternative 55: Bathymetry Results – 1:49,000
94. Alternative 56: Bathymetry Results – 1:49,000
95. Alternative 57: Bathymetry Results – 1:49,000
96. Alternative 58: Bathymetry Results – 1:49,000

B. March 14, 2013 Bumgard Island HSR Model Meeting Minutes

Katie discussed background information for the Bumgard Island reach, located approximately 3.5 miles downstream of Commerce, Missouri. She showed the group a 2010 Hydrographic Survey and the HSR model replication and pointed out the similarities that were obtained during the calibration process. She explained that the objective of the HSR model was to address a repetitive dredging problem that occurs between RM 34.50 – 27.20.

Katie then discussed her recommended alternative (Alternative 50) pointing out the structures that this alternative involved and how they improved the depths through the main channel between RM 31.90 – 27.20 while also providing flow for the side channel along Bumgard Island. The alternative included: the construction of four weirs near RM 32.00, several dike alterations (shortening/extending) between RM 32.20-31.10, the construction of a dike at RM 31.60, and construction of two weirs near RM 31.00. She stated that the alternative required some adjustments in order to improve the depths along chevrons at RM 32.8R, 32.6R and 32.4R and the Right Descending Bank (RDB) between RM 31.50 – 30.90 but other than that believed it solved a great majority of the problems being addressed. Katie pointed out some other alternatives that were tested that also provided increased depths through the main channel. She clarified that all of them involved extending, to some extent, the existing dikes between RM 32.20L – 31.10L which could potentially prevent flow from entering the side channel along Bumgard Island. The group seemed to agree with the recommended alternative but expressed some concerns. First concern was related to the amount of flow that could be entering the side channel due to the proposed weirs located at RM 30.90R and 30.70R and if the flow was too much it could affect the Left Descending Bank (LDB). There was another concern for loss of land at the south bound end of the island. Matt Mangan and Brandon Schneider suggested testing Alternative 46 with a 300 ft long dike at RM 31.60R (Structure is used in Alternative 50) and testing Alternative 50 without the proposed weir at RM 31.70. Alternative 46 included: the construction of four weirs near RM 32.00 and

several dike alterations (shortening/extending) between RM 32.20-31.10. These two suggestions were given with the objective to try to reduce the amount of flow Alternative 50 provides to the side channel. The group also mentioned that if Alternative 50 were to be constructed, they would like to see how the side channel reacts to the extended dikes between RM 32.20L – 31.10L before constructing the proposed weirs at RM 30.90R and 30.70R to evaluate if the structures are needed to provide flow to the side channel or not. Katie asked Shannon Hughes if there was any problem with the proposed dike at RM 31.60R since it is located above a waiting area. He said he didn't have any concerns with the structure sine it is about 1000 ft away providing plenty of space to access the area.

After the open discussion, Katie restated the goals and the alternatives that will be tested with the group, which consisted of industry, corps members, and environmental partners. Everybody agreed with the plan of action.

Meeting Attendees
Bumgard Island HSR Model Alternatives Review Meeting
14 March, 2013

Name	Agency
1. Bernie Heroff	ARTCO
2. Dave Ostendorf	MDC
3. Dave Knuth	MDC
4. Danny Brown	MDC
4. Joe McMullen	MDC
4. Shannon Hughes	Kirby Inland Marine
5. Mike Canada	Ingram Marine Group
5. Gary Holt	Ingram Marine Group
5. Terry Hoover	Ingram Marine Group
5. Matt Mangan	USFWS
6. Cail Robert	USFWS
7. Butch Atwood	Illinois DNR
7. Brandon Schneider	USACE
7. Dawn Lamm	USACE
7. Charles Frerker	USACE
8. Mike Rodgers	USACE
9. Tim Lauth	USACE
10. Ashley Cox	USACE
11. Brad Krischel	USACE
15. Lance Engle	USACE
16. Zach Ryals	USACE
17. Katherine Clancey	USACE
18. Ivan Nguyen	USACE

C. Sept. 18, 2013 Bumgard Island HSR Model Meeting Minutes

Katie presented the Bumgard Island HSR model study reach, located on the Middle Mississippi River near Commerce, MO. In this reach, repetitive dredging is required from RM 33.00 to 30.00 and RM 29.00 to 27.00.

Throughout several meetings, a total of 71 alternatives were discussed and a recommended alternative (Alternative 71) was proposed to construct weirs near RM 34.00, 32.00 and 31.00, construct a dike at RM 31.60 and perform some dike alterations (shortening/extending) between RM 32.20-31.10. Although the alternative showed promise in completely eliminating the dredging problem, there were concerns regarding the impacts the structures would have on Bumgard Island and the side channel. To address these concerns, it was decided that additional alternatives would be tested.

Katie presented 14 additional alternatives (Alternative 71-85) to the state agencies and industry on September 18, 2013. The alternatives included: (1) reducing the number of dike extensions, between RM 31.80 to 31.10, used in Alternative 71 (2) testing offset dike extensions between RM 31.8 to 31.10 (in combination with the weirs from Alternative 71), (3) testing the same structures as Alternative 71 but notching Dike 31.10L to make it rootless at the bankline, and (4) testing a few structures near RM 28 (in combination with the weirs from Alternative 71) to solve the dredging problem between RM 29.00 to 27.00, located just downstream of Bumgard Island.

After showing videos of the model replication and Alternatives 71-85 with bathymetric results and flow visualization, the floor was opened to questions. There were still many concerns regarding the effects the dike extensions, between RM 31.80-31.10, would have on Bumgard Island and the side channel, even if the number of extensions were reduced. The concerns were regarding loss of flow in the side channel and loss of habitat on the island. The alternatives with offset dike

extensions did not eliminate the dredging problem between RM 33.00 to 30.00 and notching Dike 31.10L at the bankline did not provide beneficial results either as it allowed more flow to the side channel but was cutting across the island. The structures near RM 28.00 reduced the dredging problem between RM 29.00 to 27.00. No one at the meeting expressed concerns with Alternative 84 which included: the construction of four weirs near RM 32.00, construction of a dike at RM 31.60, and two W-dikes, a rootless dike, and two dike extensions near RM 28.00.

It was agreed upon by the group that the best option, to reduce the dredging between RM 32.90 to 30.00, while avoiding environmental impacts, was Alternative 75. This alternative consists of the construction of two weirs near RM 34.00, four weirs near RM 32.00, a dike at RM 31.60 and two weirs near RM 31.00. This alternative will be moving forward to plans and specs for construction during late FY14 or early FY15. After construction it will be closely monitored to evaluate the changes in the reach and determine if the structures near RM 28, as shown on Alternative 84, are necessary to further address the dredging problem between RM 28.90 to 27.20. The group also discussed the possibility of constructing a few dike extensions (as shown in Alternative 71), between RM 31.80 to 31.10, but the decision will be based upon the response of the river to Alternative 75 (and possibly Alternative 84) to further address the dredging problem between RM 33.00 to 30.00.

Meeting Attendees
Bumgard Island HSR Model Alternatives Review Meeting
18 September, 2013

Name	Agency
1. Bernie Heroff	ARTCO
2. Dave Ostendorf	MDC
3. Dave Knuth	MDC
4. Shannon Hughes	Kirby Inland Marine
5. Matt Mangan	USFWS
6. Donovan Henry	USFWS
7. Butch Atwood	Illinois DNR
8. Mike Rodgers	USACE
9. Tim Lauth	USACE
10. Ashley Cox	USACE
11. Brad Krischel	USACE
12. Ken Cook	USACE
13. Paul Rhoades	USACE
14. Eddie Brauer	USACE
15. Francis Walton	USACE
16. Brian Johnson	USACE
17. Katherine Clancey	USACE
18. Ivan Nguyen	USACE

D. HSR Model 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://mvs-wc.mvs.usace.army.mil/arec/HSR_Modeling_Theory.html