Technical Report M43

WATER'S LANDING HSR MODEL
RIVER MILES 106.0-100.0

HYDRAULIC SEDIMENT RESPONSE MODEL INVESTIGATION

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District, conducted a sedimentation improvement study of the Water's Landing reach of the Middle Mississippi River between River Miles (RM) 106.0 and 100.0 near Chester, Illinois. This study reach was selected from the Stone Dike Alterations Project Report and funded by the Biological Opinion Program. The main objective of the study was to develop and evaluate design alternatives that would enhance the environmental diversity within the dike fields, in particular around River Miles 104.0 – 102.5. Along with the primary objective, a secondary goal was to alleviate repetitive channel maintenance dredging.

The study was conducted between May, 2008 and January, 2009 using a physical hydraulic sediment response (HSR) model at the St. Louis District Applied River Engineering Center in St. Louis, Missouri. The model study was performed by Mrs. Ashley Cox, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, P.E., Chief, River Engineering Section for the St. Louis District. Other Corps of Engineers personnel included: Mr. Leonard Hopkins, P.E., Chief of Hydrologic and Hydraulic Branch, Ms. June Jeffries, P.E., Project Manager, Mr. Brian Johnson Natural Resource Planner, Plan Formulation Branch, Mr. Francis Walton from the Environmental Branch, Mr. Lance Engle, Dredging Project Manager. Personnel from other agencies involved in the study included: Mr. Matthew Mangan from the U.S. Fish and Wildlife Service, Mr. David Ostendorf and Ms. Janet Sternburg, from the Missouri Department of Conservation, and Mr. Butch Atwood from the Illinois Department of Natural Resources.

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BACKGROUND

1. Problem Description

The main problem in this reach is that there is not a lot of environmental diversity around the large sand bar on the right descending bank (RDB) around River Miles (RM) 104.0 – 102.5. Another problem is repetitive maintenance dredging from Mile 104.0 to Mile 102.0 on the Middle Mississippi River. This reach is not only dangerous and risky for navigation, but is also quite expensive to maintain a navigable channel. Just over the last 5 years (2003-2007), 1,601,300 cubic yards of material has been dredged at a cost of about $2,344,000.

2. Study Purpose and Goals

The purpose of this model study was to evaluate various design alternatives with a goal of adding environmental diversity and if possible, alleviate sediment deposition which requires maintenance dredging. The goal of maintaining a safe and dependable navigation channel must be done while maintaining or improving environmental features in the reach (such as the area around chevron 103.5R and Rockwood Chute). Fish species flourish in deep pools, slow, shall channels, and around bar formations. This type of habitat can be cultivated by altering existing dikes, i.e. notching, increasing or decreasing length and/or height, or by adding new structures, i.e. dikes, chevrons, weirs, or by using a combination of alterations and new structures.

The objective of the Hydraulic Sediment Response (HSR) Model study was to determine a configuration of river training structures that will enhance the environmental features within the dike fields while reducing or eliminating sediment deposition in the navigation channel between Mississippi River Miles 104.0 and 102.5.

3. Study Reach

The study comprises a six mile stretch of the Middle Mississippi River, between Miles 106.0 and 100.0 near Chester, Illinois. Plate 1 is a location and vicinity map of the study reach. Counties located around the study reach are Randolph in Illinois and Perry in Missouri.

4. Study Reach Channel Characteristics and General Trends

Present and historic hydrographic surveys of the Mississippi River, in the HSR model study area, are shown on Plates 5-9. The plates show Range Line surveys from 2007, 2005, 1986-1987, 1982-1983, and 1939-1956.

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

River Miles	Description
105.8 – 104.5	The thalweg is located on the left descending bank (LDB) with depths between 20 and 30 feet below the Low Water Reference Plane (LWRP).
104.5 – 101.5	There is not an apparent thalweg. Depths range between 10 and 30 feet below the LWRP. Near mile 104.0 a depositional bar develops on the right descending bank (RDB). Repetitive channel dredging has occurred between mile 104.0 and 102.0
101.5 – 100.5	The thalweg crosses to the RDB with depths between 16 and 30 feet below the LWRP.
100.5 – 99.5	This is a crossing area between deep river bends. Depths range between 10 and 20 feet below the LWRP. Near mile 100.0 a bar develops on the LDB. Repetitive channel dredging occurred between mile 100.0 and 99.0.

HSR MODEL DESCRIPTION

The Water's Landing Hydraulic Sediment Response (HSR) model encompasses Mississippi River miles 106.0-100.0. Allowing for entrance and exit conditions, the actual study reach was located between Mississippi River Miles 104.5 – 101.0.

1. Scales and Bed Materials

The model employed a horizontal scale of 1 inch = 500 feet, or 1:6000, and a vertical scale of 1 inch = 45 feet, or 1:540, for an 11.1 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.

2. Appurtenances

The HSR model insert was constructed according to the 2006 high-resolution aerial photography of the study reach. The insert was then mounted in a standard HSR model flume. The riverbanks of the model were constructed from dense polystyrene foam, and modified during calibration with clay and galvanized steel mesh. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.01 inch/inch. River training structures in the model were made of galvanized steel mesh.

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to automatically control the flow of water and sediment into the model. Discharge was monitored by a magnetic flow meter interfaced with the customized computer software. The water plane was manually checked with a mechanical three-dimensional point digitizer. Resultant bed configurations were measured and recorded with a three-dimensional laser scanner.

HSR MODEL TESTS

1. Model Calibration

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

A. HSR Model Operation

In all model tests, a steady state flow was simulated in the channel. This served as the average design energy response of the river. Because of the constant variation experienced in the prototype, this steady state flow was used to theoretically analyze the ultimate expected sediment response. The flow was held steady at a constant flow rate of 2.6 Gallons per Minute (GPM) during model calibration and for all design alternative tests. An important factor during the modeling process is the establishment of an equilibrium condition of sediment transport. The high steady flow in the model simulated an average energy condition representative of the river's channel forming flow and sediment transport potential at bank full stage.

Note: There is a weir located near River Mile 103.3L that is not labeled on the plates. It is approximately 700 feet long and is angled upstream.

2. Base Test

Model calibration was achieved after favorable qualitative comparisons of the prototype surveys were made to several surveys of the model. The resultant bathymetry of this bed response served as the base test of the HSR model.
Plate 10 shows the bed configuration of the HSR model base test.

Results of the HSR model base test bathymetry and a comparison to the
1987 through 2007 prototype surveys between Mile 106.0 and Mile 100.0 indicated the following trends:

At Mile 105.5 through 104.5, both the model and the prototype surveys show the thalweg located along the LDB. The prototype's thalweg is deeper. Along the RDB a large depositional bar can be seen in both the model and prototype.

At Mile 104.5 to 102.0, the depositional bar grows from the RDB towards the LDB in both the prototype and model. The thalweg becomes shallower, but small scour holes appear around the ends of the river training structures. The scour holes are slightly more defined in the model.

Between miles 102.5 to 102.0, the transition of the thalweg from the LDB to the RDB can be seen. The crossing is deeper in the model than in the prototype.

At Mile 102.8, both the model and prototype surveys show the development of a large depositional bar along the LDB.

From Mile 102.0 to 101.5 the thalweg is located on the LDB, and is deeper in the model.

3. Design Alternative Tests

The testing process consists of installing alternative structure configurations in the model in an attempt to alter the model bathymetry and velocity distribution in a manner intended to alleviate scour and / or siltation. Evaluation of each alternative is accomplished through a qualitative comparison to the model base test bathymetry and model base test flow visualization.

Alternative 1:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.7	RDB	300 x 300	356.0
Install Chevron	104.4	RDB	300 x 300	356.0
Install Chevron	104.1	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 11)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
No major change occurred from 104.0-103.0; from 103.0-102.5 the sandbar was narrower.	The channel crossing widened, but remained relatively shallow.	A deep scour hole was shown around the trail dike at mile 103.8 LDB.

Alternative 2:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Trail Dike Extension	104.0	RDB	1350	356.0

Bathymetry Analysis (Plate 12)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
There was a slight reduction in the sand bar width.	No improvement.	No scour around new structure.

Alternative 3:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.9	LDB	150 x 150	356.0
Install Chevron	103.8	RDB	300 x 300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 13)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The chevrons moderately reduced the overall width of the sand bar from RM 104.0-103.0. From RM 103.0-102.5 the bar width slightly narrowed.	The crossing appears to have slightly widened.	The navigable channel had a more consistent line of depth.

Alternative 4:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.9	LDB	150 x 150	356.0
Install Chevron	103.8	RDB	300 x 300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Install Chevron	103.5	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 14)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The width of the upstream end of the sand bar was significantly narrower. The width of the last half mile stayed about the same.	The channel crossing was slightly deepened and slightly widened.	The proposed chevron at 103.9 LDB created a small sandbar behind it, providing a diverse habitat for wildlife.

Alternative 5:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Chevron	103.8	RDB	300 x 300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Install Dike	103.6	LDB	775	356.0
Install Chevron	103.5	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 15)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width did not change.	The channel width stayed the same, but slightly deepened.	The sand bar located around mile 102.5 on the LDB showed signs of erosion.

Alternative 6:

Type of Structure	Miles	LDB or RDB	Dimensions in Feet	Structure Top Elevation NAD 1927 (ft)
Install Dike	104.1	LDB	338	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.6	RDB	300 x 300	356.0
Install Chevron	103.4	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 16)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was significantly less from mile 104.0-103.0, but remained unchanged from mile 103.0-102.5. Throughout the stretch the navigable channel had a more consistent line of depth.	The channel width stayed the same, but deepened.	A small sand bar is shown behind the proposed dike around mile 104.0. The sand bar located around mile 102.5 on the LDB showed signs of erosion.

Alternative 7:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Extend Existing Dike	104.4	RDB	150	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike	104.0	RDB	300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike	103.5	RDB	300	356.0

Bathymetry Analysis (Plate 17)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was slightly narrower from mile 104.0-103.0; the width of the sand bar was significantly narrower from mile 103.0-102.5. The navigable channel had a more consistent line of depth.	The channel width increased in the northern part of the crossing and slightly decreased around mile 102.2. The depth of the crossing slightly increased.	Scour holes were created around existing dike 103.8L and 103.4L. The width of the sand bar along the LDB started to increase around mile 102.1.

Alternative 8:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Install Dike	104.0	LDB	300	356.0
Install Weir (angled upstream)	103.5	LDB	600	322.0
Install Chevron	103.5	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 18)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was less throughout miles 104.0-103.0. The width of the sand bar was slightly narrower from mile 103.0-102.5. The navigable channel had a more consistent line of depth.	The crossing was deeper with a slightly wider navigable channel.	Some deposition was shown behind the proposed dike at 104.0L.

Alternative 9:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Notch Existing Dike	104.7	RDB	Existing Notch width = 175' (Start notch 200' from LDB)	356.0
Install Notched Dike	104.0	LDB	775 Notch width = 175' (Start notch 375' from RDB)	356.0
Install Chevron	103.5	LDB	150 x 150	356.0

Bathymetry Analysis (Plate 19)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0 102.0	Additional Comments
The sand bar width was significantly less from mile 104.0-103.0 and the sand bar became slightly narrower from 103.0 - 102.5. The line of depth became more consistent in the navigable channel.	The depth was only slightly deeper.	A small sand bar was shown behind the proposed notched dike at 104.0L as well as the chevron at 103.55L (did not create a problem). It did create some slack water for diversity as well as push a majority of the water towards the navigation channel.

Alternative 10:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Notch Existing Dike	104.7	RDB	Existing Notch width = 175' (Start 200' from LDB)	356.0
Install Notched Dike	104.0	LDB	775 Notch width = 175' (Start 375' from RDB)	356.0
Install Chevron	103.5	RDB	150 x 150	356.0

Bathymetry Analysis (Plate 20)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was significantly decreased from mile 104.0-103.0, but the width of the sand bar slightly increased from 102.5-102.2. The navigable channel seemed to be broken up into three distinct areas.	The crossing width slightly decreased. The depth slightly increased around mile 102.5, but stayed shallow around mile 102.0.	A small sand bar (shallow area) formed behind the proposed notched dike at 104.0L. It did create some slack water for diversity.

Alternative 11:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Notch Existing Dike	103.1	LDB	Existing Notch width = 175' (Start notch 1,175' from RDB)	356.0

Bathymetry Analysis (Plate 21)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was only slightly less from mile 104.0-103.5. From mile 103.0-102.5, the sand bar width slightly wider.	The crossing narrowed, and it was only slightly deeper.	The notch in the existing dike 103.1L allowed too much flow in the side channel. It appears that allowing too much flow would erode stable banks.

Alternative 12:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.5	RDB	300 x 300	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Install Chevron	103.5	RDB	300 x 300	356.0
Install Chevron	103.4	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 22)

Effect on RDB Sand Ba Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-103.7, but remained the same from mile 103.7-102.7. The sand bar width was narrower from 102.7-102.5.	The crossing widened but it became shallower.	The navigable channel had a more consistent line of depth from 103.8-103.2. A scour hole was shown around dike 103.6L.

Alternative 13:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Extend Existing Dike	104.4	RDB	150	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Install Chevron	103.5	RDB	300 x 300	356.0
Install Weir (angled upstream)	103.5	LDB	600	322.0

Bathymetry Analysis (Plate 23)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was slightly less from mile 104.0-103.0, but the width did not change from mile 103.0-102.5. The navigable channel had a more consistent line of depth.	The crossing slightly widened and deepened.	A small scour hole is seen around the dike at mile 103.4L.

Alternative 14:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Install Chevron	103.9	LDB	150 x 150	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Install Chevron	103.1	RDB	300 x 300	356.0

Bathymetry Analysis (Plate 24)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The line of depth became more consistent in the navigable channel.	The crossing widened and deepened.	The depositional area above the downstream angled dike 103.1L was washed away (the area deepened).

Alternative 15:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Extend Existing Dike	104.4	RDB	Extend Existing 150	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200’ (Start notch 1,050’ from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200’ (Start notch 825’ from RDB)	356.0

Bathymetry Analysis (Plate 25)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The channel width increased and the depth of the crossing increased.	Small scour holes were created around existing dike 103.8L and 103.6L. There was a small channel formed by the proposed notches in the RDB depositional bar, allowing flow to reach the area near chevron 103.5R.

<u>Alternative 16:</u>

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend the RDB leg 375’ Extend Existing 300 at 130° angle Notch width = 200’ (Start notch 1,050’ from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Notch Existing Dike	103.5	RDB	Notch width = 200’ (Start notch 825’ from RDB)	356.0

Bathymetry Analysis (Plate 26)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was slightly narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The channel width increased and the depth of the crossing increased.	Small scour holes were created around existing dike 103.8L and 103.6L. There was a small channel formed by the proposed notches in the RDB depositional bar, allowing flow to reach the area near chevron 103.5R. (The secondary channel was not as defined as in alternative 15).

<u>Alternative 17:</u>

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Remove Existing Dike	104.4	RDB	Remove	-
Install Chevron	104.4	RDB	300 x 300	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200' (Start notch 1,050' from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200' (Start notch 825' from RDB)	356.0

Bathymetry Analysis (Plate 27)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The channel width increased and the depth of the crossing increased.	Small scour holes were created around existing dike 103.8L and 103.6L. There was a small channel formed by the proposed notches in the RDB depositional bar, allowing flow to reach the area near chevron 103.5R. However, the flow does not appear to have increased when compared with Alternative 15.

Alternative 18:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Remove Existing Dike	104.4	RDB	Remove	-
Install Chevron	104.4	RDB	300 x 300	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200' (Start notch 1,050' from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200' (Start notch 825' from RDB)	356.0
Transfer Existing Chevron	103.5	RDB	Transfer Existing Chevron 300' away from RDB	356.0

Bathymetry Analysis (Plate 28)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The depth increased and the channel width of the crossing increased.	The navigation channel near RM 104.0 did not seem to improve (in depth). Small scour holes were created around existing dike 103.8L, 103.6L, and 103.5L. There was a small channel formed by the proposed notches in the RDB depositional bar, allowing flow to reach the area near chevron 103.5R. The flow from the small side channel seemed to reach Chevron 103.5R better than in Alternatives 15 or 16.

Alternative 19:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Extend Existing Dike	104.4	RDB	Extend Existing 150	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200' (Start notch 1,050' from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200' (Start notch 825' from RDB)	356.0
Transfer Existing Chevron	103.5	RDB	Transfer Existing Chevron 300' away from RDB	356.0

Bathymetry Analysis (Plate 29)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The depth and the width of the channel increased.	Small scour holes were created around existing dike 103.8L and 103.6L. There was a small channel formed, allowing flow to reach chevron 103.5R. The relocation of the existing chevron allows more flow to reach it, increasing environmental diversity.

Alternative 20:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Remove Existing Dike	104.4	RDB	Remove	-
Install Chevron	104.4	RDB	300 x 300 (1,200 ft away from LDB)	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200’ (Start notch 1,050’ from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200’ (Start notch 825’ from RDB)	356.0
Transfer Existing Chevron	103.5	RDB	Transfer Existing Chevron 300’ away from RDB	356.0

Bathymetry Analysis (Plate 29)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The depth and the width of the channel increased.	A small scour hole was created around existing dike 103.8L. By placing chevron 104.4R closer to the navigation channel, more flow was diverted towards the notched dikes. There was a small channel formed, allowing flow to reach chevron 103.5R. The relocation of the existing chevron allows more flow to reach it, increasing environmental diversity.

Alternative 21:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Remove Existing Dike	104.4	RDB	Remove	-
Install Chevron	104.4	RDB	300 x 300 (1,200 ft away from LDB)	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200' (Start notch 1,050' from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200' (Start notch 825' from RDB)	356.0
Transfer Existing Chevron	103.5	RDB	Transfer Existing Chevron 450' away from RDB	356.0

Bathymetry Analysis (Plate 29)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The width of the channel and the depth increased.	By placing chevron 104.4R closer to the navigation channel, more flow was diverted towards the notched dikes. There was a small channel formed, allowing flow to reach chevron 103.5R. The relocation of the existing chevron closer to the navigation channel allows more.

Alternative 22:

Type of Structure	Miles	LDB or RDB	Dimensions in Ft	Structure Top Elevation NAD 1927 (ft)
Remove Existing Dike	104.4	RDB	Remove	-
Install Chevron	104.4	RDB	300 x 300 (1,200 ft away from LDB)	356.0
Install Chevron	104.0	RDB	300 x 300	356.0
Extend Existing Dike and Notch	104.0	RDB	Extend Existing 300 Notch width = 200’ (Start notch 1,050’ from RDB)	356.0
Install Chevron	103.7	RDB	300 x 300	356.0
Extend Existing Dike and Notch	103.5	RDB	Extend Existing 300 Notch width = 200’ (Start notch 825’ from RDB)	356.0

Bathymetry Analysis (Plate 29)

Effect on RDB Sand Bar Miles 104.0-102.5	Effect on Channel Crossing Mile 103.0-102.0	Additional Comments
The sand bar width was narrower from mile 104.0-102.5. The navigable channel had a more consistent line of depth.	The width of the channel and the depth increased.	By placing chevron 104.4R closer to the navigation channel, more flow was diverted towards the notched dikes. There was a small channel formed by the proposed notches in the RDB depositional bar, allowing flow to reach chevron 103.5R. The relocation of the existing chevron closer to the navigation channel allows more.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Test	Reduce RDB Sand Bar (Miles 104.0-102.5)	Positive Impact/ Deepen the Channel Crossing (Miles 103.0-102.0)	Negative Impact on LDB Sand Bar (Miles 102.5-101.0)
Alternative 1			
Alternative 2	X		
Alternative 3	X		
Alternative 4	X	X	
Alternative 5		X	
Alternative 6	X	X	X
Alternative 7	X	X	
Alternative 8	X	X	
Alternative 9	X		X
Alternative 10	X		
Alternative 11			
Alternative 12			
Alternative 13	X	X	
Alternative 14	X	X	X
Alternative 15	X	X	
Alternative 16	X	X	
Alternative 17	X	X	
Alternative 18	X	X	
Alternative 19	X	X	
Alternative 20	X	X	
Alternative 21	X	X	
Alternative 22	**X**	**X**	

In order to determine the best alternative, certain criteria were used to evaluate each possibility. The first condition was that the alternative had to sufficiently stop the encroachment of the sand bar into the navigation channel from mile 104.0-102.5. The second condition was that the navigable channel in the crossing from mile 103.0-102.0 was enhanced in both depth and width. Lastly, the sand bar along the LDB

LDB was to remain unaltered or only slightly modified; this condition took into account any negative impacts the alternative may have had on the sand bar from mile 102.5-101.0. An alternative was considered successful if it met all the conditions and continued to supply sufficient flow in the area around the chevron located at 103.5R, while creating sufficient environmental diversity around the RDB sand bar. Although some alternatives did meet the criterion and were considered successful, they were not recommended because they would involve structures infringing too far upon the navigation channel, there was inadequate flow to the area surrounding chevron 103.5R, or sufficient depth for construction of underwater structures was not available.

2. Recommendations

Alternative 22 is recommended due to its ability to improve the environmental diversity of the reach, reduce the RDB sand bar from mile 104.0-102.5, enhance the crossing conditions from mile 103.0-102.0, and deepen the crossing while maintaining ample flow near chevron 103.5R. This alternative should alleviate the dredging problem between miles 104.0-102.0.

The recommended design includes the following:

- Remove existing Dike at 104.4R to island (approximately 705 ft)
- Construct a 300 ft x 300 ft Chevron to +18 ft LWRP at mile 104.4R
- Construct a 300 ft x 300 ft Chevron to +18 ft LWRP at mile 104.0R
- Extend Dike 104.0R 300 ft and then create a notch 200 ft wide, 10 ft deep, and 1,050 ft from the RDB to the edge of notch (1,150 ft from RDB on center)
- Construct a 300 ft x 300 ft Chevron to +18 ft LWRP at mile 103.7R
- Extend Dike 103.5R 300 ft and then create a notch 200 ft wide, 10 ft deep, and 825 ft from the RDB to the edge of notch (925 ft from RDB on center)

Additional considerations to the above model design are revetment behind dikes 103.2L and 102.2L where there is substantial erosion as well as revetment of the caving RDB from RM 102.1-101.9. Further considerations include revetment of the head of Rockwood Chute Island, of the LDB in Rockwood Chute from mile 102.3 to Dike 101.1L, and of the RDB in Rockwood Chute from Dike 101.8L extending to Dike 101.1L. (There has been considerable erosion to these banks, as seen in the field photographs on Plates 3 and 4.)

3. Interpretation of Model Test Results

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

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

FOR MORE INFORMATION

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Fax: (314) 263-4166

E-mail: Ashley.N.Cox@mvs.usace.army.mil
Robert.D.Davinroy@mvs.usace.army.mil

Or you can visit us on the World Wide Web at:

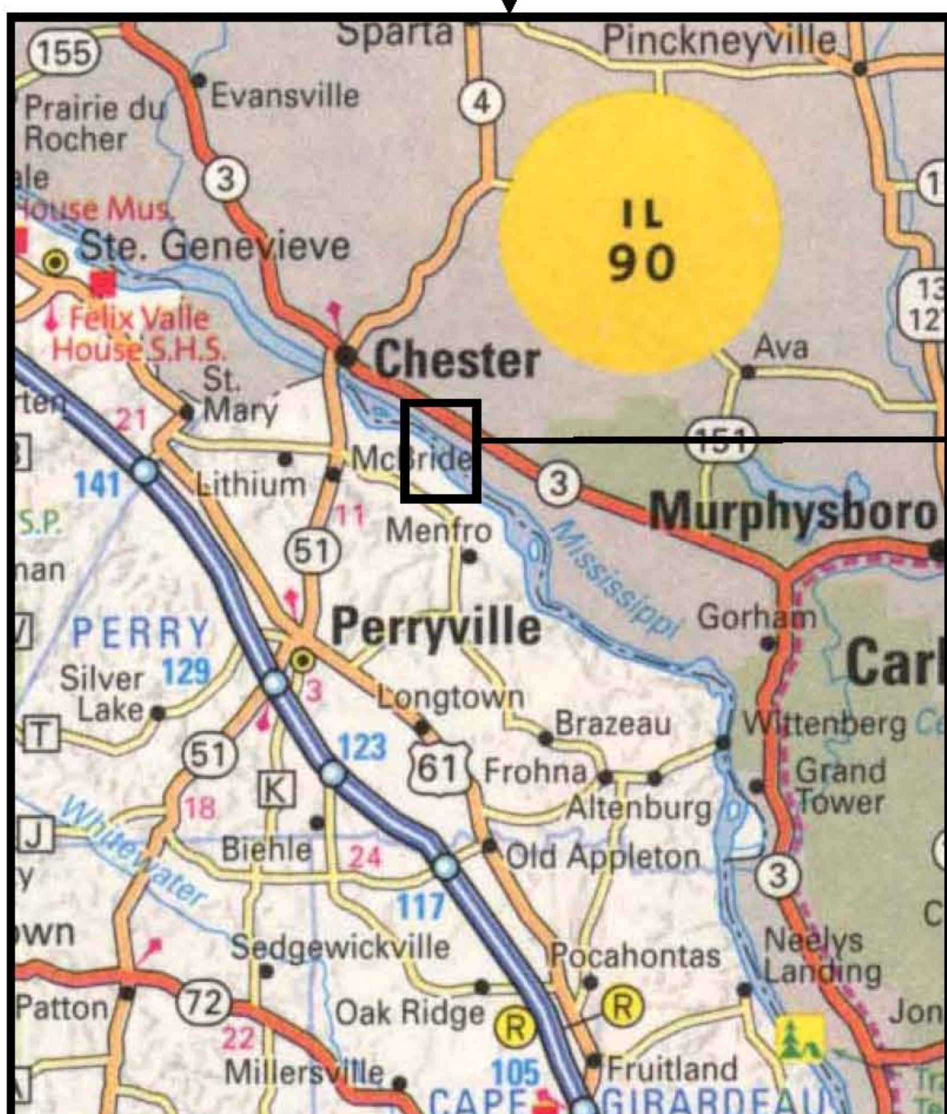
http://www.mvs.usace.army.mil/eng-con/expertise/arec/welcome_page_2.html

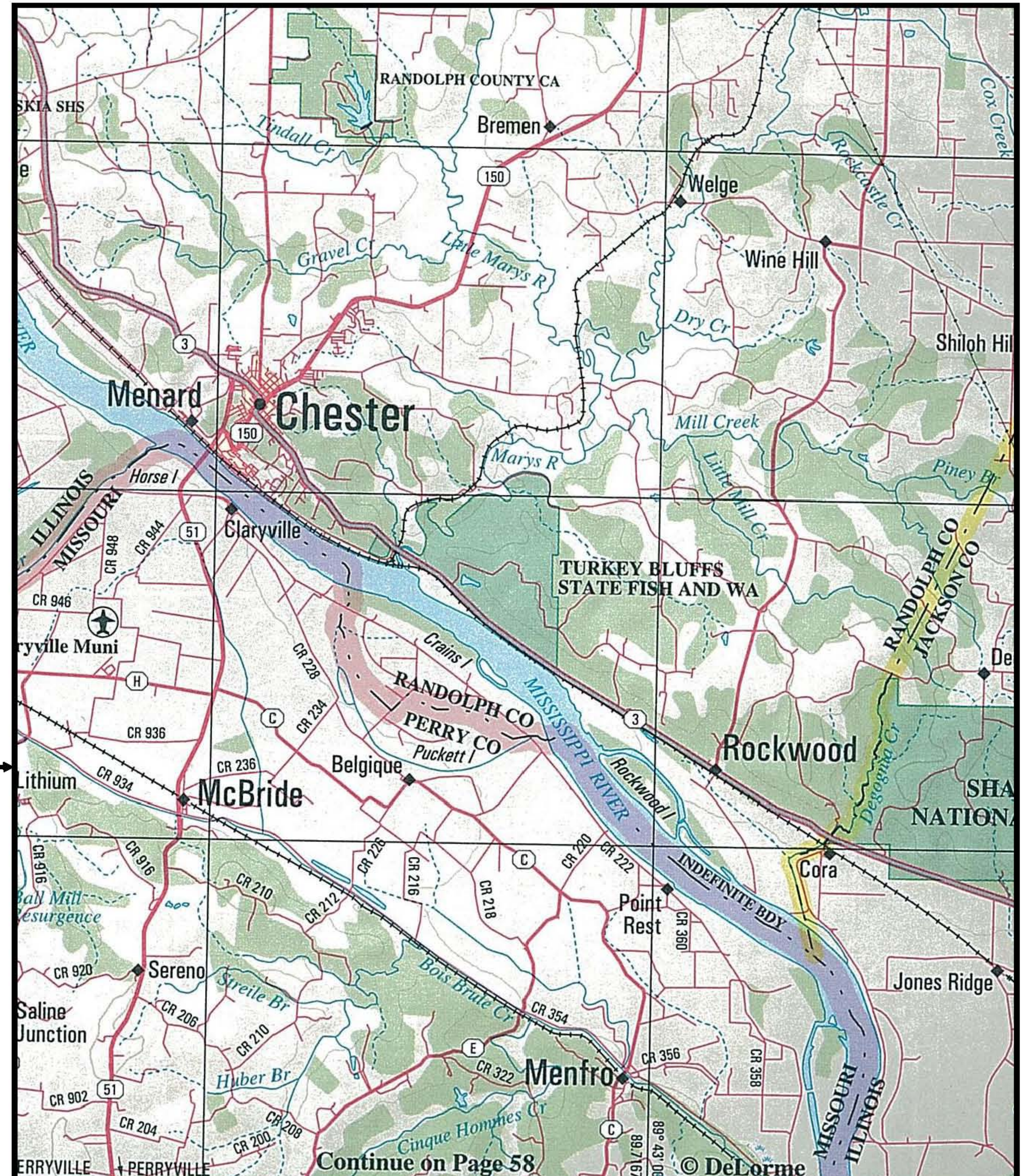
APPENDIX OF PLATES

1. Location and Vicinity Map of the Study Reach
2. Oblique Aerial Photographs
3. Field Photographs
4. Field Photographs
5. 1939-1956 Hydrographic Survey
6. 1982-83 Hydrographic Survey
7. 1986-87 Hydrographic Survey
8. 2005 Hydrographic Survey
9. 2007 Hydrographic Survey
10. Model Base Test – 1:27,000
11. Alternative 1 – 1: 27,000
12. Alternative 2 – 1:27,000
13. Alternative 3 – 1:27,000
14. Alternative 4 – 1:27,000
15. Alternative 5 – 1:27,000
16. Alternative 6 – 1:27,000
17. Alternative 7 – 1:27,000
18. Alternative 8 – 1:27,000
19. Alternative 9 – 1:27,000
20. Alternative 10 – 1:27,000
21. Alternative 11 – 1:27,000
22. Alternative 12 – 1:27,000
23. Alternative 13 – 1:27,000
24. Alternative 14 – 1:27,000
25. Alternative 15 – 1:27,000
26. Alternative 16 – 1:27,000
27. Alternative 17 – 1:27,000
28. Alternative 18 – 1:27,000
29. Alternative 19 – 1:27,000
30. Alternative 20 – 1:27,000

31. Alternative 21 – 1:27,000

32. Alternative 22 – 1:27,000





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SUBMITTED: A COX		APPROVED: R DAVINROY, P.E.
FILE NAME: .....WATERSLANDING/PLATES		PLOT DATE: 11/10/2008

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MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model - River Miles 106.0 – 100.0

LOCATION AND VICINITY MAP – USGS QUAD SHEET

PLATE NUMBER

1

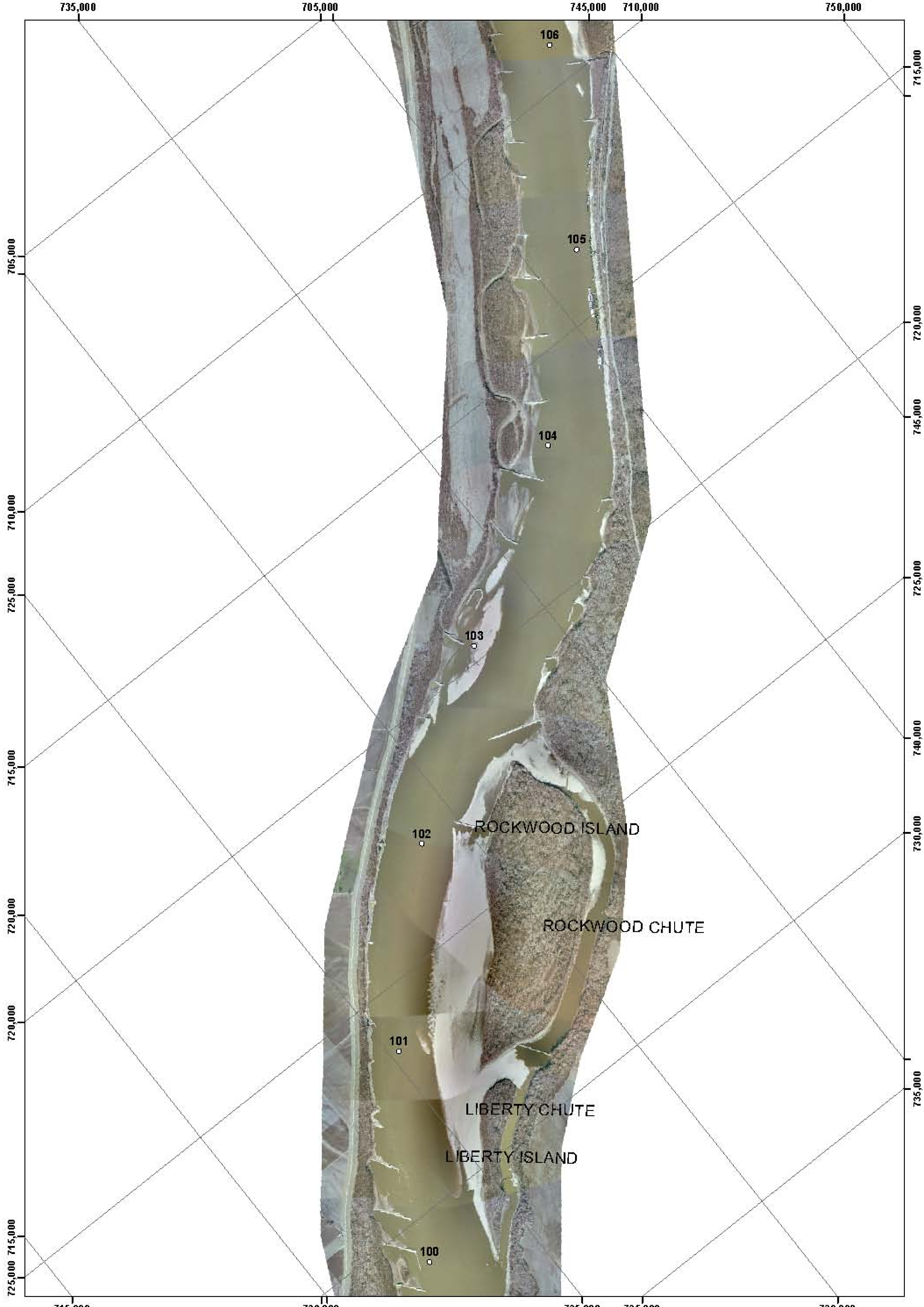

PLATE NUMBER	2

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	A. COX		2006
	A. COX	J. BROWN, P.E.	E. BRAUER
MISSISSIPPI RIVER BASIN Waters Landing HSR Model -- River Miles 106.0-100.0	A. COX	R. DAVINROY, P.E.	
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RDB of Rockwood Chute (vegetation)

Minor erosion of RDB of Rockwood Chute (approximately RM 101.8-101.1)

Erosion of LDB of Rockwood Chute (approximately RM 102.3-101.1)

More erosion of LDB of Rockwood Chute (approximately RM 102.3-101.1)

NOTE:
Chester, Illinois gage (RM 109.9): Stage = 28.68 ft / + 29.26 ft LWRP
Cape Girardeau, Missouri gage (RM 52.1): Stage = 33.09 ft / + 27.81 ft LWRP

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SURVEY DATE:
DRAWN BY: A COX
REVIEWED BY: J BROWN, P.E.
CHECKED BY: E BRAUER
SUBMITTED: A COX
APPROVED: R DAVINROY, P.E.
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PLOT DATE: 11/10/2008

WATERS LANDING
Date Photographed: May 29, 2008

PLATE NUMBER
3

North bank of Rockwood Chute Island where significant erosion has occurred

North Bank of Rockwood Chute Island

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CHECKED BY: E BRAUER

APPROVED: R DAVINROY, P.E.

PLOT DATE: 11/10/2008

DESIGNED BY: A COX

REVIEWED BY: J BROWN, P.E.

DRAWN BY: A COX

SUBMITTED: A COX

FILE NAME: ....WATERSLANDING/PLATES

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WATERS LANDING
Date Photographed: May 29, 2008

PLATE NUMBER
4

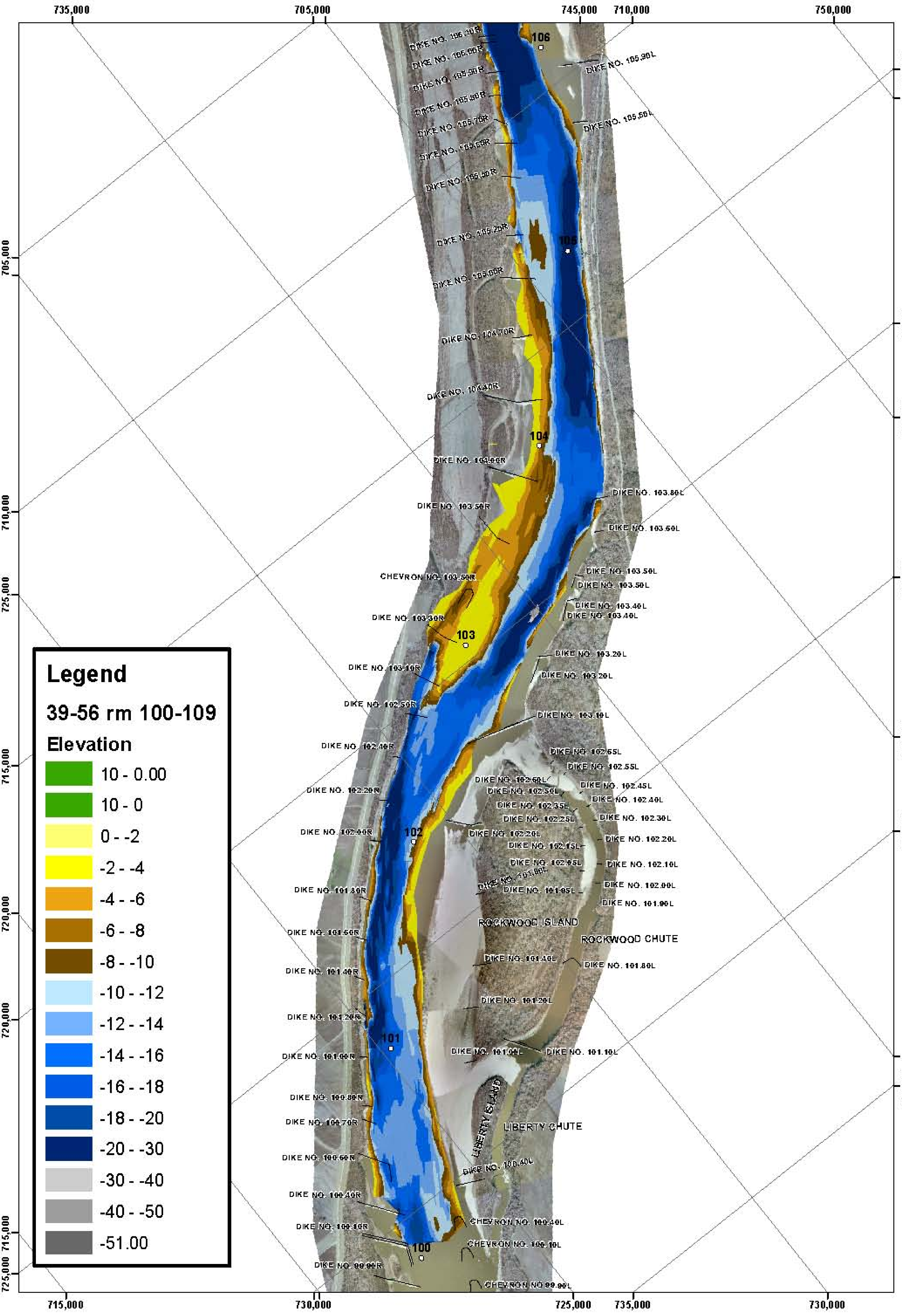

PLATE NUMBER 5

0 250 1,000 2,000 Feet

1939-1956 Survey

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	A COX	1939-1956
	A COX / J. BROWN, P.E.	E. BRAUER
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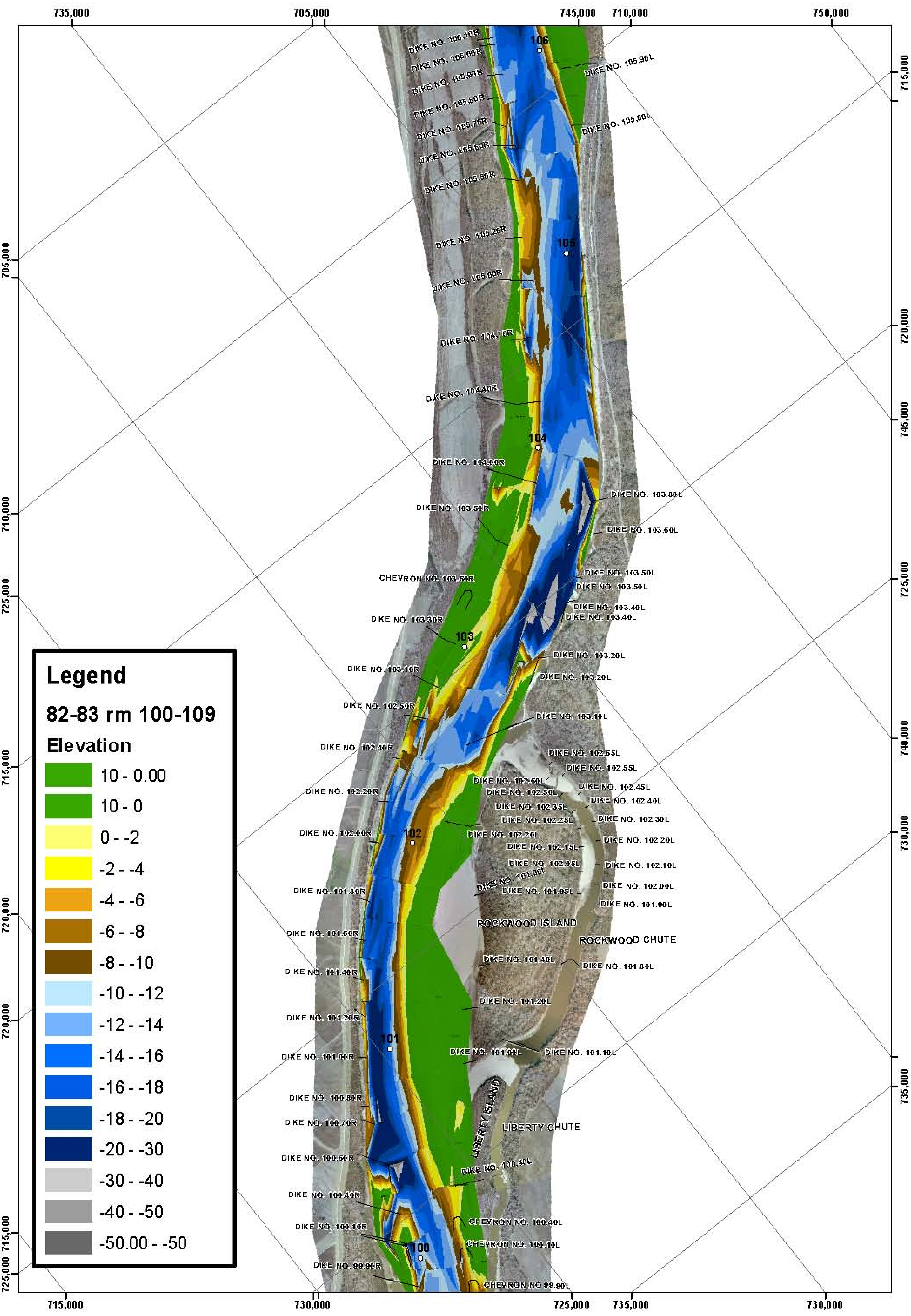

PLATE NUMBER 6

1982-1983 Survey
2006 AERIAL PHOTOGRAPH

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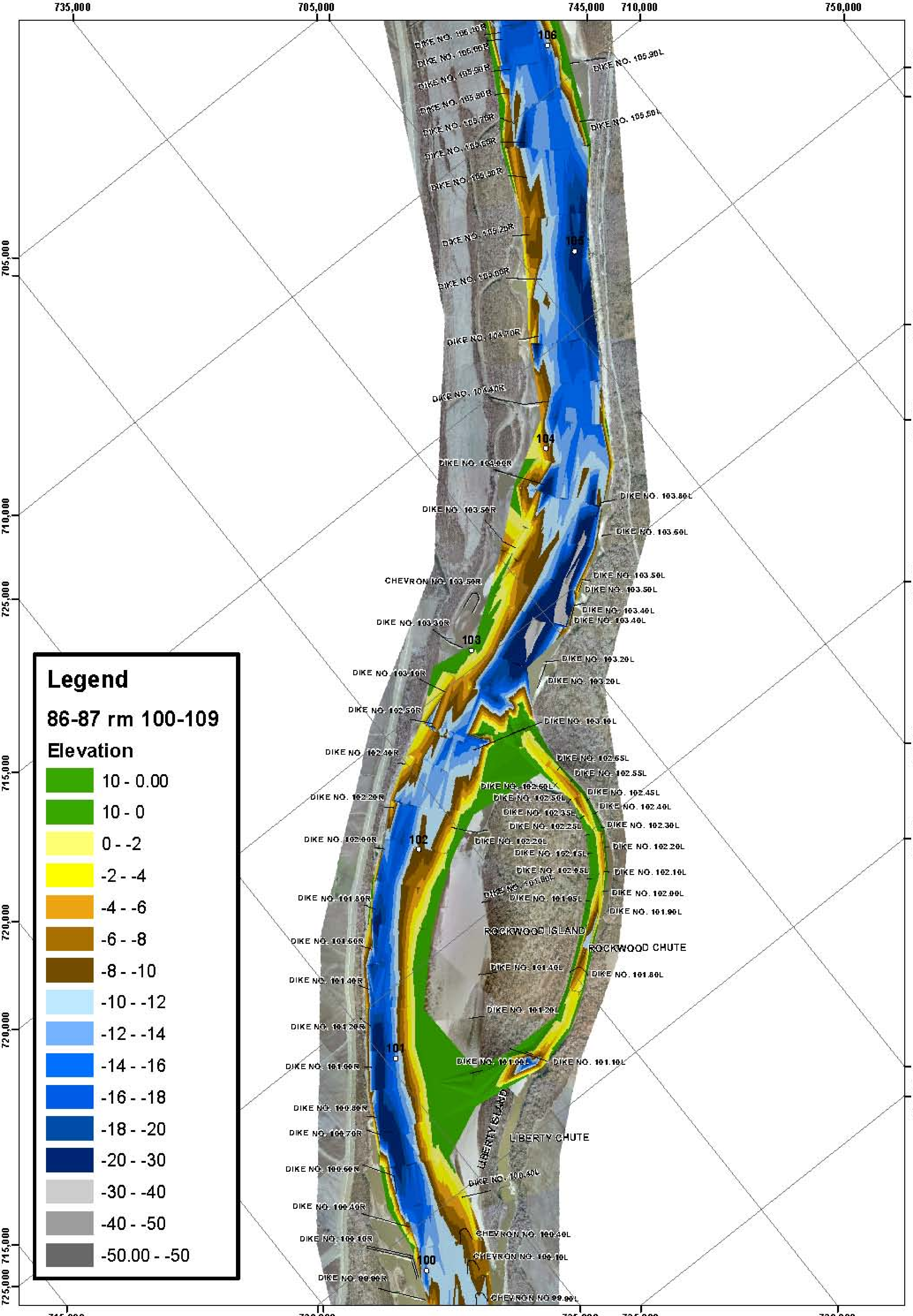

PLATE NUMBER
7

1986-1987 Survey

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST LOUIS, MISSOURI	A COX	1986-1987
	A COX / J. BROWN, P.E.	E. BRAUER
MISSISSIPPI RIVER BASIN Waters Landing HSR Model -- River Miles 106.0-100.0	A. COX	R DAVINROY, P.E.
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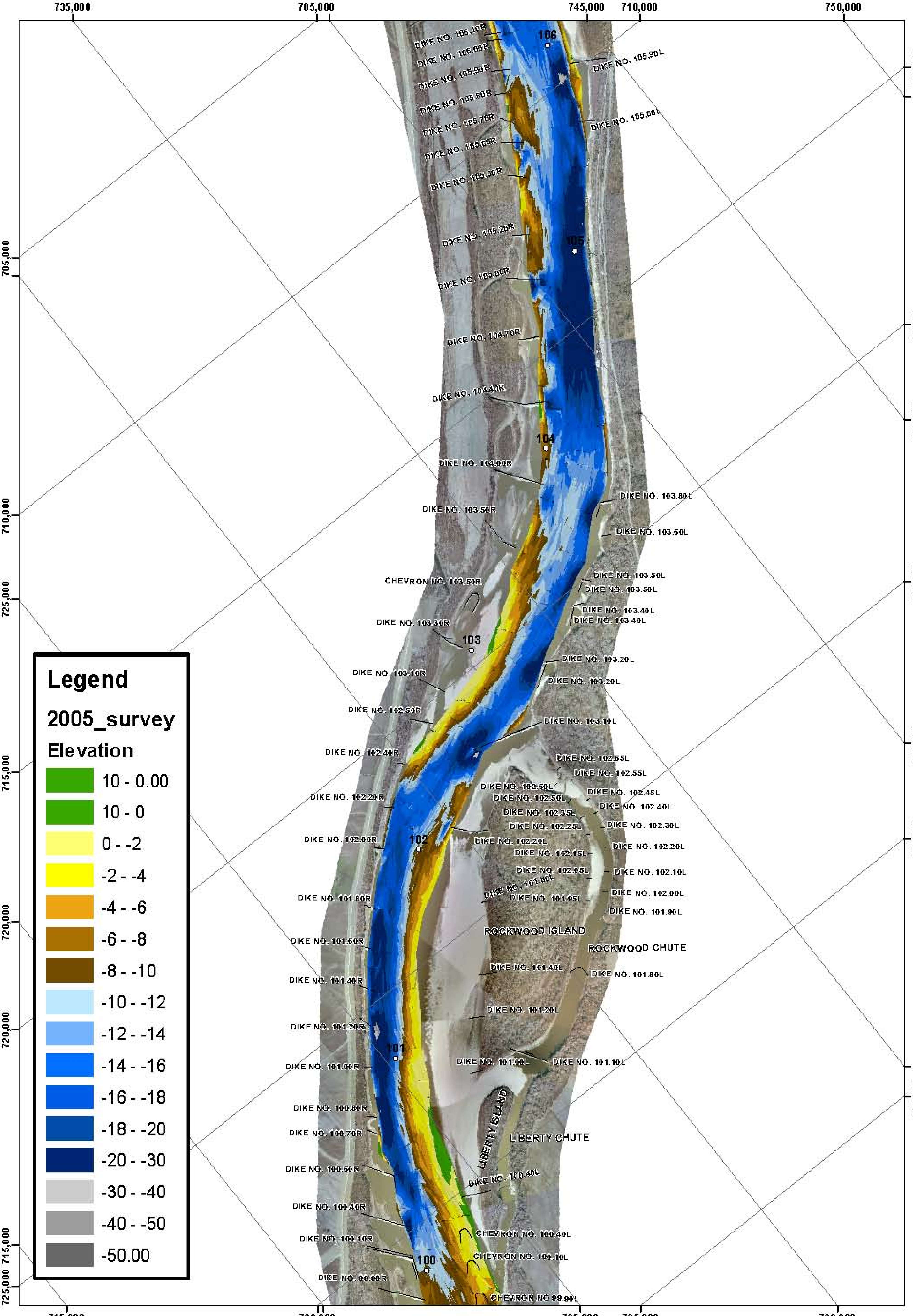

PLATE NUMBER 8

2005 Survey

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN

Waters Landing

HSR Model -- River Miles 106.0-100.0

A COX	2005
A COX	J. BROWN, P.E. / E. BRAUER
A COX	R DAVINROY, P.E.
...\WATERS LANDING/PLATES	11/10/2006

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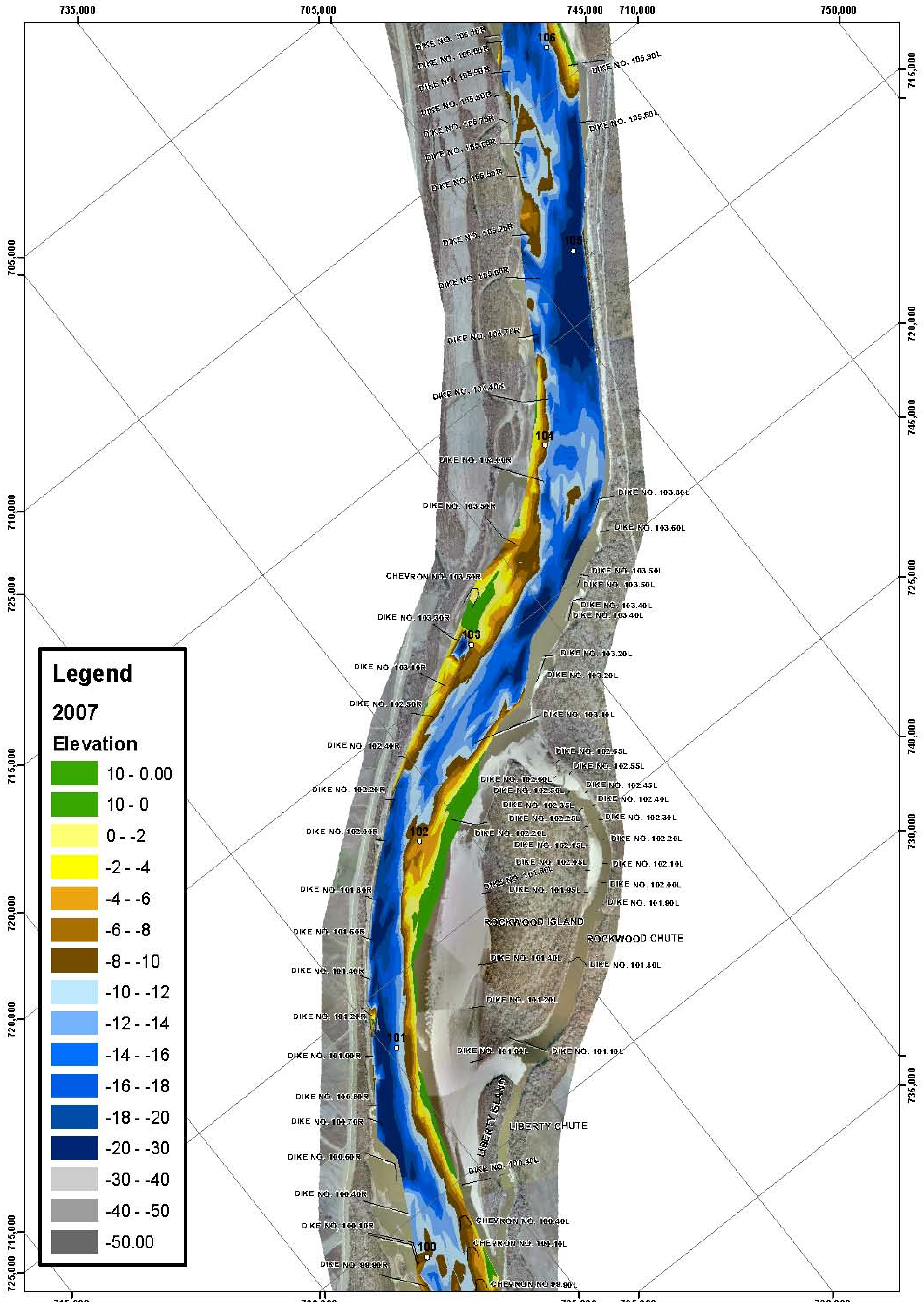

PLATE NUMBER 9

2007 Survey

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI	A COX	2007
	A COX / J. BROWN, P.E.	E. BRAUER
MISSISSIPPI RIVER BASIN Waters Landing HSR Model -- River Miles 106.0-100.0	A. COX	R DAVINROY, P.E.
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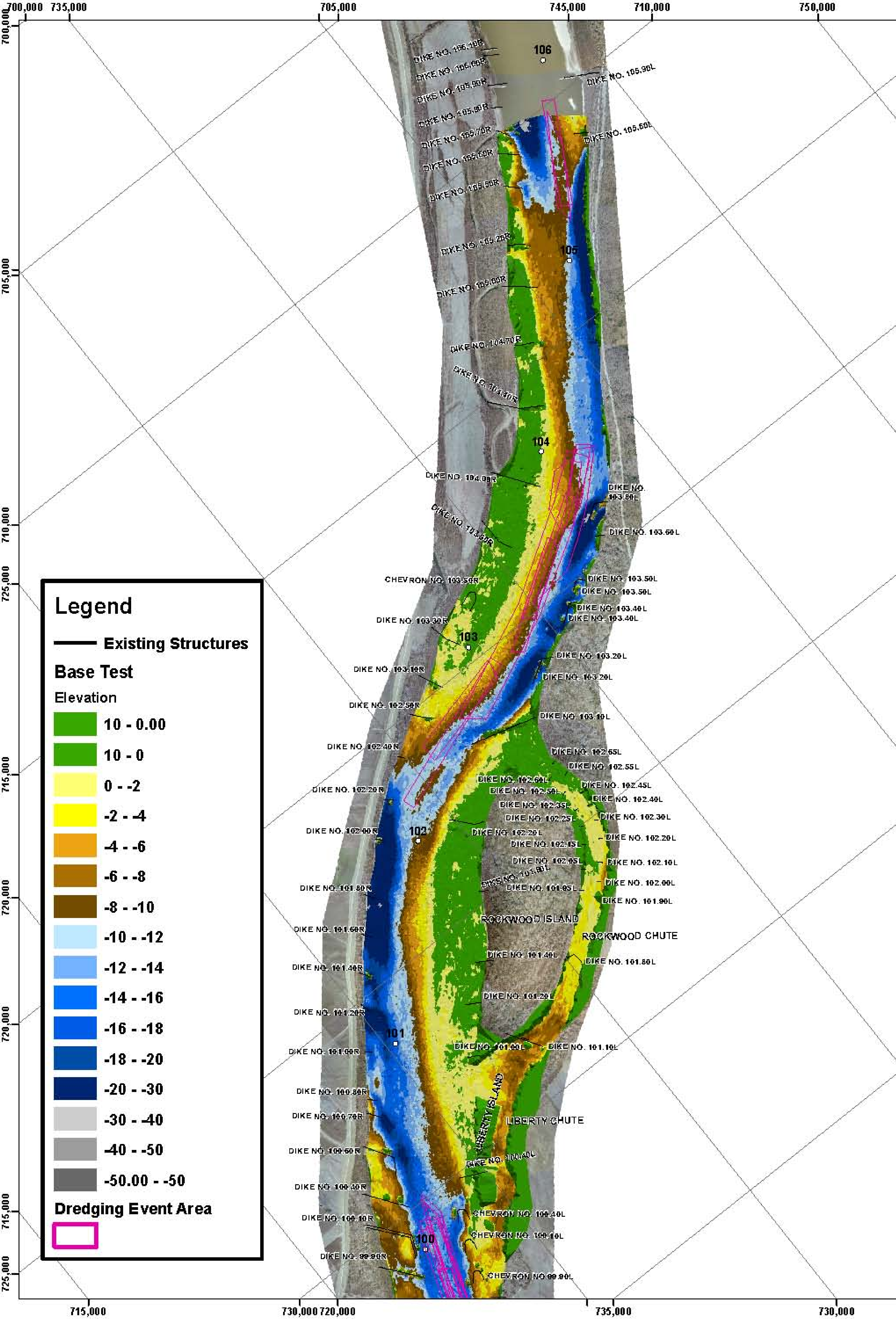

PLATE NUMBER 10

Base Test
2006 AERIAL PHOTOGRAPH

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Waters Landing
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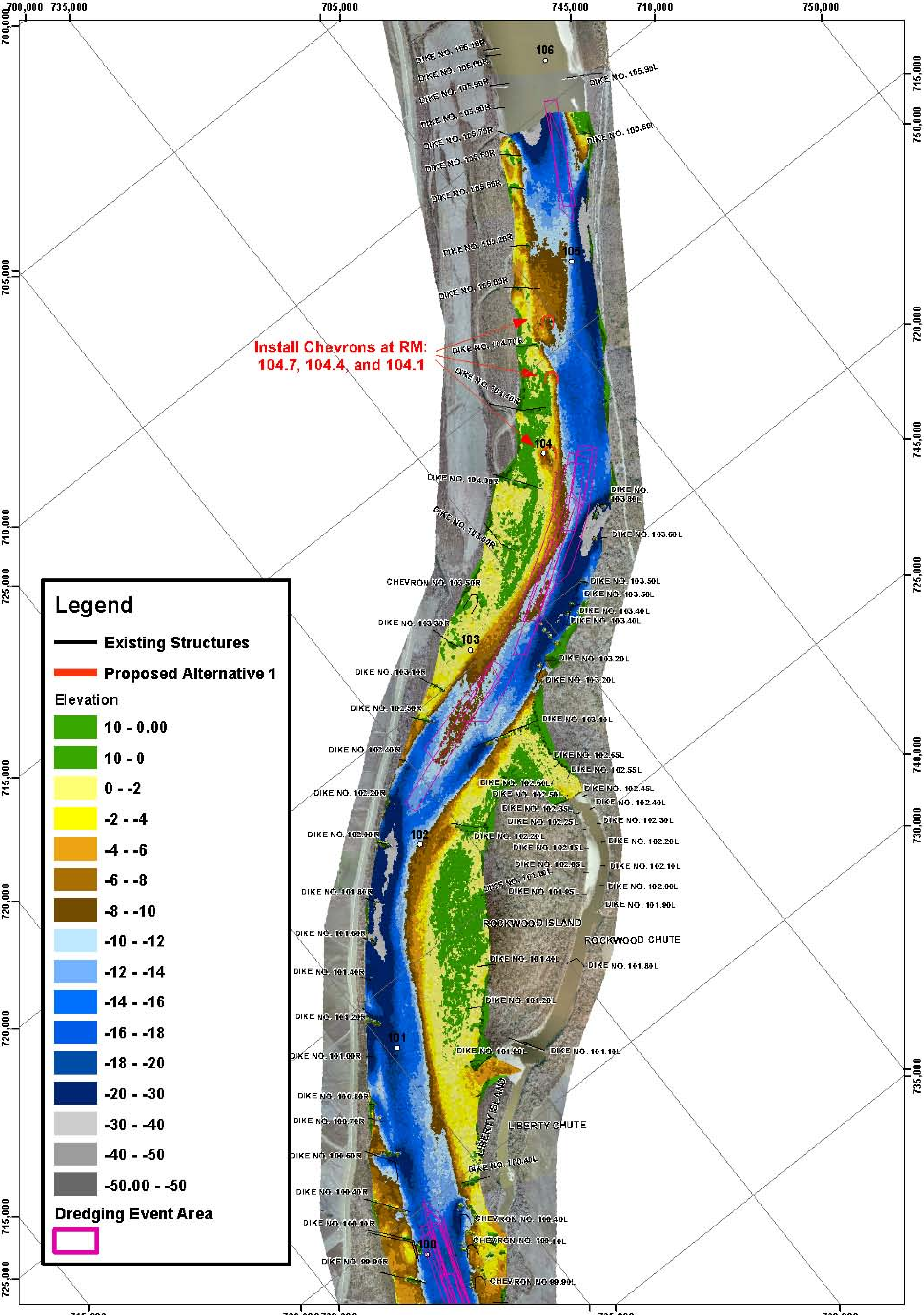

PLATE NUMBER 11

Alternative 1

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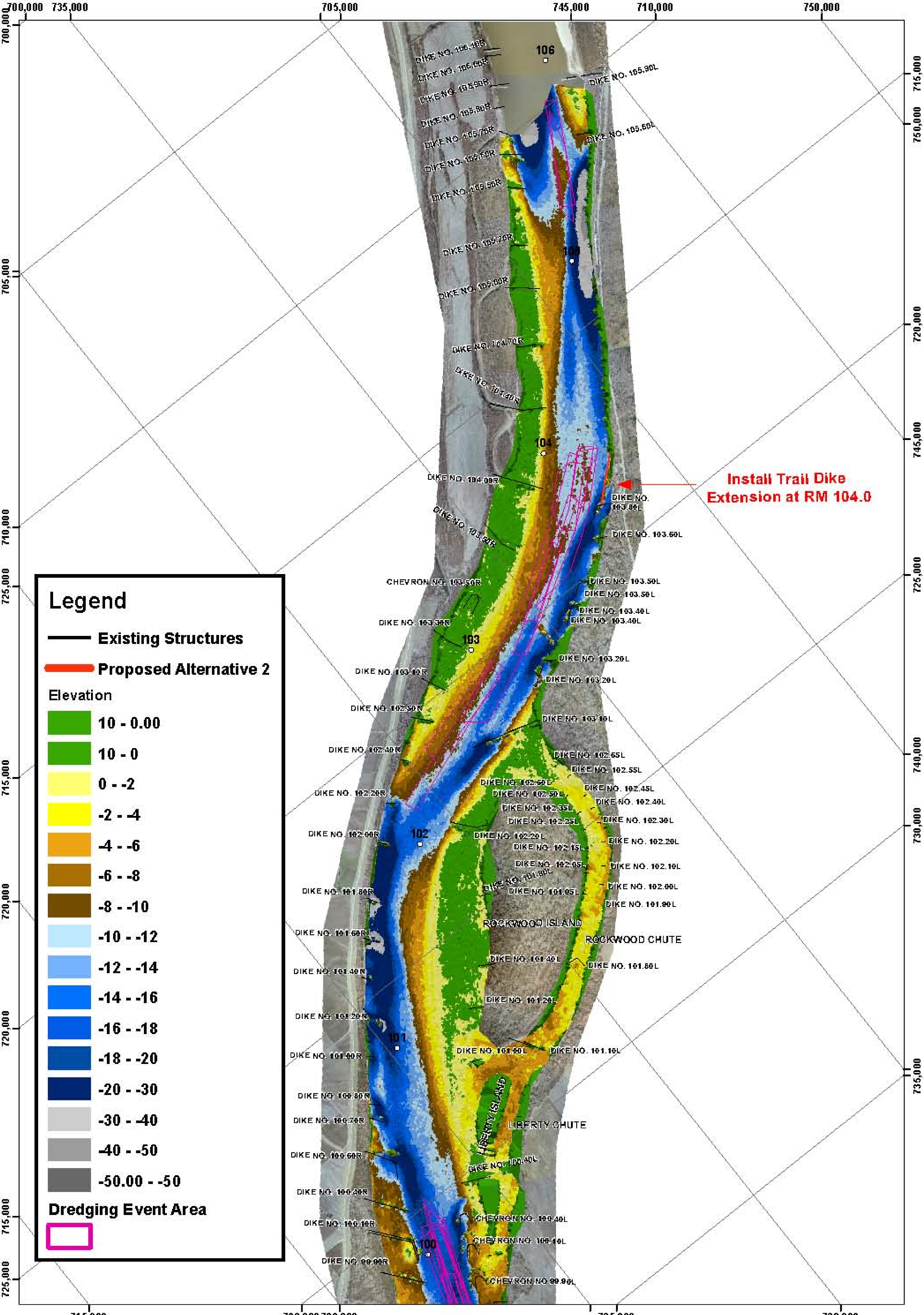

PLATE NUMBER 12

0 250 1,000 2,000 Feet

Alternative 2

2006 AERIAL PHOTOGRAPH

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HSR Model -- River Miles 106.0-100.0

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A. COX	R. DAVINROY, P.E.	
...WATERS LANDING/PLATES	11/10/2008	

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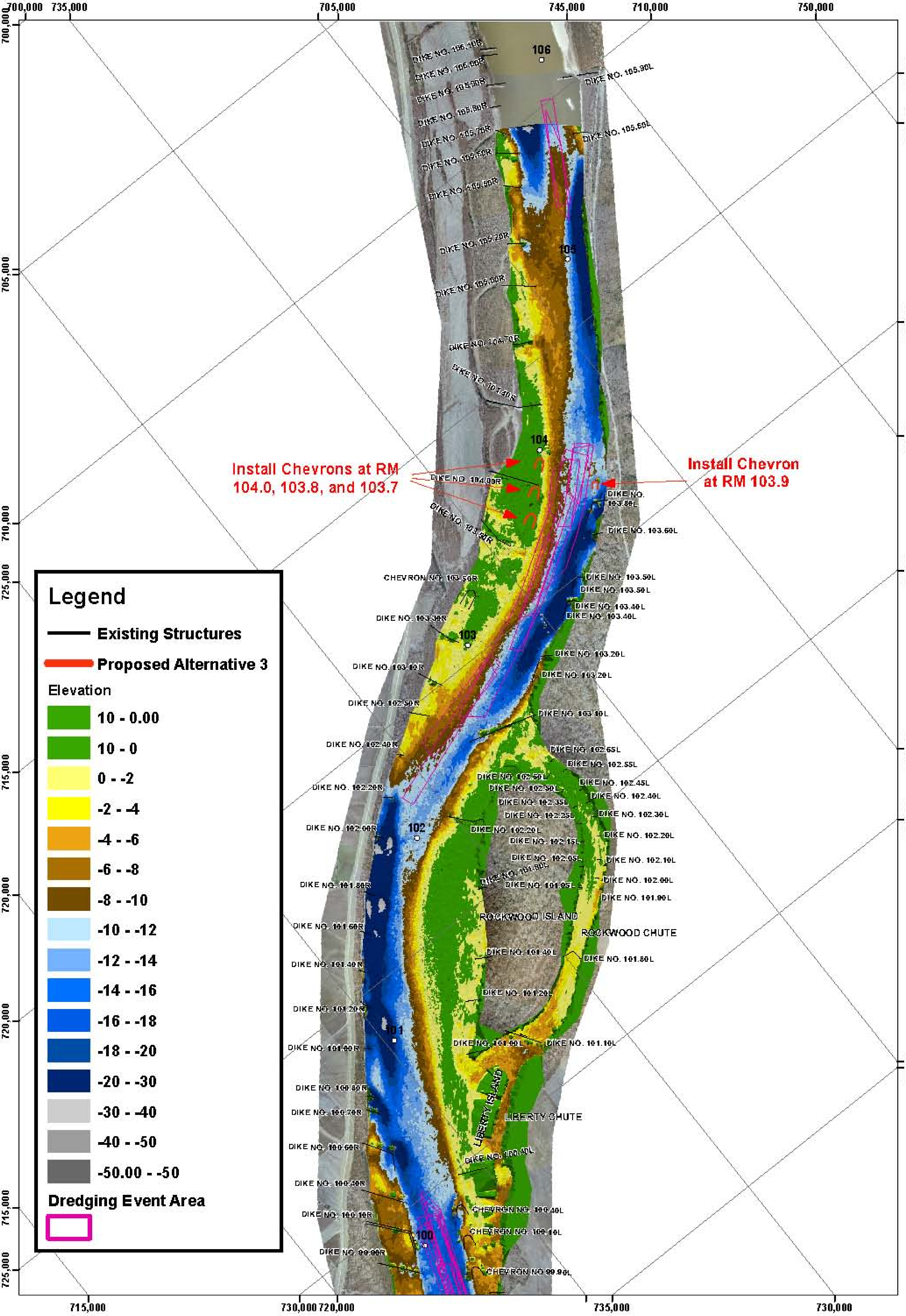

PLATE NUMBER 13

Alternative 3

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A COX | R DAVINROY, P.E.

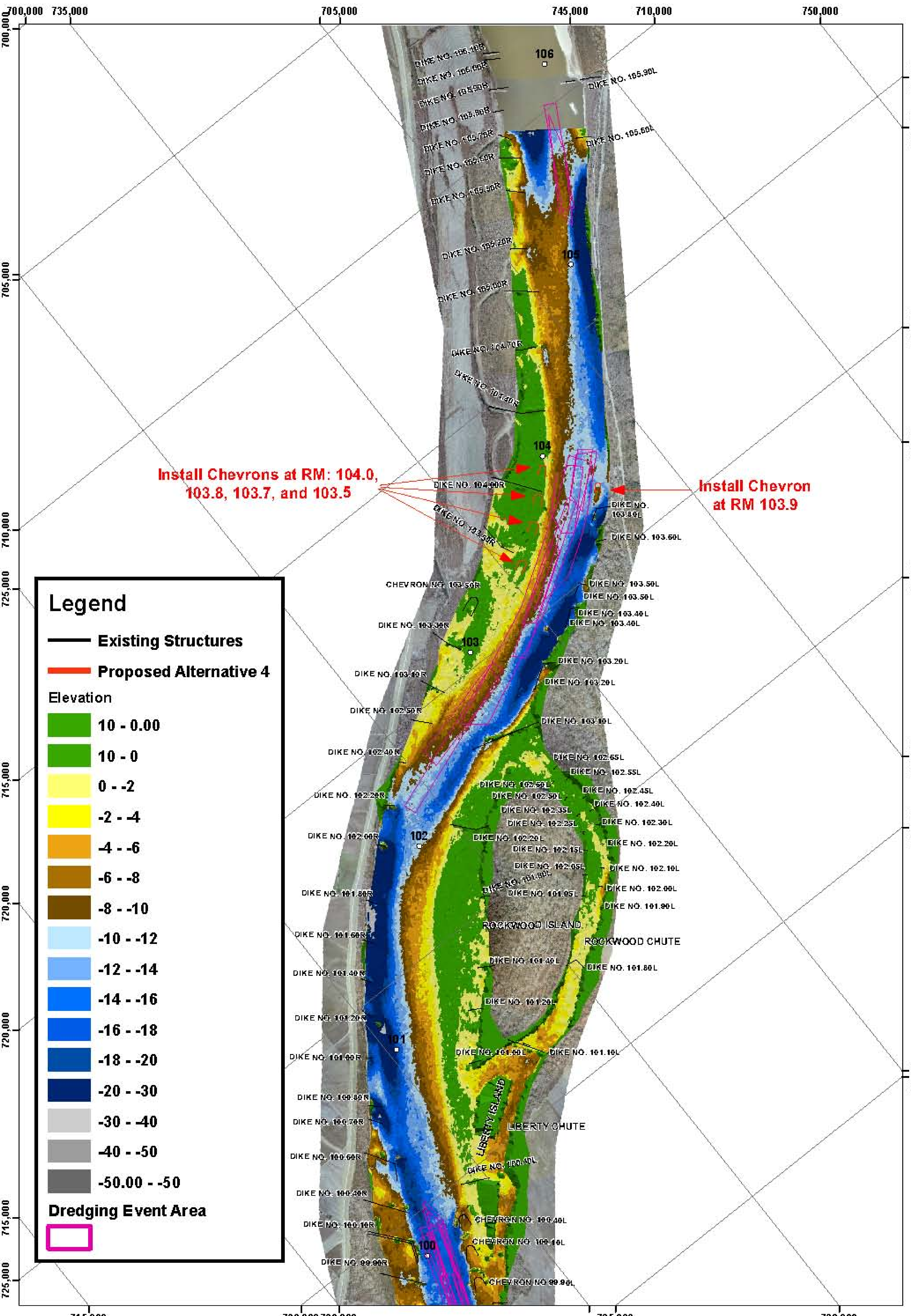

PLATE NUMBER 14

Alternative 4

2006 AERIAL PHOTOGRAPH

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Waters Landing
HSR Model -- River Miles 106.0-100.0

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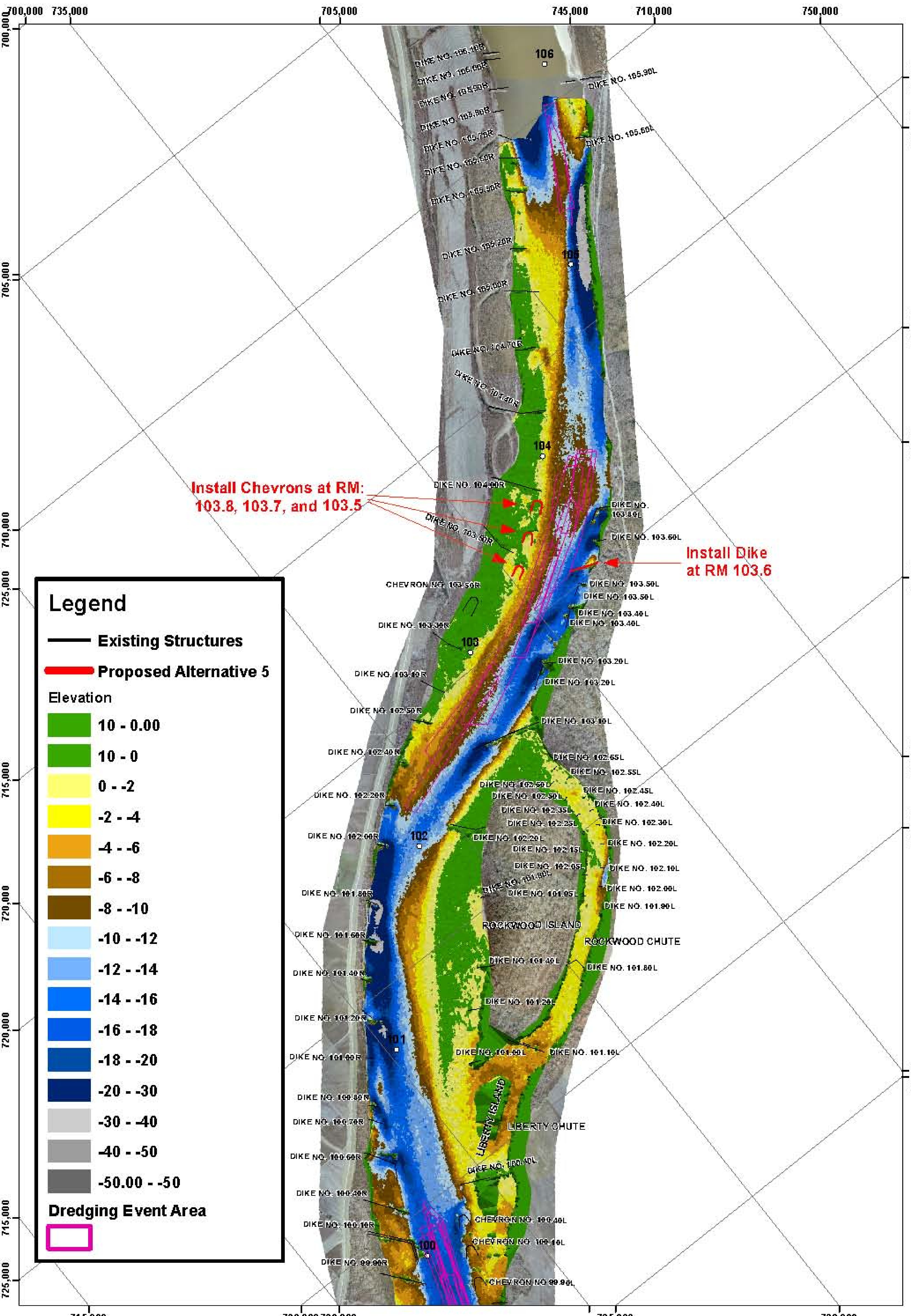

PLATE NUMBER 15

Alternative 5
2006 AERIAL PHOTOGRAPH

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MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX | 09/11/2008 Scan
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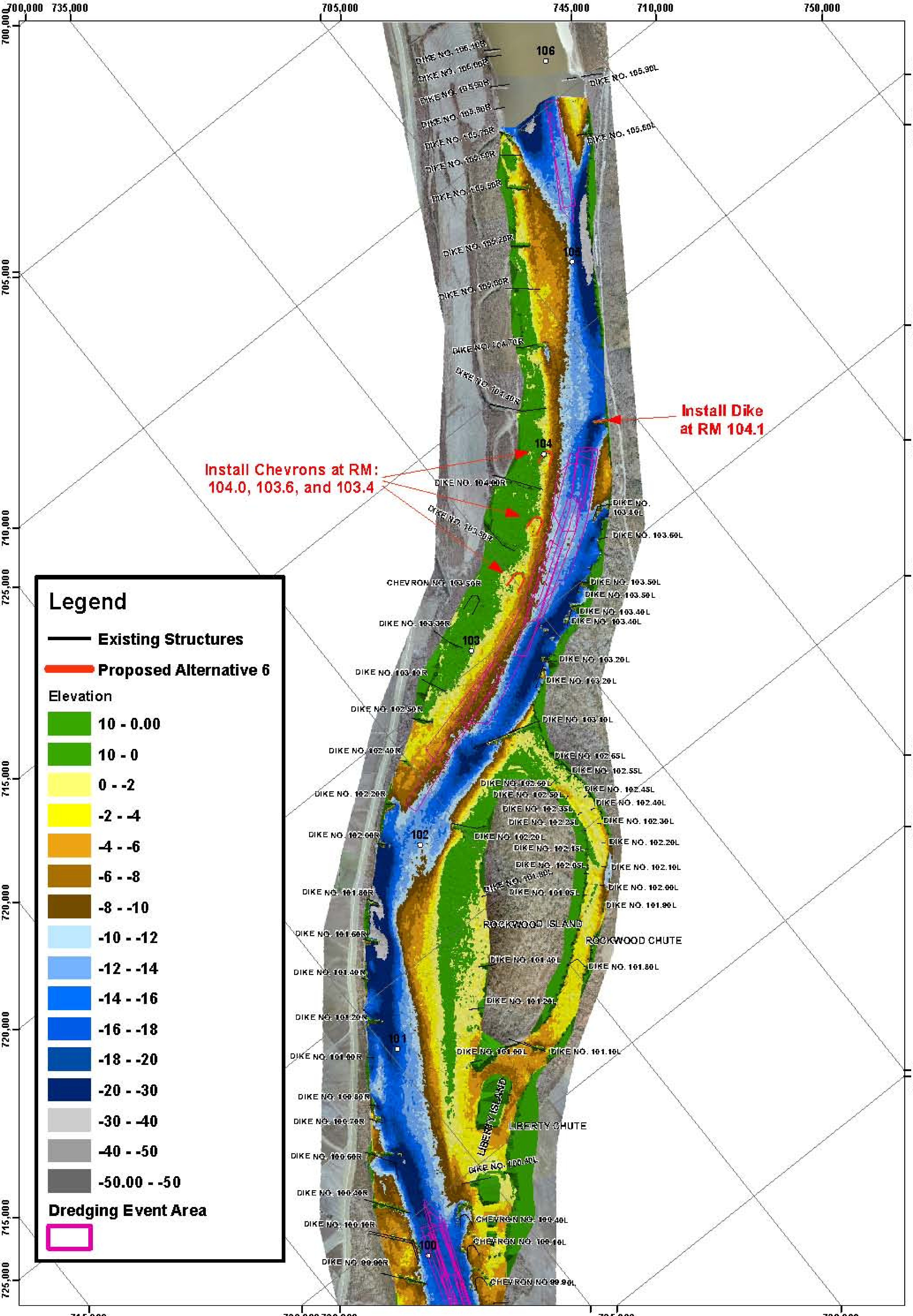

PLATE NUMBER 16	Alternative 6 2006 AERIAL PHOTOGRAPH	U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI MISSISSIPPI RIVER BASIN Waters Landing HSR Model -- River Miles 106.0-100.0	A. COX · 09/15/2006 Scan A. COX · J. BROWN, P.E. · E. BRAUER A. COX · R. DAVINROY, P.E. ...WATERS LANDING/PLATES · 11/10/2008

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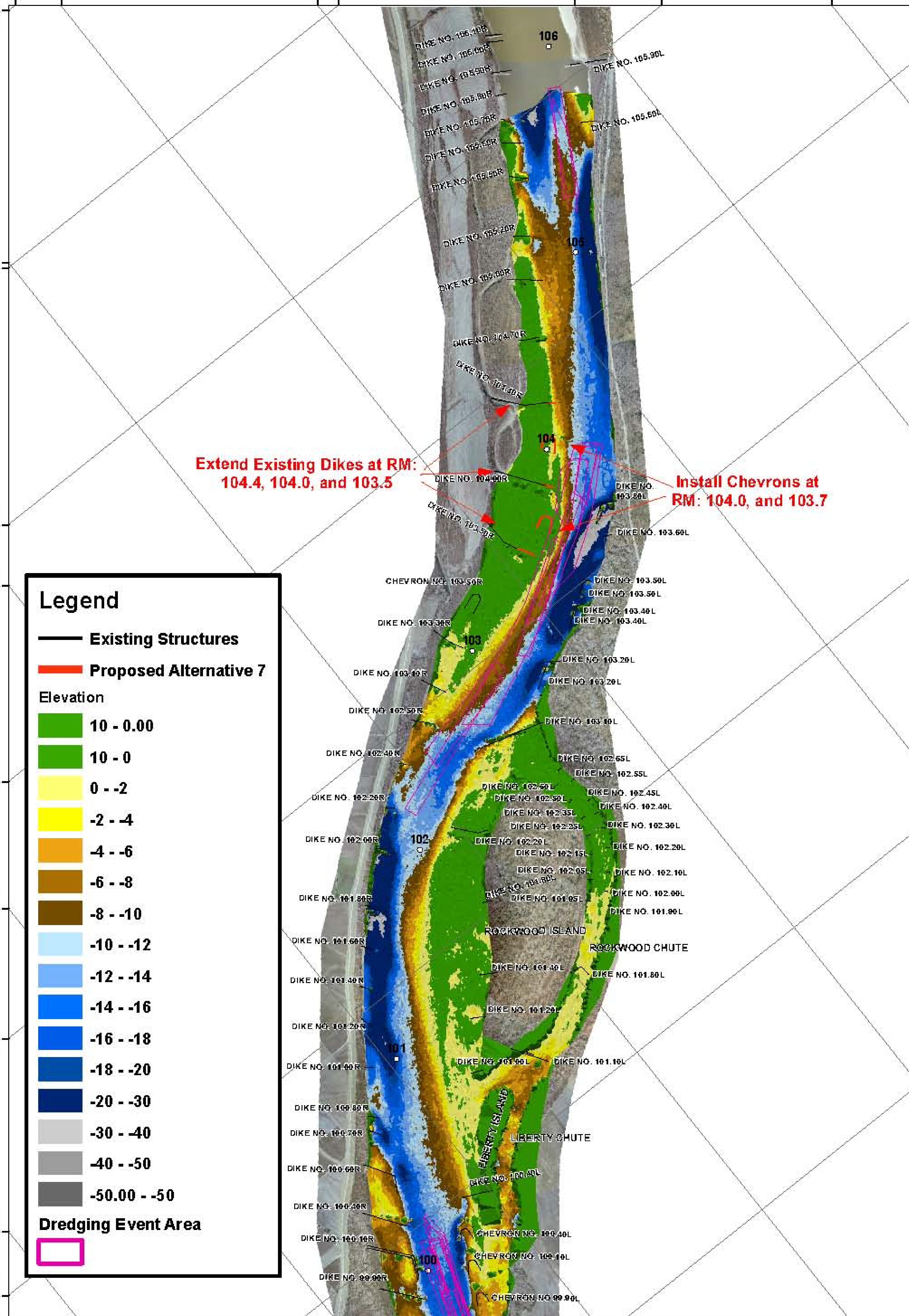

PLATE NUMBER 17

Alternative 7

2006 AERIAL PHOTOGRAPH

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ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

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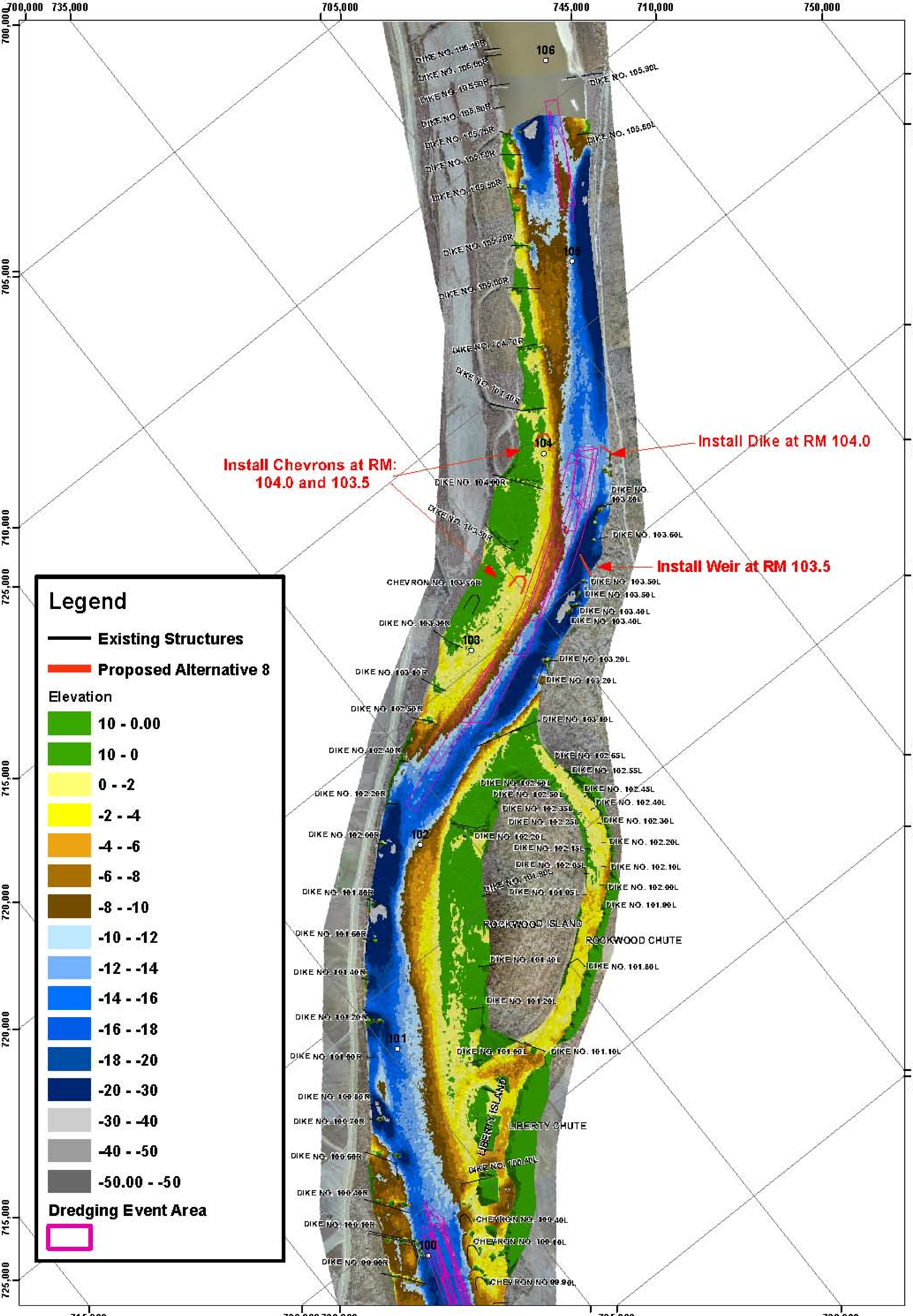

PLATE NUMBER 18

Alternative 8

2006 AERIAL PHOTOGRAPH

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ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 10/20/2008 Scan
A. COX | J. BROWN, P.E. | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 11/10/2008

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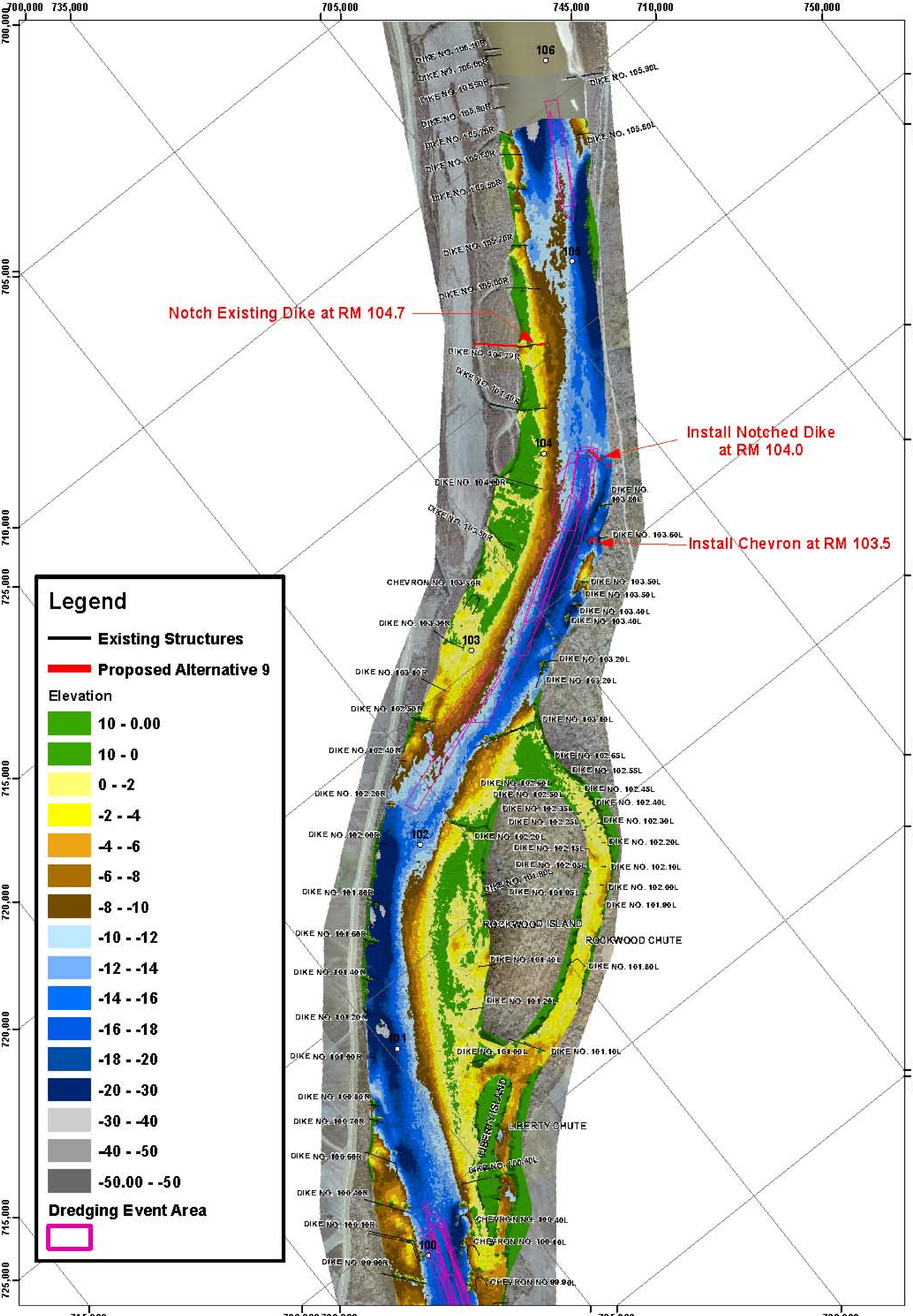

PLATE NUMBER 19	Alternative 9 2006 AERIAL PHOTOGRAPH	U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI MISSISSIPPI RIVER BASIN Waters Landing HSR Model -- River Miles 106.0-100.0	A COX A COX A. COX ...WATERS LANDING/PLATES	10/08/2008 Scan J. BROWN, P.E. E. BRAUER R. DAVINROY, P.E. 11/10/2008

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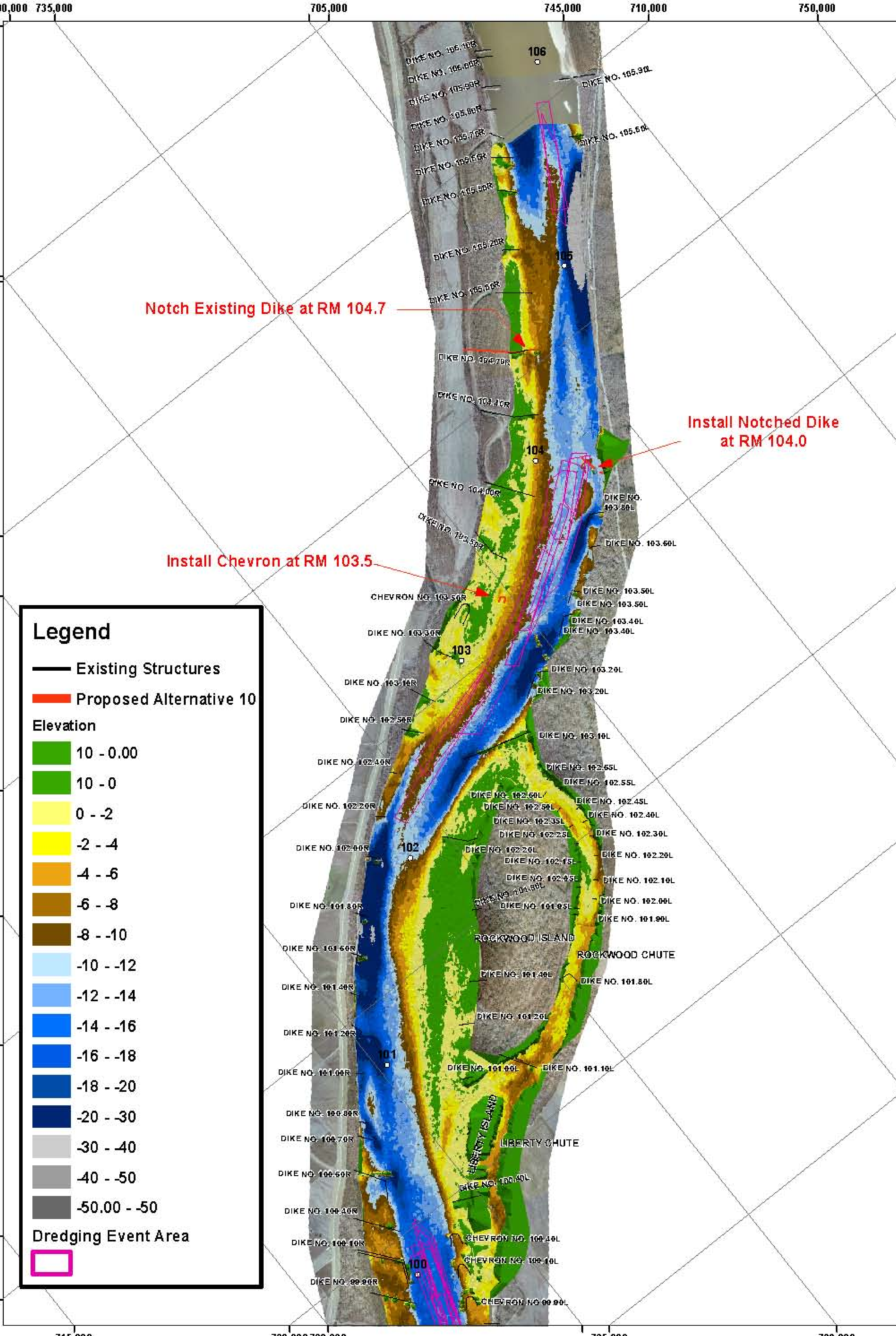

PLATE NUMBER 20

Alternative 10

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION CORPS OF ENGINEERS ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN

Waters Landing

HSR Model -- River Miles 106.0-100.0

A. COX | 09/25/2008 Scan

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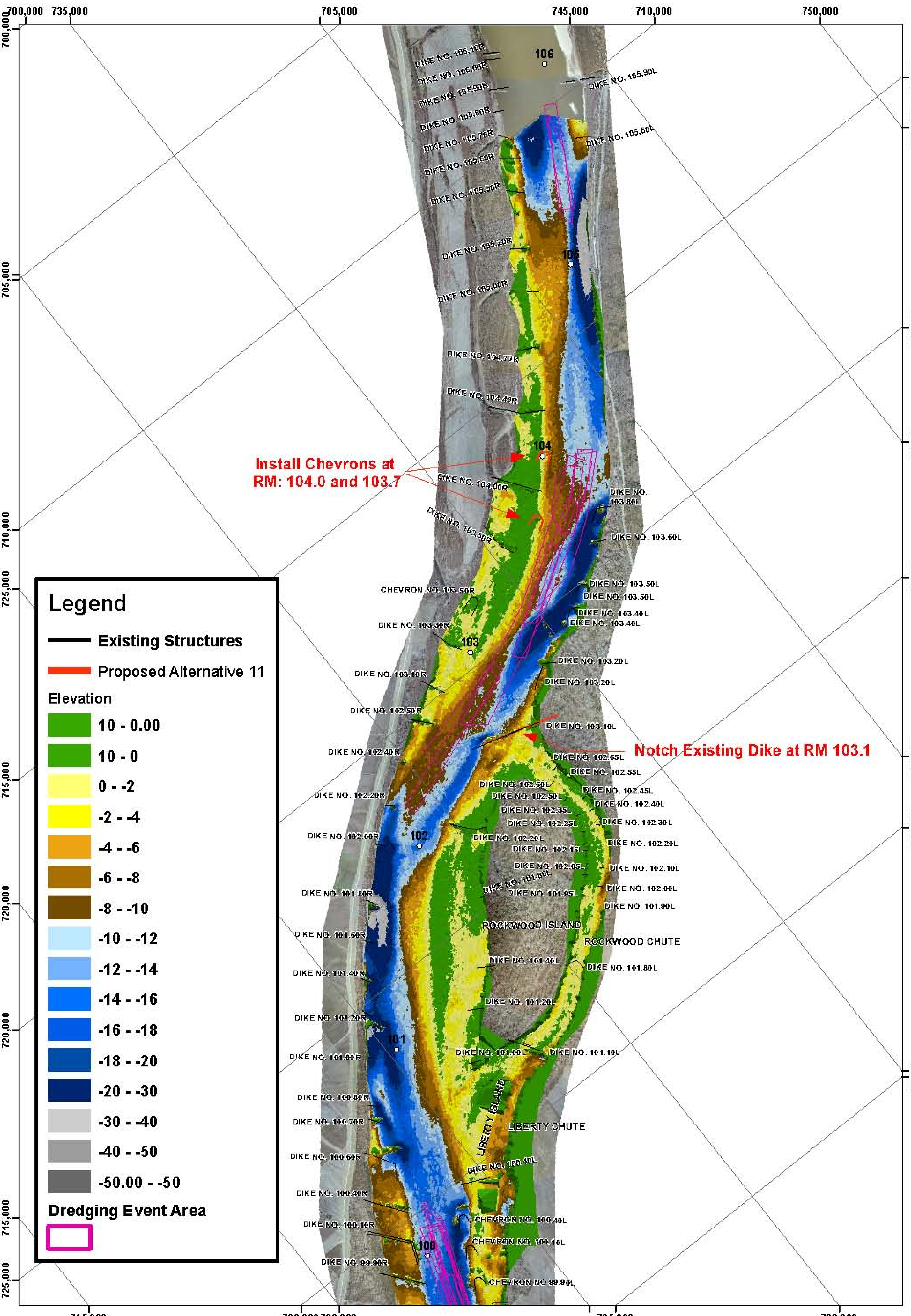

PLATE NUMBER 21

Alternative 11
2006 AERIAL PHOTOGRAPH

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CORPS OF ENGINEERS
ST LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX | 09/29/2008 Scan
A COX | J. BROWN, P.E. | E. BRAUER
A. COX | R DAVINROY, P.E.
...WATERS LANDING/PLATES | 11/10/2008

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

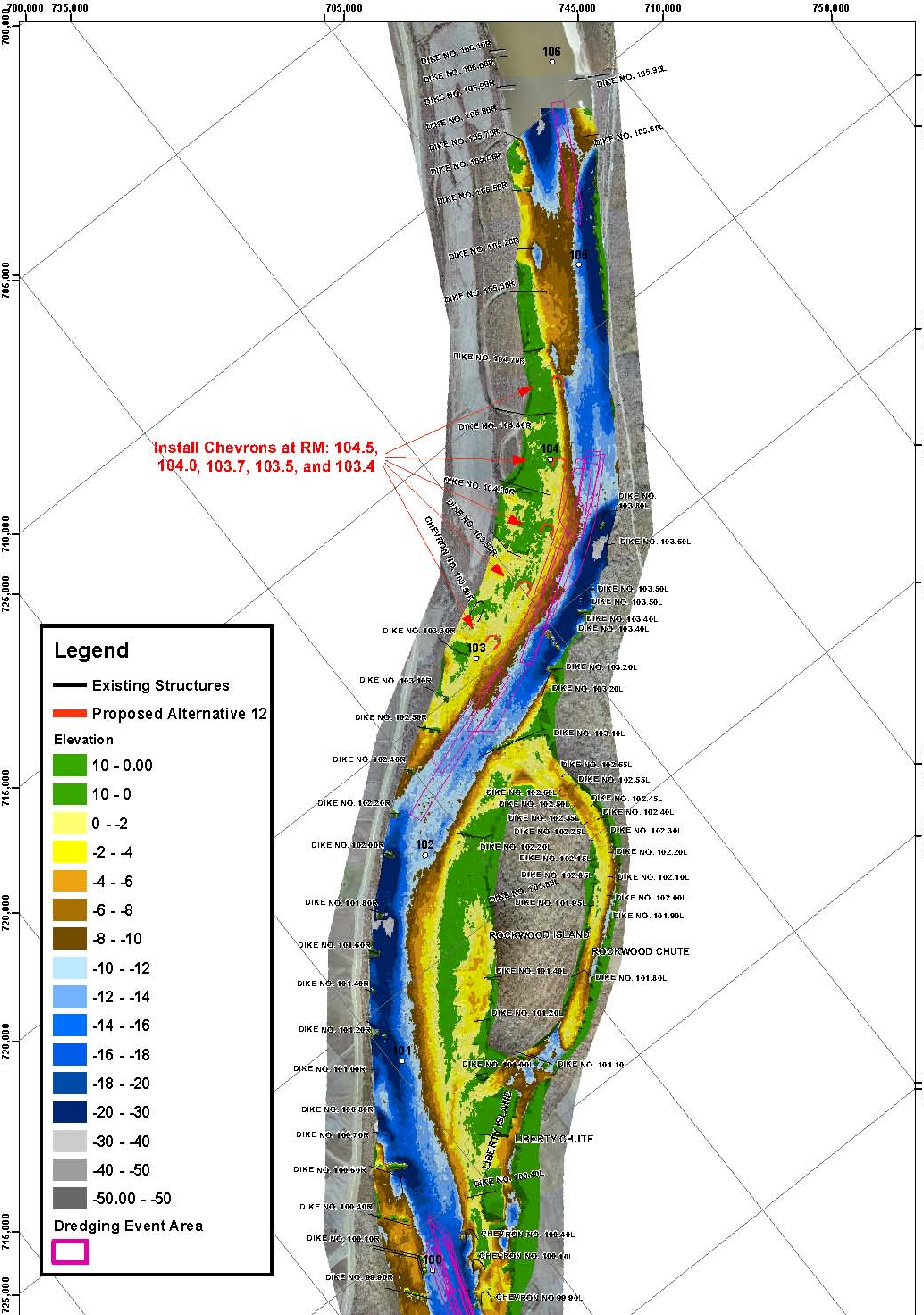

PLATE NUMBER	22

Alternative 12

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 09/30/2008 Scan
A. COX | J. BROWN, PE | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 11/10/2008

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

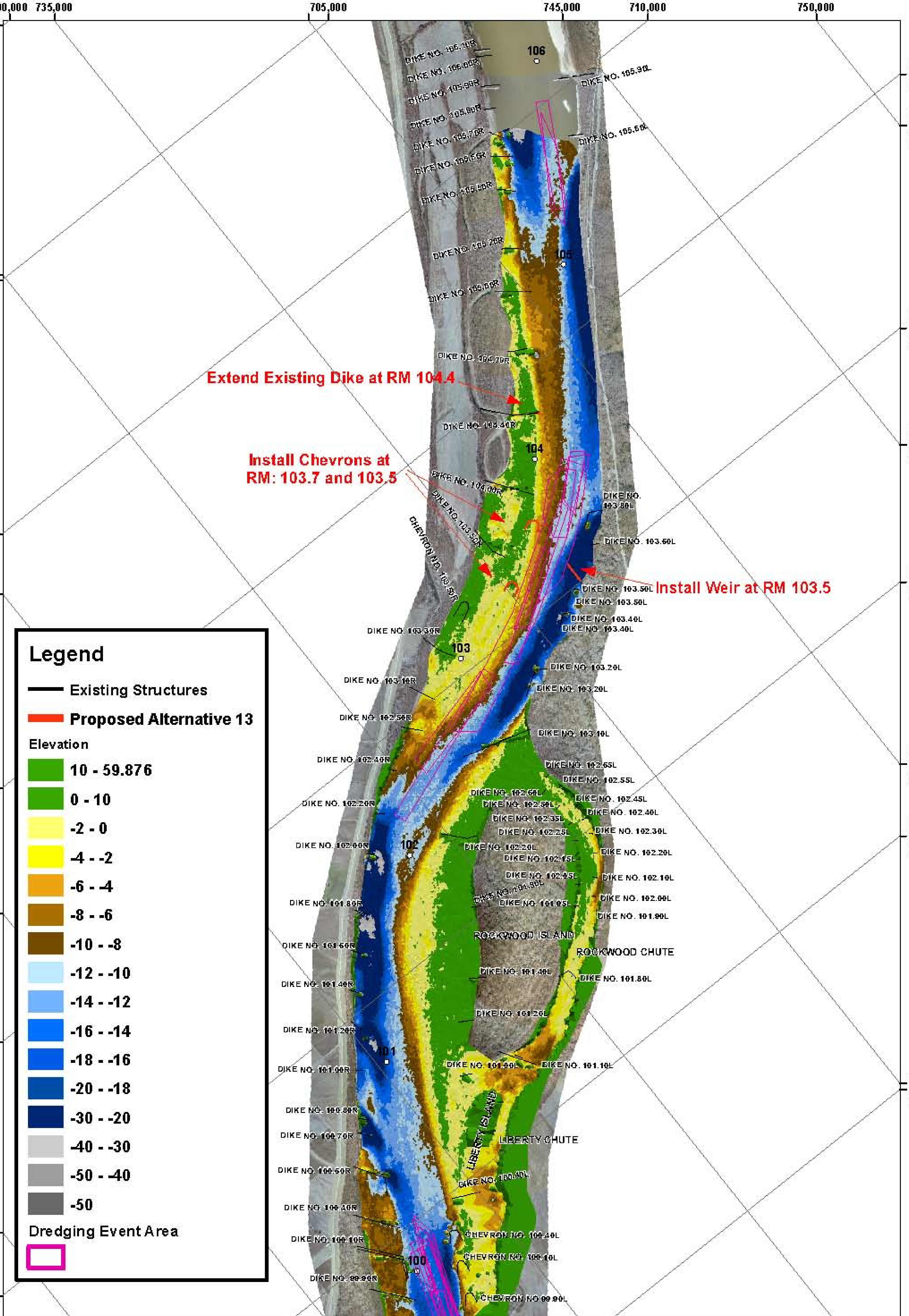

PLATE NUMBER 23

Alternative 13

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX | 10/16/2008 Scan
A COX | J. BROWN, P.E. | E. BRAUER
A COX | R DAVINROY, P.E.

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St. Louis District

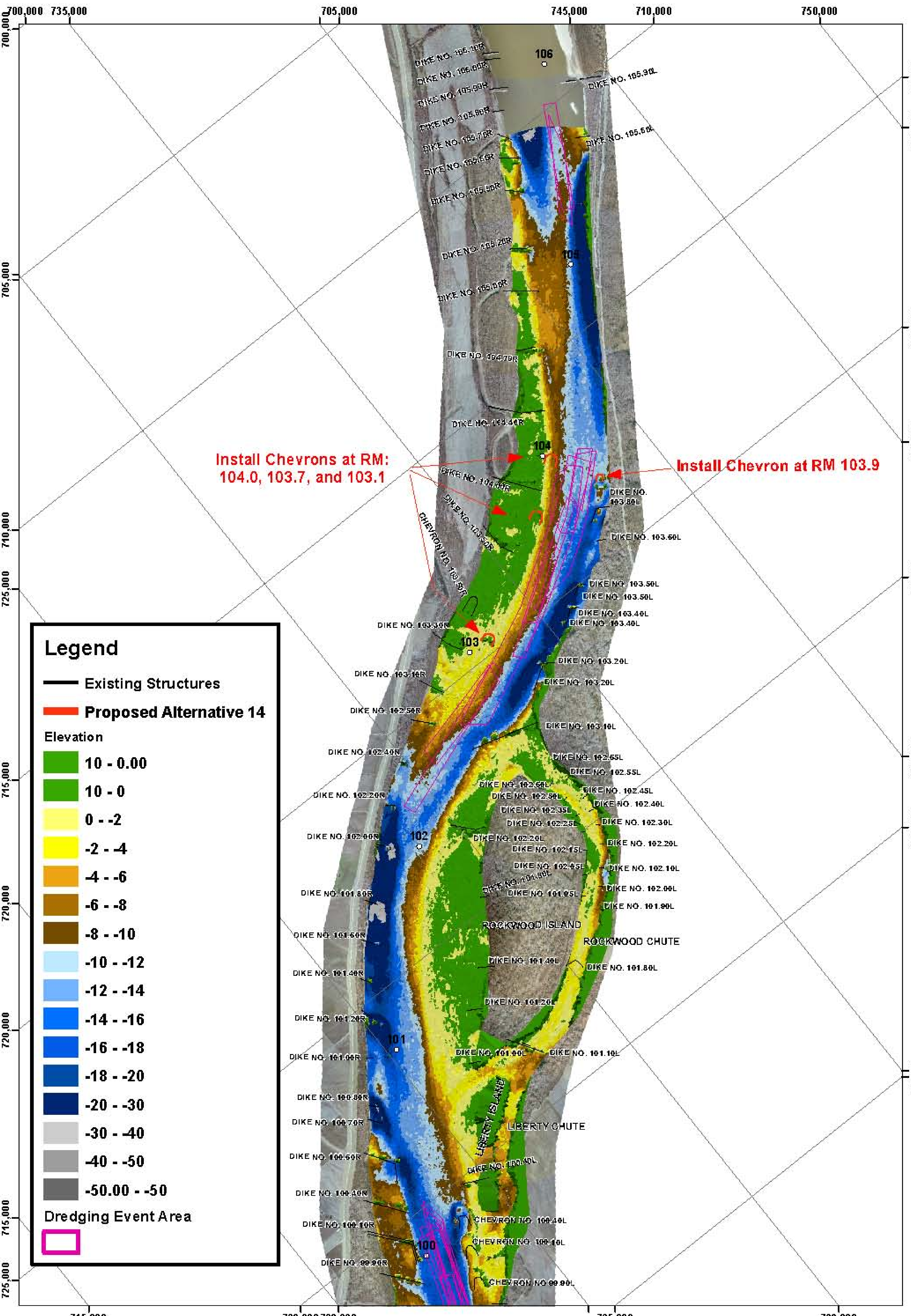

PLATE NUMBER 24

Alternative 14

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX	10/20/2008 Scan	
A COX	J. BROWN, P.E.	E. BRAUER
A COX	R DAVINROY, P.E.	
...WATERS LANDING/PLATES	11/10/2008	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

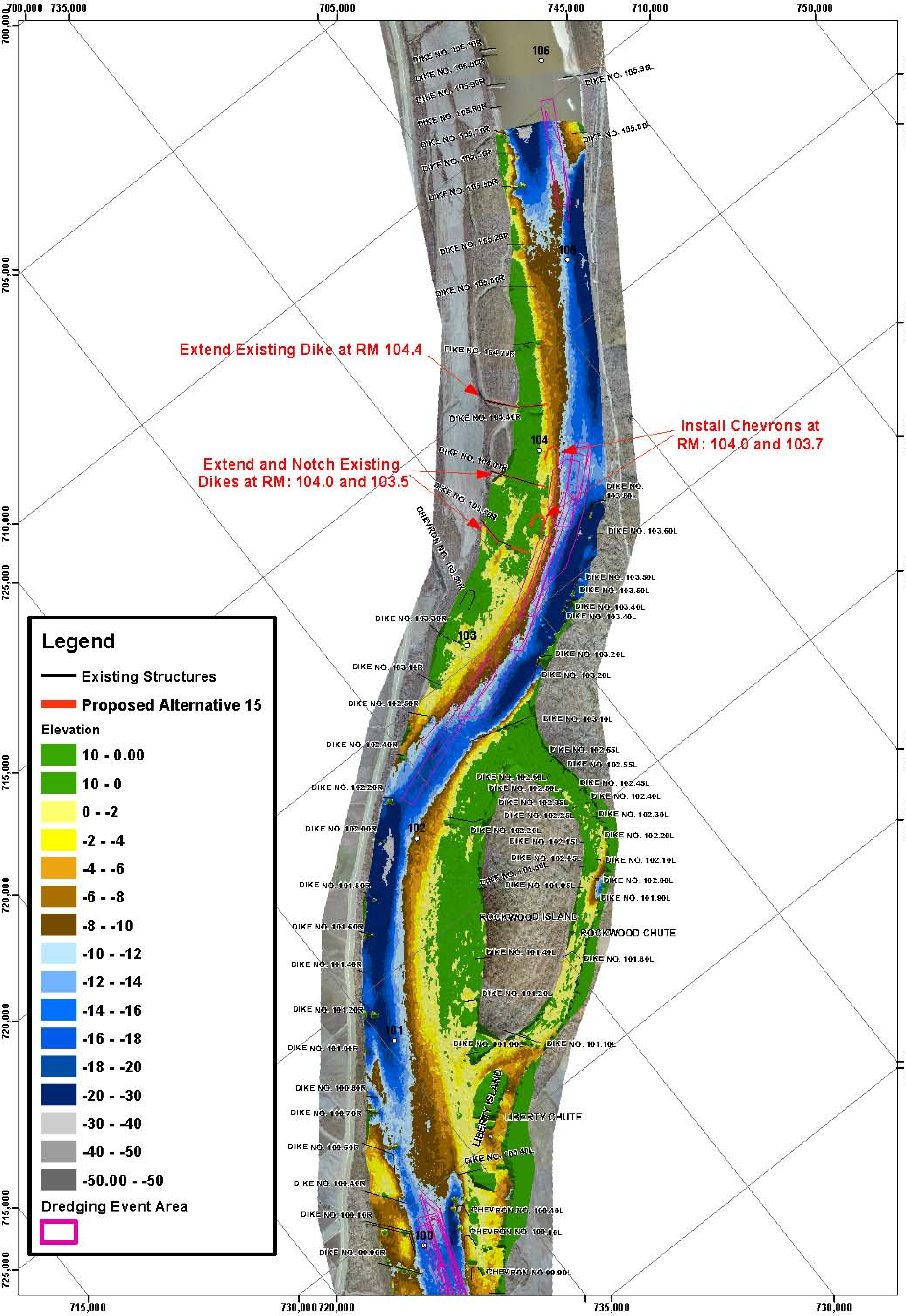

PLATE NUMBER
25

Alternative 15
2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 10/28/2008 Scan
A. COX | J. BROWN, P.E. | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 11/10/2008

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US Army Corps of Engineers
St. Louis District

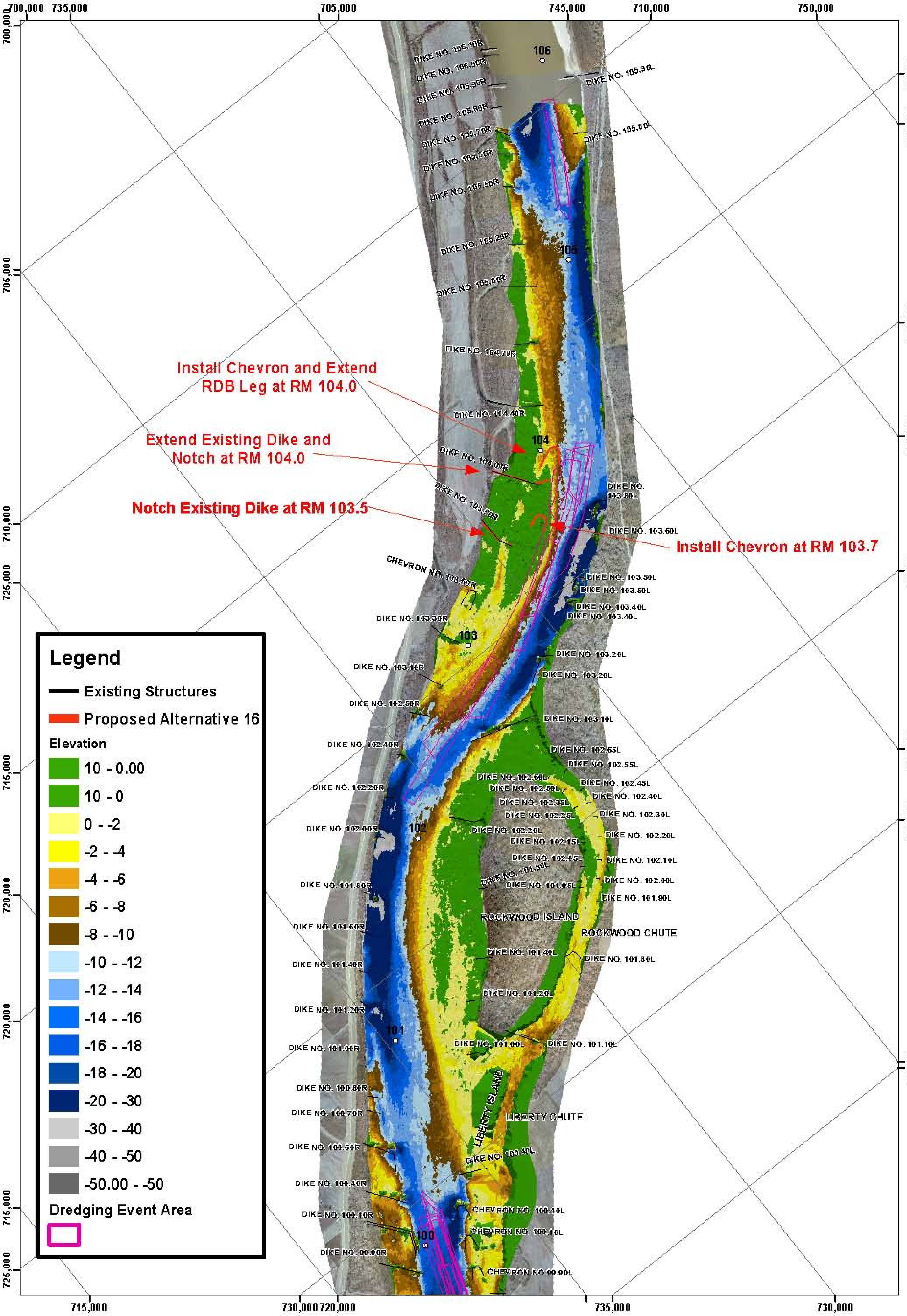

PLATE NUMBER 26

0 250 1,000 2,000 Feet

Alternative 16

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX	11/04/2008 Scan	
A COX	J. BROWN, P.E.	E. BRAUER
A. COX	R. DAVINROY, P.E.	
...WATERS LANDING/PLATES	11/10/2008	

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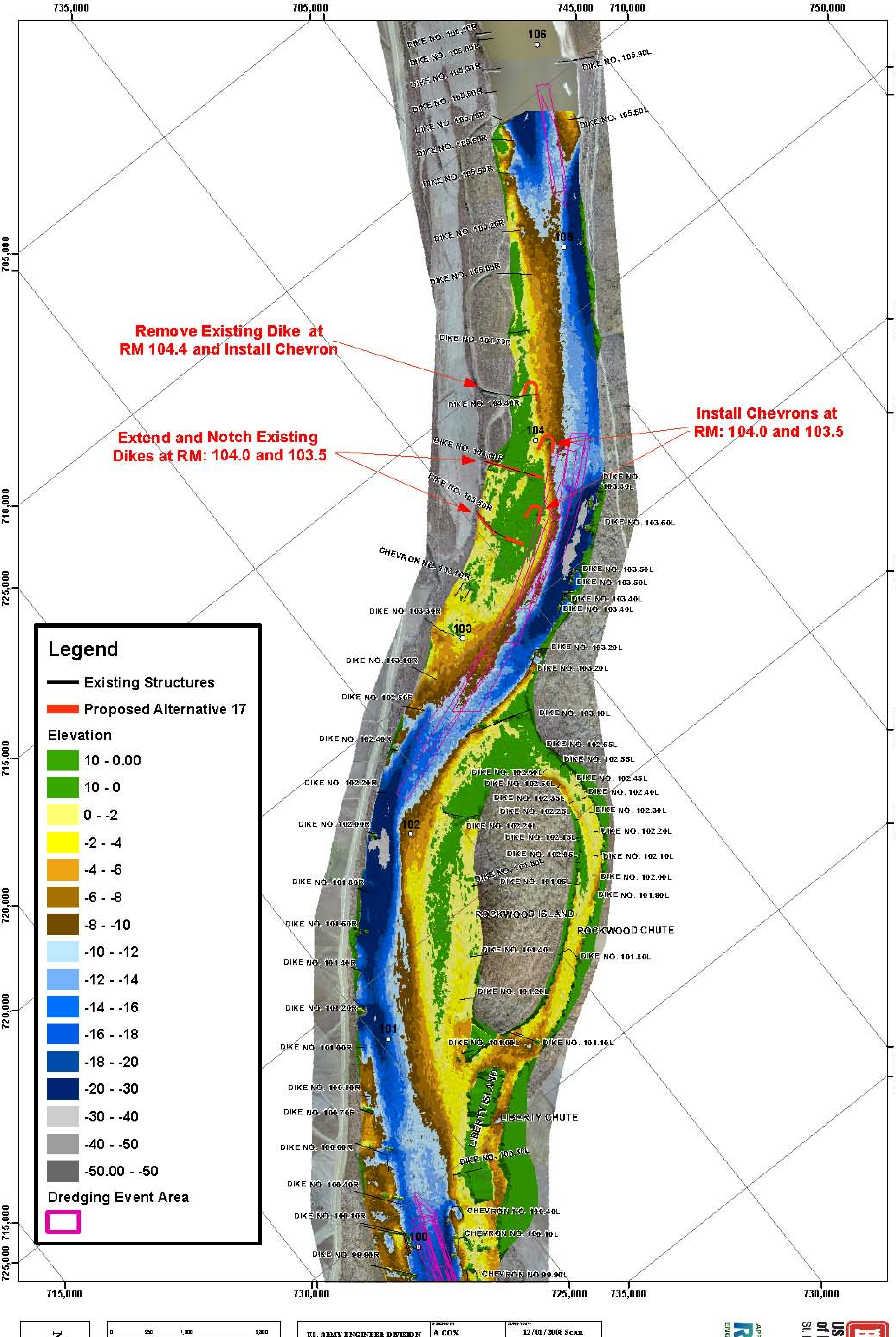

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Alternative 17

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 12/01/2008 Scan
A. COX | J. BROWN, P.E. | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 12/02/2008

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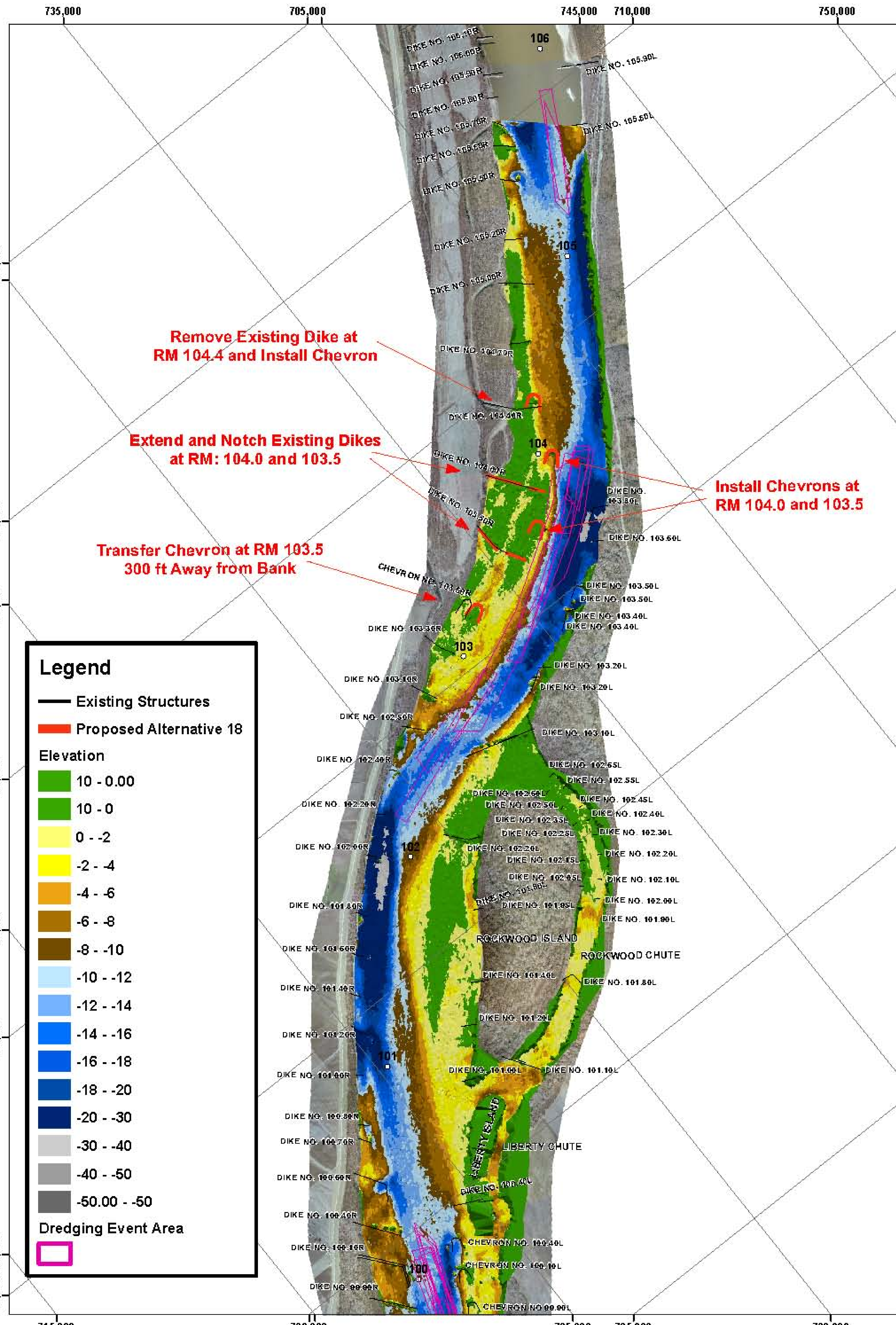

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Alternative 18

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX | 12/01/2008 Scan

A COX | J. BROWN, P.E. | E. BRAUER

A COX | R DAVINROY, P.E.

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US Army Corps of Engineers
St. Louis District

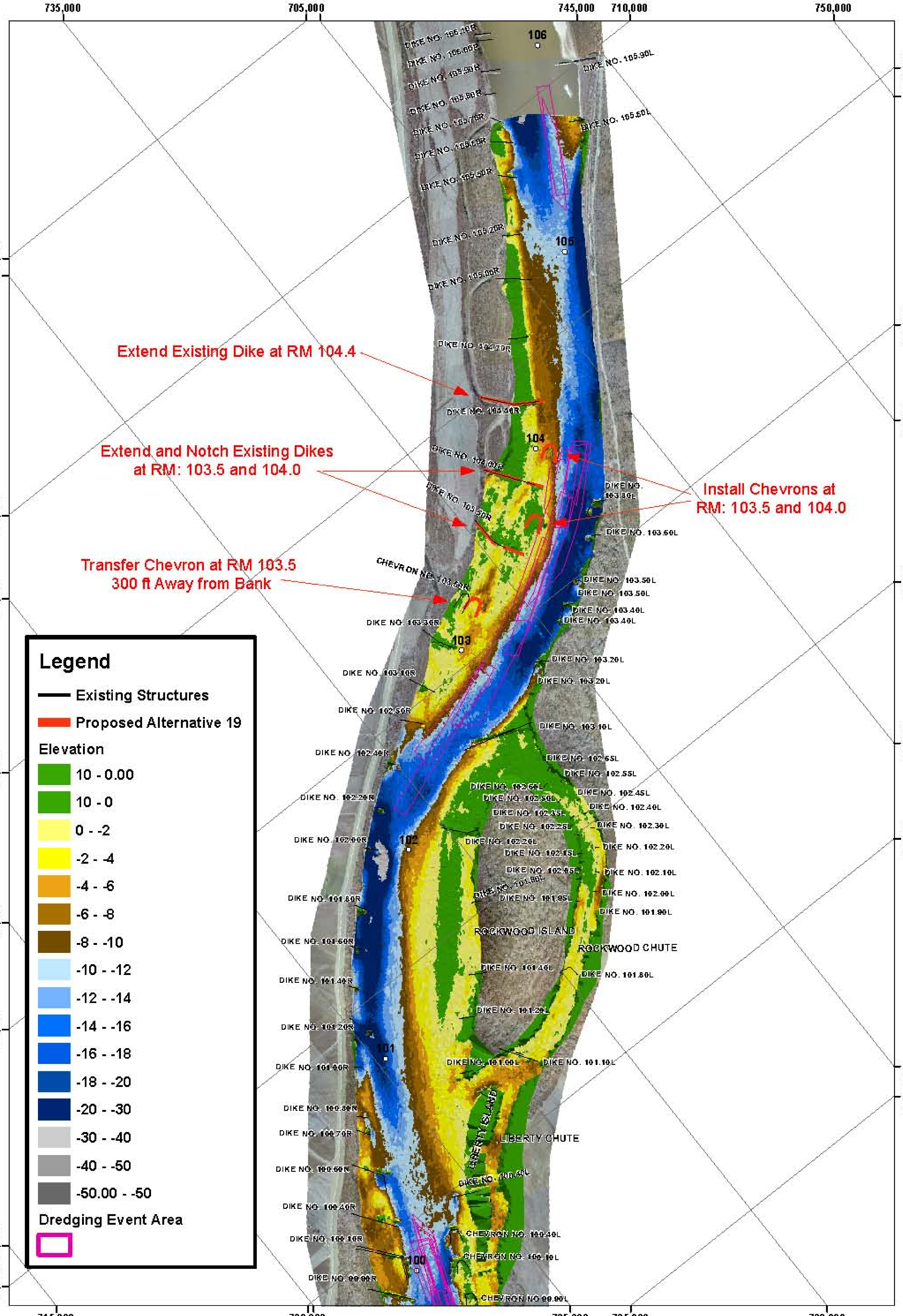

PLATE NUMBER 29

Alternative 19

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 12/02/2008 Scan
A. COX | J. BROWN, P.E. | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 12/02/2008

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

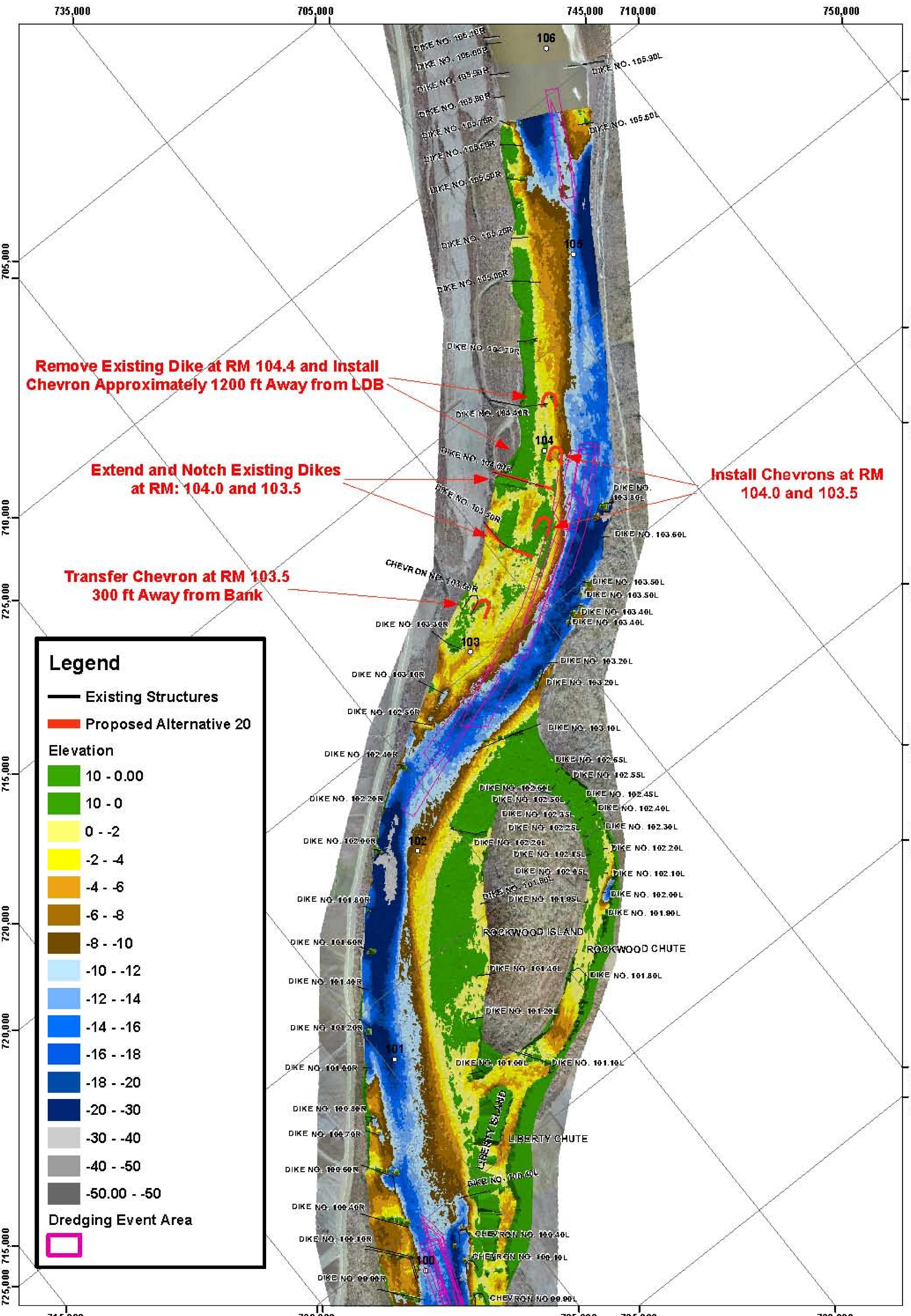

PLATE NUMBER
30

Alternative 20
2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX	12/03/2008 Scan	
A. COX	J. BROWN, P.E.	E. BRAUER
A. COX	R. DAVINROY, P.E.	
...WATERS LANDING/PLATES	12/04/2008	

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US Army Corps of Engineers
St. Louis District

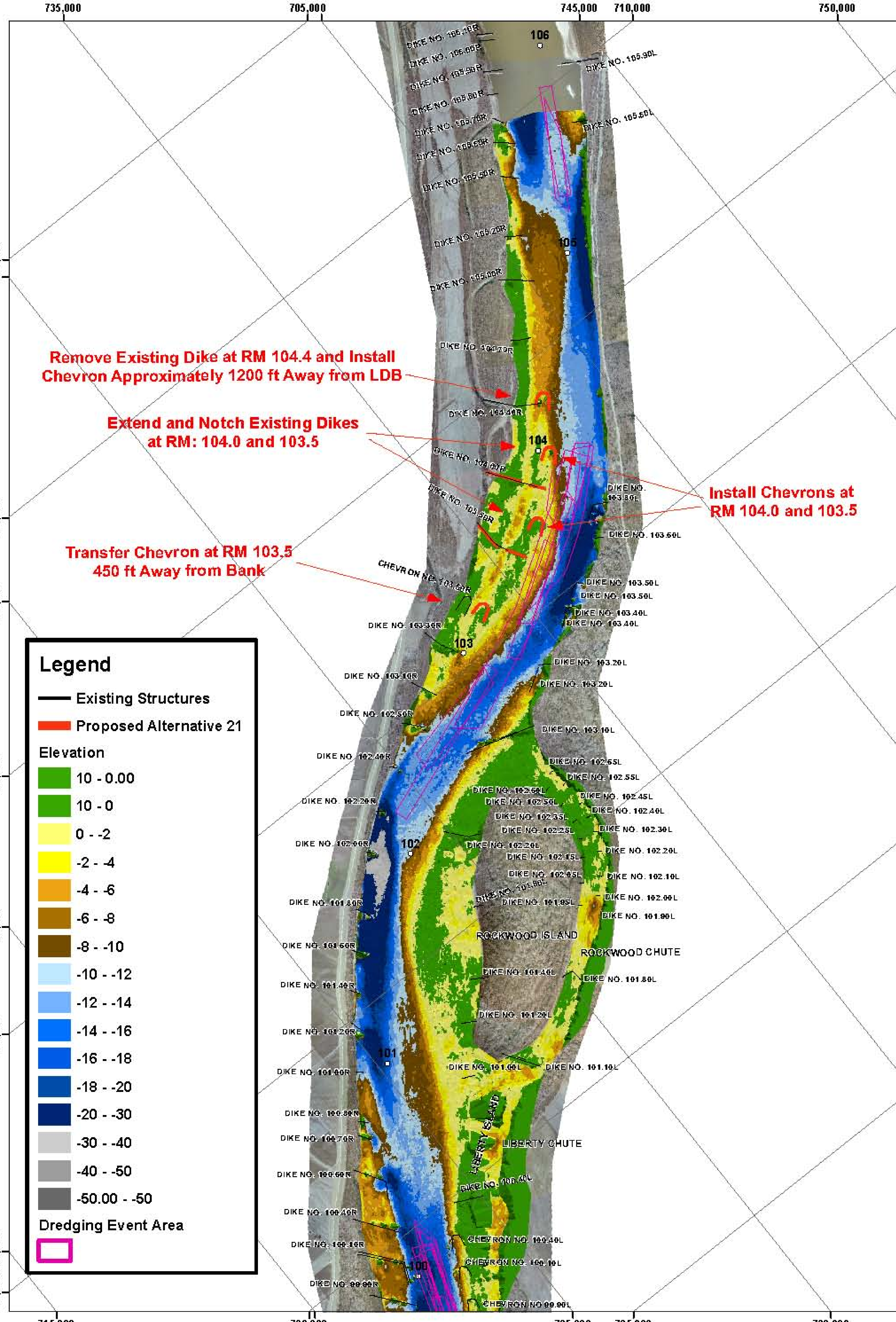

PLATE NUMBER

31

Alternative 21

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A COX	12/04/2008 Scan	
A COX	J. BROWN, P.E.	E. BRAUER
A COX	R DAVINROY, P.E.	
...WATERS LANDING/PLATES	12/04/2008	

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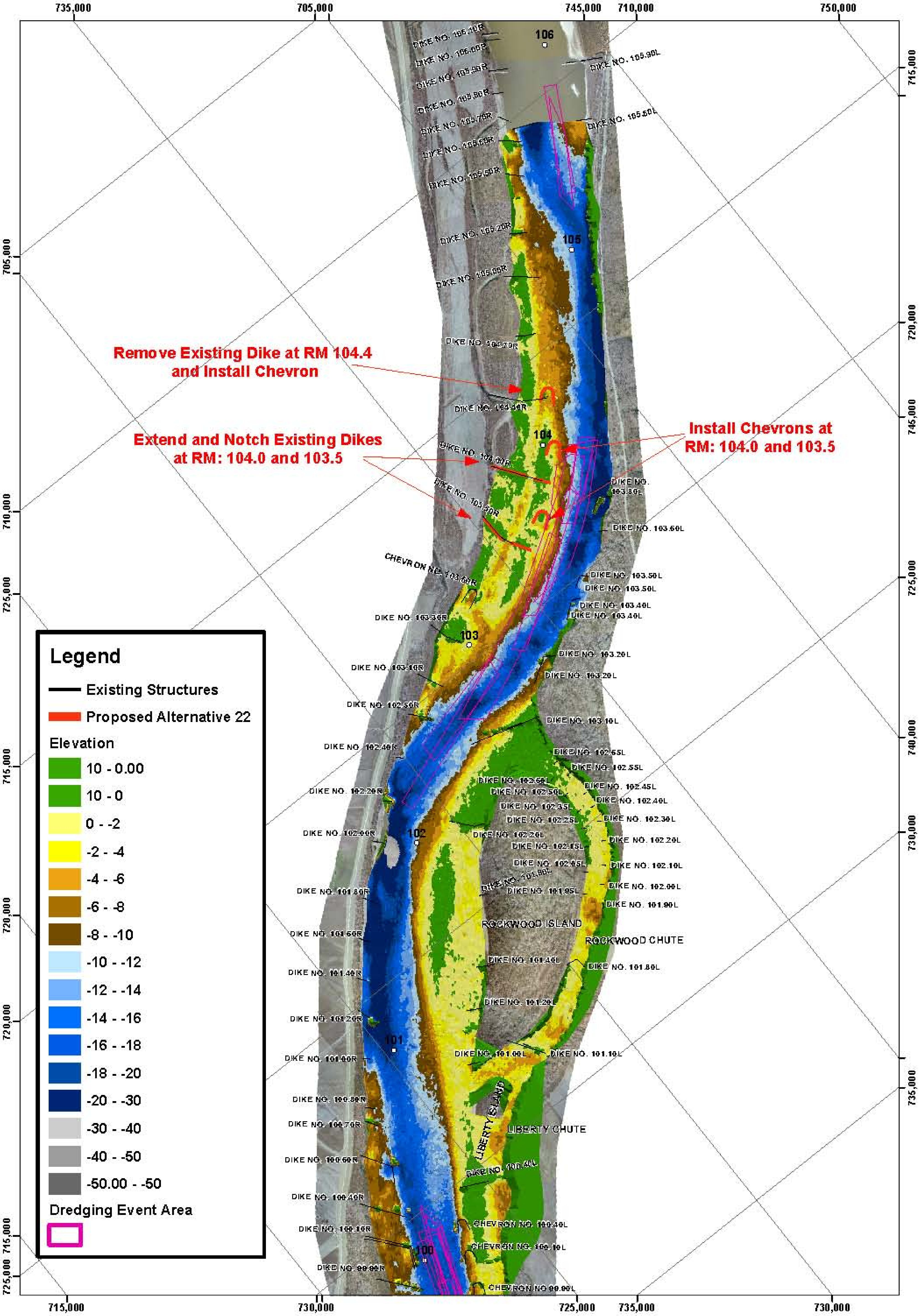

PLATE NUMBER 32

Alternative 22

2006 AERIAL PHOTOGRAPH

U.S. ARMY ENGINEER DIVISION
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI

MISSISSIPPI RIVER BASIN
Waters Landing
HSR Model -- River Miles 106.0-100.0

A. COX | 12/05/2008 Scan
A. COX | J. BROWN, P.E. | E. BRAUER
A. COX | R. DAVINROY, P.E.
...WATERS LANDING/PLATES | 12/05/2008

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