TECHNICAL REPORT M56

FINAL REPORT— MAY 2011

US Army Corps of Engineers
St. Louis District

CAPE ROCK HYDRAULIC SEDIMENT RESPONSE MODEL STUDY

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ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APPLIED RIVER ENGINEERING CENTER
FOOT OF ARSENAL STREET
ST. LOUIS, MISSOURI 63118

Sponsored by and Prepared for: U.S. Army Corps of Engineers-St. Louis District Biological Opinion Program

In Cooperation With: ILLINOIS DEPARTMENT OF NATURAL RESOURCES
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CITY OF CAPE GIRARDEAU

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UPPER MISSISSIPPI RIVER MILES 57.0-50.0

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District initiated a study of the Middle Mississippi River between Miles 57.0 and 50.0 near Cape Girardeau, Missouri. The purpose of the study was to evaluate environmental design alternatives for the development of side channel and island habitat, utilizing an existing dike field on the Mississippi River. This study was funded as part of the Biological Opinion Program of the U. S. Army Corps of Engineers, St. Louis District. The primary goal of this study was to diversify aquatic habitat by modifying present dike structures, developing new side channels and bar formations while maintaining the integrity of the navigation channel.

Mr. Edward J. Brauer, hydraulic engineer, and Mr. Edward H. Riiff, engineering technician, under direct supervision of, Mr. David C. Gordon, P.E. Hydraulic Engineer and Mr. Robert D. Davinroy, P.E., Chief of River Engineering, conducted the study between January 2007 and January 2009. Other personnel involved with the study included: Mr. Leonard Hopkins, P.E., Project Manager for the Biological Opinion Program, Mr. Brian Johnson from the Environmental Branch of the Planning, Programs, and Project Management Division, Mr. Lance Engle, Dredging Project Manager. Personnel from other agencies involved in the study included: Mr. Butch Atwood from the Illinois Department of Natural Resources, Ms. Joyce Collins and Mr. Matt Mangan from the U.S. Fish and Wildlife Service, Mr. David Ostendorf and Mr. Mark Boone from the Missouri Department of Conservation, Kevin Priester from Alliance Water Resources, Brad Dillow from the Cape Girardeau Fire Department and Tom Schulte from United States Senator Kit Bond's office.

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BACKGROUND

1. Study Reach

The study reach was located approximately 100 miles south of St. Louis, Missouri. The study comprised a 7-mile stretch of the Middle Mississippi River, between Miles 57.0 and 50.0. Plate 1 is a location and vicinity map of the study reach. The study area was located in Cape Girardeau County in Missouri, and Union and Alexander Counties in Illinois.

Plate 2 is a 2006 aerial photograph illustrating the planform and nomenclature of the Middle Mississippi River between Miles 57.0 and 50.0. The right descending bank (RDB) consists of limestone bluffs and rock outcroppings. The bluffs are approximately 300 feet tall and act as a natural revetment to the channel. The major rock outcropping is Cape Rock near Mile 54.2. This outcropping has a large impact on the study reach. Major tributaries in the study reach are: Flora Creek and Scism Creek which are located on the RDB near Mile 55.4, Sloan Creek which is located on the RDB near Mile 52.8 and Cape La Croix Creek which is located on the RDB near Mile 50.5. Adjacent to the left descending bank is a large floodplain. The floodplain consists of sand, silts and clays with an occasional sedimentary rock outcrop. The 1880's Mississippi River Commission survey shows the bed material in this reach as being mostly rock and sand. Similar results were found in the field by analyzing sediment samples and side scan sonar images.

At the time of the study there were 10 dikes and 10 weirs located in the study reach. The details of the navigation structures can be found in Table 1 and 2.

Dike Name	Length (ft)	Elevation (Blue Book) in LWRP	Dike Name	Length (ft)	Elevation (Blue Book) in LWRP
56.4L	300	19	51.8L	490	
56.3L	230	20	51.4L	670	22
55.8L	540	15	51.0L	1170	22
55.4L	300	12	50.7L	560	21
55.2L	550/300	13	50.5L	780	
54.8L	1120	16	50.1L	1000	22
53.0L	250	16	56.4R	450	15
52.6L	730		56.2R	400	15
52.3L	780	22	56.0R	370	15
52.1L	580	22	55.8R	270	21

Table 1: Dike Information

Weir Name	Length (ft)	Weir Name	Length (ft)
57.5L	570	56.0L	670
57.3L	550	55.8L	550
57.1L	530	54.9R	550
57.0L	590	54.8R	550
56.9L	650	54.7R	600
56.7L	730	54.6R	530
56.6L	630	54.1R	450
56.4L	670	54.0R	670
56.3L	600	53.9R	1000
56.2L	770	53.8R	1300

Table 2: Weir Information

2. Problem Description

The limestone bluffs along the RDB and dike structures along both the LDB and RDB contract this reach of the Middle Mississippi River to form a uniformly deep and narrow channel. The contracted channel is excellent for navigation purposes. However, more aquatic habitat diversity is desired throughout the reach. Fish species thrive in slow, shallow channels, deep pools and around bar formations. This type of habitat may be developed from the alteration of existing dikes, i.e. notching, increasing or decreasing length and height, or by adding new dikes, or by a combination of these methods.

3. History

A. Planform Changes

Historic land and hydrographic surveys were analyzed to better understand the formation of the current planform. The planform in 1817 (Plate 3), extracted from 1817-1821 Government Land Office Surveys, had an average width of about 4200 feet. Plate 4 is an 1866 Mississippi River land survey conducted under Bvt. Major General G.K. Warren. The average planform width in 1880 (Plate 5), extracted from 1880 Mississippi River Commission surveys, was around 5000 feet. In an effort to curtail erosion and maintain a navigation channel wood pile dikes and side channel closure structures were constructed in the 1880's. The earliest river training structure constructed in this reach was a 3300 foot long dike that was angled downstream starting on the LDB at Mile 53.0. By 1928 the present channel alignment had taken shape (Plate 6) and the planform width was 4699 feet. By 1976 the dikes were extended to the current location. By 2003 the planform width had decreased to 4000 feet.

Width				
	1817	**1881**	**1928**	**2003**
Planform	4211	4918	4697	3952
Main Channel	2741	3780	2876	2514
Side Channel	1619	1366	836	839

Table 3: Historic Planform Widths

The most upstream area of the study reach has seen moderate changes over the past 190 years. Devils Island, although in approximately the same location, was two separate islands in 1817 separated by a wide side channel. Schenimann Chute was not created until after 1928. The only change observed adjacent to the City of Cape Girardeau was a narrowing of the planform due to river training structures.

The Marquette Island area has seen major planform changes over the past 190 years. The river has meandered approximately 4000 feet since 1866 . Although the thalweg has always been located on the RDB, the wider navigable channel was found on the LDB until it was cut off in the 1940's.

B. Dredging

Dredging occurred in the Cape Rock reach of the Middle Mississippi River (RM 50.0-58.0) 71 times between 1964 and 2006 for a volume of approximately 18,000,000 cubic yards of material (shown in Figure 1). The annual average of dredge events was 1.9 and 1.1 in 1964-1995 and 1995-2006 respectively. The annual average quantity dredged was 532,855 cubic yards and 116,191 in 1964-1995 and 1995-2006 respectively. This data shows that since the construction of the weirs, the Cape Rock reach has been dredged less often. When dredging does occur, less material has been removed than in the past. Plate 7 shows dredging and placement locations since 1989. Dredging appears to have been conducted to add width rather than depth in the reach. Dredging has occurred in three main areas, along the point bar between RM 56 and 54, along the sandbar between RM 54 and 53 and once adjacent to dikes number 52.3L, 52.2L and 52.1L.

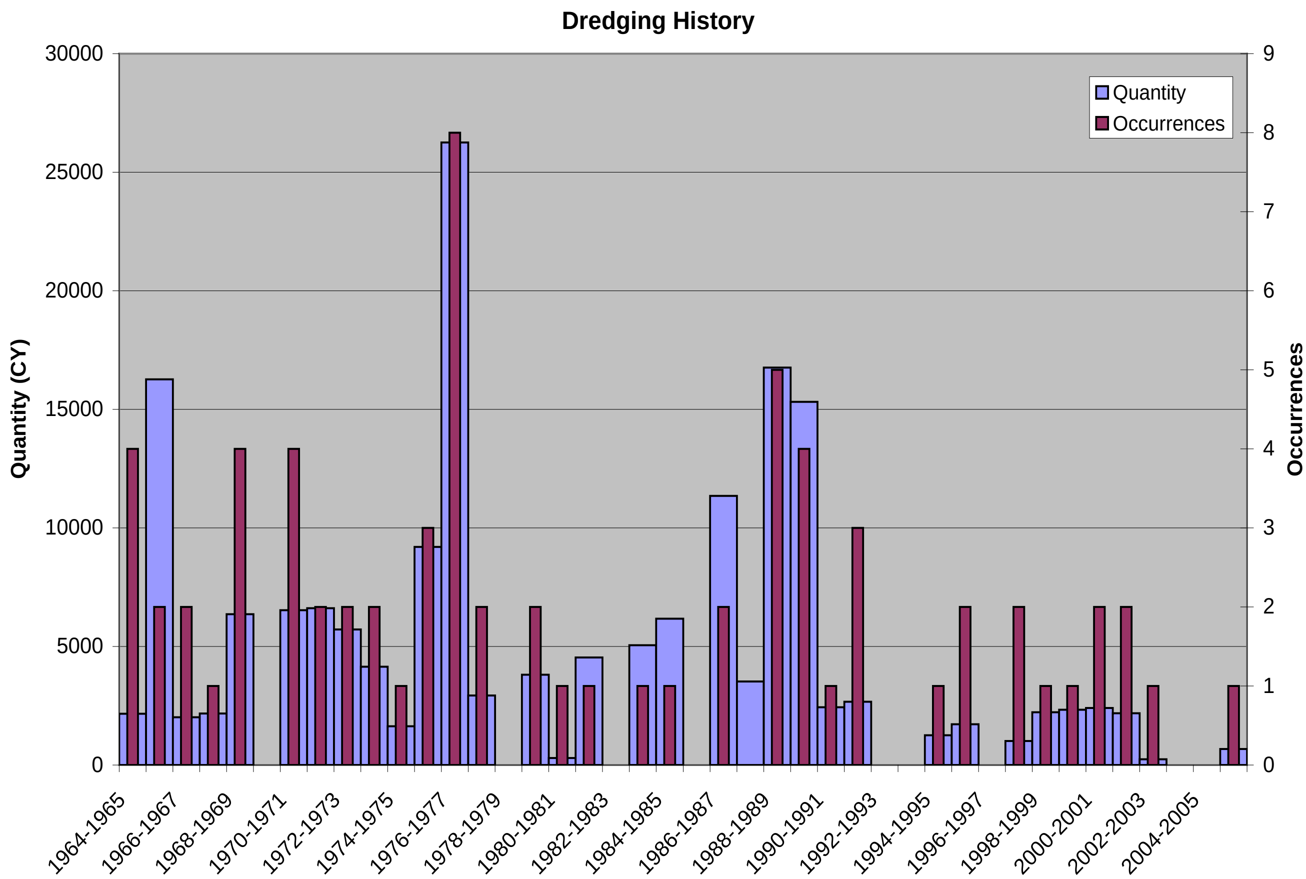

Figure 1: Dredging History

C. Accidents

The U.S. Coast Guard accident database separated accidents in three distinct categories: allisions, collisions, and groundings. Collisions are accidents with another non-moving object, allisions are accidents between two moving vessels and groundings are when the vessel runs aground. The accident database covered the time period from 1994 to 2009. Between the time period covered in the accident database there were 17 collisions, 10 allisions and 130 groundings in the study reach. All of the collisions were between a vessel and the Bill E. Emerson Memorial Bridge. Of the 130 groundings, 90 happened outside the marked navigation channel. It is important to note that the accident database covers years following the construction of the Cape Rock weir field. As a result of the weirs, the accidents decreased substantially at RM 54.0.

4. Field Observations

Personnel from the Applied River Engineering Center inspected the study reach by foot and shallow draft boat. These reconnaissance missions allowed the site to be photographed and studied. The site visit is described below with the water surface elevation referenced to LWRP at the Cape Girardeau, Missouri gage.

+16.28 Cape Girardeau Gage (August 16, 2007)

Field observations were recorded and photographs were taken of the structures within the study reach. Tow boats were also observed through the study reach to determine how they navigate through the study reach. Additionally, side scan sonar images were collected near Cape Rock. Side scan sonar was utilized to help distinguish the extent of rock outcropping along the RDB around Cape Rock.

5. Study Purpose and Goals

The purpose of this study was to design and evaluate various structural modifications to the existing dike fields intended to enhance the aquatic habitat diversity and flow dynamics within the reach. The first goal was to create island and side channel aquatic habitat within the dike field while maintaining current depths in the navigation channel. The second goal was to decrease depth adjacent to the Red Star boat ramp without effecting the depths, width, or safety of the navigation channel. Increased depth at the Red Star boat ramp would have allowed it to be used and lower stages. The increased availability of the boat ramp would increase public safety by allowing emergency access for the Cape Girardeau Fire Department and search and rescue teams.

HSR MODEL DESCRIPTION

1. Scales and Bed Materials

In order to investigate the sediment transport conditions described previously, a physical HSR model was designed and constructed. Plate 8 is a photograph of the HSR model used in this study. The vertical zero reference plane of the prototype water surface was assumed to be LWRP (low water reference plane) condition. The model employed a horizontal scale of 1 inch = 500 feet, or 1:6000, and a vertical scale of 1 inch = 50 feet, or 1:600, for a 10 to 1 distortion ratio of linear scales. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those of the prototype. The bed material was granular plastic urea, Type II, with a submerged specific gravity of 0.40.

2. Appurtenances

The HSR model insert was constructed according to the 2006 high-resolution aerial photograph of the study reach. The insert was then mounted in a standard HSR hydraulic flume. The riverbanks of the model were constructed from dense polystyrene foam, and modified during calibration. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.008 inch/inch. River training structures in the model were made of galvanized steel mesh for proper scaling of roughness.

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

HSR MODEL TESTS

1. Model Calibration

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

A. HSR Model Operation

The flow was held steady at a constant flow rate of 2.80 GPM during model calibration and for all design alternative tests. This flow represented bankfull discharge in the Middle Mississippi River channel serving as the average design energy response of the river. The most important factor during the modeling process is the establishment of an equilibrium condition of sediment transport.

B. Prototype Data and Observations

To determine the general bathymetric characteristics and sediment response trends that existed in the prototype, several present and historic hydrographic surveys were examined. Plates 9 through 15 are plan view hydrographic survey maps of the Mississippi River from January 16, 1956, December 16-17, 1971, March 26, 1977, February 22, 1983, March 24-25, 1986, March 4, 2003, July 30, 2007 respectively. The channel alignment entering the reach remained constant over the time period analyzed. A description of the prototype can be found in Table 4.

Prototype Description	
Location (RM)	Description
56.2 - 54.8	Entering the study reach the thalwag was located along the LDB over the weir field with depths of -15 ft LWRP with small scour holes between the weirs
54.8 - 54.1	The channel crossed from the LDB to the RDB where it flowed over the weir field on the outside of the bend. A point bar was formed on the inside of the bend that extended downstream to approximately to RM 53.8. Depths along the outside of the bend were between -20 -30 LWRP.
54.1- 53.8	The channel crossed over the cape rock weirs to the LDB. The depths over the weirs reached -40 to -50 ft LWRP.
53.8 - 52.3	The channel lied along the LDB with depths of -20 to - 30 ft until the next crossing at approximately RM 52.3. Deposition occurred along the RDB resulting in depths of -2 to -4 ft LWRP outside of the channel.
52.3 - 52.1	The channel crosses from the LDB to the RDB causing deposition along the LDB.
52.1-51.4	The channel remains along the RDB through the remainder of the study reach. It is important to note that the depest part of the channel lies approximately 750 feet off of the bankline. This is due to the rock shel along the RDB.

Table 4: Prototype Description

The area downstream of Cape Rock was very dynamic until the construction of bendway weirs in the reach in 1992. Prior to the construction of these structures the channel was split with the main thalweg along the LDB and a side channel along the RDB. These two channels surrounded a deposition area. The weirs were constructed to improve channel alignment and reduce the dredging associated with the unpredictability of the channel and side channel. After construction of the weirs, the thalweg crossing started at Cape Rock resulting on greater depths along the LDB leaving a large deposition area along the RDB.

2. Base Test

Model calibration was achieved once it was determined through qualitative comparisons that the prototype surveys were similar to several surveys of the model. The resultant bathymetry of this calibrated bed response served as the base test of the HSR model (Plate 16). This base test survey served as the comparative bathymetry for all design alternative tests. A comparison between the base test and prototype surveys can be found in Table 5. Overall, the trends of the model base test were very similar to the hydrographic surveys and were thus used with confidence for design alternative analysis.

Base Test - Prototype Comparison	
Location (RM)	Description
56.2 - 54.8	The trends were similar between the prototype surveys and base test in this section. The depths in the base test are slightly less than in the prototype. This was the result of this reach being part of the entrance conditions of the model.
54.8 - 54.1	The trends in this reach were very similar between the base test and the prototype surveys. In both surveys there existed a large sandbar along the LDB and a narrow navigation channel along the RDB over the weir field. The depths in both surveys were approximately - 20 ft LWRP
54.1- 53.8	The thalweg crossing from the RDB to the LDB over the weir field occurred at the same place in both surveys in this section. The depth of the crossing in the base test was shallower than that shown in the prototype survey. The base test thalweg crossing depth was consistent with other surveys of the reach. Note that a channel formed in the base test out of Picayune Chute that was not reflected in the prototype survey. Field visits confirmed that there existed a similar channel at certain stages. The crossing in this section in the base test was directly related to the amount of flow leaving Picayune Chute.
53.8 - 52.3	In both the prototype and base test surveys the thalweg was aligned along the LDB with a large sandbar along the RDB.
52.3 - 52.1	The channel crossing from the LDB to the RDB in this section was similar between the prototype survey and the base test. The crossing in the base test had depths that were slightly shallower than that of the prototype.
52.1-51.4	The base test and prototype in this section were very similar with an exception of minor differences along the RDB at RM 52.2. This was due to the modeling of the bankline with clay as a result of the rock shelf in the prototype.

Table 5: Base Test - Prototype Comparison

3. Design Alternative Tests

All design alternatives studied in the HSR model utilized the existing dike configurations in the prototype surveys. Modifications to the existing dikes included uprooting, notching and extending. Some design alternatives included the addition of blunt nosed chevrons. Thirty design alternative plans were tested to examine methods of modifying the sediment transport response trends that would create aquatic habitat diversity within this reach of the Middle Mississippi River. The effectiveness of each design was evaluated by comparing the resultant bed configuration to that of the base test. Impacts or changes induced by each alternative were evaluated by observing the sediment response of the model.

A team participation meeting was held at the Applied River Engineering Center (AREC) in St. Louis, Missouri prior to the testing of alternatives to outline objectives and concerns in the study reach. Personnel from the St. Louis District Corps of Engineers, Missouri Department of Conservation, Illinois Department of Natural Resources and U.S. Fish and Wildlife Service

A second team participation meeting was held at AREC following the testing of Alternatives to conduct a qualitative evaluation of the ramifications to the main channel and the side channels. Personnel from the St. Louis District Corps of Engineers, Missouri Department of Conservation, Illinois Department of Natural Resources, U.S. Fish and Wildlife Service, Alliance Water in Cape Girardeau, Cape Girardeau Fire Department and U.S. Senator Kit Bond carefully examined and discussed each alternative.

Alternatives tested are described in the below tables and shown on Plates 17-46. Alternatives were labeled as successful if they fulfilled two objectives: 1.) Increased environmental diversity including the creation of some form of side channel and bar formation with no negative impact to the navigation channel 2.) Reduced deposition along the RDB adjacent to the Red Star boat ramp.

Alternative Number	Structure	Type of Structure	Dimension/Height (ft)	Alternative Successful: Objective 1	Alternative Successful: Objective 2	Comments
1	52.9R	Chevron	276 x 275 / +15	NO	NO	Chevron 52.9R had no impact.
2	53.1R	Chevron	275 x 275 / +15	NO	NO	Chevrons 53.1R and 52.9R had no impact.
	52.9R	Chevron	276 x 275 / +15			
3	53.2R	Chevron	277 x 275 / +15	NO	NO	Chevrons 53.2R , 53.1R and 52.9R had no impact.
	53.1R	Chevron	278 x 275 / +15			
	52.9R	Chevron	279 x 275 / +15			
4	53.6R	Chevron	280 x 275 / +15	NO	NO	Chevron 53.6R had no impact.
5	53.6R	Chevron	281 x 275 / +15	NO	NO	Chevrons 53.6R and 53.5R had no impact.
	53.5R	Chevron	282 x 275 / +15			
6	53.4R	Chevron	283 x 275 / +15	NO	NO	Chevrons 53.4R and 53.2R had no impact.
	53.2R	Chevron	284 x 275 / +15			
7	53.7L	Dike	500 / +15	NO	NO	Dike 53.7L had a negative effect on the channel.
8	53.0L	Dike	500 / +15	NO	NO	Extending dike 53.0 to its previous alignment had a negative effect on the channel.
9	53.6L	Weir	600 / -15	NO	NO	Weir 53.6L had little impact on the channel.
10	53.6L	Weir	500 / -15	NO	NO	Weirs 53.6L and 53.5L had little impact on the channel.
	53.5L	Weir	650 / -15			
11	53.6L	Weir	500 / -15	NO	YES	Weirs 53.6L, 53.5L and 53.3L increased the channel depth along the RDB between Miles 52.3 and 53.3.
	53.5L	Weir	650 / -15			
	53.3L	Weir	830 / -15			
12	53.6L	Weir	500 / -15	NO	YES	Weirs 53.6L, 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3.
	53.5L	Weir	650 / -15			
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
13	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
14	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L, and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			

15	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3. Notching dike 52.3L had no impact.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.3L	Notched Dike	-400/ -15			
16	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3. Notching dikes 52.3L and 52.2L had no impact.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-600/ -15			
17	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between Miles 52.3 and 53.3. Notching dikes 52.3L, 52.2L and 52.1L had no impact.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-600/ -15			
	52.1L	Notched Dike	-400/ -15			
18	53.5L	Weir	650 / -15	YES	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dike 52.3L created a small side channel. Notching dike 52.2L had no impact. The sandbar created by this structure alignment narrowed the navigation channel to 1200' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-600/ -15			
19	53.5L	Weir	650 / -15	YES	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a small diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1200' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.2L	Notched Dike	-600/ -15			
	52.1L	Notched Dike	-400/ -15			

20	53.5L	Weir	650 / -15	YES	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a small diverse side channel. The sandbar created by this structure alignment narrowed the channel to 1300' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-600/ -15			
	52.1L	Notched Dike	-400/ -15			
21	53.5L	Weir	650 / -15	YES	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a small diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1300' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-300/ -15			
	52.1L	Notched Dike	-250/ -15			
22	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a large, deep diverse side channel. The sandbar created by this structure narrowed the navigation channel to 1100' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-300/ -15			
23	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a large, deep diverse side channel. The sandbar created by this structure narrowed the navigation channel to 1100' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-300/ -15			
	52.2L	Notched Dike	-400/ -15			
24	53.5L	Weir	650 / -15	YES	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a small diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1300' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-400/ -15			
	52.2L	Notched Dike	-300/ -15			
	52.1L	Notched Dike	-350/ -15			

25	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevrons 52.9L, 52.7L and notching dikes 52.3L, 52.2L and 52.1L created a long, deep and diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1100' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.9L	Chevron	275 x 275 / +15			
	52.7L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-500/ -15			
	52.2L	Notched Dike	-400/ -15			
	52.1L	Notched Dike	-300/ -15			
26	53.5L	Weir	650 / -15	NO	YES	Weirs 53.5L, 53.3L and 53.1L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a long, deep and diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1000' between River Miles 52.3-52.2.
	53.3L	Weir	830 / -15			
	53.1L	Weir	930 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-500/ -15			
	52.2L	Notched Dike	-400/ -15			
	52.1L	Notched Dike	-350/ -15			
27	53.7	Weir	575 / -15	NO	YES	Weirs 53.7L, 53.5L and 53.3L, although not as much as other alternatives, increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L, 52.2L and 52.1L created a long, deep and diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1100' between River Miles 52.3-52.2.
	53.5L	Weir	650 / -15			
	53.3L	Weir	830 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-500/ -15			
	52.2L	Notched Dike	-350/ -15			
	52.1L	Notched Dike	-350/ -15			
28	53.3L	Weir	650 / -15	YES	YES	Weirs 53.3L, 53.2L and 53.0L increased the channel depth along the RDB between River Miles 53.3 and 52.3. Chevron 52.8L and notching dikes 52.3L and 52.2L created a long and diverse side channel. The sandbar created by this structure alignment narrowed the navigation channel to 1300' between River Miles 52.3-52.2.
	53.2L	Weir	900/ -15			
	53.0L	Weir	1000 / -15			
	52.8L	Chevron	275 x 275 / +15			
	52.3L	Notched Dike	-450/ -15			
	52.2L	Notched Dike	-350/ -15			
	52.1L	Notched Dike	-250/ -15			

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

There were two objectives that each alternative was tested against. Objective 1 was to successfully create some form of side channel with no negative impact to the navigation channel and objective 2 was to reduce deposition along the RDB adjacent to the Red Star boat ramp. Alternatives 18-21, 24, 28-30 (Plates 34-37, 40, 44-46 respectively) were successful in meeting the criteria of Objective 1. Alternatives 11-30, (Plates 27-46 respectively) were successful in meeting the criteria of Objective 2. Alternatives 18-21, 24, 28-30 accomplished both objectives.

2. Recommendations

The alternative that was recommended by the model study is Alternative 30 (Plate 46) because it satisfied the model study objectives with the least amount of construction. Following the completion of the model study, the recommended alternative was presented as a general plan at the E-Action meeting with river engineers from other districts in the Mississippi Valley Division. There was a consensus that more study was necessary on the impacts to the navigation channel as a result of the proposed weirs. This response was echoed by the River Industry Action Committee (RIAC). Their concern was that the weirs would significantly alter the alignment of the navigation potentially making it unsafe. As a result of their concerns, it is recommended that no weirs be constructed until further analysis is performed.

The result of the weirs in the model study was that the thalweg moved from the LDB towards the RDB further upstream than the existing condition. Without the weirs, the navigation channel would remain along the LDB until it crossed at Mile 52.3 as shown in the prototype surveys. It is because of the existing alignment of the thalweg that the modeler believed that the construction of Alternative 30; the construction of Chevron 52.7 L and the modifications to Dikes 52.3L and 52.2L would still be successful in adding environmental diversity in the reach and creating a side channel and sandbar/Island complex in the study reach with no negative impact on the navigation channel.

The recommended design included the following:

- RM 52.7L: Construct new 200 x 300 ft chevron
    - Structure top elevation = 15 ft St. Louis Gage
- RM 52.3L: Construct a 420 ft notch in the existing structure
    - Bottom elevation of notch = -15 ft LWRP
- RM 52.2L: Construct a 350 ft notch in existing structure
    - Bottom elevation of notch = -15 ft LWRP

3. Interpretation of Model Test Results

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

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

FOR MORE INFORMATION

For more information about HSR modeling or the Applied River Engineering Center, please contact Edward Brauer at:

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U.S. Army Corps of Engineers - St. Louis District
Hydrologic and Hydraulics Branch
Foot of Arsenal Street
St. Louis, Missouri 63118

Phone: (314) 865-6332
Fax: (314) 865-6352

E-mail: Edward.J.Brauer@usace.army.mil

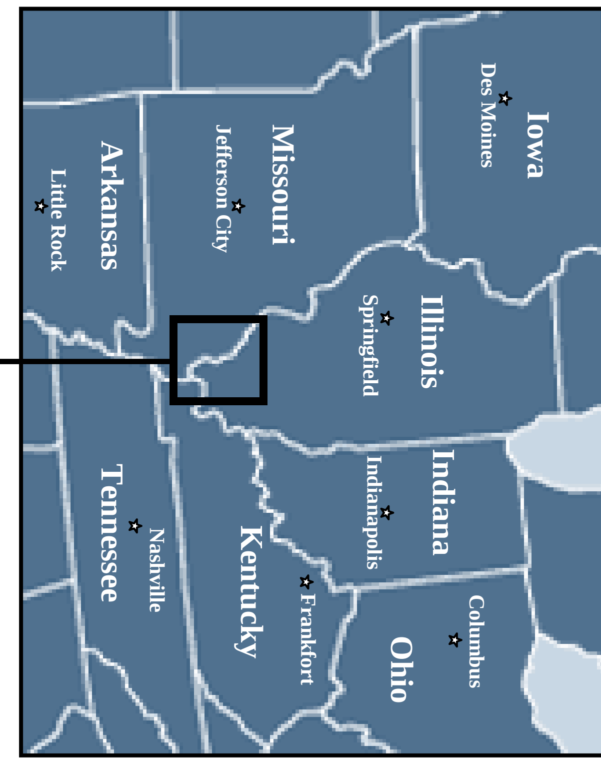
Or you can visit us on the World Wide Web at:
http://www.mvs.usace.army.mil/eng-con/expertise/arec/welcome_page_2.html

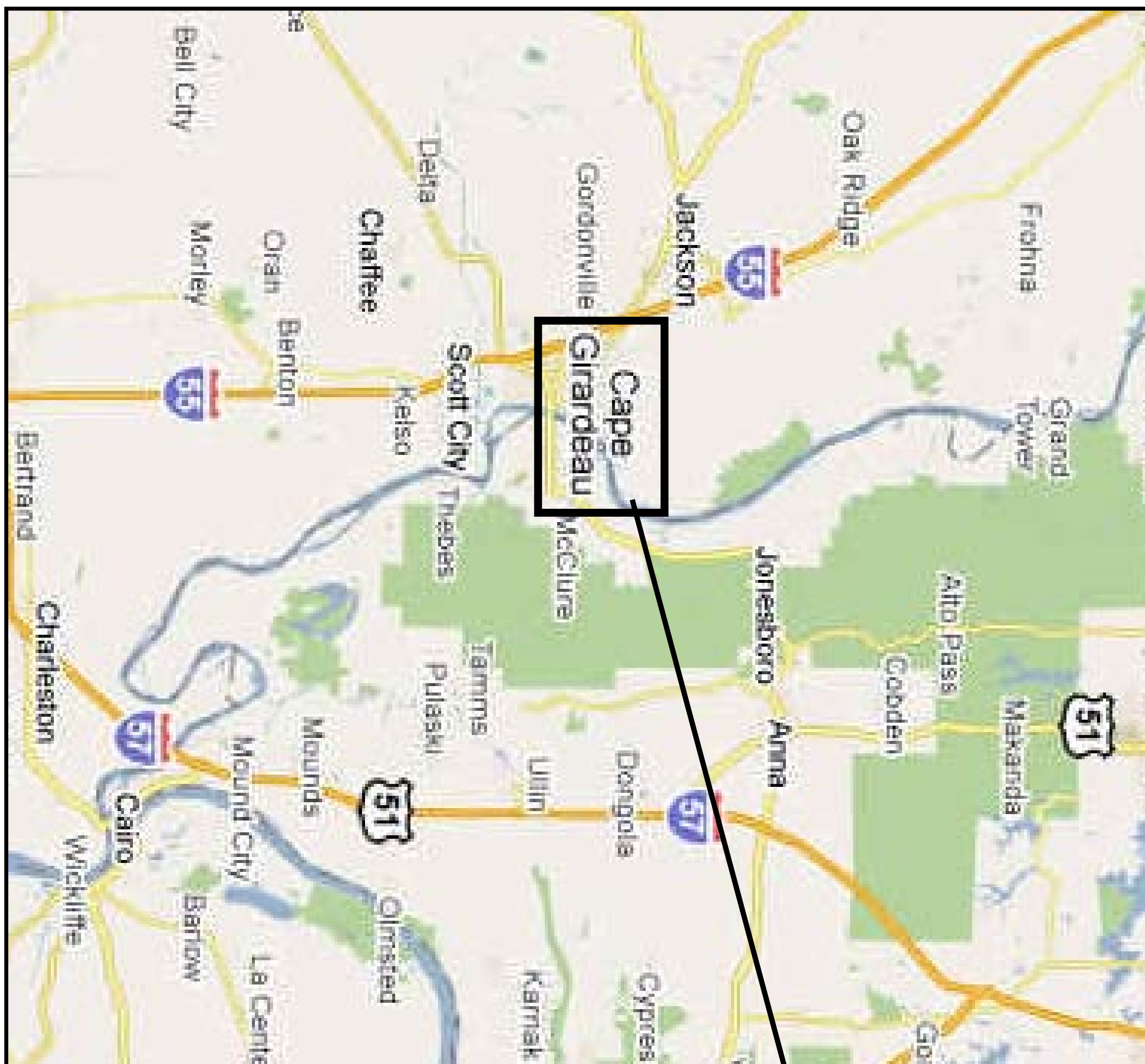
APPENDIX OF PLATES

Plate number 1 through 46 follow:

1. Location and Vicinity Map of the Study Reach
2. 2006 Aerial Photograph of the Study Reach
3. 1817 Government Land Office Survey (1"=1500')
4. 1866 Mississippi River Survey (1"=1500')
5. 1881 Topographic and Hydrographic Survey (1"=1500')
6. 1928 Aerial Photograph (1"=1500')
7. Dredge Locations Within the Study Reach (1"=1500')
8. Hydraulic Sediment Response Model Photograph (1"=1500')
9. January 16, 1956 Hydrographic Survey (1"=1500')
10. December 16-17, 1971 Hydrographic Survey (1"=1500')
11. March 26, 1977 Hydrographic Survey (1"=1500')
12. February 22, 1983 Hydrographic Survey (1"=1500')
13. March 24-25, 1986 Hydrographic Survey (1"=1500')
14. March 4, 2003 Hydrographic Survey (1"=1500')
15. July 30, 2007 Hydrographic Survey (1"=1500')
16. Base Test (1"=1500')
17. Alternative 1 (1"=1500')
18. Alternative 2 (1"=1500')
19. Alternative 3 (1"=1500')
20. Alternative 4 (1"=1500')
21. Alternative 5 (1"=1500')
22. Alternative 6 (1"=1500')
23. Alternative 7 (1"=1500')
24. Alternative 8 (1"=1500')
25. Alternative 9 (1"=1500')
26. Alternative 10 (1"=1500')
27. Alternative 11 (1"=1500')

28. Alternative 12 (1”=1500’)
29. Alternative 13 (1”=1500’)
30. Alternative 14 (1”=1500’)
31. Alternative 15 (1”=1500’)
32. Alternative 16 (1”=1500’)
33. Alternative 17 (1”=1500’)
34. Alternative 18 (1”=1500’)
35. Alternative 19 (1”=1500’)
36. Alternative 20 (1”=1500’)
37. Alternative 21 (1”=1500’)
38. Alternative 22 (1”=1500’)
39. Alternative 23 (1”=1500’)
40. Alternative 24 (1”=1500’)
41. Alternative 25 (1”=1500’)
42. Alternative 26 (1”=1500’)
43. Alternative 27 (1”=1500’)
44. Alternative 28 (1”=1500’)
45. Alternative 29 (1”=1500’)
46. Alternative 30 (1”=1500’)





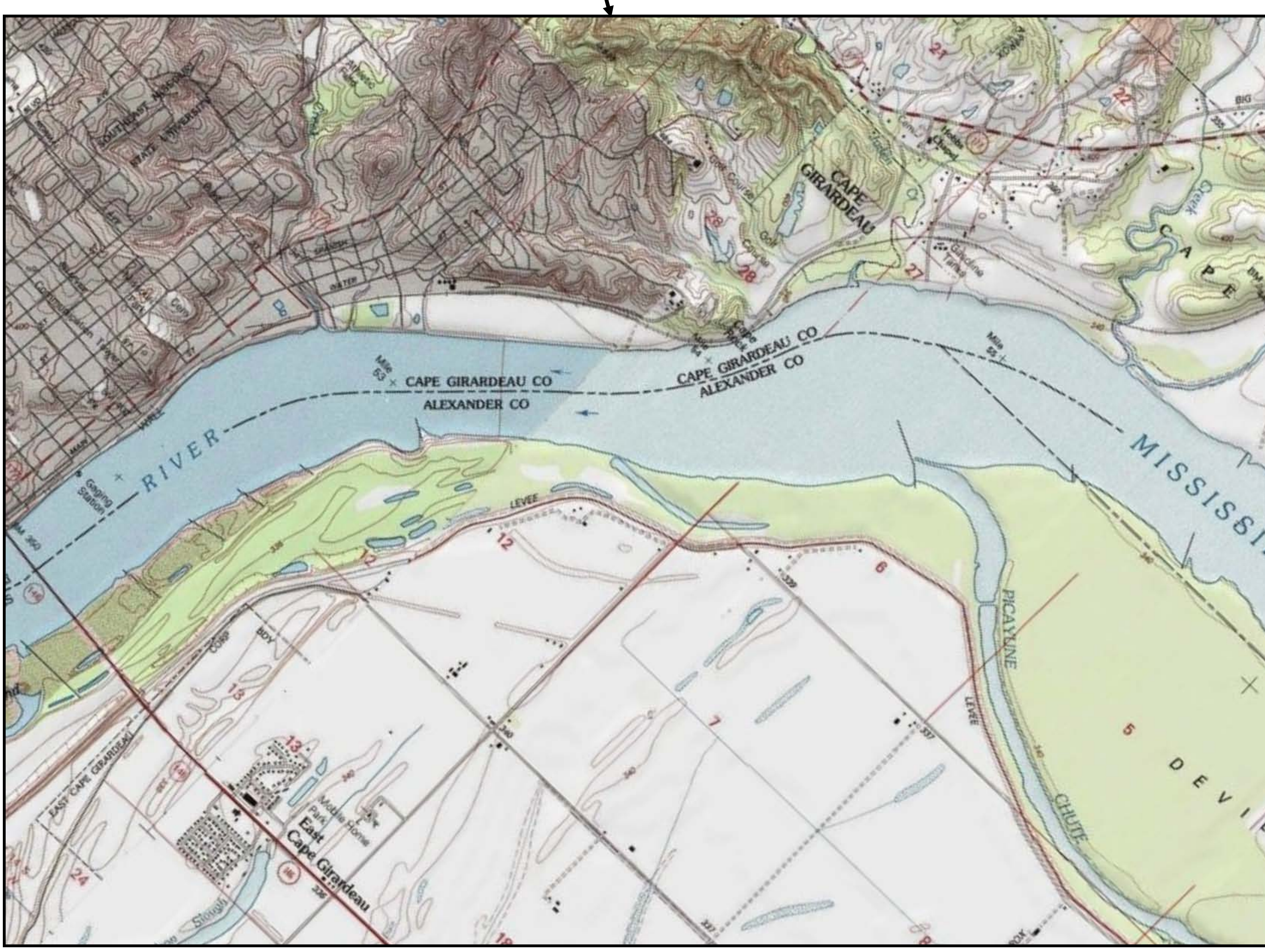


PLATE NUMBER	**1**

LOCATION AND VICINITY MAP

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: January 26, 2011
	PREPARED BY: E. BRAUER, P.E. / DRAWN BY: E. BRAUER, P.E.
UPPER MISSISSIPPI RIVER BASIN Cape Rock HSR Model River Miles 57.0-50.0	CHECKED BY: R. DAVINROY, P.E.
	FILE NAME: L:\Cape Rock

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District®

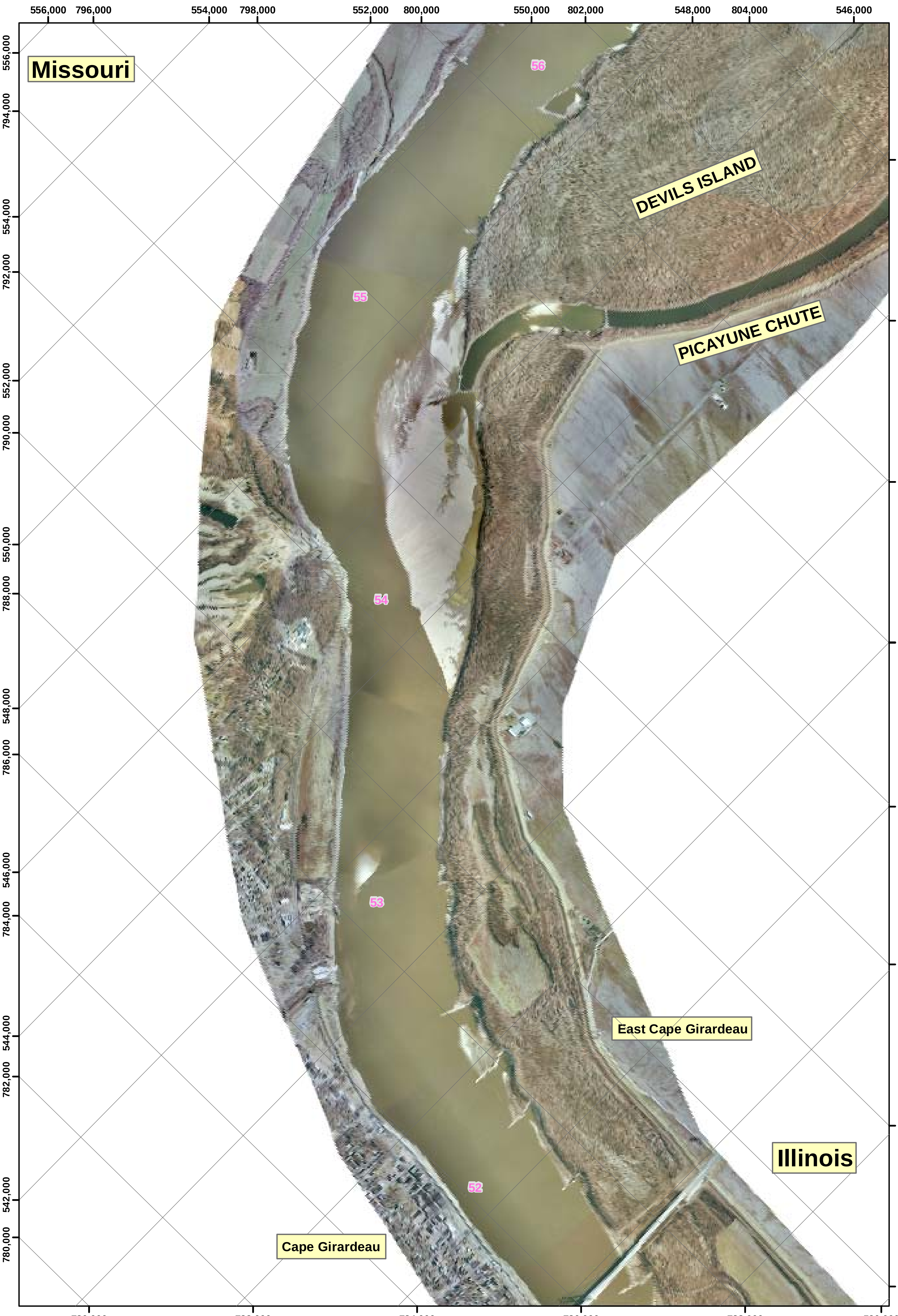


PLATE NUMBER
2

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

2006 Aerial Photograph
of the Study Reach

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

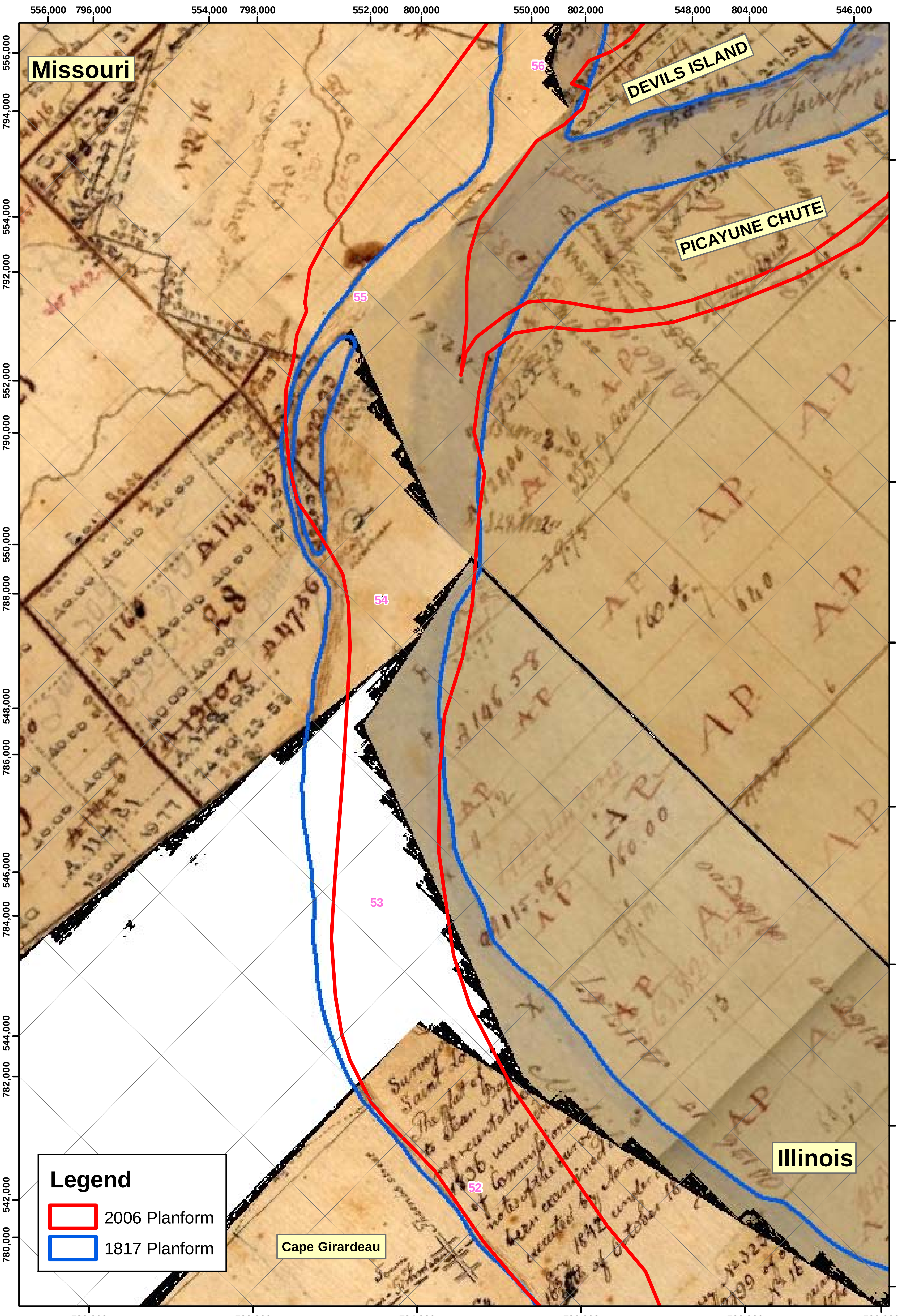


PLATE NUMBER

3

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1817 Government Land Office Survey

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

N E S W

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St. Louis District

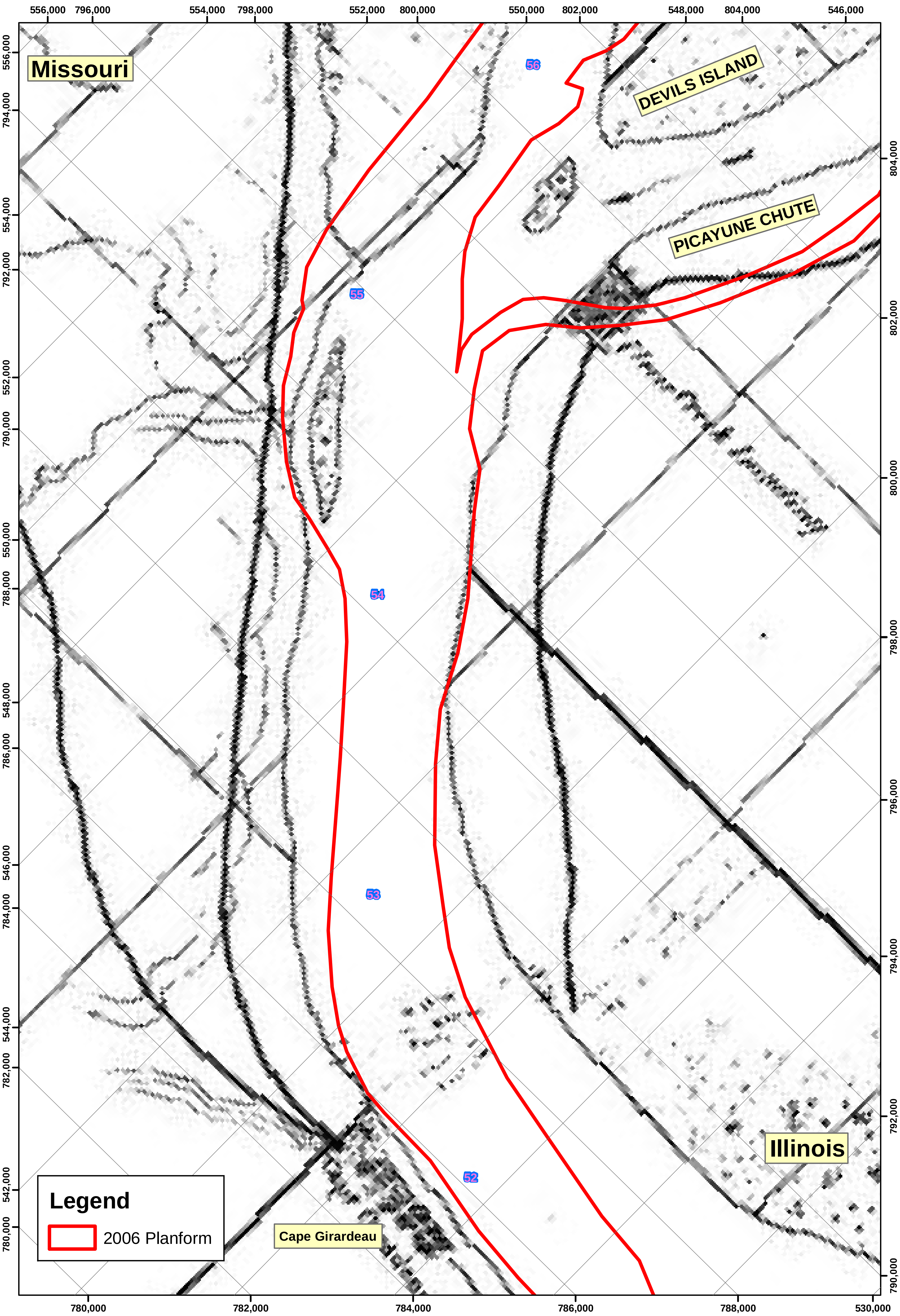

PLATE NUMBER

4

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1866 Mississippi River Survey

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

N E S W

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St. Louis District

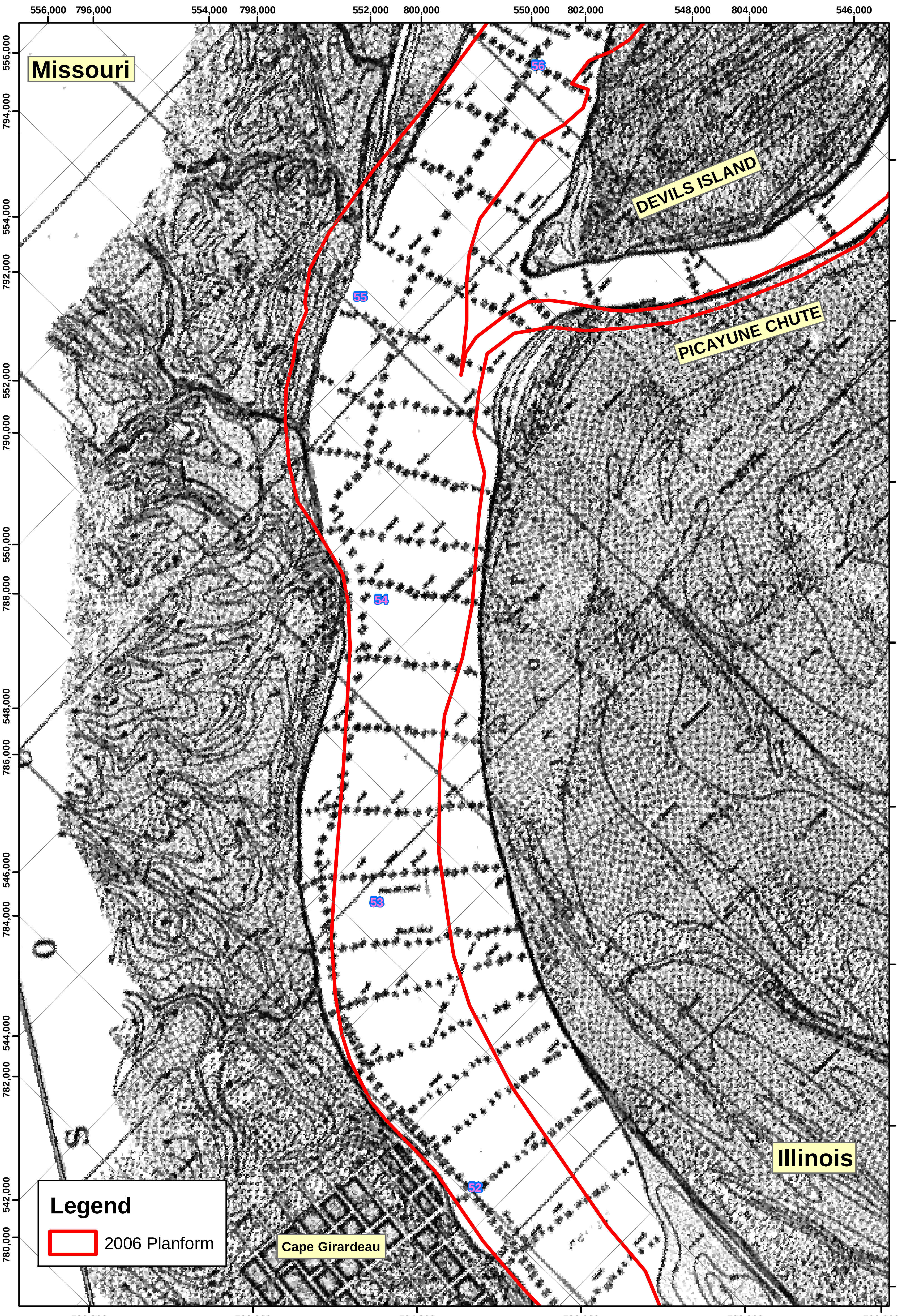

PLATE NUMBER

5

0 750 1,500 3,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1881 Topographic and Hydrographic Survey

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011

PREPARED BY: E. BRAUER, P.E.

DRAWN BY: A. ROCKWELL

CHECKED BY: R. DAVINROY, P.E.

FILE NAME: L:\Cape Rock

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St. Louis District

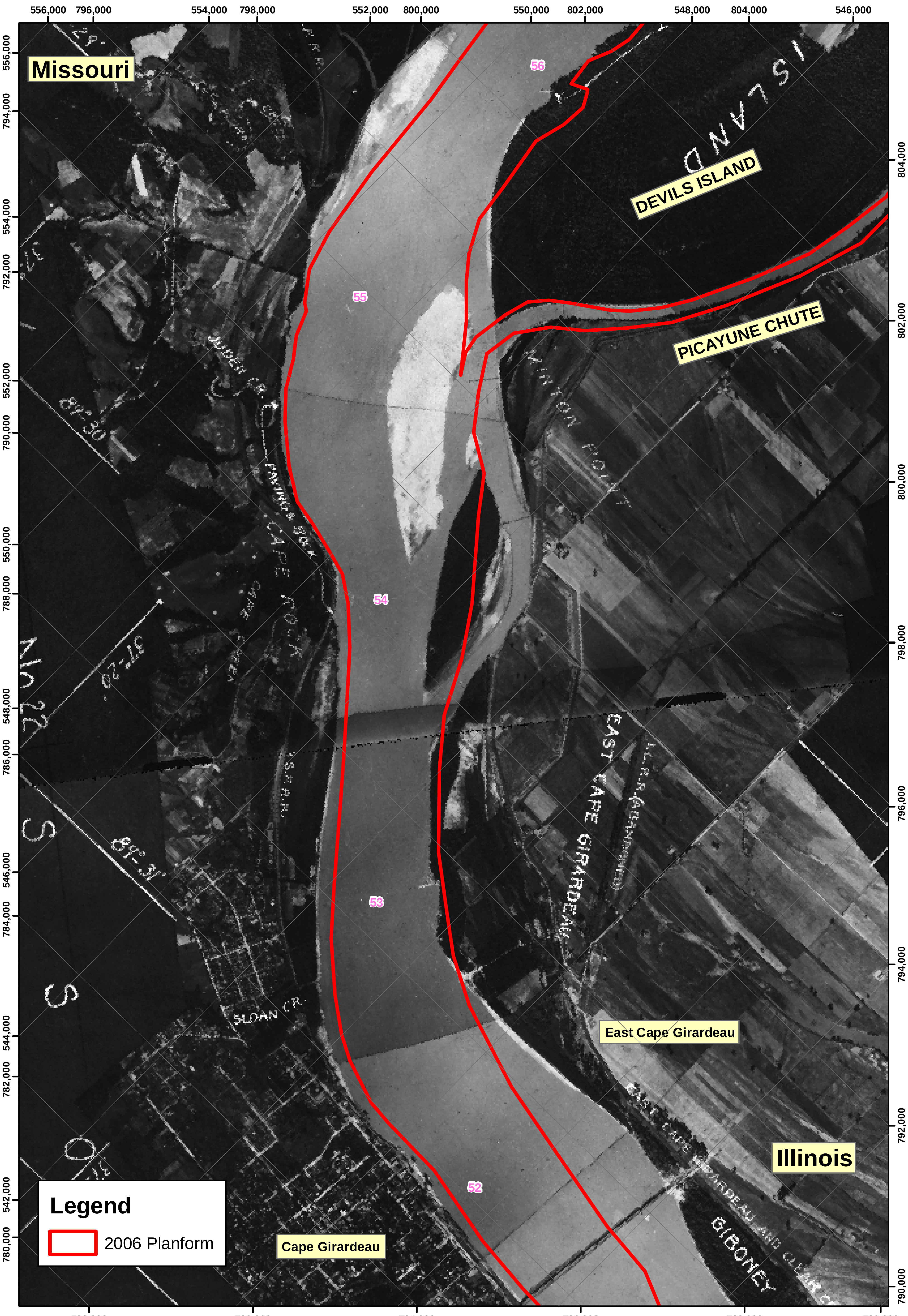

PLATE NUMBER
6

0 750 1,500 3,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1928 Aerial Photograph

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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St. Louis District

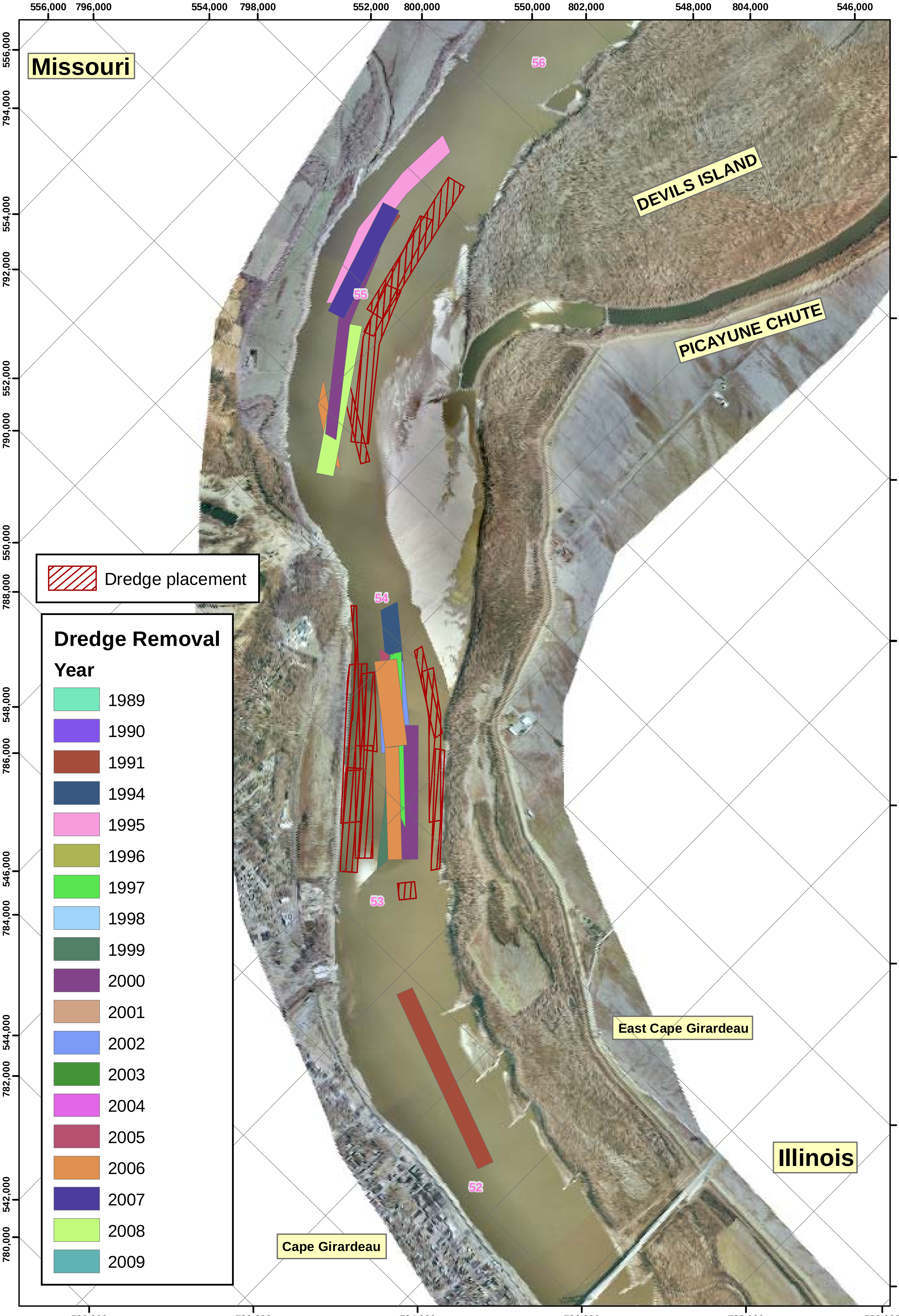

PLATE NUMBER

7

0 750 1,500 3,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Dredge Locations Within the Study Reach
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: May 17, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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St. Louis District

PLATE NUMBER
8

Model Photograph

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: January 26, 2011	
	PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
UPPER MISSISSIPPI RIVER BASIN Cape Rock HSR Model River Miles 57.0-50.0	CHECKED BY: R. DAVINROY, P.E.	
	FILE NAME: L:\Cape Rock	

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US Army Corps of Engineers
St. Louis District®

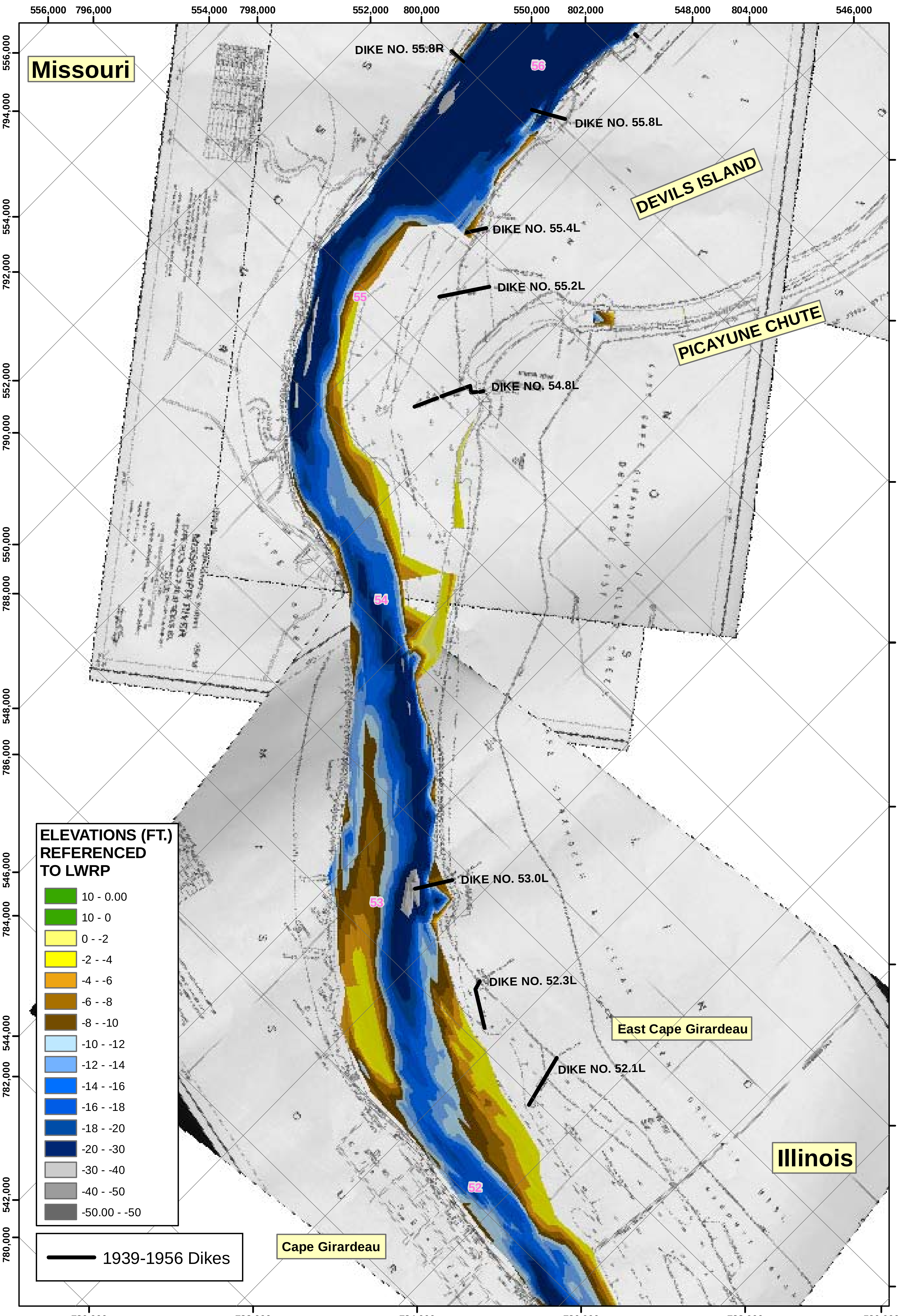

PLATE NUMBER

9

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

January 16,1956
Hydrographic Survey
+5.3 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 26, 2011	
	PREPARED BY: E. BRAUER, P.E	DRAWN BY: A. ROCKWELL
UPPER MISSISSIPPI RIVER BASIN Cape Rock HSR Model River Miles 57.0-50.0	CHECKED BY: R. DAVINROY, P.E.	
	FILE NAME: L:\Cape Rock	

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US Army Corps of Engineers St. Louis District

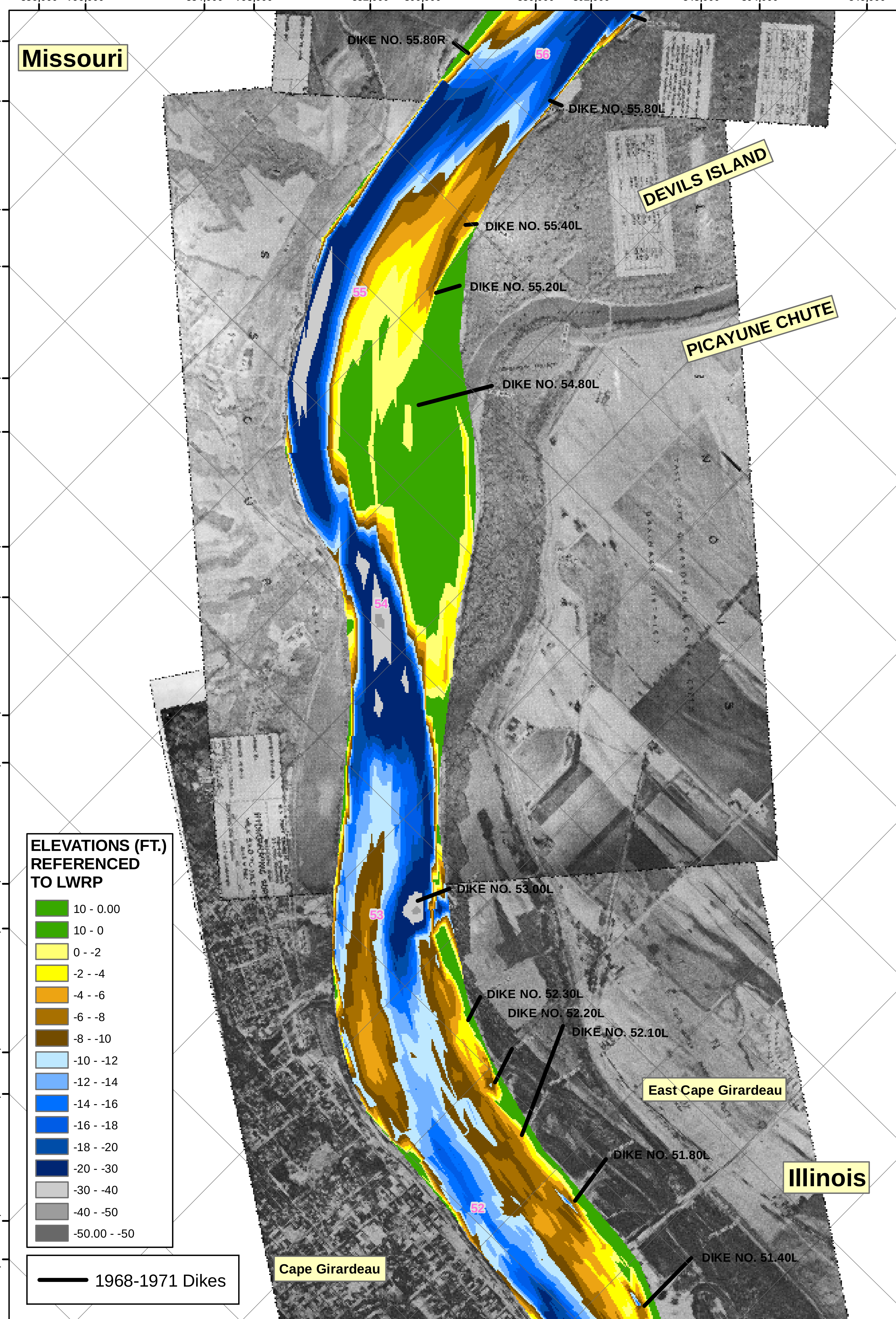

PLATE NUMBER
10

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

December 16-17, 1971
Hydrographic Survey
+20.9 - +23.3 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

N E S W

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US Army Corps of Engineers
St. Louis District

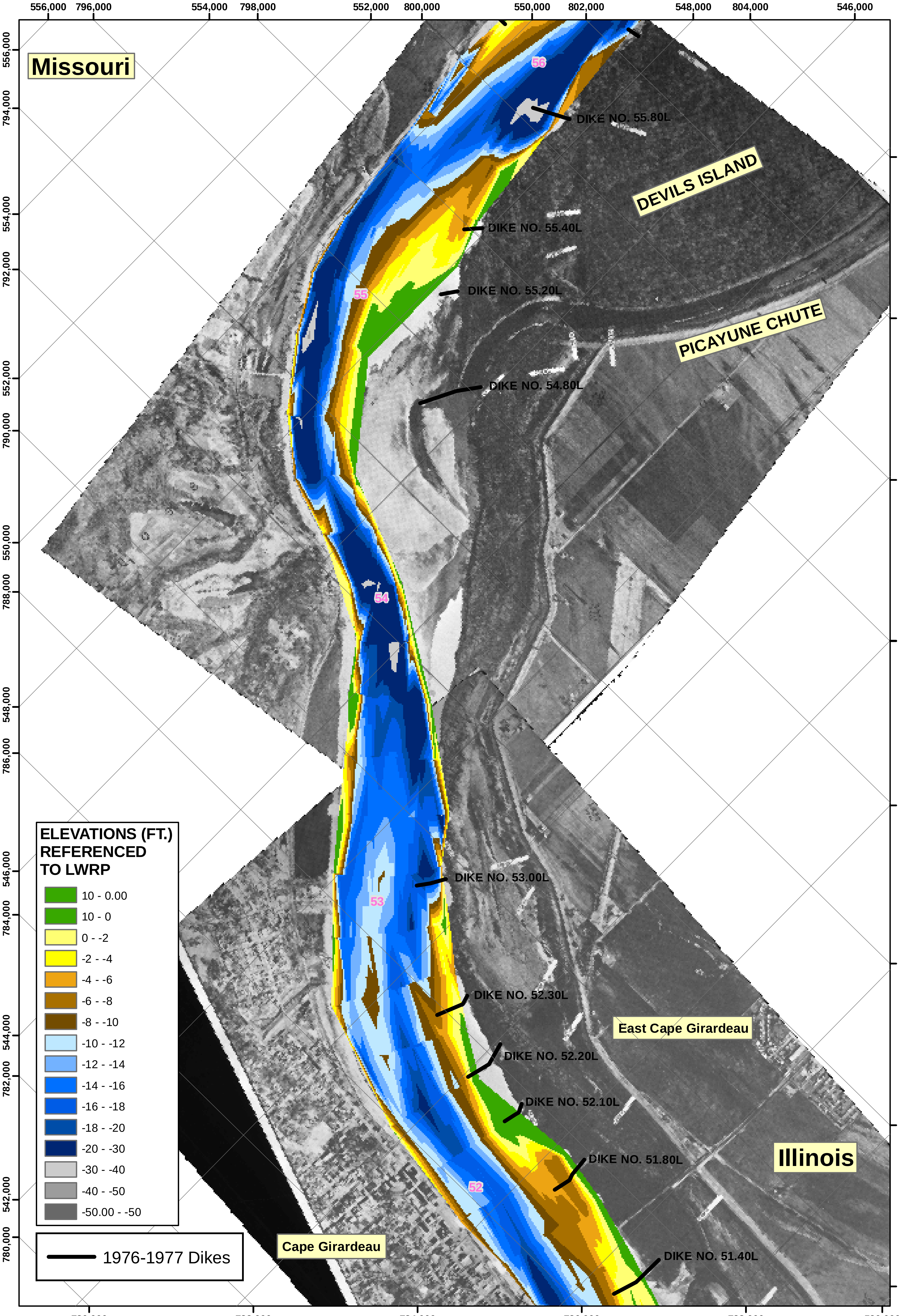

PLATE NUMBER
11

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

March 26,1977
Hydrographic Survey
+12.2 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

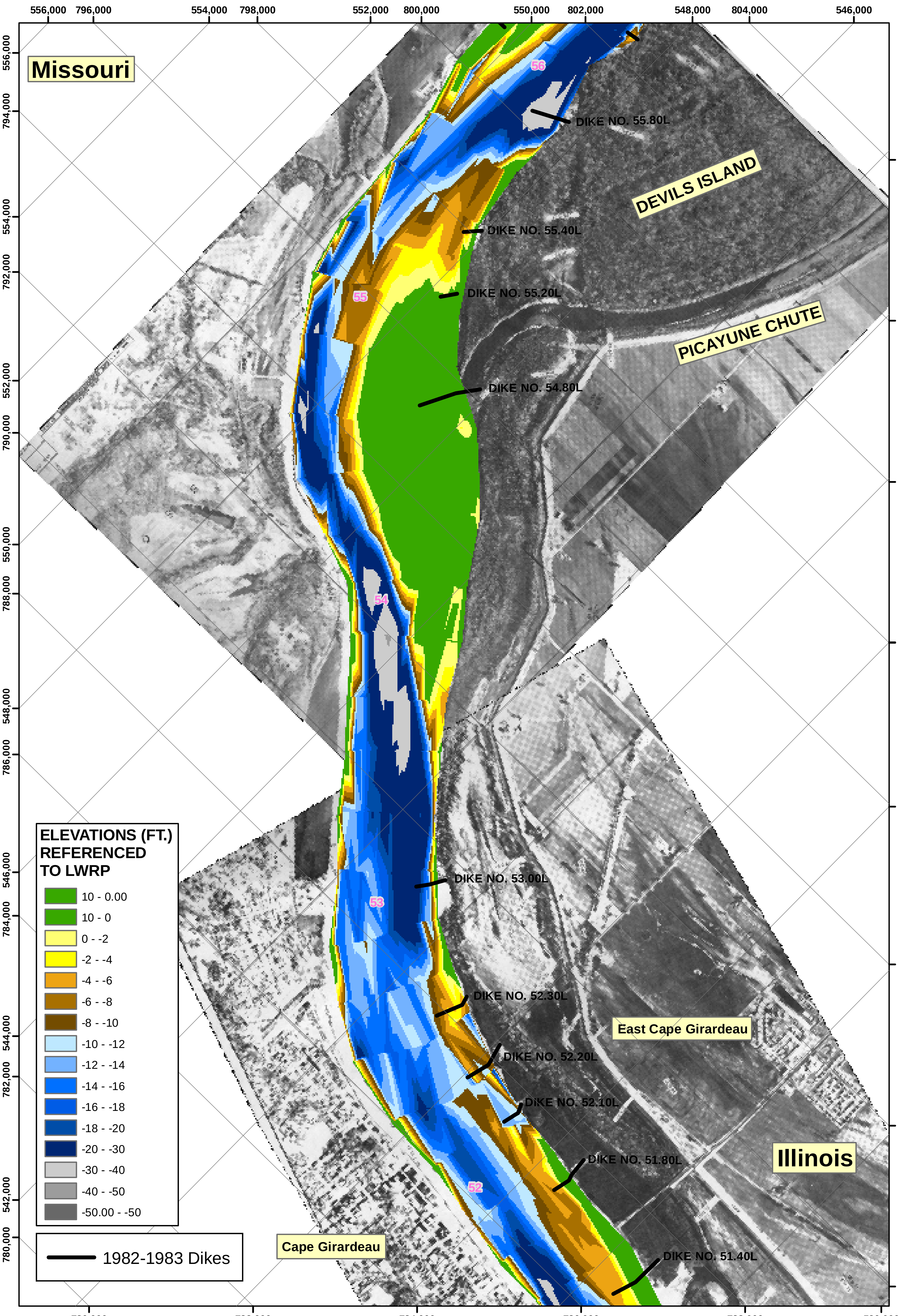

PLATE NUMBER
12

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

February 22,1983
Hydrographic Survey
+25.0 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

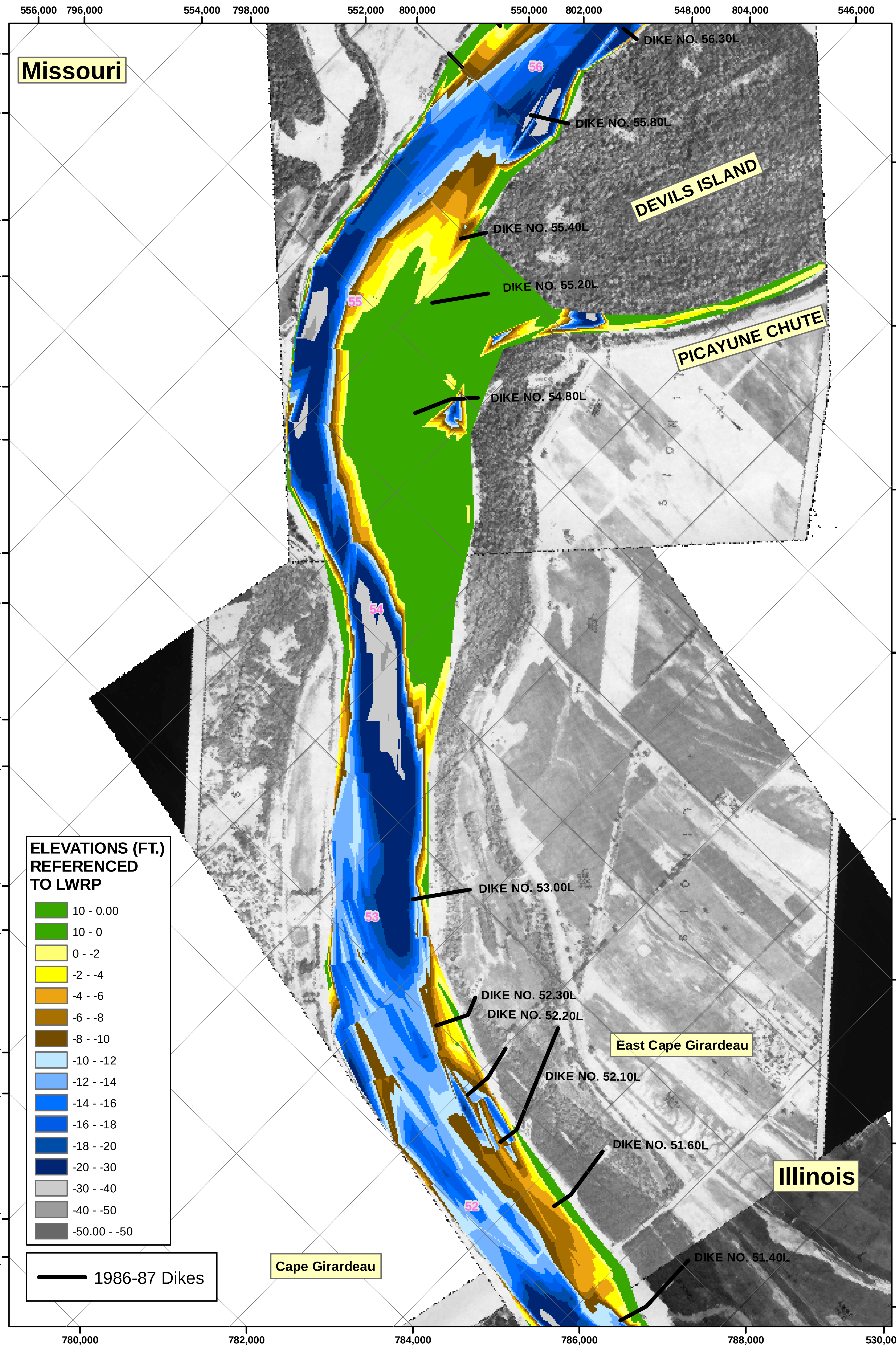

PLATE NUMBER
13

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

March 24-25,1986
Hydrographic Survey
+28.13 - +28.62 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
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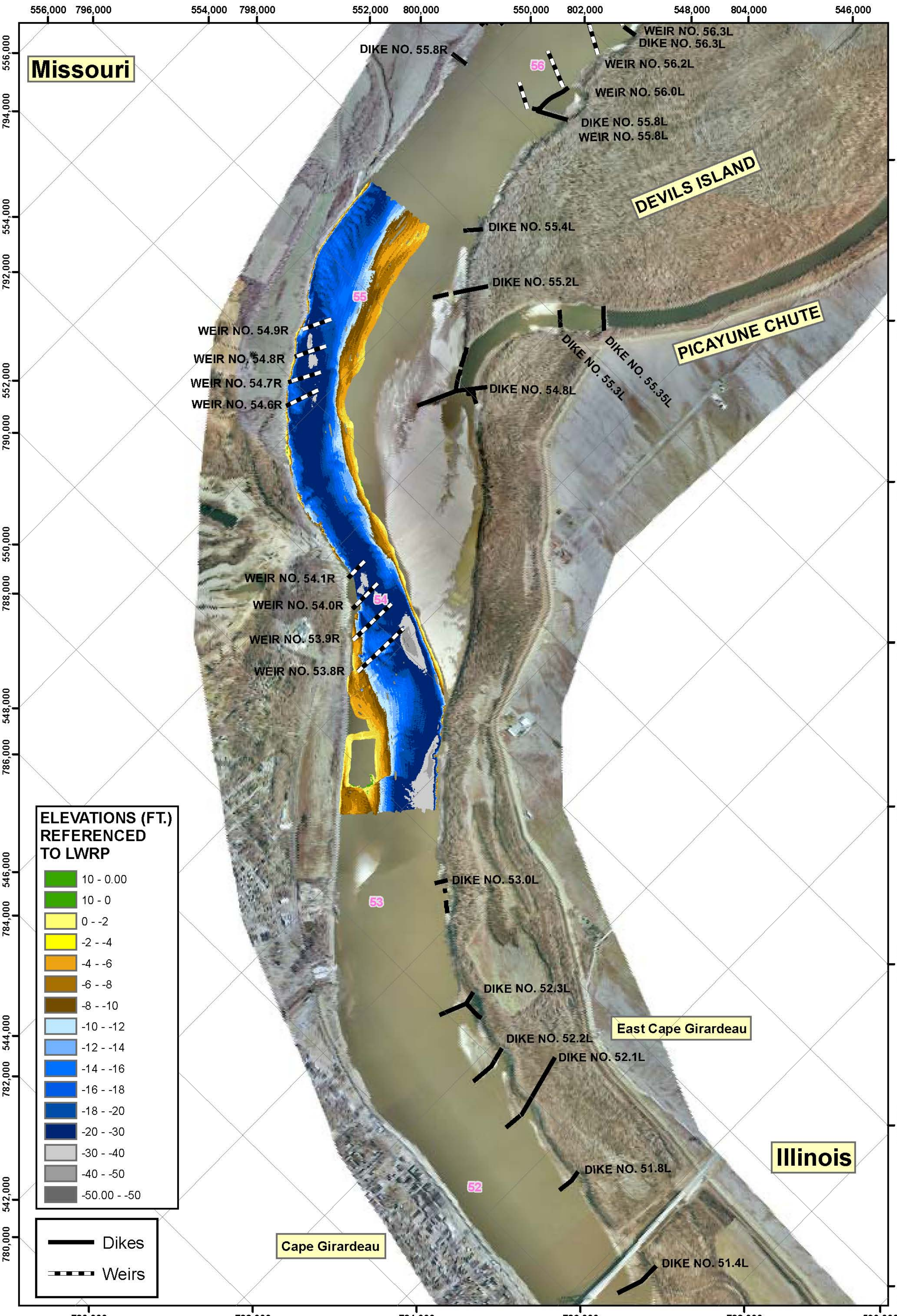

PLATE NUMBER

14

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

March 4, 2003 Bendway Weir Field
Hydrographic Survey
+13.94 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

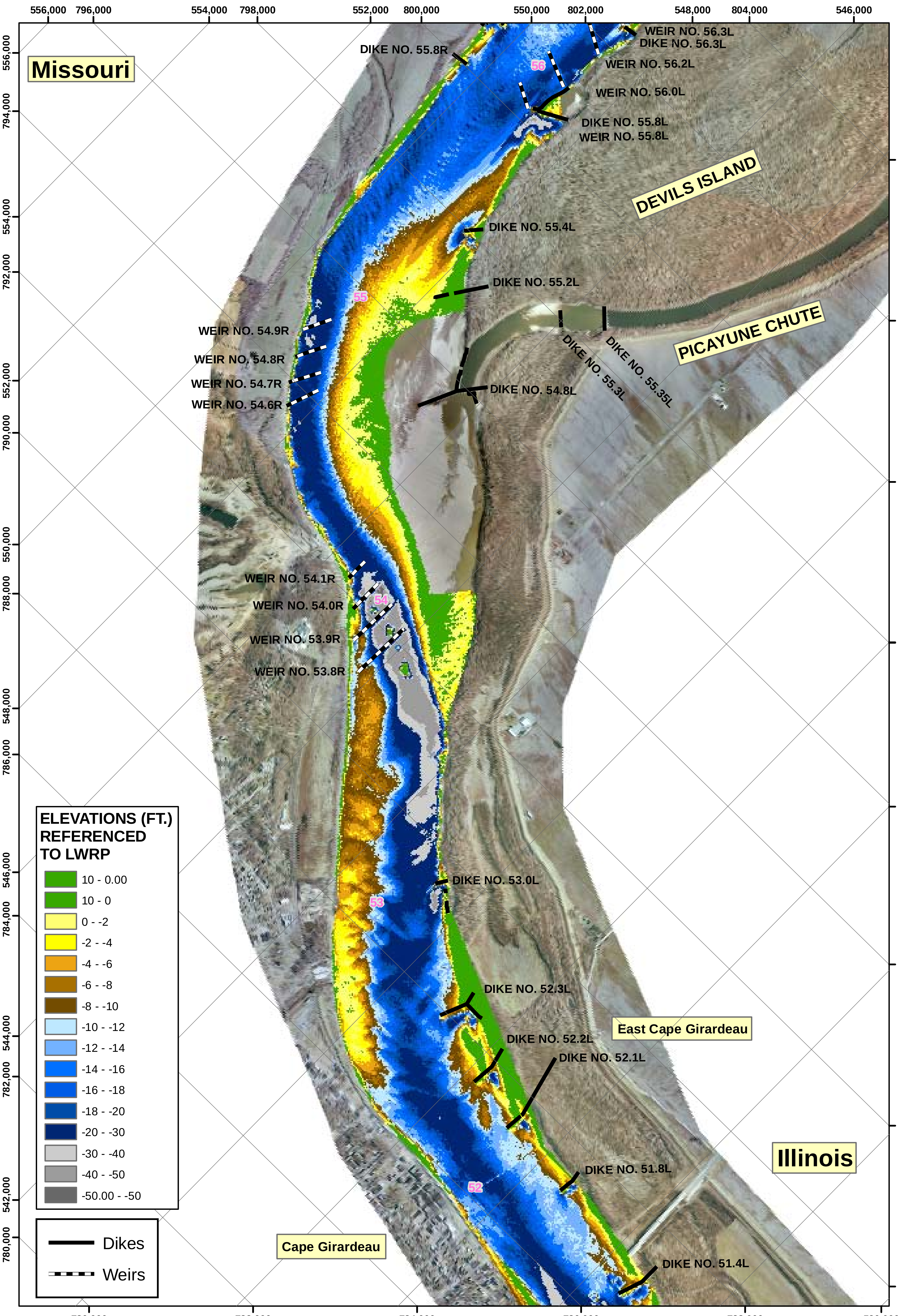

PLATE NUMBER 15

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

July 30, 2007
Hydrographic Survey
+14.65 Cape Girardeau Gage

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: April 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: A. ROCKWELL
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

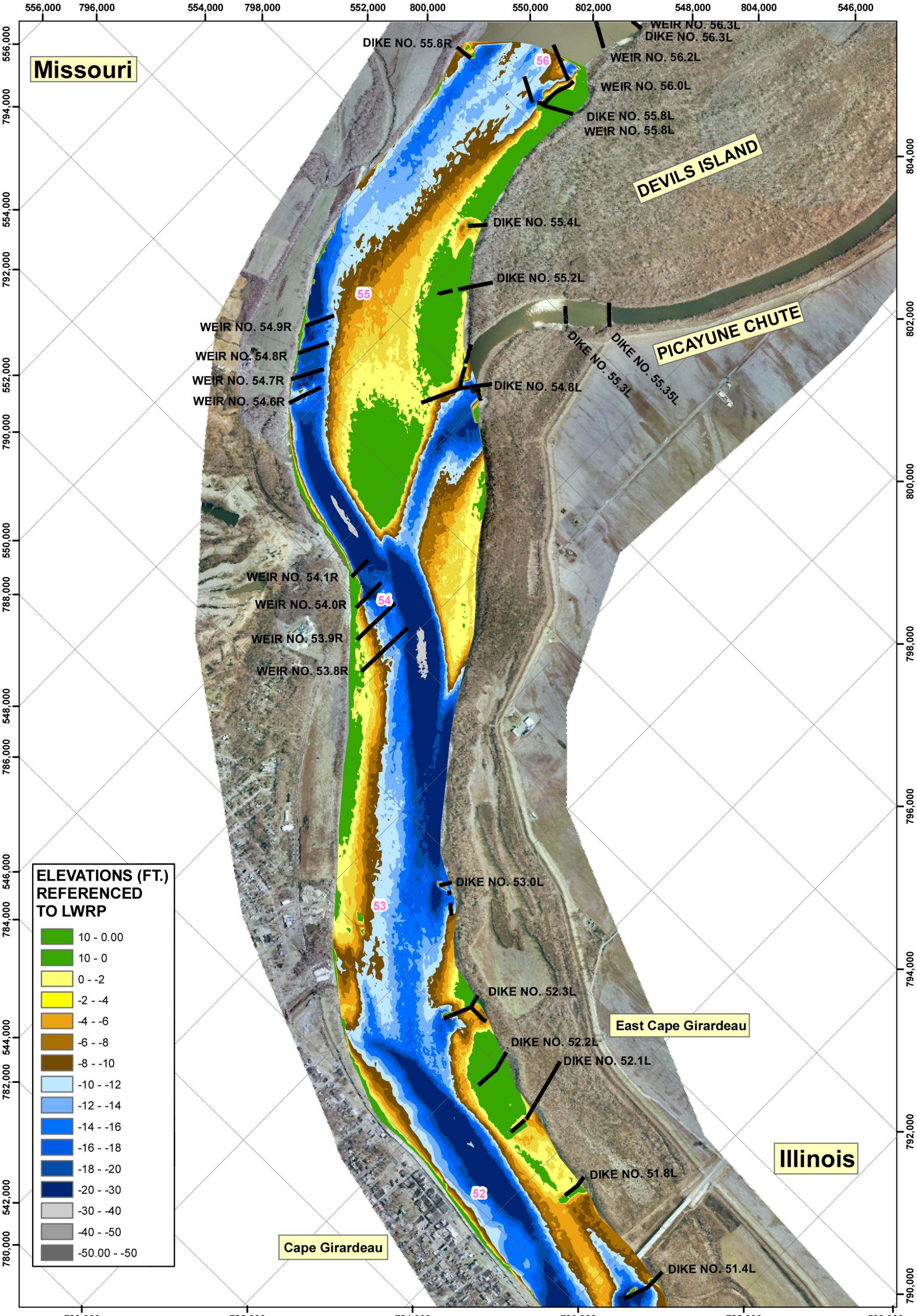

PLATE NUMBER 16

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

BASE TEST
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

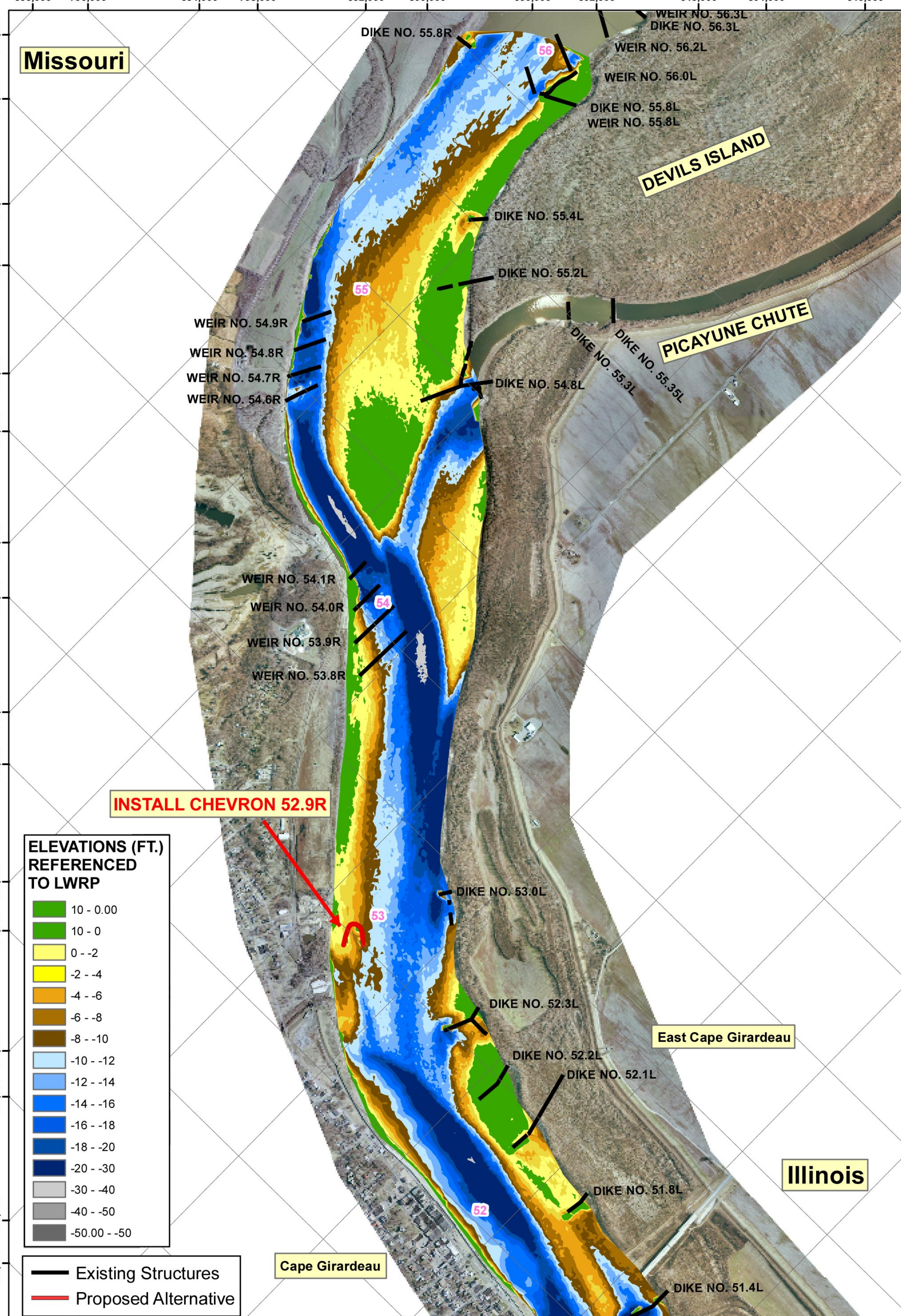

PLATE NUMBER 17

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 1
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District

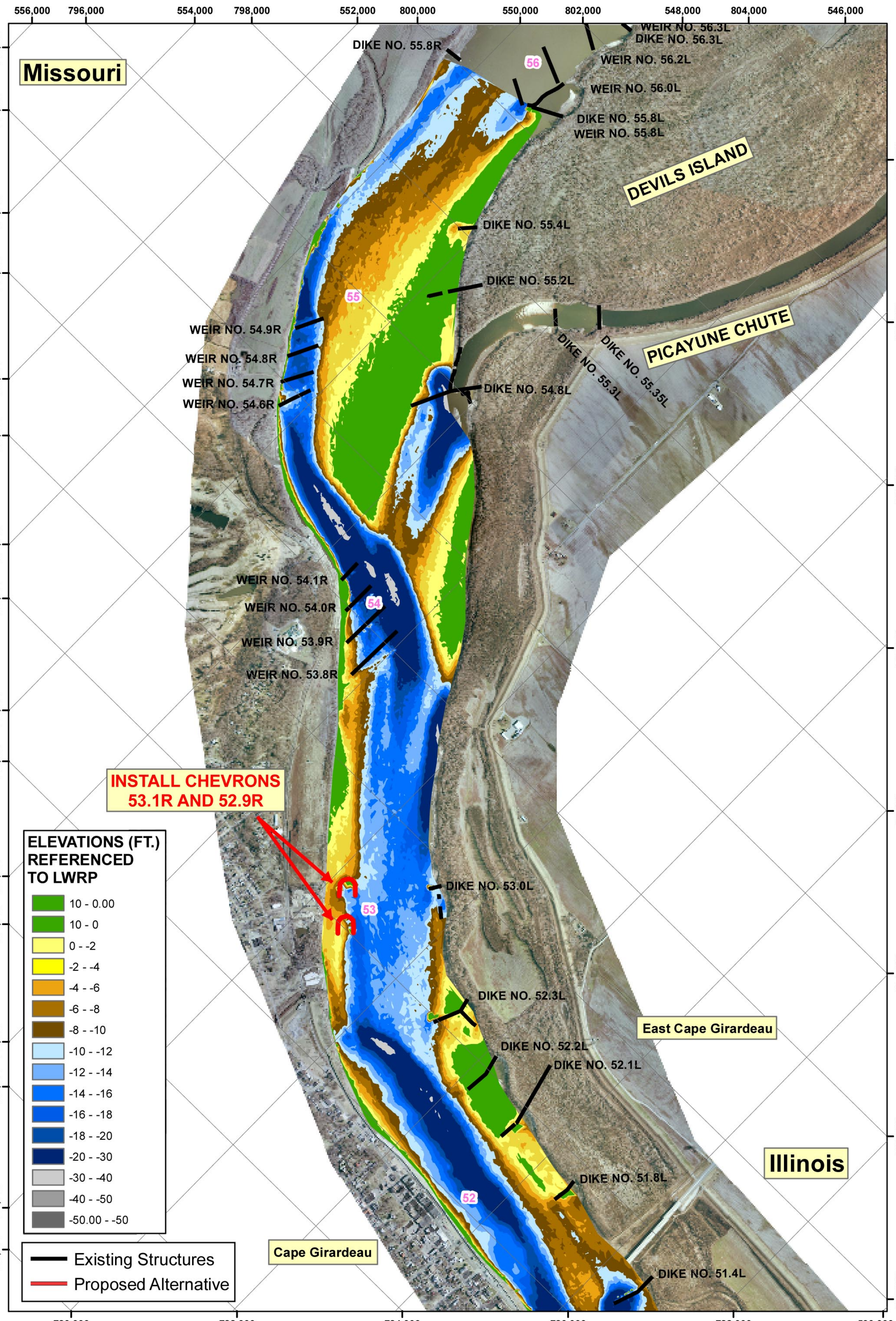

PLATE NUMBER 18

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 2
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock

N E S W

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St. Louis District

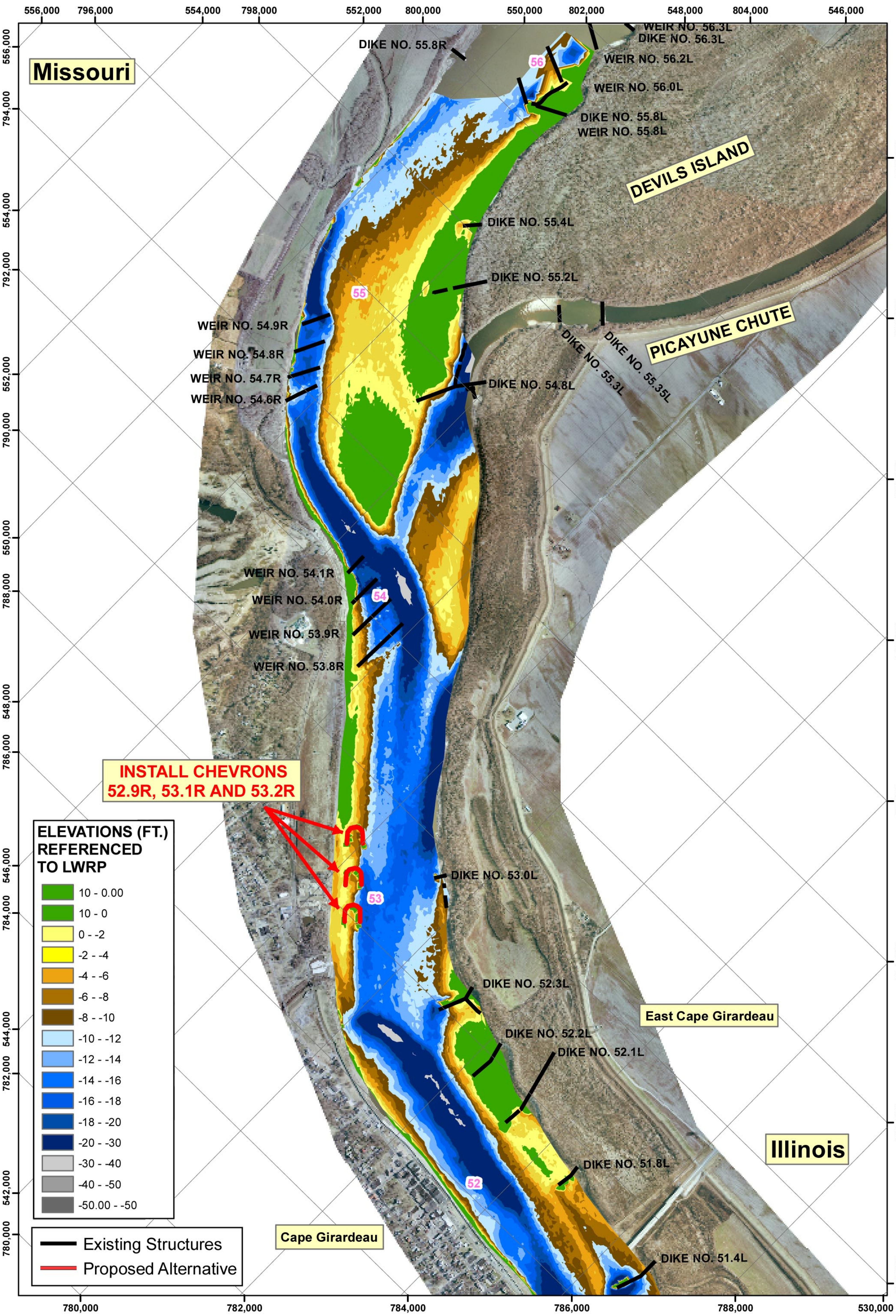

PLATE NUMBER

19

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 3

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

APPLIED RIVER ENGINEERING CENTER

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St. Louis District

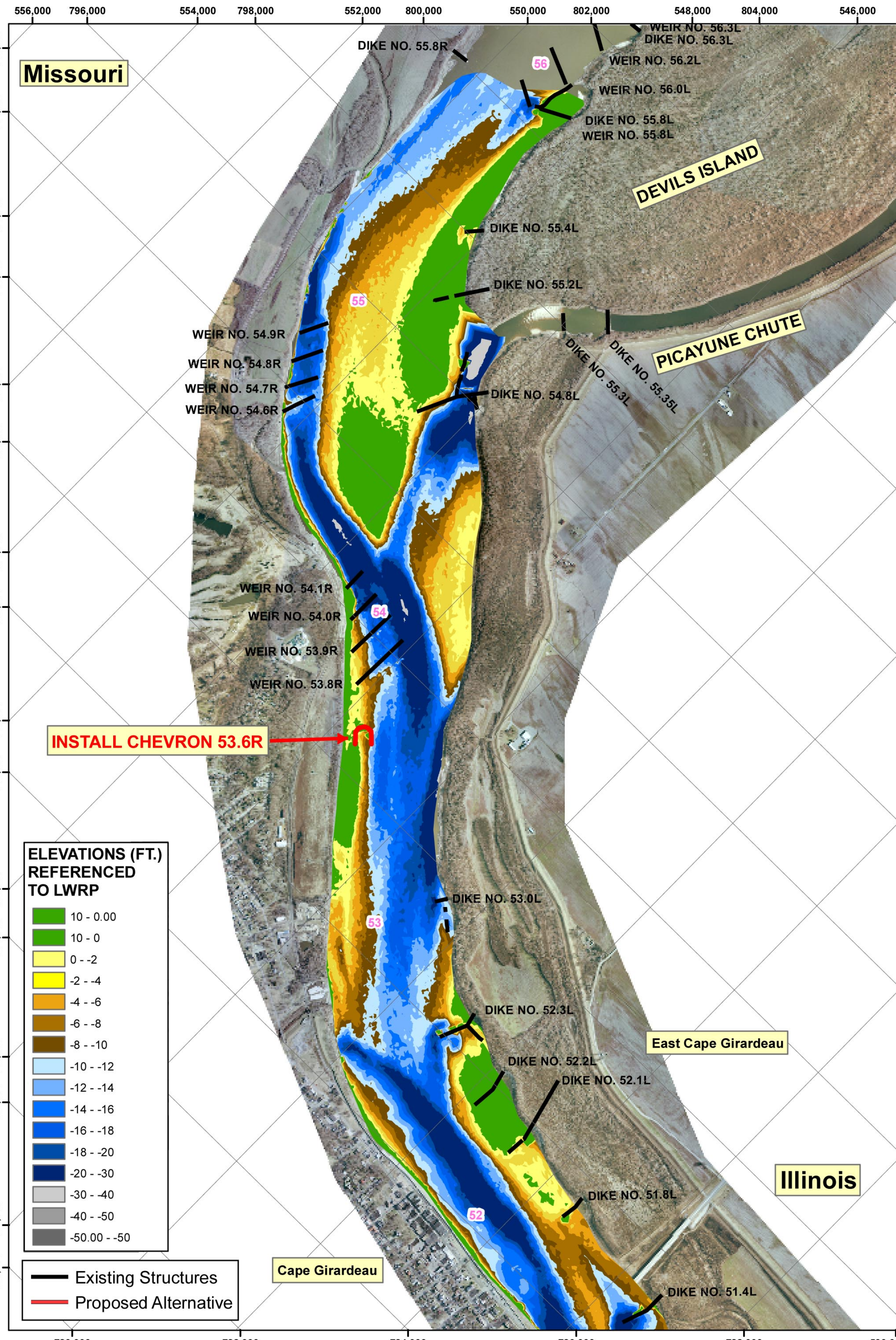

PLATE NUMBER
20

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 4
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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St. Louis District

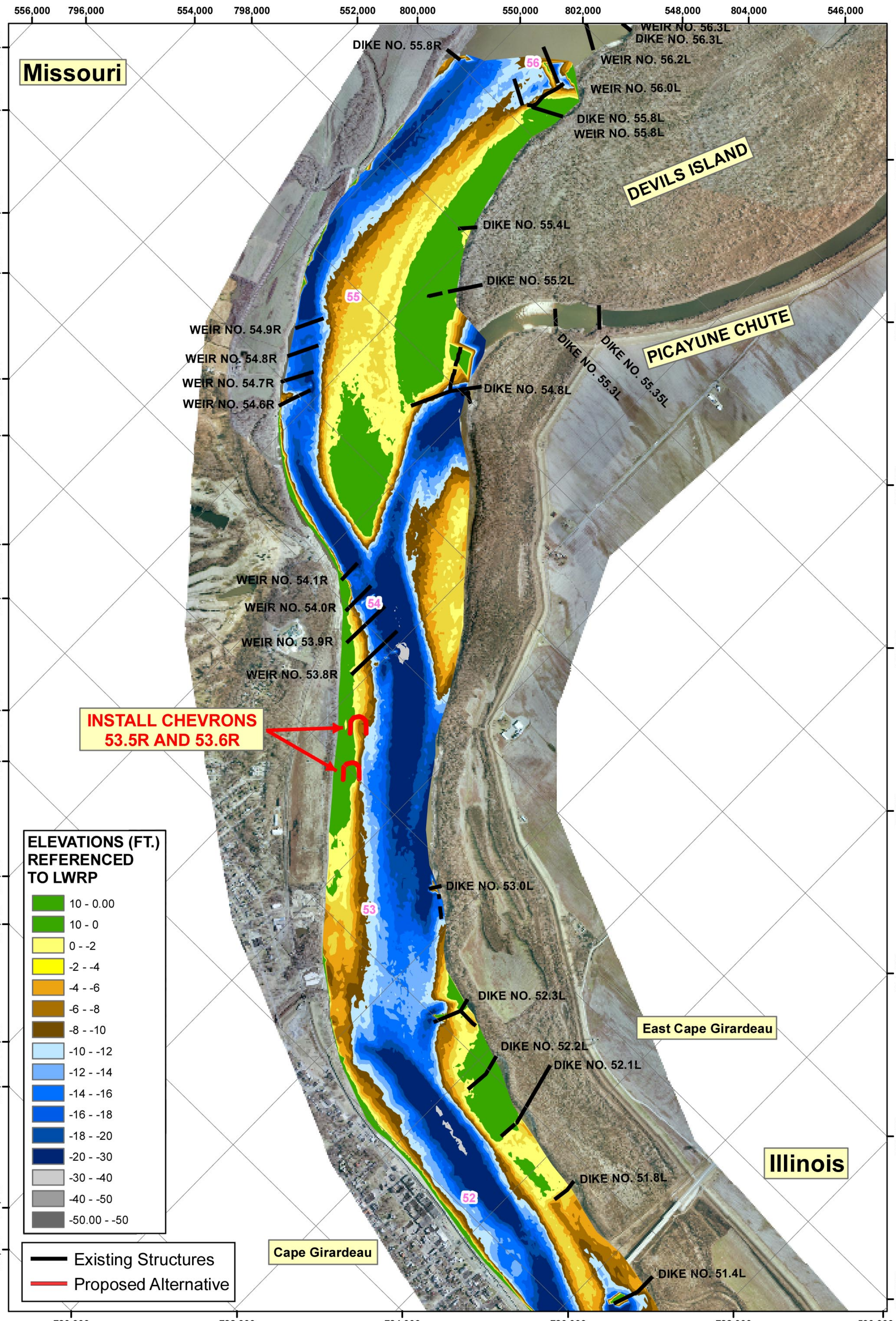

PLATE NUMBER

21

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 5

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011

PREPARED BY: E. BRAUER, P.E. DRAWN BY: E. BRAUER, P.E.

CHECKED BY: R. DAVINROY, P.E.

FILE NAME: L:\Cape Rock

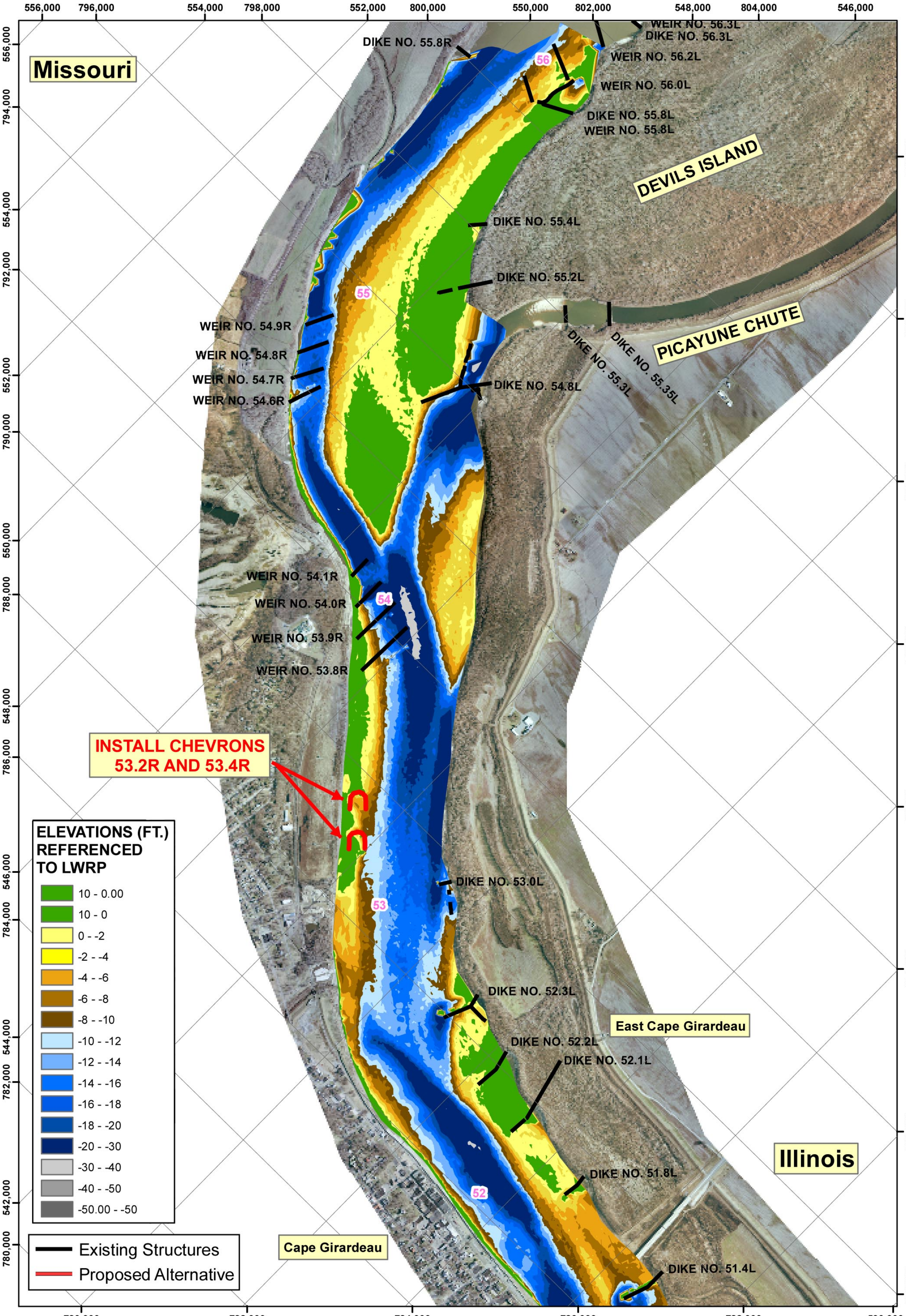

PLATE NUMBER

22

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 6

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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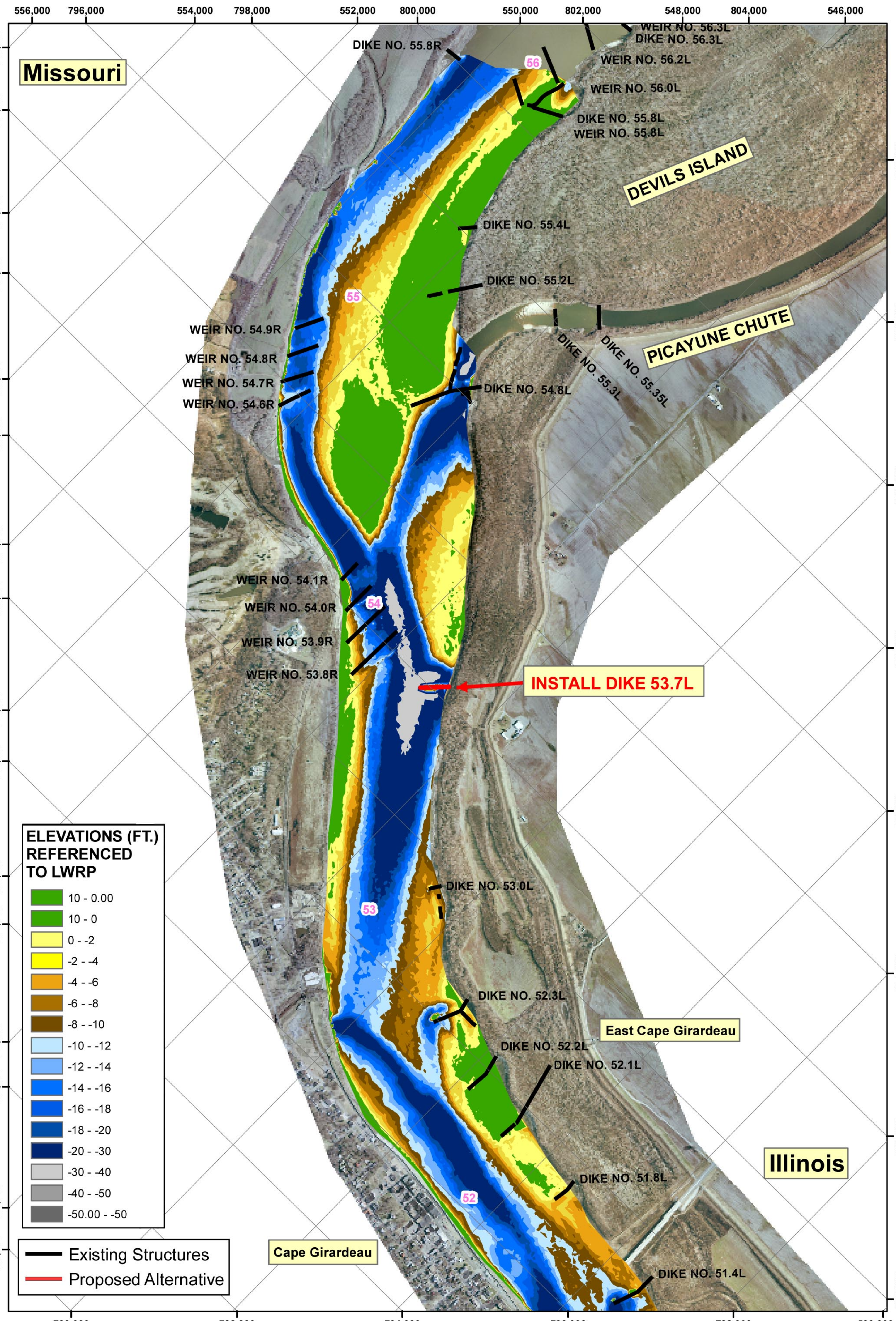

PLATE NUMBER 23

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 7
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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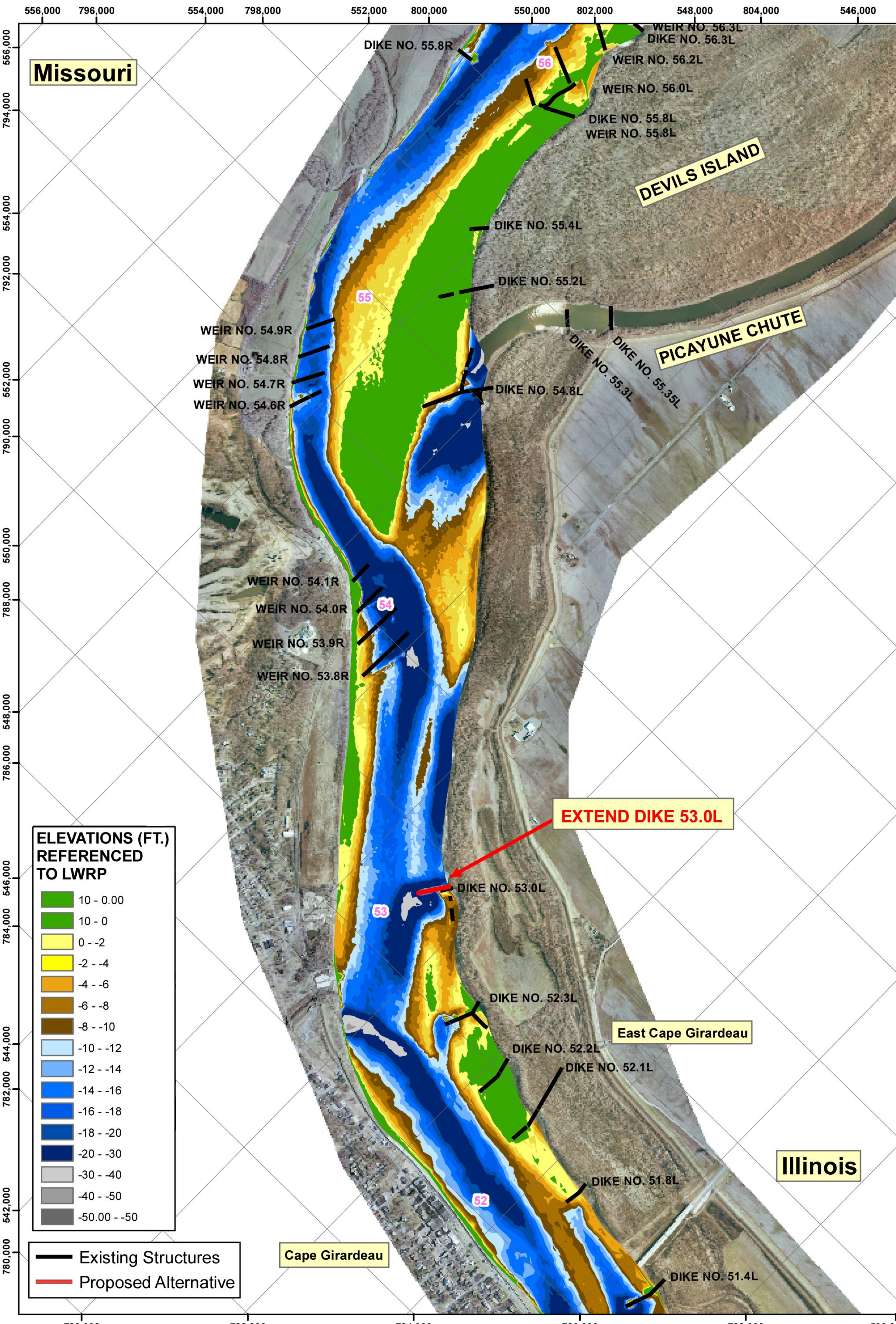

PLATE NUMBER 24

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 8
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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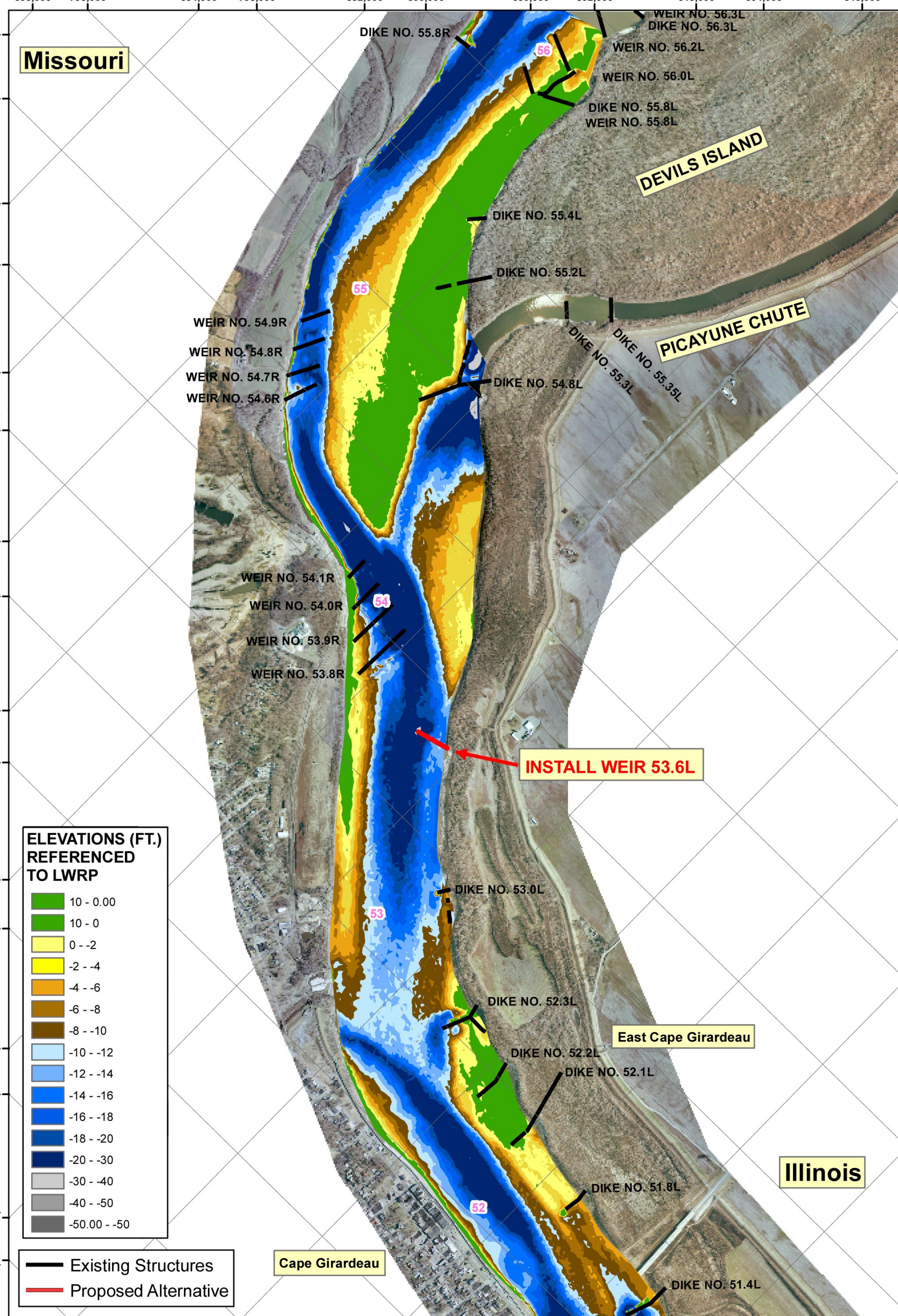

PLATE NUMBER
25

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 9

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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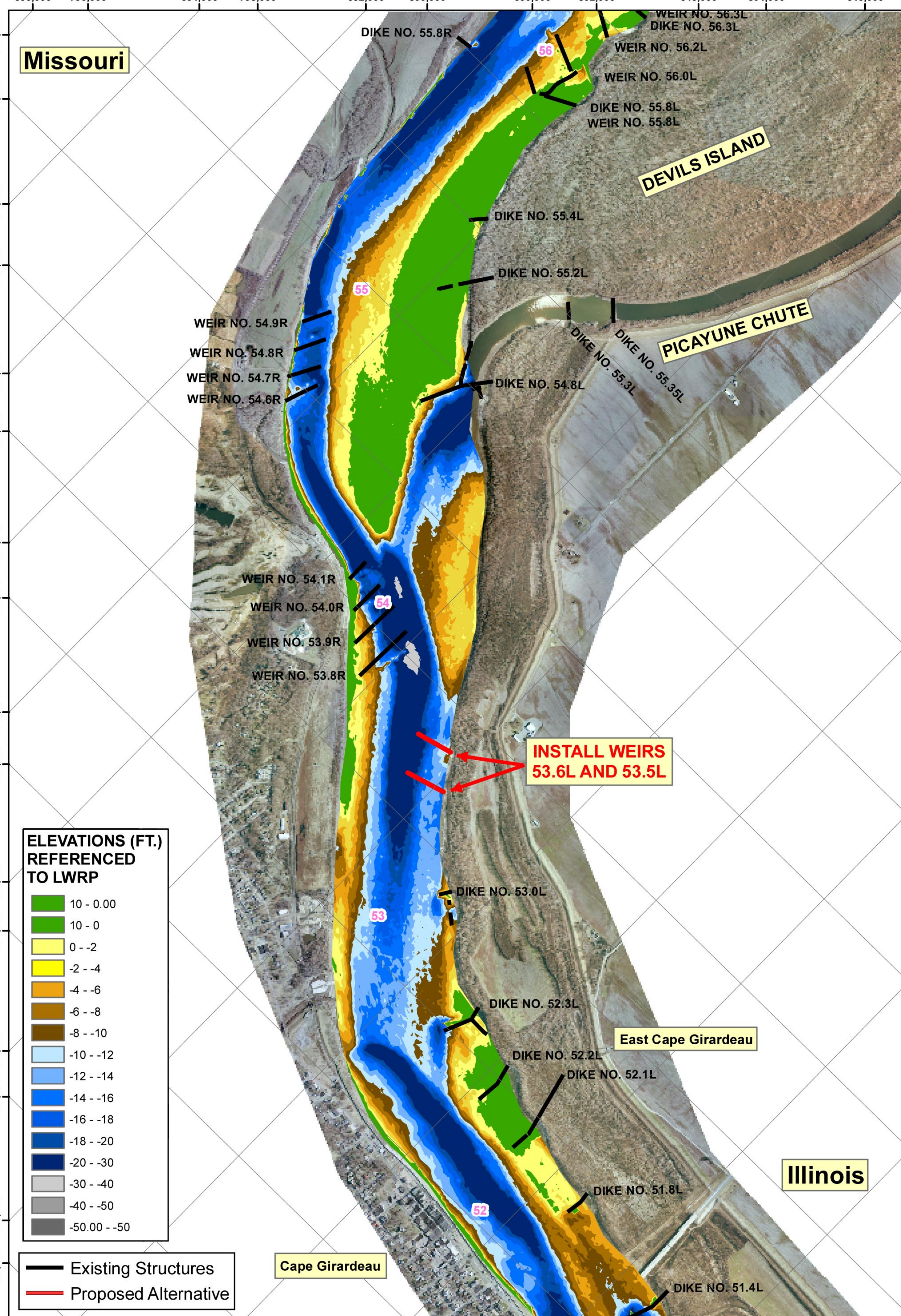

PLATE NUMBER 26

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 10
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
PREPARED BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock

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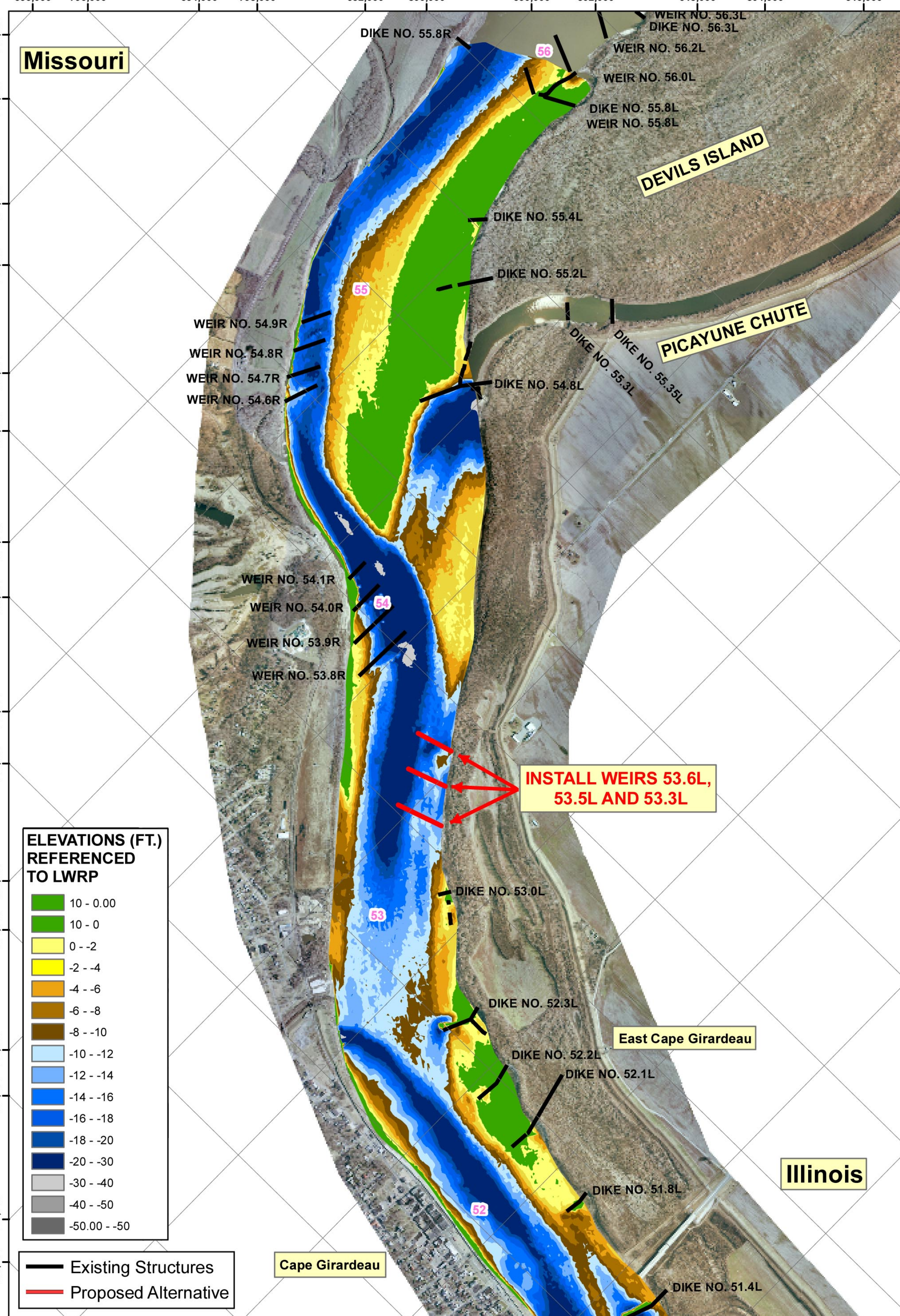

PLATE NUMBER 27

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 11
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock	

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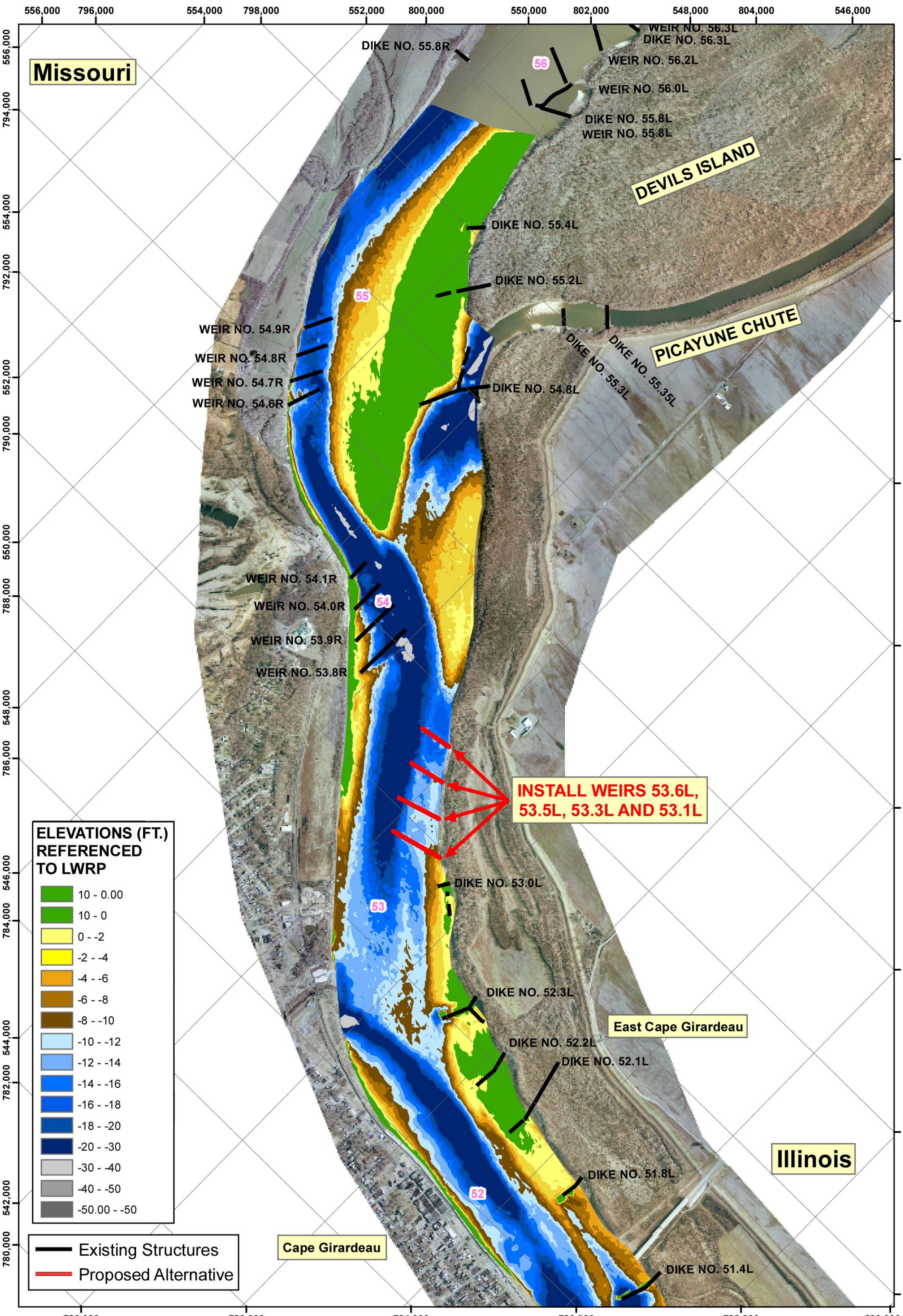

PLATE NUMBER 28

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 12
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock	

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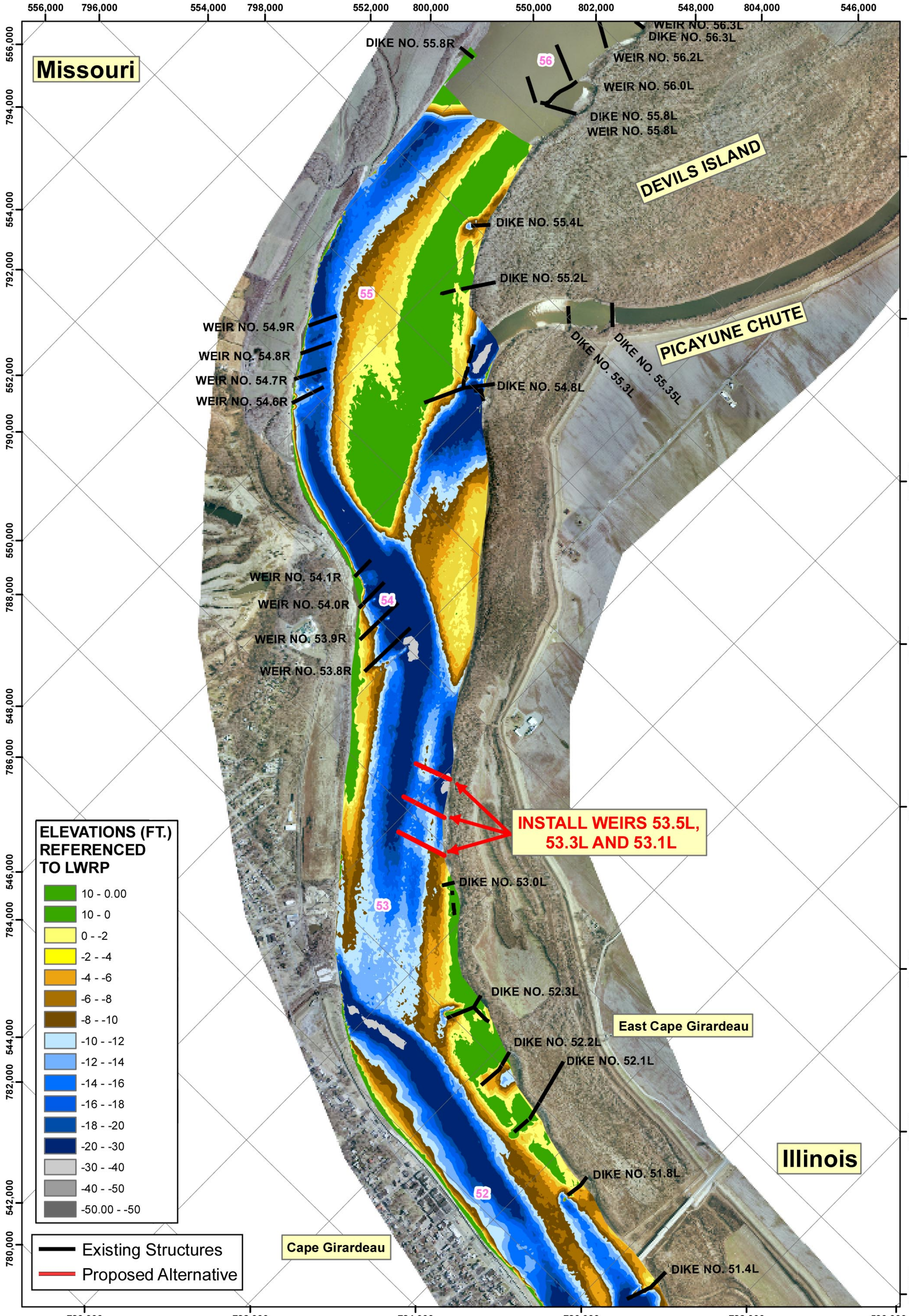

PLATE NUMBER 29

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 13
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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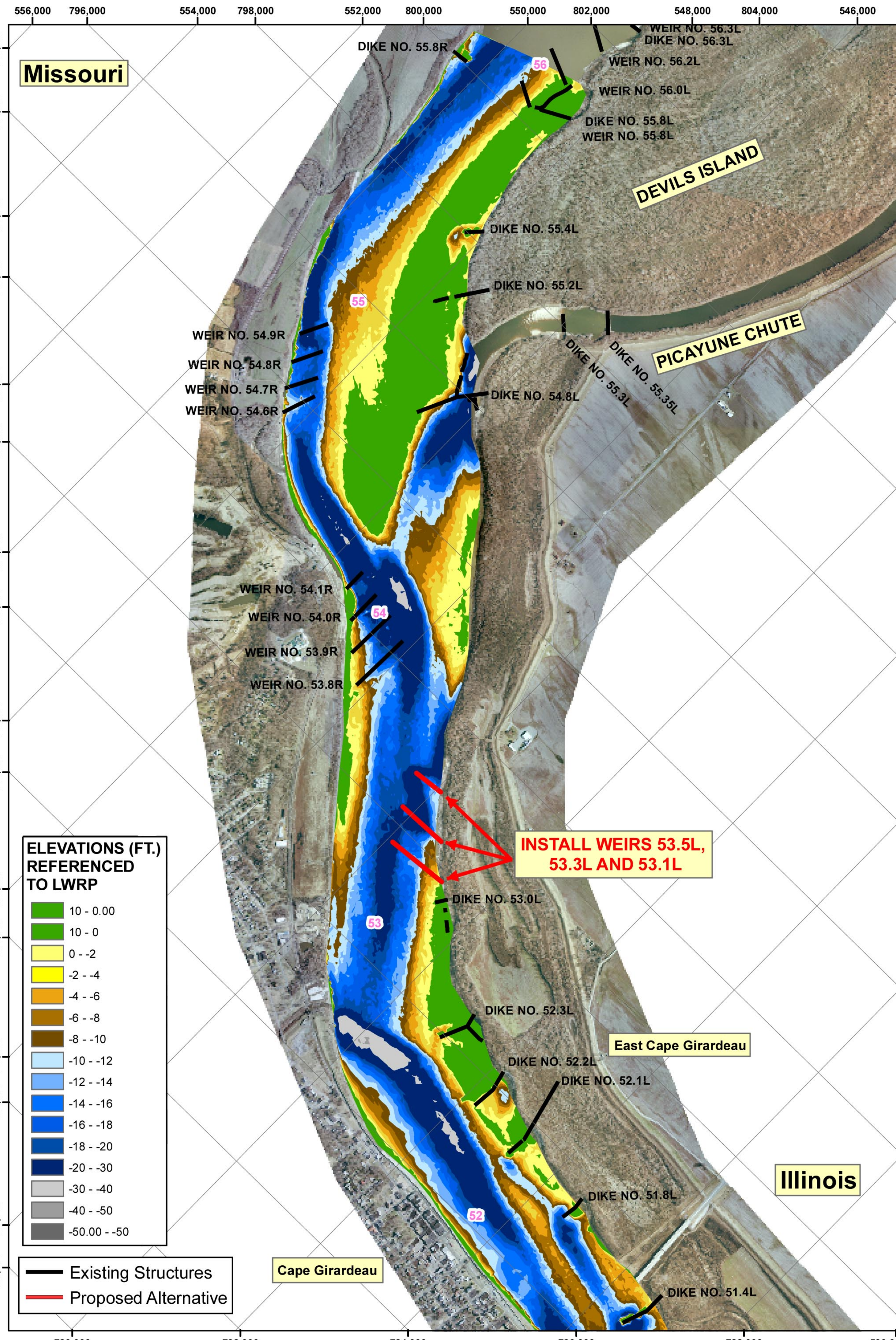

PLATE NUMBER 30

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 14
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
PREPARED BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock

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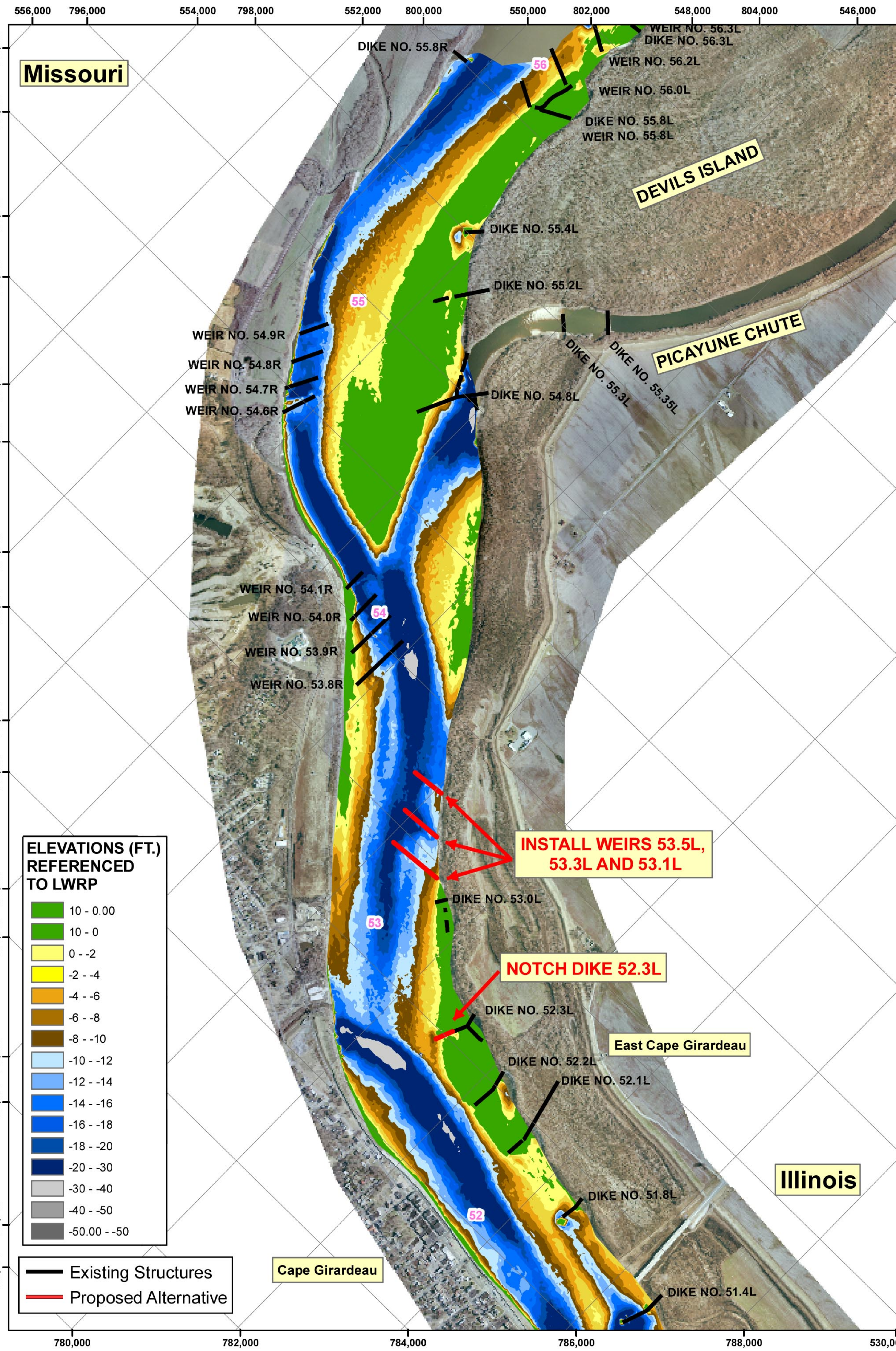

PLATE NUMBER

31

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 15

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011

PREPARED BY: E. BRAUER, P.E. DRAWN BY: E. BRAUER, P.E.

CHECKED BY: R. DAVINROY, P.E.

FILE NAME: L:\Cape Rock

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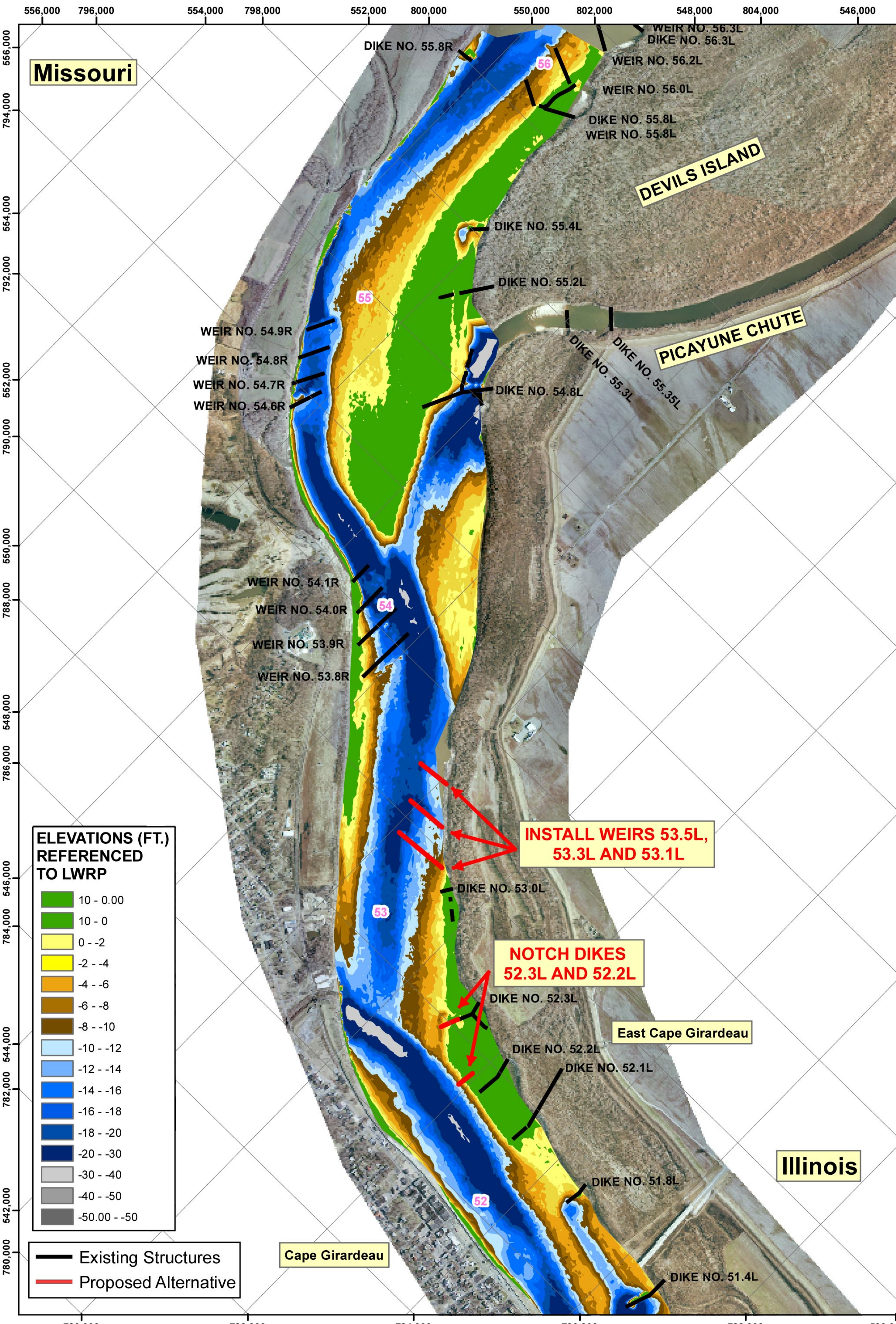

PLATE NUMBER 32

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 16
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
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FILE NAME: L:\Cape Rock

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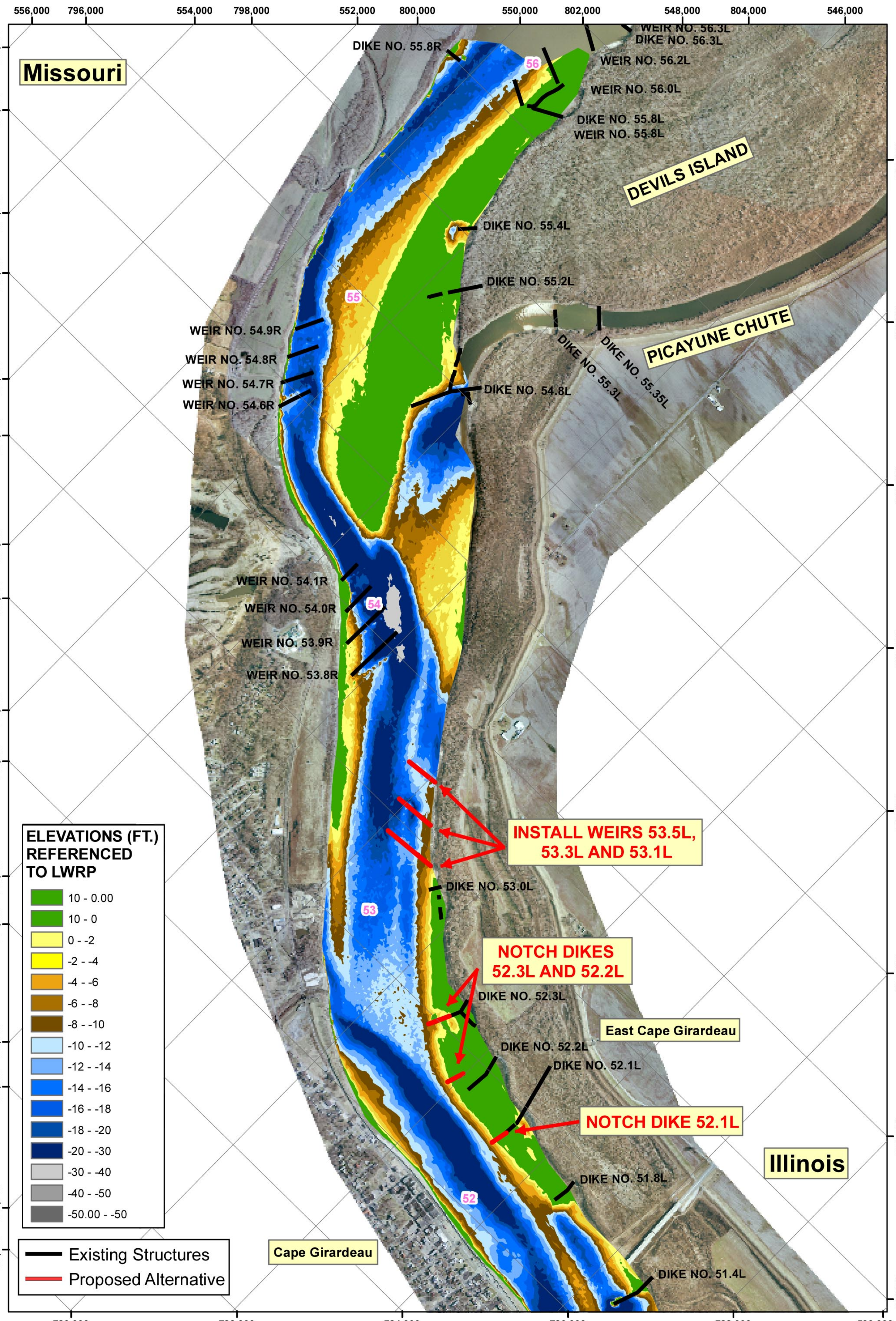

PLATE NUMBER 33

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 17
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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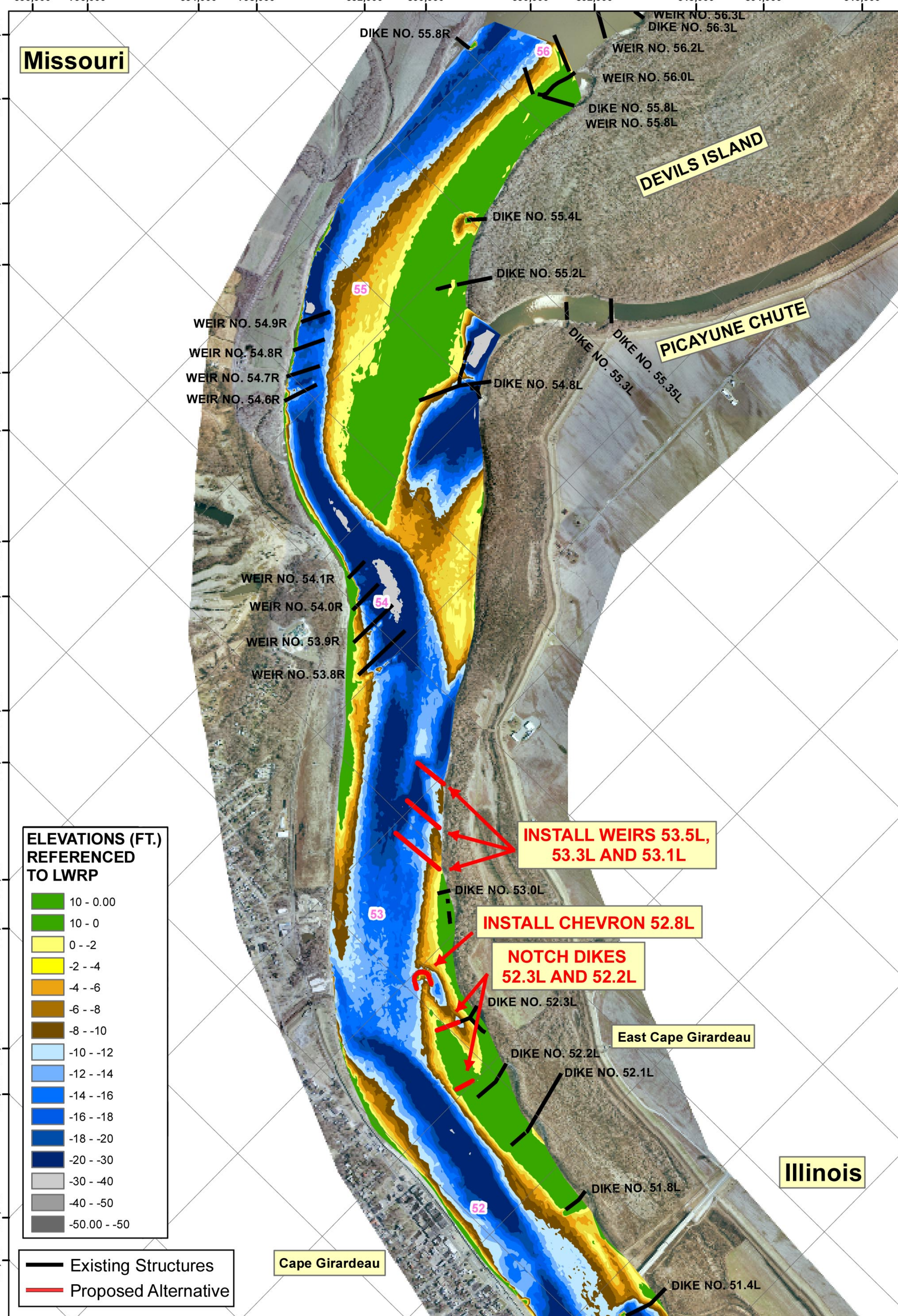

PLATE NUMBER

34

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 18

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
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FILE NAME: L:\Cape Rock	

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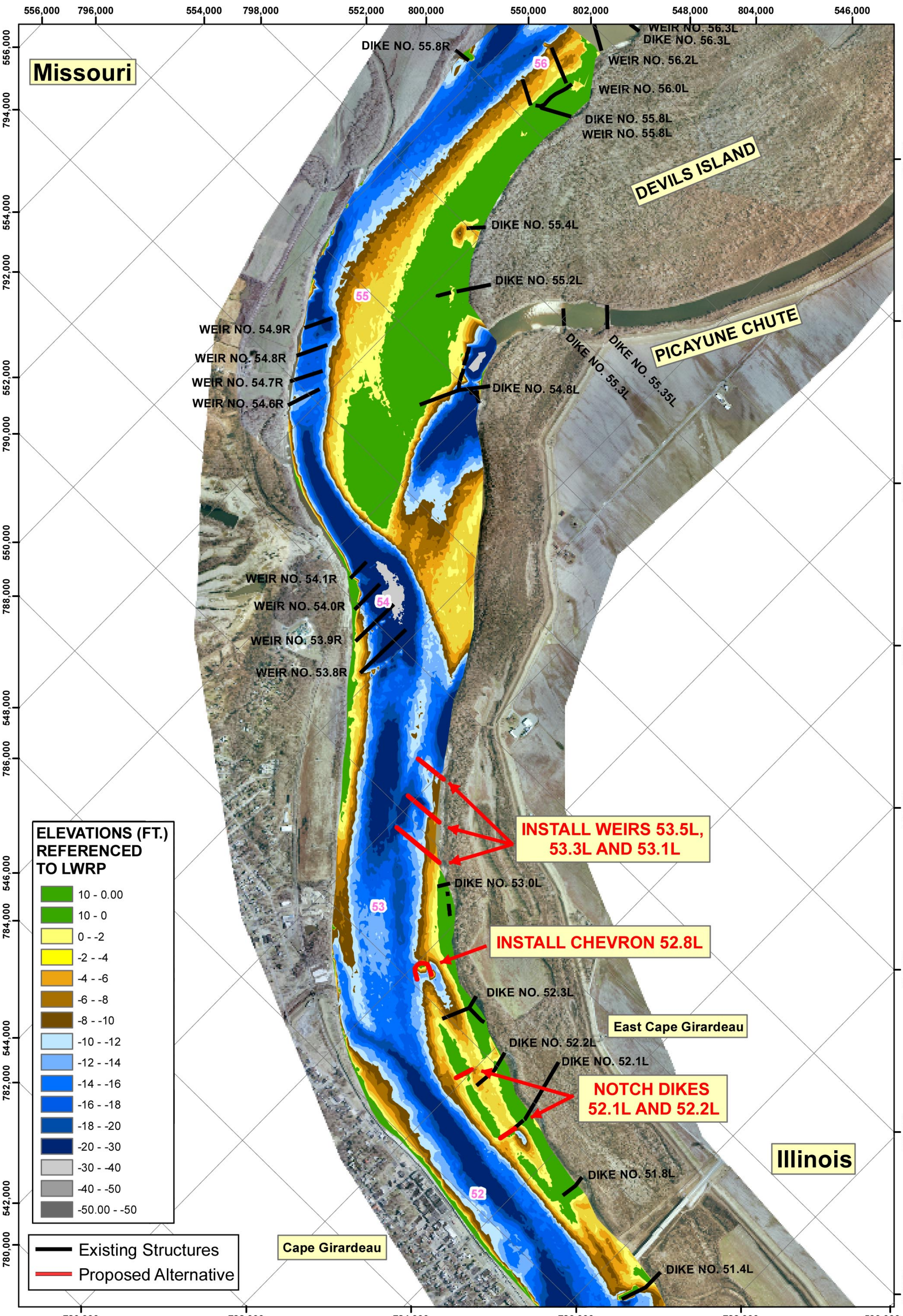

PLATE NUMBER

35

0 750 1,500 3,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 19

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011

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FILE NAME: L:\Cape Rock

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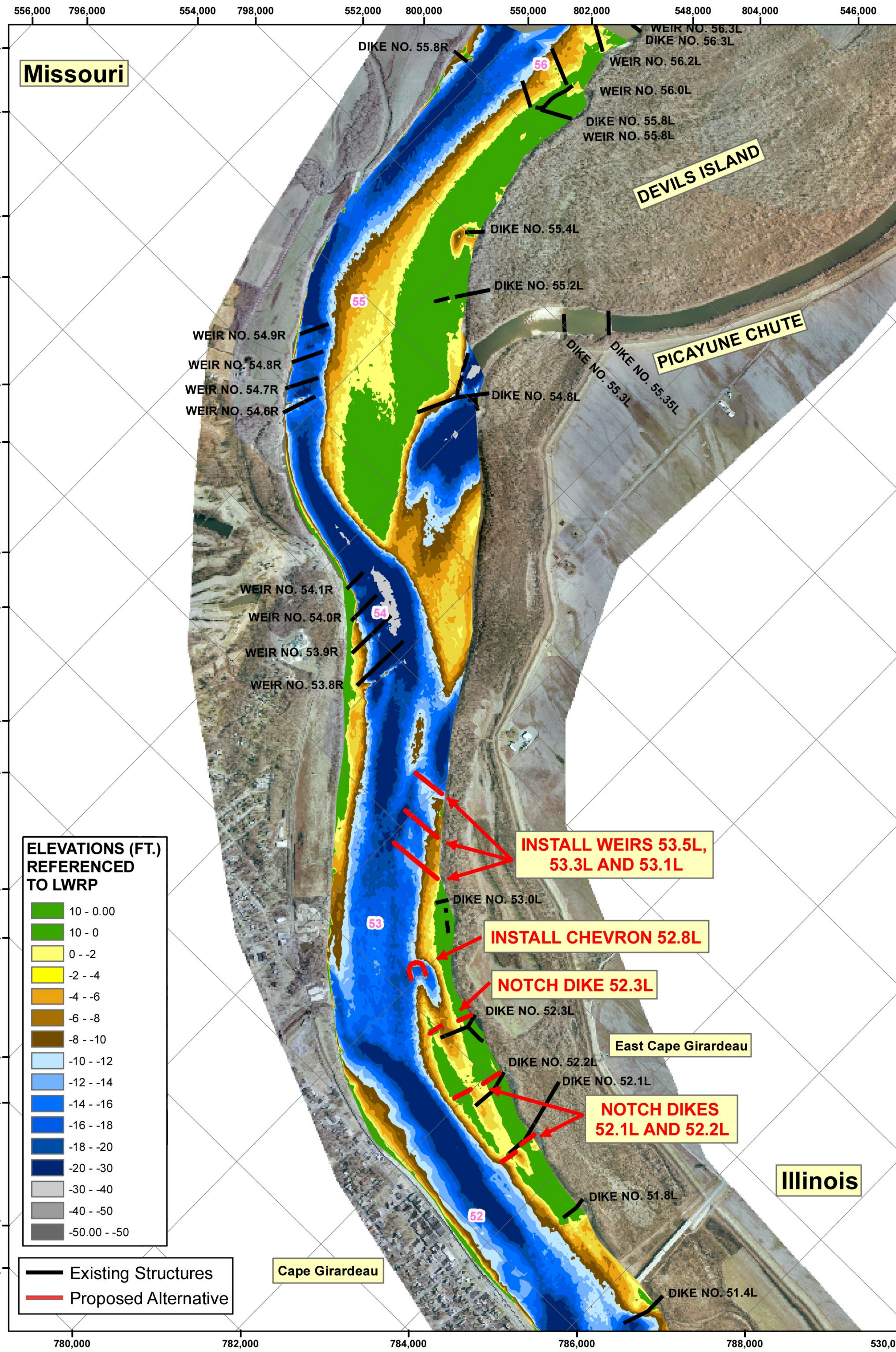

PLATE NUMBER 36

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 20
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
PREPARED BY: E. BRAUER, P.E.
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CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

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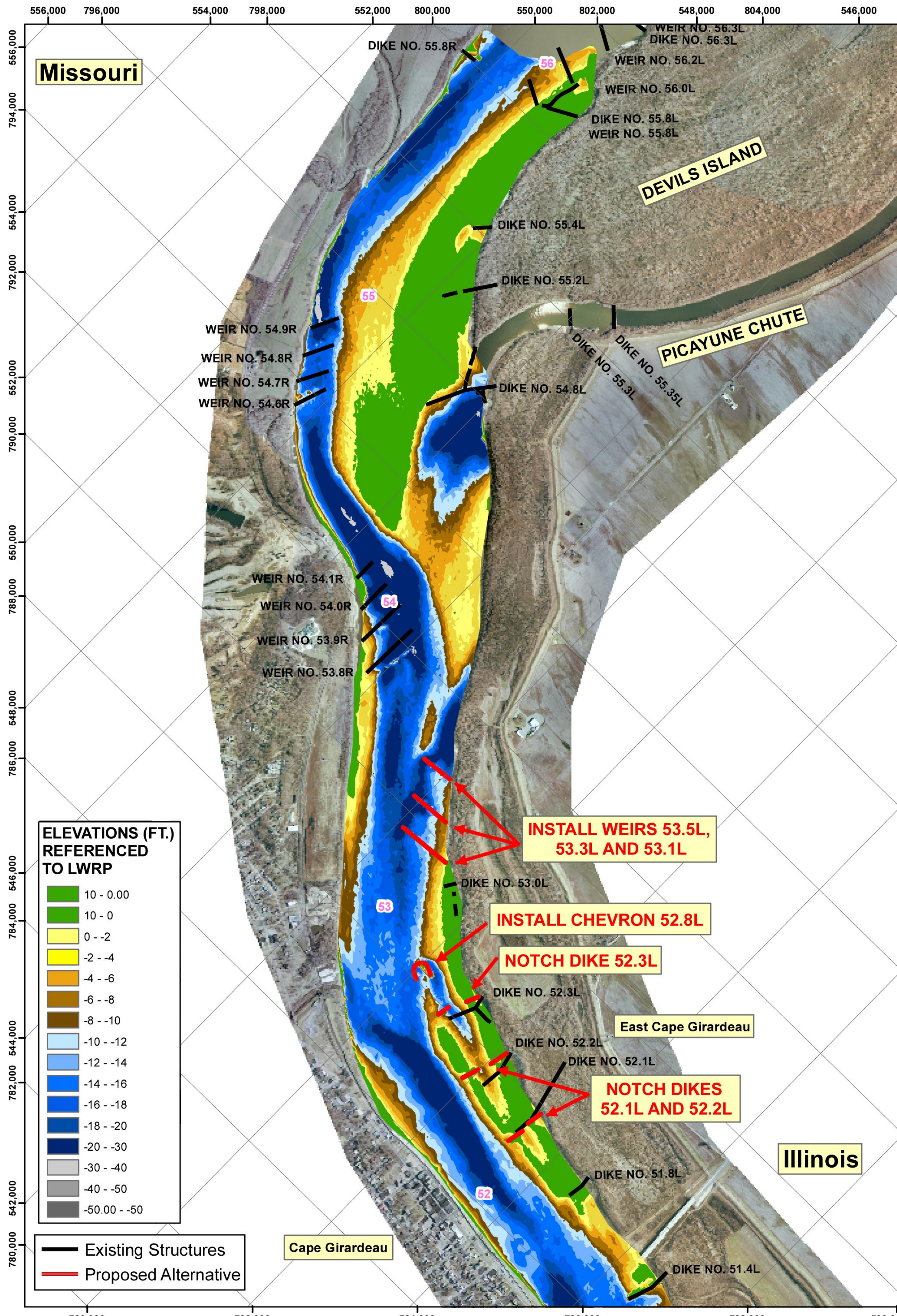

PLATE NUMBER 37

0 750 1,500 3,000 Feet

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ALTERNATIVE 21
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
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FILE NAME: L:\Cape Rock

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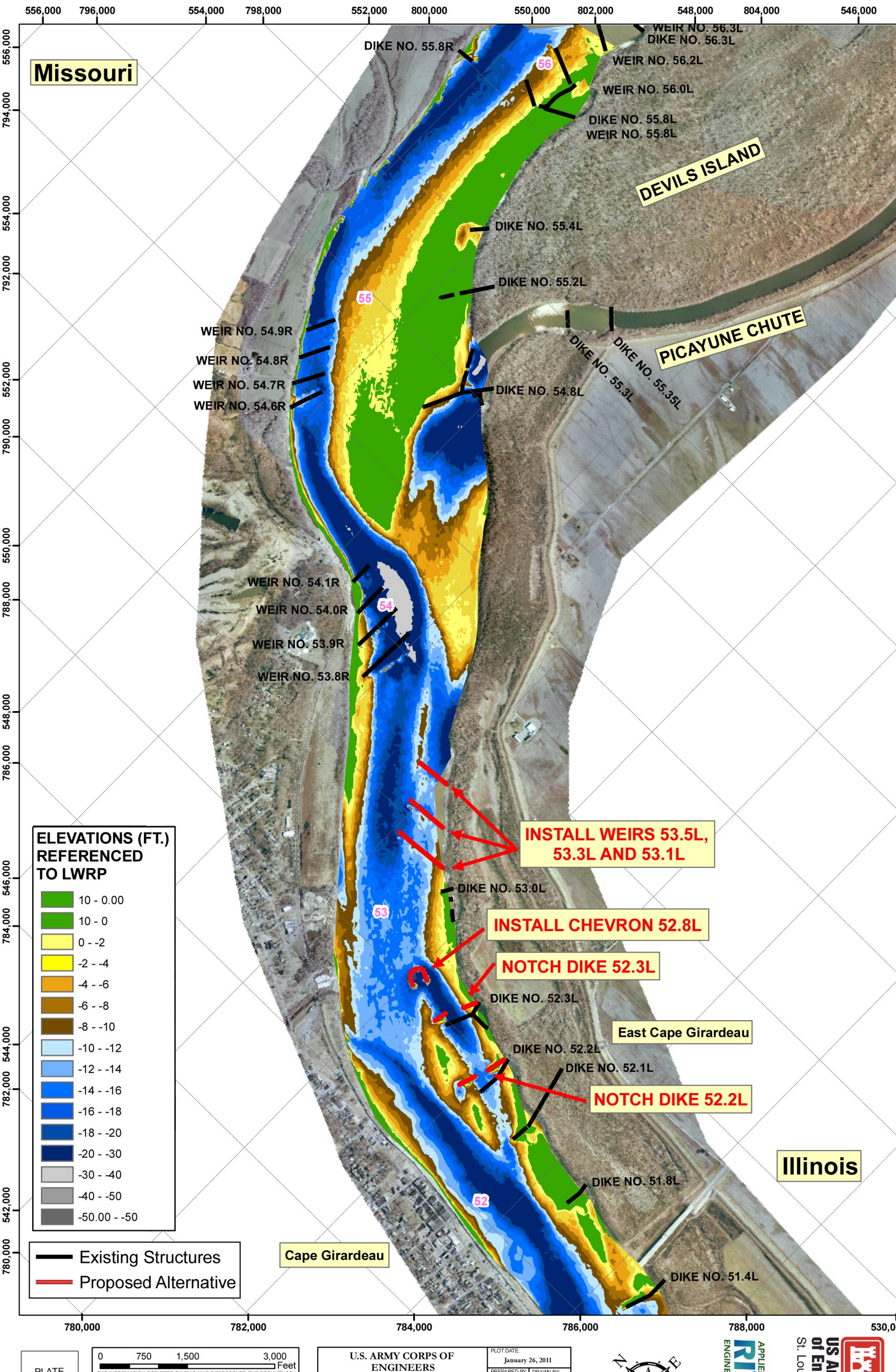

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PLATE NUMBER 38

ALTERNATIVE 22
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
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FILE NAME: L:\Cape Rock	

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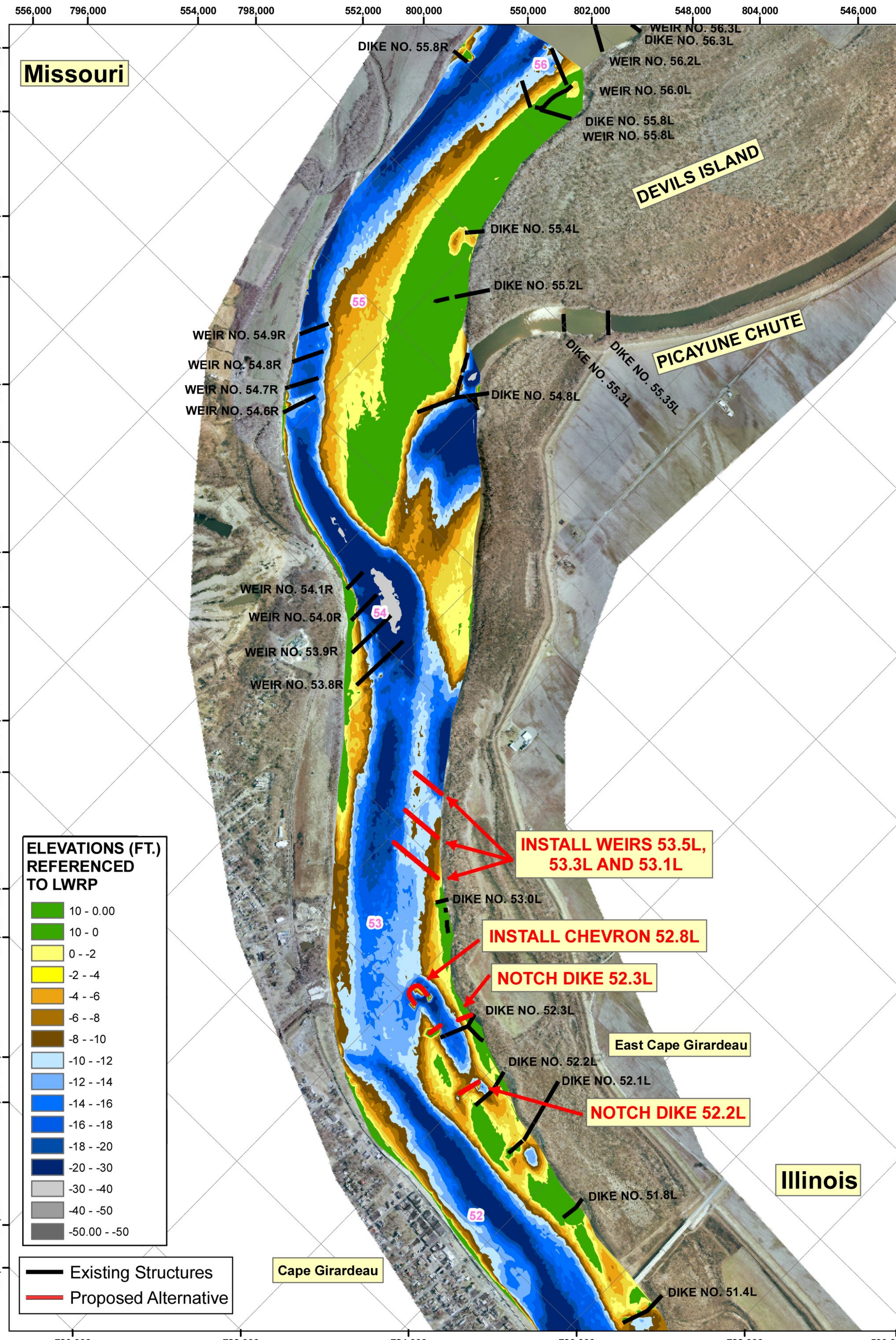

PLATE NUMBER 39

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 23
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
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FILE NAME: L:\Cape Rock

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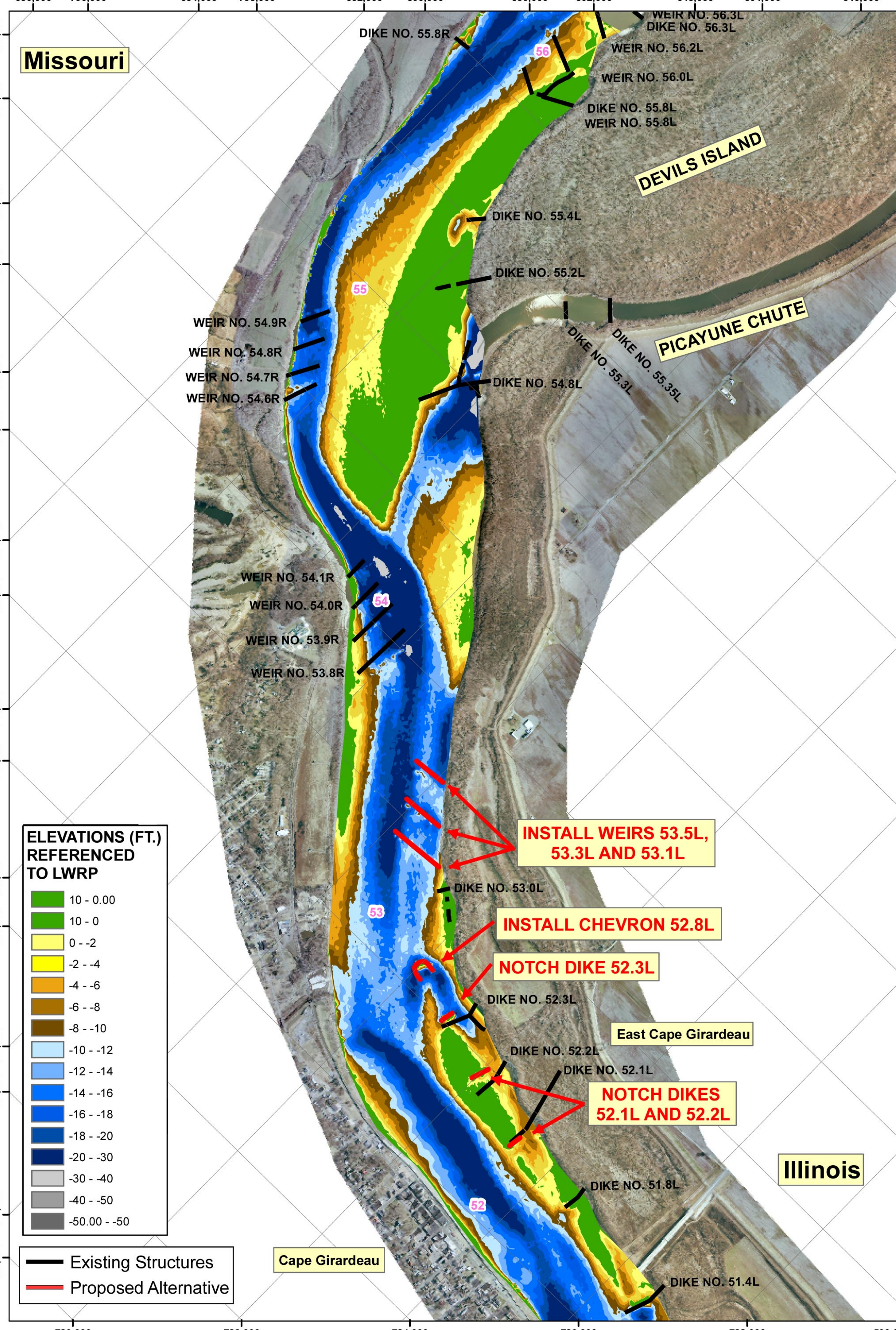

PLATE NUMBER 40

0 750 1,500 3,000 Feet

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ALTERNATIVE 24
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

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FILE NAME: L:\Cape Rock

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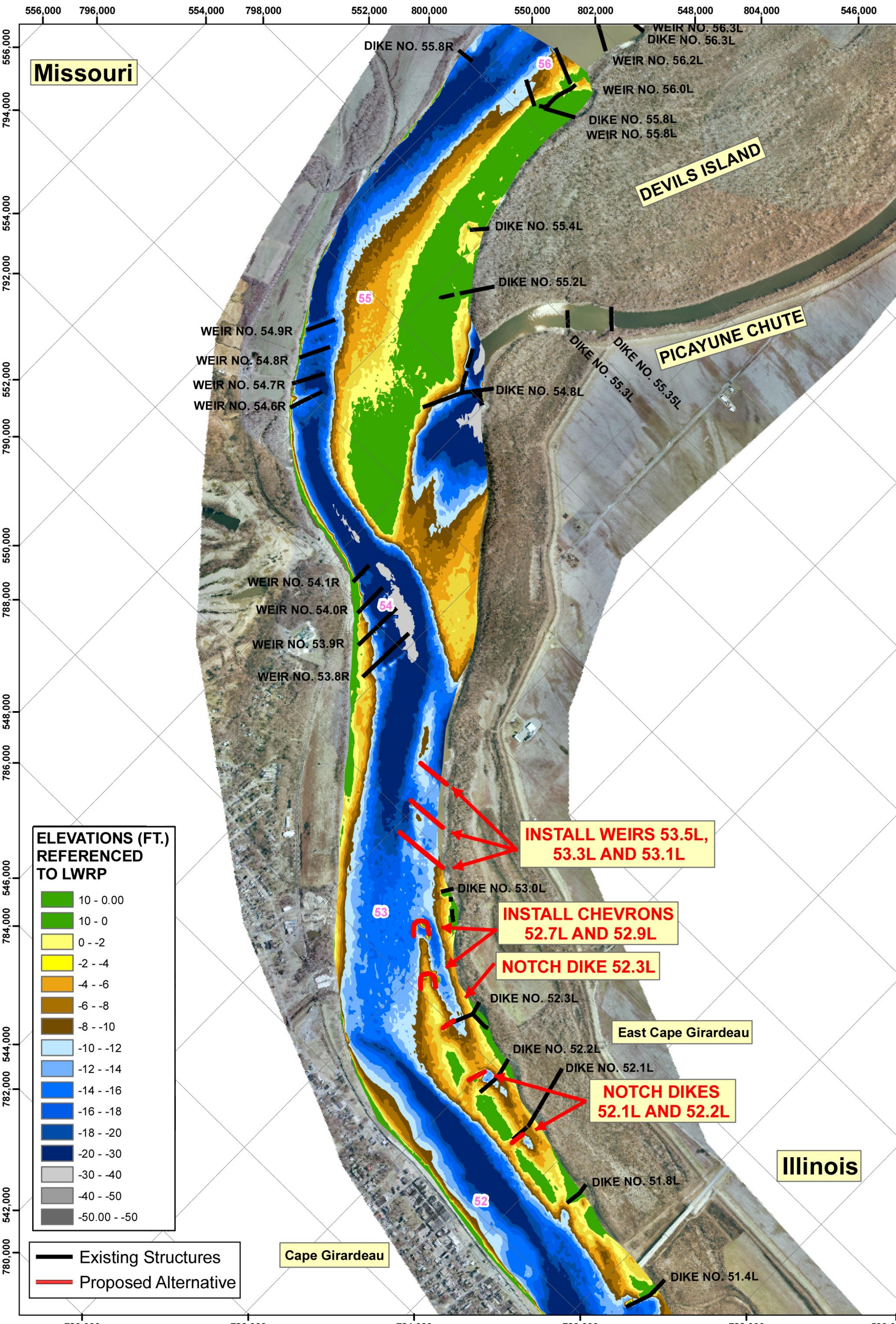

PLATE NUMBER 41

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 25
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers®
St. Louis District

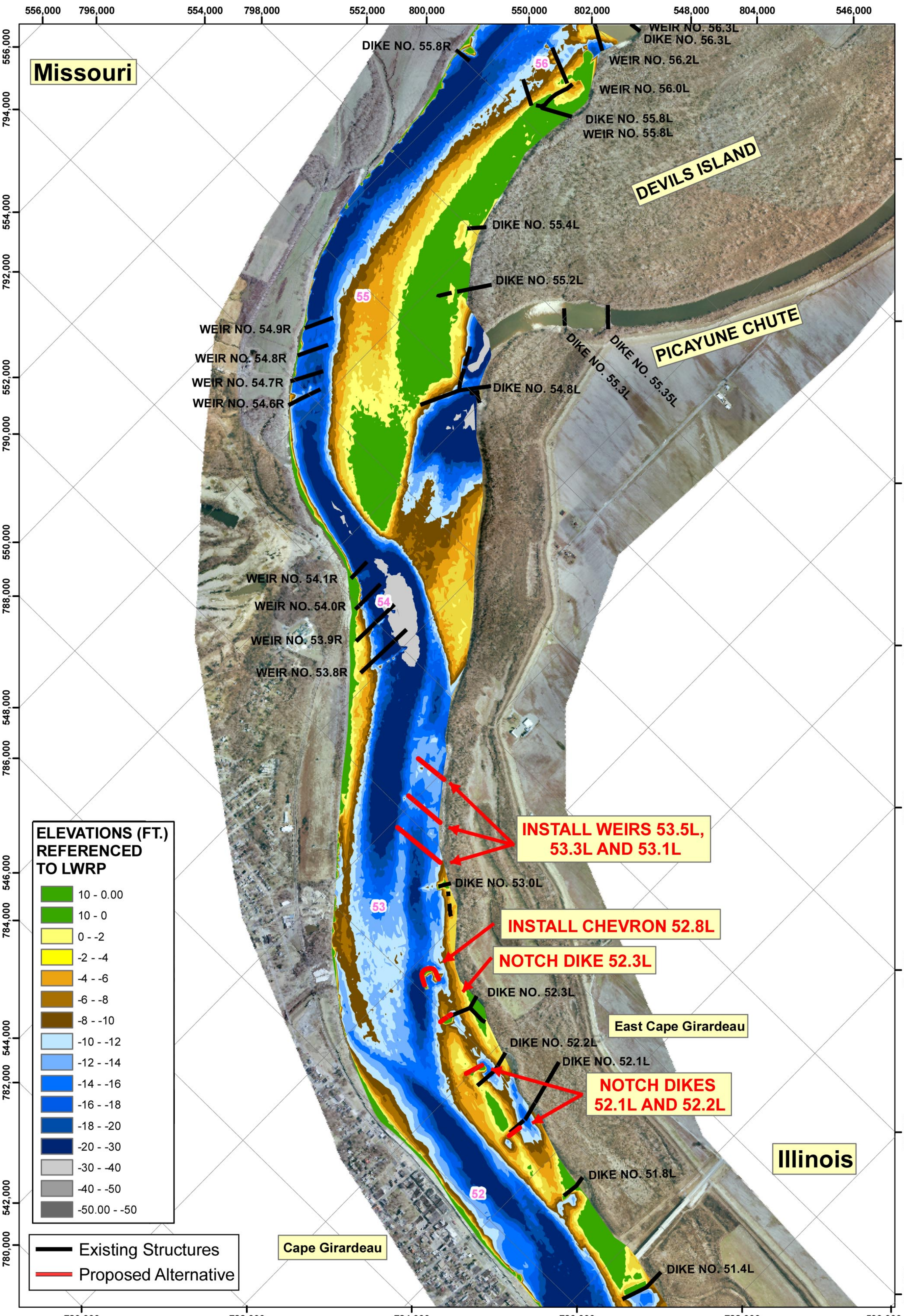

PLATE NUMBER
42

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 26
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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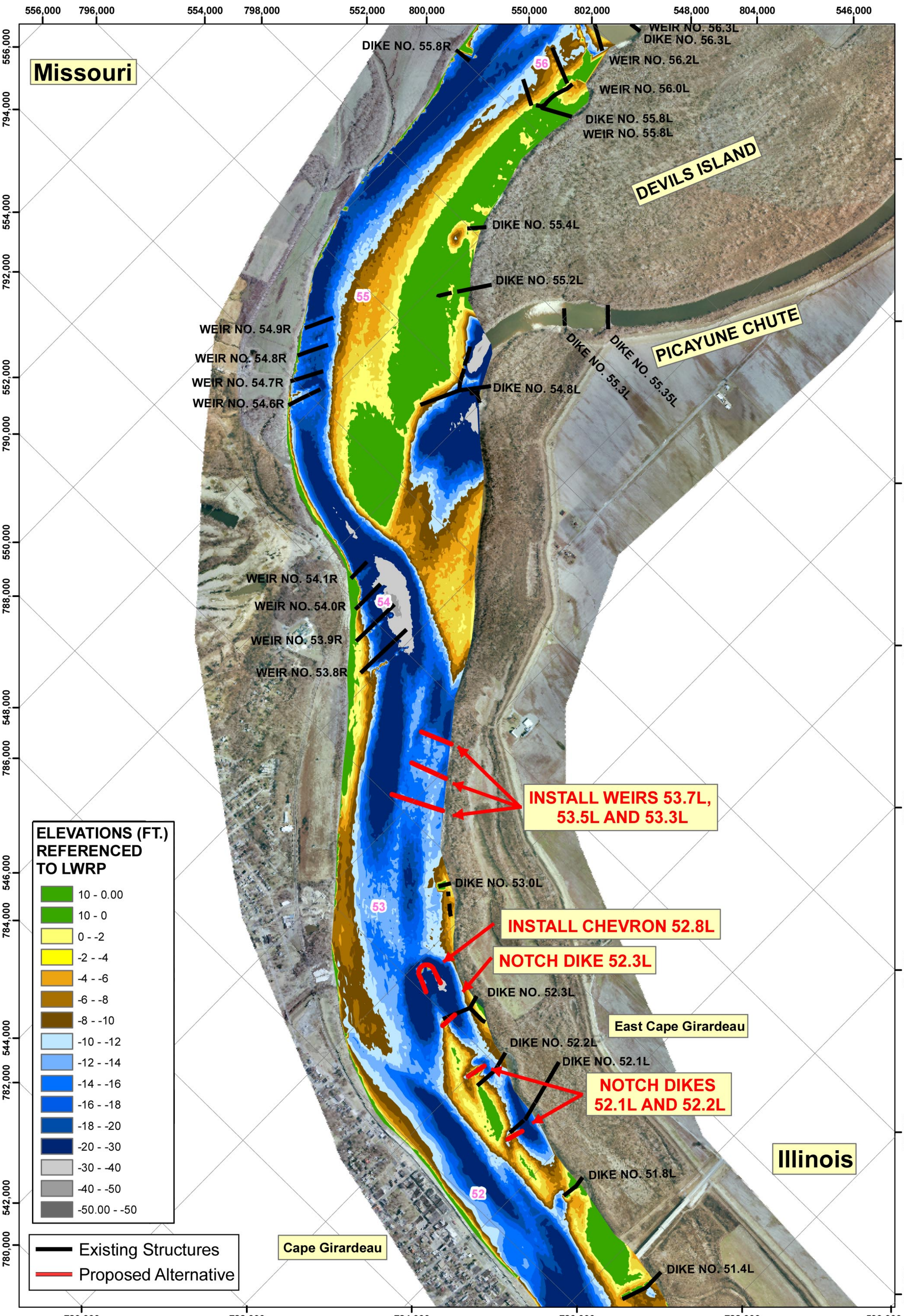

PLATE NUMBER 43

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 27
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District

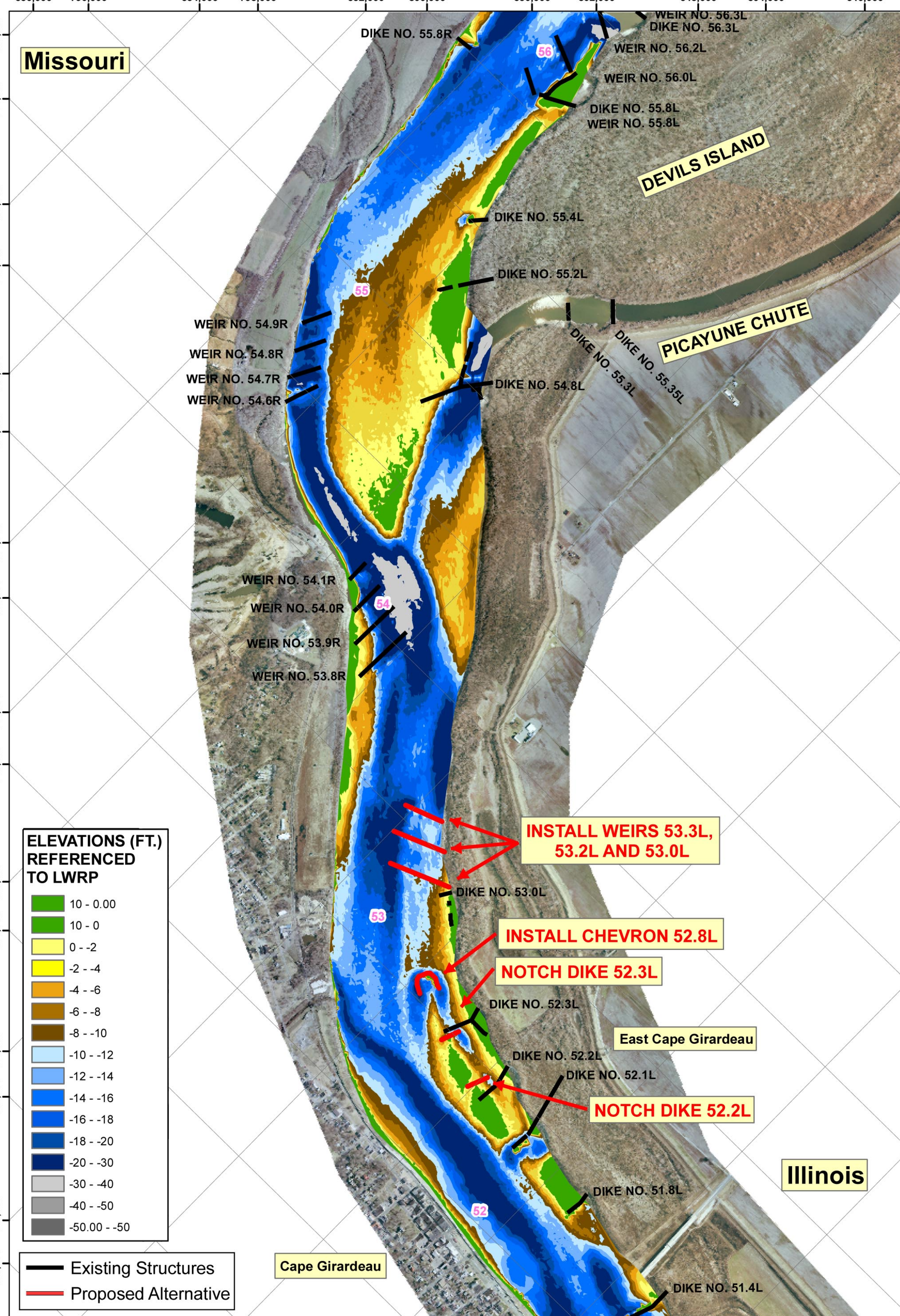

PLATE NUMBER 44

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 28

2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011
PREPARED BY: E. BRAUER, P.E.
DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.
FILE NAME: L:\Cape Rock

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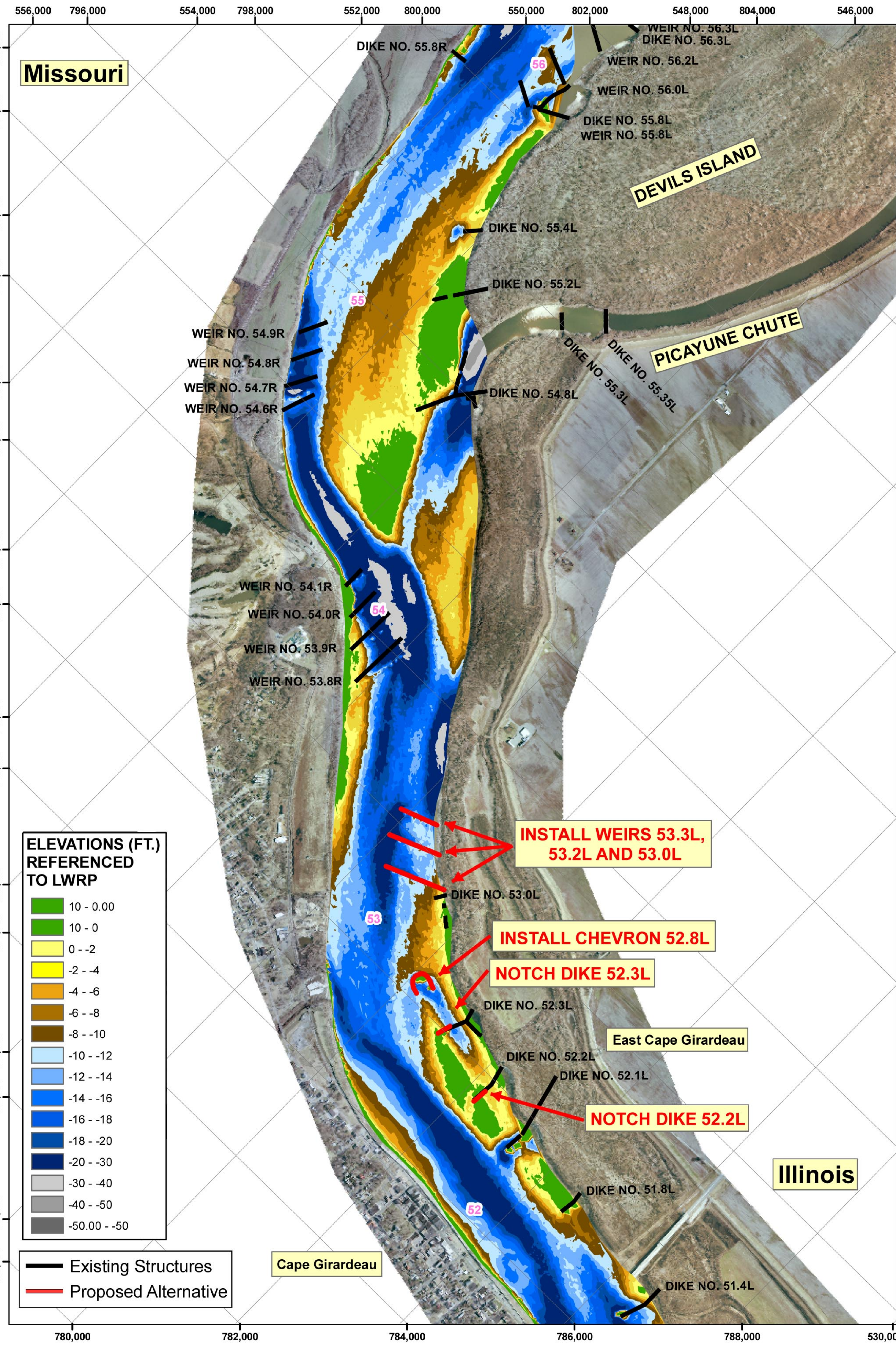

PLATE NUMBER
45

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 29
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

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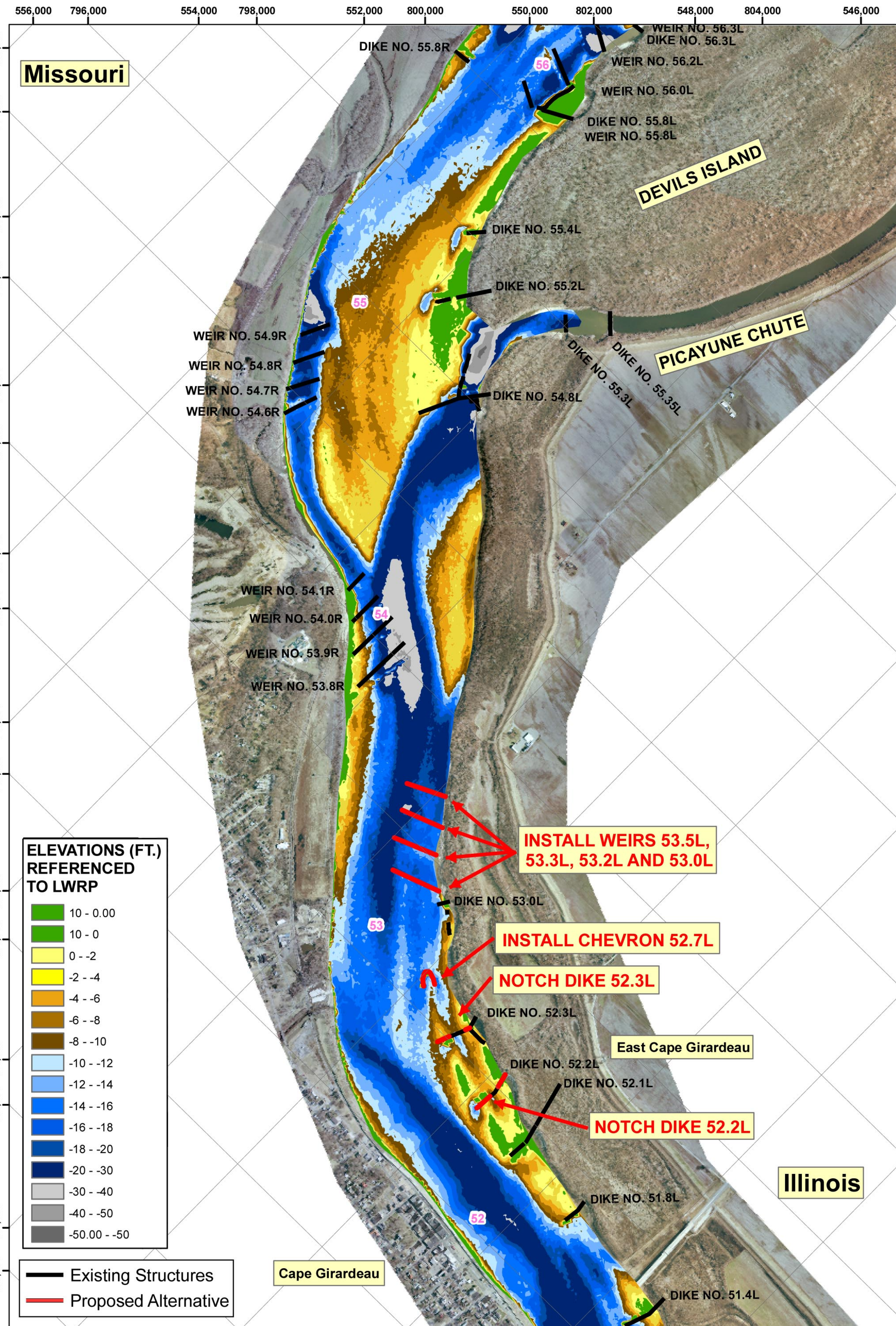

PLATE NUMBER 46

0 750 1,500 3,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

ALTERNATIVE 30
2006 AERIAL PHOTOGRAPH

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Cape Rock HSR Model
River Miles 57.0-50.0

PLOT DATE: January 26, 2011	
PREPARED BY: E. BRAUER, P.E.	DRAWN BY: E. BRAUER, P.E.
CHECKED BY: R. DAVINROY, P.E.	
FILE NAME: L:\Cape Rock	

N E S W

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