Technical Report M1

SEDIMENTATION STUDY OF THE MISSISSIPPI RIVER SANTE FE CHUTE, DOOLAN CHUTE HYDRAULIC MICRO MODEL INVESTIGATION

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U.S. Army Corps of Engineers Avoid and Minimize Program,
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In cooperation with
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Missouri Department of Conservation Long Term Resource Monitoring Station

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INTRODUCTION

A sedimentation study was initiated in order to evaluate a number of environmental design alternatives and modifications in two particular side channels of the Middle Mississippi River. The study of Sante Fe Chute was sponsored by the St. Louis District Avoid and Minimize Program. The study of the Doolan Chute complex was sponsored by the U.S. Fish and Wildlife Service. The total study area consisted of a 5 mile reach of river, between River Miles 40 and 35.

The study was conducted during the period between February 1996 and April 1996. The study was performed by Mr. Robert Hetrick and Mr. Dave Gordon of Kennedy Associates, Inc., under direct supervision of Mr. Robert Davinroy, District Potamologist for the St. Louis District.

Personnel also involved and overseeing the study included Mr. Claude N. Strauser, Chief of the Potamology Section, Mr. Steve Redington, Chief of the River Engineering Unit, and Mr. Ron Yarbrough, Avoid and Minimize Program Manager.

Personnel from other agencies involved in the study included:
Mr. Butch Atwood from Illinois Department of Natural Resources, Ms. Jenny Frazier, Mr. Bob Hrabik, Mr. Mike Peterson, and Ms. Leslie Conaway, from the Missouri Department of Conservation Long Term Research Monitoring Station, Mr. Mark Haas, Mr. Gordon Farabee, Mr. Ken Brumett and Mr. Ken Dalrymple, from the Missouri Department of Conservation, Mr. Bob Clevenstine, Mr. Tom Bell, and Ms. Joyce Collins, from the U.S. Fish and Wildlife Service.

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BACKGROUND

This report details the investigation of a sedimentation study using a physical hydraulic micro model. The micro model methodology was used to evaluate existing conditions and various design measures to improve the environment in the Sante Fe / Doolan Chute reach of the Mississippi River (Miles 40 to 35).

A variety of environmental design alternatives were submitted by representatives of the aforementioned agencies. The main goal was to evaluate the positive impacts of these alternatives, if any, on the resultant bed configuration (sediment transport response) and flow patterns within the Mississippi River study reach. Creating desirable biological diversity while at the same time ensuring a reliable navigation channel was the major challenge of this study.

1. Problem Description

A. Sante Fe Chute

Plate 1 is a map depicting the characteristics, configuration, and nomenclature of the Mississippi River, miles 40 to 35. The upper end of Sante Fe Chute begins at River Mile 39.7L. This side channel parallels the main channel for a distance of approximately 5 miles. Doolan Chute begins at river mile 39.0R and re-enters the main channel at river mile 31.0R.

The Sante Fe / Doolan Chute side channel complex serves a vital role in the health of the fisheries of the Middle Mississippi River. It has been well documented that side channels, both continuous and detached, serve as important backwater habitat for a variety of fish species.

With this premise it is important to note that diversity in the form of alternating bars and deep scour holes were desired in these side channels. This type of habitat does not exist in Sante Fe Chute. Plate 2 is a plan view, 1995 bathymetric survey of Sante Fe Chute. Elevation contour data from this survey indicated that the bed of Sante Fe Chute was relatively high and homogenous throughout most of the chute. A small scour hole occurred in the upper end of the chute just downstream of the spur dike /closure structure at mile 39.6 L. The largest natural scour hole pattern in the chute occurred near mile 39.0 on the left descending bank. Some depth was also noted on the lower end of the chute, however, this was a result of a dredge cut used for nearby levee repair.

In 1992, river engineers of the St. Louis District made an inspection of this chute and noted, as verified by the 1995 survey, that there were minimal water depths throughout most of Sante Fe Chute. The jet boat used for inspection drew approximately 6 inches of draft and had a very difficult time navigating in the chute. Several times the jet boat touched bottom. Engineers observed that for the most part, the left descending bank of the chute was erosional and vertical.

B. Doolan Chute

Doolan Chute parallels the river on the right descending bank, but is not attached to the main channel. Remnants of the chute start at approximately River Mile 38.7R, and eventually the chute re-enters the Mississippi River main channel at River Mile 31.0R.

Plate 3 depicts the historical condition of the chute in 1958. The entrance of the chute occurred on the right descending bank at mile 38.9. The entrance width was approximately 600 feet. The channel depth in this area was approximately 0 feet relative to the Low Water Reference Plane (LWRP), or approximately +5 at the Cape Girardeau gage. Although vegetation markings in the chute just downstream of the entrance indicate that the channel was probably as high as the normal vegetation growth line.

The width of the historical chute varied from as little as 200 feet at the lower end to as wide as 300 feet. A conservative estimate on the average width was approximately 250 feet, which is very similar to the present day chute width.

Little is known of the depths of the historical channel, although indications at the entrance and exit conditions from the hydrographic survey indicate that the chute, at least in these areas, was relatively shallow. It is assumed that the elevation of the banks of Doolan Chute was approximately the height of the banks of the main channel, or approximately a +30 LWRP, as indicated from the 1958 survey.

A site investigation of Doolan Chute was conducted by Robert Hetrick during the week of 19 February to gain a better understanding of the present day conditions of the chute remnants. Plate 4 is a USGS quad sheet of the Doolan Chute area. This map shows the locations of the photographs taken in the field. Remnants of Doolan Chute still exist today. Although the chute is no longer attached to the main channel, approximately 70 percent of the original reach still exists.

The physical characteristics of Doolan Chute could be categorized into two regimes. The first regime, the upper one mile of the chute, contained a poorly defined channel. The second regime, the lower two miles of the chute, contained a well defined channel.

From the tip of dike 39.1, as shown on Plate 5 (Photograph #1), there was no indication of any chute. The bankline was constant across this section, as well as the density and age of the vegetation. Approximately 300 feet inland of the chute entrance, a small levee crossed the chute. Photograph #2 (Plate 5) was taken from the top of this levee looking riverward. The land surface and vegetation density was uniform throughout the area with the exception of a few small marshes. The upper photograph on Plate 6 (Photograph #3) was taken from the same levee looking landward. The only indication of a chute was a small drainage ditch extending from the landward side of the levee to another larger levee approximately ¼ mile inland. The drainage ditch was approximately 5-10 feet wide and 3-5 feet deep. From this point, the chute followed a treeline for approximately 2 miles. Throughout this reach, there were no obvious signs of a defined channel or bankline.

The lower photograph on Plate 6 (Photograph #4) was taken from the levee looking upstream along the northern section of Goat Island. The chute contained a defined channel that was approximately 75-100 feet in width. The transition from the poorly defined channel to the well defined channel occurred approximately ½ to ¾ mile upstream of Goat Island.

The photographs on Plate 7 (Photographs #5 and #6) were taken looking upstream and downstream, respectively, from the road that crossed Doolan Chute, approximately 2 miles downstream of Goat Island. The photographs show the typical channel characteristics that were present between Goat Island and the road crossing. At the road crossing, there was an 8-10 foot diameter steel culvert.

The chute downstream of the culvert contained a well defined channel similar to the channel upstream. This defined channel continued downstream to the confluence with the main channel of the Mississippi River.

C. Main Navigation Channel

Plates 8 and 9 are 1986 and 1993 plan view hydrographic survey maps of the Mississippi River main channel. At River Mile 40, a crossing existed with navigation depths averaging between -15 to -20 feet LWRP. The channel transitioned to the left descending bank adjacent and just parallel to the closure structure at mile 39.4L. The depths varied between -20 and -50 feet LWRP, depending upon which survey was used (it must be noted that the survey of 1993 was a high water survey, while the survey of 1986 was a low water survey).

The channel remained against the left descending bank until approximately mile 38.3, where it transitioned to the right descending bank. Depths in this area were between -10 and -15 feet LWRP. The channel remained against the right descending bank through the study reach, forming a long bendway channel. With exception, one particular dike on the left descending bank at Mile 36.7L produced a scour hole in excess of -30 feet LWRP (1986 survey).

2. Study Purpose and Goals

The study was performed to address two separate sediment transport issues. The first objective was to create environmental diversity in Sante Fe Chute in the form of shallow and deep water environments, with areas of fast and slow flow, while maintaining the integrity of the navigation channel. The second objective was to explore the possibility of re-attaching the remnants of the upper end of Doolan Chute with the main channel. The major consideration of this objective was to determine the impacts of this measure on the main navigation channel.

MICRO MODEL DESCRIPTION

1. Scales and Bed Materials

Plate 10 is a photograph of the Sante Fe/ Doolan Chute hydraulic micro model used in this study. The scales were 1inch = 600 feet, or 1:7200 horizontal and 1 inch =100 feet, or 1:1200 vertically for a 6:1 distortion ratio. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to the prototype. The bed material was granular plastic urea, Type II, with a specific gravity of 1.23.

2. Apperturences

The model was constructed according to 1994 aerial photographs of the Mississippi River. In all model tests, the effective discharge or hydrograph was simulated (2). Hydrographs were simulated electronically by a function generator. Stages were recorded by a digital electronic micrometer. Resultant bed configurations were surveyed with a 3-dimensional digitizer and computer interface.

MICRO MODEL TESTS

1. Calibration and Verification

The calibration/verification of the micro model involved the adjustment of water discharge, sediment load, time scale, and floodplain tilt (slope). These parameters were adjusted until the measured bed response of the model was similar to the prototype (3).

A. Design Hydrograph

Plate 11 illustrates the design hydrograph used in this study. This hydrograph served as an effective discharge response (2). Because of the constant variation experienced in the prototype, the effective discharge was used to theoretically analyze the average expected sediment response during any given year. The time increment or duration of the design hydrograph was 3.5 minutes.

B. Prototype Surveys and Ice Photo

Several prototype surveys were used to determine the general bed characteristics that existed in the prototype (Plates 2, 8, and 9). A 1994 low water ice photograph of the study reach of the Mississippi River was also used to compare surface flowlines (Plate 12).

Once a favorable comparison of several surveys of both the prototype and model were made, the model was considered calibrated. The resultant survey of this bed response served as both the verification and base test of the micro model (1).

2. Base Test

Plate 13 shows the resultant bed configuration of the micro model base test. This survey served as the comparison survey for all future design alternative tests. The base test was developed from the simulation of successive design hydrographs until bed stability was reached and a similar bed response was achieved as compared with prototype surveys.

Plates 14 and 15 are flow visualizations of the main channel and Sante Fe Chute, respectively. Nearly identical patterns were seen in the flow visualization of the base test condition in the micro model as compared to the ice photo on plate 12.

Results of the base test indicated the following trends:

a. Mile 39.4. Upper End of the Study Reach. The navigation channel had a tendency to fall directly against the closure structure at Mile 39.4. A sandbar formed adjacent to the channel between Miles 39.7R and 38.6R.

b. Between Mile 38.4 and Mile 38.0, a crossing formed with depths between -10 and -20 feet LWRP. This area has been an historic dredging site. The two prototype surveys (Plate 8 and 9) show the tendency for shoaling in this area.

c. At Mile 37.8R, a scour hole developed at dikes 37.8R and 37.6R. The channel remained against the right descending bank for the remainder of the study reach.

d. The channel became deep (-50 to -60 LWRP) between river miles 36.2R and 35.1R.

e. In Sante Fe Chute, there was a tendency for some deepening to occur on the landward side of the closure structure. Just downstream of this area, the bed immediately developed as a high bar to elevations in excess of 0 LWRP.

f. On the left descending bank of Sante Fe Chute, in the vicinity of River Mile 39.0, a scour hole to depths in excess of -20 LWRP developed. From this point downstream, the bed was considerably high and flat, with depths in excess of 0 LWRP.

g.   Very little energy or sediment transport potential was observed in Sante Fe Chute, especially in the lower one half of the channel. From flow visualization tests, it became apparent that the main channel backwater influence created this condition at all simulated flow conditions.

h. In Sante Fe Chute, just upstream of Dike No. 35.0L, a scour hole with depths between -10 and -20 LWRP was artificially molded in the bed. This hole represented the recent dredging site used for the construction of levee repairs after the 1993 flood (see Plate 2). Because of the main channel backwater influence, this hole remained intact during all future tests.

3. Alternative Plans

A number of alternative design plans were tested. As previously discussed, all tests were initiated to create environmental diversity and enhancement while at the same time ensuring the integrity of the navigation channel. The effectiveness of each plan was evaluated by comparing the plan results to the base test condition.

A. Sante Fe Chute Alternatives

Alternative A. Removal of Closure Structure 39.6L. Plate 16 is a plan view contour map of the resultant bed configuration of alternative A. Results of this test indicated that removal of the closure structure caused the downstream navigation channel to shoal excessively (0 to -10 LWRP). The tendency for channel flushing in Sante Fe Chute was non-existent, with some additional sediment actually entering the side channel and filling in the scour hole located near River Mile 39.0.

Alternative B. Alternating Level Crested Hardpoints at +30 LWRP. Plate 17 is a plan view contour map of the resultant bed configuration of alternative B. Tests indicated that small scour holes with depths between -10 and -20 LWRP could be developed in the upper half of Sante Fe Chute. The bed development energy within the channel drastically reduced approximately halfway through the dike field.

Plate 18 is a plan view flow visualization of alternative B. The flow visualization illustrated that a sinusoidal flow pattern was developed after installation of this plan.

Alternative C. Alternating Level Crested Hardpoints at +30 LWRP with Upstream Angle. Plate 19 is a plan view contour map of the resultant bed configuration of alternative C. Tests indicated that some channel development could be developed in Sante Fe Chute with this plan.

Plate 20 is a plan view flow visualization of alternative C.

Alternative D. Chevrons, Sloping from +30 LWRP at Bankline to +15 LWRP at Mid-channel. Plate 21 is a plan view contour map of the resultant bed configuration of alternative D. Tests indicated that some marginal scour holes could be developed in the middle of Sante Fe Chute with this design.

Plate 22 is a plan view flow visualization of alternative D. The flow visualization illustrated that flow was concentrated toward the middle of the side channel and away from the outer banks.

Alternative E. Alternating Level Crested Hardpoints at +30 LWRP with Length Modification and Downstream Dredging. Plate 23 is a plan view contour map of the resultant bed configuration of alternative E. Tests indicated that larger and deeper scour holes could be developed as compared with alternative A. In the lower half of Sante Fe Chute, scour holes were artificially molded in the bed to simulate dredging. Material from these holes was placed in adjacent areas to create an alternate bar scheme. All tests indicated that the artificially created bed configuration pattern remained unchanged during all design flow conditions due to the downstream backwater effects from the main channel.

Alternative F. Closure Structure 39.6L at +15 LWRP. Plate 24 is a plan view contour map of the resultant bed configuration of alternative F. The results were very similar to alternative A. The downstream crossing shoaled excessively. Sediment entered Sante Fe Chute and filled in the scour hole near River Mile 39.0.

Alternative G. Notches in Closure Structure 39.6L. Two notches were placed in the closure structure. Each notch was 250 feet in length and 5 feet in depth. Plate 25 is a plan view contour map of the resultant bed configuration of alternative G. Results of this test indicated a tendency for shoaling in the downstream crossing.

B. Doolan Chute Alternatives

For alternatives H and I, the entrance of Doolan chute was approximately 450 feet wide. The average width of the chute was approximately 200 feet. It was not the intent to exactly match the layout and characteristics of the chute, since limited field data existed. The intent was to initiate a representative amount of water flow through the chute and determine the effects of this diverted flow on the navigation channel.

Sediment was placed in Doolan Chute to an elevation of approximately -10 LWRP. The closure structure was placed at the appropriate elevation. Continuous design hydrographs were run and the bed of Doolan Chute developed as both flow and sediment entered the chute. After the bed stabilized through the chute, one additional hydrograph was run and the resultant main channel bed configuration was surveyed.

Alternative H. Doolan Chute Linkage With the Main Channel, Entrance Conditions at 0 LWRP. Plate 26 is a plan view contour map of the resultant main channel bed configuration for alternative H after 15 hydrographs. Results of this test indicated a tendency for shoaling in the downstream crossing of the main channel.

Alternative I. Doolan Chute Linkage With the Main Channel, Entrance Conditions at +20 LWRP. A closure structure was placed at the entrance of Doolan Chute to limit flow through the chute to stages only above +20 LWRP. Plate 27 is a plan view contour map of the resultant main channel bed configuration for alternative I. This alternative did not cause shoaling in the downstream crossing of the navigation channel. Bed stability in Doolan chute required 7 more hydrographs to develop than alternative H.

CONCLUSIONS

The following is a summary of findings and recommendations of the model study:

- The shoaling problem in the crossing between miles 38.9 to 38.2 is very sensitive. Any loss of flow below +20 LWRP in Sante Fe Chute will compromise the navigation channel. For this reason, alternatives A, F, G, and H were not considered viable.

- The bed configuration of Sante Fe Chute in the prototype has stabilized and has formed a natural “sediment wedge.” There is very little sediment transport energy potential throughout the chute. The formation of this “sediment wedge” and lack of sediment transport energy is due to the physical alignment of the chute and the backwater effect created by the main channel.

- Additional sediment allowed into Sante Fe chute by closure structure modification will cause deposition throughout the entire chute and fill in the scour hole that exists near River Mile 39.0.

- Alternatives B, C, D, E, and I are possible solutions to creating environmental diversity in Sante Fe Chute. None of these alternatives adversely effected the navigation channel.

- Alternative E created the most diversity in Sante Fe Chute. This alternative caused favorable redistribution of existing bed sediments while forming alternating scour and depositional areas. The resultant bed configuration from this plan created a sinuous flow pattern.

- Alternative I showed that re-opening Doolan chute was a viable possibility only if the entrance to the chute was maintained to at least +20 LWRP. This could be accomplished by the placement of a closure structure across the entrance to the chute. Additionally, the upper third of the chute would need to be excavated to allow flow through the chute. The excavation limits and amount of material to be removed was not investigated and was considered out of the scope of work for this project.

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.

Finally, it should be noted that the innovative ideas set forth in this study were developed as a result of a cooperative effort between all of the aforementioned agencies. "Hands on" experimentation at the Applied River Engineering Center (Plate 28) enabled both biologists and engineers to formulate design alternatives and experiments in the micro model.

BIBLIOGRAPHY

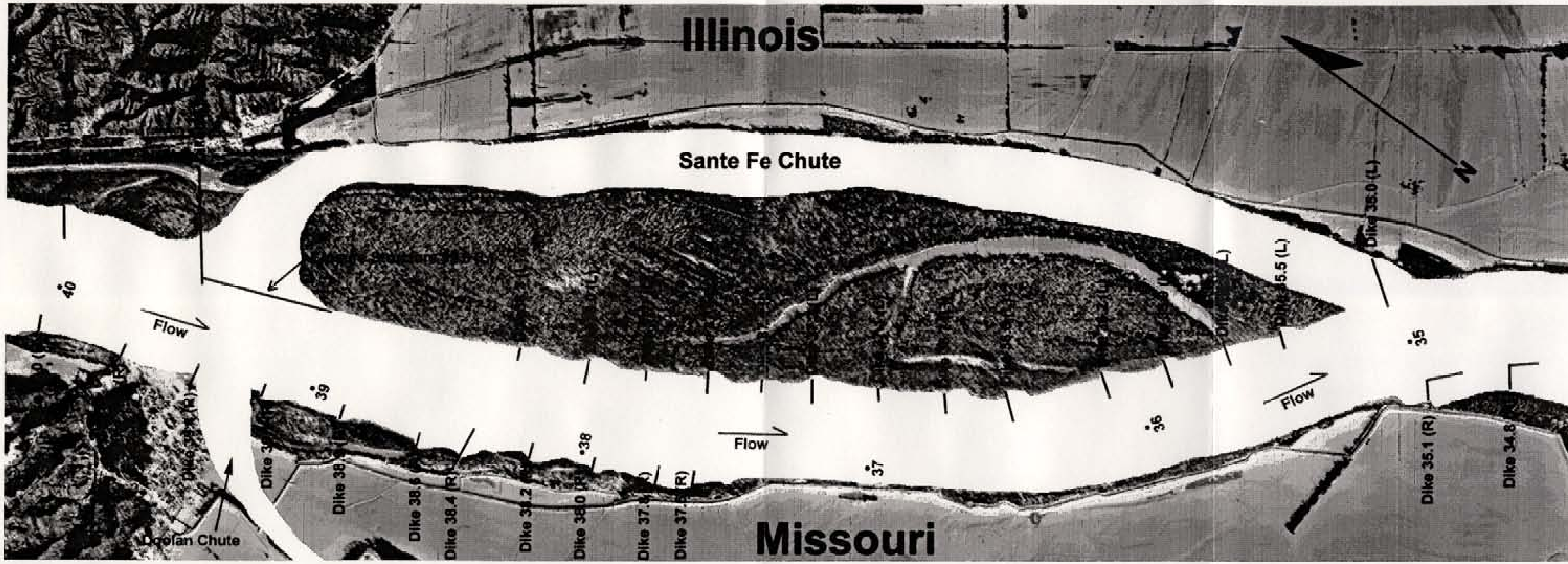
1. Davinroy, Robert D., Physical Sediment Modeling of the Mississippi River on a Micro Scale, University of Missouri-Rolla Thesis, Rolla, Missouri, October 1994.

2. Leopold, Luna B., A View of the River, Harvard University Press, Cambridge Massachusetts, London, England, 1995.

3. Davinroy, Robert D., Micro Scale Sediment Modeling (Micro Modeling) of Inland Waterways, Proceedings of the Sixth Federal Interagency Sedimentation Conference, Las Vegas, Nevada, 1996.

APPENDIX

Plates 1 through 28 will follow.



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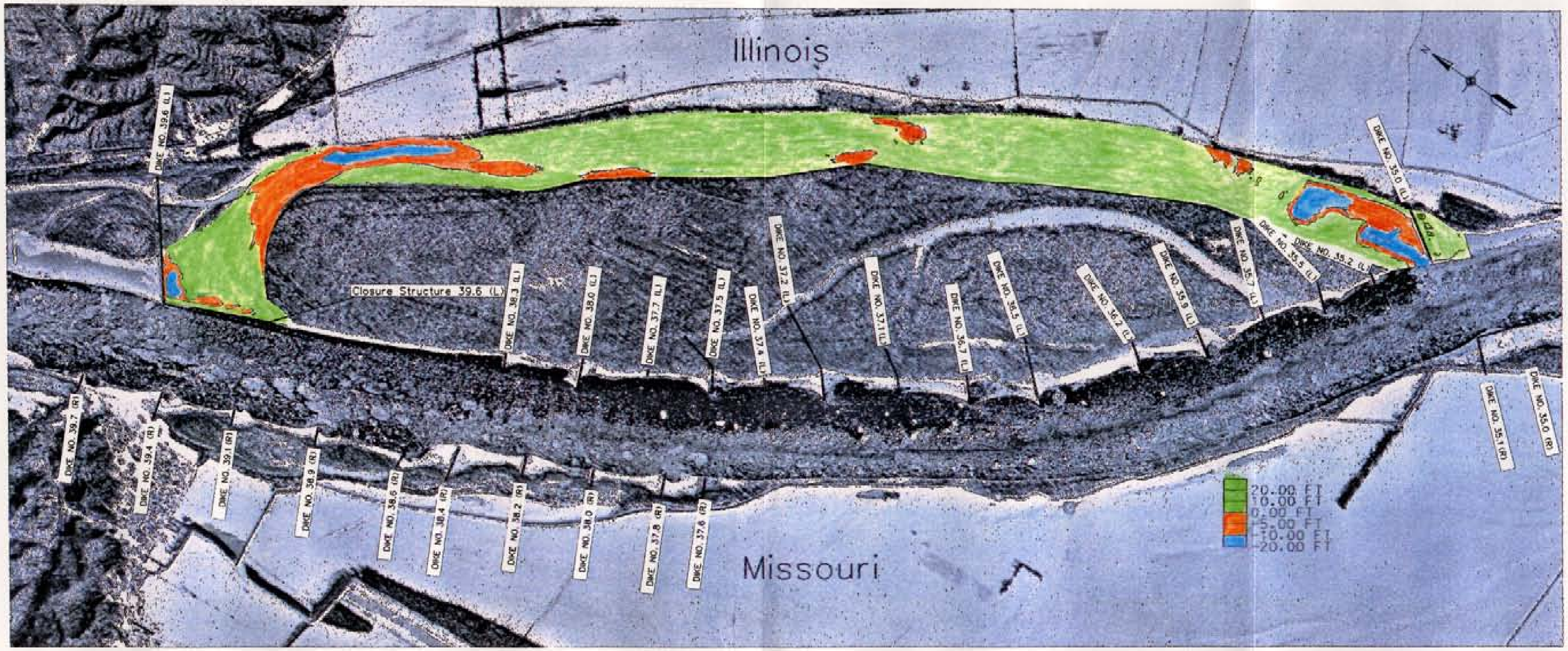
DATE: 29 July [illegible]

Sante Fe/Doolan Chute Micro-Model Study
Mississippi River Miles 40 - 35

Photograph of Sante Fe Study Reach

PLATE NO.
1



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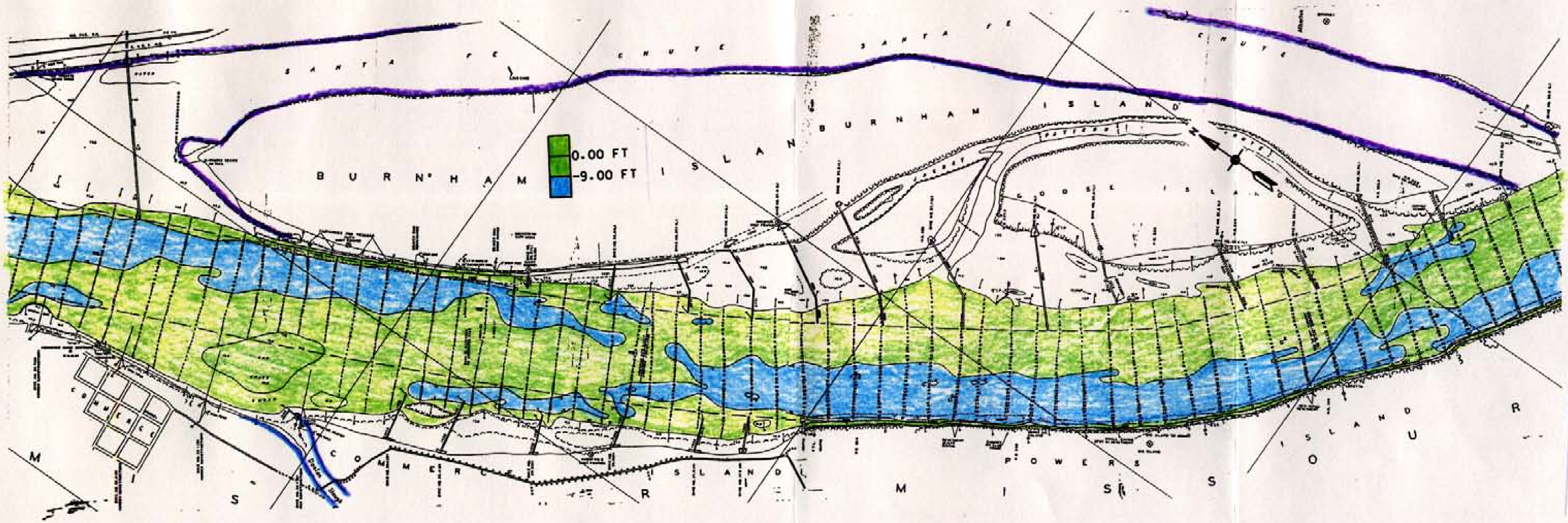
1995 Sonte Fe Chute Prototype Survey

PLATE NO. 2



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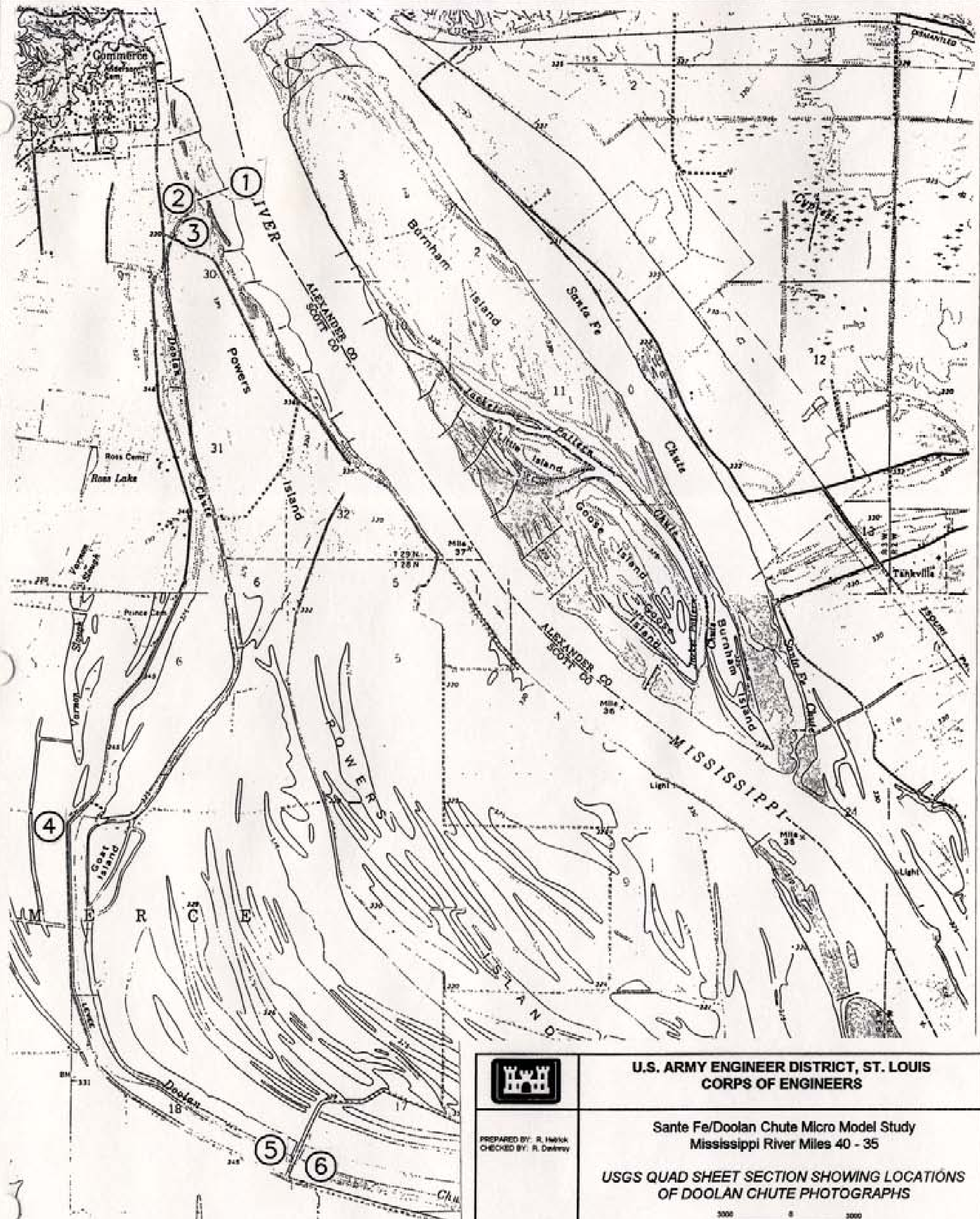
1958 PROTOTYPE SURVEY

PLATE NO. 3



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Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35

USGS QUAD SHEET SECTION SHOWING LOCATIONS OF DOOLAN CHUTE PHOTOGRAPHS

3000 0 3000

PLOT SCALE: 1 in = 3000 ft

PLATE NO. 4

Photograph #1; Doolan Chute

Photograph #2; Doolan Chute

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Photographs #1 and #2 of Doolan Chute

PLATE NO
5

Photograph #3; Doolan Chute

Photograph #4; Doolan Chute

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Photographs #3 and #4 of Doolan Chute

PLATE NO.
6

Photograph #5; Doolan Chute

Photograph #6; Doolan Chute

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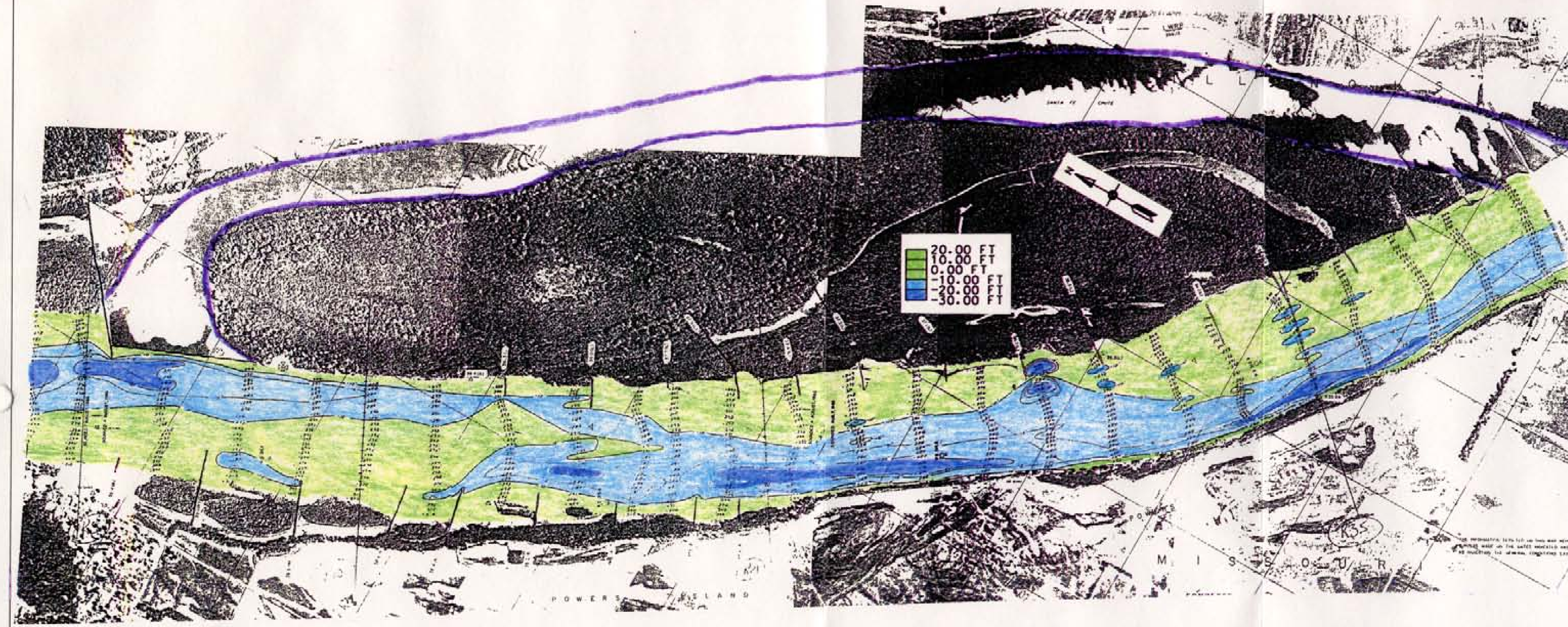
Mississippi River Miles 40 - 35

Photographs #5 and #6 of Doolan Chute

PLATE NO.
7



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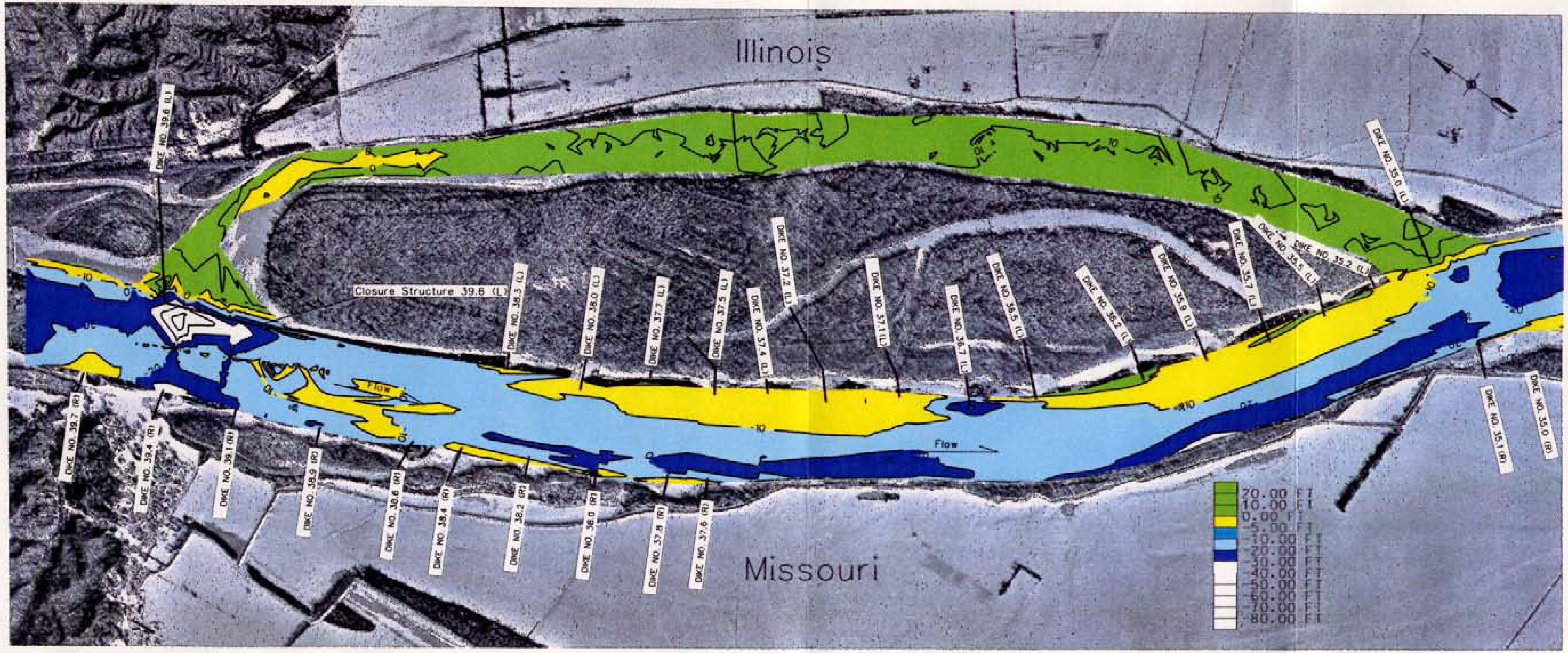
1986 PROTOTYPE SURVEY

PLATE NO 8



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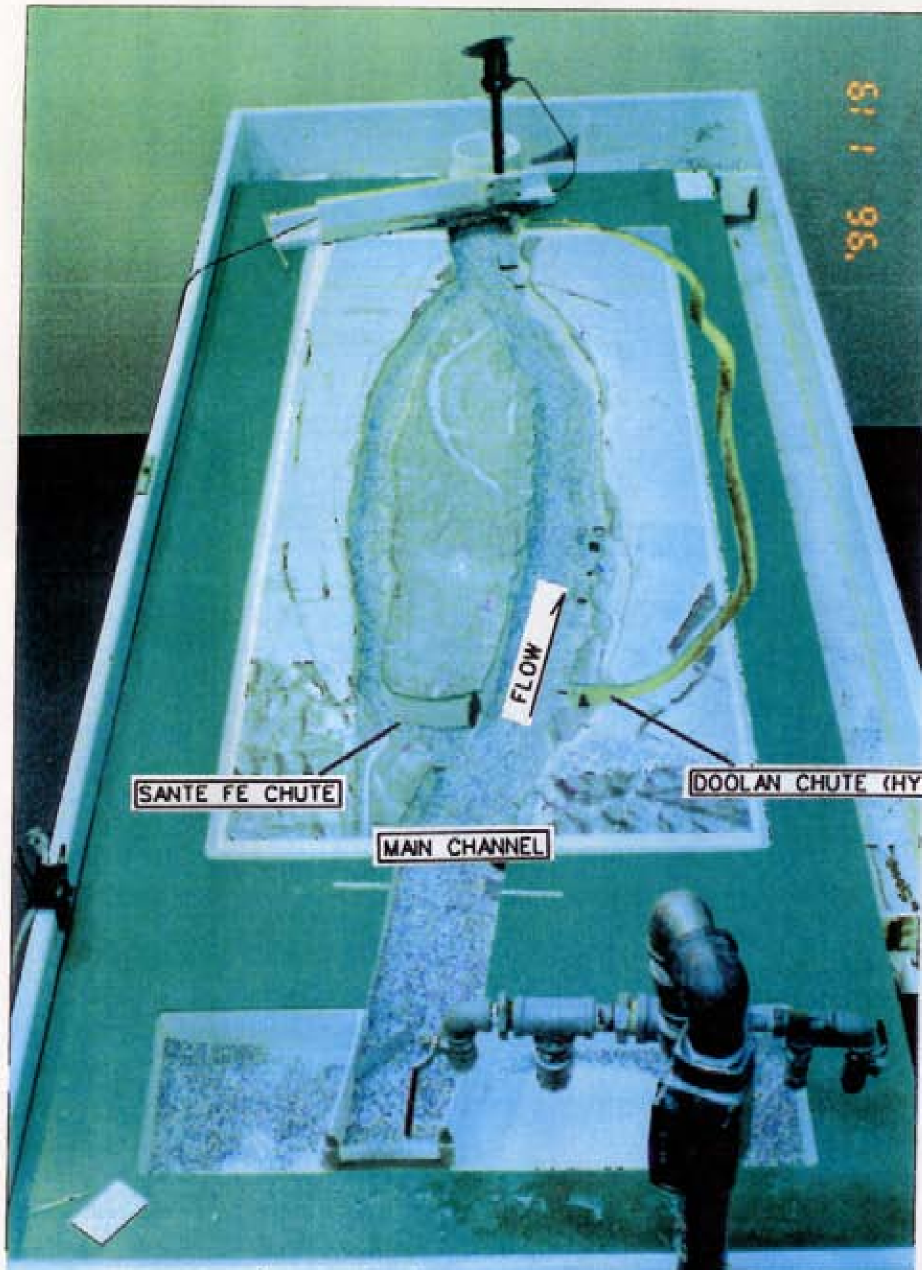
1993 PROTOTYPE SURVEY

PLATE NO. 9



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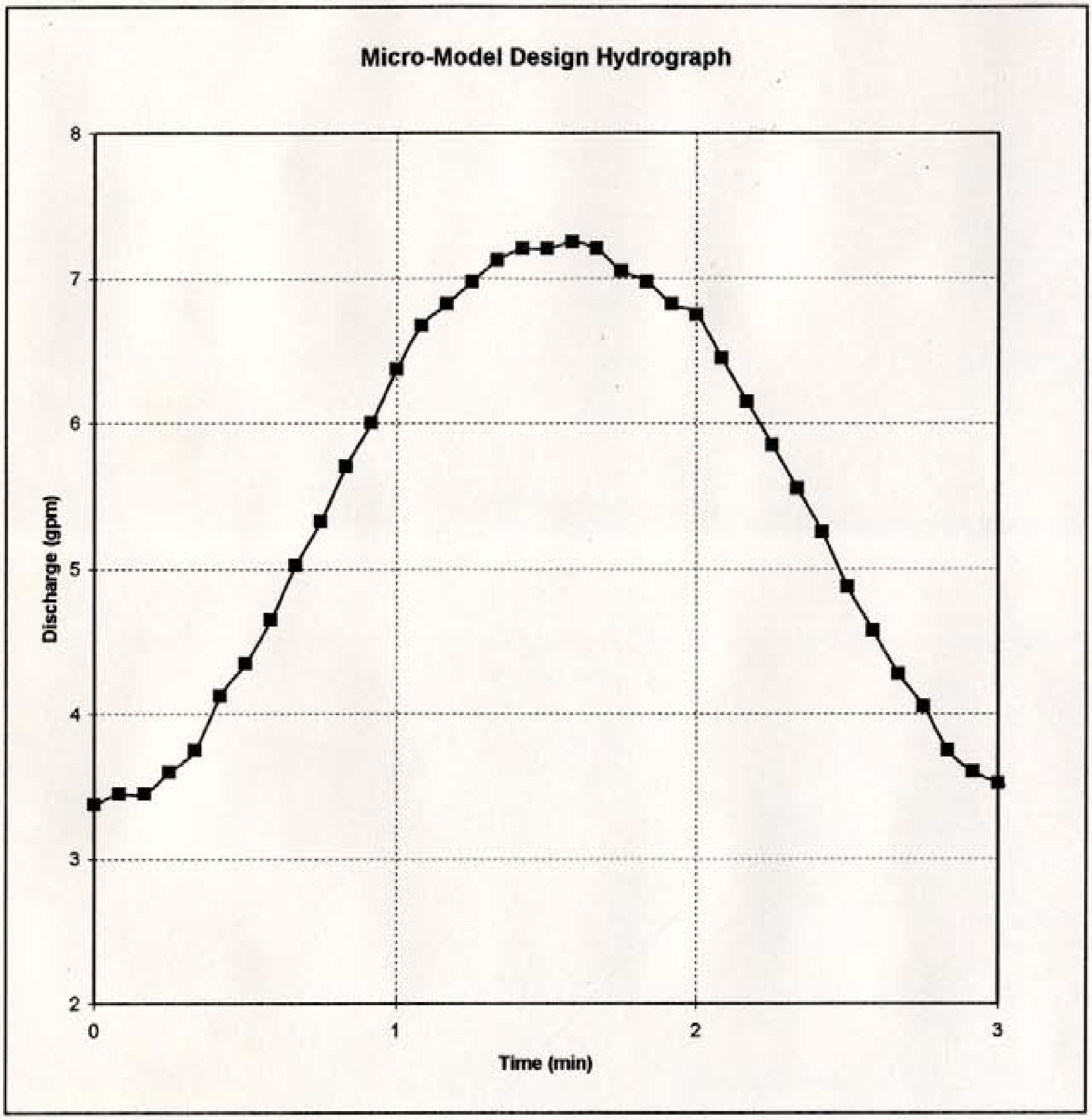
Mississippi River Miles 40 - 35

Photograph of Sante Fe Chute Micro Model

PLATE NO.
10



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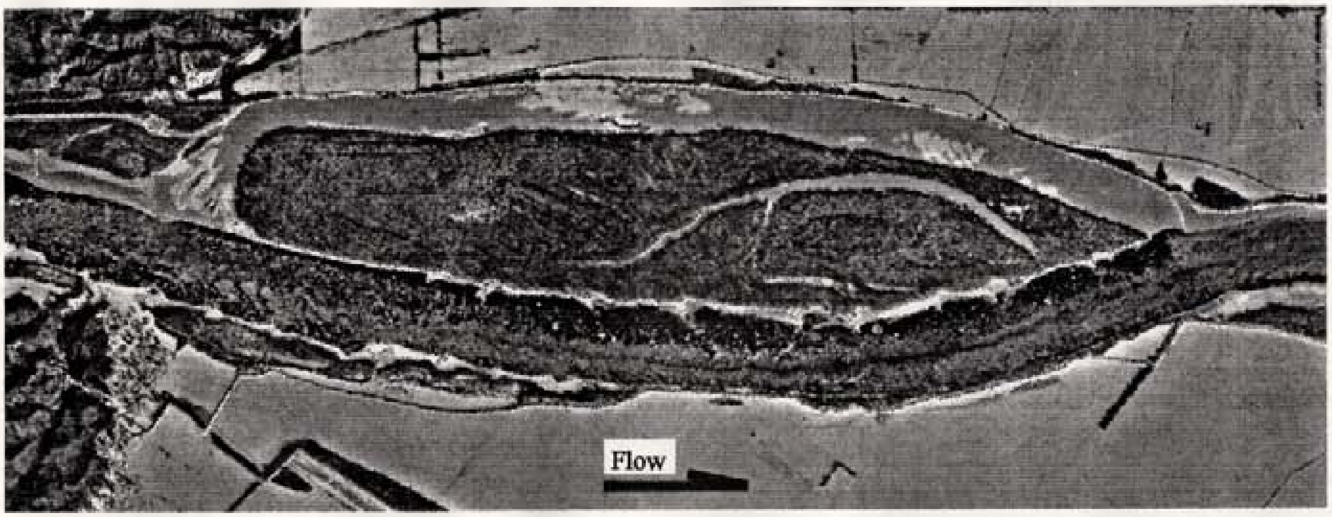
PREPARED BY: R. [illegible] CHECKED BY: R. [illegible]	Sante Fe/Doolan Chute Micro Model Study Mississippi River Miles 40 - 35 *Effective Discharge Hydrograph*
	PLATE NO. 11



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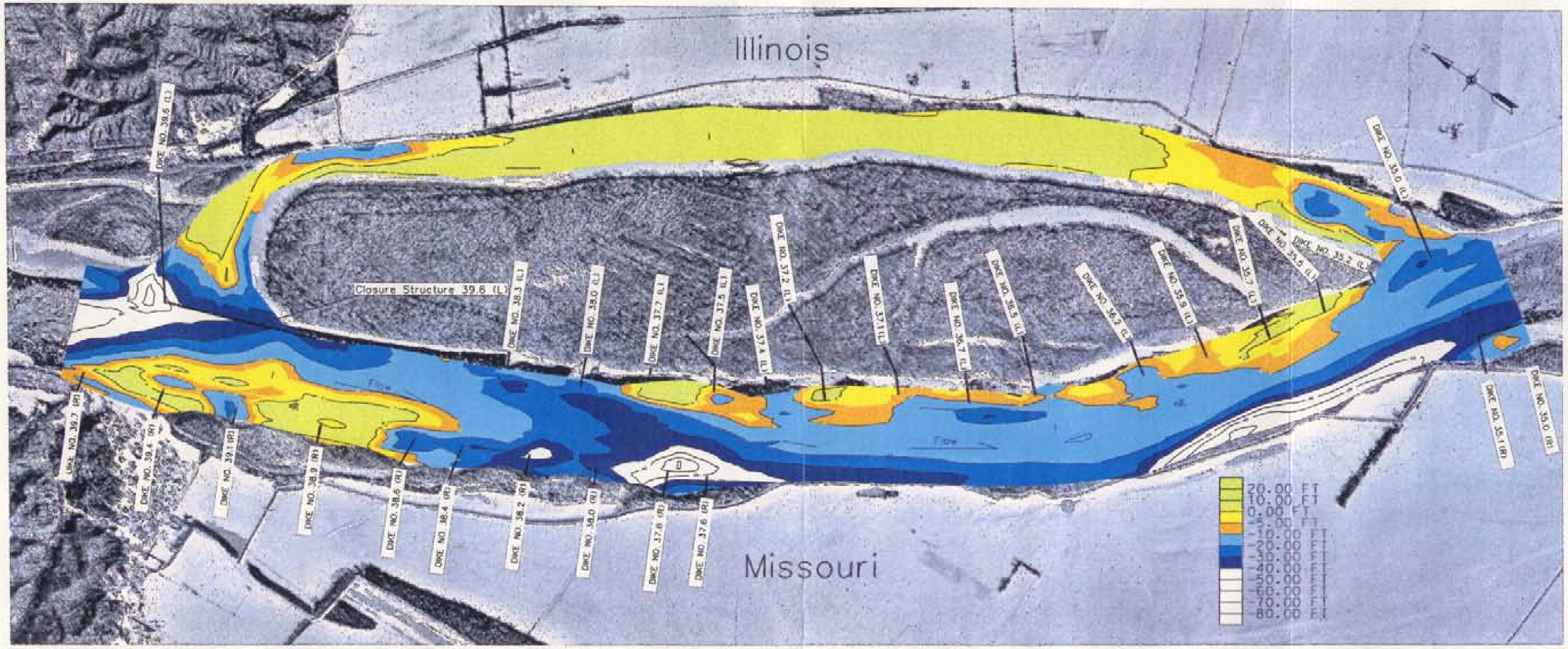
Mississippi River Miles 40 - 35

Prototype Ice Photo

PLATE NO.
12



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DRAWN BY: R. Hetrick
CHECKED BY: R. Davinroy

DATE: 20 July 1998

Sante Fe/Doolan Chute Micro-Model Study
Mississippi River Miles 40 - 35

Base Test

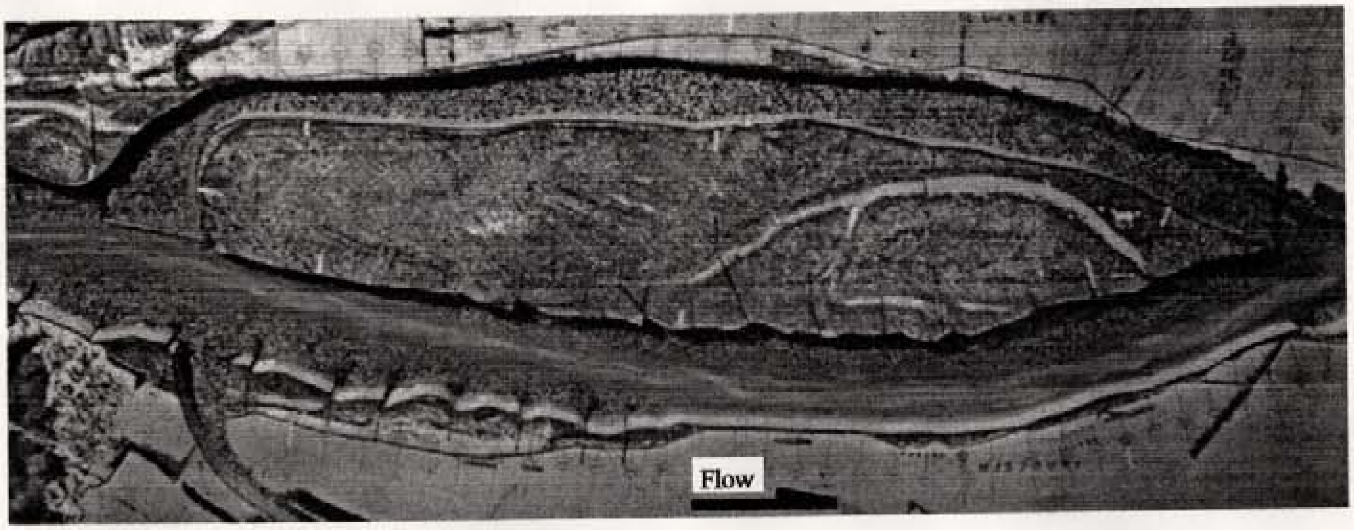
2000 1000 0 2000

DESIGN FILE: D:\DGN\MODEL\SANTEFE\BASE.DGN

PLOT SCALE: 1 in = 2000 ft

PLOT DATE: 24 Sept 1998

PLATE NO. 13



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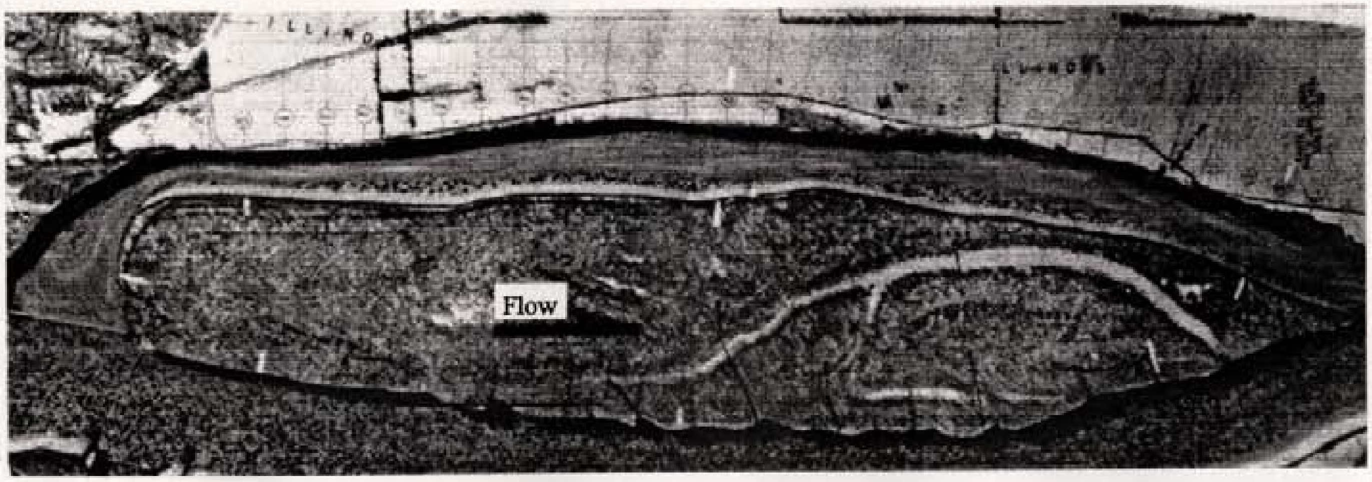
Mississippi River Miles 40 - 35

Flow Visualization of Main Channel Base Conditions

PLATE NO.
14



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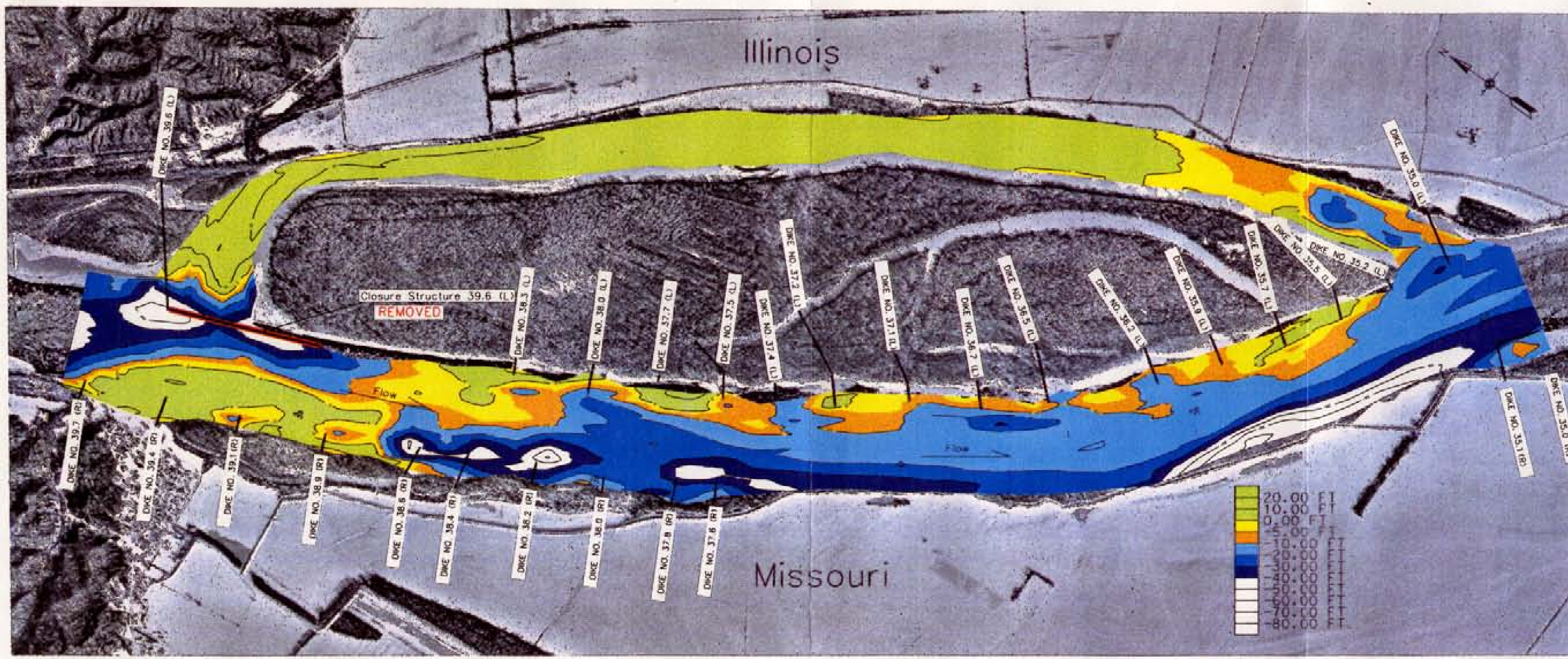
Mississippi River Miles 40 - 35

Flow Visualization of Sante Fe Chute Base Conditions

PLATE NO.
15



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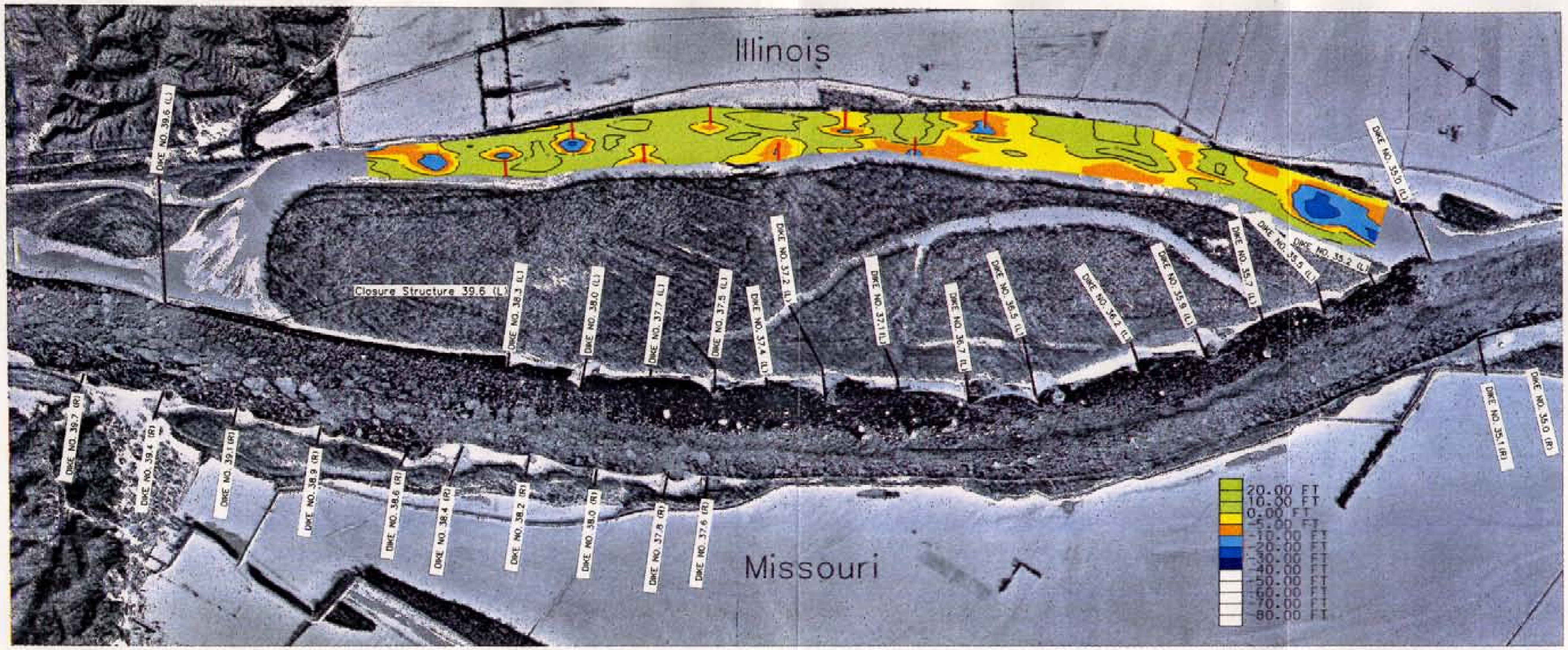
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE A
CLOSURE STRUCTURE 39.6(L) REMOVED

PLATE NO. 16



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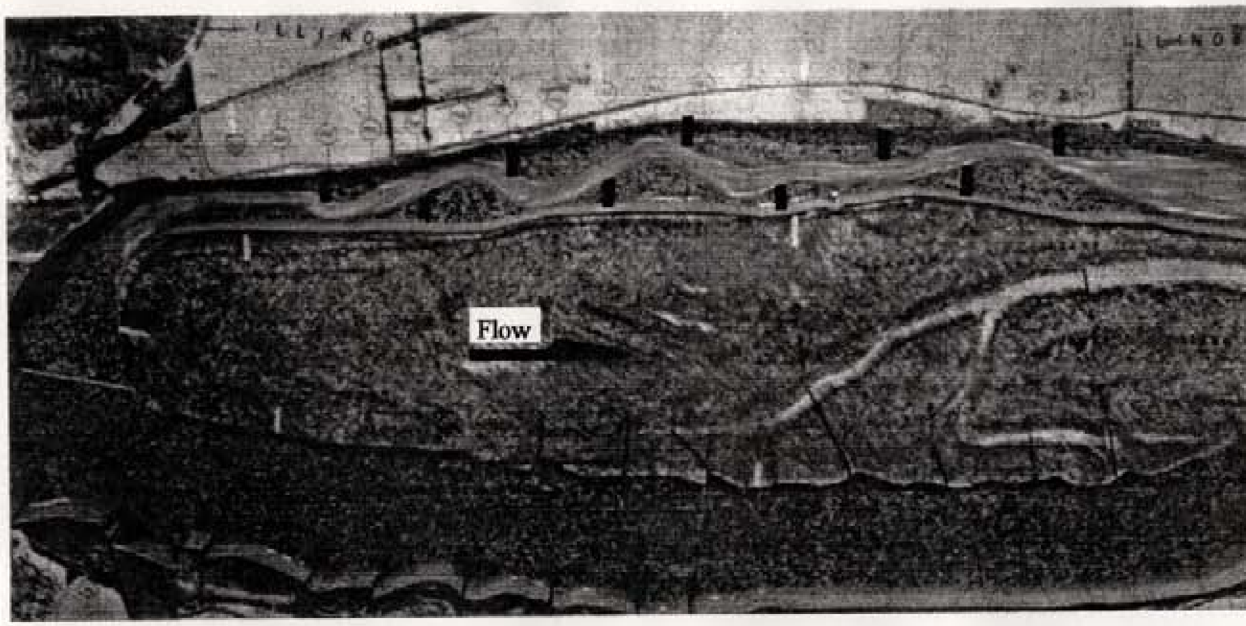
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35

ALTERNATIVE B

ALTERNATING LEVEL CRESTED HARDPOINTS AT + 30 LWRP

PLATE NO. 17



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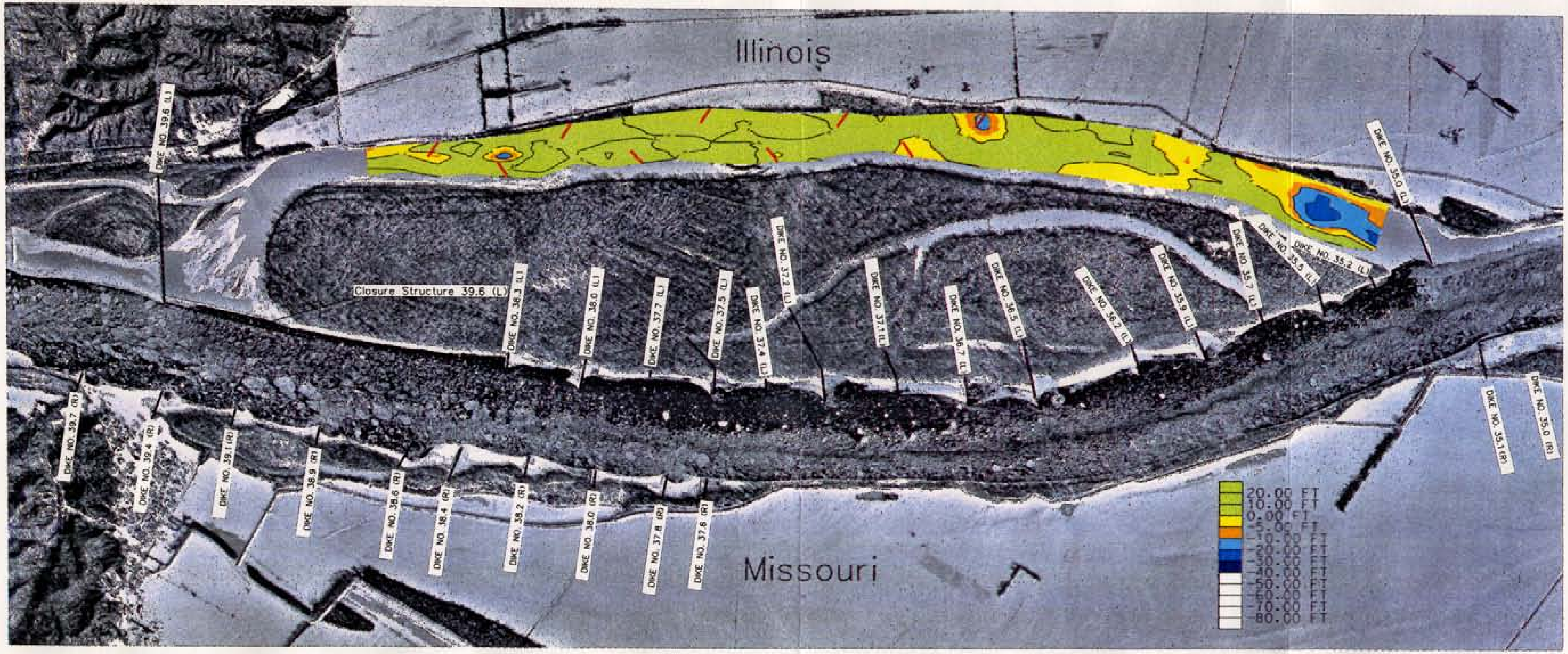
PREPARED BY: R. Heinck
CHECKED BY: R. Davinroy

Sante Fe/Doolan Chute Micro-Model Study
Mississippi River Miles 40 - 35

Flow Visualization of Alternative B

PLATE NO.
18



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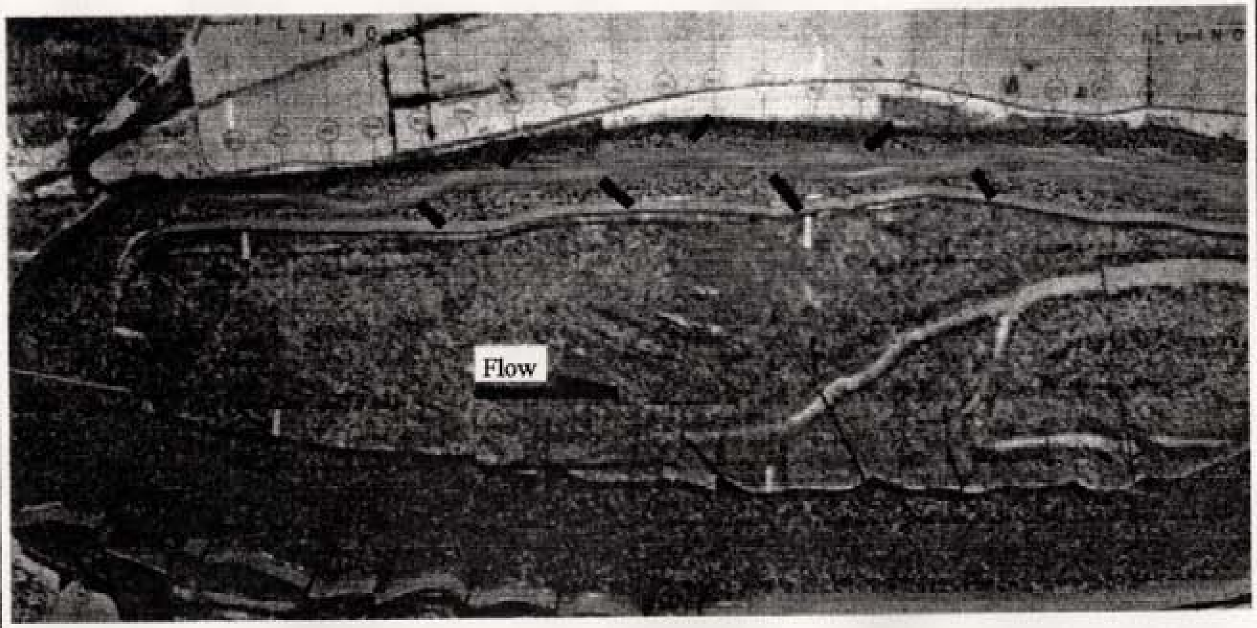
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE C
ALTERNATIVE LEVEL CRESTED HARDPOINTS AT -30 LWRP WITH UPSTREAM ANGLE

PLATE NO. 19



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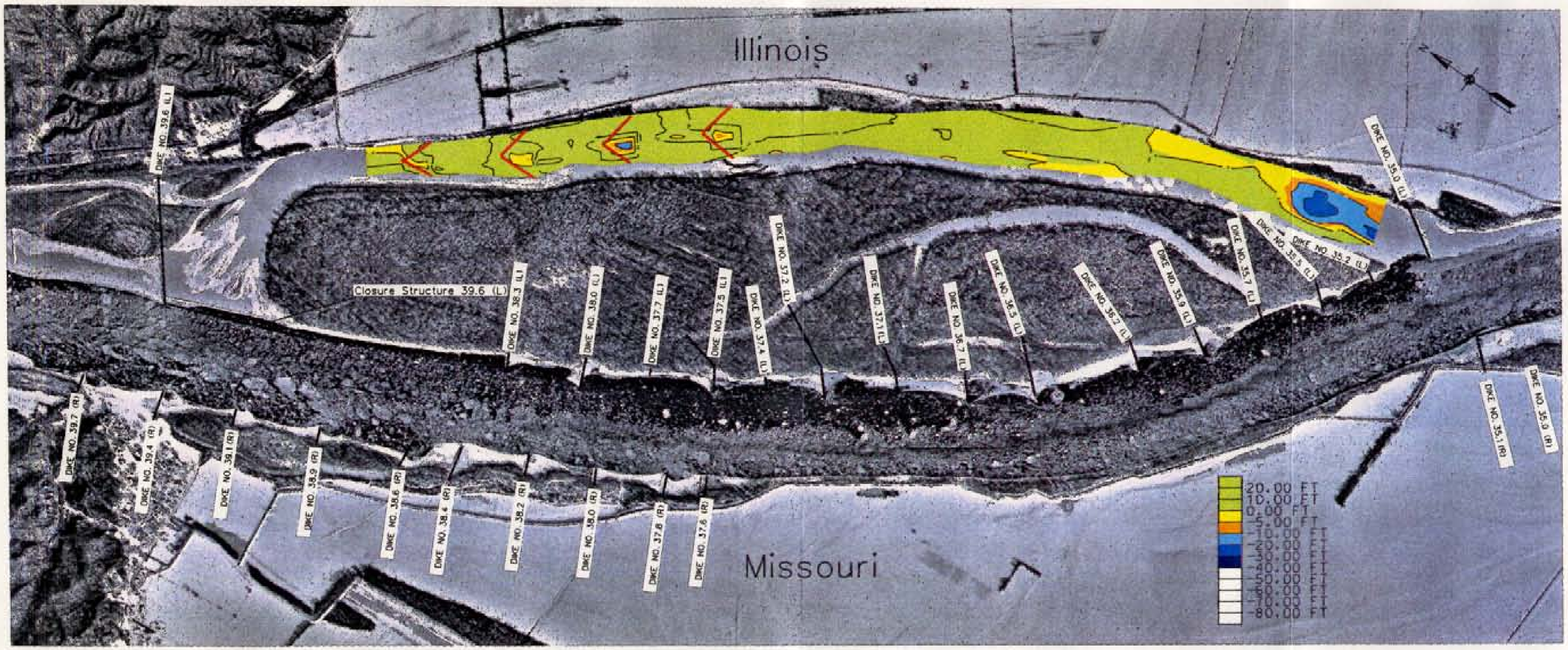
PREPARED BY: R. Hetrick
CHECKED BY: R. Davinroy

Sante Fe/Doolan Chute Micro-Model Study
Mississippi River Miles 40 - 35

Flow Visualization of Alternative C

PLATE NO.
20



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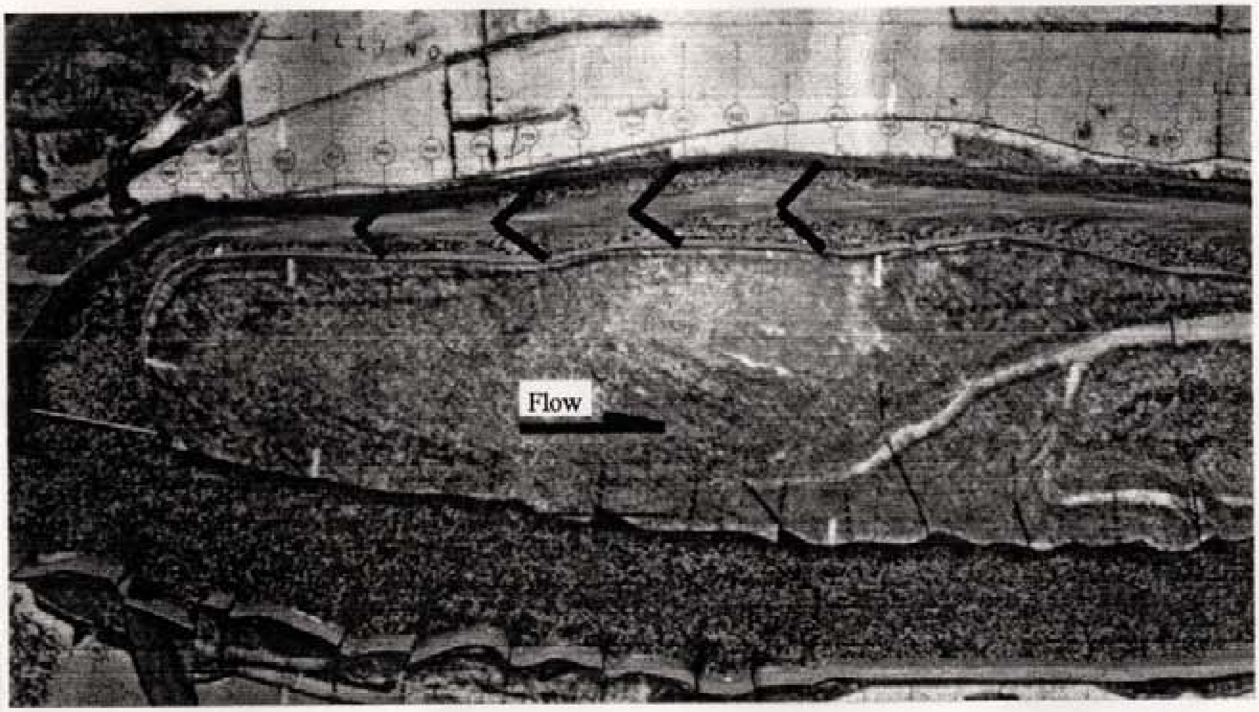
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE D
CHEVRONS, SLOPING FROM +30 LWRP AT BANKLINE TO +15 LWRP AT MID-CHANNEL

PLATE NO. 21



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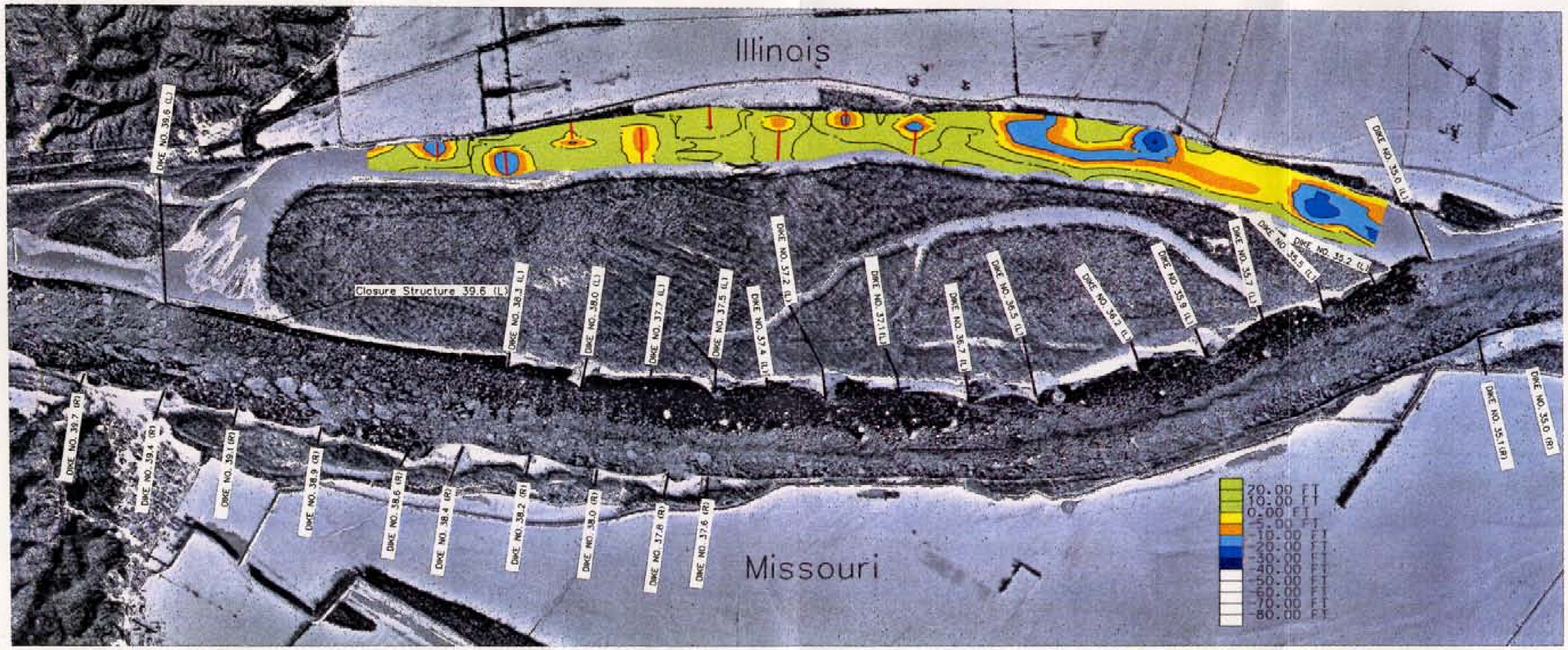
PREPARED BY: R. Heinck
CHECKED BY: R. Davinroy

Sante Fe/Doolan Chute Micro-Model Study
Mississippi River Miles 40 - 35

Flow Visualization of Alternative D

PLATE NO.
22



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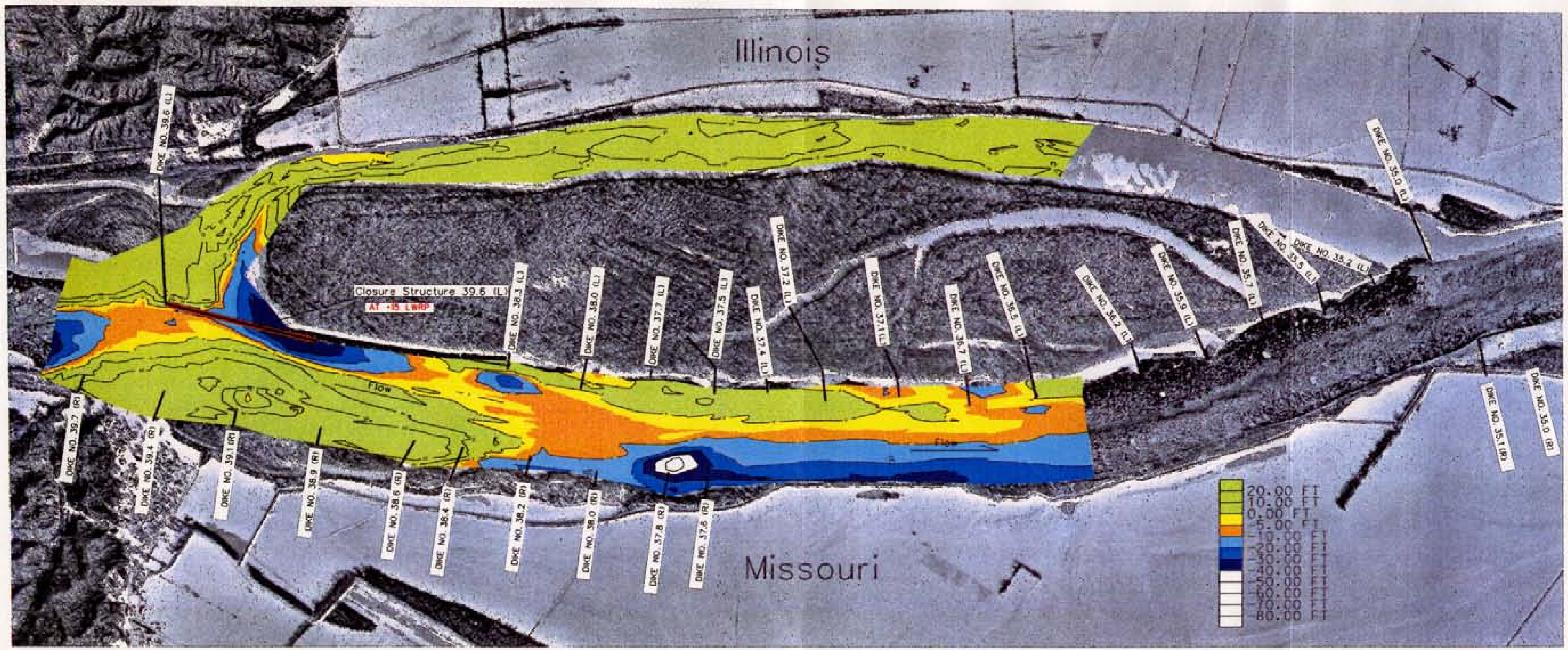
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE E
ALTERNATIVE LEVEL CRESTED HARDPOINTS AT -30 LWRP
WITH LENGTH MODIFICATION AND DOWNSTREAM DREDGING

PLATE NO. 23



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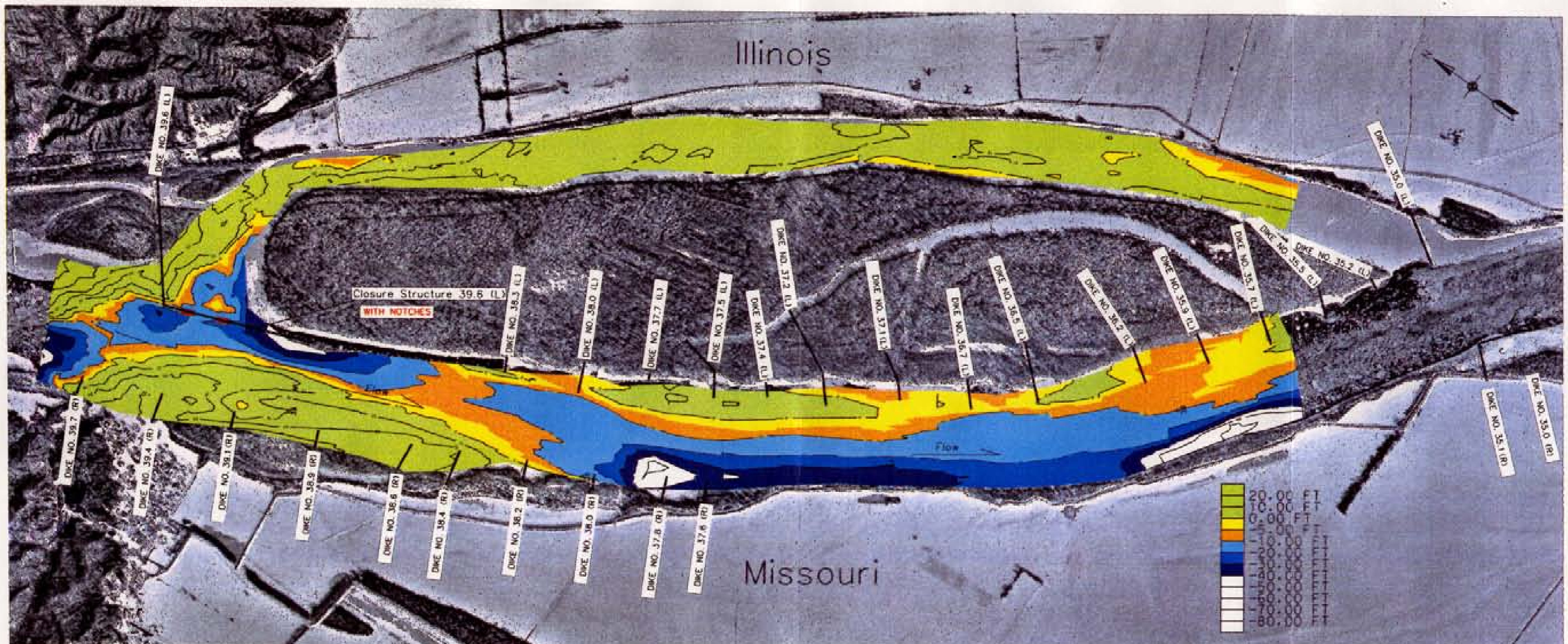
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE F
CLOSURE STRUCTURE 39.6(L) AT +15 LWRP

PLATE NO. 24



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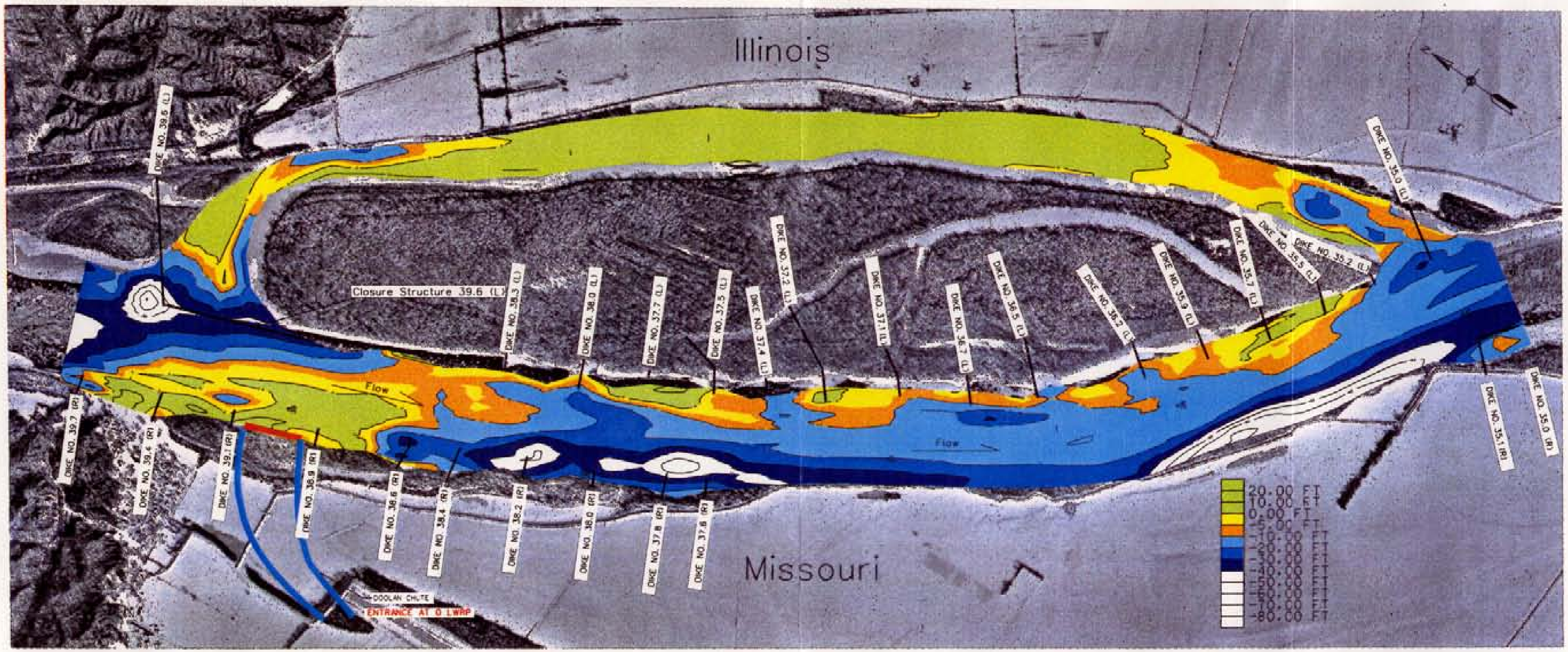
Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35

ALTERNATIVE G

NOTCHES IN CLOSURE STRUCTURE 39.6(L)

PLATE NO. 25



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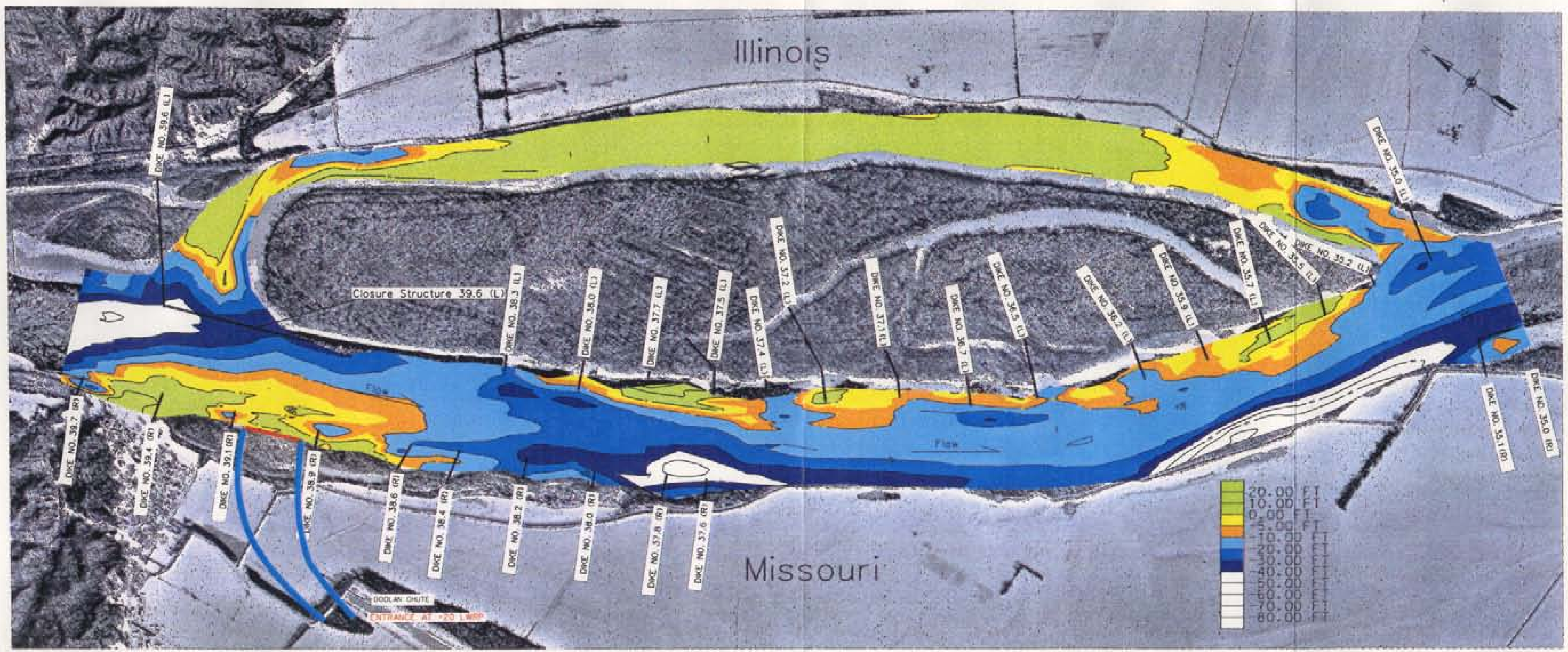
Santa Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE H
DOOLAN CHUTE LINKAGE WITH THE MAIN CHANNEL,
ENTRANCE CONDITIONS AT 0 LWRP

PLATE NO. 26.



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Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35
ALTERNATIVE I
DOOLAN CHUTE LINKAGE WITH THE MAIN CHANNEL,
ENTRANCE CONDITIONS AT -20 LWRP

PLATE NO. 27

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PREPARED BY: R. Helrick
CHECKED BY: R. Davinroy

Sante Fe/Doolan Chute Micro Model Study
Mississippi River Miles 40 - 35

Biologists and Engineers Formulating Ideas at the Applied River Engineering Center

PLATE NO.
28