MISSISSIPPI RIVER POTAMOLOGY STUDIES

by

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INTRODUCTION

Potamology is "the science of rivers." The potamology program of the Vicksburg District of the Corps of Engineers is involved in the development of the science of the Mississippi River within the Vicksburg District. Our ultimate goal is to develop a workable knowledge of the basic principles controlling the transport of water and sediment in the Lower Mississippi River, and to apply this knowledge toward effectively and economically stabilizing the river for flood control and navigation.

The Mississippi River has a watershed of $1\frac{1}{4}$ million square miles in thirty-one states and two Canadian provinces. This represents 41 percent of the total land area of the United States, exclusive of Alaska and Hawaii. During a major flood year, the water discharged by the Mississippi River would cover the state of Mississippi to a depth of about 26 feet. The minimum and maximum recorded discharges at Vicksburg for the period of record are about 94,000 and 2,280,000 cfs, respectively. Gage readings at Vicksburg during the period of record have varied from -6.8 to +58.4. Maximum point velocities may approach 15 ft per second during floods.

The average size of the bed material in the Vicksburg District portion of the river is about 0.4 mm. The average slope through the Vicksburg District is about 0.4 ft per mile, varying from a few hundreths of a foot per mile to about one foot per mile.

BACKGROUND OF THE STABILIZATION PROGRAM

After the disastrous flood of 1927, Congress adopted a comprehensive plan for flood control in the Mississippi River alluvial valley by passage of the Flood Control Act of 1928. This act has been modified and expanded many times since then.

The primary purpose of channel stabilization on the Lower Mississippi River is flood control; therefore, first consideration in any plan of stabilization must be protection of levees and provision of a channel which will safely pass floodflows. The secondary purpose, and one which has recently become increasingly important, is the establishment of a channel which has the alignment and depths required for navigation.

Following the 1927 flood, the urgent need was to reduce flood heights and protect levees threatened by caving banks. To do this, thirteen cutoffs were made during the 1930's in the Vicksburg District. The cutoff program was most beneficial in reducing flood heights. For example, flood heights at Arkansas City, Arkansas, have been lowered by about 15 feet and at Vicksburg, Mississippi, by about 11 feet. Though the cutoffs were of great benefit in lowering flood heights, they increased our channel stabilization problems considerably. By cutting 115 miles off the length of the river in the Vicksburg District, the cutoffs steepened the slope of the river and upset its equilibrium. The river's attempts to regain its original length accelerated bank caving. The river also compensated for its increased slope by developing shallower, wider, and hydraulically rougher cross sections. During this period, channel stabilization was mostly confined to critical levee locations. While "putting out the fires," so to speak, we had little chance to plan ahead for overall stabilization. Today, however, most critical levee locations have been protected and the channel stabilization program has shifted from the defensive to the offensive. More consideration can now be given to proper channel alignment and to the overall effects of channel stabilization.

PROBLEMS IN CHANNEL STABILIZATION

Reaches of the river which require channel stabilization may be divided into three types: meandering reaches, divided flow reaches, and long, straight reaches. Figures (1), (2), and (3) illustrate these types.

A meandering reach caves its banks on the concave side. This type reach usually has good alignment and depths for navigation, and complete stabilization may usually be accomplished by revetting the caving banks on the desired alignment.

A divided flow reach presents a more difficult stabilization problem. Here we must decide which channel is the most desirable, then attempt to confine the river to it and stabilize it with dikes, revetment, and dredging.

A long, straight reach also presents a difficult stabilization problem. A long, straight reach is characterized by shifting alternate and middle bars and an undependable navigation channel. The problem here is to decide in what position the channel should be stabilized and then to determine the most effective and economical means of stabilization.

In addition to these three specific types of channel stabilization problems are problems of a broader nature which in the long run may prove to be more difficult to solve. Some of these are:

1. What will be the ultimate effects of altering the discharge hydrographs and sediment loads with flood control works, channel improvement works, and channel and watershed stabilization works?

2. What will be the ultimate effects of confining the Mississippi River into an unnatural nonmeandering regime?

3. What would be the ultimate effects of diversion of considerable quantities of water across watershed boundaries?

4. What is the maximum navigable depth which can be maintained in a given reach of river and what will be the cost of obtaining it?

We have made great strides in our efforts thus far to stabilize the Mississippi, but we still have many problems. We have found that successful stabilization cannot be accomplished by the application of theoretical formulae alone, nor by using techniques and designs that have worked in the past alone. Instead, successful stabilization requires a mixture of hydraulic engineering and experience to develop sound principles which can be used to solve the problems just discussed. Our potamology studies are attempting to provide answers to both the specific, immediate problems and the more general, long range problems so that we may accomplish our basic objective of stabilizing the Mississippi River to satisfy the needs of both flood control and navigation.

POTAMOLOGY DATA COLLECTION

Potamology studies by the Vicksburg District began in 1962 and were directed toward hydraulic analyses of typical cross sections of the Mississippi River. These original studies isolated the more important variables and led to some promising relationships. The original studies also pointed out the need for more intensive and complete data. Consequently, in May 1966 we began detailed data collection and studies of particular reaches of the river. The Vicksburg District portion of the river is being divided into "study reaches" varying from 6 to 20 miles in length. The maximum length of a reach is limited by the stipulation that all the data gathered during any survey should be gathered in a short enough time period that the flow may be considered steady during the survey. This time period is usually 3-5 days. The minimum length of a reach is limited by the stipulation that the reach should be long enough to cover a well-defined typical condition or problem area.

We are now gathering data on eighteen study reaches covering about 200 miles of river in the Vicksburg District. We are slowly expanding our system of study reaches as our capability permits, with the ultimate goal of having study reaches covering the entire 300 miles of the Mississippi River within the Vicksburg District. Figures (4) and (5) show the present extent of our study reaches.

Some of the typical conditions covered by our study reaches are as follows:

1. Ozark-Eutaw: a stabilized meandering reach

2. Cottonwood Bar: a divided-flow reach

3. Cracraft-Carolina: a long, straight reach

Data is being collected on each study reach at representative points on the discharge hydrograph. Each potamology survey of a reach provides us with the following data:

1. Hydrographic survey

2. Bed form profiles

3. Surface current directions

4. Discharge and horizontal velocity distribution

5. Subsurface current directions

6. Bed material samples

7. Water surface profiles

The data collection is done by a potamology task force consisting of a sounding party, a discharge party, and a gage party.

The sounding party makes the hydrographic survey and the bed form profiles and measures surface current directions with floats. The discharge party measures the discharge and horizontal velocity distribution through the reach, measures subsurface current directions at selected ranges, and takes bed material samples. The gage party establishes the water surface profile through the reach. To illustrate the data collection program we'll look at a typical potamology survey of a typical study reach.

Hydrographic Survey (Figure 6). The sounding party, using an electronic means of measuring horizontal distance and a sonic depth recorder, sounds cross sections through the reach at intervals of 0.2 mile. The sounded depths are converted to elevations in feet, msl, and the river channel is contoured at ten-foot intervals from the elevation of the average low water plane.

Bed Form Profiles and Surface Current Directions. We make two types of bed form profiles. One type is a short profile along the path of the surface streamline. These profiles are about 1,200 feet long and are made at intervals of 500 to 1,000 feet across the channel. The sounding party obtains these profiles by placing a float in the water and operating the depth recorder continuously while following the float down the river. A fix is made on the float location every 30 seconds and plotted on the map. In this way the direction and speed of the surface current is recorded on the map, and simultaneously the bed form along the streamline is recorded on the fathometer scroll (Figures 7 and 8). The second type of bed form profile is a long profile along a predetermined straight line with position fixes marked on the fathometer scroll at each 50-meter station on the profile line (Figures 7 and 9). In this way, it is possible to record a bed form profile along the same line and with position fixes at the same points each time a reach is surveyed.

Discharge and Horizontal Velocity Distribution. These measurements are made by the discharge party at selected study ranges through the reach at intervals of 0.6 to 0.8 mile. On each study range, velocity measurements are made at intervals of 100 to 400 feet across the range. Figure (10) shows the velocity distribution for study range 573.6. Ordinarily the velocity is measured at a point at 0.4 of the depth in the vertical. An average velocity distribution curve in the vertical for the Lower Mississippi River has been previously established by many measurements (Reference 1). It is known that the bed form and sediment load affect the velocity distribution in the vertical to some extent; however, this average curve is considered to be applicable to all conditions within the range of acceptable accuracy. Therefore, a velocity measurement at one point in the vertical is considered sufficient to define the average velocity in the vertical.

Subsurface Current Directions. The surface current directions as measured by floats are supplemented at selected ranges by current direction and magnitude measurements at 0.2 and 0.8 of the depth (Figures 7 and 11). These subsurface current direction measurements are obtained with a converted magnetic airplane compass attached to the Price meter weight. The instrumentation has not proven to be as precise as was initially hoped for, but has proven useful in documenting macroturbulence and the existence of secondary flow in bends of the river. More precise instrumentation, for example, a gyrostabilized platform with a pair of acoustic transducers on each of two or three axes, is as yet prohibitively expensive.

Bed Material Samples. Bed material samples are taken at selected study ranges through the reach using a BM-54 sampler (Reference 2). A mechanical analysis is made of each sample and the gradation curve is plotted.

Water Surface Profile. The gage party establishes the water surface profile through the reach during the survey period by setting and reading well-type gages at selected locations, usually at about 0.8 mile intervals. The major obstacle to reliable gage data was establishment of a common datum relative to all of the gages within the limits of accuracy required. Frequently we are dealing with slopes of 0.1 foot per mile; therefore, errors have to be kept to a minimum. The water surface profile is plotted from the gage data. The energy grade line is established by computing the average velocity head $V^2/2g$ at the gage locations and adding it to the water surface elevation (Figure 12). The velocity distribution coefficient α is assumed to approximate unity.

In addition to the intensive potamology data collection just discussed, suspended sediment measurements and analyses are being made routinely at several stations on the Mississippi in the Vicksburg District. The need for a comprehensive data collection program for the entire Lower Mississippi is recognized and progress is being made toward this end.

MODEL STUDIES

Movable bed model studies of selected reaches and of general stabilization problems on the Lower Mississippi River are being conducted at the Waterways Experiment Station. These studies have been extremely useful in demonstrating the relative effectiveness of various stabilization techniques.

SUMMARY

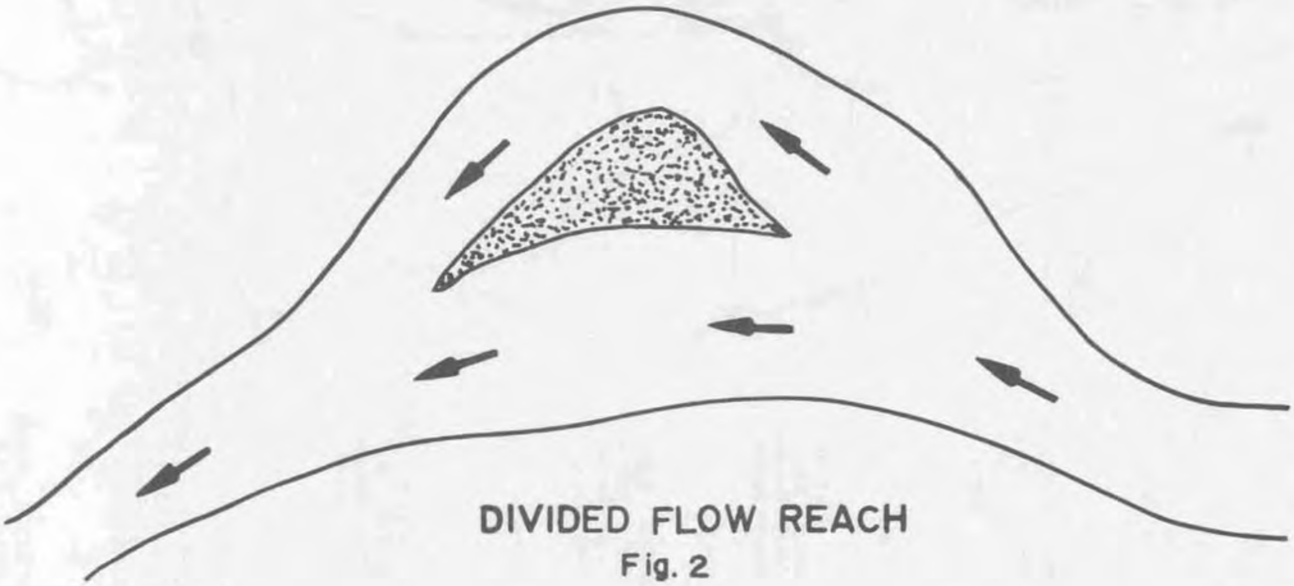
Our goal is to understand and document the basic principles involved in the transport of water and sediment on the Lower Mississippi River. The current intensive data collection program and analyses are directed toward this goal, and should establish guidelines for stabilization of the Lower Mississippi River for flood control and navigation.

REFERENCES

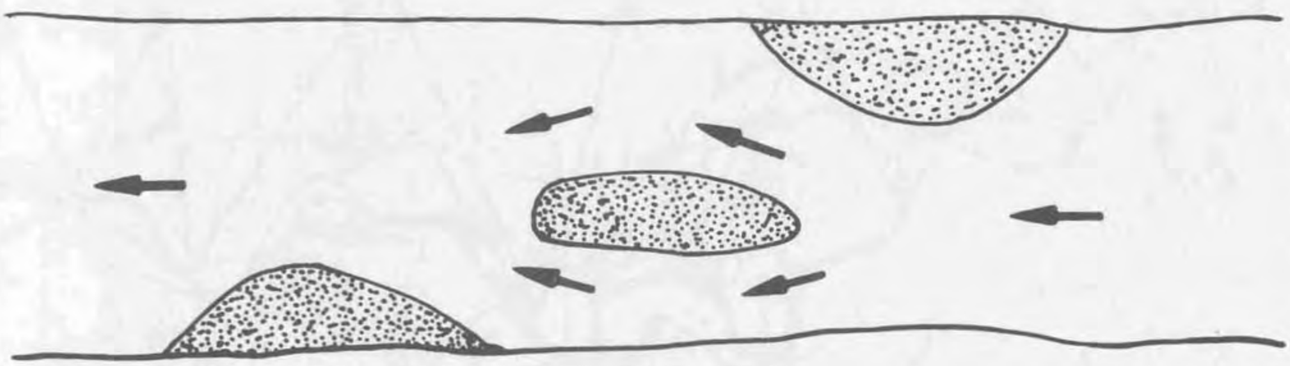
1. Toffaletti, F. B., "Deep River Velocity and Sediment Profiles and the Suspended Sand Load," Proceedings of the Federal Interagency Sedimentation Conference, Misc. Pub. No. 970, ARS, USDA, pp. 207-228, 1963.

2. Subcommittee on Sedimentation, Interagency Committee on Water Resources, Determination of Fluvial Sediment Discharge, Report No. 14, St. Anthony Falls Hydraulic Laboratory, Minneapolis, 1963.

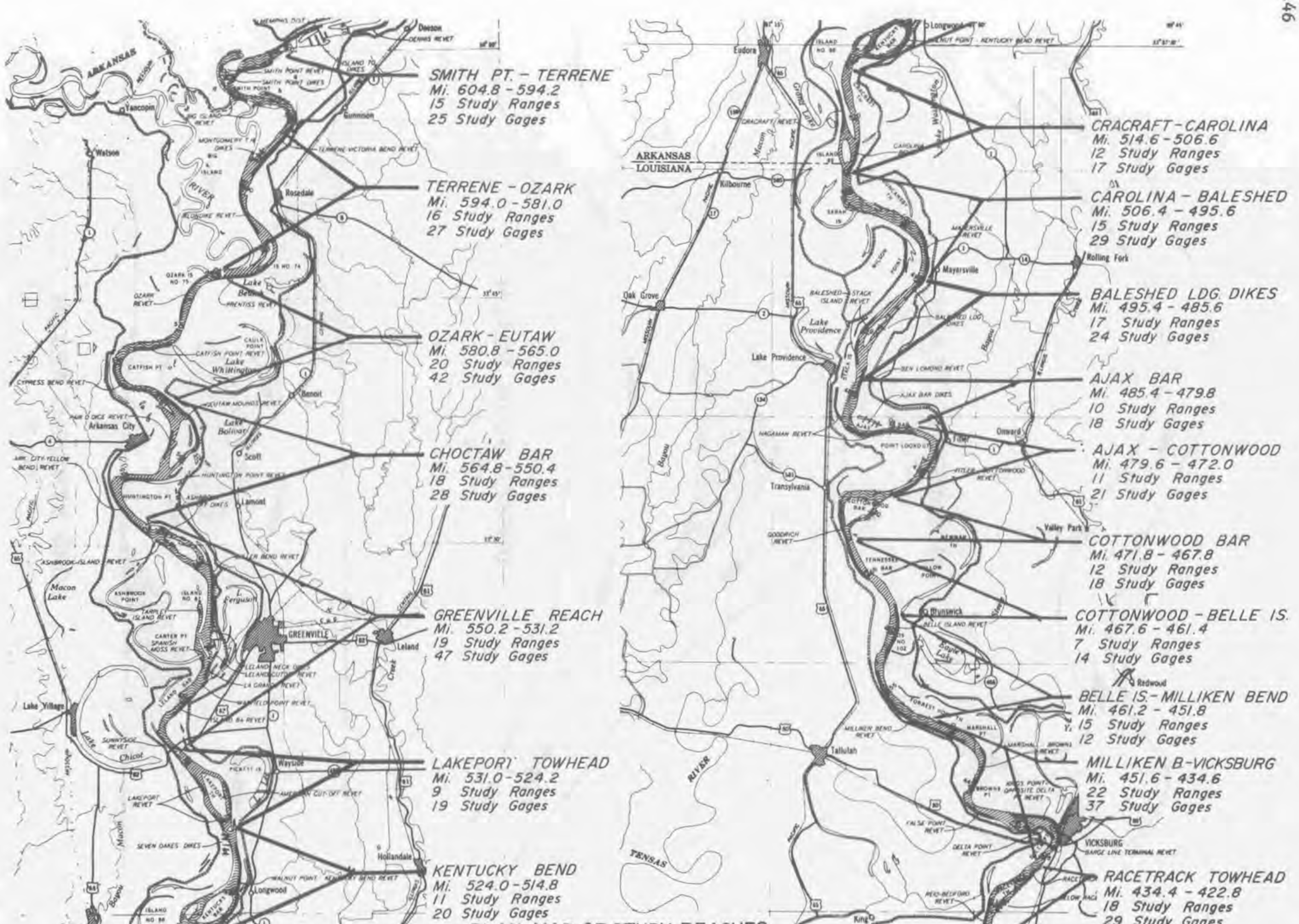
MEANDERING REACH
Fig. 1



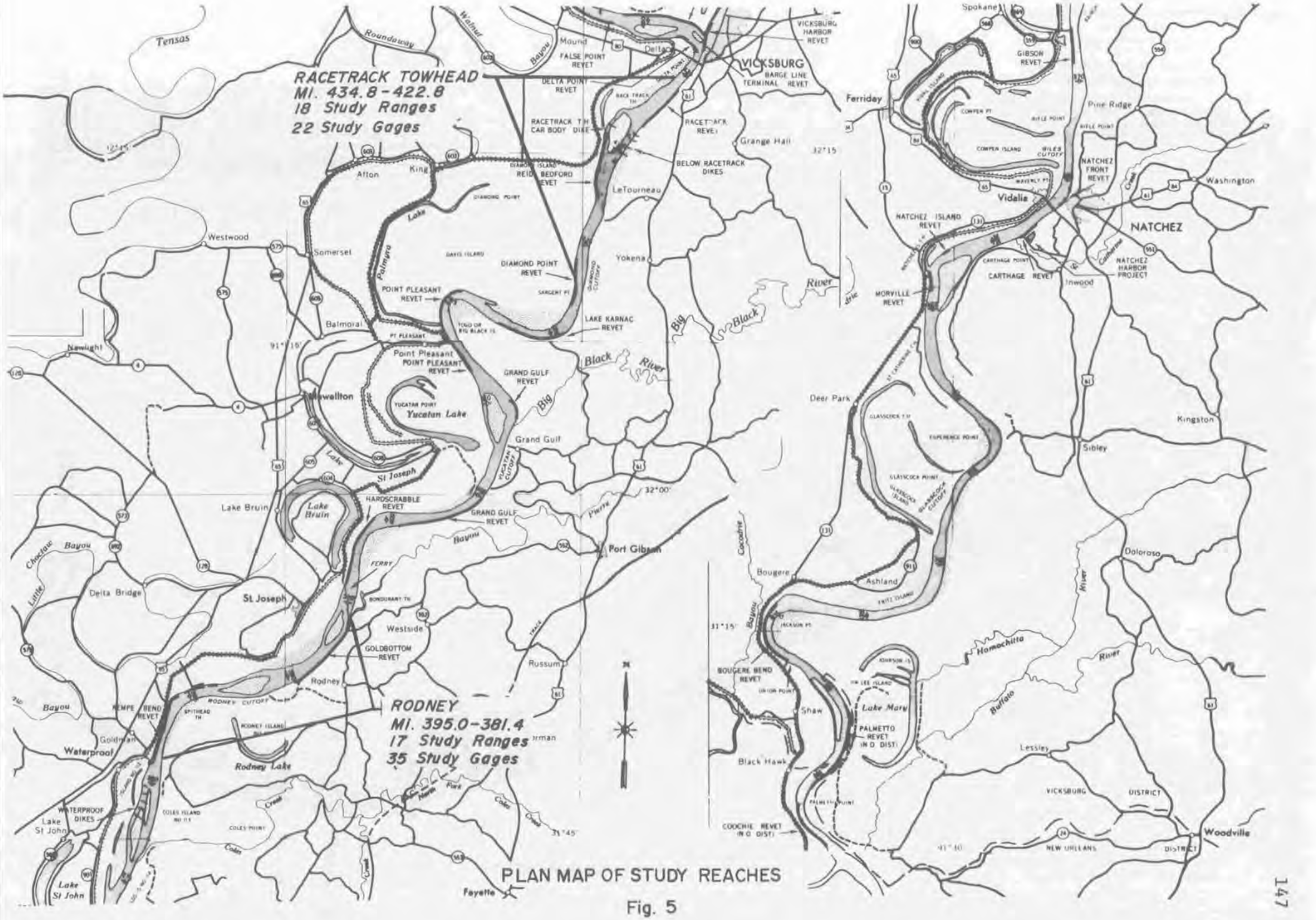
DIVIDED FLOW REACH
Fig. 2



LONG STRAIGHT REACH
Fig. 3

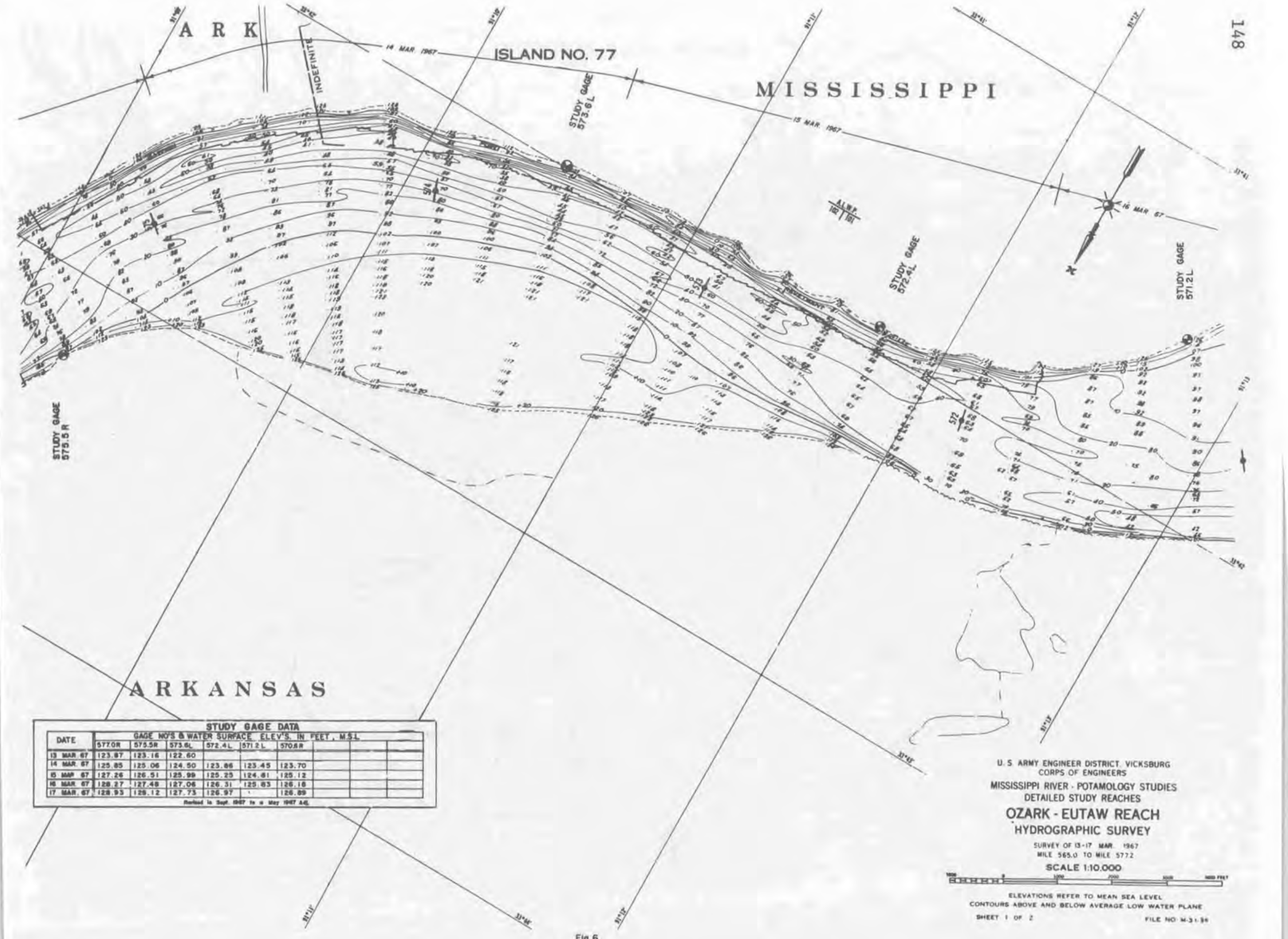


PLAN MAP OF STUDY REACHES
Fig. 4



PLAN MAP OF STUDY REACHES

Fig. 5

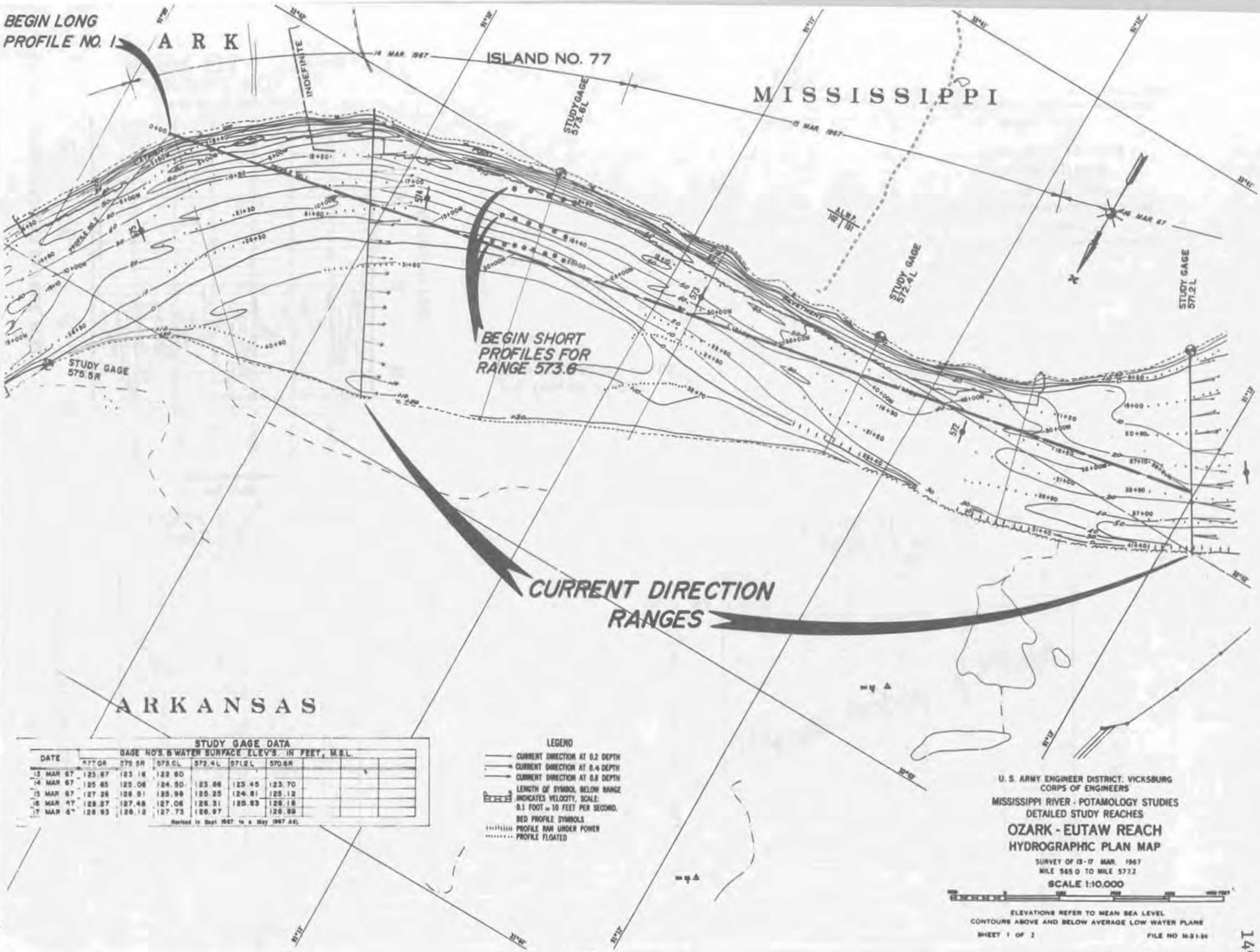


STUDY GAGE DATA

DATE	GAGE NO'S & WATER SURFACE ELEV'S. IN FEET, M.S.L.								
	577.0R	575.5R	573.6L	572.4L	571.2L	570.8R			
13 MAR. 67	123.87	123.16	122.60						
14 MAR. 67	125.85	125.06	124.50	123.86	123.45	123.70			
15 MAR. 67	127.26	126.51	125.99	125.25	124.61	125.12			
16 MAR. 67	128.27	127.48	127.06	126.31	125.83	126.18			
17 MAR. 67	128.93	128.12	127.73	126.97	'	126.89			

Revised in Sept. 1967 to a May 1967 ALWP.

Fig. 6



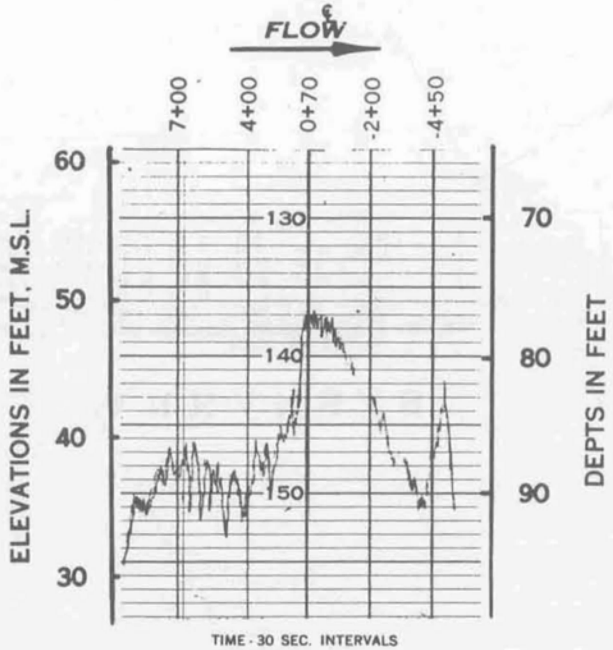
STUDY GAGE DATA

DATE	GAGE NO'S. & WATER SURFACE ELEV'S. IN FEET, M.S.L.								
	577.0R	575.5R	573.6L	572.4L	571.2L	570.6R			
13 MAR 67	123.67	123.16	122.60						
14 MAR 67	125.65	125.06	124.50	123.66	123.45	123.70			
15 MAR 67	127.26	126.51	125.99	125.25	124.81	125.12			
16 MAR 67	128.27	127.48	127.06	126.31	125.83	126.18			
17 MAR 67	128.93	128.12	127.73	126.97		126.89			

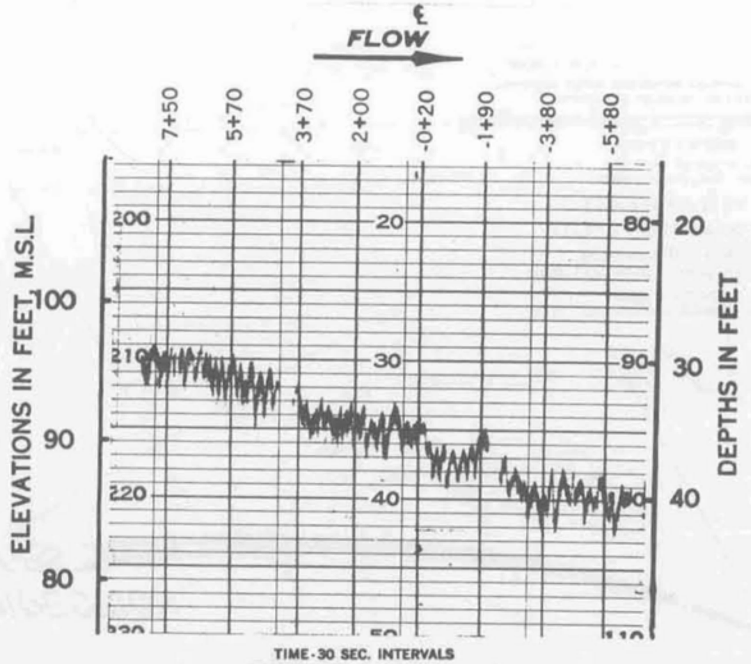
Revised in Sept. 1967 to a May 1967 A4).

Fig. 7

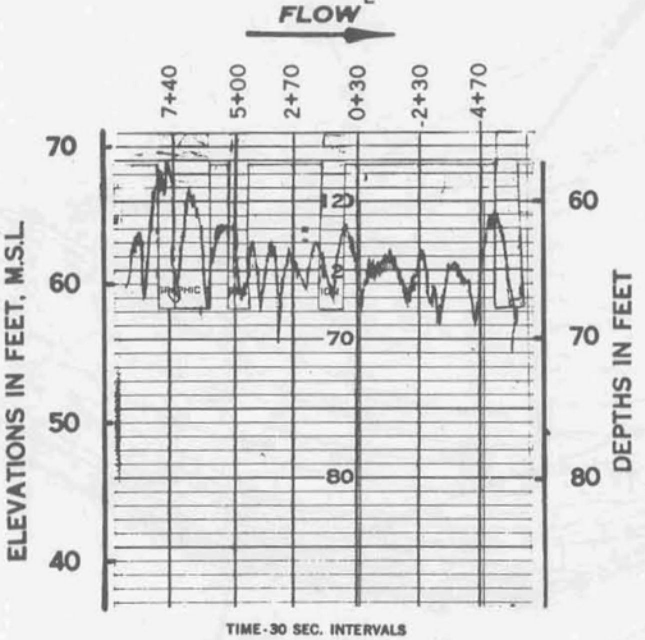
DISTANCES IN FEET ABOVE AND BELOW RANGE (NOT TO SCALE)



PROFILE NO. 1
RANGE STA. 9+90



PROFILE NO. 3
RANGE STA. 20+00



PROFILE NO. 2
RANGE STA. 15+40

W.S. Elevation = 126'
Elevation of A.L.W.P. = 102'

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MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

OZARK-EUTAW

BED PROFILES DATA

RANGE 573.6

TYPE OF REACH STABLE REACH-SHORT RADIUS BENDS
SHEET 5 OF 17 DATE OF SURVEY 15 MAR 67

Fig. 8

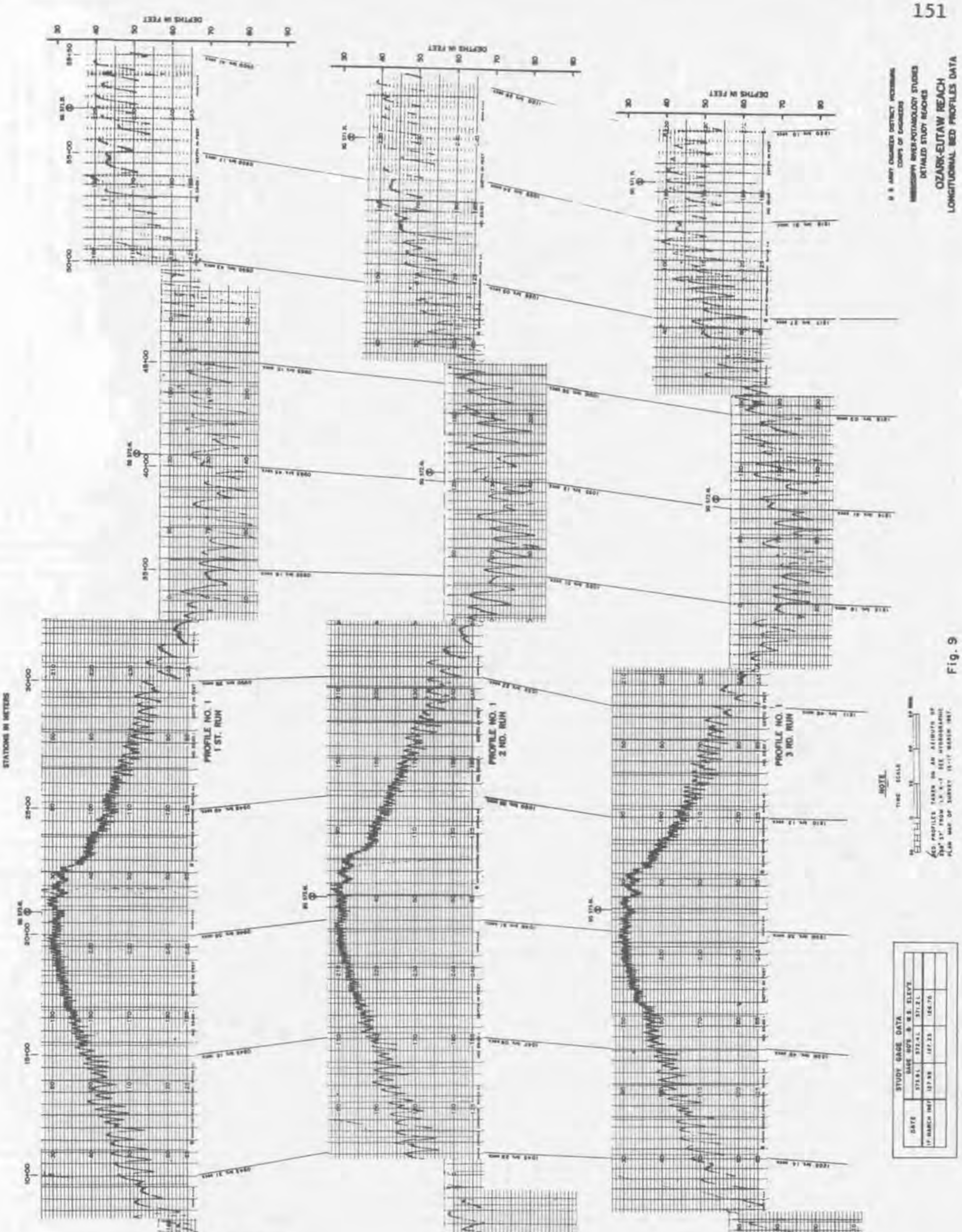
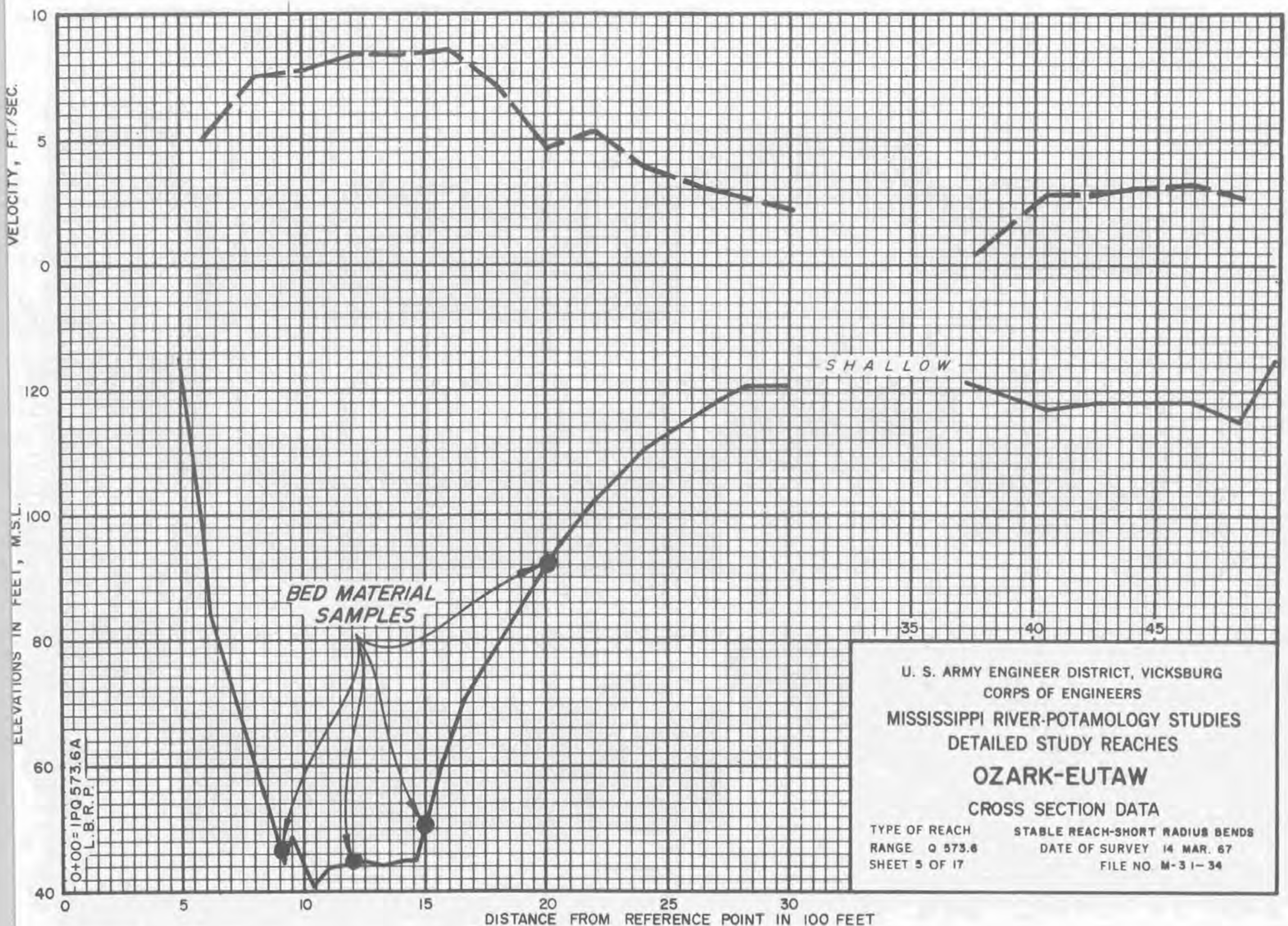

OZARK-EUTAW REACH
LONGITUDINAL BED PROFILES DATA
DETAILED STUDY REACHES
CORPS OF ENGINEERS
STATIONS IN METERS
DEPTHS IN FEET
PROFILE NO. 1
1 ST. RUN
PROFILE NO. 1
2 ND. RUN
PROFILE NO. 1
3 RD. RUN
STUDY GAGE DATA
NOTE
TIME SCALE

Fig. 9


VELOCITY, FT./SEC.
ELEVATIONS IN FEET, M.S.L.
10
5
0
120
100
80
60
40
0
5
10
15
20
25
30
35
40
45
SHALLOW
BED MATERIAL SAMPLES
0+00=IPQ 573.6A L.B.R.P.
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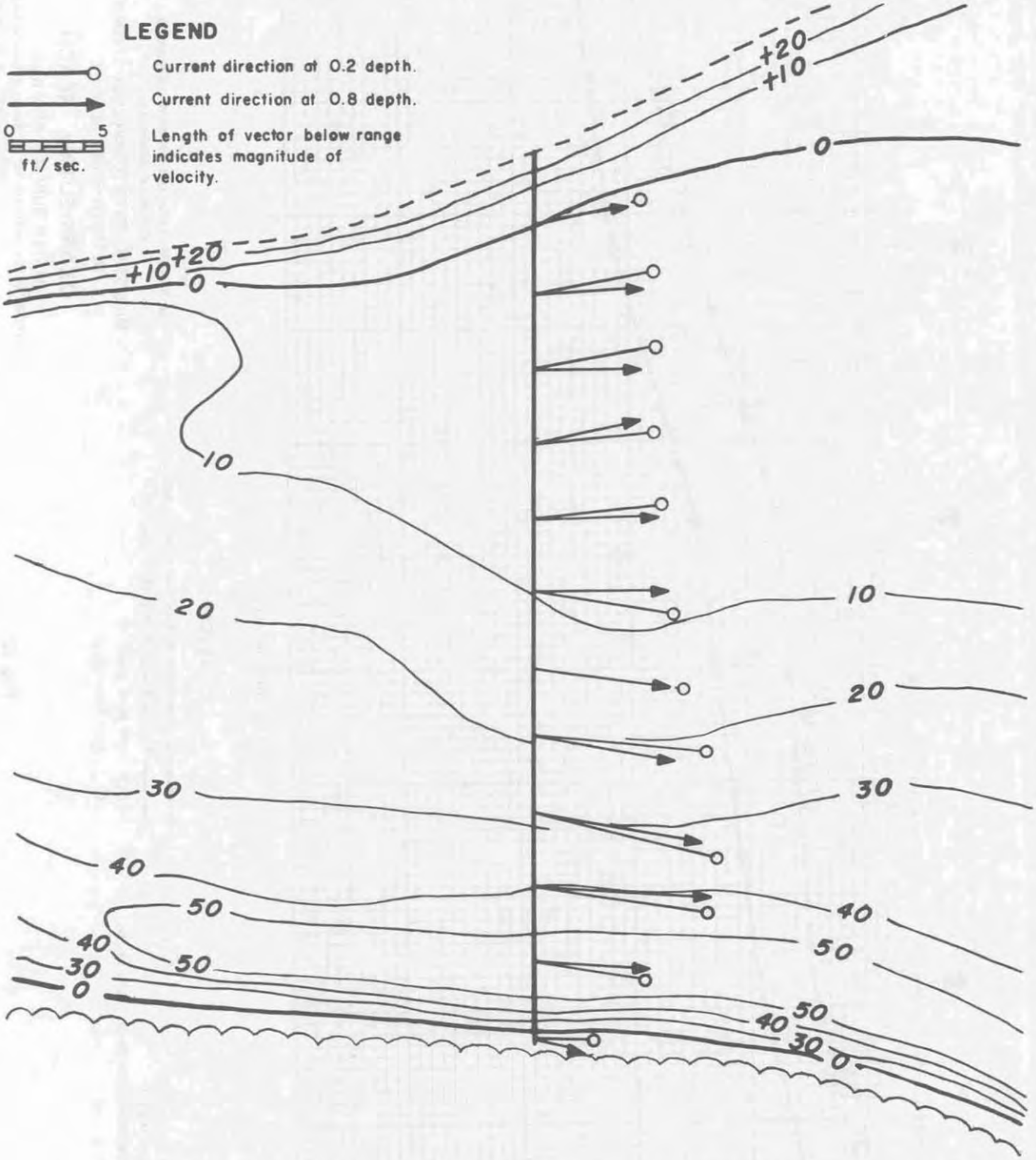
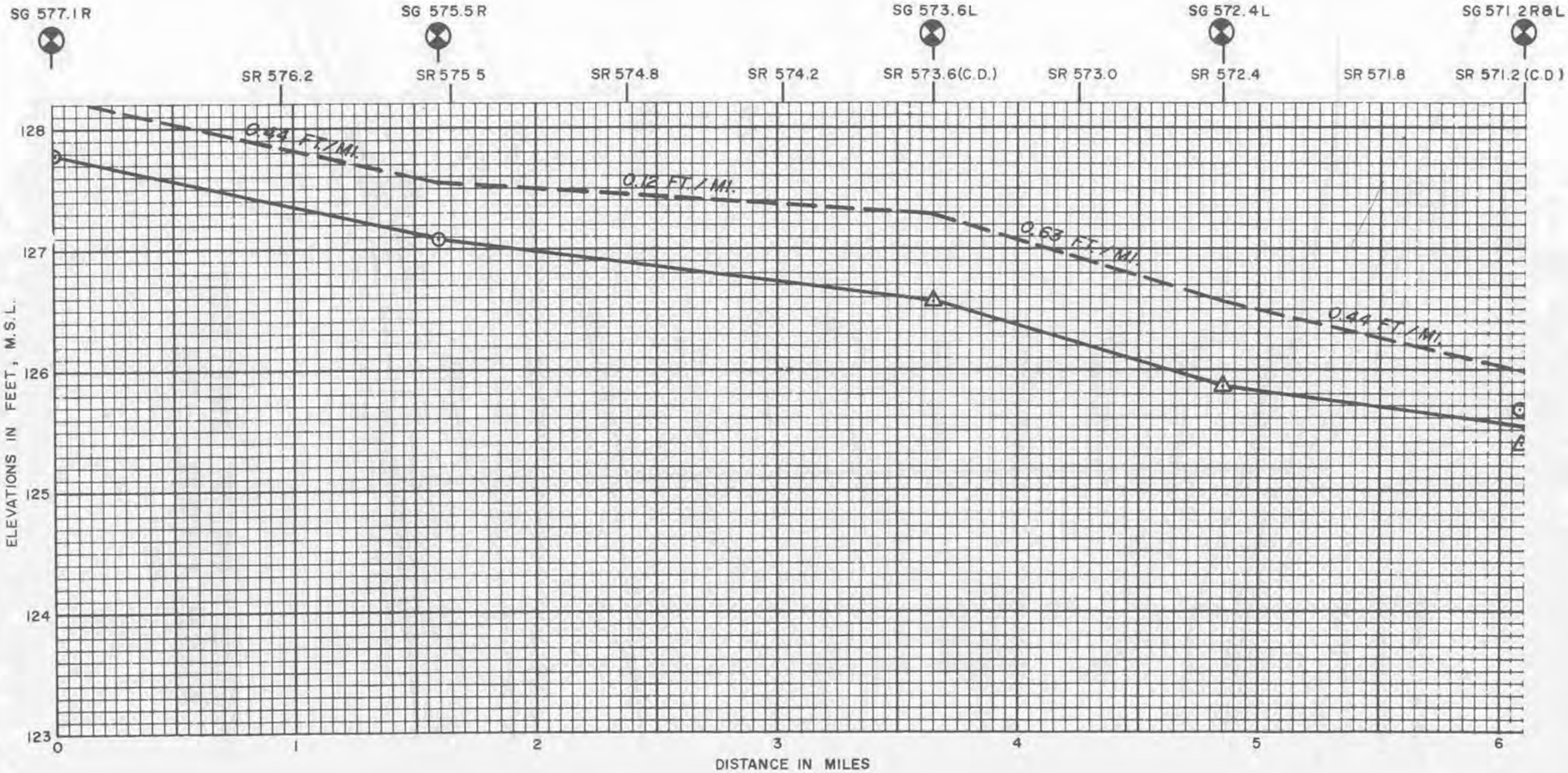
MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES
OZARK-EUTAW
CROSS SECTION DATA
TYPE OF REACH STABLE REACH-SHORT RADIUS BENDS
RANGE Q 573.6 DATE OF SURVEY 14 MAR. 67
SHEET 5 OF 17 FILE NO. M-3 I-34
DISTANCE FROM REFERENCE POINT IN 100 FEET

Fig. 10



SUB-SURFACE CURRENT DIRECTION
AT STUDY RANGE 571.2
Fig. 11



LEGEND

Average Water Surface Profile 14-17 Mar. 67
Average Energy Profile 14-17 Mar. 67
Left Bank Gages
Right Bank Gages

NOTES:

A.L.W.P. Stage = +23.0

Average Energy Slope Entire Reach = 0.39 Ft./Mi.

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MISSISSIPPI RIVER-POTAMOLOGY STUDIES
DETAILED STUDY REACHES

OZARK-EUTAW REACH

WATER SURFACE PROFILES

TYPE OF REACH — STABLE REACH - SHORT RADIUS BENDS
DATE OF SURVEY 22-25 AUG. 66

Fig. 12