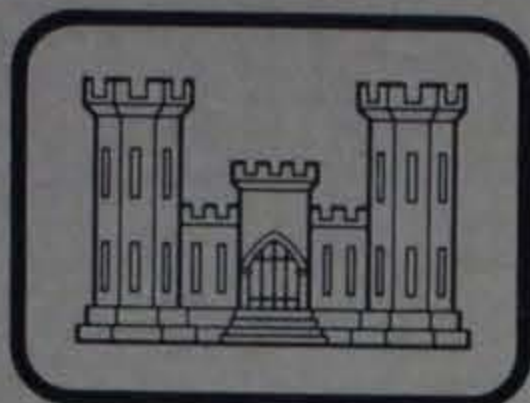US-CE-C Property of the United States Government

MISCELLANEOUS PAPER HL-79-2

# THE DYNAMIC LOOP EFFECT ON THE MISSISSIPPI RIVER, PROJECT DESIGN FLOOD FLOW LINE

by

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    The unusually high 1973 and 1975 flood seasons on the Mississippi River revealed apparent significant reductions in flood-carrying capacity. In addition, a heretofore unappreciated phenomenon known as loop effect appeared to have a large impact on stage-discharge relations. As a part of a general re-analysis of the design flood flow line, a study was initiated to help quantify the dynamic loop effect. The purpose of the study was to estimate the loop

(Continued)

20. ABSTRACT (Continued).

magnitude at the design flood to be added to the separately evaluated steady-state design flood flow line.

A previously developed numerical model for calculations of variable stage-discharge relations was used. The study showed that this model could not account for all of the loop magnitude, probably due to flow complexity and model assumptions. An ad hoc method to simulate the total loop was implemented involving double-valued, variable Manning's n corresponding to the rising or falling phase of the flow hydrographs. The method of simulation suggests a higher channel resistance at falling river stages. Extrapolation to the design flood is based on the assumption of similarity of river behavior to the 1973 flood. This assumption is consistent with the steady flow line computations using river resistance extrapolation from the 1973 flood data to the design flood.

The modified model was applied to three representative gaging stations to quantify the loop magnitude along the lower river. Results of the study indicate that the dynamic loop allowance should be as follows:

          Vicksburg    - 0.9 ft
          Helena       - 1.0 ft
          Baton Rouge  - 0.5 ft

In summary, an allowance of approximately 1.0 ft should be added to the flow line from about Helena to Red River Landing. An amount of 0.5 ft should be sufficient from Red River Landing to about Baton Rouge.

# PREFACE

This investigation was sponsored by the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD), and funded jointly by the U. S. Army Engineer Districts, Memphis, Vicksburg, and New Orleans. The study was conducted during the period March 1976 to October 1978 by the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and M. B. Boyd, Chief of the Hydraulic Analysis Division. A preliminary report presenting final computational results at the Vicksburg and Helena gaging stations and tentative results at Baton Rouge was presented to LMVD in May 1977.

The study was conducted and this report was prepared by Mr. Carl Huval. Mr. M. B. Boyd contributed substantial technical input to the study. Special assistance in providing data was contributed by Mr. Malcolm Dove, LMVD, as well as personnel from the Vicksburg, Memphis, and New Orleans Districts.

Commander and Director of WES during the investigation and the preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

# CONTENTS

## CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

| Multiply | By | To Obtain |
| --- | --- | --- |
| cubic feet per second | 0.02831685 | cubic metres per second |
| feet | 0.3048 | metres |
| feet per second | 0.3048 | metres per second |
| feet per second per second | 0.3048 | metres per second per second |
| miles (U. S. statute) | 1.609344 | kilometres |
| square feet | 0.09290304 | square metres |

# THE DYNAMIC LOOP EFFECT ON THE MISSISSIPPI RIVER
# PROJECT DESIGN FLOOD FLOW LINE

## PART I:  INTRODUCTION

### The Problem

1.  Recent large-scale flooding during the 1973 and 1975 flood seasons on the Mississippi River and its tributaries indicated that apparently significant reductions had occurred in the flood-carrying capacity of the river in some reaches.[1]  These changes resulted in higher stages for given discharges and could have a major impact on the degree of flood protection provided by engineering works such as levees.  As a result of the 1973 flood, a reanalysis of the project design flood flow line was initiated by the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD), and the U. S. Army Engineer Districts, New Orleans, Vicksburg, and Memphis.  The main effort of the district studies involved the use of a steady-state flow model, HEC-2, Water Surface Profiles,[2] to recompute the project flood flow line along the river.  The 1973 flood peak stage and discharge data and recent channel cross-section measurements were used to recalibrate and then extrapolate to design flows.

2.  In addition to apparent reduction in channel capacity, discharge measurements indicated that some increase in stage was attributable to loop effect.  It is well known[3] that changing discharge during a flood can produce a so-called "hysteresis loop" in the stage-discharge rating curve such as the one shown in Figure 1.  For this type of rating curve, there can be several different stages for a given discharge.  The lower stage value is associated with the rising limb of the discharge hydrograph and the higher value occurs during the recession of the discharge.  A hysteresis loop, which is caused by a variable energy slope due to changing discharge, has also been referred to as a "dynamic loop" since it occurs because of the changing or dynamic nature of the flood
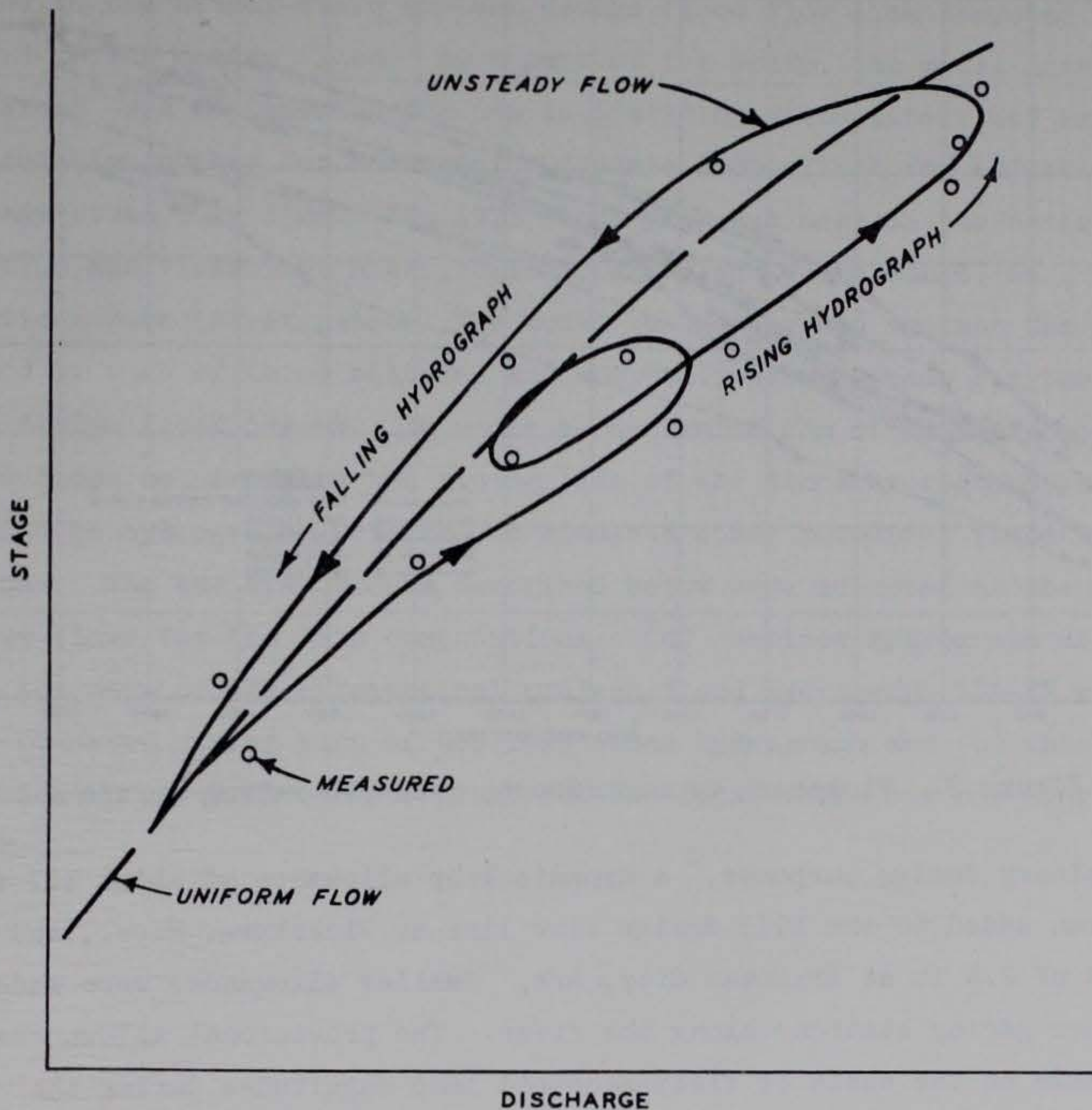
Figure 1.   Typical loop rating curve

discharge.   A plot of several recent loop rating curves at Vicksburg is
shown in Figure 2.   Prior to the 1973 flood, the 1950 flood was the most
recent major flood event on the Mississippi River.   As shown in Fig-
ure 2, an adopted rating curve had been used for design based on the
1950 flood.   The 1973, 1974, and 1975 flood rating curves are signifi-
cantly higher than the one for 1950.   As shown in Figure 2, the stage-
discharge relation can be very complex, since it is dependent on several
river and inflow factors.

    3.   The 1973 flood showed that the project design flood flow line
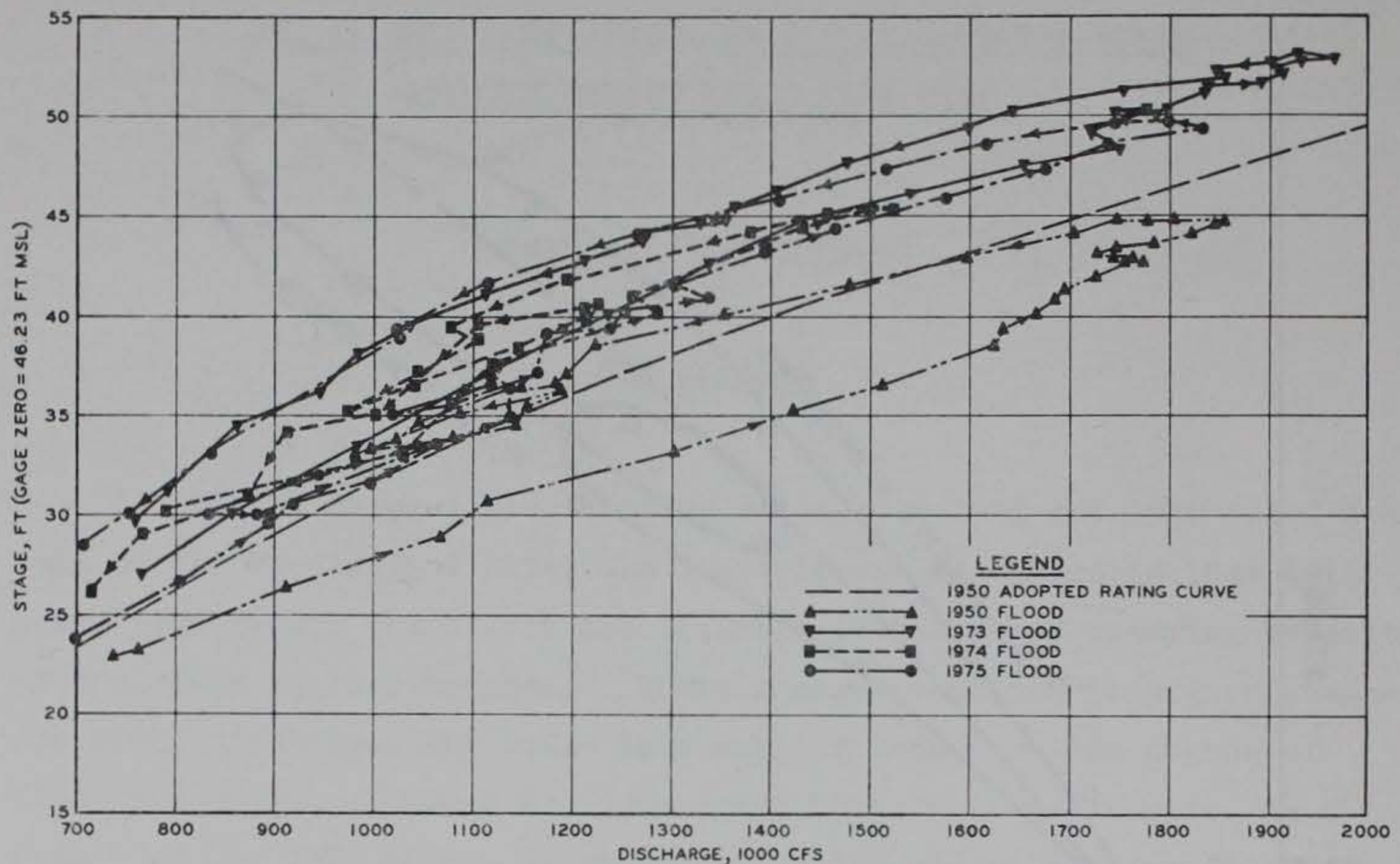had to account for the looping effect on the Mississippi River.   For

Figure 2.  Vicksburg recent floods, measured rating curves

preliminary design purposes,[1] a dynamic loop allowance of about 1.7 ft*
had been added to the 1973 design flow line at Vicksburg, Miss., and an
amount of 2.4 ft at Arkansas City, Ark.  Smaller allowances were made
at other gaging stations along the river.  The provisional allowances
were made on the basis of field-measured loop magnitudes during the
1973 flood and a study of past rating curves along the river.  A flow
line review study requirement by the LMVD was to use an analytical and
hydrologically consistent method for computation of the dynamic loop
effect.

Purpose and Scope of Study

4.  The purpose of this study is to identify dynamic loop and other
unsteady flow effects during the 1973 flood and to estimate the loop

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* A table of factors for converting U. S. customary units of measure-
ment to metric (SI) units is presented on page 3.

magnitude at the design flood.  The loop magnitude is the amount to be
added to the steady-state project design flood flow line computed using
HEC-2 at the design flood.  As a part of the study, the model developed
by Fread[4] was implemented for use in providing a consistent and improved
calculation method for determining dynamic loop effect for adjusting the
steady-state flow line.  The 1973 flood year was used as the basic cali-
bration and Vicksburg, Miss., Helena, Ark., and Baton Rouge, La., gaging
stations were investigated.  The model was calibrated against the 1973
flood at each of those stations and computations were made for the proj-
ect design flood 58A-EN.  In order to determine the effects of consecu-
tive loops occurring on the rising limb of the flood hydrograph, several
discharge hydrographs were run to simulate other potential flood hydro-
graphs.  The two hydrographs described below were selected as the main
input flows for the loop computations:  (a) combined hydrograph using
the top part of the hypothetical project flood hydrograph 58A-EN with
the observed rising part of the 1973 flood hydrograph and (b) the hypo-
thetical project flood hydrograph 58A-EN alone, which has one single
peak.

PART II: THE MODEL

## Background

5. The river engineer is frequently concerned with the conversion of flood stages at a given location along a stream channel into corresponding discharges or vice versa. This is accomplished by a relation between stage and discharge which applies to that particular gaging station. Such a relation or "rating curve" is usually developed empirically from a number of previous streamflow measurements and the corresponding stages. Unfortunately, the observed measurements of stage and discharge will not usually form a unique relation, i.e., a single value of stage does not correspond to a single value of discharge. Deviations of the measurements from a single-valued rating curve can be the result of such factors as:

a. Discharge measurement errors.

b. Shifting control due to scour or fill and alluvial bed form changes.

c. Variable water-surface slope along the channel due to unsteady flows.

d. Local effects causing variable water-surface slope due to backwater from a tributary or overbank storage.

e. Water temperature effect on alluvial bed movement.

6. While the effects due to errors, sediment movement, and tributary and overbank flows are not easily quantified, flow accelerations due to unsteady nonuniform flow can be computed. In a recent report, Fread[4] presented a relatively simple mathematical model that retains most of the dynamic loop effects. The method was proved accurate for calculating the dynamic stage-discharge relation at a number of river gaging stations.

## Model Details

7. A thorough description of the model with the computer program documentation has been presented by Fread.[4] The basic concept is to

model the stage-discharge relation for a particular gaging station location on the river, i.e., equation terms involving spatial gradients of discharge and flow depth are transformed into time variations at the location. The model development requires several assumptions that are applicable for a short section of channel containing the gaging station or forecast point:

a. Lateral inflow or outflow is negligible.

b. Channel width is essentially constant, i.e., $\partial B/\partial x \approx 0$ .

c. Energy losses from channel friction and turbulence are described by the Manning equation.

d. Geometry of the section is essentially permanent, i.e., any scour or fill is negligible.

e. Bulk of the flood wave is moving approximately as a kinematic wave which implies that the energy slope is approximately equal to the channel bottom slope.

f. Flow at the section is controlled by the channel geometry, friction, and bottom slope and by the shape of the flood wave.

8. If the bulk of the flood wave moves approximately as a kinematic wave, the following expression can be used to transform the spatial gradient to time variations of flow depths:

$$\frac{\partial y}{\partial x} = -\frac{1}{c}\frac{\partial h}{\partial t} - \frac{2}{3}\frac{S_o}{r^2}$$

where

$y$ = depth of flow, ft

$x$ = distance along the river channel, ft

$c$ = kinematic wave velocity, fps

$h$ = water-surface elevation above mean sea level, ft

$t$ = time, sec

$S_o$ = effective bottom slope of the channel

$r$ = ratio of the channel bottom slope to an average flood wave slope

The last term on the right of the equation is a correction factor and is usually small for large river applications. The kinematic wave velocity $c$ is computed from the Kleitz-Seddon law.

9

$$c = \frac{1}{B}\frac{dQ}{dh}$$

where

    B = channel width at the water surface, ft

    Q = discharge, cfs

If the channel is wide and prismatic and flow can be determined by
Manning's equation, the wave velocity is

$$c = K\frac{Q}{A}$$

where $K = 5/3 - (2A/3B^2)(dB/dh)$. In the above development, the hydrau-
lic radius R is approximated by the hydraulic depth D. The result
of the above expression for wave velocity is that the propagation
speed of the flood wave in the river is a multiple of the river mean
velocity. The quantity K varies from 1.3 to 1.7 for triangular- to
rectangular-shaped channels, respectively. For a given channel geom-
etry, the speed of wave propagation varies uniquely with discharge
and stage. The wave speed is assumed the same for the rising and
falling portion of the input hydrograph. Overbank storage or flows,
backwater areas, tributary effects, and other dynamic phenomena are
not accounted for in the model and can become important with complex
river systems.

    9. With the definition of the wave speed c given above and the
method shown by Fread[4] to evaluate r , it is possible to obtain the
following equation relating stage and discharge:

$$Q = 1.486\frac{AD^{2/3}}{n}\left\{ S_o + \left[ \frac{A}{KQ} + \left(1 - \frac{1}{K}\right)\frac{BQ}{gA^2} \right]\delta h_s + \frac{Q'/A' - Q/A}{g\Delta t} \right.$$

$$\left. + \frac{2S_o}{3r^2}\left(1 - \frac{BQ^2}{gA^3}\right)\right\}^{1/2}$$

where

$\delta h_s$ = change in water-surface elevation during the time interval $\Delta t$ , in fps ($\delta h_s$ = (h - h')/$\Delta t$ , where h' is the stage at time t - $\Delta t$).

Q' = discharge at time t - $\Delta t$ , cfs

A' = cross-sectional area at time t - $\Delta t$ , sq ft

g = acceleration due to gravity

$\Delta t$ = small interval of time, sec

The above equation is utilized in the model as a basis for computing discharge when the rate of change of stage is known or stage when the rate of change of discharge is known. The unknowns Q and h in the above equation are not expressed in an explicit manner, thus requiring a trial-and-correct solution. The solution of the equation is by Newton iteration and is explained fully by Fread.[4]

## Model Implementation

10. The model (called DYNMOD by Fread) had been implemented by LMVD on the WES Honeywell 635 computer by the time-sharing system. Several modifications had been introduced for ease of application. The model requires the input of either a discharge or stage hydrograph and will compute the other hydrograph. In this application, stage hydrographs were input for calibration against field-measured stage-discharge relations at the gaging stations. The model was then used in the discharge input mode to study loop rating curves using several design discharge hydrographs.

11. Channel input geometric data consist of: (a) the channel effective bottom slope ($S_o$), (b) the cross-sectional area (A) and the surface width (B) as a function of the elevation, and (c) the Manning's coefficient (n) as a function of the elevation. These are input into the model in the form of data tables at about 10 elevation intervals. The area and width were obtained from the tabulated 1973 and 1975 discharge observation data and measured cross sections at the gaging stations. Plate 1 shows the cross section at the Vicksburg gaging site

11

during the 1973 and 1974 high-water hydrographic surveys.  A low-water
survey for 1971 is also shown for comparison.  Plotted channel cross-
sectional area and widths for the 1973 and 1975 flood years are shown in
Plate 2 for the Vicksburg gaging section.  The graphical method of ex-
trapolating to design stage levels is also shown.  A preliminary esti-
mate of the effective slope was obtained from the average low-water
plane, 1973 peak flood data, and channel bottom slope at the gaging
stations.  Trial computations required adjustment of this value to give
a better representation of the loop rating curves.  The Manning's  n
values were calculated by fitting single-line rating curves at the
gaging stations using Manning's equation and known channel slope and
geometry.  Several combinations of slope and resulting  n  values were
tried.

# PART III: MODEL CALIBRATION AND APPLICATION

## Vicksburg, Miss.

12. After model familiarization, the first step was to recompute
a published test case given in the basic reference by Fread.[4] This pro-
vided a check to ensure proper function of the computer code. Several
improvements to the model were developed during the study. The data
input and output structure was revised to permit the use of files for
ease of data manipulation. A plotting capability using an available
Hewlett-Packard plotter was developed for easier interpretation of the
output information.

13. Most of the model testing and modifications described below
were made during the calibration phase at the Vicksburg, Miss., gaging
station. Several combinations of river slopes and channel roughness
were tried. The river slope at Vicksburg is about 0.000064 ft/ft.
Computations were made at effective slopes from 0.000064 to 0.00001 and
comparisons were made with the measured stage-discharge data. The
smaller slopes tend to increase the dynamic loop width, but also tend
to amplify daily stage variations. A compromise is thus required to
give reasonable model response for reproduction of the 1973 rating curve.
A value of 0.000032 was finally selected. Table 1 gives a summary of
the geometric input and channel roughness data at Vicksburg. The data
tabulated are representative of the main channel only. The plot in
Plate 3 shows the resulting computed and measured stage-discharge curves
at Vicksburg; the measured channel discharge plotted has been corrected
for the overbank flow. It was apparent from these results that the
basic DYNMOD model would not reproduce the magnitude of the loops as
compared with the measured 1973 stage-discharge curve. The dynamic loop
effect at lower discharges for within bank-full rising and falling
stages is reproduced very well but the computed main loop is only about
one half the observed main loop.

14. The model DYNMOD was modified by using different Manning's  n
roughness values for rising and falling periods of the flood. The

basic model uses a single set of  n  values which along with other input data define a mean rating curve.  The difference between the computed dynamic stage-discharge relation and the steady-flow curve represents the estimate of the dynamic terms.  Since the results shown in Plate 3 suggest that the dynamic terms are not large enough to account for the observed loop, a variable set of  n  values was used to obtain better agreement with the observed 1973 flood data.  In effect, the different n  values for rise and fall were used to account for several factors which cannot be properly evaluated and modeled by DYNMOD, such as channel geometric changes from scour, changes in effective resistance coefficients due to changing bed forms, interactions with overbank stor- age and flow, backwater storage, and inaccuracy of estimates of the dynamic terms.

15.  Manning's  n  values to be used for rising and falling por- tions of the flood were developed by drawing two rating curves through the 1973 flood data (Plate 3) and computing the corresponding  n  values (Table 1).  The rating curves were extrapolated to stages slightly above the design stage to provide roughness values for that stage range (Plate 5).  After modifying the DYNMOD model to permit use of the differ- ent  n  values for rise and fall, a stage-discharge curve was again computed for the 1973 flood.  There was substantial improvement in agree- ment for the main loop but the within bank-full loop was distorted.  The computation tended to switch between the two sets of  n  values at each rise or fall of the stage hydrograph.  The model was then further modi- fied to allow the introduction of a switch to be used to control the model to use the rising or falling set of  n  values, depending on pre- determined values of stage and discharge.  This modification allows the use of the rising  n  values up to a preset elevation or discharge, switches to the falling  n  values on the first fall which occurs after the hydrograph passes through the reference elevation or discharge, and retains the use of the falling  n  values for the remainder of the com- putation even if another rise occurs.  Using this procedure and a refer- ence elevation of 97 ft msl (about 50.8 stage at Vicksburg), the computed stage-discharge curve for the 1973 flood compared favorably with the

observed curve (Plate 4) and the model was considered calibrated for further use at the Vicksburg gaging station.

16. The design discharge at Vicksburg for the 58A-EN project design flood (PDF) is 2,710,000 cfs. The peak flow during the 1973 flood was 1,960,000 cfs which is about 75 percent of the PDF. In order to study loop effects at design flows, an extrapolation of channel geometry and roughness was required. Plate 2 shows the method of extrapolation. Channel area and width were extrapolated from the 1973 and 1975 data plots, taking into consideration a plot of the river cross section. Overbank areas and widths were eliminated by vertical extension of the main channel above bank-full. The areas and widths used in the computations above bank-full flow were representative of the main channel only, which was necessary because of model limitations.

17. An initial trial computation was made by extrapolating the 1973 rating curve at Vicksburg to design flows. Two rating curves representative of the rising and falling part of the hydrograph were extrapolated graphically. After additional study, it was decided that calibrated channel Manning's values from the 1973 flood would be extrapolated to design flows. Plate 5 shows a plot of channel roughness variation with stage and the extrapolation for the rising and falling part of the hydrograph. Overbank flows during the 1973 flood were subtracted from the total discharge. The PDF hydrograph was also modified to account for estimated overbank flows at design discharges. Overbank flow was subtracted from the total design flow, based on steady-flow conveyance computations furnished by the Vicksburg District. The method of flow partition was based on computations made using the steady-flow backwater computations using HEC-2. The peak flow at Vicksburg, for example, was reduced from 2.71 million cfs to 2.56 million cfs. The resulting design hydrographs are tabulated in Table 2.

18. After the calibration and modifications previously discussed had been made to DYNMOD, two computations were made using as input the project design flow hydrograph 58A-EN and a composite hydrograph which follows the 1973 flood through its peak flow of about 1.96 million cfs, then assumes a subsequent rise to the design flow of 2.56 million cfs

15

following the shape of the 58A-EN hypothetical flood (Table 2). Results of the computations are shown in Plate 6. The double-valued Manning's  n  computation was used to simulate the effects of a 1973 type of flood followed by the design flood, using the falling  n  values for flows above the 1973 peak and up to design discharges. The run using only the rising  n  values and the 58A-EN flood simulates the Vicksburg rating curve if the channel roughness had not increased for corresponding stages during the design flood. The difference between the two curves at design flows is a measure of the dynamic loop effect (plus other unaccounted for factors such as overbank effects and bedform changes). Assuming that the higher channel roughness would be appropriate if the design hydrograph followed the 1973 peak flows, the difference in the two curves can be used for estimating loop effect. The computations indicate a difference of about 1.7 ft in the peak stages with and without the loop effect at Vicksburg.

## Helena, Ark.

19. A plot of the Helena discharge range cross section is shown in Plate 7 for the 1973 and 1975 high-water surveys. The 1973 cross section was used to calculate the cross-sectional area and channel width and these values are plotted in Plate 8. Other width and area measurements made in 1973 and 1975 flood years at the discharge range are also plotted in Plate 8.

20. A calibration procedure was used at Helena similar to that developed for the Vicksburg gaging station. The final results of several trial computations at Helena are shown in Plate 9. The switch from rising to falling  n  values was set to 48.6-ft stage and 1,550,000 cfs for Helena to provide the best fit to the 1973 flood discharge data. The plot indicates good agreement with the channel discharge measurements. The channel geometric data and Manning's  n  computations are presented in Table 3. The cross-sectional area and width were based on the average data plotted in Plate 8. Channel area and width at design stage were obtained by plot extrapolation. The calculated set of

16

Manning's n is shown plotted in Plate 10. Several channel slopes were tried from the apparent channel slope of 0.00011 down to a value of 0.000032 ft/ft; a slope of 0.000064 was finally selected. The effective channel slope and computed roughness values at Helena are about twice those at the Vicksburg gaging station. The channel roughness values at Helena appear to be in agreement with other recent studies[5,6] of Mississippi River channel roughness. The Vicksburg values seem to be low. Increasing the slope at Vicksburg to 0.000064 would increase n values by $\sqrt{2}$ or 41 percent, which would still be lower than the Helena data. Several factors not accounted for in the model, such as Yazoo backwater area effects and changing river sinuosity with stage, could be the reason for these apparent discrepancies.

21. Computations were run using the 58A-EN design flood at Helena and a design discharge hydrograph made up of 1973 daily Helena discharges phased into the 58A-EN hypothetical flood at Helena. These data are tabulated in Table 4. The design hydrograph was corrected for overbank flows based on backwater computations by the Memphis District. One run was made using the 1973/58A-EN hydrograph with different Manning's n values on the rising and falling parts of the hydrographs. Plate 11 presents the results. Similar reasoning at Helena to that developed at Vicksburg relative to the sequence of flood flows and channel roughness suggests that the difference between the two curves at design flows is a measure of the dynamic loop and other effects. The difference in the two curves can be used for estimating loop effect and indicates the total loop effect to be about 2.0 ft at Helena.

## Baton Rouge, La.

22. The channel cross section at the Baton Rouge gaging range is plotted in Plate 12 based on the January 1974 hydrographic survey. There is no overbank area at Baton Rouge. The calibration procedure was modified at the Baton Rouge gaging station. A study of the 1973 data indicated large scatter in the channel cross-sectional area and width with stage (see Plate 13). During the 1973 flood, discharge measurements

17

were made only during rising stages from 39 ft to 42 ft and falling stages to about 32 ft. The loop rating curve is very hard to define and extrapolate to design flows without discharge data to show the rising and falling hydrographs at a wide range of river stages. Additional data were reviewed from the 1974 and 1975 high water but these showed similar data scatter and a narrow range of river stage. In addition, measurement techniques and discharge range location apparently were varied during 1974 and 1975.

23. Area and width data from the 1950 flood were also plotted in Plate 13 and showed much less scatter. Discharge measurements were made over a wider range of stages during the 1950 flood. The 1950 discharge range was located 3.1 miles downstream from the 1973 discharge range which was at the U. S. Highway 190 Bridge or river mile 230.8, 1962 AHP. It was decided to calibrate the model using both 1950 and 1973 flood years. The channel data for the 1950 discharge measurements appeared adequate. A study of the 1973 discharge data indicated that most of the measurements were made at a discharge range about 200 ft downstream of U. S. Highway 190 Bridge. The channel cross section shown in Plate 12 was used as the best source of geometric information for the 1973 flood. Table 5 presents the adopted geometric data for the 1950 and 1973 floods. Note that Manning's n values were not varied for the rising and falling portion of the hydrograph. As suggested above, the basic data did not warrant the use of multivalued Manning's n coefficients. As had been done previously at Vicksburg and Helena gaging stations, several channel slopes were tried from 0.00001 to 0.000032 ft/ft. The value of 0.000016 ft/ft was used.

24. The calibrations of the model to the 1950 and 1973 measured discharge data are shown in Plates 14 and 15, respectively. The 1950 calibration gave poor reproduction of the rising part of the hydrograph up to about the 41-ft stage. Agreement was adequate at higher stages. The 1973 calibration showed large fluctuations and very complex stage discharge relations at stages above 39 ft. It is speculated that gate operation at the Morganza Floodway caused these variations. The resulting Manning's n values are plotted in Plate 16.

18

25.  The project design flood hydrograph 58A-EN at Baton Rouge was furnished by the New Orleans District and is shown in Table 6.  Because of the designed operation of the Morganza Floodway during a large flood, flows at Baton Rouge would be kept below 1,500,000 cfs.  In order to provide a realistic hydrograph that gives some weight to flow sequences, a composite design hydrograph was obtained at Baton Rouge.  This hydrograph was calculated by combining the 58A-EN hydrograph with increased 1973 daily flows from April 18 through June 30.  The daily flows at Baton Rouge were multiplied by the ratio of 1,500,000 to 1,347,000 (1.114) assuming the design flow maximum of 1,500,000 cfs occurred on 18 April 1973.  This was the first discharge measurement available at Baton Rouge after the opening of the Morganza Floodway on 17 April 1973.  This hydrograph is an attempt to simulate the river behavior at Baton Rouge which is representative of 1973 conditions at the design flow of 1,500,000 cfs.  Both design hydrographs are shown in Table 6.

26.  Computations were made with both design hydrographs and are shown in Plates 17 and 18.  The design flood 58A-EN computations show a dynamic loop effect of about 0.7 ft near the peak flow and a maximum stage of 45 ft.  The composite 1973/58A-EN design flood computations result in a loop effect somewhat less than 1.0 ft and a maximum stage of 45.2 ft.  Results of both computations indicate a dynamic loop effect of about 1.0 ft at Baton Rouge.  The amount of dynamic effect in the Mississippi River in the Old River to Baton Rouge reach during a design flood will be greatly dependent on the mode of operation of the Old River Control Structure and Morganza Floodway.  If these operations are expected to be greatly different than design or 1973 conditions, dynamic effects from gate manipulations may cause higher stages.  A more thorough analysis using a complete dynamic model would be needed to ascertain stage response to variable gate structure operations.

PART IV:  DISCUSSION OF RESULTS

27.  For high flows at the Vicksburg and Helena gaging stations,
the computation follows the extrapolated  n  values for either the ris-
ing or falling portions of the 1973 flood (Plates 6 and 11).  The differ-
ence between computations for the different flood sequences is attributed
to loop effect.  The rationale supporting this type of projection is:
had the last rise to design flow occurred in 1973 or a similar antece-
dent flood, the roughness values compatible with the falling portion of
the antecedent flood would be more appropriate during that rise than the
rising  n  values associated with the lower channel roughness.  The use
of the modified Fread model DYNMOD in this fashion is to provide for a
judgment prediction of the loop effect rather than as a precise predic-
tive or modeling tool.  Nevertheless, the loop adjustment suggested
by these projections is believed to be valuable in supplementing the
steady-state flow line computed from HEC-2.  In other words, the dynamic
model was used in the analogous manner as steady-state computations were
made and the model is believed consistent and comparable in accuracy.

28.  The setting of the project design flow line is to be used for
the design of levee crest heights and other water-control structures
along the main stem of the Mississippi River.  Previous flow line compu-
tations in 1957 had been made using steady-state backwater computations
and maximum design discharges.  The rating curves used were a series of
single-valued curves based on field measurements during the 1945 and
1950 floods.  This type of computation was repeated using the 1973
flood data as a part of the flow line reanalysis.  The previous LMVD
report[1] recognized the need to allow for dynamic effects over and above
the steady-state flow line.  Steady-state (or equivalently, single line)
rating curves are usually an average between the rising and falling part
of the hydrographs.  A loop magnitude allowance that would be consistent
with the steady-state flow line would then be about one half the total
dynamic loop magnitude.

29.  Results obtained with the DYNMOD model suggest that channel
dynamic effects are small near design flow conditions even though they

may be substantial at smaller flows. Even at the lower flows, dynamic effects do not appear to account for the entire loop observed during the 1973 flood. With the model used herein, it was necessary to lump the effects of several factors into the roughness coefficient. This emphasizes the need for accuracy in extrapolating roughness coefficients to design flows and for investigations to evaluate the effects of other complex river factors. Better definition of the effects of some of these factors can be obtained with more detailed studies using modeling methodologies such as developed for the junction near Cairo, Ill.[7] Fread has recently suggested a methodology for more accurate treatment of the overbank effect[8] that includes overbank storage and flow between main channel meanders. Evaluating the effects of changing channel geometry and roughness due to bed changes will be more difficult. Because of the difficulty in predicting bed changes and their effects, it would appear advisable to use available modeling methodology to accurately evaluate all factors associated with a fixed geometry system before concluding that the sediment transport phenomena must be treated to obtain predictions of acceptable accuracy.

## PART V: CONCLUSIONS

30.  As a result of the investigation reported, the following con-
clusions have been formulated:

a.  The study of loop rating curves on the Mississippi River
has shown that the Fread model DYNMOD will account for
about one half of the total loop magnitude when using only
a single set of  n  values.

b.  With computations using a single set of  n  values, peak
design discharges produced the same maximum stage regard-
less of the shape of the discharge hydrograph, indicating
that the dynamic factors alone do not properly account
for total loop effect.

c.  The sequence of hydrograph flows does not have an appre-
ciable effect on the rating curve predicted by DYNMOD
using a single set of  n  values.  The dynamic loop
effect on the rating curve is small at and near design
flows where rates of rise are usually small.

d.  The introduction of double-valued Manning's  n  for rising
and falling hydrographs with a preset switch is necessary
for simulating the 1973 flood event or other multiple
peaked flood events.

e.  Using the modified model DYNMOD, it is possible to simu-
late dynamic effects at design flows, assuming that the
loop behavior during the 1973 flood could have occurred
at design flows.

f.  The rating curves computed assuming single-valued rough-
ness with stage when compared with the rating curves com-
puted assuming double-valued roughness give a reasonable
extrapolation of the full dynamic loop effect.  Several
hydraulic phenomena such as tributary flows, channel-
overbank interaction, and channel bed changes are lumped
into the roughness values used in the model to simulate
the 1973 flood.

g.  Considering the method in which the steady-state model
calibration was accomplished, and the computational proce-
dure used in the modified model DYNMOD, it is concluded
that one half of the total loop effect should be used as
the allowance for loop effect in establishing levee grades
throughout the studied reach.  Averaging the values cal-
culated at Vicksburg and Helena, and using one half of
the average, the total loop effect to be added to steady-
state stages would be 1.0 ft.

22

h. An allowance of approximately 1.0 ft should be added to the flow line from about Helena to Red River Landing. An amount of 0.5 ft should be sufficient from Red River Landing to about Baton Rouge.

# REFERENCES

1. Mississippi River Commission, CE, "1973 Adjustments to the 58A-EN Project Design Flood Flowline, Mississippi River and Tributaries Project," Oct 1973, Vicksburg, Miss.

2. The Hydrologic Engineering Center, Department of the Army, CE, "HEC-2, Water Surface Profiles," Computer Program No. 22-J2-L232, Dec 1968 (Rev Aug 1969), Sacramento, Calif.

3. Henderson, F. N., <u>Open Channel Flow,</u> McMillan Co., 1966, New York, N. Y.

4. Fread, D. L., "A Dynamic Model of Stage-Discharge Relations Affected by Changing Discharge," NOAA Technical Memorandum NWS HYDRO-16, Nov 1973, National Weather Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Washington, D. C.

5. U. S. Army Engineer District, Vicksburg, CE, "M.R.&T. Project Flood Flow Line Review Report," Jun 1976, Vicksburg, Miss.

6. Robbins, L. G., "Roughness Characteristics of the Lower Mississippi," Symposium on Inland Waterways for Navigation, Flood Control, and Water Diversions--RIVERS 76, Aug 1976, Published by American Society of Civil Engineers, Fort Collins, Colo.

7. Johnson, B. H., "Unsteady Flow Computations on the Ohio-Cumberland-Tennessee-Mississippi River System," Technical Report H-74-8, Sep 1974, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

8. Fread, D. L., "Flood Routing in Meandering Rivers with Flood Plains," Symposium on Inland Waterways for Navigation Flood Control and Water Diversions--RIVERS 76, Published by American Society of Civil Engineers, Aug 1976, Fort Collins, Colo.

# BIBLIOGRAPHY

Louque, R. E., Jr., "New Flowline for the Lower Mississippi River," Water Resources Bulletin, Vol 12, No. 5, Oct 1976.

Lower Mississippi Valley Division, CE, "Lower Mississippi River - Main Stem, Cairo to Gulf of Mexico, Flood of 1973, Post Flood Report," Appendix L, 1974, Vicksburg, Miss.

U. S. Army Engineer District, Memphis, CE, "M.R.&T. Project Flood Flow Line Review Report," Jan 1977, Memphis, Tenn.

U. S. Army Engineer District, New Orleans, CE, "M.R.&T. Project Flood Flow Line Review Report," Dec 1976, New Orleans, La.

U. S. Army Engineer District, Vicksburg, CE, "Flood of 1973, Post Flood Report, Mississippi River and Tributaries Flooding," Oct 1973, Vicksburg, Miss.

Table 1

Input Channel Data, Vicksburg, Miss.

Bottom Slope = 0.000032 ft/ft

| Stage ft | Elevation ft msl | Area × 1000 sq ft | Width ft | Manning's n | |
| --- | --- | --- | --- | --- | --- |
| | | | | Rising Hydrograph | Falling Hydrograph |
| 13.77 | 60.0 | 105 | 2250 | 0.0286 | 0.0309 |
| 19.77 | 66.0 | 121 | 2480 | 0.0256 | 0.0272 |
| 29.77 | 76.0 | 145 | 2820 | 0.0202 | 0.0226 |
| 39.77 | 86.0 | 169 | 3120 | 0.0168 | 0.0186 |
| 44.77 | 91.0 | 183 | 3230 | 0.0159 | 0.0172 |
| 49.77 | 96.0 | 199 | 3300 | 0.0152 | 0.0163 |
| 53.77 | 100.0 | 220 | 3320 | 0.0148 | 0.0158 |
| 58.77 | 105.0 | 240 | 3320 | 0.0144 | 0.0153 |
| 63.77 | 110.0 | 262 | 3320 | 0.0141 | 0.0149 |

# Table 2

## Design Flood Hydrographs, Vicksburg, Miss.

## Daily Discharge, 1000 cfs

| Project Design Flood (PDF) 58A-EN | | | PDF 58A-EN Corrected for Overbank | | | 1973/58A-EN | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 520 | 2140 | 2670 | 520 | 2061 | 2525 | 500 | 842 | 1755 | 1962 | 2551 |
| 565 | 2175 | 2660 | 565 | 2092 | 2516 | 550 | 790 | 1770 | 1998 | 2542 |
| 630 | 2205 | 2650 | 630 | 2119 | 2508 | 600 | 747 | 1783 | 2029 | 2534 |
| 695 | 2230 | 2640 | 695 | 2141 | 2499 | 650 | 727 | 1780 | 2061 | 2525 |
| 750 | 2255 | 2630 | 750 | 2163 | 2491 | 700 | 721 | 1779 | 2092 | 2516 |
| 795 | 2275 | 2620 | 795 | 2181 | 2482 | 750 | 720 | 1779 | 2119 | 2508 |
| 825 | 2295 | 2605 | 825 | 2198 | 2469 | 800 | 761 | 1780 | 2141 | 2499 |
| 865 | 2315 | 2590 | 865 | 2215 | 2456 | 850 | 790 | 1784 | 2163 | 2491 |
| 900 | 2330 | 2575 | 900 | 2229 | 2443 | 900 | 823 | 1790 | 2181 | 2482 |
| 940 | 2345 | 2560 | 940 | 2242 | 2430 | 950 | 853 | 1796 | 2198 | 2469 |
| 980 | 2360 | 2540 | 980 | 2256 | 2413 | 1000 | 921 | 1797 | 2215 | 2456 |
| 1025 | 2375 | 2520 | 1024 | 2269 | 2396 | 1050 | 937 | 1799 | 2229 | 2443 |
| 1070 | 2385 | 2500 | 1067 | 2278 | 2378 | 1100 | 1048 | 1793 | 2242 | 2430 |
| 1110 | 2400 | 2480 | 1106 | 2291 | 2361 | 1128 | 1126 | 1788 | 2256 | 2413 |
| 1145 | 2415 | 2460 | 1140 | 2304 | 2343 | 1130 | 1158 | 1783 | 2269 | 2396 |
| 1180 | 2430 | 2435 | 1173 | 2317 | 2321 | 1145 | 1190 | 1760 | 2278 | 2378 |
| 1220 | 2450 | 2410 | 1211 | 2335 | 2300 | 1173 | 1234 | 1745 | 2291 | 2361 |
| 1265 | 2475 | 2385 | 1254 | 2356 | 2278 | 1184 | 1253 | 1760 | 2304 | 2343 |
| 1315 | 2505 | 2360 | 1301 | 2382 | 2256 | 1198 | 1280 | 1792 | 2317 | 2321 |
| 1370 | 2530 | 2330 | 1354 | 2404 | 2229 | 1209 | 1307 | 1810 | 2335 | 2300 |
| 1425 | 2555 | 2300 | 1405 | 2426 | 2203 | 1216 | 1337 | 1822 | 2356 | 2278 |
| 1475 | 2575 | 2265 | 1452 | 2443 | 2172 | 1222 | 1365 | 1836 | 2382 | 2256 |
| 1530 | 2595 | 2230 | 1503 | 2460 | 2141 | 1226 | 1394 | 1842 | 2404 | 2229 |
| 1585 | 2615 | 2190 | 1555 | 2478 | 2105 | 1226 | 1432 | 1851 | 2426 | 2203 |
| 1640 | 2635 | 2140 | 1605 | 2495 | 2061 | 1221 | 1465 | 1870 | 2443 | 2172 |
| 1695 | 2655 | 2085 | 1657 | 2512 | 2011 | 1206 | 1510 | 1892 | 2460 | 2141 |
| 1750 | 2675 | 2025 | 1707 | 2529 | 1958 | 1194 | 1556 | 1897 | 2478 | 2105 |
| 1805 | 2690 | 1960 | 1758 | 2542 | 1899 | 1180 | 1600 | 1904 | 2495 | 2061 |
| 1855 | 2700 | | 1803 | 2551 | | 1160 | 1654 | 1911 | 2512 | 2011 |
| 1900 | 2705 | | 1844 | 2555 | | 1138 | 1670 | 1909 | 2529 | 1958 |
| 1945 | 2705 | | 1885 | 2555 | | 1113 | 1688 | 1907 | 2542 | 1899 |
| 1990 | 2705 | | 1926 | 2555 | | 1060 | 1703 | 1916 | 2551 | |
| 2030 | 2700 | | 1962 | 2551 | | 1005 | 1720 | 1930 | 2555 | |
| 2070 | 2690 | | 1998 | 2542 | | 945 | 1731 | 1940 | 2555 | |
| 2105 | 2680 | | 2029 | 2534 | | 898 | 1742 | 1952 | 2555 | |

## Table 3

### Input Channel Data, Helena, Ark.

### Bottom Slope = 0.000064 ft/ft

| Stage ft | Elevation ft msl | Area × 1000 sq ft | Width ft | Manning's n | |
|---|---|---|---|---|---|
| | | | | Rising Hydro-graph | Falling Hydro-graph |
| 15 | 156.70 | 109 | 2620 | 0.0502 | 0.0556 |
| 20 | 161.70 | 122 | 2670 | 0.0412 | 0.0475 |
| 30 | 171.70 | 149 | 2800 | 0.0330 | 0.0363 |
| 35 | 176.70 | 163 | 2880 | 0.0295 | -- |
| 40 | 181.70 | 178 | 2970 | 0.0287 | 0.0306 |
| 45 | 186.70 | 195 | 3150 | 0.0277 | 0.0297 |
| 51 | 192.70 | 220 | 3170 | 0.0260 | 0.0281 |
| 62 | 203.70 | 260 | 3170 | 0.0250 | 0.0268 |
| 65 | 206.70 | 272 | 3170 | 0.0246 | 0.0262 |

# Table 4

## Design Flood Hydrographs, Helena, Ark.

### Daily Discharge, 1000 cfs

| Project Design Flood (PDF) 58A-EN | | | PDF 58A-EN Corrected for Overbank | | | 1973/58A-EN | | | |
|---|---|---|---|---|---|---|---|---|---|
| 440 | 2290 | 1965 | 440 | 2101 | 1823 | 400 | 499 | 1849 | 2015 |
| 515 | 2305 | 1960 | 515 | 2114 | 1819 | 500 | 509 | 1905 | 1977 |
| 575 | 2320 | 1960 | 575 | 2126 | 1819 | 600 | 517 | 1956 | 1939 |
| 620 | 2335 | 1960 | 620 | 2139 | 1819 | 700 | 541 | 1998 | 1900 |
| 670 | 2345 | 1955 | 670 | 2148 | 1815 | 800 | 600 | 2033 | 1870 |
| 715 | 2355 | 1945 | 715 | 2156 | 1806 | 900 | 707 | 2058 | 1849 |
| 765 | 2365 | 1930 | 765 | 2165 | 1794 | 913 | 796 | 2084 | 1832 |
| 815 | 2370 | 1915 | 815 | 2169 | 1781 | 908 | 875 | 2101 | 1823 |
| 870 | 2375 | 1895 | 870 | 2173 | 1764 | 911 | 944 | 2114 | 1819 |
| 915 | 2380 | 1875 | 915 | 2178 | 1747 | 933 | 1002 | 2126 | 1819 |
| 965 | 2385 | 1855 | 965 | 2182 | 1730 | 951 | 1056 | 2139 | 1819 |
| 1005 | 2390 | 1835 | 1004 | 2186 | 1713 | 967 | 1086 | 2148 | 1815 |
| 1035 | 2400 | 1815 | 1030 | 2195 | 1695 | 987 | 1110 | 2156 | 1806 |
| 1060 | 2410 | 1795 | 1051 | 2203 | 1678 | 1004 | 1136 | 2165 | 1794 |
| 1095 | 2420 | 1770 | 1081 | 2212 | 1657 | 1023 | 1164 | 2169 | 1781 |
| 1130 | 2435 | 1740 | 1111 | 2225 | 1631 | 1044 | 1189 | 2173 | 1764 |
| 1170 | 2445 | 1705 | 1145 | 2233 | 1602 | 1052 | 1215 | 2178 | 1747 |
| 1215 | 2455 | 1665 | 1183 | 2242 | 1567 | 1048 | 1259 | 2182 | 1730 |
| 1260 | 2460 | 1620 | 1222 | 2246 | 1529 | 1033 | 1308 | 2186 | 1713 |
| 1310 | 2460 | 1575 | 1265 | 2246 | 1491 | 1018 | 1350 | 2195 | 1695 |
| 1365 | 2450 | 1530 | 1311 | 2237 | 1452 | 1006 | 1391 | 2203 | 1678 |
| 1425 | 2435 | 1480 | 1363 | 2225 | 1410 | 998 | 1425 | 2212 | 1657 |
| 1495 | 2415 | 1425 | 1422 | 2207 | 1363 | 989 | 1438 | 2225 | 1631 |
| 1575 | 2390 | 1370 | 1491 | 2186 | 1316 | 974 | 1449 | 2233 | 1602 |
| 1665 | 2360 | 1315 | 1567 | 2160 | 1269 | 949 | 1478 | 2242 | 1567 |
| 1755 | 2320 | 1270 | 1644 | 2126 | 1230 | 910 | 1509 | 2246 | 1529 |
| 1840 | 2280 | 1225 | 1717 | 2092 | 1192 | 845 | 1537 | 2246 | 1491 |
| 1920 | 2235 | 1180 | 1785 | 2054 | 1154 | 773 | 1560 | 2237 | 1452 |
| 1995 | 2190 | | 1849 | 2015 | | 691 | 1571 | 2225 | 1410 |
| 2060 | 2145 | | 1905 | 1977 | | 616 | 1580 | 2207 | 1363 |
| 2120 | 2100 | | 1956 | 1939 | | 570 | 1600 | 2186 | 1316 |
| 2170 | 2055 | | 1998 | 1900 | | 542 | 1620 | 2160 | 1269 |
| 2210 | 2020 | | 2033 | 1870 | | 521 | 1644 | 2126 | 1230 |
| 2240 | 1995 | | 2058 | 1849 | | 503 | 1717 | 2092 | 1192 |
| 2270 | 1975 | | 2084 | 1832 | | 497 | 1785 | 2054 | 1154 |

## Table 5

### Input Channel Data, Baton Rouge, La.

### Bottom Slope = 0.000016 ft/ft

| Stage ft | Elevation ft msl | Area × 1000 sq ft | Width ft | Manning's n |
|----------|------------------|-------------------|----------|-------------|
| | | **1950 Flood Data** | | |
| 20 | 19.48 | 140 | 3090 | 0.0201 |
| 25 | 24.48 | 155 | 3110 | 0.0192 |
| 30 | 29.48 | 170 | 3130 | 0.0183 |
| 32.5 | 31.98 | 178 | 3180 | 0.0180 |
| 35 | 34.48 | 185 | 3360 | 0.0168 |
| 40 | 39.48 | 201 | 3650 | 0.0143 |
| 45 | 44.48 | 220 | 3690 | 0.0133 |
| 47 | 46.48 | 226 | 3690 | 0.0129 |
| | | **1973 Flood Data** | | |
| 20 | 19.48 | 139 | 2330 | 0.0240 |
| 25 | 24.48 | 152 | 2380 | 0.0222 |
| 30 | 29.48 | 164 | 2490 | 0.0201 |
| 35 | 34.48 | 177 | 2820 | 0.0175 |
| 40 | 39.48 | 190 | 2880 | 0.0152 |
| 45 | 44.48 | 205 | 2920 | 0.0138 |
| 47 | 46.48 | 211 | 2930 | 0.0134 |

# Table 6

## Design Flood Hydrographs, Baton Rouge, La.

## Daily Discharge, 1000 cfs

| Project Design Flood (PDF) 58A-EN | | 1973/58A-EN | | |
|---|---|---|---|---|
| 648 | 1500 | 648 | 1502 | 1347 |
| 666 | | 666 | 1409 | 1336 |
| 690 | | 690 | 1513 | 1247 |
| 708 | | 708 | 1441 | 1325 |
| 723 | | 723 | 1520 | 1258 |
| 738 | Flow steady at 1500 for 63 days | 738 | 1460 | 1214 |
| 760 | | 760 | 1459 | 1180 |
| 786 | | 786 | 1403 | 1225 |
| 817 | | 817 | 1471 | 1158 |
| 850 | | 850 | 1432 | 1136 |
| 883 | | 883 | 1411 | 1125 |
| 916 | | 916 | 1439 | 1114 |
| 941 | 1500 | 914 | 1425 | 1111 |
| 966 | 1450 | 966 | 1443 | 1112 |
| 995 | 1400 | 995 | 1465 | 1125 |
| 1028 | 1350 | 1028 | 1479 | 1114 |
| 1062 | 1300 | 1062 | 1460 | 1081 |
| 1100 | 1250 | 1100 | 1491 | 1078 |
| 1142 | 1200 | 1142 | 1470 | 1085 |
| 1178 | 1150 | 1178 | 1489 | 1058 |
| 1210 | 1100 | 1210 | 1538 | 1040 |
| 1239 | 1050 | 1239 | 1484 | 1030 |
| 1269 | 1000 | 1269 | 1454 | 1051 |
| 1298 | 950 | 1298 | 1441 | 1031 |
| 1327 | 900 | 1327 | 1410 | 1023 |
| 1348 | 850 | 1348 | 1384 | 978 |
| 1374 | 800 | 1374 | 1453 | 958 |
| 1395 | 750 | 1395 | 1448 | 945 |
| 1416 | | 1416 | 1445 | 927 |
| 1437 | | 1437 | 1414 | 892 |
| 1458 | | 1458 | 1414 | 898 |
| 1479 | | 1479 | 1425 | 724 |
| | | 1500 | 1381 | |
| | | 1383 | 1392 | |
| | | 1356 | 1347 | |
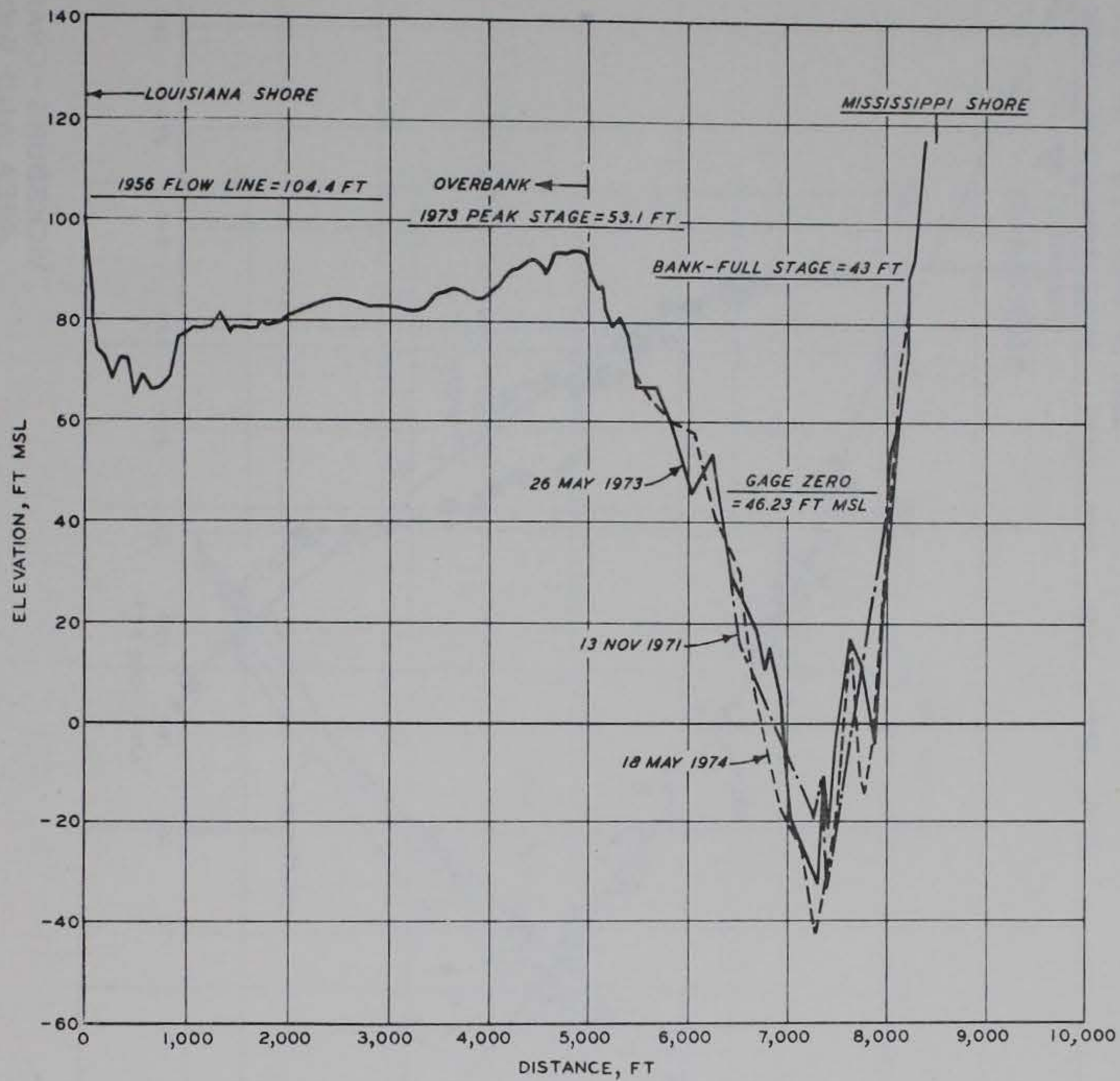
VICKSBURG—CROSS SECTION
AT DISCHARGE RANGE
RIVER MILE 435.24

PLATE 1
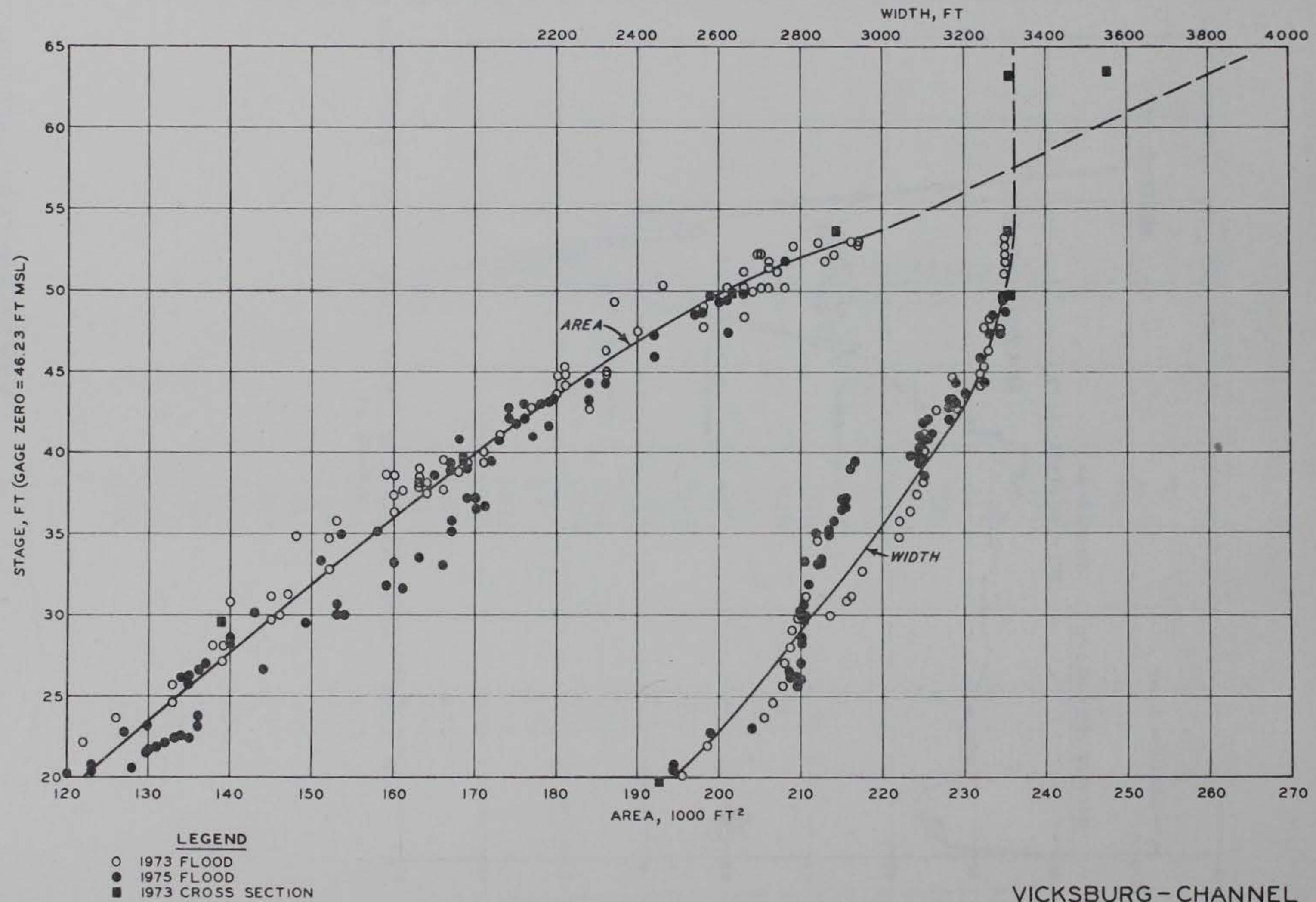
VICKSBURG — CHANNEL
AREA AND WIDTH

PLATE 2

LEGEND
O  1973 FLOOD
●  1975 FLOOD
■  1973 CROSS SECTION
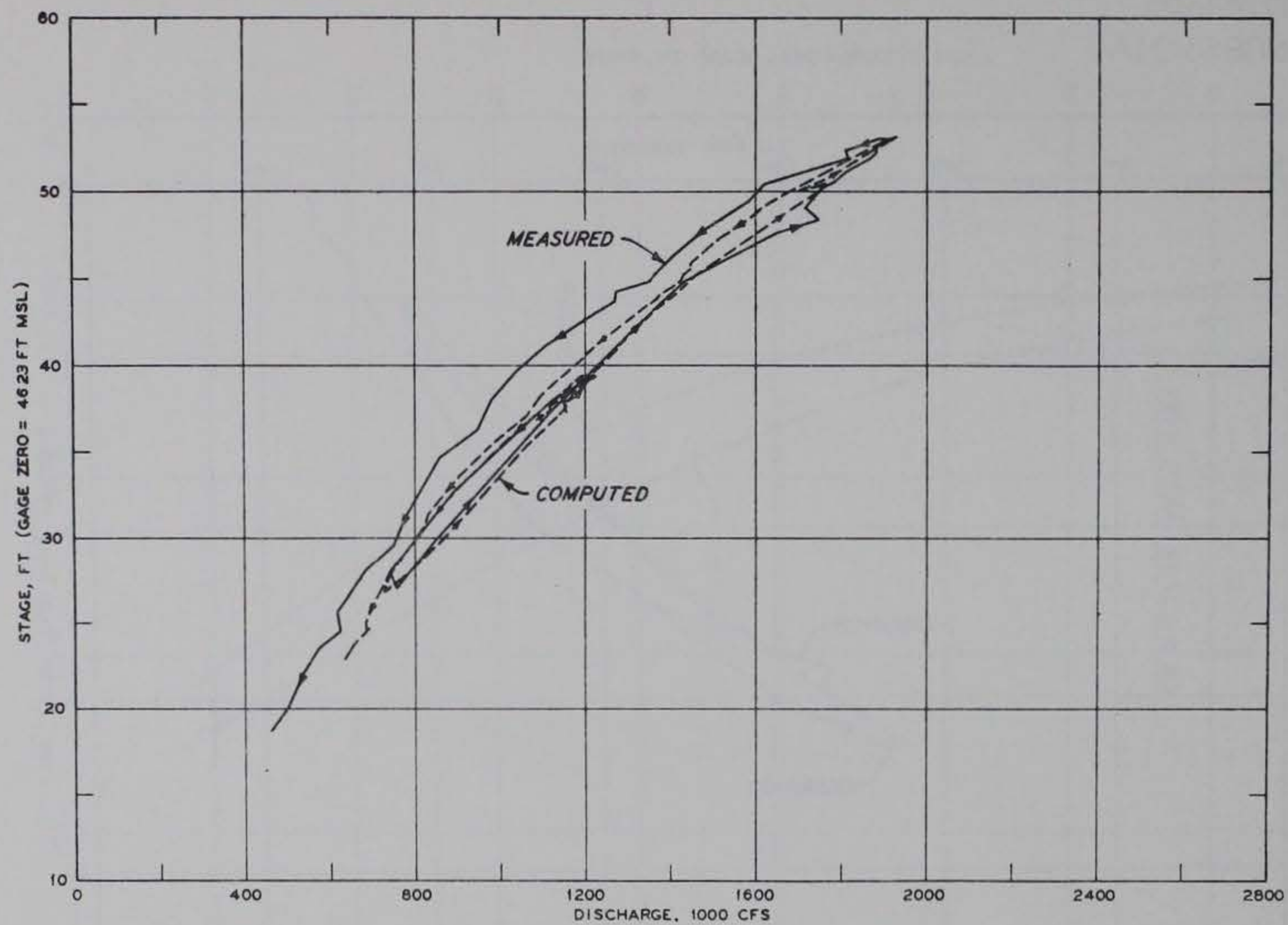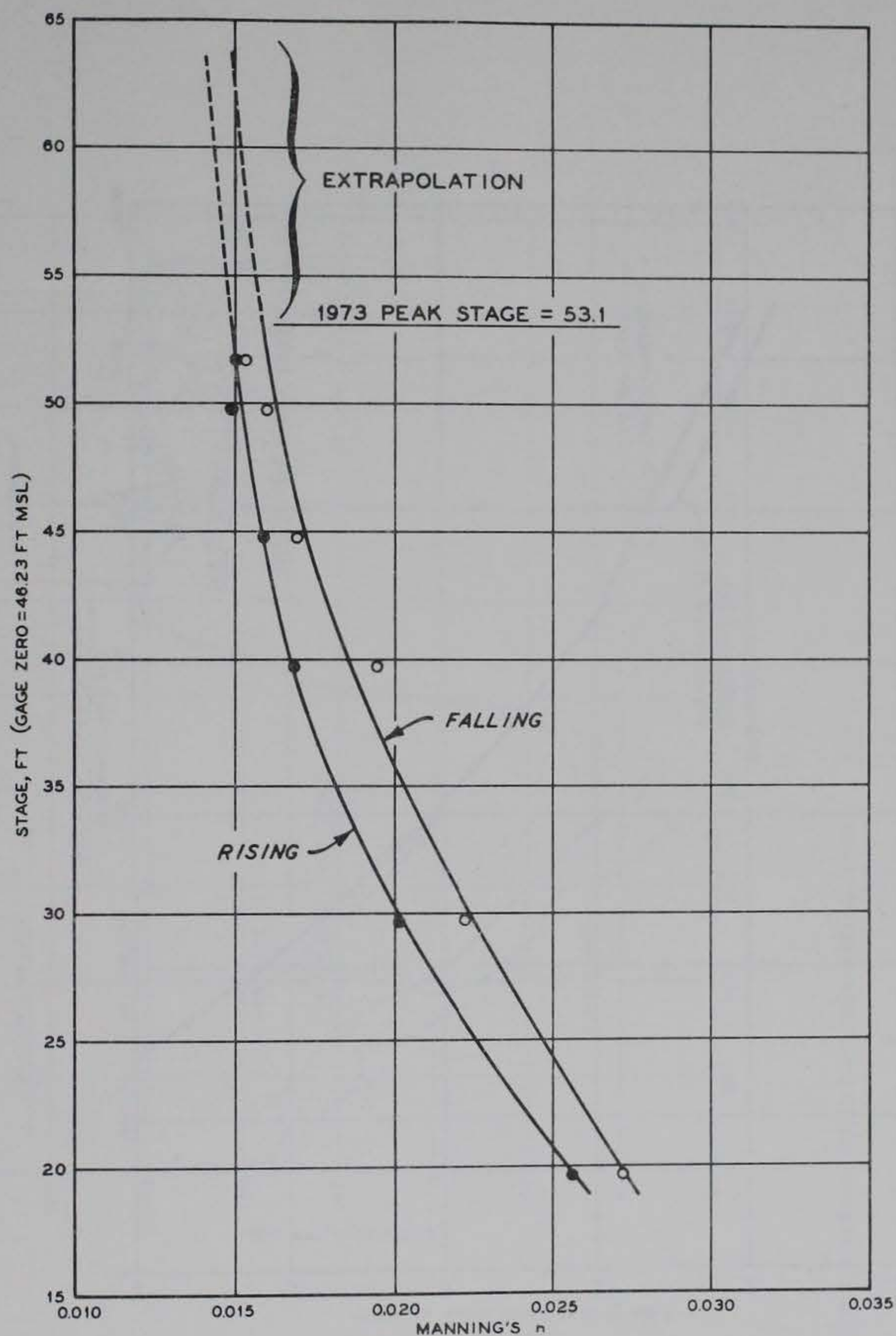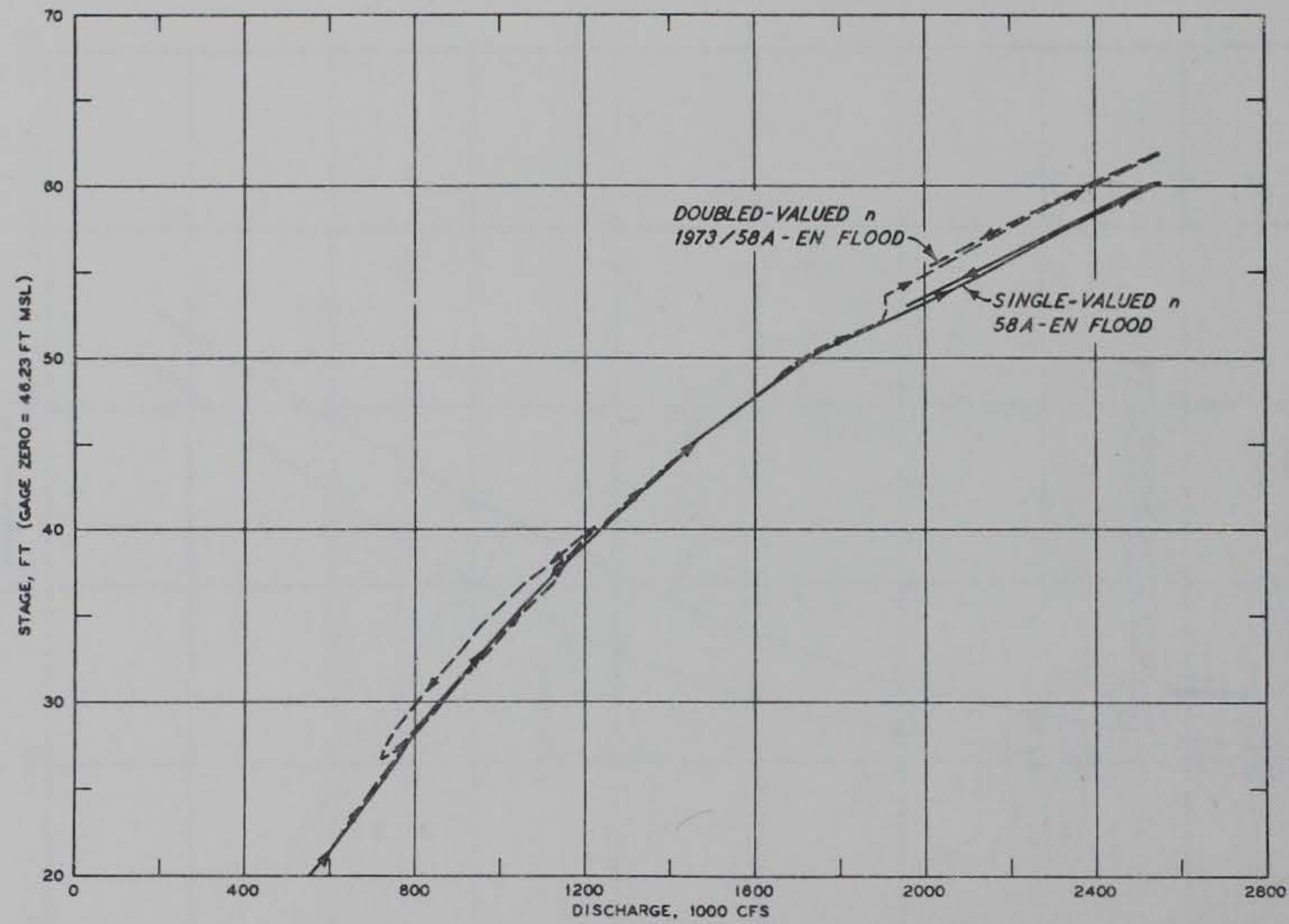
VICKSBURG - 1973 FLOOD
COMPUTED RATING CURVE
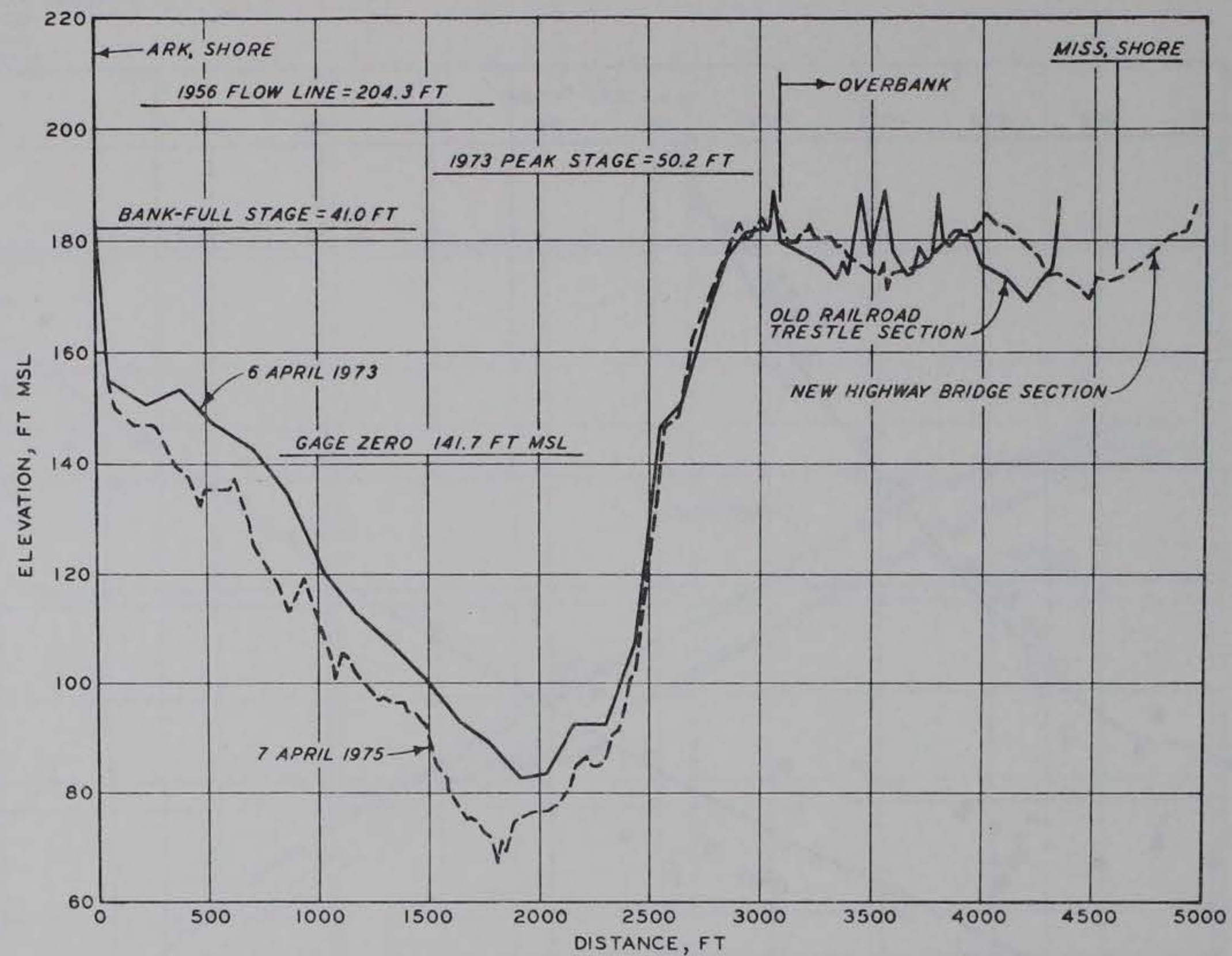USING SINGLE-VALUED
MANNING'S n IN MODEL
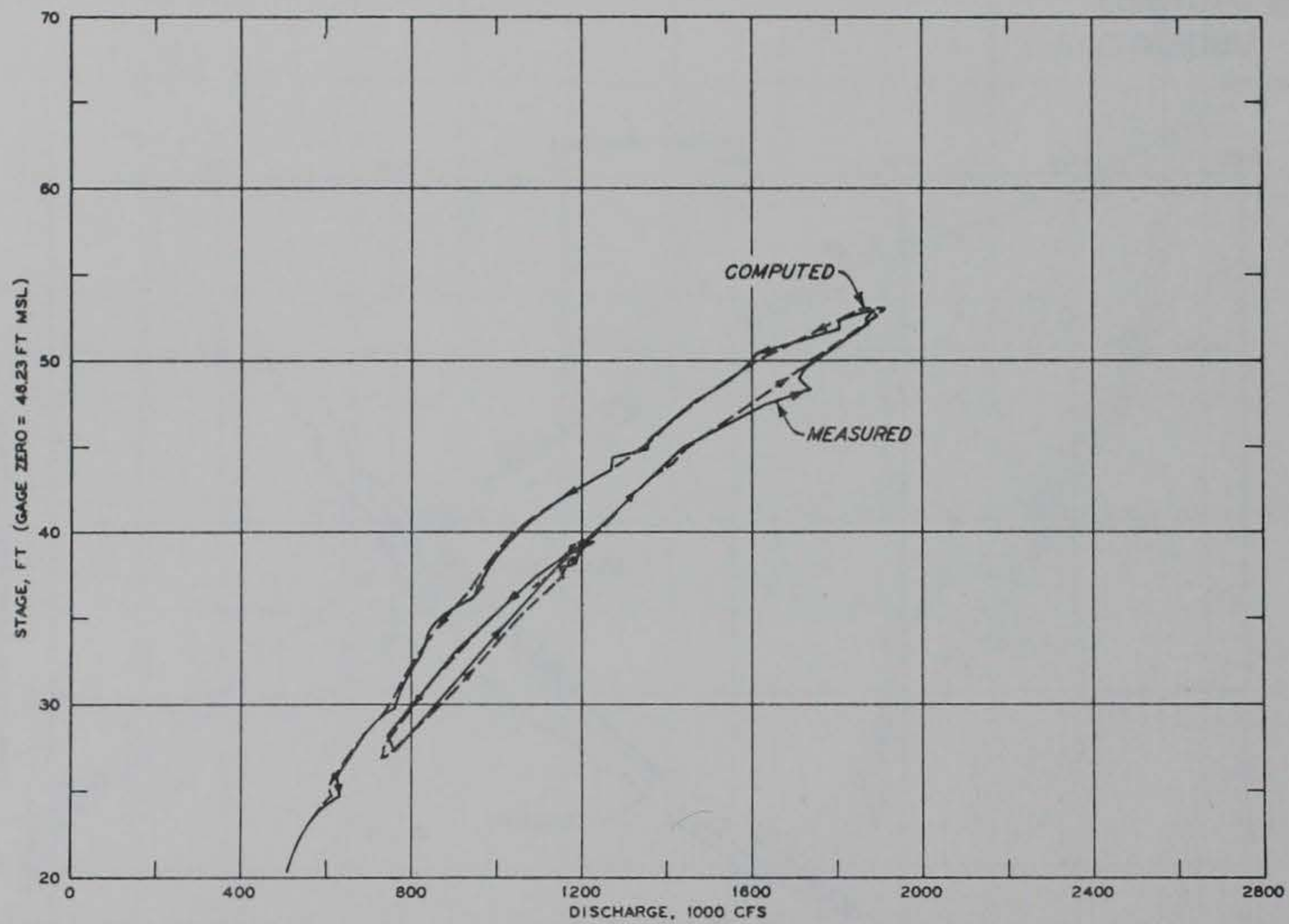
PLATE 3

VICKSBURG - 1973 FLOOD
COMPUTED RATING CURVE
USING DOUBLE-VALUED
MANNING'S n IN MODEL

PLATE 4

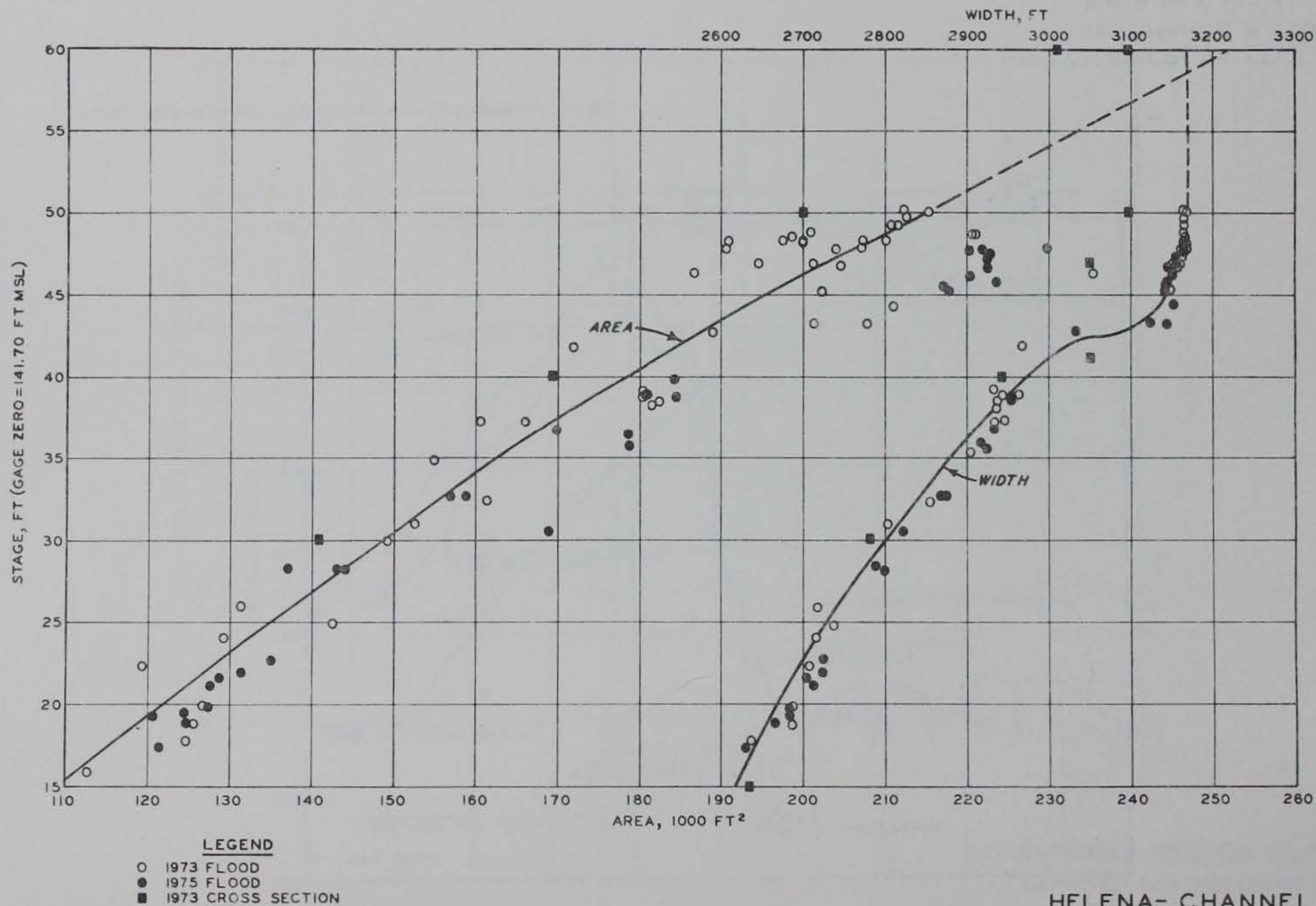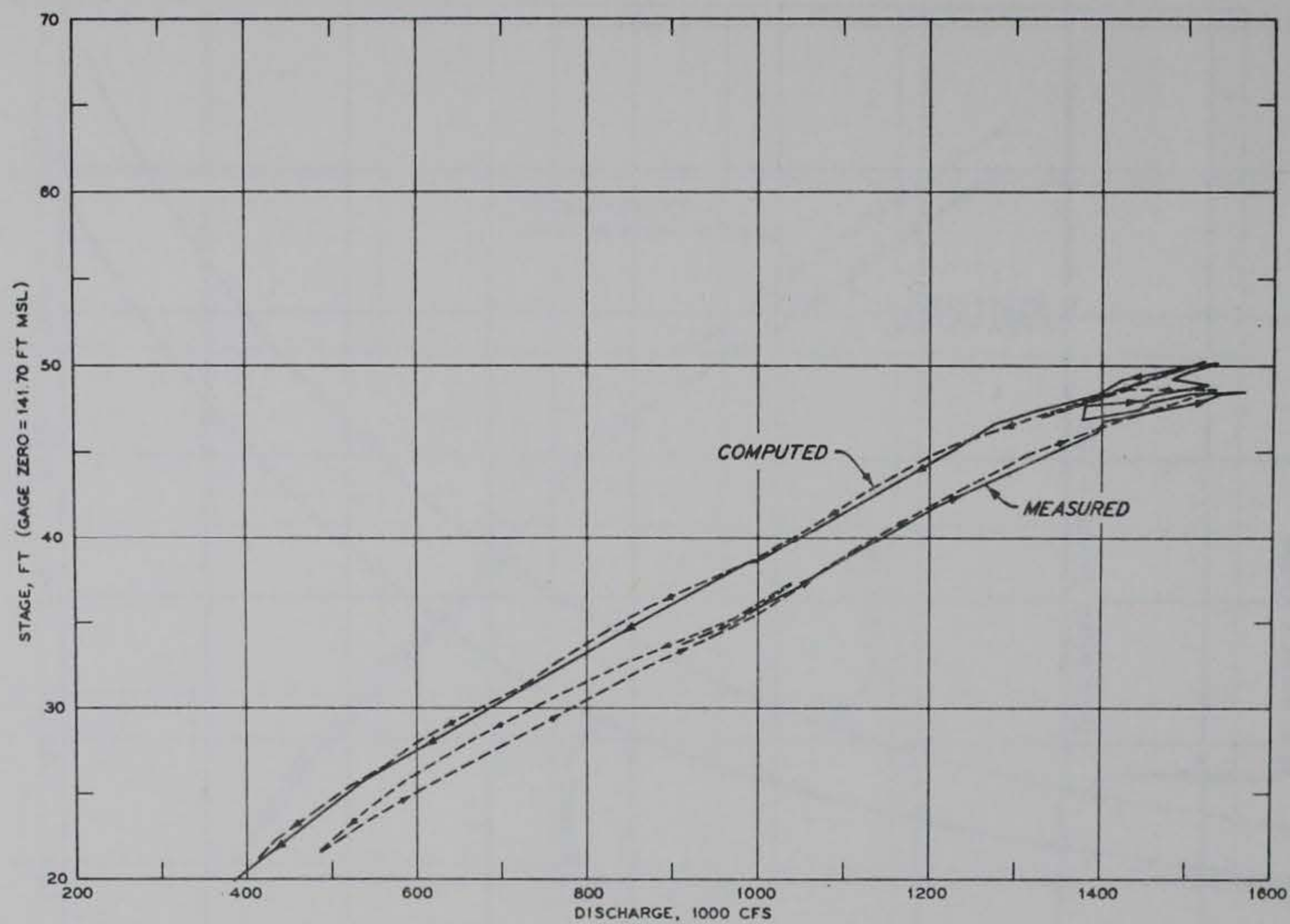VICKSBURG - 1973 FLOOD
EXTRAPOLATION OF
CHANNEL ROUGHNESS

PLATE 5

PLATE 6



VICKSBURG - DESIGN FLOOD
COMPUTED RATING CURVES
USING MODEL

NOTE: OVERBANK SECTION MOVED 1 MILE DOWNSTREAM IN 1975.

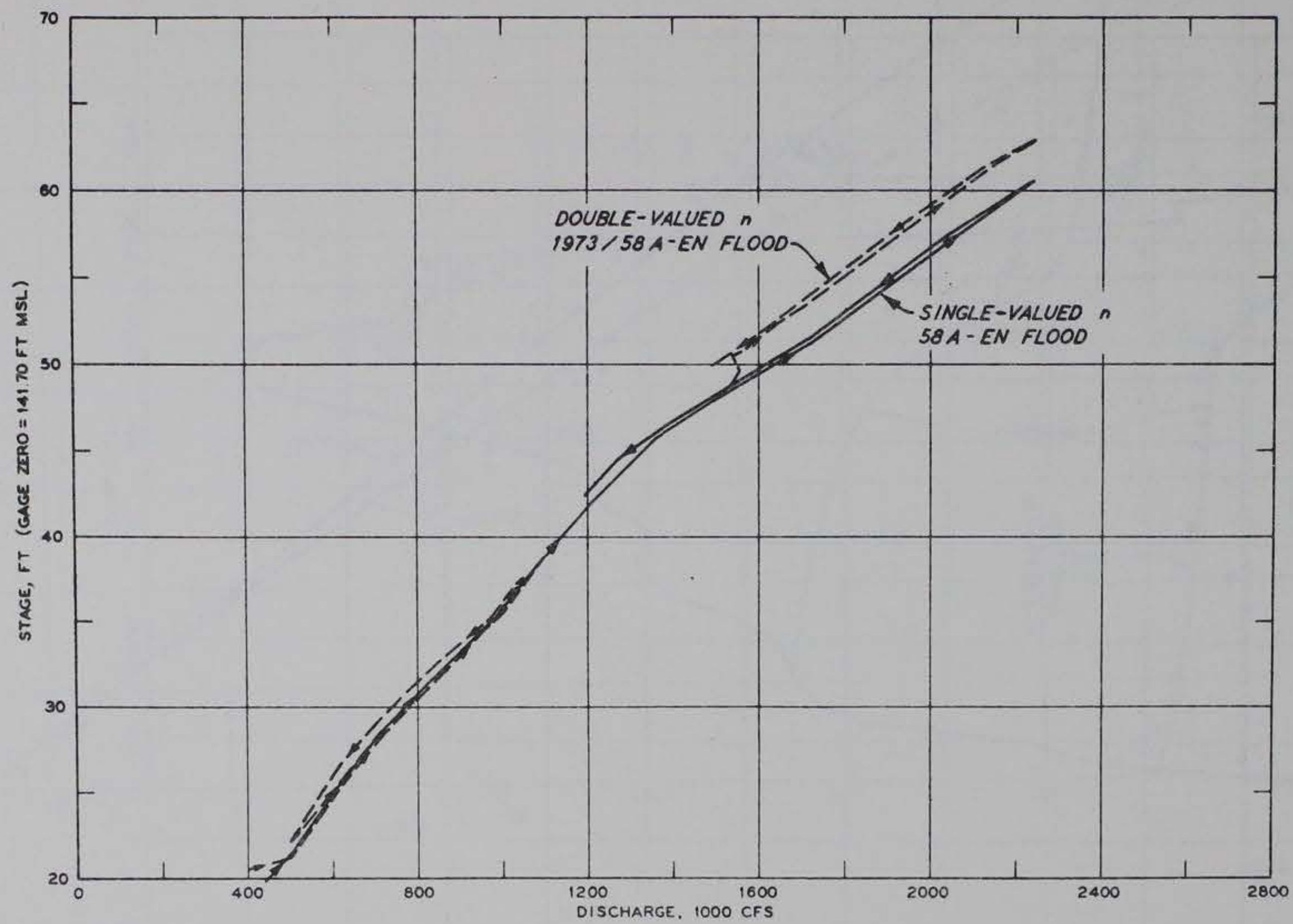HELENA — CROSS SECTION
AT DISCHARGE RANGE
RIVER MILE 663.3

PLATE 7

HELENA- CHANNEL
AREA AND WIDTH

HELENA - 1973 FLOOD
COMPUTED RATING CURVE
USING DOUBLE-VALUED
MANNING'S n IN MODEL

PLATE 9
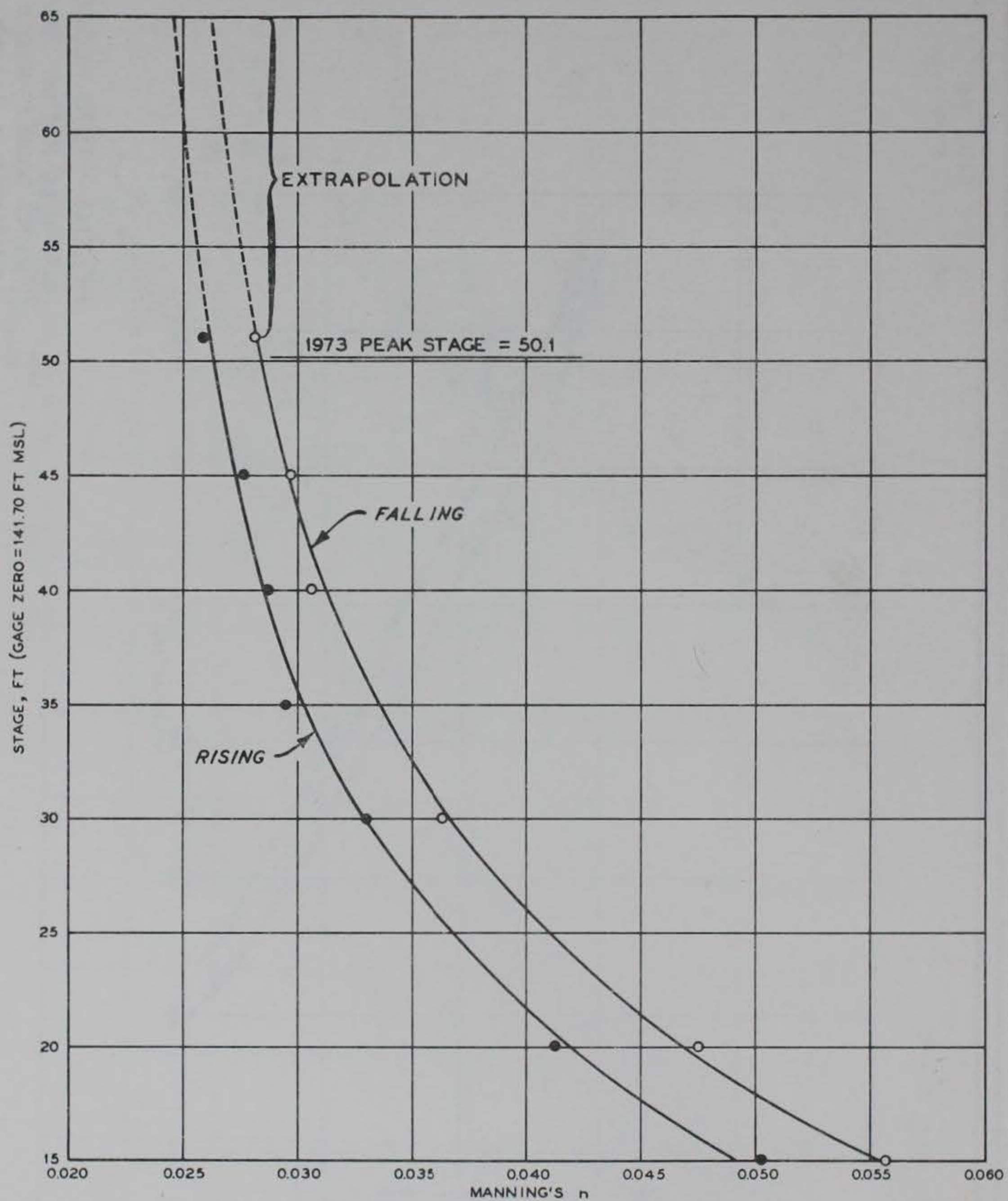
HELENA - 1973 FLOOD
EXTRAPOLATION OF
CHANNEL ROUGHNESS
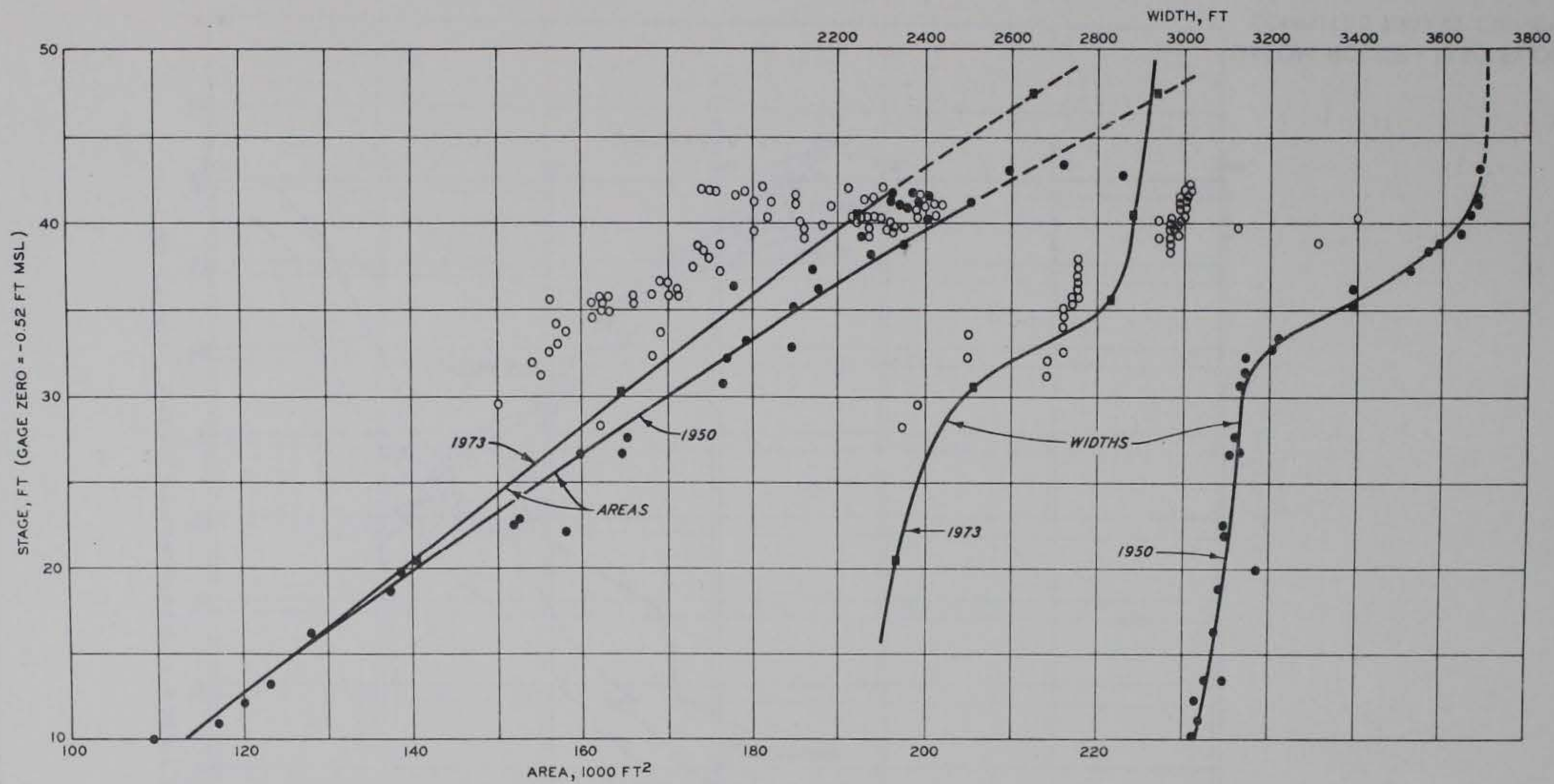
PLATE 10

HELENA-DESIGN FLOOD
COMPUTED RATING CURVES
USING MODEL

PLATE 11

1957 FLOW LINE = 46.4 FT

1973 PEAK STAGE = 42.1 FT

BANK-FULL STAGE = 30 FT

GAGE ZERO
= -0.52 FT MSL

WEST BANK

EAST BANK

ELEVATION, FT MSL

DISTANCE, FT

BATON ROUGE - CROSS SECTION
AT DISCHARGE RANGE

RIVER MILE 233.75
SURVEY 30 JAN 1974

PLATE 12

BATON ROUGE - CHANNEL
AREAS AND WIDTHS
1950 AND 1973

LEGEND
O  1973 FLOOD
●  1975 FLOOD
■  1973 CROSS SECTION

PLATE 13

PLATE 14
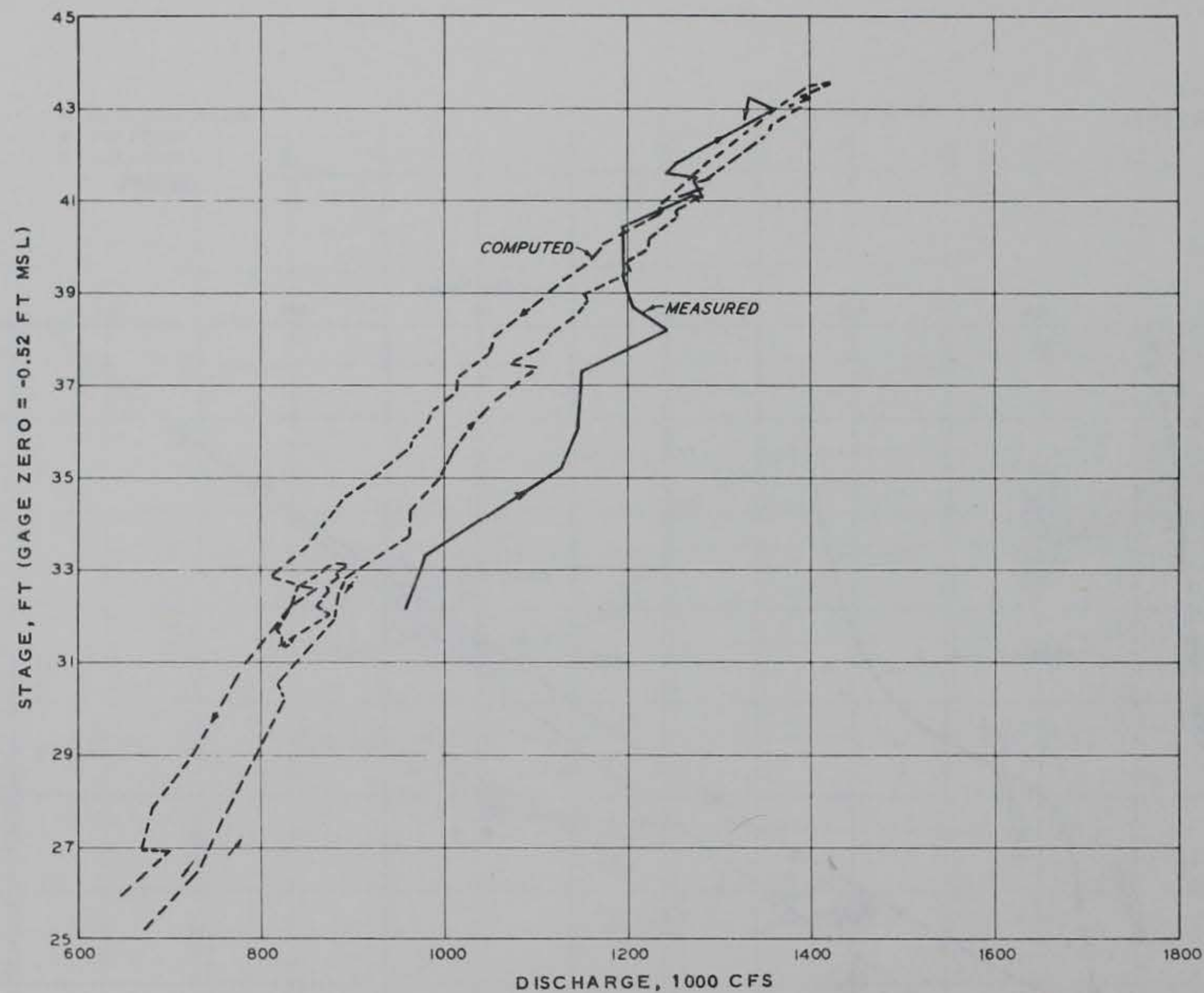


BATON ROUGE - 1950 FLOOD
COMPUTED RATING CURVES

STAGE, FT (GAGE ZERO = -0.52 FT MSL)

DISCHARGE, 1000 CFS

PLATE 15
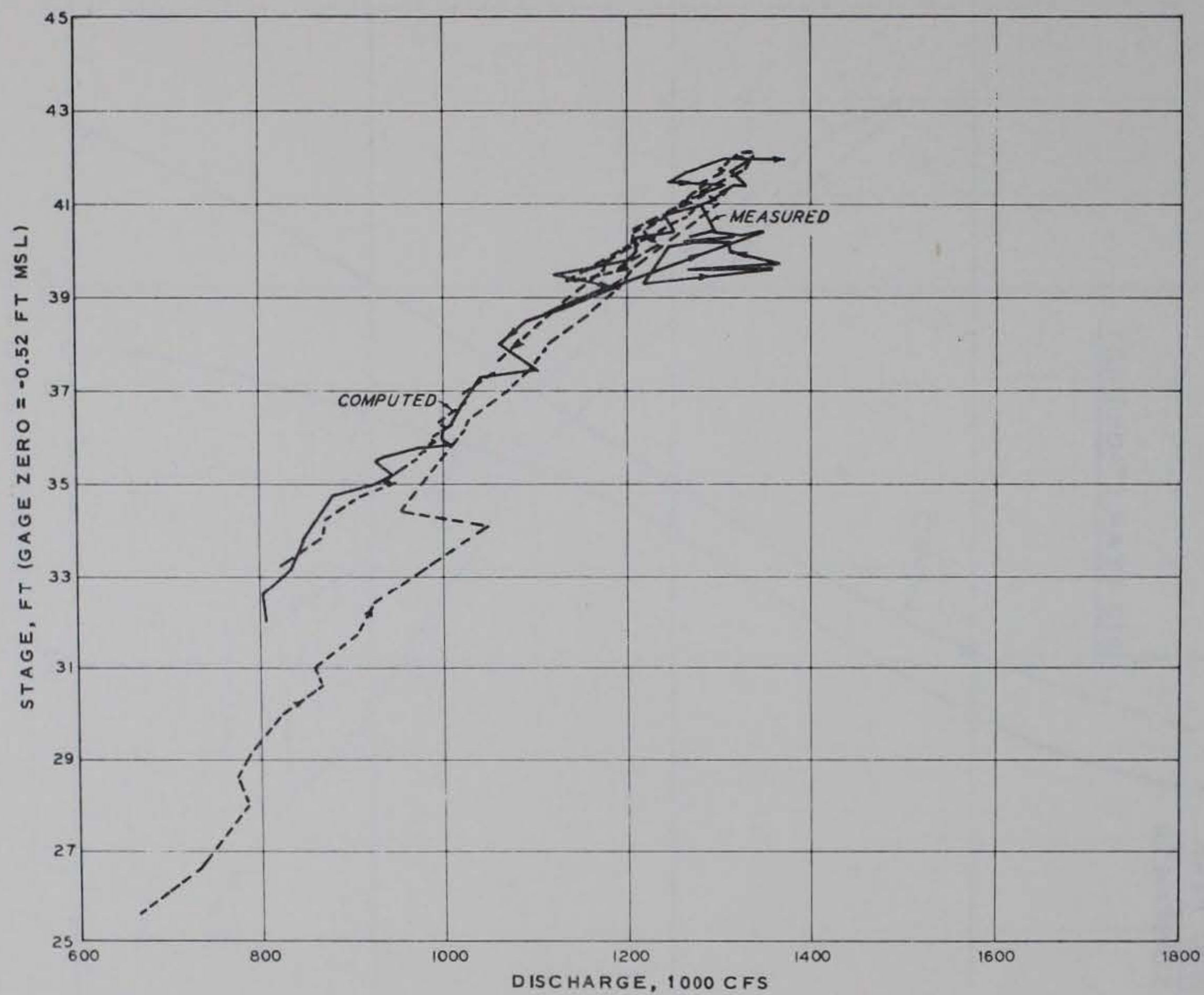
BATON ROUGE - 1973 FLOOD
COMPUTED RATING CURVES

BATON ROUGE – 1950 AND 1973 FLOODS
EXTRAPOLATION OF CHANNEL ROUGHNESS

PLATE 16

STAGE, FT (GAGE ZERO = -0.52 FT MSL)

DISCHARGE, 1000 CFS
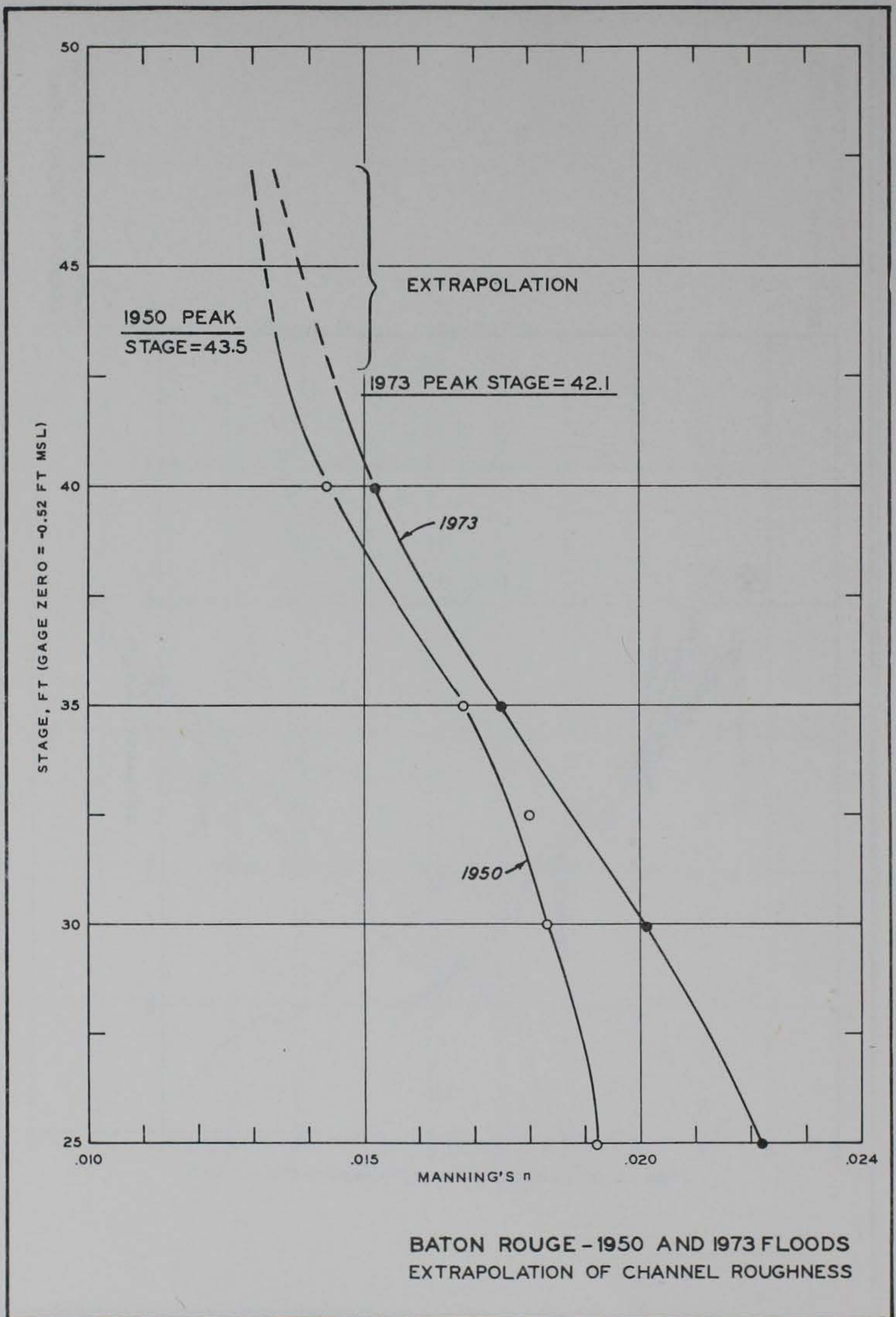
BATON ROUGE - DESIGN FLOOD 58A-EN
COMPUTED RATING CURVE USING
1973 DATA CALIBRATION

PLATE 17

PLATE 18



STAGE, FT (GAGE ZERO = -0.52 FT MSL)

DISCHARGE, 1000 CFS
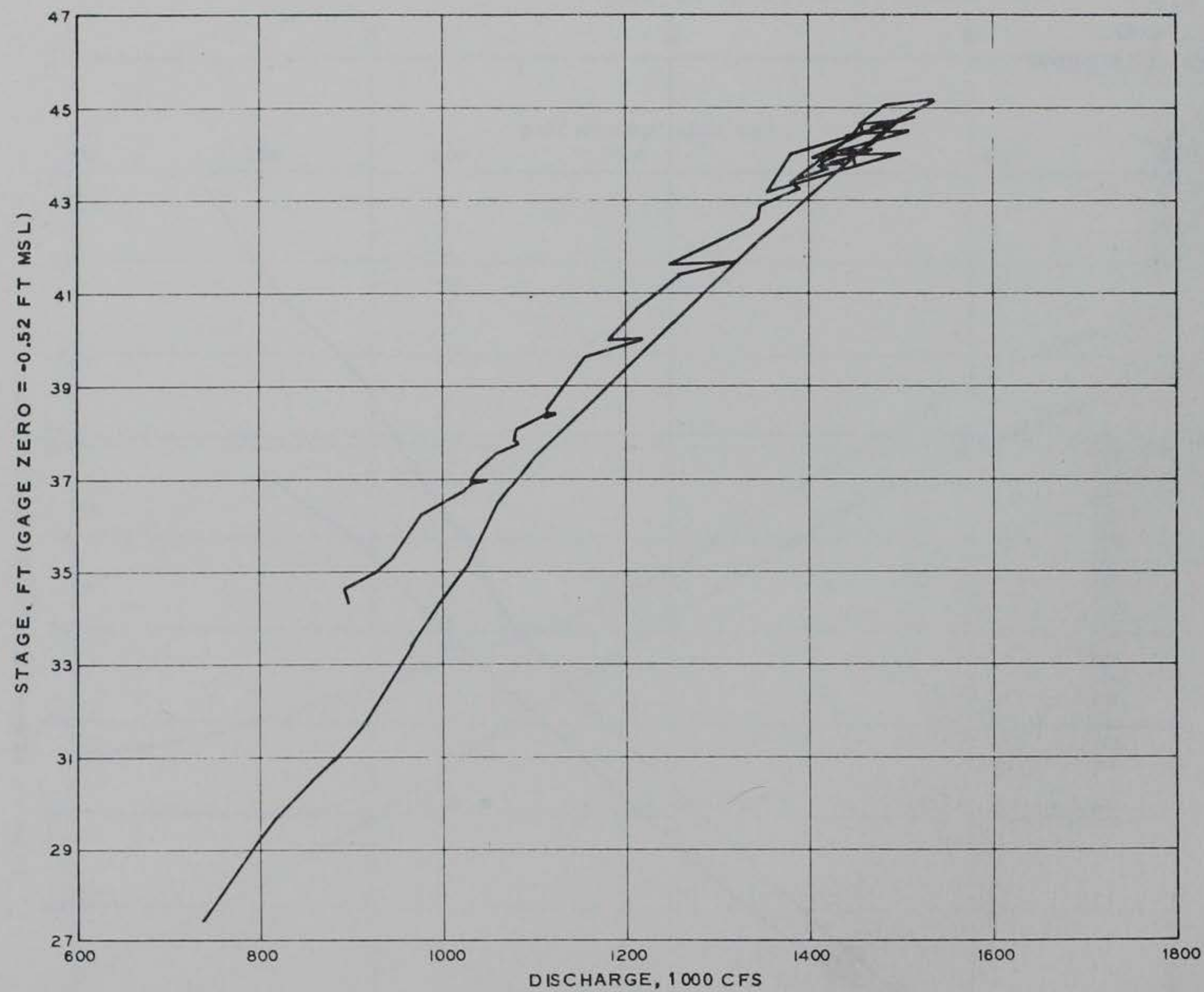
BATON ROUGE - DESIGN FLOOD 1973/58A-EN
COMPUTED RATING CURVE USING
1973 DATA CALIBRATION