AD-756 412

INVESTIGATION OF UNDERSEEPAGE AND ITS CONTROL, LOWER MISSISSIPPI RIVER LEVEES. APPENDIX E: ANALYSIS OF 1961 PIEZOMETRIC DATA

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

May 1964

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

INVESTIGATION OF UNDERSEEPAGE AND ITS CONTROL, LOWER MISSISSIPPI RIVER LEVEES

APPENDIX E: ANALYSIS OF 1961 PIEZOMETRIC DATA

TECHNICAL MEMORANDUM NO. 3-424

May 1964

Prepared for

The President, Mississippi River Commission

by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

INVESTIGATION OF UNDERSEEPAGE AND ITS CONTROL, LOWER MISSISSIPPI RIVER LEVEES

APPENDIX E: ANALYSIS OF 1961 PIEZOMETRIC DATA

TECHNICAL MEMORANDUM NO. 3-424

May 1963

Prepared for

The President, Mississippi River Commission

by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS

I

Preface

In September 1940 the Mississippi River Commission initiated a general study of the phenomena of underseepage and its control along Lower Mississippi River levees. The study was prompted by the occurrence of heavy underseepage and sand boils along numerous reaches of these levees during the 1937 flood. The results of this investigation, which utilized the combined efforts of the Memphis, Vicksburg, and New Orleans Districts and the U. S. Army Engineer Waterways Experiment Station (WES), are contained in WES TM No. 3-424, Investigation of Underseepage and Its Control, Lower Mississippi River Levees, October 1956. Appendices A through D, describing studies related to the problem of underseepage, were bound with the report.

This report, Appendix E, contains an analysis and summary of piezometric data obtained during the 1961 high water. The relatively high river stage which occurred in 1961 provided an opportunity for checking the previous high-water analysis and determining whether any significant changes in seepage boundary conditions had occurred since that time. The study reported herein was authorized by the Mississippi River Commission in 1st indorsement dated 16 June 1961 to WES letter dated 1 June 1961, subject "Status of Soils Division Projects for MRC and LMVD for FY 1961 and Request for Funds for Projects for FY 1962."

The piezometric data obtained during the 1961 high-water period were furnished by the Memphis, Vicksburg, and New Orleans Districts. The analysis of data contained herein was made by Messrs. W. C. Sherman and C. C. Trahan, and the report was prepared by Mr. Trahan under the general direction of Messrs. W. J. Turnbull, W. G. Shockley, J. R. Compton, and W. C. Sherman, Soils Division, WES.

Director of the WES during the course of this investigation was Colonel Alex G. Sutton, Jr., CE, and Technical Director was Mr. J. B. Tiffany.

Contents

List of Tables

List of Illustrations

List of Plates

List of Plates (Continued)

E-1

INVESTIGATION OF UNDERSEEPAGE AND ITS CONTROL

LOWER MISSISSIPPI RIVER LEVEES

APPENDIX E: ANALYSIS OF 1961 PIEZOMETRIC DATA

Introduction

1. In 1940 the Mississippi River Commission initiated a comprehensive study of underseepage and its control along the Lower Mississippi River levees. The purpose of this study was to provide data on the relation of soil conditions, geologic features, and underseepage and to improve methods for analyzing subsurface seepage. The results of this investigation are contained in WES TM No. 3-424, Investigation of Underseepage and Its Control, Lower Mississippi River Levees, October 1956. One phase of the investigation consisted of installation of piezometers at selected sites along the Lower Mississippi River to obtain data on the development of substratum hydrostatic pressures, and distances from the levee to the effective source of seepage entry. Analysis of piezometric data was based primarily on the 1950 high-water data.

2. It was recommended in the above-mentioned study that the piezometer systems be maintained and observed during periods of significant high water, and that the data be analyzed as they became available. The project flood stage at most of the sites is considerably higher than the river stages experienced since installation of the piezometers; therefore, valuable information is still to be gained at higher river stages. Since completion of the referenced study, a relatively high water occurred in 1961 which provided an opportunity for checking the previous high-water analysis and determining whether any significant changes in the seepage boundary conditions had occurred since that time.

3. During the 1961 high water, the Mississippi River reached a maximum stage of the same order of magnitude as that recorded during the 1950 high water, resulting in heads ranging from 6 to 14 ft on the levees at the piezometer sites. As the 1961 high water was only the second major high water that had occurred at a majority of the sites since the piezometers were installed, it was considered that data obtained during this

high water would provide a check on the analysis made of the 1950 high water. This appendix presents the analysis of the piezometer data obtained during the 1961 high water and a comparison with the 1950 high-water analysis.

Description of Piezometer System

4. Installation of piezometers was initiated in 1943 and completed in 1948. The sites of the piezometer systems are shown in fig. E1 and are as follows:

Memphis District	Vicksburg District	New Orleans District
Caruthersville, Mo.	Upper Francis, Miss.	Kelson, La.
Gammon, Ark.	Lower Francis, Miss.	Baton Rouge, La.
Commerce, Miss.	Bolivar, Miss.	Cotton Bayou, La.
Trotters 51, Miss.	Eutaw, Miss.	
Trotters 54, Miss.	L'Argent, La.	
Stovall, Miss.	Hole-in-the-Wall, La.	
Farrell, Miss.		

All of the above-listed piezometer sites are located along the Mississippi River with the exception of Cotton Bayou, La., which is located on the Red River.

5. Piezometer data were obtained from four of the above-listed sites during the 1943 high water. During the 1950 high water, when the Mississippi River reached its highest stage since the piezometers were installed, fairly complete piezometer readings were obtained at all of the sites. Analyses of data obtained in the 1943 and 1950 high water are given in TM No. 3-424.

1961 Piezometer Data

6. During the 1961 high water, piezometer readings were obtained at all of the piezometer sites except Cotton Bayou, La., where the head acting on the levee was relatively low. Readings from selected piezometers and concurrent river stages at each of the sites are plotted on odd-numbered plates E1 through E29. At Upper Francis, Lower Francis, Bolivar, and Eutaw, Miss., only two sets of readings were taken; one set

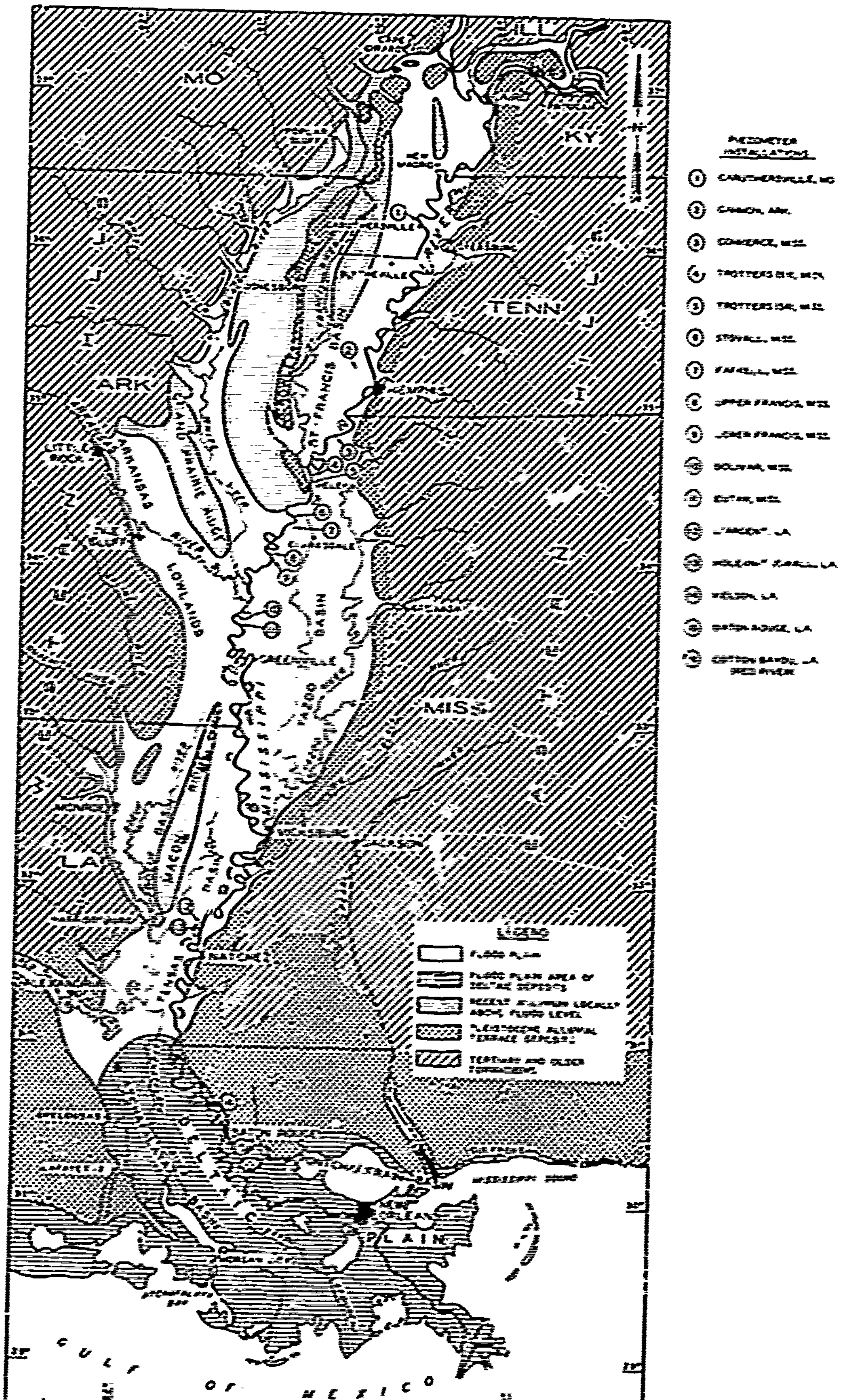


Fig. E1. Alluvial Valley of the Lower Mississippi River and locations of piezometer installations was taken at about the crest of the high water, and one set about a week after the river crest. Readings at L'Argent and Hole-in-the-Wall, La., were taken about a week before the crest of the high water and again at about the crest. At all other sites, piezometer readings were taken at periodic intervals during the rise and fall of the river stage.

7. At each piezometer site, the principal piezometer line, perpendicular to the center line of the levee, was selected for analysis. The principal lines are identical with those selected for the analysis of the 1950 high-water data. The piezometer readings and hydraulic grade line for the condition of maximum river stage at each of these piezometer lines are shown in even-numbered plates E2 through E30.* Piezometric data for other lines used in the initial analysis are also shown in some instances. At several of the piezometer sites, piezometers along the line selected for analysis were sluggish, indicated low readings as compared to other adjacent piezometers, or were completely inoperative. At Caruthersville, Mo., Stovall, Miss., and Hole-in-the Wall, La., the risers of piezometers located on the riverside of the levee were submerged during the 1961 high water. Those piezometers along the lines selected for analysis which were considered to be functioning improperly and those which were submerged during the 1961 high water are listed in table E1. It is recommended that in the near future the faulty piezometers be renovated or replaced, and the risers of those piezometers which were submerged in the 1961 high water be extended so that the piezometers can be read during the next major high water. Readings of the above-mentioned piezometers would greatly facilitate analyzing the data obtained during the next major high water.

Method of Analysis

8. When a levee is subjected to a differential hydrostatic head as a result of river stages being higher than the adjacent land, seepage enters the pervious substratum through the bed of the river, riverside borrow pits, and/or the riverside topstratum. The resulting artesian head

* Legend for the generalized stratification shown in these plates is shown only in plate E2.

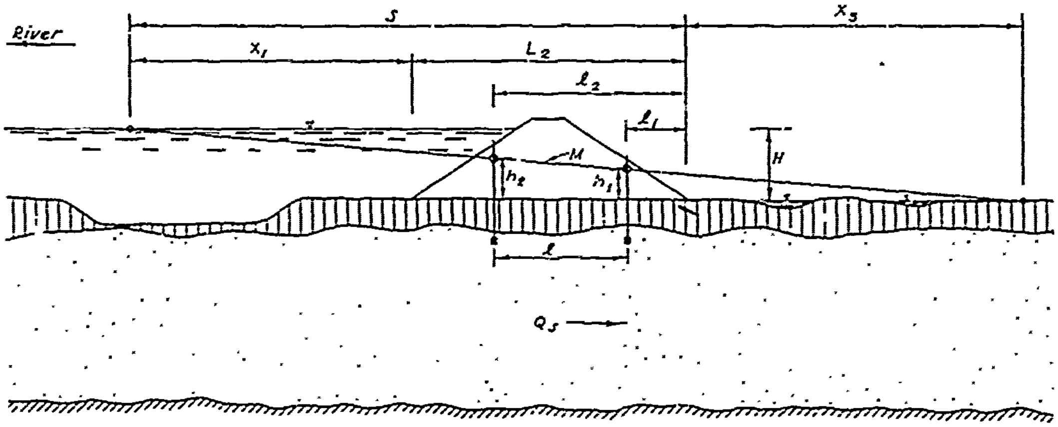
and hydraulic gradient in the sand stratum beneath the levee cause flow beneath and landward of the levee. The principal purposes of the piezometer installations along the Lower Mississippi River are to determine the hydraulic gradients beneath the levee and the distances to the effective source of seepage entry and exit during high-water periods. The effective source of seepage entry into the pervious stratum is defined as that vertical plane riverward of the levee where a hypothetical open seepage entry face, fully penetrating the pervious aquifer, with an impervious surface blanket between this plane and the levee, would produce the same flow and hydrostatic pressure beneath and landward of the levee as occur under the actual conditions riverward of the levee. It may also be defined as the vertical line through the point where the hydraulic grade line intersects the river stage elevation. The effective seepage exit is defined as that vertical plane landward of the levee where a hypothetical open drain face, with an impervious blanket between this plane and the landside levee toe, would result in the same hydrostatic pressure at the levee toe and the same amount of seepage passing beneath the levee as occur under actual conditions. It can also be defined as the intersection of the hydraulic grade line with the ground surface or tailwater elevation.

9. Analysis of the 1961 high-water data consisted primarily of determining the hydraulic grade line in the substratum sand, and the distance from the landside levee toe to the effective source of seepage entry and the effective seepage exit as the principal piezometer line of each site. The hydraulic grade line at the crest of the 1961 high water is plotted for the principal piezometer line of each site (for example, see plate E2). The distances from the landside toe of the levee (or berm) to the effective source of seepage (s), and the effective seepage exit (x_3) were determined from piezometers located beneath the levee, and berm (if present), using the following equations (see fig. E2 for nomenclature):

$$s = \ell_1 + \frac{H - h_1}{M} \qquad (1)$$

$$x_3 = \frac{h_1}{M} - \ell_1 \qquad (2)$$

where M is the slope of the hydraulic grade line. Where there were three or four piezometers beneath the levee, values of s and x_3 were



<u>Notation</u>

s = distance from landside toe of levee (or berm) to effective source of seepage entry

x_1 = effective length of blanket riverside of levee

x_3 = distance from landside toe of levee (or berm) to effective seepage exit

L_2 = base width of levee, and berm if present

H = total net head on levee

h_1, h_2 = piezometric heads at two piezometers on a line perpendicular to the levee at distances ℓ_1 and ℓ_2, respectively, from landside toe of levee

M = slope of hydraulic grade line beneath levee

$$= \frac{h_2 - h_1}{\ell_2 - \ell_1}$$

Fig. E2. Nomenclature for determination of s and x_3 from piezometer readings

determined graphically. In the analysis of data for the 1950 high water, values of s and x_3 were determined on selected days for rising river stages during the high-water period; these values were plotted versus river stage as shown in fig. E3 for piezometers at the Caruthersville site. From similar plots for each site, values of s and x_3 were extrapolated to project flood.* The extrapolation of x_3 to project flood was obtained by solving the following equation from the main report, using the conditions which were estimated to exist at project flood:

$$h_o = H\left(\frac{x_3}{s + x_3}\right) \qquad (3)$$

where h_o is the excess head at the landside toe of the levee. The values of s and x_3 extrapolated to project flood are shown in table E2, together with similar values determined for the 1950 and 1961 high water. The 1950 values of s and x_3 shown in table E2 are the intersections of the curves of best fit through the data points and the maximum 1950 river stage. Values shown for 1961 are those determined for the maximum 1961 river stage. Also shown in table E2 are the net head on the levee H, and excess head at the landside toe of the levee (or berm) h_o for project flood, and for the 1950 and 1961 high waters. The values of H were considered to be the difference between the river stage and the average ground surface or tailwater elevation on the landside of the levee. Values of h_o are actual excess heads measured by piezometers near the landside toe of the levee or berm.

10. At several of the piezometer sites, the tailwater elevation behind the levee was not recorded when the piezometers were read. Without a record of tailwater, an accurate computation of effective seepage exit (x_3) and excess head at the toe of the levee (h_o) could not be made at these sites. It is recommended that during the next major high water the elevation of the tailwater (water in ditches behind the levee) be recorded at the same time that piezometers are read.

11. At all piezometer sites, the net head on the levee during the 1950 high water was higher than the head observed during the 1961 high water. The difference between the maximum net heads for the 1950 and 1961 high waters varied from 0.4 ft at Eutaw, Miss., to 7.1 ft at Kelson, La. No indications of excessive seepage or sand boils were reported for the

* Project flood stages referred to in this report are those existing prior to 1956. A list of these stages for each piezometer site together with the current (1963) project flood stages adapted in 1956 is shown in table E3.

1961 high water. A discussion of the 1961 high-water data and a comparison of 1961 and 1950 high-water data at each piezometer site are presented in the following paragraphs.

Analysis of Data from Piezometer Sites

Caruthersville, Mo.

12. At piezometer line A, which is representative of conditions at Caruthersville, Mo., the maximum net head on the levee (H) during the 1961 high water was 8.9 ft compared to 9.4 ft in 1950. The hydraulic grade line for the maximum 1961 river stage is shown in plate E2. Also shown in this plate are piezometric data at line C and along the toe of the berm (line D). The 1961 data indicated that piezometer 4 was sluggish as compared with piezometers 5 and 6 (see plate E1), and the riser of piezometer 3 was submerged during the crest of the 1961 high water; therefore, only piezometers 5 and 6 were used to determine s and x_3 at line A. Insufficient data precluded determination of the hydraulic grade line at line C.

13. The effective seepage entrance for the crest of the 1961 high water at line A was indicated to be 1100 ft from the landside toe of the levee, or just riverward of the abandoned riverside levee (see plate E2). In 1950 the computed source of seepage was 560 ft from the landside toe of the levee, or at about the deepest part of the riverside borrow pit. It is possible that since 1950 silting has occurred in the bottom of the riverside borrow pit, resulting in an increase in the distance to the effective seepage entrance (s). The value of x_3 computed for the 1961 high water was 480 ft, or about twice the value determined in 1950 (see fig. E3). The net head at the toe of the levee (h_o) in 1961 (1.8 ft) was about the same as that observed in 195' (2.0 ft).

Gammon, Ark.

14. At Gammon, Ark., line C was selected for determinations of s and x_3 for the 1961 high water. The hydraulic grade line at line C for the crest of the 1961 high water is shown in plate E4. Values of s and x_3 were determined graphically using data from piezometers C-3, -4, and -5 (see plate E3 for piezometer data). As seen in table

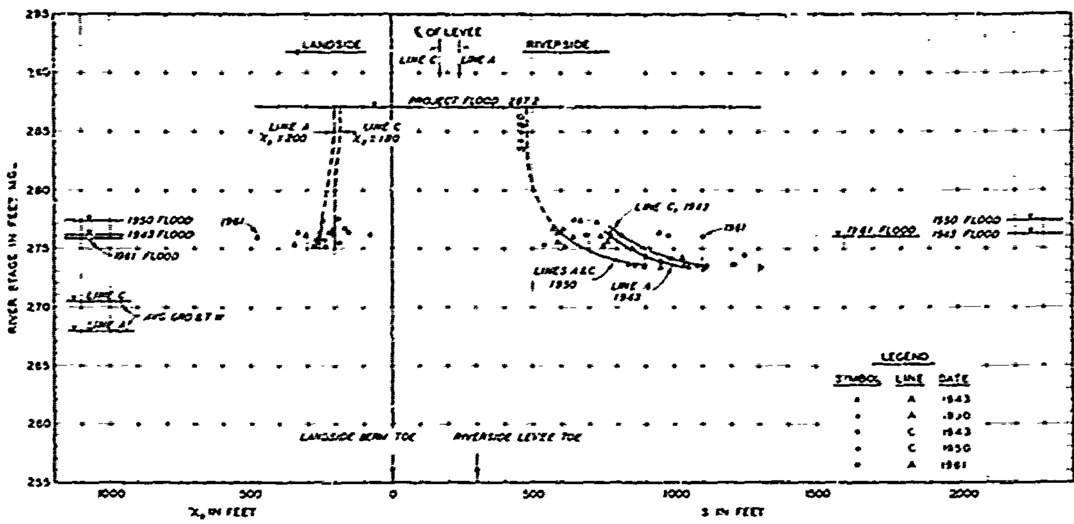


Fig. E3. Distance to effective seepage source and exit, Caruthersville, Mo.

E2 and fig. E4, the 1961 values of s and x_3 were in good agreement with those values determined in 1950, indicating that conditions at Gammon, Ark., have not changed since the 1950 high water. The net head on the levee (H) observed during the crest of the 1961 high water was 10.1 ft, as compared to an H of 11.9 ft observed in 1950. The head at the landside toe of the levee (h_o) was slightly less in 1961 than the head observed

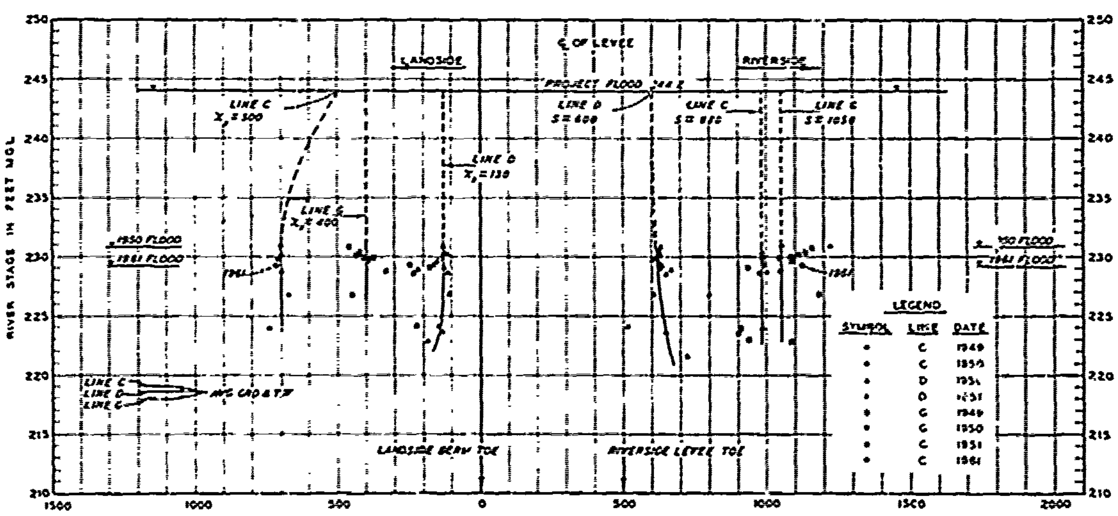


Fig. E4. Distance to effective seepage source and exit, Gammon, Ark.

during the 1950 high water (see table E2). The head at the toe (h_o) in percent net head (H) was about the same in 1961 as in 1950.

Commerce, Miss.

15. Piezometer line H was selected as representative of conditions at Commerce, Miss. As in previous high waters, piezometric data at Commerce indicated that the piezometric heads measured by piezometers with tips at greater depths in the sand aquifer were significantly greater than the head just beneath the topstratum (see plate E6). Values of s and x_3 for the 1961 high water were determined graphically using data from piezometers H-14Y, -11Z, and -7Y located at middepth of the aquifer (see fig. E5 for piezometer data). As seen in table E2 and fig. E5, the distance to the effective seepage entrance in 1961 was about 400 ft less than that determined during the 1950 high water. This decrease in distance may have resulted from erosion of the bottom of the riverside borrow pit since 1950.

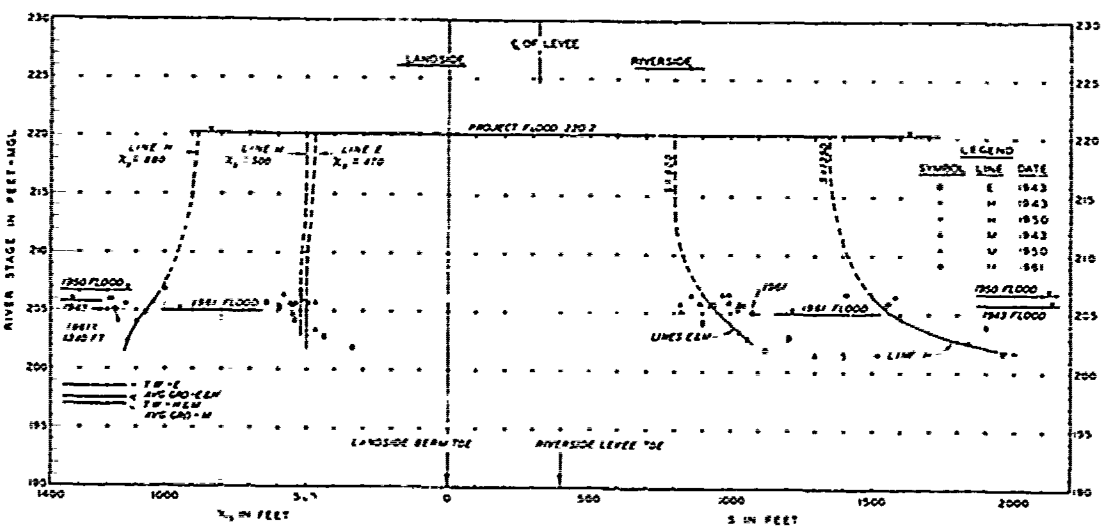


Fig. E5. Distance to effective seepage source and exit, Commerce, Miss.

16. At the crest of the 1961 high water, the net head on the levee at line H was 8.0 ft, as compared to a maximum net head of 9.2 ft observed in 1950. In 1961 the maximum head at the toe (h_c) was 2.2 ft, the same as that observed in 1950. In general, the piezometric heads observed landside of the levee in 1961 were about the same as those observed in 1950. In 1961 the average tailwater just landside of the levee was at

about elevation 197.0, or about 0.5 ft less than the tailwater observed in 1950. This slight difference in tailwater resulted in a greater value of x_3 computed for 1961 as compared to x_3 computed for the 1950 high water (see fig. E5).

Trotters 51. Miss.

17. Line H was selected for determining s and x_3. The hydraulic grade line at line H is shown in plate E8. As seen in this plate, the reading of piezometer 2-X was low as compared to adjacent piezometers. Piezometric data shown in plate E7 indicated that the piezometer was sluggish; therefore, values of s and x_3 were determined from piezometers 5-X and 4-X. As seen in fig. E6, the 1961 values of s and x_3 are considerably less than similar values determined from the 1950 data. It is considered that the decrease in s may be the result of changes in conditions of the riverside borrow pits. The net head on the levee during the 1961 high water was 6.4 ft, as compared to 9.0 ft observed in 1950. At the crest of the 1961 high water, h_o was 1.2 ft as compared to 3.0 ft in 1950.

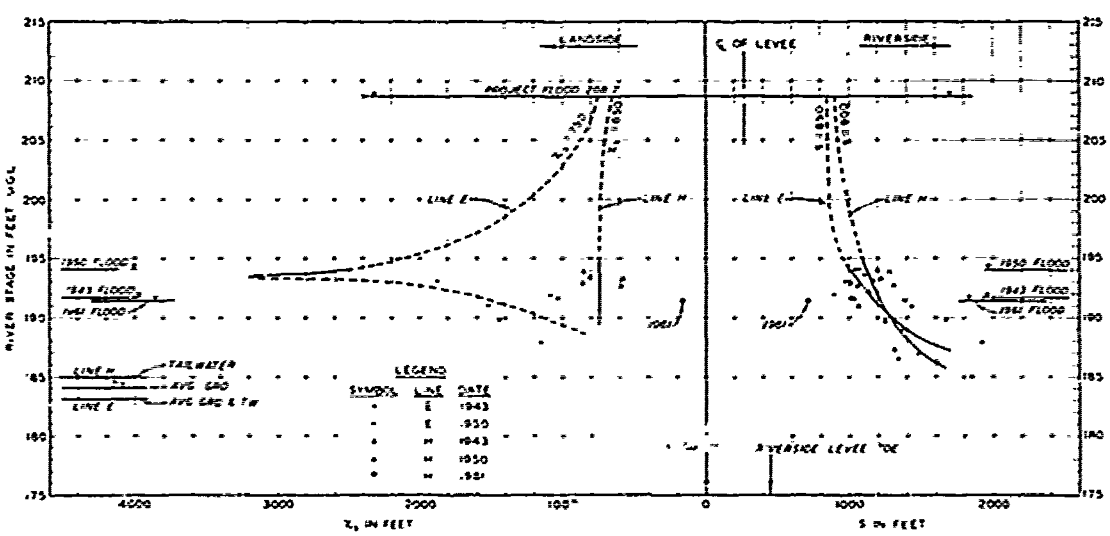


Fig. E6. Distance to effective seepage source and exit, Trotters 51, Miss.

Trotters 54. Miss.

18. The 1961 high-water data at Trotters 54, Miss., were previously analyzed and the results reported in WES TM 3-341, Control of Underseepage by Relief Wells, Trotters, Mississippi; Appendix G: Analysis of 1961 Well

Flow and Piezometric Data, July 1962. In the analysis of the data, values of s were computed for rising river stages at the three piezometer lines (lines M, R, and Q) perpendicular to the levee. The 1961 piezometer observations at Trotters are [illegible]wn in plate E9; hy[illegible]raulic grade lines for various river stages at line [illegible] shown in plate E10. The average values of s for the three pi[illegible] lines are plotted vs river stage in fig. E7, together with sim[illegible] for previous high-water periods. In

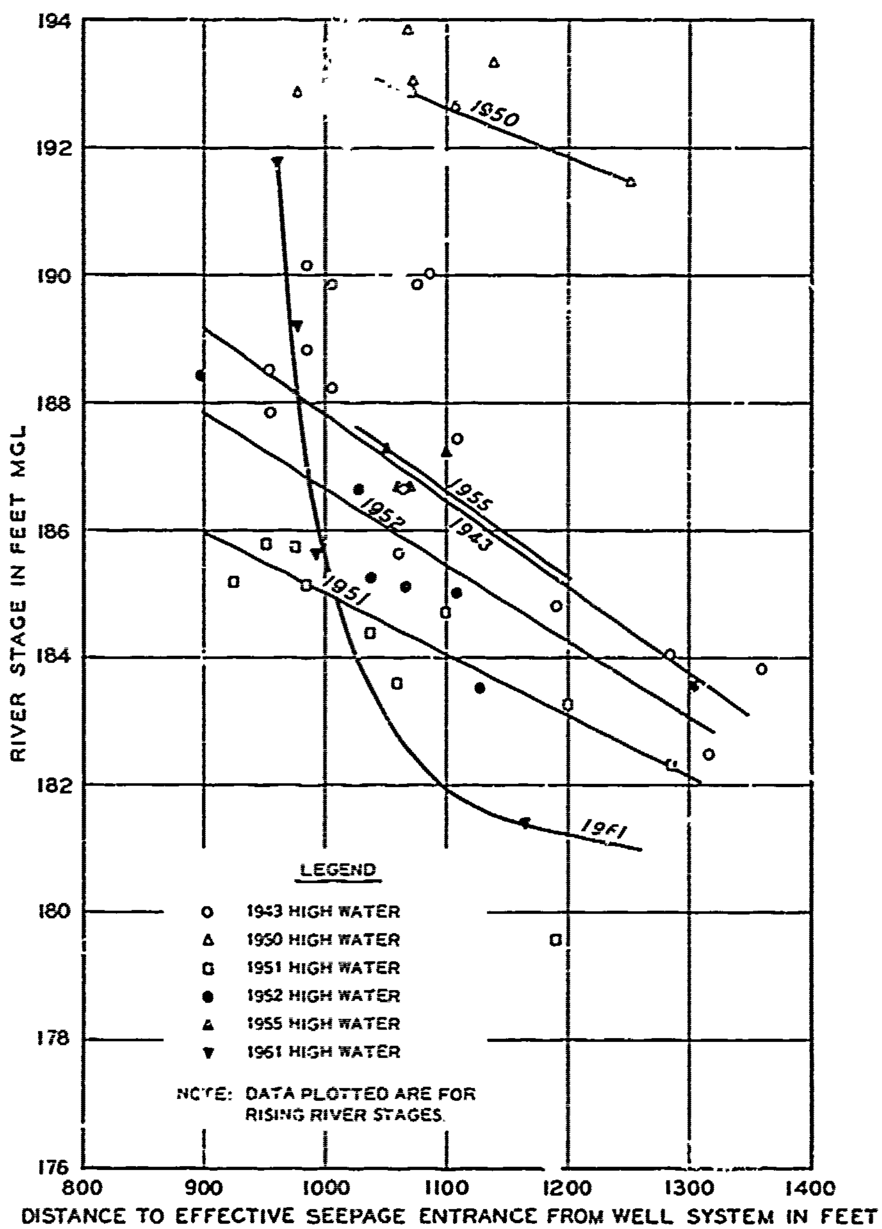


Fig. E7. Distance to effective seepage source, Trotters 54, Miss.

1961, s decreased with increasing river stages, but at a much slower rate than for previous high waters. The 1961 data indicated that s probably would not be less than the value of 900 ft selected for design of the well system.

19. The maximum net head on the levee (H) observed in 1961 was 12.9 ft as compared to 13.8 ft observed in 1950. In 1950, piezometers were read when the relief well system was opened and when it was closed; in 1961 the wells remained open during the entire high water. The computed values of x_3 and observed h_o in 1961 were therefore smaller than those values obtained with wells closed in the 1950 high water (see table E2). The ratio of h_o/H was 11 percent in 1961 as compared to 22 percent in 1950.

Stovall, Miss.

20. At Stovall, Miss., line B was selected for determining s and x_3. Data from selected piezometers at Stovall are shown in plate E11; the hydraulic grade line at line B for the 1961 high water is shown in plate E12. During the 1961 high water the readings of piezometer E-13 were lower than readings of adjacent piezometers and the riser of piezometer E-12 was clogged. Values of s and x_3 were determined from readings of piezometers E-11 and -15. As shown in fig. E8 and table E2, values of s and x_3 determined in 1961 were in good agreement with those values determined for the 1950 high water, indicating that conditions at

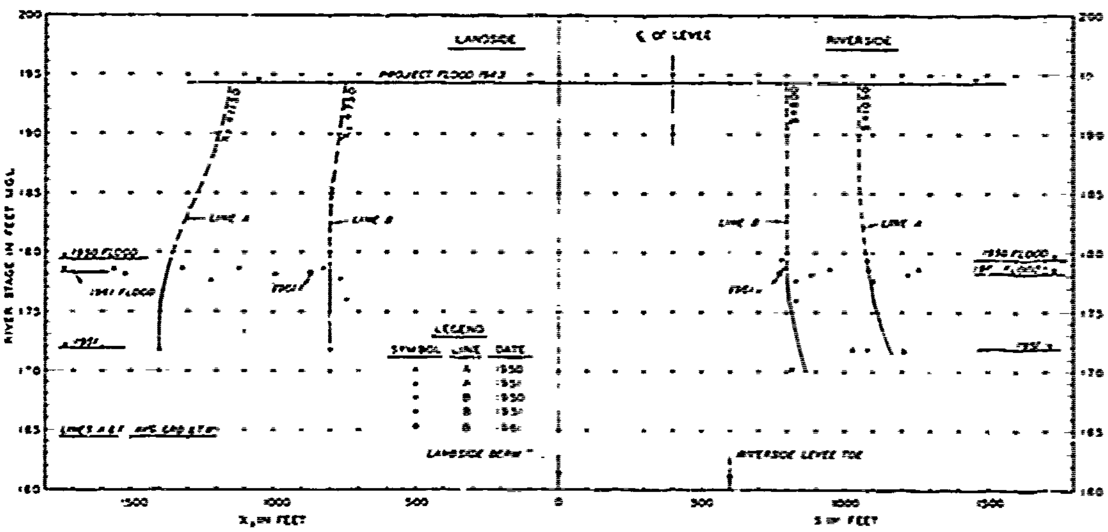


Fig. E8. Distance to effective seepage source and exit, Stovall, Miss.

Stovall have not changed appreciably since the 1950 high water. The maximum net head on the levee (H) observed at line B in 1961 was 14.3 ft, as compared to a maximum net head of 14.9 ft observed in 1950. The observed excess head at the toe of the berm (h_o) in 1961 (5.6 ft) was only slightly less than the head observed in 1950 (6.0 ft).

<u>Farrell, Miss.</u>

21. At Farrell, Miss., only one piezometer line (line A) was installed perpendicular to the levee. At line A, piezometers were installed immediately below the topstratum and also just below a clay seam about 25 ft below ground surface (see plate E14). In the analysis of 1950 high-water data, the sand stratum above the clay seam was designated the "upper aquifer," and the sand stratum below the clay seam was designated the "lower aquifer." The maximum net head on the levee in 1961 was 3.4 ft, which was one-half the maximum net head observed in 1950. Data from selected piezometers at Farrell are shown in plate E13. During the 1961 high water, the piezometers just below the topstratum were dry, indicating that no seepage occurred in the upper aquifer. The hydraulic grade line indicated by piezometers in the lower aquifer is shown in plate E14. The value of s computed from this grade line was 970 ft (see fig. E9). As seen in fig. E9, the latter value was in good agreement with the value of s (860 ft) computed for the 1950 high water. In 1961 the hydraulic grade line intersected the average ground

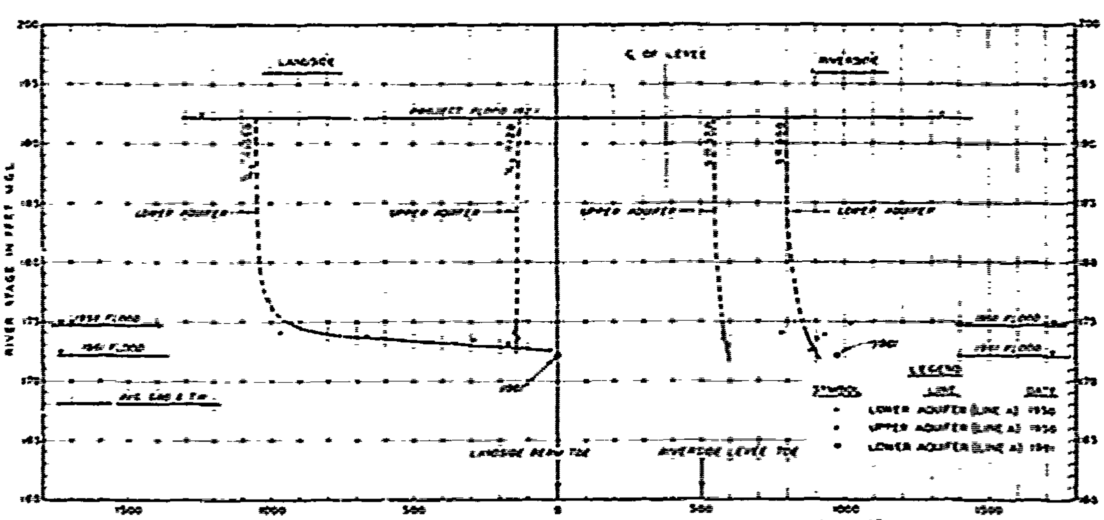


Fig. E9. Distance to effective seepage source and exit, Farrell, Miss.

surface at about the landside berm toe, indicating a value of zero for x_3. This would verify the trend observed during the 1950 high water (see plot of x_3 vs river stage, fig. E9).

Upper Francis, Miss.

22. Piezometer line B was considered typical of conditions at Upper Francis, Miss. The hydraulic grade line at the maximum 1961 river stage at line B is shown in plate E16. As seen in this plate, piezometer B-1 indicated a low reading and was probably not functioning properly. Values of s and x_3 were determined graphically from piezometers B-2, -3, and -4 (see plate E15 for piezometer data). As seen in fig. E10, the 1961 values of s were in good agreement with values obtained for the 1950 high water. During the 1961 high water, there was no excess head at the toe of the levee where the ground surface is at about elevation 161; however, piezometer data indicate that excess head of from 1 to 2 ft did exist landward of the levee where the ground surface is below elevation 160. In the analysis of the 1950 high water, values of x_3 were computed on the assumption that the average ground surface landward of the levee was at elevation 160. Using this same assumption, a value of 50 ft was computed for x_3 for the maximum 1961 river stage. Although this value is very small, it verifies the trend of increasing values of x_3 with rising river stages observed for the 1950 high water (see plot of x_3 vs river stage in fig. E10).

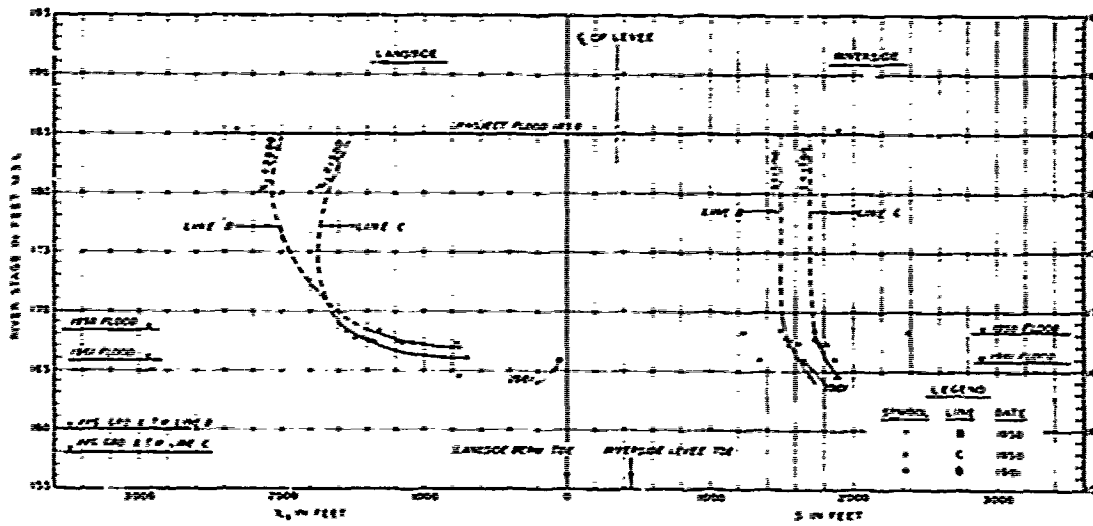


Fig. E10. Distance to effective seepage source and exit, Upper Francis, Miss.

Lower Francis, Miss.

23. Line C was selected for determining values of s and x_3 for Lower Francis, Miss. The hydraulic grade line at the crest of the 1961 high water at line C is shown in plate E18. Also shown is the hydraulic grade line at line E and the piezometric head along the levee toe (line H). The maximum net head on the levee in 1961 was 9.6 ft as compared to a net head of 13.6 observed in 1950. The excess head at the toe of the berm as measured by piezometer C-7 in 1961 was 1.5 ft as compared to an excess head of 1.7 ft observed in 1950. Values of s and x_3 were computed for the 1961 data using piezometers C-4 and -6 (see plate E17 for piezometer data). As seen in fig. E11, the 1961 values of s and x_3 were in good agreement with values determined in 1950, indicating that seepage conditions at Upper Francis have not changed since 1950.

Bolivar, Miss.

24. Piezometer line D was considered representative of conditions at Bolivar, Miss. The hydraulic grade line at line D for the maximum 1961 river stage is shown in plate E20. The tip of piezometer D-1 was apparently clogged, and values of s and x_3 were determined using data from piezometers D-2 and -3 (see plate E19 for piezometer data). The value of s in 1961 as shown in fig. E12 is in good agreement with values determined for the 1950 high water. At Bolivar, there are borrow pits directly behind the landside toe of the levee. During the 1961 high water, the water

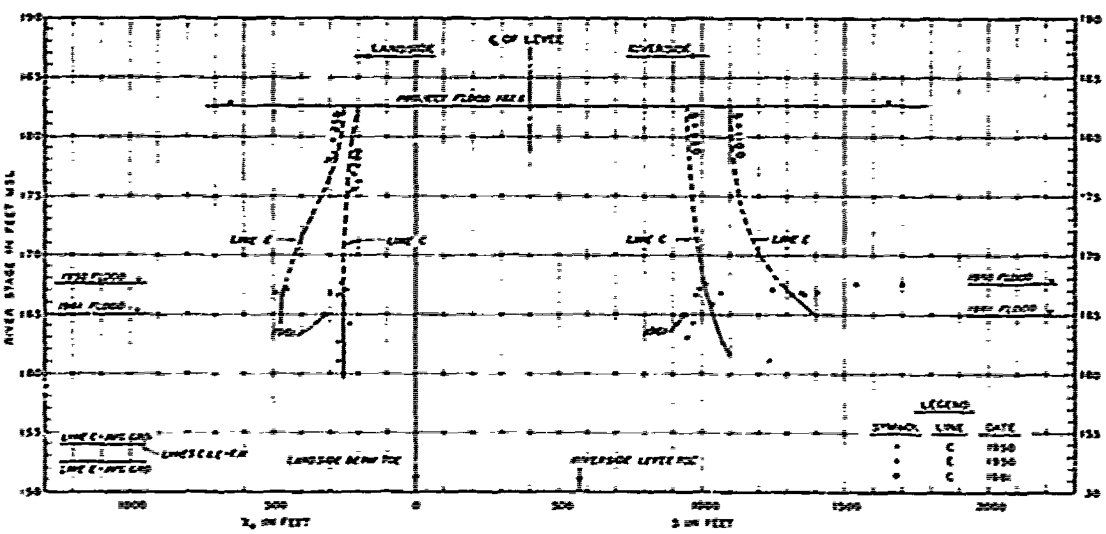


Fig. E11. Distance to effective seepage source and exit, Lower Francis, Miss.

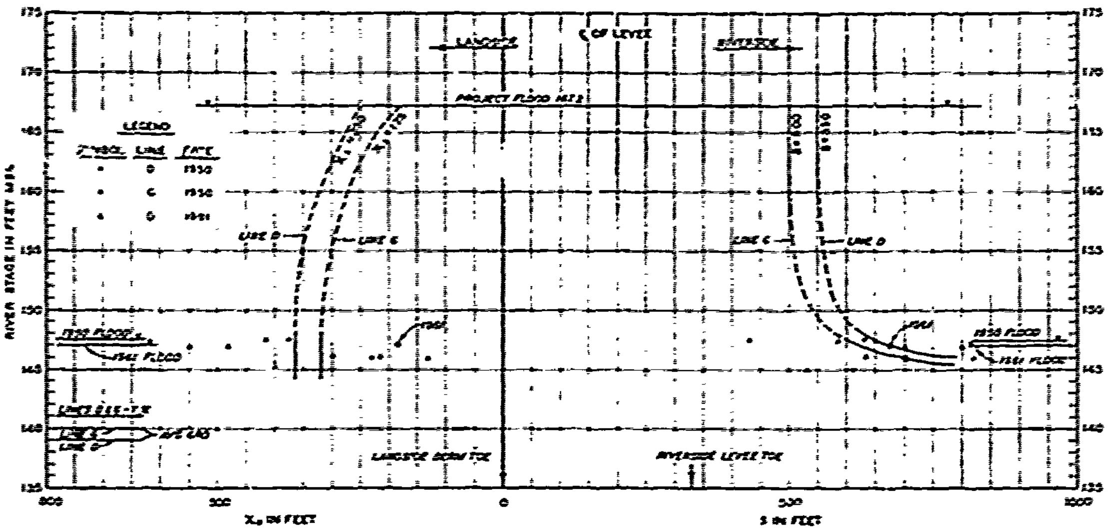


Fig. E12. Distance to effective seepage source and exit, Bolivar, Miss.

surface in these borrow pits (tailwater) was not recorded when the piezometers were read; therefore, it is not possible to accurately compute 1961 values for x_3 and h_o. During the 1950 flood, the water surface in these borrow pits was at about elevation 141. Assuming that the tailwater was at this same elevation during the 1961 high water, the maximum net head on the levee in 1961 would have been 6.0 ft as compared to 6.8 ft in 1950. The 1961 value of x_3 computed on this assumption was 185 ft. This value is somewhat smaller than values determined for the 1950 high water. However, considering the scatter of data obtained for the 1950 high water, the 1961 values of x_3 appear to compare reasonably with 1950 values (see plot of x_3 vs river stage, fig. E12).

Eutaw, Miss.

25. Only one line of piezometers, line D, was installed perpendicular to the center line of the levee at Eutaw. Piezometers were installed in the silty sand stratum beneath the clay topstratum and in the deeper underlying sand. In 1961, as well as in 1950, the piezometric heads in the deep sand, as shown in plate E22, were somewhat greater than the head in the silty sand stratum. At the maximum 1961 river stage, the heads in the deep sand were from 3 to 6 ft greater than the heads in the silty sand stratum.

26. Values of s and x_3 for the 1961 high water were computed graphically from readings of piezometers D-1, -2, -4, -7, and -10 (see plate E21). As seen in fig. E13 the 1961 values of s were in good

agreement with values computed for the 1950 high water. As the water level in the borrow pits behind the landside toe of the levee berm was not recorded during the 1961 high water, an accurate estimate of x_3 could not be determined for the 1961 high-water data. In the analysis of the 1950 high-water data it was assumed that the average ground surface and tailwater landside of the levee were at elevation 135. Based on this same assumption, the maximum net head on the levee in 1961 was 5.8 ft as compared to 6.2 ft observed in 1950; h_o in 1961 was 2.0 ft as compared to 6.0 ft in 1950, and the computed x_3 in 1961 was 260 ft. The latter value is considerably less than x_3 values for the 1950 high water (see fig. E13).

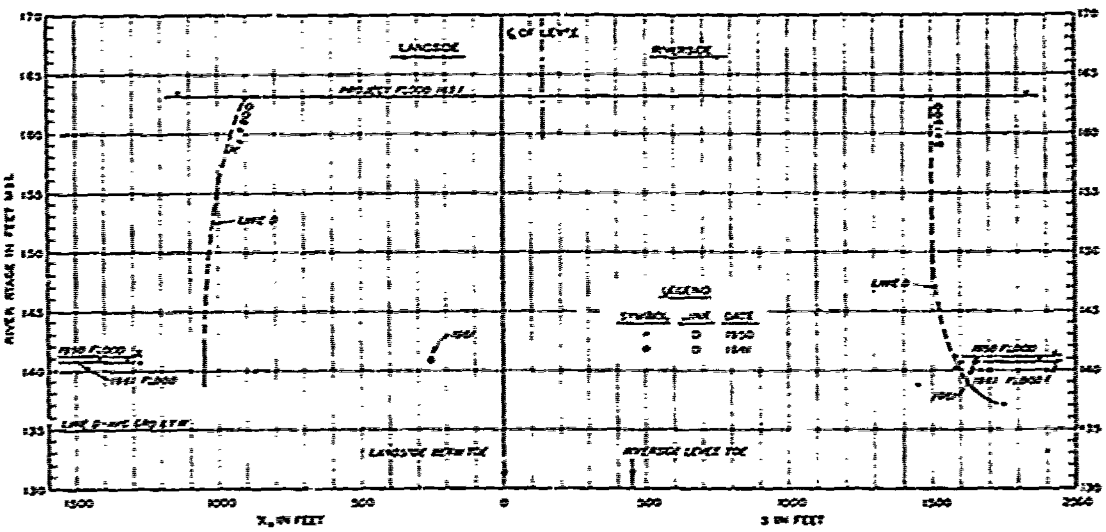


Fig. E13. Distance to effective seepage source and exit, Eutaw, Miss.

L'Argent, La.

27. Only one piezometer line, line B, was installed perpendicular to the levee. Piezometer observations at line B, as shown in plate E23, were insufficient to establish an accurate hydraulic grade line. Further, as shown in plate E24, readings of piezometers B-1 and -3 were evidently in error. Piezometer B-1 indicated a reading at the same elevation as the river stage; this would mean, if correct, seepage entrance at the riverside toe of the levee. Piezometer B-3 indicated a piezometric head greater than the head at the toe of the levee. Because of the erratic data at L'Argent, s and x_3 were not computed. It is recommended that all

piezometers along line B be flushed and pumped before the next high water.

Hole-in-the-Wall, La.

28. Piezometer line B was considered representative of conditions at Hole-in-the-Wall, La. The hydraulic grade line at line B is shown in plate E26. At line B the risers of piezometers B-1 and -2 were submerged during the crest of the 1961 high water; therefore, only piezometers B-3, -4, -5, and -6 were used to determine the source of seepage entrance (see plate E25 for piezometer data). The values of s computed in 1961 were considerably greater than the values computed for the 1950 high water (see fig. E14). At the crest of the 1961 high water, the net head on the levee was only 5.4 ft. As seen in plate E26, no excess head developed landward of the levee during the 1961 high water, and therefore it is considered that artesian flow did not exist. Consequently, the values of s determined for 1961 probably are unreliable.

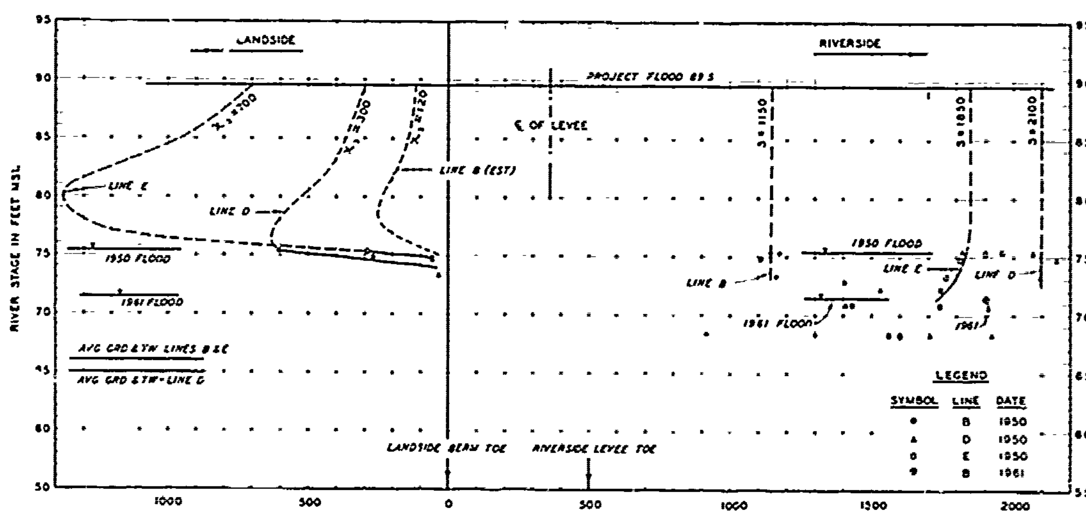


Fig. E14. Distance to effective seepage scurce and exit, Hole-in-the-Wall, La.

Kelson, La.

29. At Kelson, La., a line of piezometers (line B) was installed beneath the levee to determine the hydrostatic pressures in the sandy silt stratum directly beneath the levee. The silty sand stratum is underlain by a thick stratum of clay and a stratum of silt, which in turn is underlain by pervious sand. The hydraulic grade line in the silty sand

stratum at the crest of the 1961 flood is shown in plate E28. From the piezometer data shown in plate E27, it appears that piezometer A-1 was not functioning properly and values of s were determined from piezometers A-2, -3, and -4. ⌐ › value of s computed for 1961 is 240 ft, which agrees well with th values computed for the 1950 high water (see fig. E15) indicating that seepage continues to enter the silt stratum in the bottom of the borrow pit adjacent to the levee. There was no excess head landward of the levee during the 1961 high water; therefore, there is no value of x_3 shown in fig. E15.

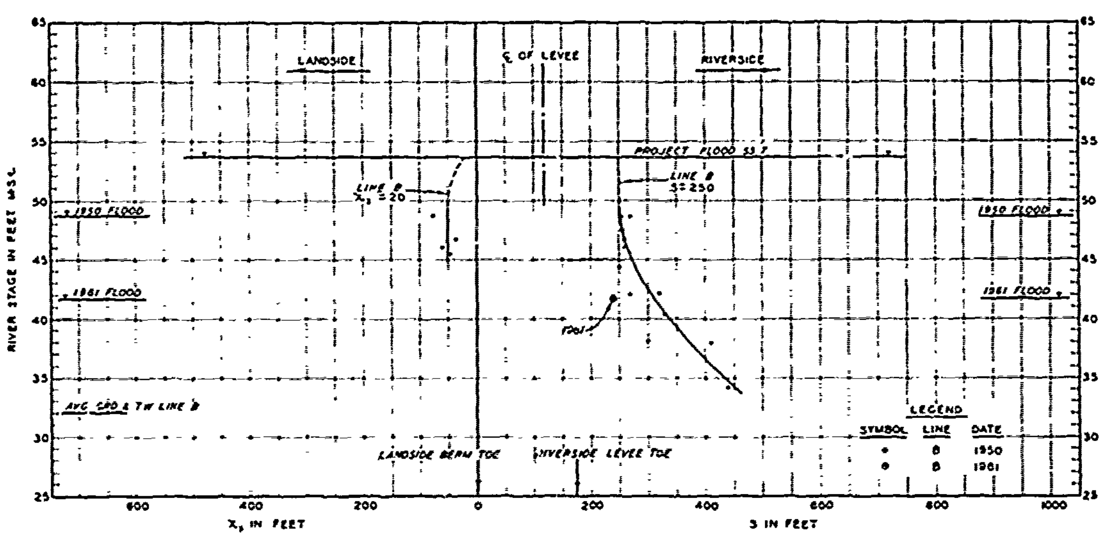


Fig. E15. Distance to effective seepage sourc2 and exit, Kelson, La.

Baton Rouge, La.

30. Piezometer line C was considered representative of conditions at Baton Rouge, La. The hydraulic grade line at the crest of the 1961 high water is shown in plate E30. The 1961 data indicated a very flat hydraulic grade line, as did the 1950 data. Values of s and x_3 were determined graphically from the readings of piezometers P-21B, P-21C, P-45, and P-24 (see plate E29 for piezometer data). The 1961 value of s was considerably higher than the s computed for the 1950 high water at the same river stage. However, because of the flat hydraulic grade line the computed values of s for 1961 may not be accurate. The 1961 value of x_3 was in good agreement with

values of x_3 computed for the 1950 high water, as shown in fig. E16.

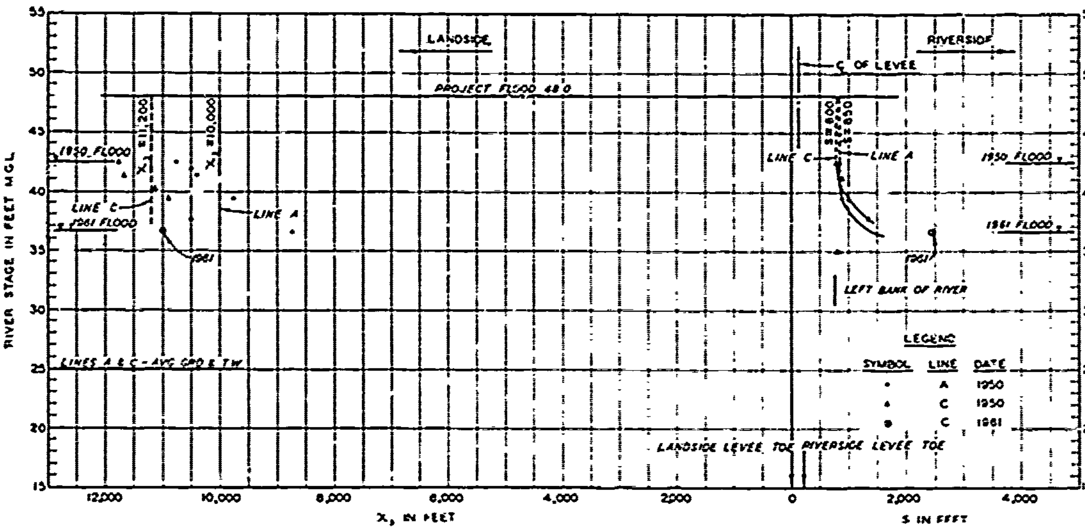


Fig. E16. Distance to effective seepage source and exit, Baton Rouge, La.

Conclusions and Recommendations

Conclusions

31. The following conclusions are based on the data and studies presented in this report:

a. The 1961 high water, which was the second major high water to have occurred at the majority of the piezometer sites since the piezometers were installed resulted in net heads on the levee only slightly lower than those produced in the 1950 high water. The difference between the maximum net heads for the 1950 and 1961 high waters varied from 0.4 ft at Eutaw, Miss., to 7.1 ft at Kelson, La. No indications of excessive seepage or sand boils were reported for the 1961 high water.

b. With some exceptions, the distances to the effective source of seepage entry (s) in 1961 were generally in the same order of magnitude as those determined in 1950. At Caruthersville the distance increased by a factor of about 2, and at Baton Rouge the distance increased by a factor of 3; however, because of the flat hydraulic grade line at the latter site, the value of s computed for the 1961 high water may not be accurate. At Hole-in-the-Wall the value of s increased by a factor of 1.7; however, as a truly artesian flow did not exist beneath the levee in 1961, the value of s determined for 1961 was probably unreliable. At Commerce and Trotters 51 substantial reductions in the value of s were noted and these reductions are probably due to increased scour in riverside borrow pits.

c. Except at a few sites, the distances to the effective exit computed for the 1961 high water did not agree closely with values computed for the 1950 high-water data. The lack of agreement is attributed to faulty piezometers, uncertain tailwater elevations, and variations inherent in procedural technique which, as pointed out in the main report, may result in errors of as much as 20 percent.

d. The maximum excess hydrostatic head at the toe of the levee or berm in 1961, expressed as a percentage of the net head acting on the levee, was generally about equal to or less than that observed in 1950.

Recommendations

32. It is recommended that:

a. The existing piezometer systems be maintained and observed during significant high waters and the data analyzed as they become available.

b. Faulty piezometers listed in table E1 be renovated or replaced and the risers of those piezometers which were submerged in the 1961 high water be extended so that the piezometers can be read during the next major high water.

c. During the next major high water, the elevation of the tailwater (water in ditches behind the levee) be recorded at the same time that piezometers are read.

Table E1

Piezometers Functioning Improperly or Submerged During 1961 High Water

Site	Piezometers Functioning Improperly	Piezometers with Risers Flooded
Caruthersville, Mo.	4	3
Trotters 51, Miss.	H-2X	--
Stovall, Miss.	E-12, E-13	D-10
Upper Francis, Miss.	B-1	--
Bolivar, Miss.	D-1	--
Hole-in-the-Wall, La.	--	B-1, B-2
Kelson, La.	A-1	--

Table E2

Summary of 1950 and 1961 High-Water Data at Piezometer Sites

Site	Station	Line	H, ft Project Flood	H, ft 1950	H, ft 1961	s, ft Project Flood	s, ft 1950	s, ft 1961	x_3, ft Project Flood	x_3, ft 1950	x_3, ft 1961	h_o, ft Project Flood	h_o, ft 1950	h_o, ft 1961	h_o/H % 1950	h_o/H % 1961
Caruthersville	26/0+00	A	19.2	9.4	8.9	480	560	1100	200	240	480	3.2	2.0	1.8	21	21
Gammon	138/26+00	C	25.2	11.9	10.1	980	980	1120	500	700	720	3.3	3.3	2.7	28	27
Commerce	23/10+75	H	22.7	9.2	8.0	1350	1500	1090	880	1,000	1,340	3.2	2.2	2.2	25	27
Trotters 51	52/22+00	H	23.7	9.0	6.4	900	1100	710	650	735	170	6.0	3.0	1.2	33	19
Trotters 54	54/1+05	M	27.7	13.8	12.9	950	1050	925	650	770	---	3.0	3.0	1.4*	22	11*
Stovall	77/38+00	B	29.8	14.9	14.3	800	800	675	750	800	870	9.8	6.0	5.6	44	39
Farrell	81/24+00	A**	24.1	6.8	3.4	550	580	--	120	140	---	2.4	2.4	---	28	--
		A†	24.1	6.8	3.4	800	860	970	1,000	1,050	0	17.5	6.2	0	72	0
Upper Francis	39+00	B	25.0	8.3	5.8	1500	1520	1640	2,000	1,400	50	15.3	1.5	0	21	0
Lower Francis	130+00	C	28.6	13.6	9.0	950	1010	935	200	250	320	3.8	1.7	1.5	13	17
Bolivar	2199+75	D	26.2	6.5	6.0	550	650	675	250	365	185	4.2	2.4	1.3	37	22
Eutaw	2860+00	D	28.1	6.2	5.8	1500	1600	1650	900	1,050	260	11.0	6.0	2.0	65	35
L'Argent	3542+33	B	31.0	16.4	13.4	3000	3150	††	4,200	3,000	††	14.9	14.9	††	35	--
Hole-in-the-Wall	3618+95	D	23.5	9.4	5.4	1150	1150	1900	120	0	0	1.9	1.2	0	13	0
Kelson	2700+71	B	21.7	16.7	9.6	250	250	240	20	50	0	8.9	4.6	0	28	0
Baton Rouge	94+42	C	23.0	17.4	11.6	800	800	2450	11,200	11,200	11,000	15.2	13.4	8.4	73	72

* With relief wells on 50-ft centers flowing.
** Upper aquifer
† Lower aquifer.
†† Insufficient data for computations.

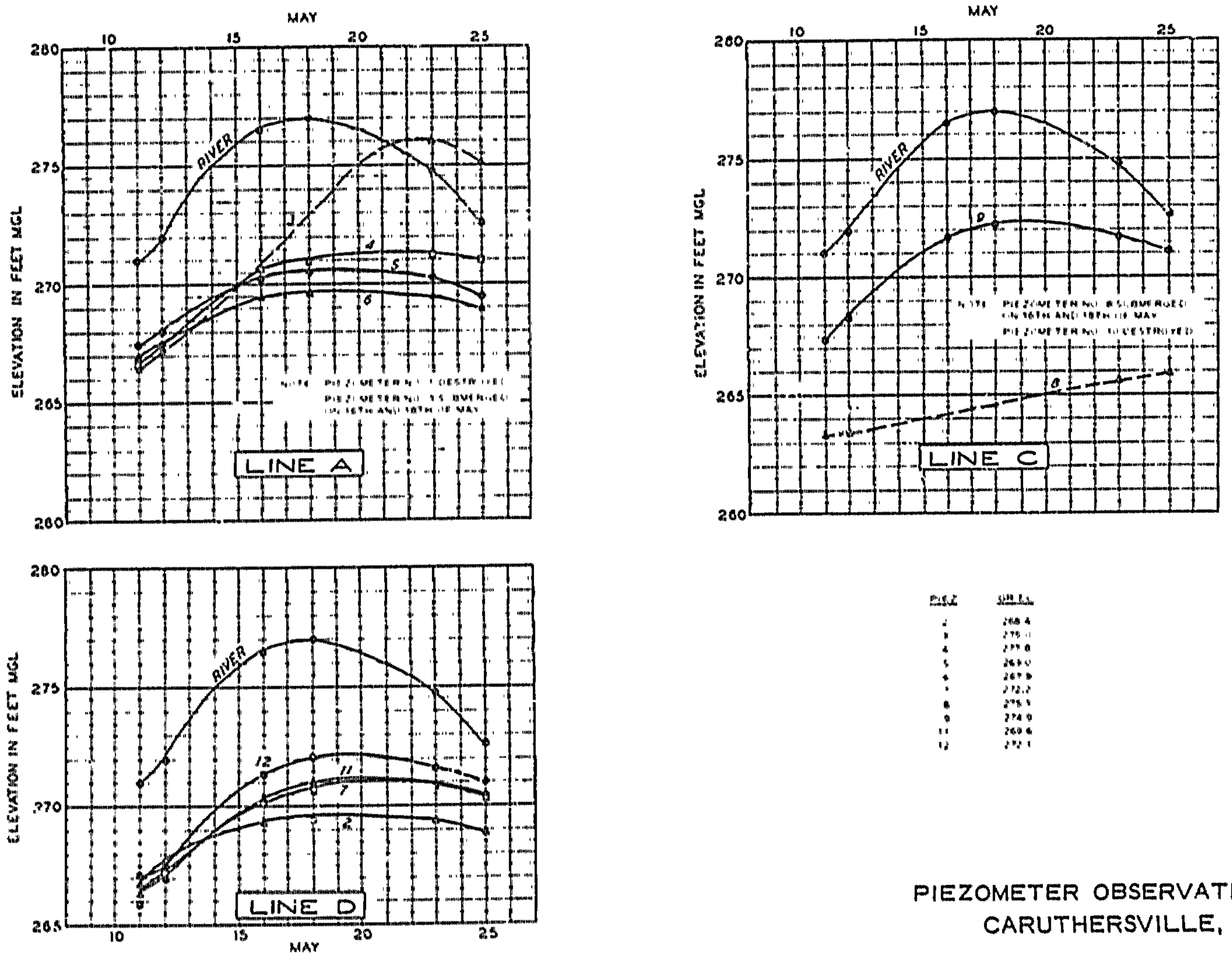
Table E3

Comparison Between Elevations of Project Flood Flow Line in Main Report and Present (1956) Project Flood Flow Line for Lower Mississippi River Levees

Piezometer Site	Station	Project Flood, El*	
		Prior to 1956**	1956
Caruthersville, Mo.	26/0+00	(287.2)	(283.8)
Gammon, Ark.	138/26+00	(244.2)	(342.5)
Commerce, Miss.	23/10+75	(220.2)	(218.9)
Trotters 51, Miss.	52/22+00	(208.7)	(206.4)
Trotters 54, Miss.	54/1+05	(207.7)	(206.1)
Stovall, Miss.	77/38+00	(194.3)	(190.7)
Farrell, Miss.	81/24+00	(192.1)	(187.1)
Upper Francis, Miss.	39+00	185.0	182.2
Lower Francis, Miss.	130+00	182.6	181.3
Bolivar, Miss.	2199+75	167.2	163.7
Eutaw, Miss.	2860+00	161.1	157.6
L'Argent, La.	3542+33	90.0	86.6
Hole-in-the-Wall, La.	3618+95	89.5	86.1
Kelson, La.	2700+71	53.7	50.6
Baton Rouge, La.	94+42	48.0	45.2

* Elevations in parentheses are in ft mgl; all other elevations are in ft msl.

** Shown in main report.



PIEZOMETER OBSERVATIONS, 1961
CARUTHERSVILLE, MO.

PLATE E1

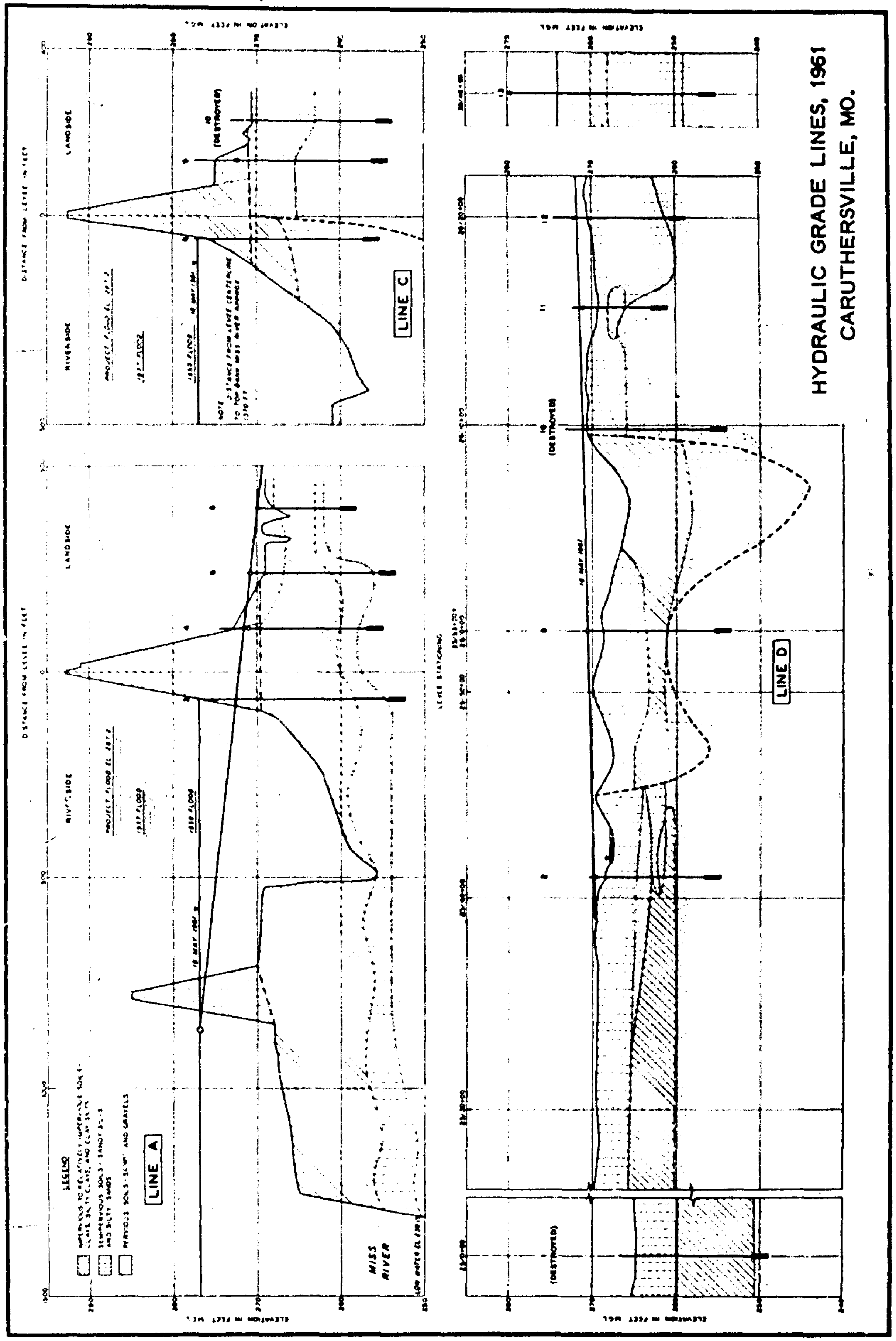
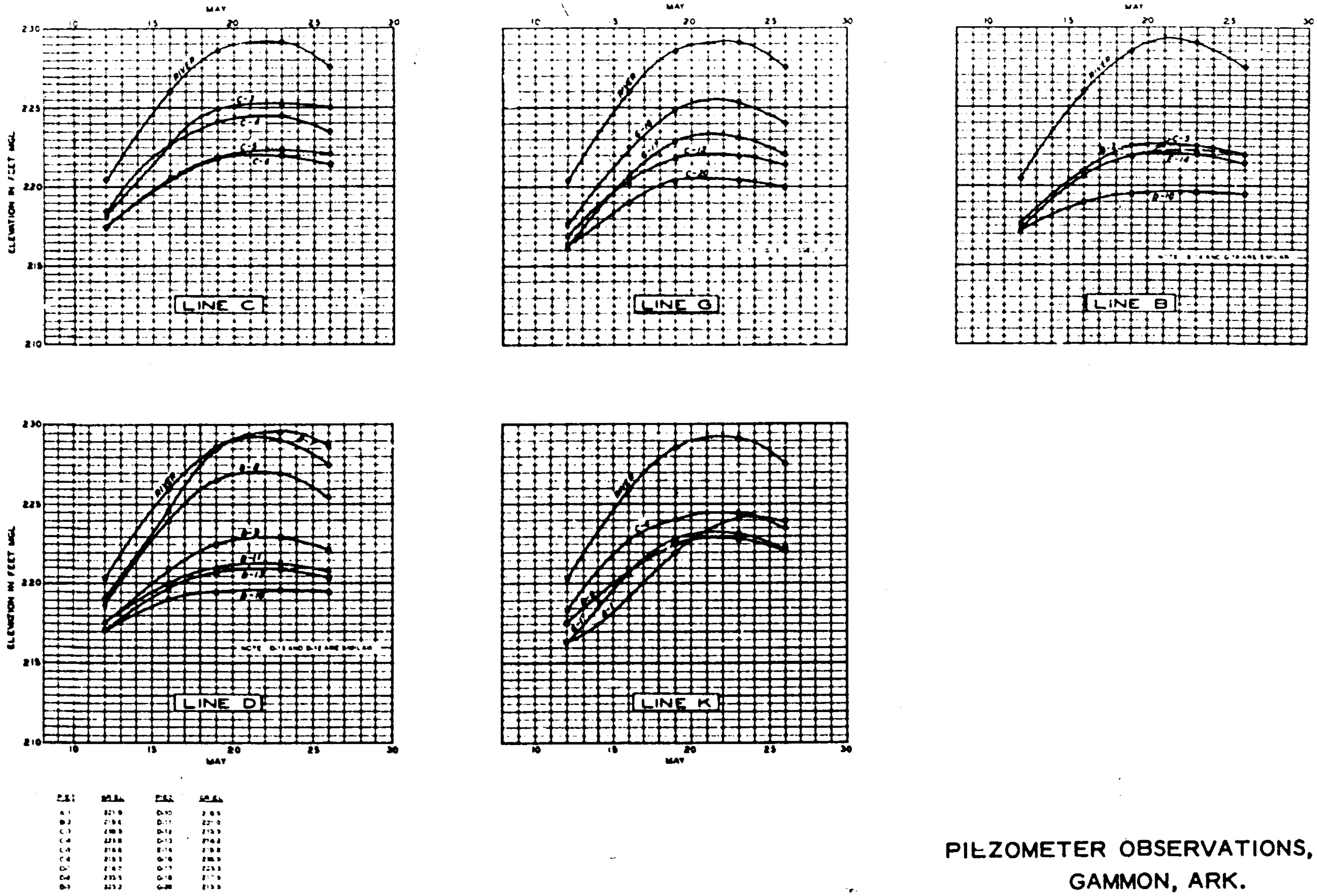
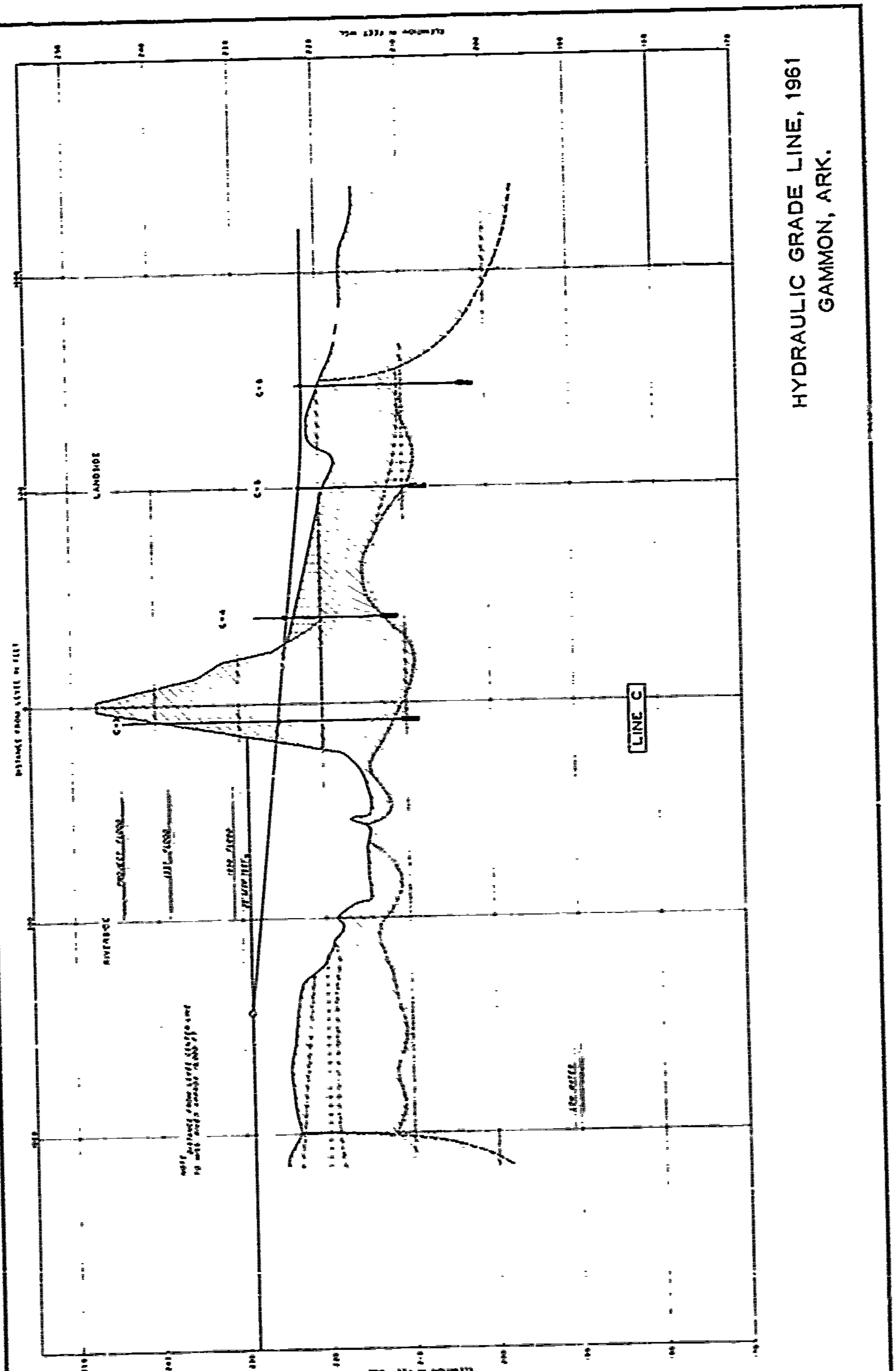

HYDRAULIC GRADE LINES, 1961
CARUTHERSVILLE, MO.
LINE A
LINE C
LINE D
LEGEND
RIVERSIDE
LANDSIDE
MISS RIVER
10 (DESTROYED)

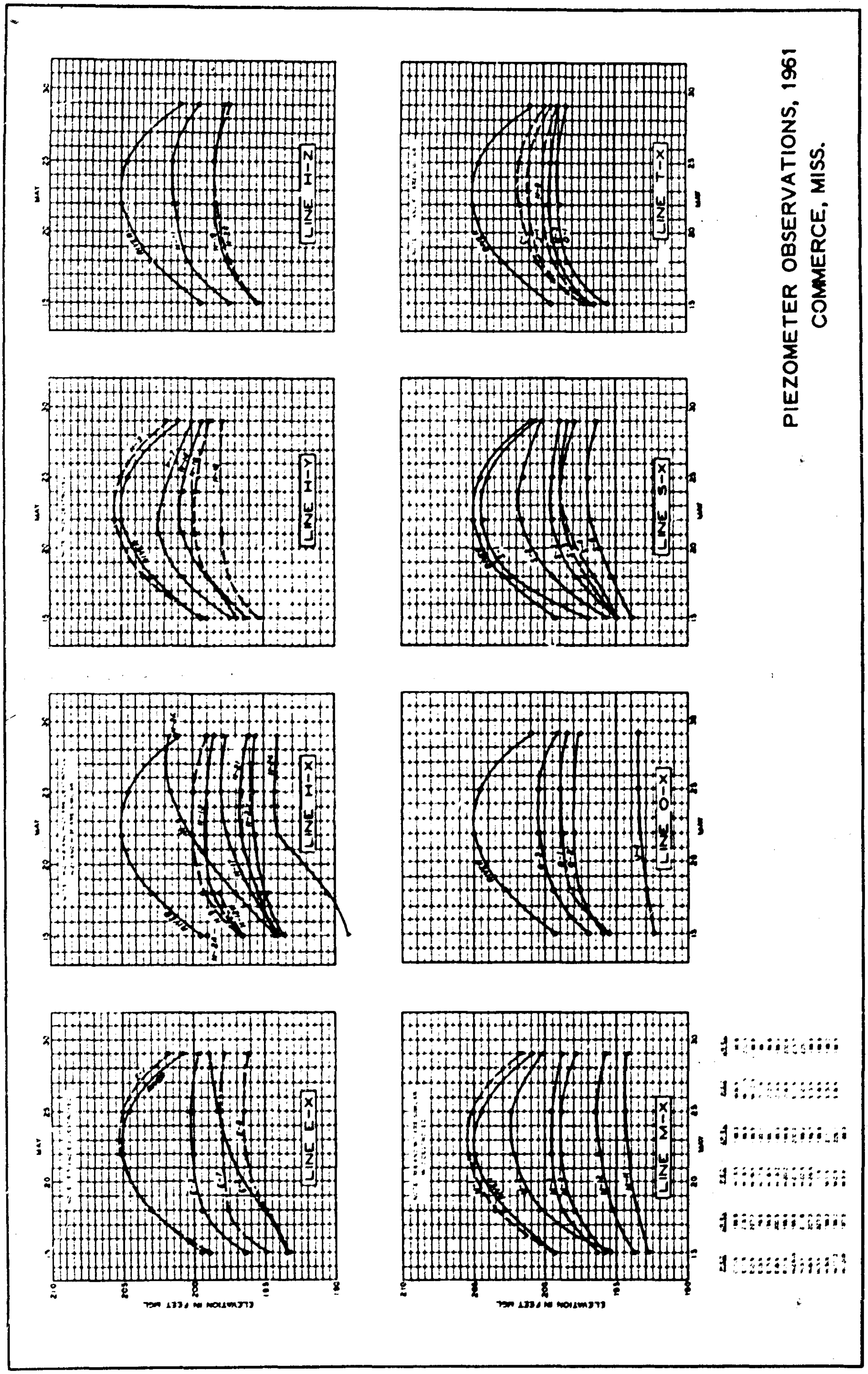
PLATE E2



PIEZOMETER OBSERVATIONS, 1961
GAMMON, ARK.



HYDRAULIC GRADE LINE, 1961
GAMMON, ARK.



PIEZOMETER OBSERVATIONS, 1961
COMMERCE, MISS.

PLATE E5

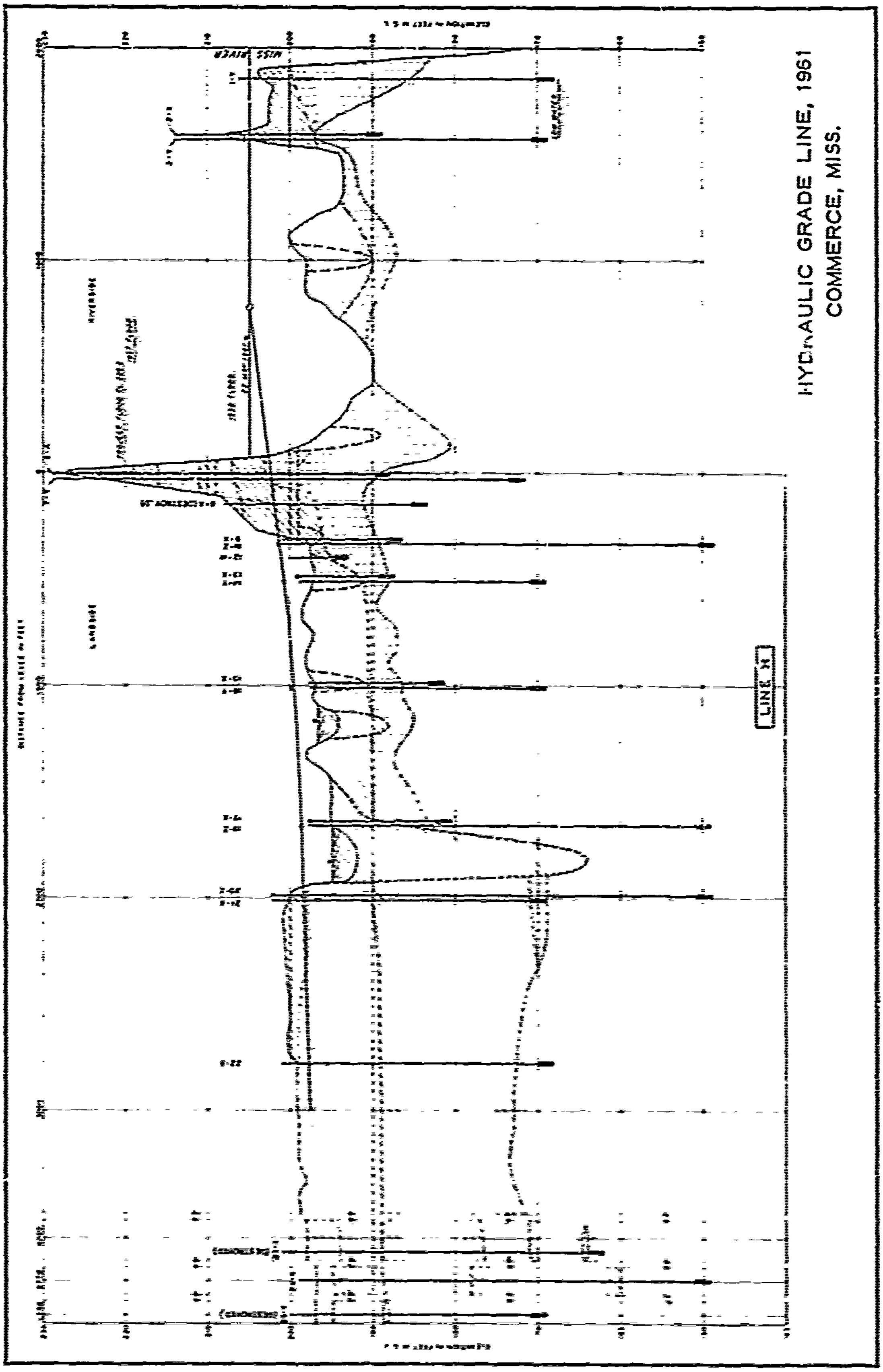
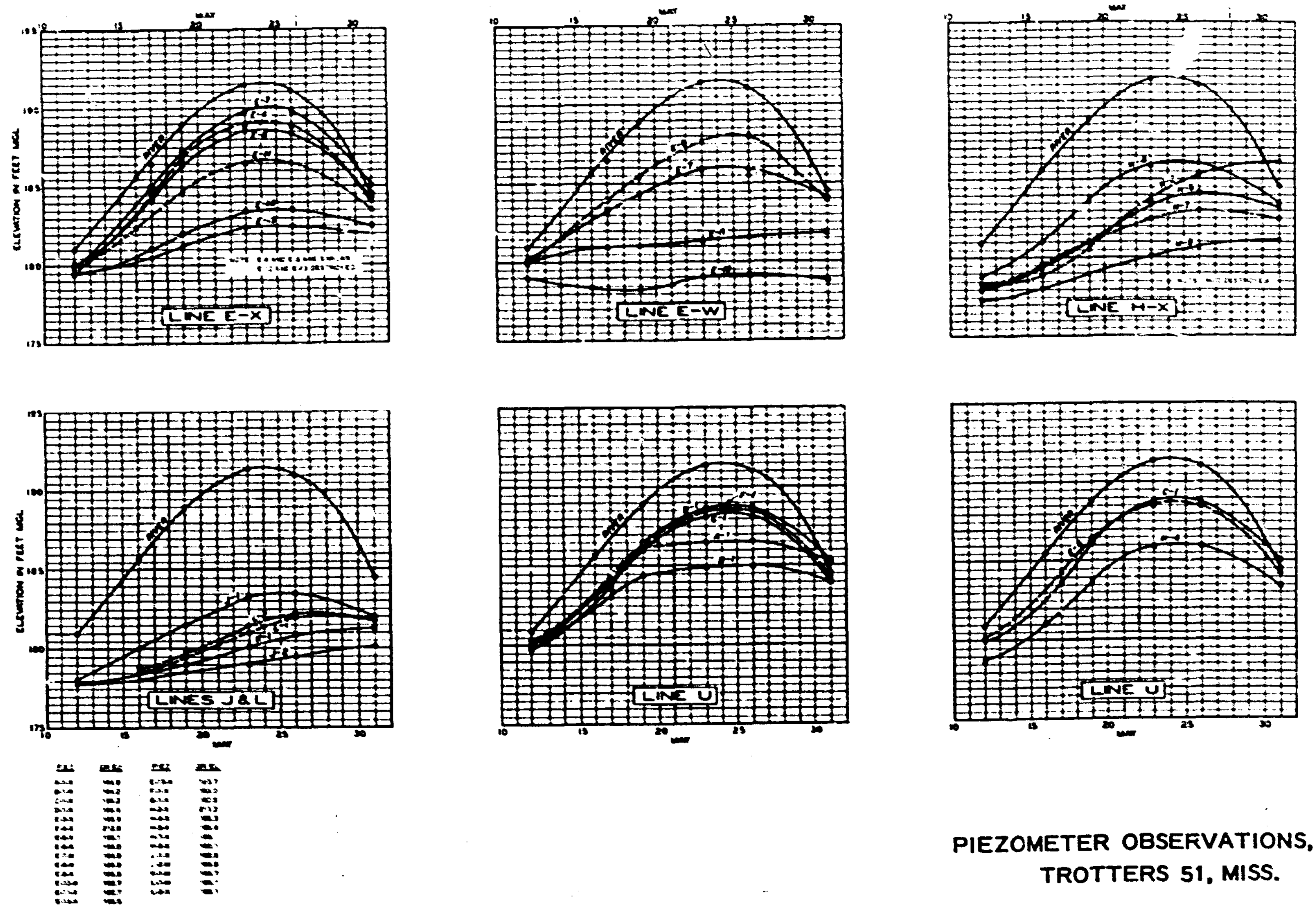


PLATE E6



PIEZOMETER OBSERVATIONS, 1961
TROTTERS 51, MISS.

PLATE E7

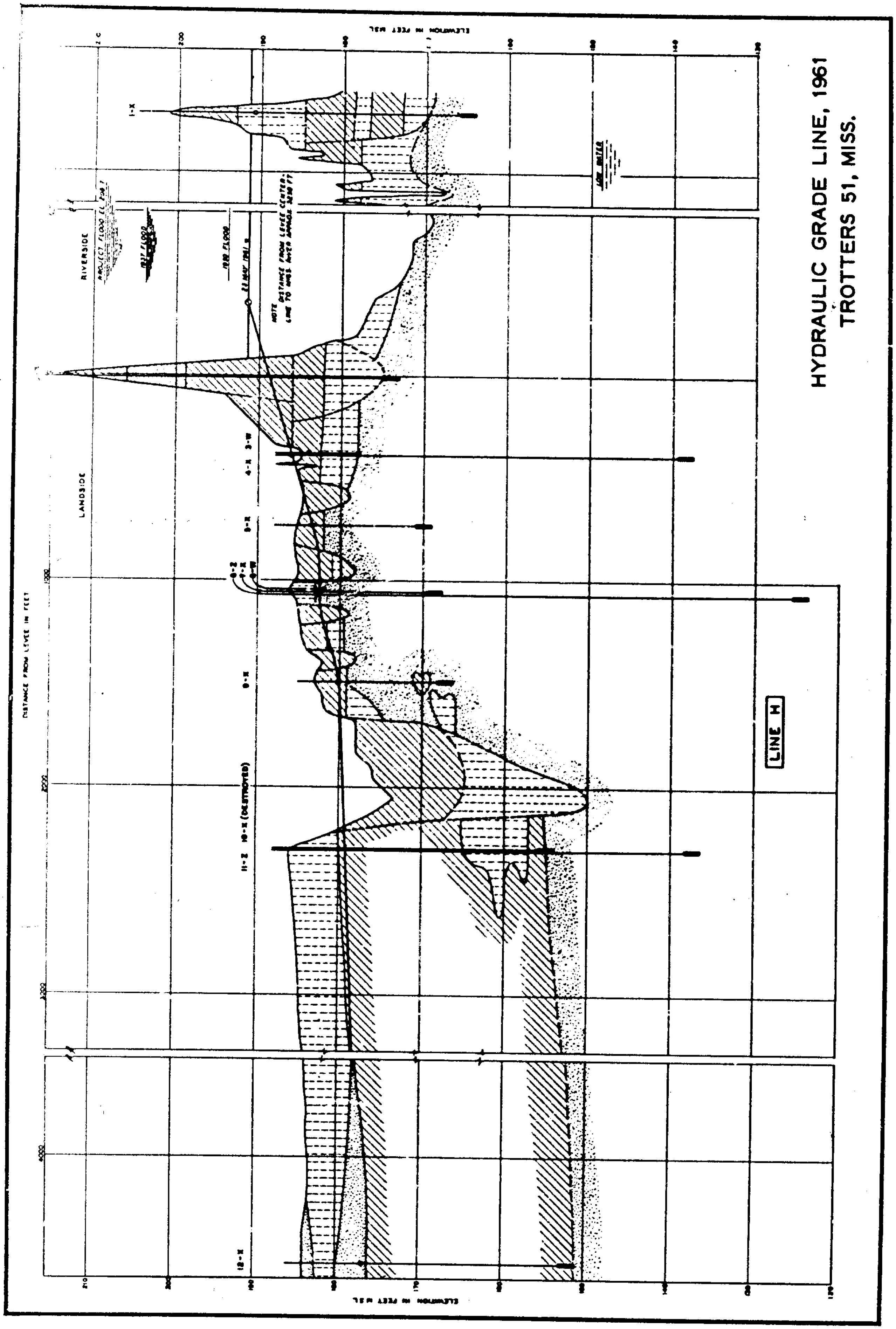
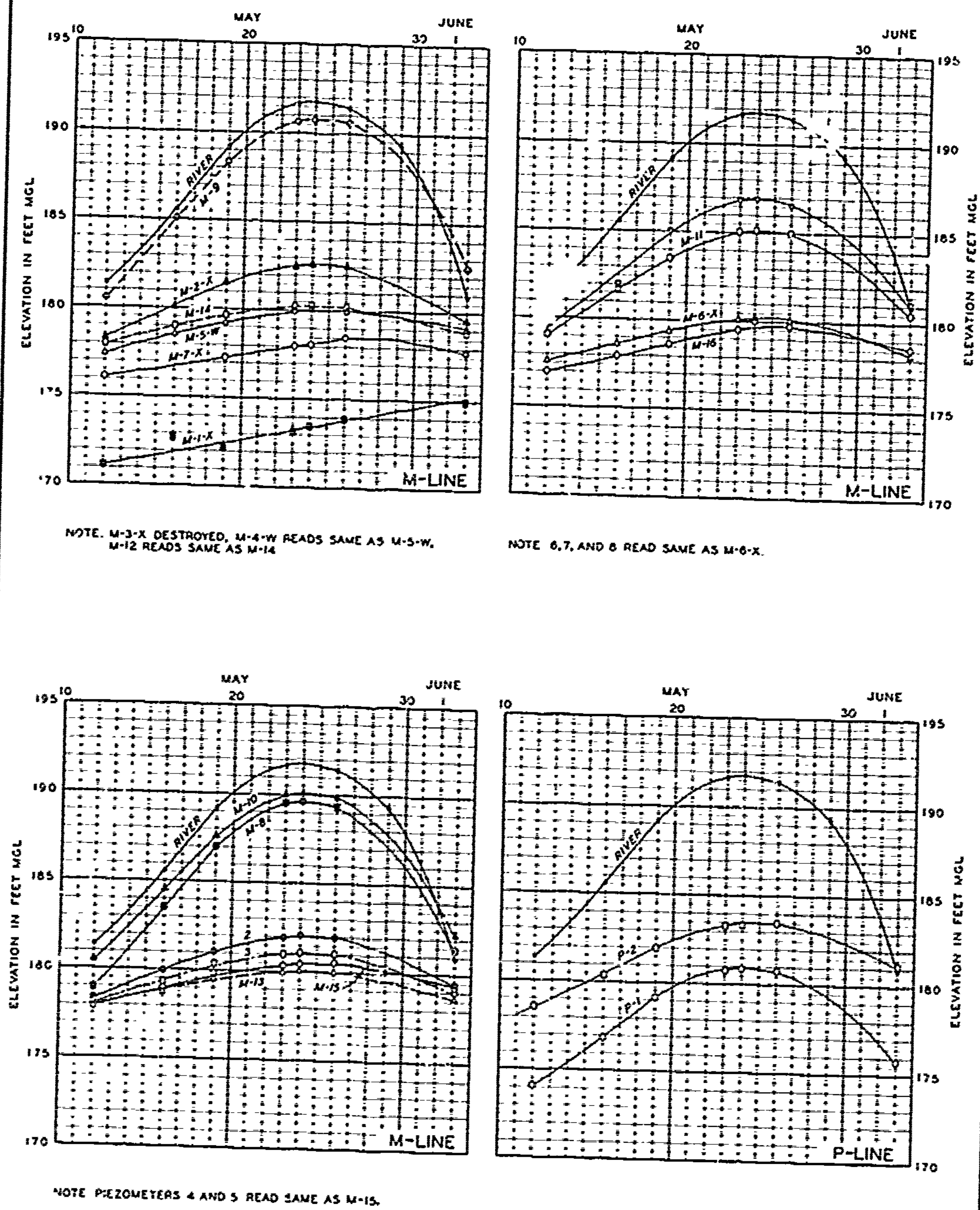

HYDRAULIC GRADE LINE, 1961
TROTTERS 51, MISS.
LINE H
RIVERSIDE
LANDSIDE
DISTANCE FROM LEVEE IN FEET
ELEVATION IN FEET M.S.L.

PLATE E8



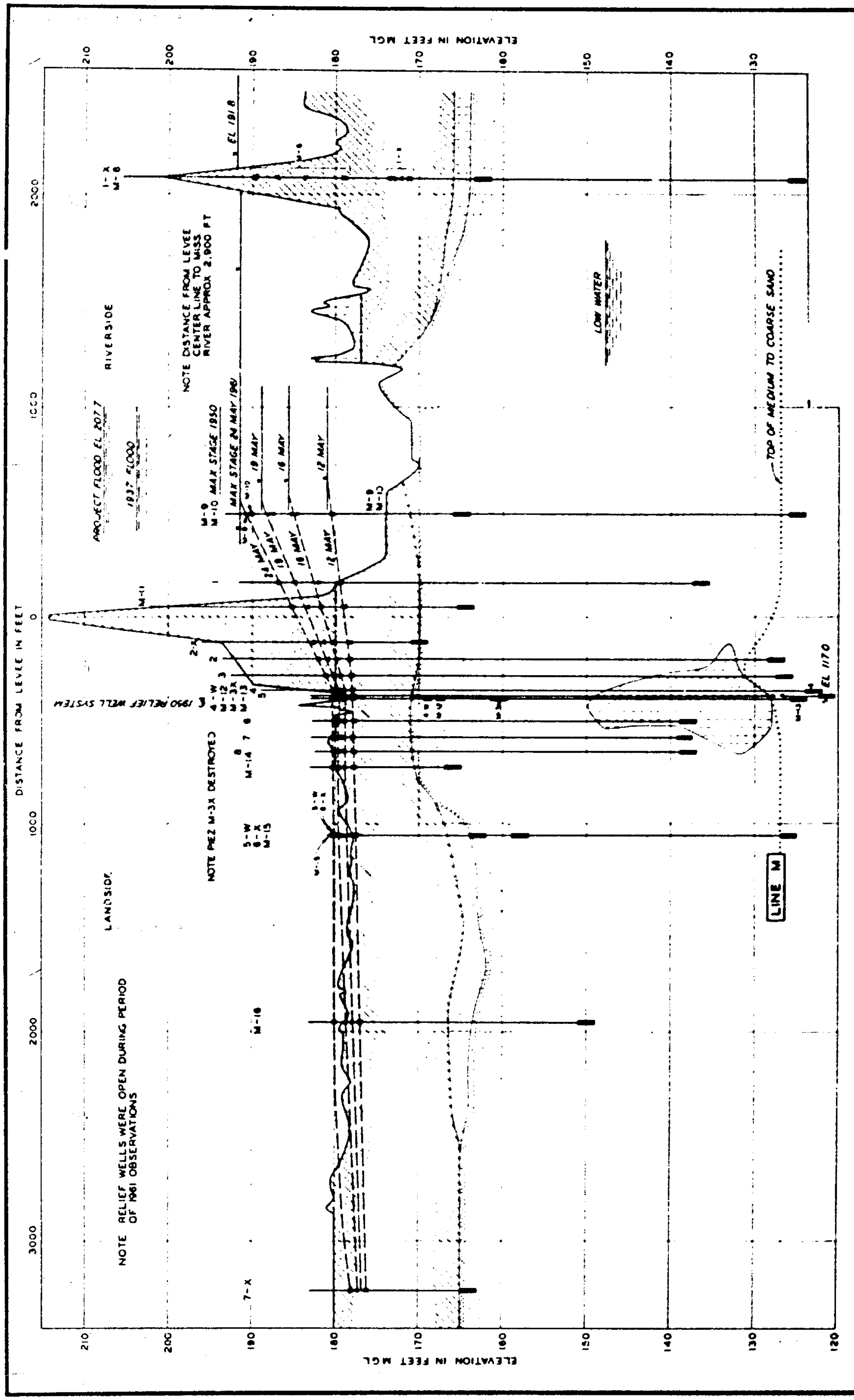
NOTE. M-3-X DESTROYED, M-4-W READS SAME AS M-5-W, M-12 READS SAME AS M-14

NOTE 6, 7, AND 8 READ SAME AS M-6-X.

NOTE PIEZOMETERS 4 AND 5 READ SAME AS M-15.

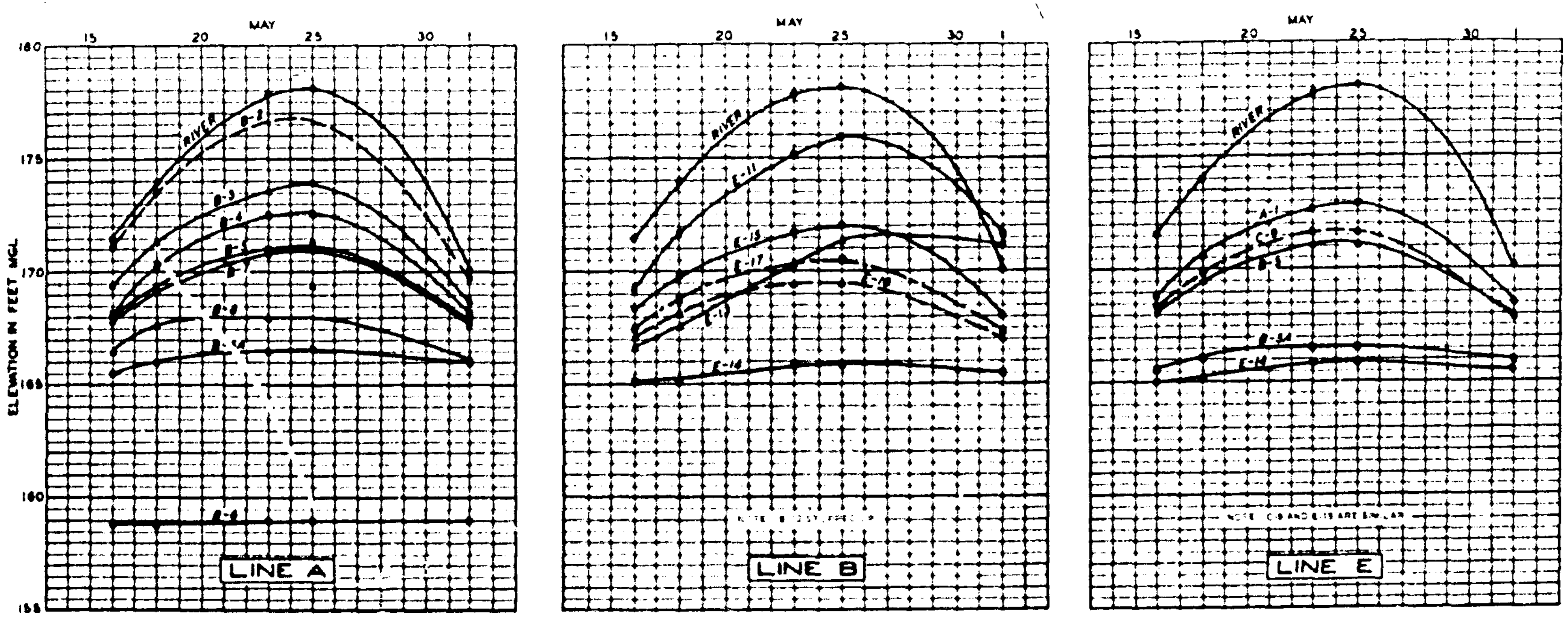
PIEZOMETER OBSERVATIONS, 1961
TROTTERS 54, MISS.

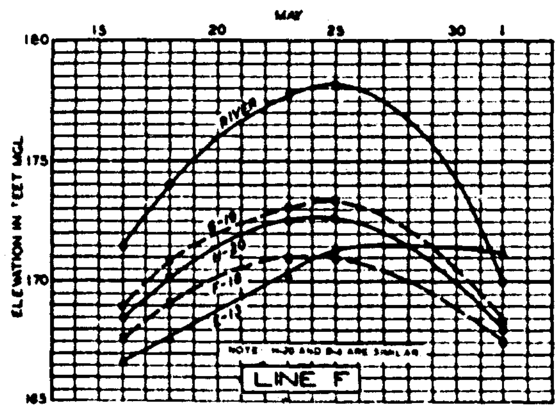
PLATE E9



HYDRAULIC GRADE LINE, 1961
TROTTERS 54, MISS.

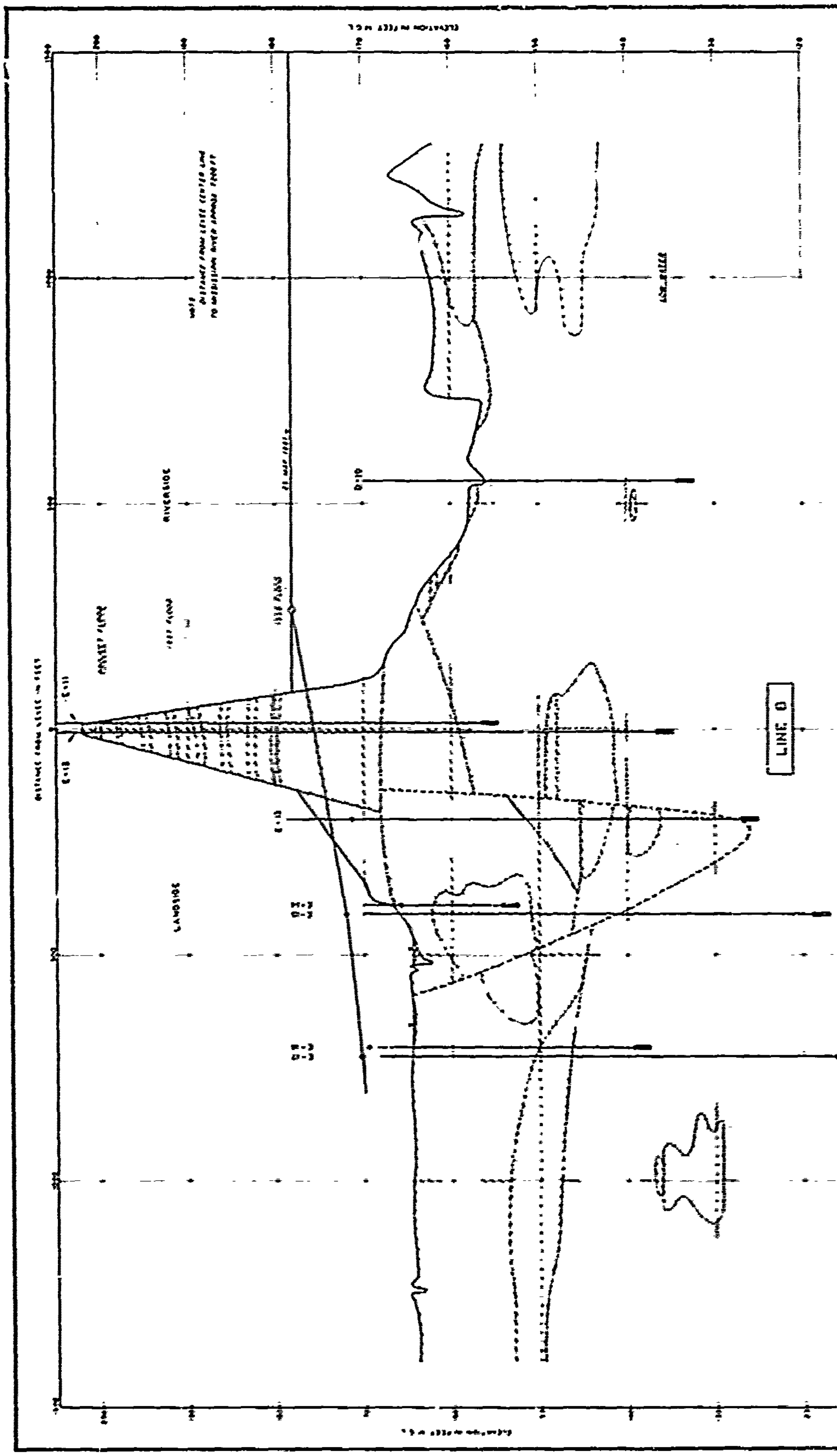
PLATE E10





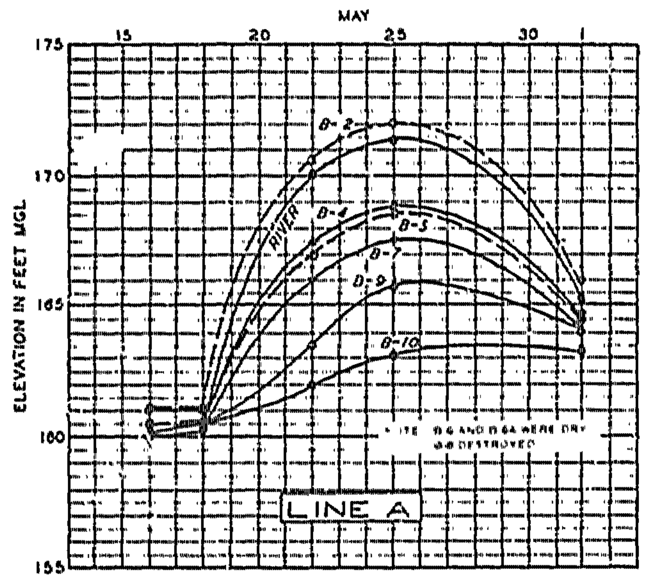
PIEZ	GR. EL.	PIEZ	GR. EL.
A-1	[illegible]	E-11	[illegible]
B-2	[illegible]	E-13	[illegible]
B-3	[illegible]	E-14	[illegible]
B-4	[illegible]	E-15	[illegible]
B-5	[illegible]	E-16	[illegible]
B-5A	[illegible]	E-17	[illegible]
B-6	[illegible]	F-18	[illegible]
B-7	[illegible]	G-19	[illegible]
B-8	[illegible]	H-20	[illegible]
C-9	[illegible]		

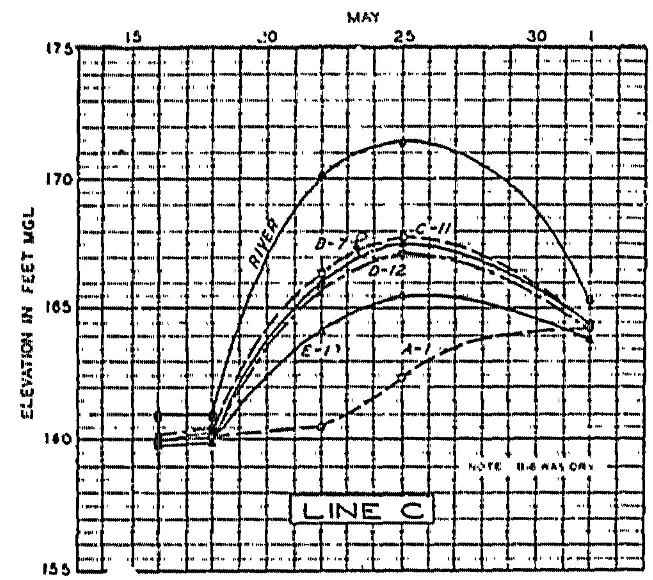
PIEZOMETER OBSERVATIONS, 1961
STOVALL, MISS.



HYDRAULIC GRADE LINE, 1961
STOVALL, MISS.

PLATE E12

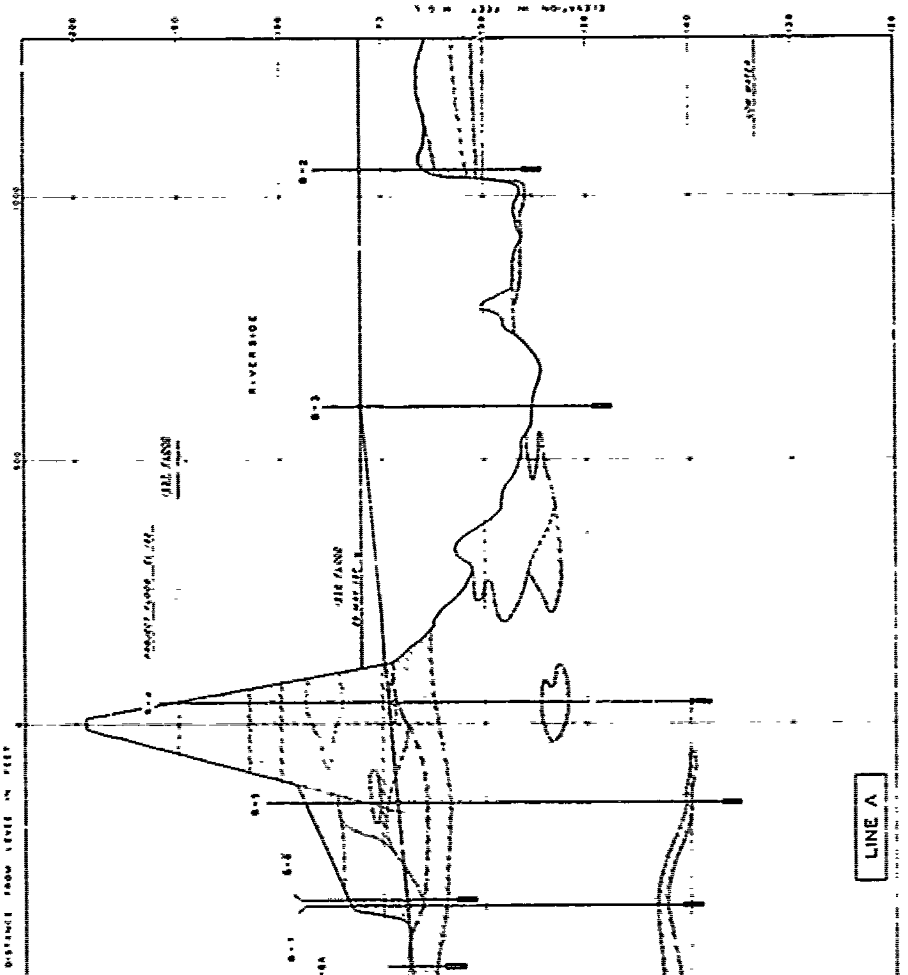




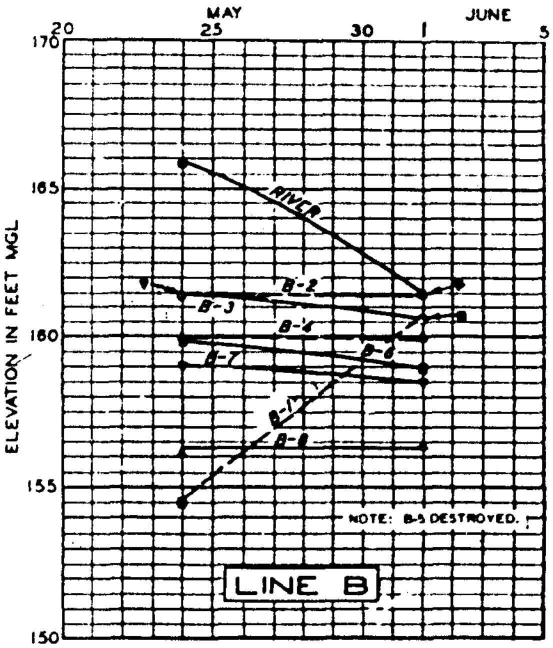
PIEZ.	GR. EL.
A-1	[illegible]
B-2	[illegible]
B-4	[illegible]
B-5	177.5
B-6	173.8
B-6A	[illegible]
B-7	173.8
B-9	168.4
B-10	163.3
C-11	175.4
D-12	169.8
E-13	168.5

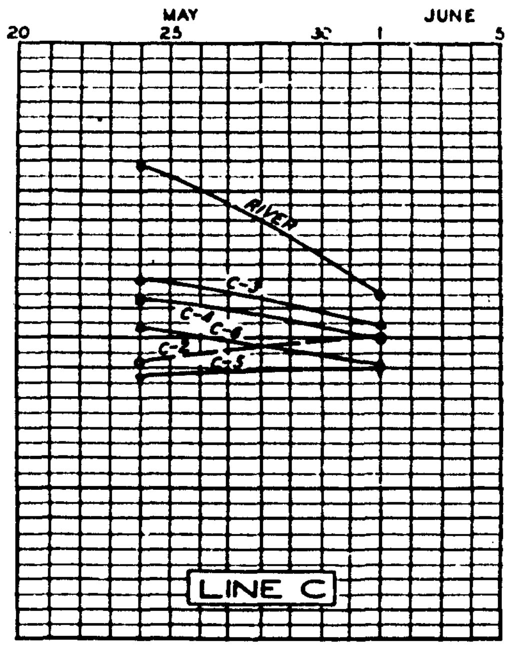
PIEZOMETER OBSERVATIONS, 1961
FARRELL, MISS.

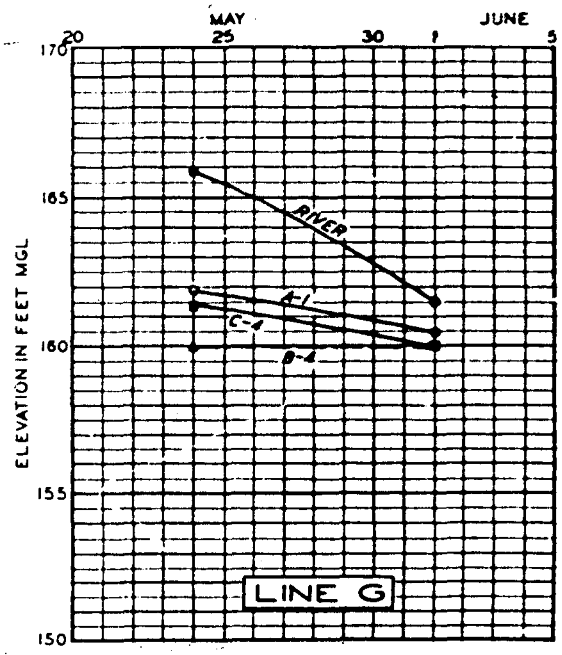
PLATE E13



HYDRAULIC GRADE LINE, 1961
FARRELL, MISS.







PIEZ	GR EL	PIEZ	GR EL
A-1	162.5	B-7	156.9
B-1	153.5	B-8	156.1
B-2	183.0	C-2	[illegible]
B-3	170.9	C-3	[illegible]
B-4	161.4	C-4	161.3
B-5	160.4	C-5	157.9
B-6	158.4	C-6	157.9

PIEZOMETER OBSERVATIONS, 1961
UPPER FRANCIS, MISS.

PLATE E15

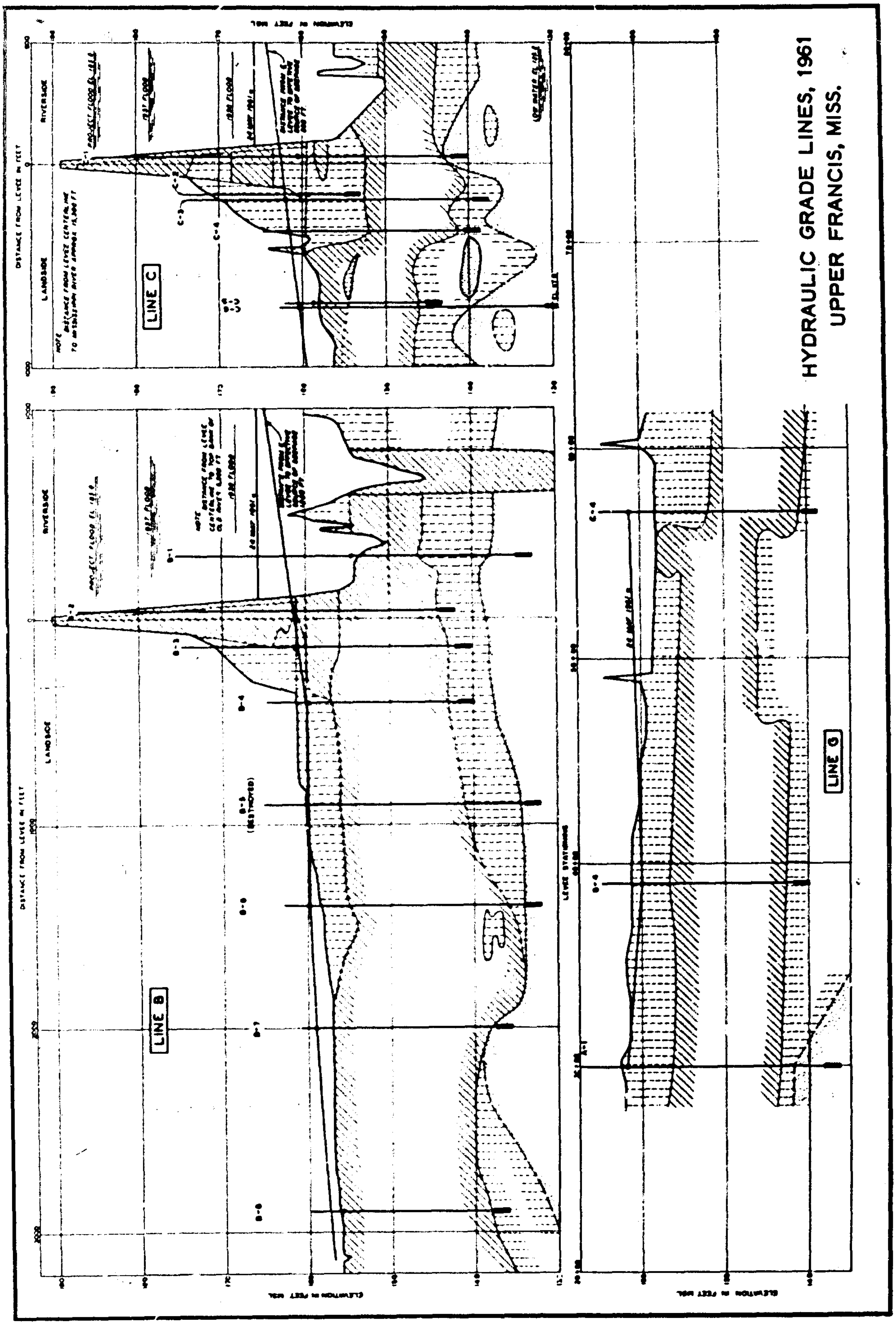
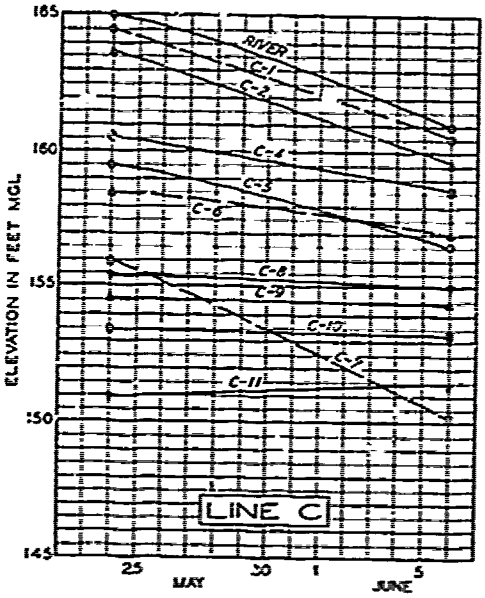
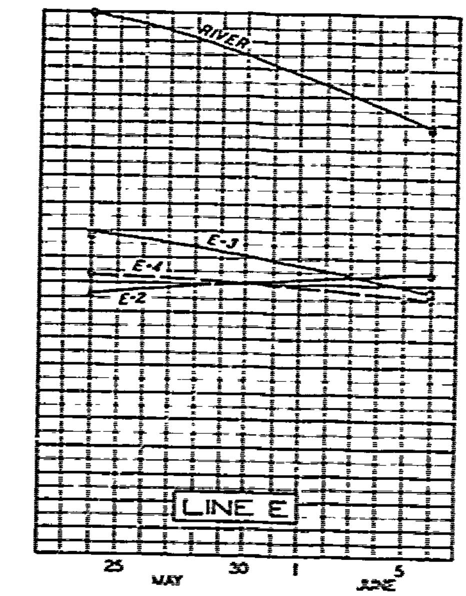
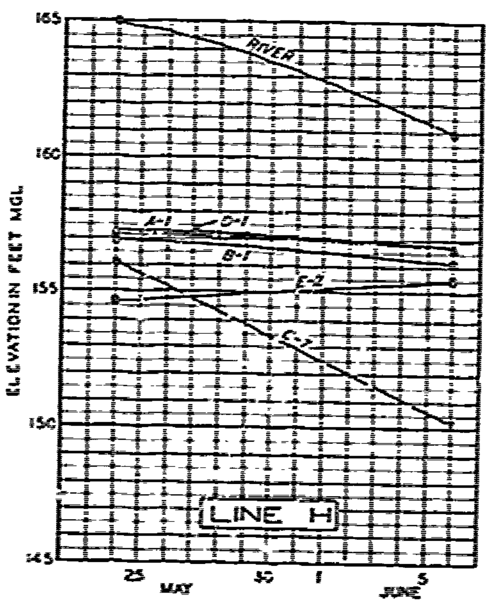

HYDRAULIC GRADE LINES, 1961
UPPER FRANCIS, MISS.
LINE C
LINE B
LINE G

PLATE E16







[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

PIEZOMETER OBSERVATIONS, 1961
LOWER FRANCIS, MISS.

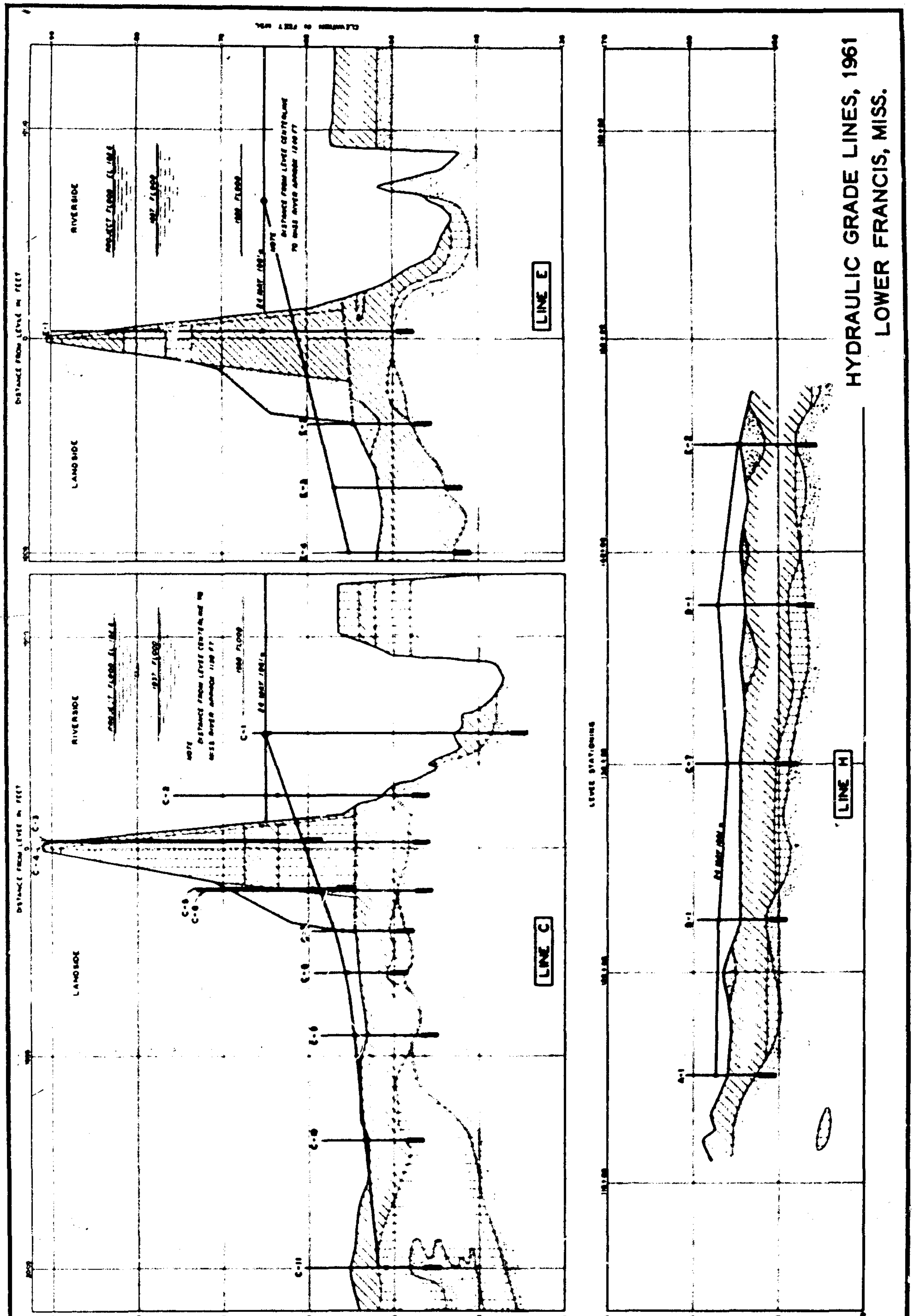
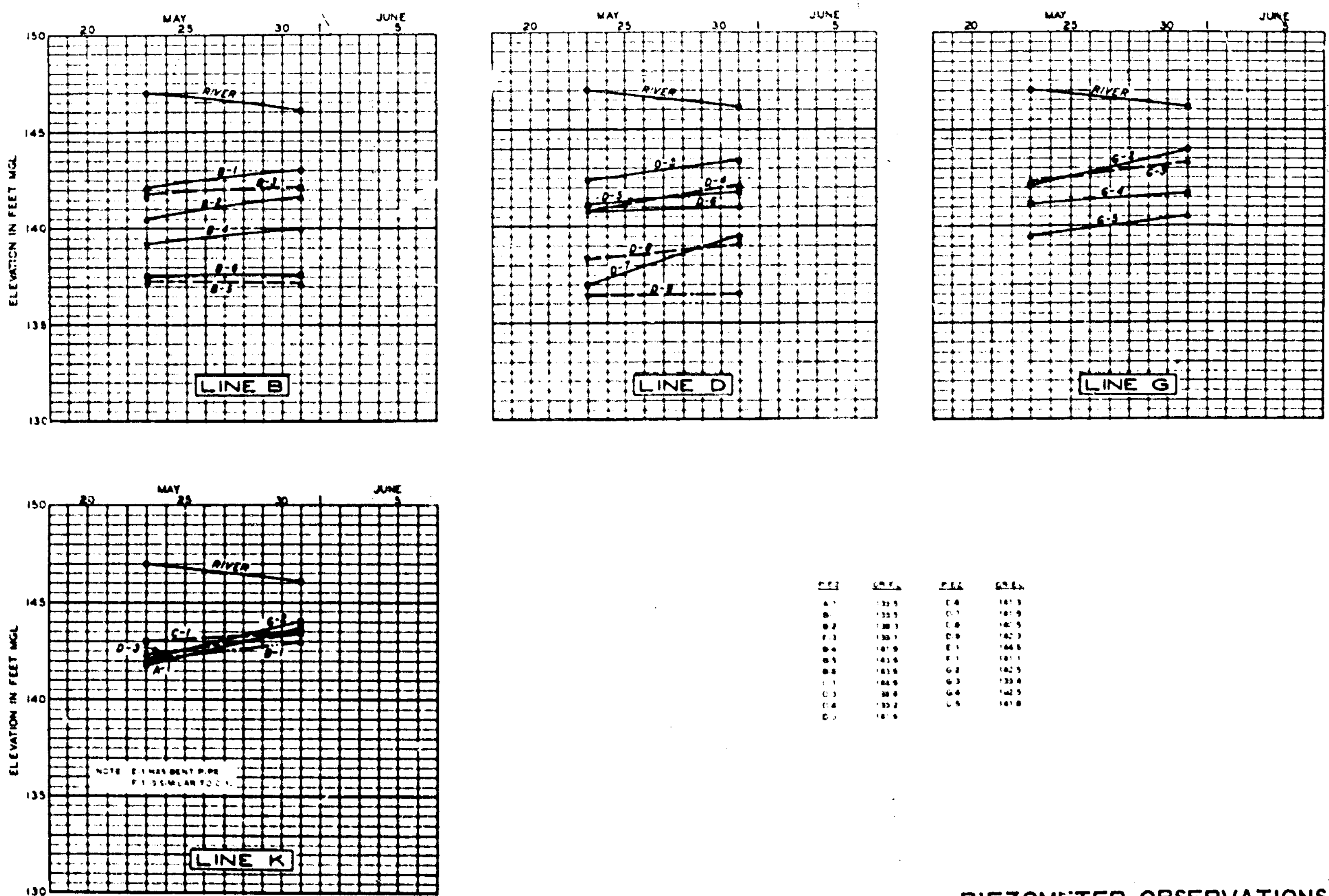
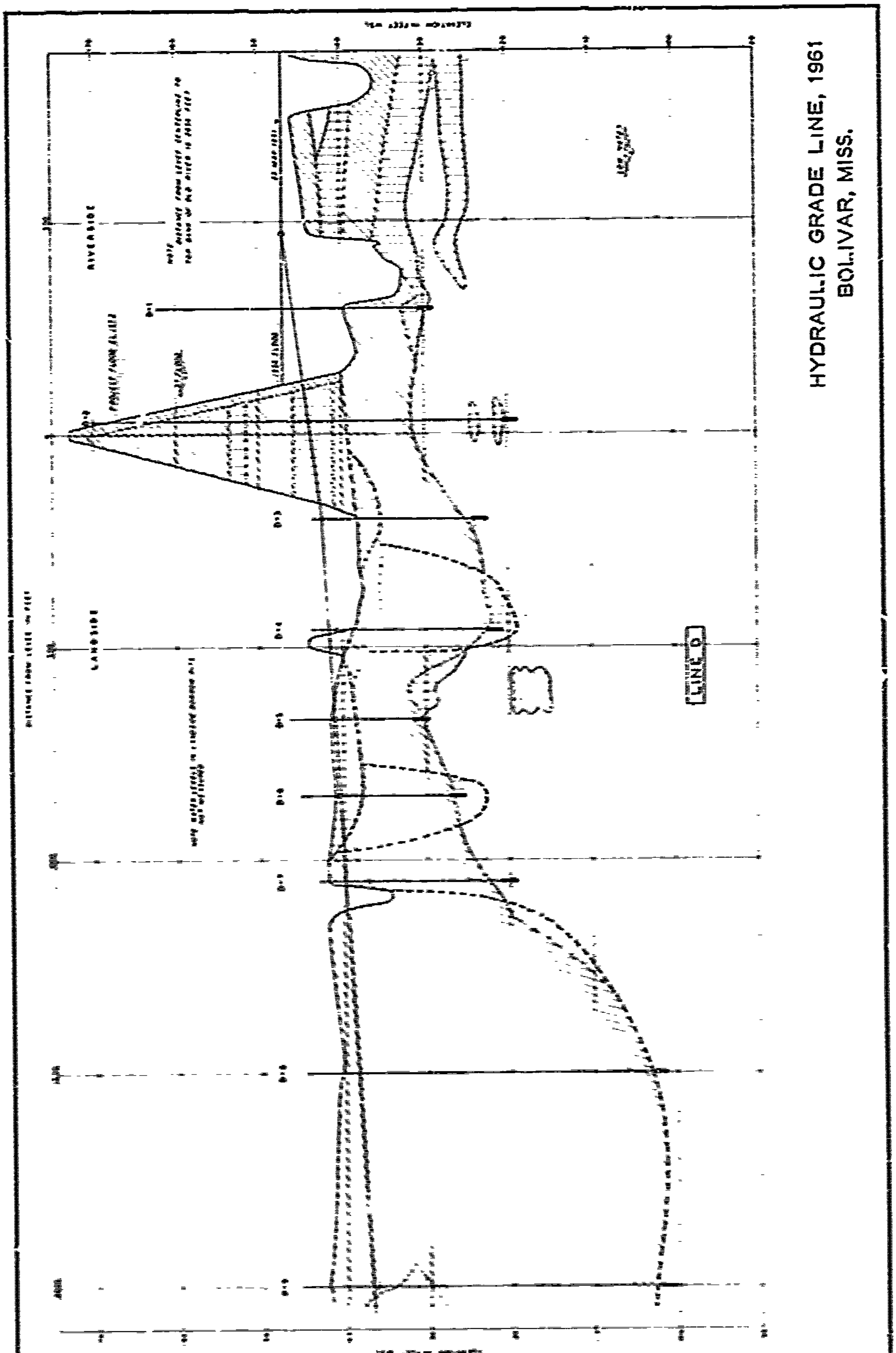

HYDRAULIC GRADE LINES, 1961
LOWER FRANCIS, MISS.
RIVERSIDE
LANDSIDE
LINE E
RIVERSIDE
LANDSIDE
LINE C
LINE H

PLATE E18



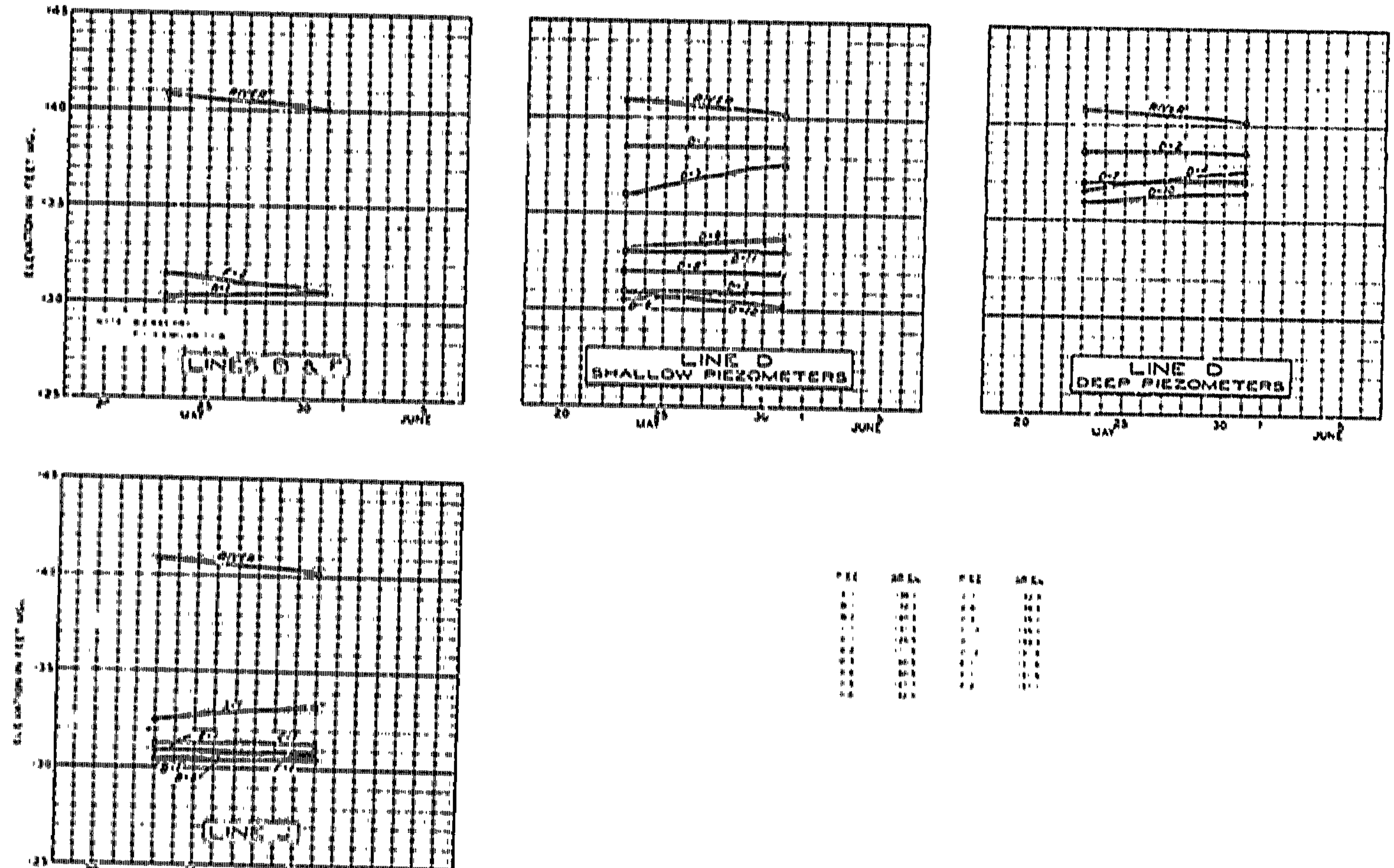
[illegible]	[illegible]	[illegible]	[illegible]
A-1	[illegible]	D-6	[illegible]
B-1	[illegible]	D-7	[illegible]
B-2	[illegible]	D-8	[illegible]
B-3	[illegible]	D-9	[illegible]
B-4	[illegible]	E-1	[illegible]
B-5	[illegible]	F-1	[illegible]
B-6	[illegible]	G-2	[illegible]
C-1	[illegible]	G-3	[illegible]
D-3	[illegible]	G-4	[illegible]
D-4	[illegible]	G-5	[illegible]
D-5	[illegible]		

PIEZOMETER OBSERVATIONS, 1961
BOLIVAR, MISS.

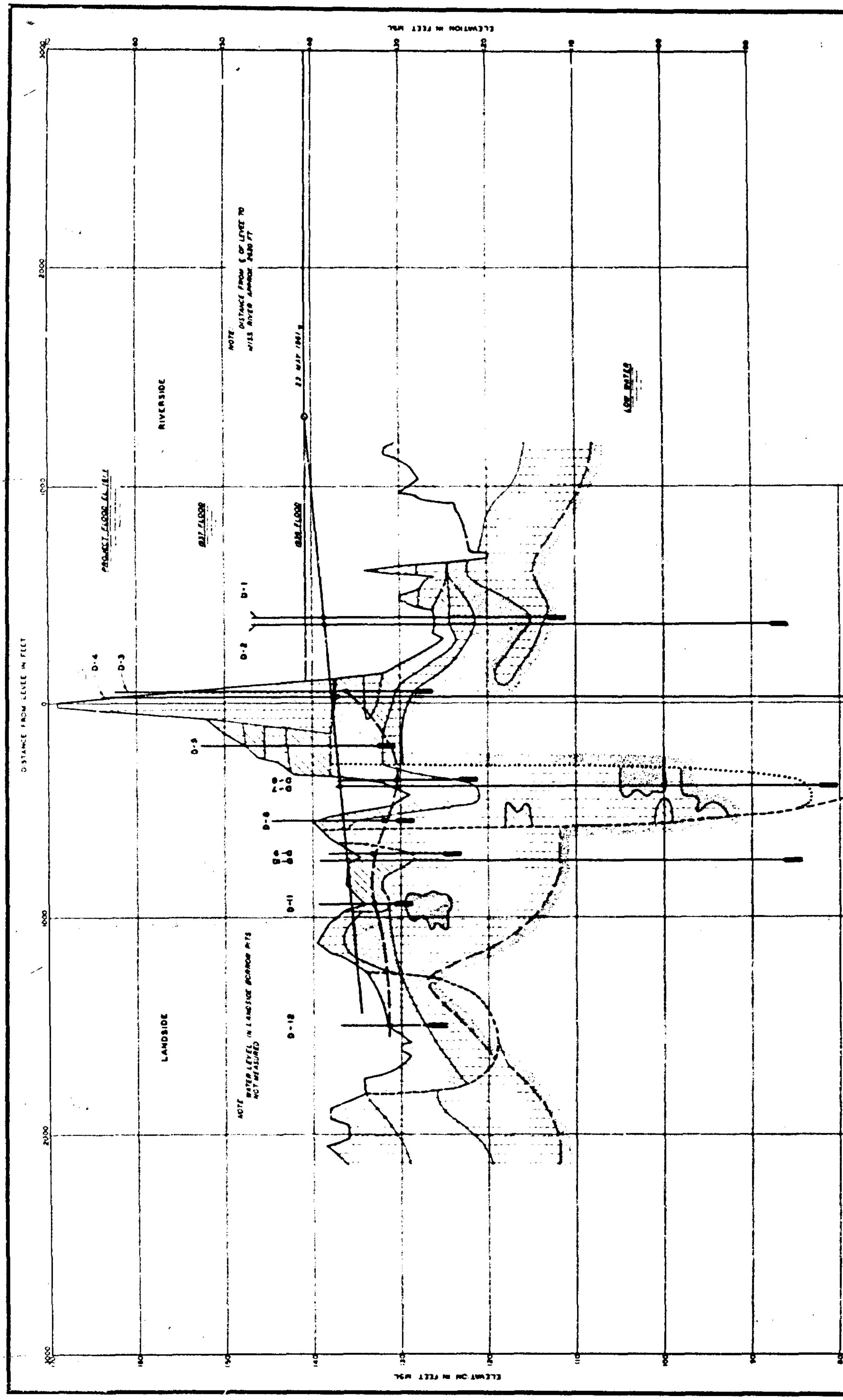


HYDRAULIC GRADE LINE, 1961
BOLIVAR, MISS.

PLATE E20

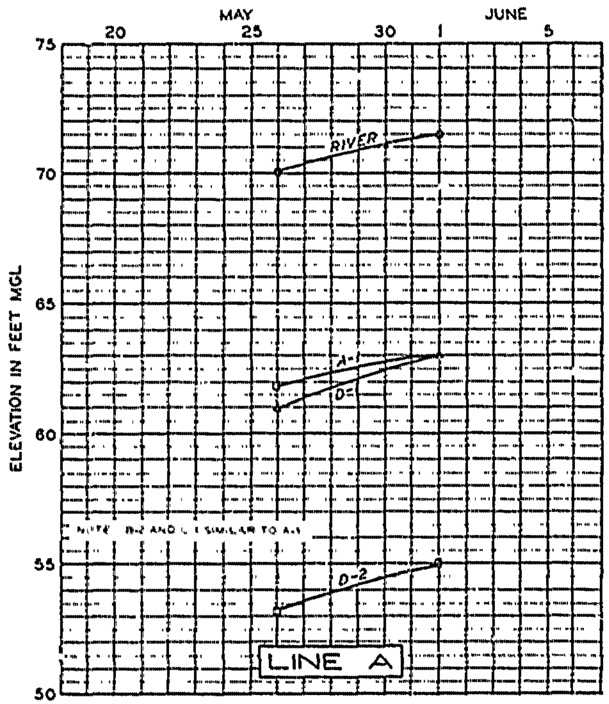


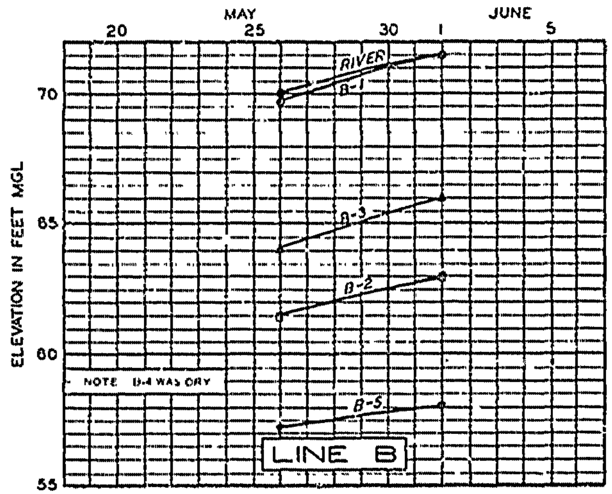
PIEZOMETER OBSERVATIONS, 1961
EUTAW, MISS.



HYDRAULIC GRADE LINE, 1961
EUTAW, MISS.

PLATE E22

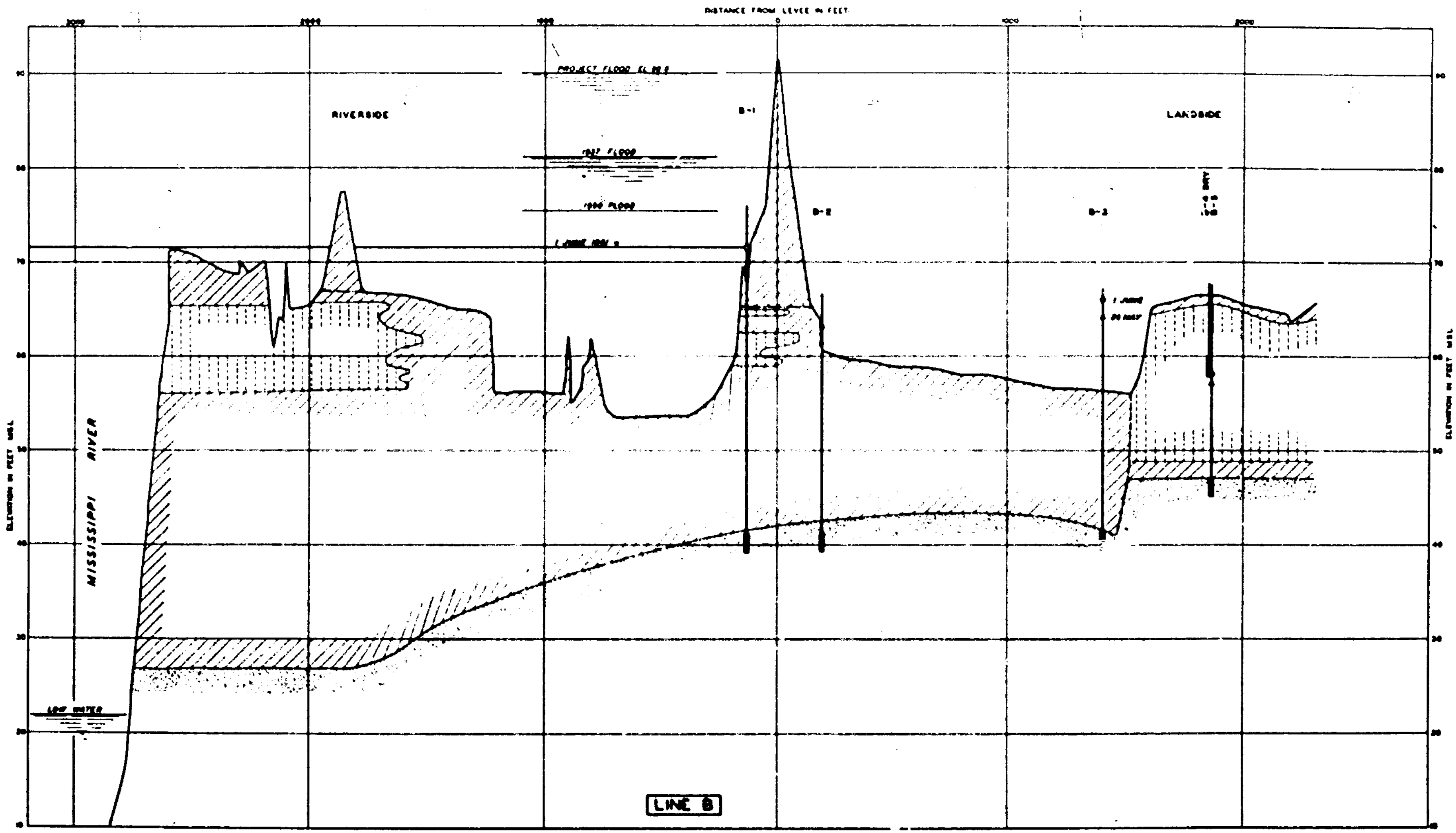




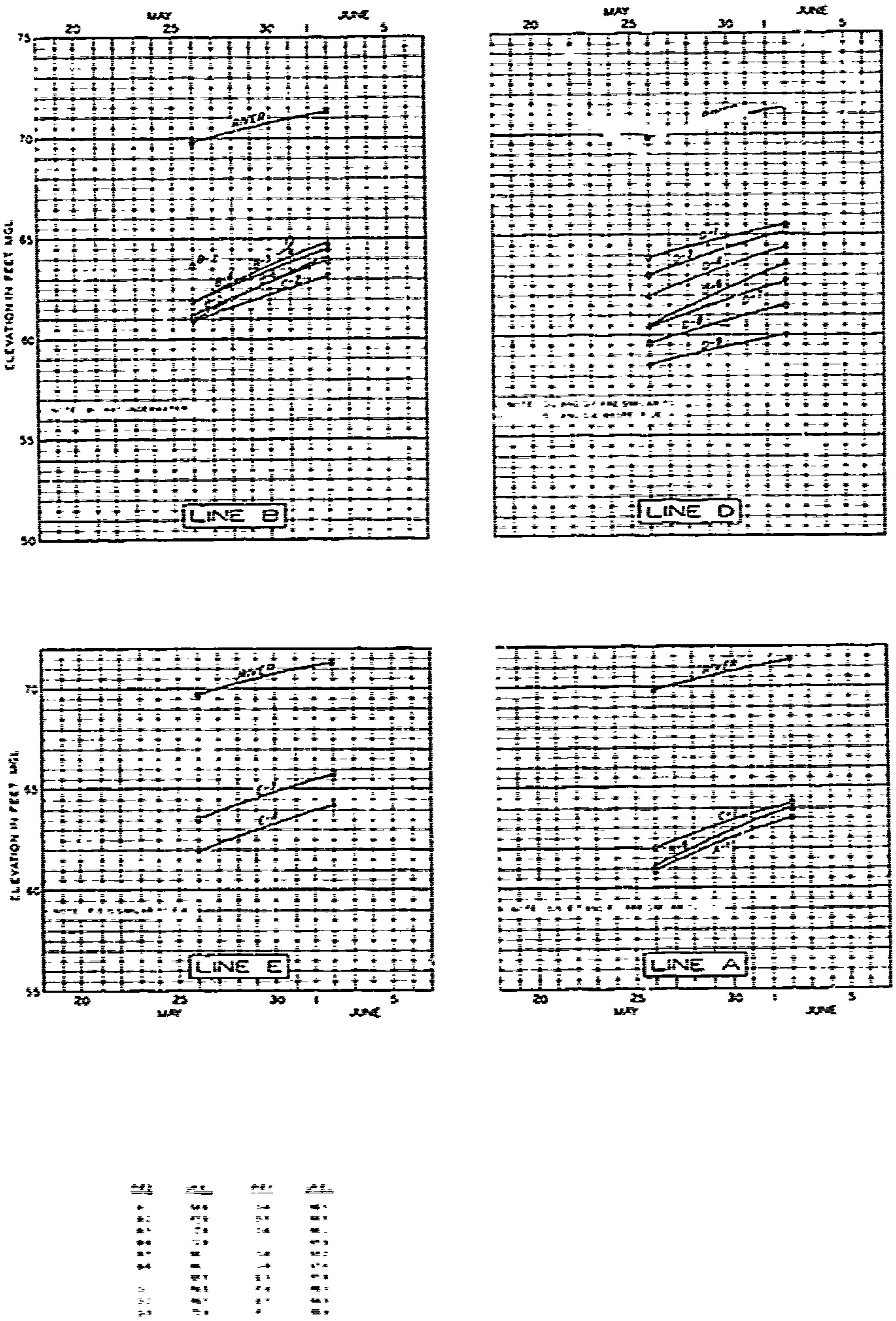
PIEZ	GR. EL.
A-1	59.5
B-1	67.6
B-2	60.6
B-3	56.3
B-4	66.5
B-5	66.5
[illegible]	63.3
D-1	64.7
D-2	64.6

PIEZOMETER OBSERVATIONS, 1961
L'ARGENT, LA.

PLATE E23



HYDRAULIC GRADE LINE, 1961
L'ARGENT, LA.



PIEZOMETER OBSERVATIONS, 1961
HOLE-IN-THE-WALL, LA.

PLATE E25

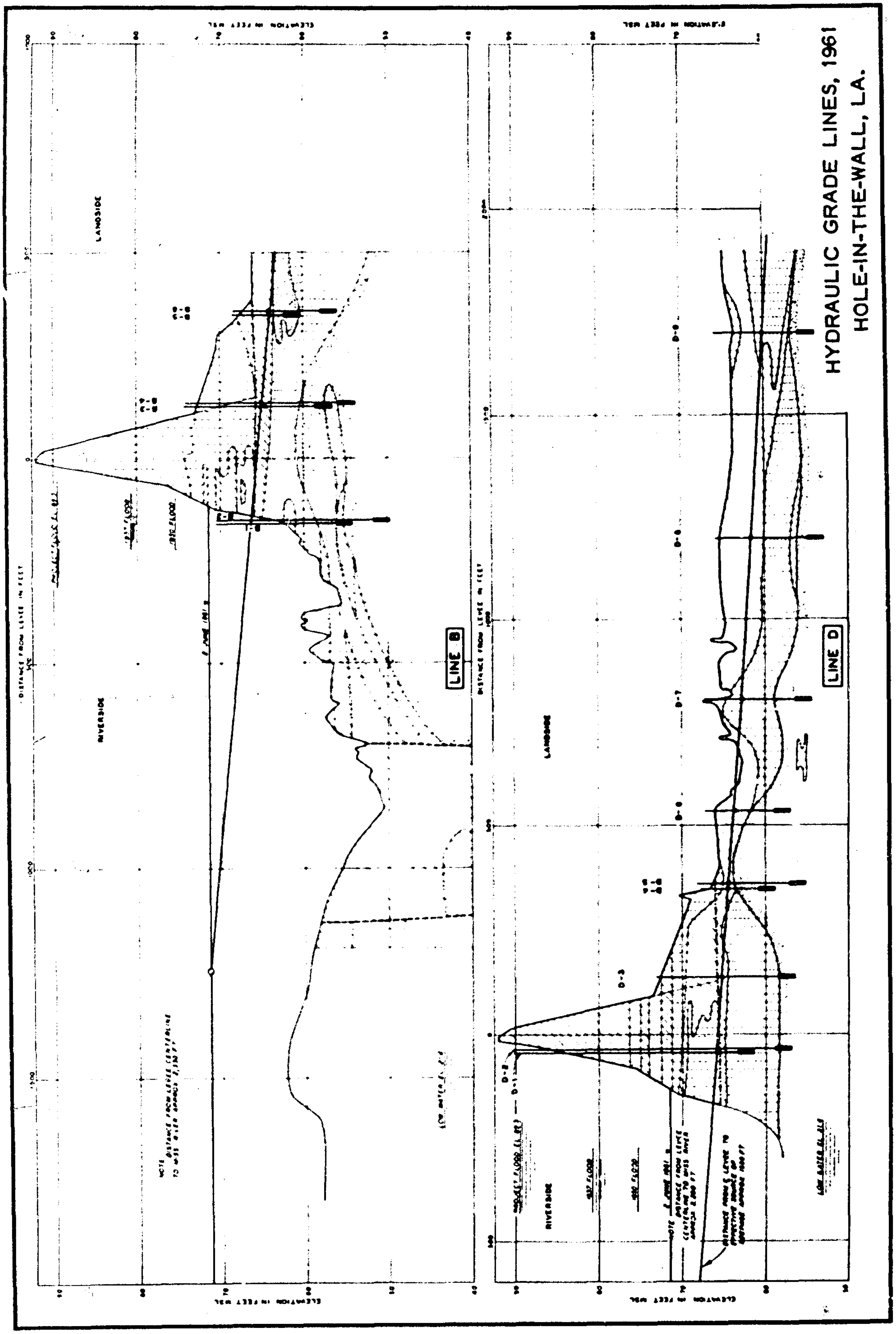
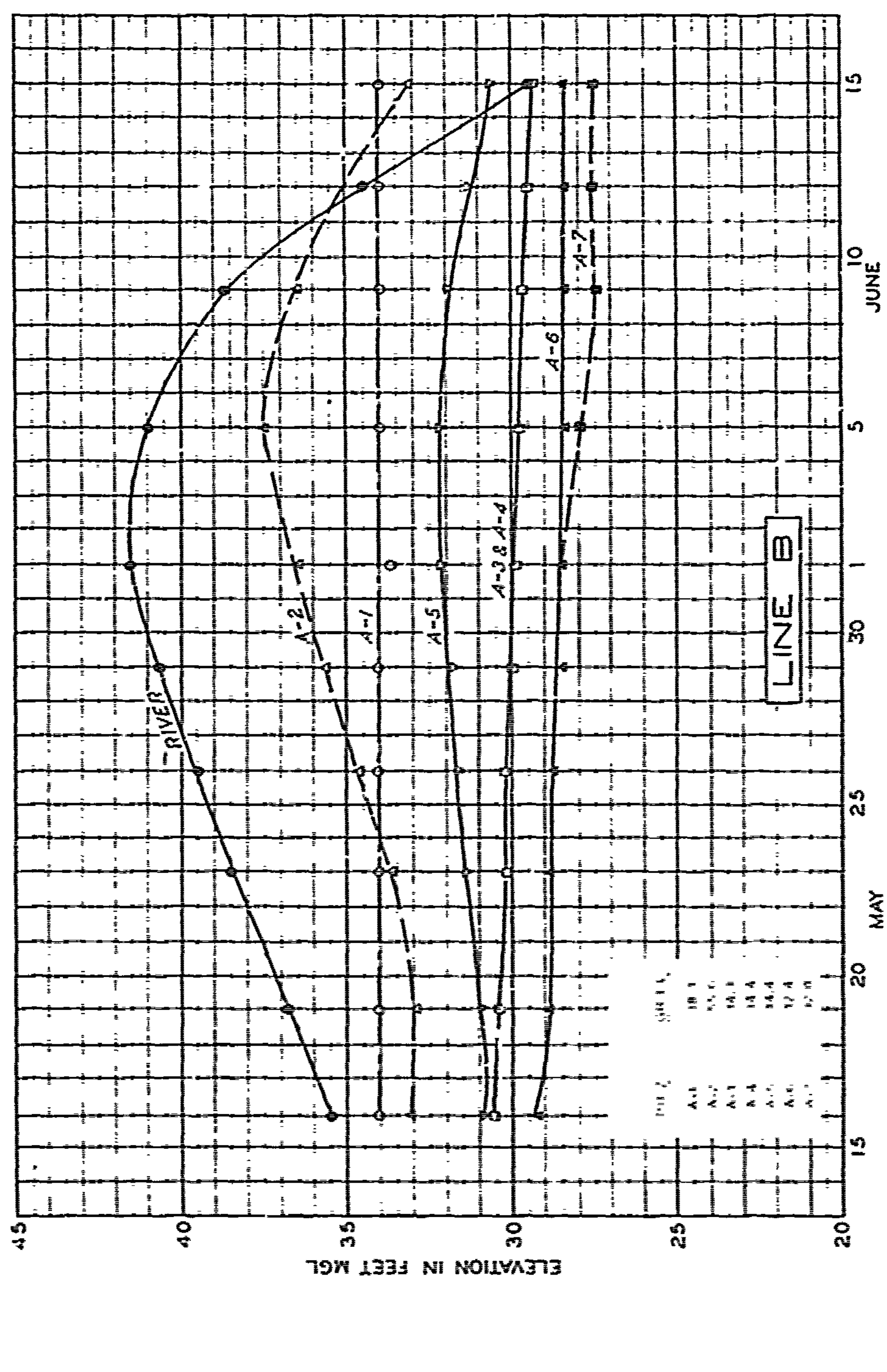

HYDRAULIC GRADE LINES, 1961
HOLE-IN-THE-WALL, LA.
LINE B
LINE D
LANDSIDE
RIVERSIDE
LANDSIDE
RIVERSIDE

PLATE E26



PIEZOMETER OBSERVATIONS, 1961
KELSON, LA.

PLATE E27

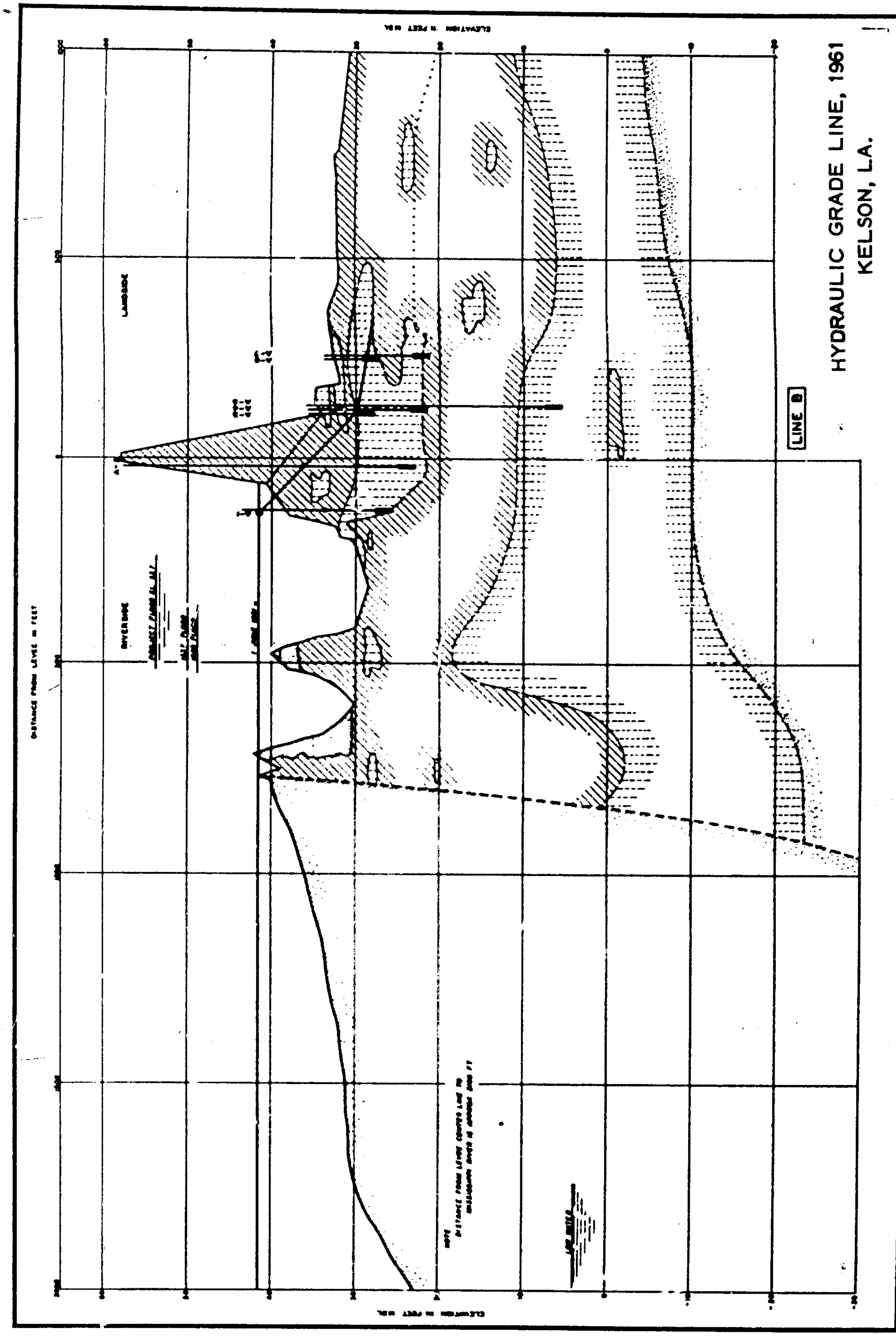


PLATE E28

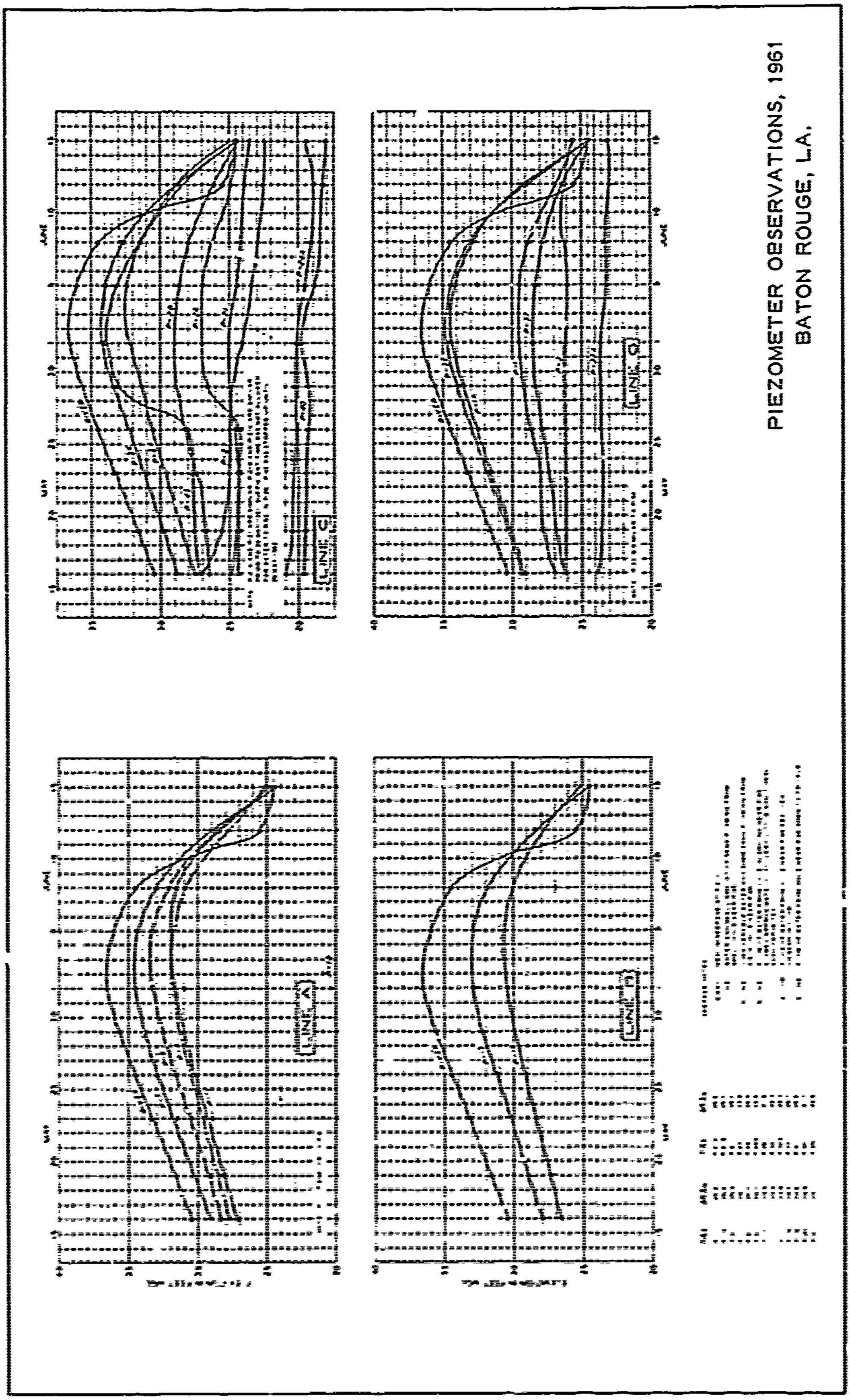
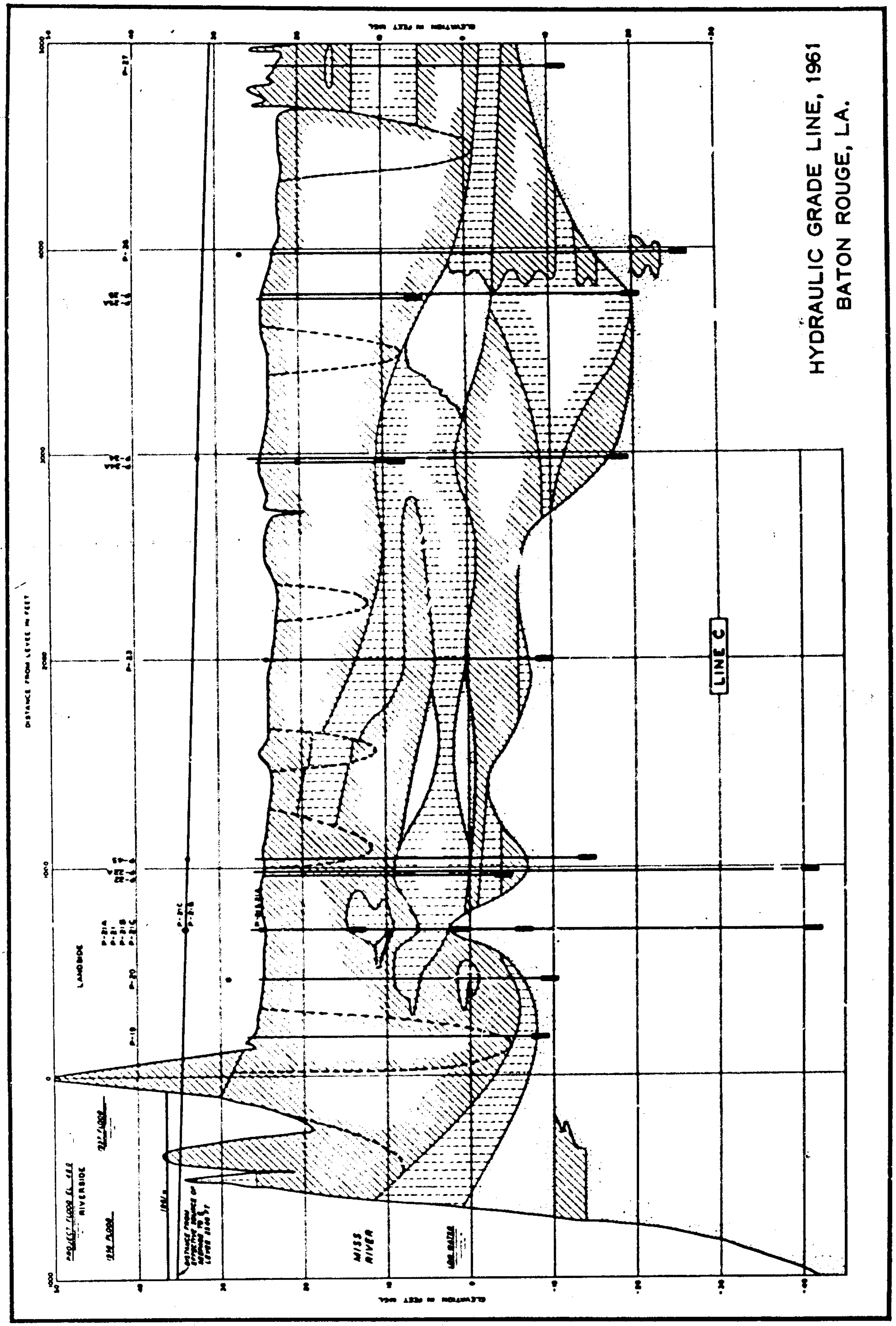

PIEZOMETER OBSERVATIONS, 1961
BATON ROUGE, LA.
LINE C
LINE D
LINE A
LINE B
MAY
JUNE

PLATE E29


HYDRAULIC GRADE LINE, 1961
BATON ROUGE, LA.
LINE C