UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ELEVATIONS AND DISCHARGES PRODUCED BY A SIMULATED FLOOD WAVE ON THE LOWER SABINE RIVER, LOUISIANA AND TEXAS, CAUSED BY A THEORETICAL DAM FAILURE

Open-File Report 79-678

Prepared in cooperation with the
Sabine River Compact Administration

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ILLUSTRATIONS

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) OF METRIC UNITS

The analyses and compilations in this report were made with inch-pound units of measurement. To convert inch-pound units to metric units, the following conversion factors should be used:

Multiply inch-pound units	By	To obtain metric units
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

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ABSTRACT

The Toledo Bend Reservoir is located on the lower Sabine River between Louisiana and Texas. The objective of this study was to calculate the flood wave that would result from the theoretical failure of 25 percent of Toledo Bend Dam and route the wave downstream to Orange, Tex. Computations assumed failure (1) at the peak of the 100-year flood when discharge of the Sabine River would be 102,000 cubic feet per second and (2) when the average discharge would be 10,000 cubic feet per second. Two techniques were used in the dam-break model. The method of characteristics was used to propagate the shock wave after the dam fails. The linear implicit finite-difference solution was used to route the flood wave after the shock wave has dissipated.

The magnitude of the flood was determined for sites near Burkeville, Bon Wier, Ruliff, and Orange, Tex., along the lower Sabine River. For these sites, respectively, the following peak elevations were calculated: 119, 82, 31, and 13 feet for the 100-year flood and 110, 75, 27, and 9 feet for the average discharge.

INTRODUCTION

The Toledo Bend Dam, which forms the Toledo Bend Reservoir, is located on the Sabine River at river mile 156.5 (above confluence with the Gulf of Mexico). A general location map of the reservoir and adjacent areas is shown in figure 1. The drainage area at the damsite is 7,178 mi^2. The reservoir is formed by a rolled earthfill dam, 11,243 ft long and about 80 ft high. Water is released through two turbines used for generating electrical power and through 11 tainter gates. The capacity of the reservoir is 4,476,000 acre-ft at an elevation of 172 ft,[1/] which is the approximate elevation that the water level is maintained.

1/ All elevations given in this report are referenced to the "National Geodetic Vertical Datum of 1929," which is approximately equal to "Mean Sea Level Datum of 1929."

Figure 1.--General location of the Sabine River basin.

If the dam should fail, the floodwaters would spread to a width of 5 to 7 mi in the area between the dam and Orange, Tex. Several communities in the reach below the dam would be inundated, including Orange.

This study was made at the request of the Sabine River Compact Administration on behalf of the Sabine River Authorities of Louisiana and Texas, who are required by the Federal Energy Regulatory Commission to have a plan for warning the residents of the area in the event a dam failure should appear imminent. However, the study is hypothetical, and there are presently no indications that the dam might fail.

The objective of this study was to predict the extent of flooding from a failure of Toledo Bend Dam. Specifically, water-surface elevations and floodflow discharges for selected sites on the river were determined. It was assumed that failure would occur during the peak of the 100-year flood, when discharge of the Sabine River would be 102,000 ft^3/s, and also during an average discharge period, when 10,000 ft^3/s would be flowing in the stream. A 25-percent partial failure of the dam was assumed.

DESCRIPTION OF STREAM SYSTEM

The Toledo Bend Reservoir is located on the Sabine River, 156.5 mi above its confluence with the Gulf of Mexico. Drainage area at the damsite is 7,178 mi^2. The natural slope of the stream is about 0.6 ft/mi, and the width of the low-water channel is about 400 ft. The upstream end of the reservoir is near Logansport, La., 110.6 mi upstream from the dam, and has a drainage area of 4,100 mi^2. Tributaries flowing into the reservoir from each side have a total drainage area of 3,078 mi^2.

MODEL DESCRIPTION

The model used to define the extent of flooding along the Sabine River is described in the following sections.

Mathematical

Two mathematical models were coupled to simulate a flood wave on the Sabine River downstream from Toledo Bend Reservoir. One is the method of characteristics model (MOC), and the other is the linear implicit finite-difference model (LIF). Chen and Druffel (1977) described utilization of these modeling techniques for computing dam-break flood waves in nonprismatic channels.

The method of characteristics model was used from the instant of failure until the shock-wave front dissipated all of the shock energy. Then the linear implicit finite-difference model was used to route the flood wave through the end of the study reach and to the completion of the simulation period. The criterion for transfer from the method of characteristics model to the linear implicit finite-difference model was the complete disappearance of the shock-wave front (discontinuity) at the leading edge of the flood wave (Froude number less than or equal to 1 at all points in the reach). Both models are unsteady-state models that use the complete Saint-Venant flow equations and compute water-surface elevations and discharge hydrographs at each cross section.

Boundary Conditions

The Sabine River was modeled from mile 9.0 (Orange, Tex.) to mile 267.1 (Logansport, La.). Cross-sectional properties that affect flow (dimensions, roughness, and hydraulic radius) were determined at selected intervals along the river. The cross sections were determined by picking elevations from topographic maps; these data were supplemented with field surveys of cross sections of the main channel at each of the five gaging stations.

The only inflow into the system that was used as model input was inflow from the Sabine River near Logansport, La. In this study, tributary inflow and seepage outflow were assumed to be zero. Flood-plain storage also was assumed to be zero. Any structures in the flood plain were assumed to fail instantly, and the resulting energy loss was considered negligible. The channel boundaries were assumed to be rigid, and no degradation from the extreme flood event was allowed. Manning's roughness coefficients used in the models were based on engineering judgment and computations, including verification, for each of the five gaging stations. The elevation of the water surface in the reservoir is maintained at 172.0 ft. If failure occurs during a 100-year flood on the Sabine River, the difference between the elevation of the water surface in the reservoir and the river below the dam will be only about 55 ft because of the higher tailwater elevation. If failure occurs during an average discharge, the difference in elevation will be about 75 ft. The assumption was made that 25 percent of the dam would abruptly fail.

Calculation of the Dam-Break Flood

Procedural steps for computing the dam-break flood wave for each of the breach geometries considered were:

Step 1: Input data on (1) channel geometry, roughness coefficient, and bed elevation at each reference cross section and (2) size and shape of the study breach.

Step 2: Determine the initial depths and velocities in the reservoir and river channel using the MOC model. The initial reservoir conditions were determined using the gradually varied steady-flow equation. In the river reach, the initial conditions were determined by the uniform flow equation.

Step 3: Run the MOC model until the shock (discontinuity) resulting from the dam break has dissipated (Froude number less than or equal to 1 at all points in the reach).

Step 4: Input the velocities and depths resulting from Step 3 into the LIF model as initial conditions upstream from the leading edge and route the flood wave through the end of the study reach. The initial conditions downstream from the leading edge were determined by a step-backwater computation for the LIF model.

Step 5: For the selected points of interest, output the stage and discharge hydrographs and the arrival time of the leading edge of the flood wave.

Evaluation of Models

Both models have been used to solve several hypothetical dam-break problems. In most cases the computer results obtained from both models checked quite well with the continuity condition. That is to say, the initial volume of water in the reservoir was maintained while the wave front propagated downstream.

For a hypothetical dam-break simulation, it is not practical, perhaps impossible, to execute the steps of calibration and verification normally required in numerical modeling. In this study of Toledo Bend Dam the input data are assumed to be accurate, the mathematical models are assumed to be theoretically sound, and the assumptions are judged to be reasonable. The only possible tests for accuracy were to check whether the models conserved mass, reasonably dissipated the flow energy as the wave progressed downstream (that is, the total energy line decreased going downstream), and provided results that appear reasonable from an engineering standpoint. Using these criteria, the results presented are believed to be accurate within the limits of the input data and assumptions made.

RESULTS

The mathematical model was used to compute water-surface elevations and discharges at various cross sections in the study reach for each time step. A 25-percent breach was used to represent a reasonably assumed dam failure. If 25 percent of the dam fails abruptly during the 100-year flood, a maximum discharge of 792,000 ft^3/s will occur at the dam. The flood wave will attenuate as it moves downstream; and the maximum discharges at Burkeville, Bon Wier, Ruliff, and Orange, Tex., (fig. 11) will be 635,000, 485,000, 410,000, and 398,000 ft^3/s, respectively. The simulated elevation and discharge hydrographs for Burkeville, Bon Wier, Ruliff, and Orange, for failure during the 100-year flood, are shown in figures 2, 3, 4, and 5, respectively. The time shown is the time after 25 percent of the dam fails. Figure 5 shows that the initial response at Orange would occur 45 hours after failure and that the peak water-surface elevation of 13.0 ft at Orange would occur 75 hours after failure.

For failure during average discharge, a maximum discharge of 365,000 ft^3/s will occur at the dam; the simulated water-surface elevation and discharge hydrographs for Burkeville, Bon Wier, Ruliff, and Orange are shown in figures 6, 7, 8, and 9, respectively. Figure 9 shows that the initial response at Orange would occur 84 hours after failure and that the peak water-surface elevation of 8.8 ft at Orange would occur 104 hours after failure.

The water-surface profile along the Sabine River for the peak elevations calculated for failure during the 100-year flood is shown in figure 10. Peak elevations along the river were transferred to a topographic map to show the boundary of the area subject to flooding (fig. 11). The width of the flooded area between the dam and Orange would range from 5 to 7 mi. Several communities in the reach would be inundated, including Orange. The results are considered to be a rough approximation of the timing and severity of flooding.

When flood elevations rise to about 30 ft near the Beauregard-Calcasieu Parish, La., line, water from the Sabine River will overtop the drainage divide and flow into Bear Head Creek, a tributary of the Houston River. The amount of water that will flow into Bear Head Creek during a 100-year-flood dam break is difficult to determine, but it is estimated to be about 1 percent of the flow in the Sabine River. The water-surface elevation of Bear Head Creek at Louisiana Highway 12 will probably be equal to the water-surface elevation of the Sabine River at Louisiana Highway 12, which is 31.5 ft. The water-surface elevations downstream along the Houston River, although not delineated in figure 7, will probably be about equal to those of the May 1953 flood. The peak water-surface elevation of the May 1953 flood at the mouth of the Houston River was 12.75 ft.

REFERENCE

Chen, Cheng-lung, and Druffel, L. A., 1977, Dam-break flood wave computation by method of characteristics and linearized implicit schemes, in Proceedings of dam-break flood routing model workshop held in Bethesda, Maryland, on October 18-20, 1977: Washington, D.C., U.S. Water Resources Council, Hydrology Committee, p. 312-345.

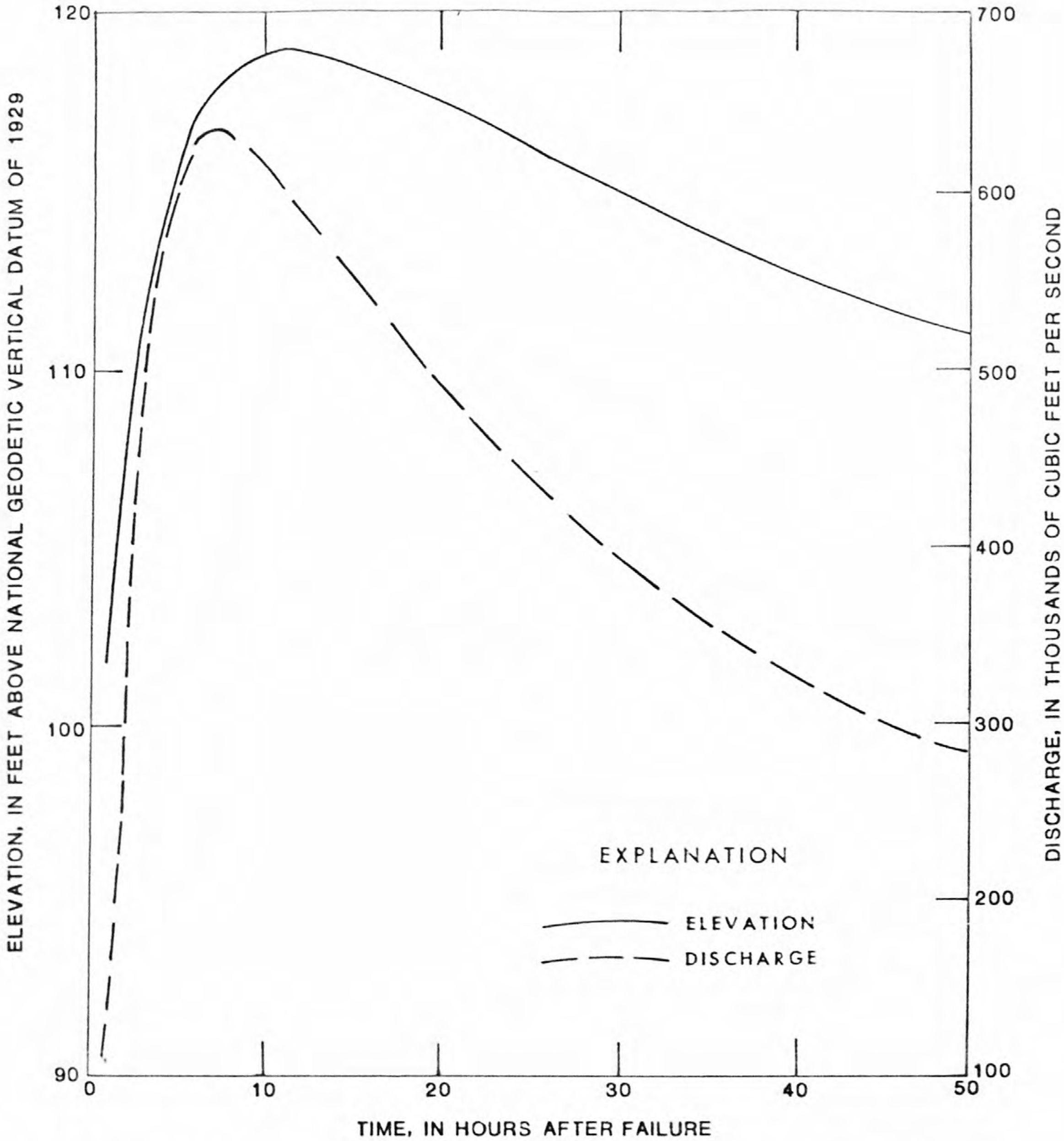

Figure 2.--Elevation and discharge hydrographs for the Sabine River at Burkeville, Tex., after 25-percent dam failure during 100-year flood.

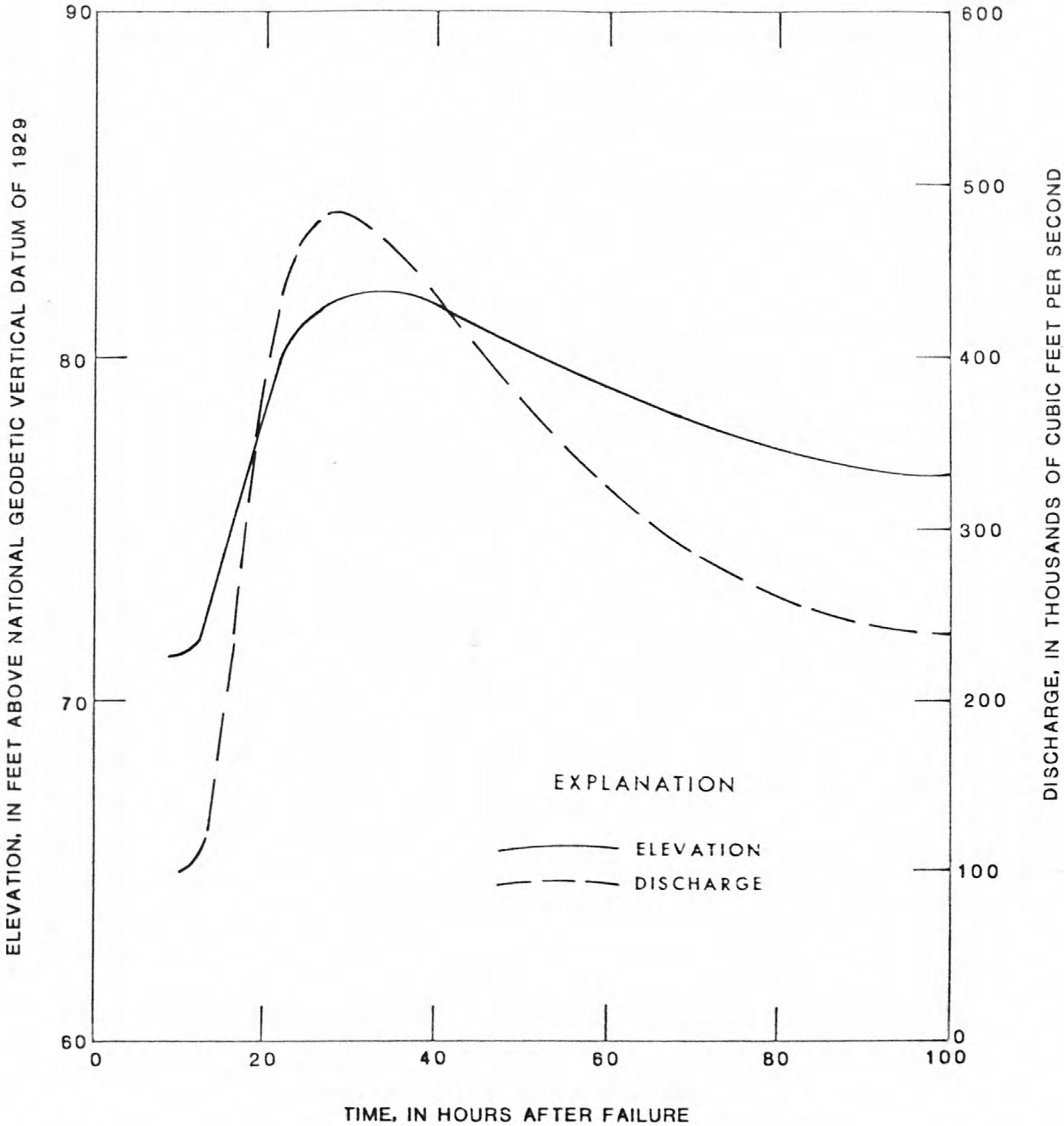

Figure 3.--Elevation and discharge hydrographs for the Sabine River at Bon Wier, Tex., after 25-percent dam failure during 100-year flood.

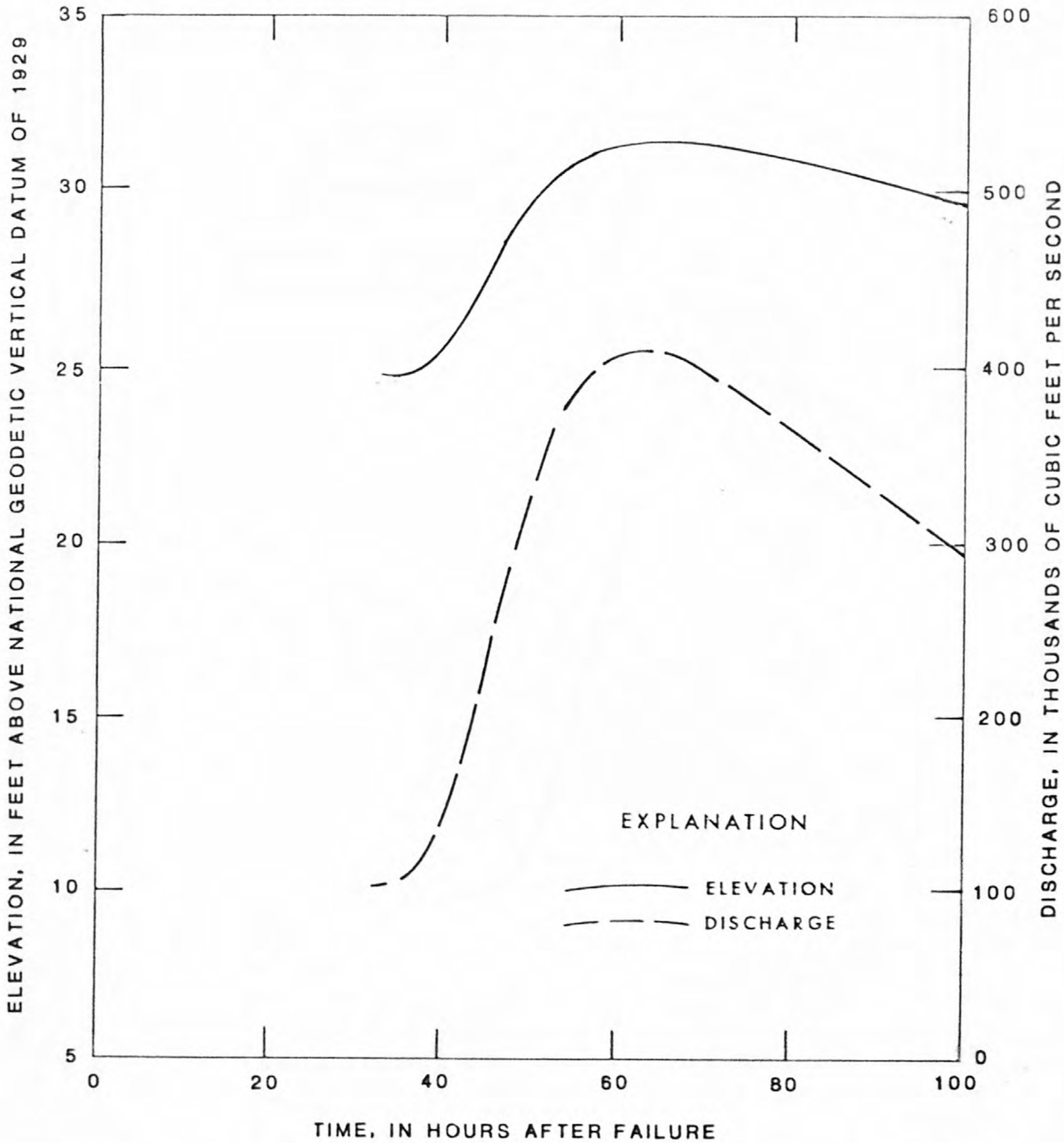

Figure 4.--Elevation and discharge hydrographs for the Sabine River at Ruliff, Tex., after 25-percent dam failure during 100-year flood.

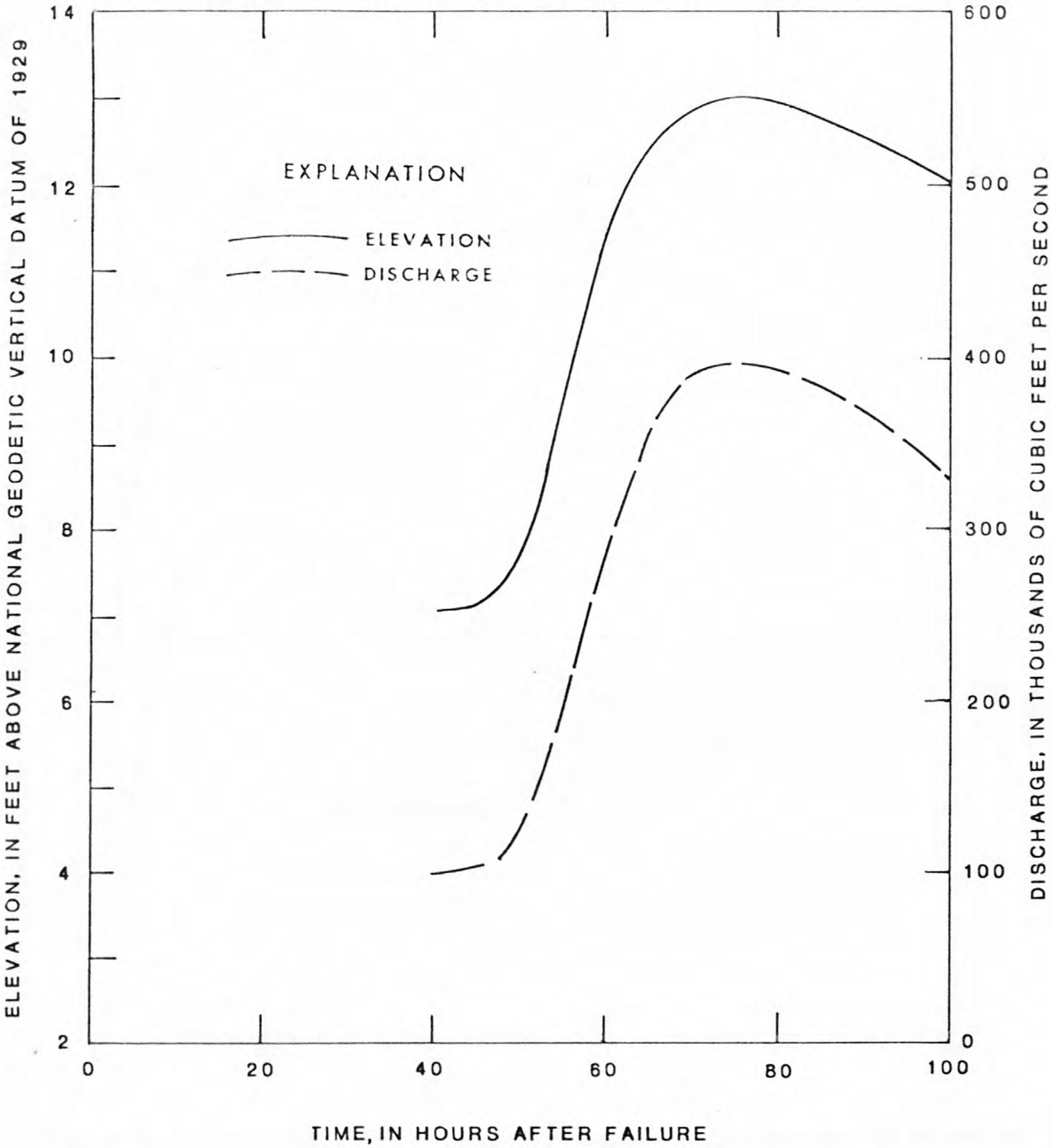

Figure 5.--Elevation and discharge hydrographs for the Sabine River at Orange, Tex., after 25-percent dam failure during 100-year flood.

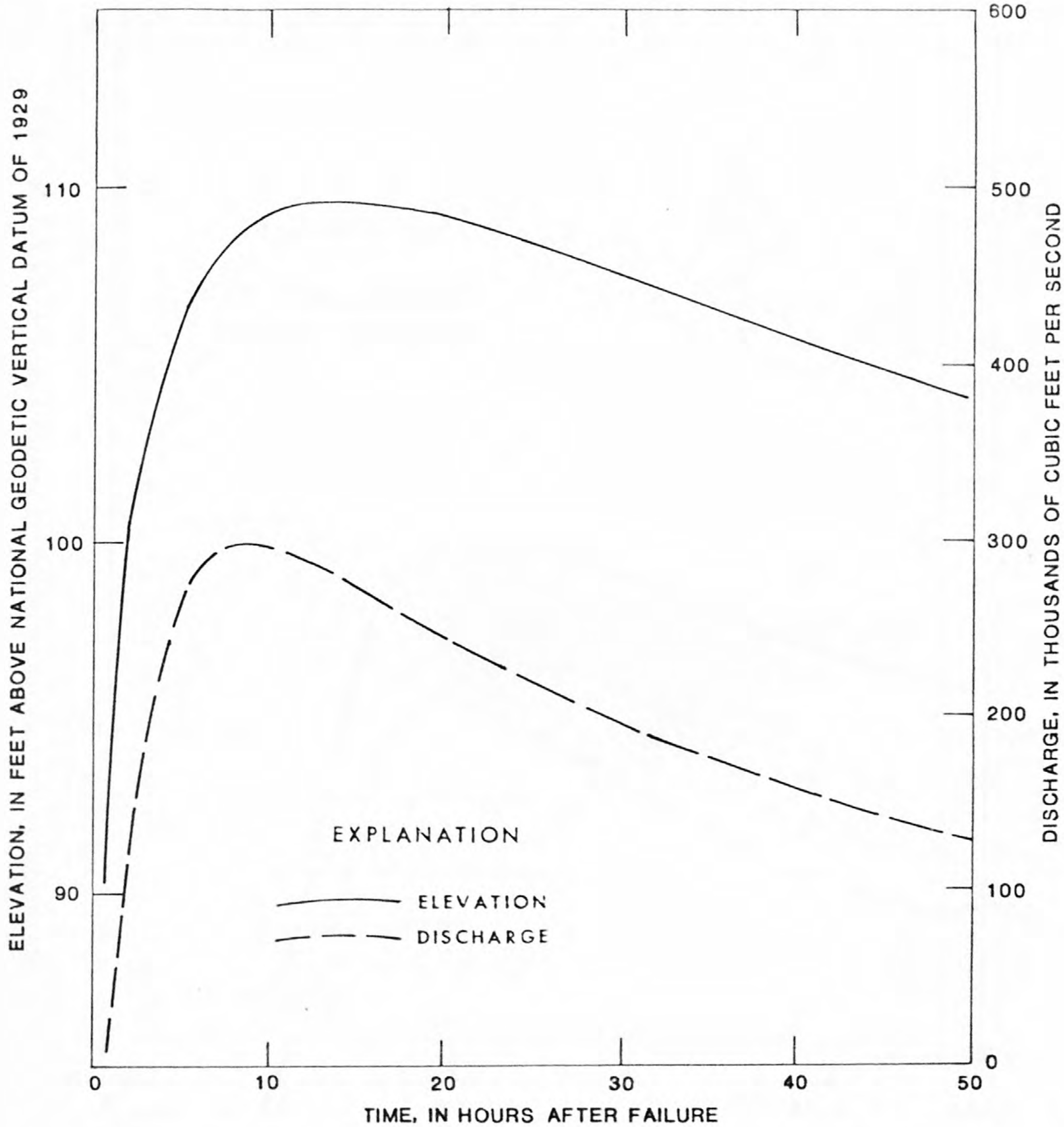

Figure 6.--Elevation and discharge hydrographs for the Sabine River at Burkeville, Tex., after 25-percent dam failure during average discharge.

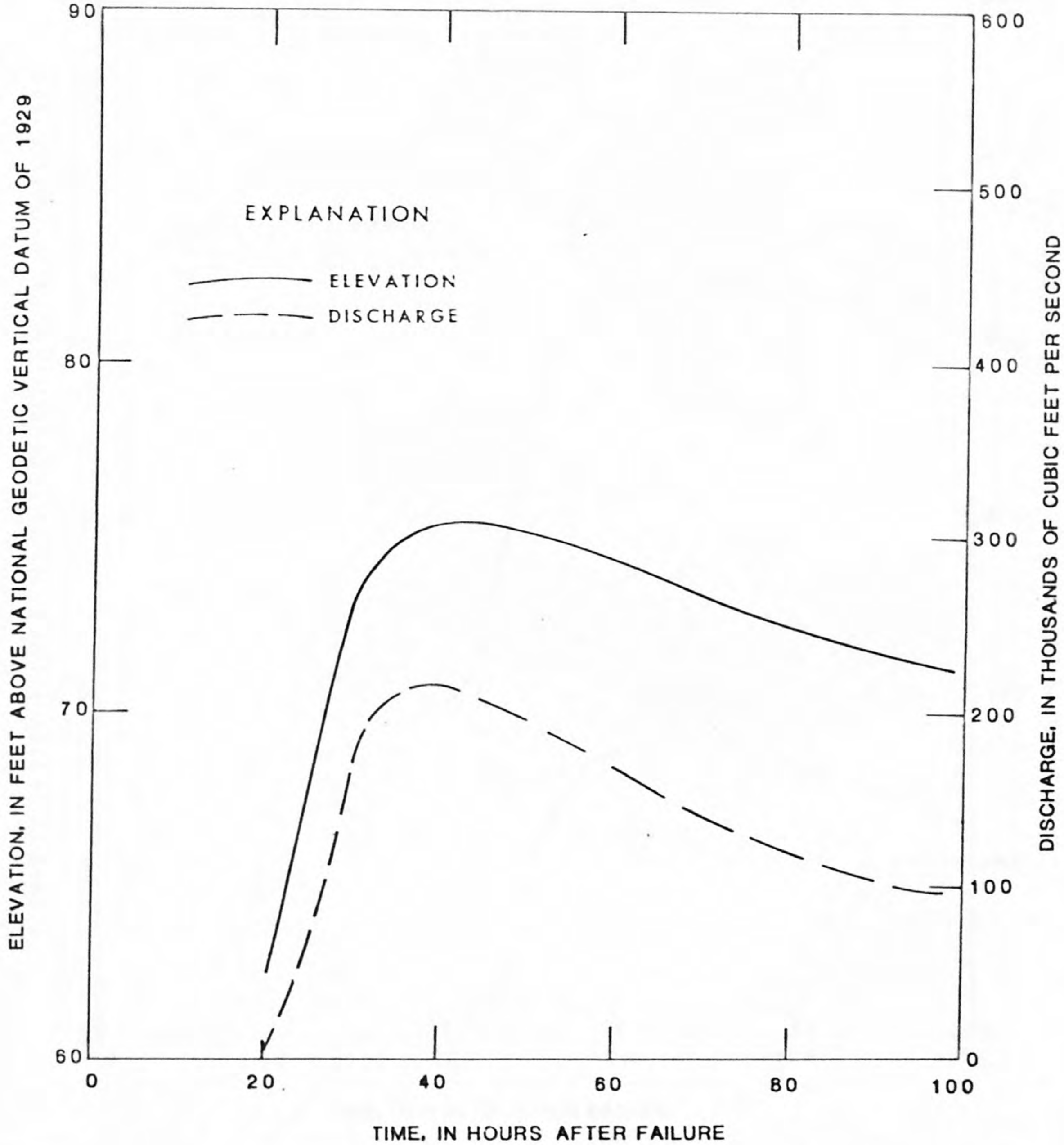

Figure 7.--Elevation and discharge hydrographs for the Sabine River at Bon Wier, Tex., after 25-percent dam failure during average discharge.

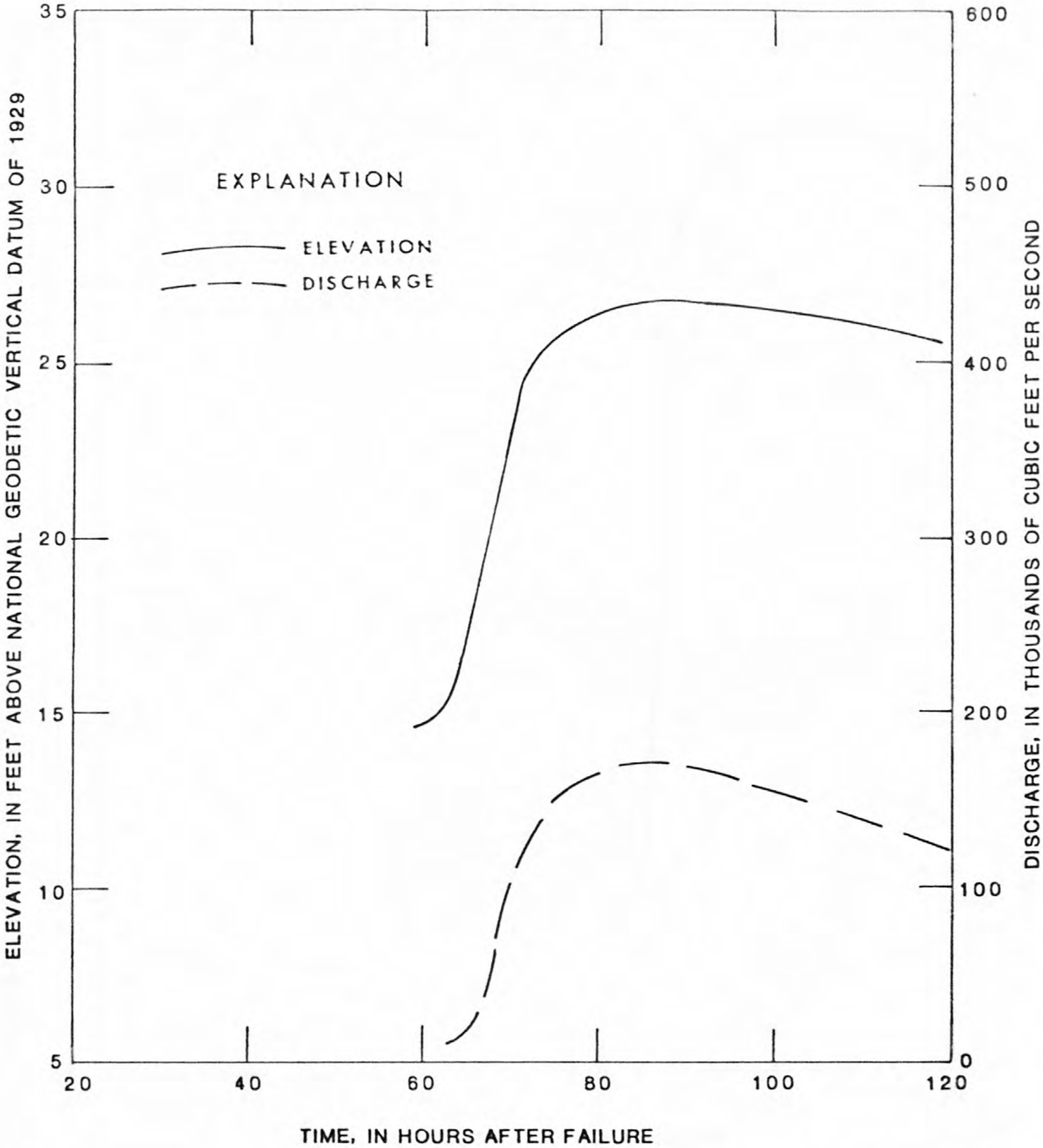

Figure 8.--Elevation and discharge hydrographs for the Sabine River at Ruliff, Tex., after 25-percent dam failure during average discharge.

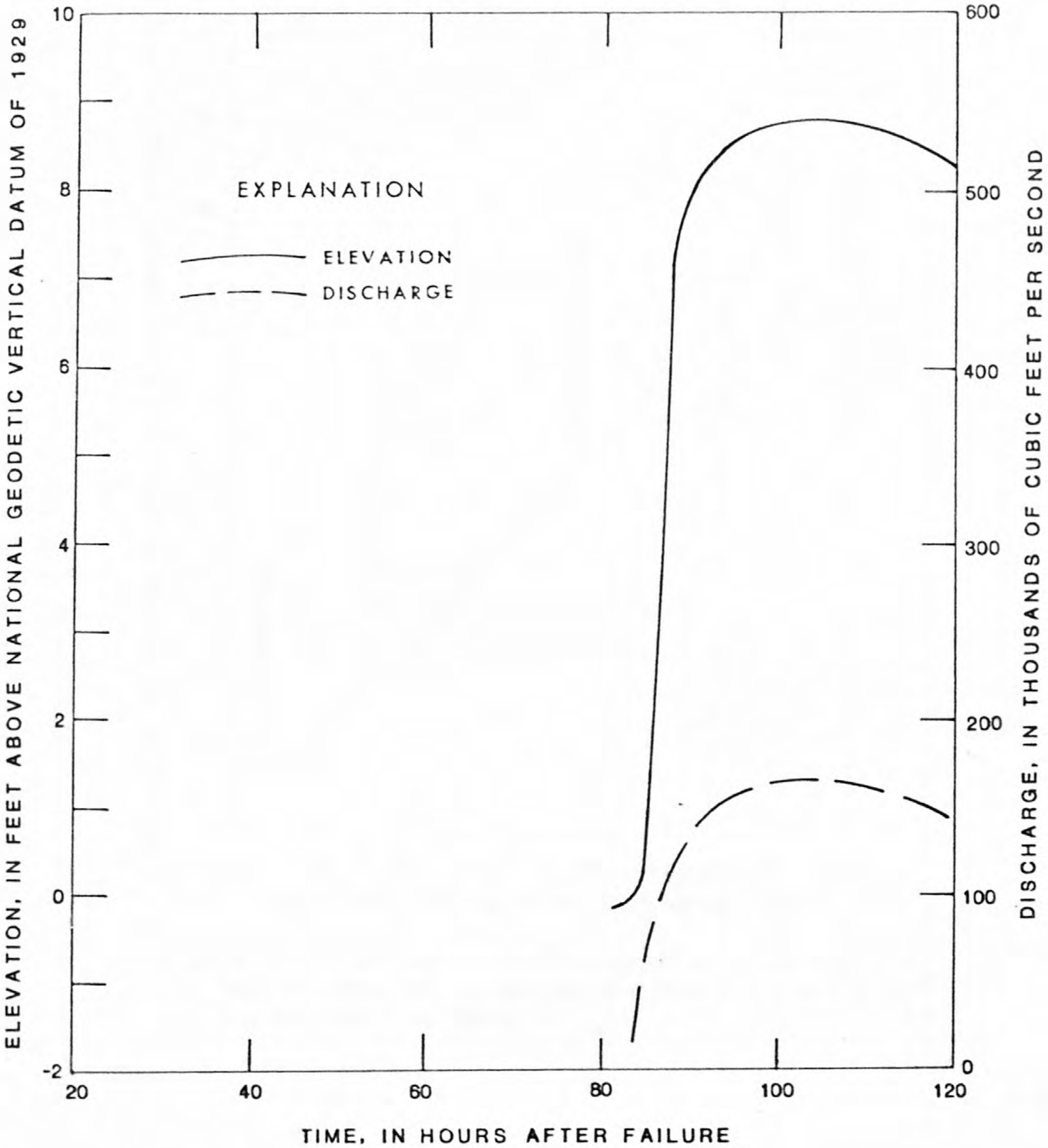

Figure 9.--Elevation and discharge hydrographs for the Sabine River at Orange, Tex., after 25-percent dam failure during average discharge.

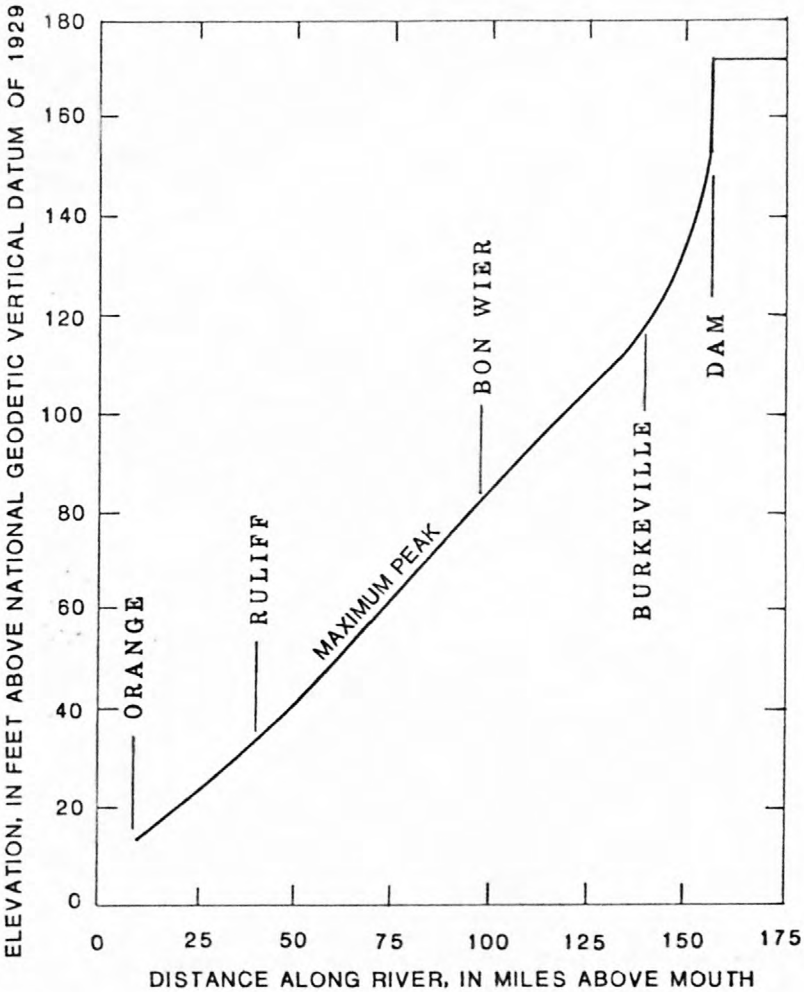

Figure 10.--Peak water-surface profile along the Sabine River after 25-percent dam failure during 100-year flood.