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Hydrologic Investigations of the Burge Branch Watershed

For
1960, 1961, 1962 Water Years

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INTRODUCTION

To design hydraulic structures, it is necessary to estimate the volumes and rates of runoff that may occur. These estimates are most accurate when based on long term records of rainfall and runoff from the watershed involved. Such records have not been collected from most small watersheds and, due to cost and time limitations, they will not be collected. One practical method of estimating runoff volumes and rates involves determining the relationships between important watershed characteristics and runoff. This information may then be used to adjust rainfall and runoff data from a gaged watershed so that it is applicable to similar, nearby watersheds.

Many of the relationships between watershed characteristics and runoff have already been studied and are now understood on a qualitative if not quantitative basis. However, the relationships between combinations of soil conservation practices and runoff have not received sufficient study, and are not well understood. Although many studies of the effects of individual soil conservation practices on runoff have been conducted on small plots (1/100 acre to 5 acres), few studies have been conducted to determine the effects of combinations of these practices on watersheds containing between 5 and 500 acres. Combinations of soil conservation practices may have an appreciable effect on runoff from 5 to 500-acre watersheds. Watersheds of this size are important because they are of the size most often involved in the design of stabilization and flood retarding structures on agricultural land.

In order to provide additional information concerning runoff from watersheds of the 5 to 500-acre size, the University of Missouri and the United States Geological Survey began cooperative studies of the Burge Branch Watershed located near Arrow Rock, Missouri, in October, 1959. This study is part of a larger project also begun in 1959 by the University of Missouri to study the economic, technological, and social status of the farms in Blackwater and Lamine Townships in Cooper County (10)

This bulletin is the first of an expected series of reports dealing with the hydrological data collected from the Burge Branch Watershed. The purpose of the study reported in this bulletin was to analyze and summarize the data collected from the Burge Branch Watershed, and to determine, if possible, the effects on runoff of the soil conservation practices applied to the watershed.

DEFINITIONS OF TERMS USED

Hydrograph--A graph indicating flow of water with respect to time.
Lag time--Time from beginning of most intense rainfall to peak rate of runoff.
Rating curve--A graph indicating the relation between the elevation of the stream water surface and the stream discharge rate.
Runoff frequency--Over a long period of years, the average number of times a runoff event of a given magnitude is likely to occur; i.e., the "100-year frequency runoff event" is an event which has a probability of being equaled or exceeded once in every 100 years or one chance in 100 of occurring in any one year.
Runoff rate--The rate of flow past a given point at a given instant, expressed as volume per unit of time (usually cubic feet per second).
Water year--A period of time equal to one year, but beginning and ending during some period of low flow. For purposes of this study--October 1 to September 30.
Weir--A barrier placed in a stream to constrict the flow and cause it to fall over a crest. Used for measurement of the runoff rate.

REVIEW OF LITERATURE

Soil Conservation practices may reduce volumes of direct runoff by either increasing soil infiltration rates or by increasing permanent surface storage. These practices may produce delays in runoff (and hence peak rate of flow reductions) by increasing the amount of interflow, by increasing the length of the longer watercourses, by reducing the velocity of flow, or by increasing temporary storage.

Effects of Reservoirs on Runoff

Often the effects on runoff of one or a very small group of reservoirs is predictable. When the inflow rates of runoff, the volumes of storage, and spillway capacities for each reservoir stage are known, the outflow rates may be computed for a given storm by various flood routing procedures.

Where several reservoirs are involved, flood routing procedures become complicated and inaccurate. For this reason and because evaporation and infiltration losses are difficult to predict, direct measurements have been useful.

Frank R. Crow has undertaken studies near Stillwater, Okla. to determine the effects of small farm ponds on runoff from small watersheds. (3) (4) His studies were conducted on two grassland watersheds containing 92 and 206 acres, respectively. The 92-acre watershed (average slope, 5 percent) included one pond containing 1.15 acre-feet of storage located at the upper end of a branch of the main channel. The 206-acre watershed (average slope, 6 percent) included three ponds containing 5.84 acre-feet total storage. The ponds were located at the upper end of the three principal drainage channels on the watershed. The records from the four-year study included 14 months of excess rainfall (over 36 inches per year) and 34 months of deficient rainfall (under 27 inches per year). From the study it was concluded that the pond in the 92-acre watershed reduced total watershed runoff by an average of 2.25 percent. The three ponds in the 206-acre watershed reduced total runoff from that watershed by an average of 4.76 percent. A double mass plotting showed that the ponds produced maximum reductions in runoff (about 10 percent) during dry periods, and had little or no effect during very wet periods.

In his discussion, Crow defined three separate conditions that have an influence on runoff:

Condition I. Pond level is low. Available storage capacity exceeds direct rainfall and rainfall runoff. Pond will not fill during storm. Watershed area is reduced by the amount of the pond drainage area and remains constant throughout runoff period.

Condition II. Pond is partially filled. Available storage capacity is less than direct rainfall and runoff. Pond will fill before the end of storm runoff. Watershed area is variable during runoff period.

Condition III. Pond is full at beginning of storm. All storm runoff flows through spillway and contributes to total watershed runoff.

These conditions show how important the initial pond water level is in determining runoff. Crow has suggested that the pond water stage should be recorded on all experimental watersheds by stage recorder, or, if this is impracticable, at least by taking periodic measurements using a staff gage.

The upstream ponds investigated by Crow had little effect upon peak rates of runoff except to the extent that they reduced the size of the watershed during dry periods (Condition I).

Austin W. Zingg studied the effects of small farm ponds on runoff from the Meremac River basin in Missouri (18). He used flood routing procedures and assumed 12 ponds per square mile. In one case he assumed "ordinary" farm ponds with a capacity of 2.3 acre feet and a drainage area of eight acres. In another case he assumed "retarding" farm ponds with a capacity of 2.3 acre feet below the pipe spillway and a capacity for 1.3 inches of runoff from the watershed between the pipe spillway and the side spillway. The watershed size was eight acres. From an analysis of 16 years of hydrologic data he estimated that the ordinary ponds would reduce damage-producing floods by two percent and that the retarding ponds would result in an average reduction in floods of eight percent.

Effects of Graded Terraces on Runoff

The effects of graded terraces on runoff have been studied on small plots of less than 10 acres; they have also been studied to a limited extent on watersheds ranging in size up to about 500 acres. Generally, it has been found that graded terraces significantly reduce peak rates of runoff. The reductions in rates of flow are probably the result of temporary storage and rerouting of the runoff. Terraces apparently will not consistently reduce volumes of runoff. In a few cases terraced areas produced more runoff than comparable, but unterraced areas.

Studies were made by the Soil Conservation Service at Bethany, Mo., on Shelby and related soils. (12) The plots used were from five to eight acres in size, were contour farmed, and were cropped in a rotation including corn, oats, wheat, and clover. A study of the 10 largest storms in the eight years of record was made comparing records from the terraced areas with records from the unterraced areas. The average rainfall per storm (for the 10 largest storms) was 1.5 inches, and the average peak rate of rainfall was 2.6 inches per hour from the unterraced watershed compared to 1.2 inches per hour from the terraced watershed. This represents more than a 50 percent reduction in peak flow for fairly large storms on these small plots. (9)

At Bethany, the reductions in average yearly runoff volumes due to terracing ranged from 16.5 percent for a two-year period of corn, up to 43.6 percent for a two-year period of oats on the watersheds. (12) (13) Most of the volume reduction occurred during small storms. During the nine most severe storms in the eight years of record, between 50 and 60 percent of the rain appeared as runoff, and the average reduction in volumes of runoff due to terraces amounted to only 11 percent. During two of the large storms, slightly more runoff was produced from the terraced watersheds than from the unterraced watersheds. (8)

In another study, this one at the Red Plains Experiment Station near Guthrie, Okla., on three to four-acre plots of cotton and cowpeas. results similar to those from Bethany, Mo., were obtained. The 10 largest storms of record produced an average of 3.8 inches of rain per storm. The peak rates of runoff from these storms averaged 0.7 inch per hour from the terraced plot and 1.6 inches per hour from the unterraced plot. As at Bethany, this represents approximately a 50 percent reduction in peak runoff rates for fairly large storms. The terraced areas had 1.26 inches (33 percent) runoff on the average for the 10 largest storms compared with 1.64 inches (43 percent) for the unterraced areas. The difference was about 0.4 inch or about 24 percent reduction due to terracing. (9) (16)

At La Crosse, Wis. experiments have been conducted on Fayette soils in two to four-acre plots planted in a six-year rotation of corn, barley, and four years of hay. (15) Both the terraced and unterraced watersheds were contour-cultivated. In order to make a comparison of peak rates of runoff, Leopold and Maddock (9) again averaged the 10 largest storms of record. They found this gave an average storm size of 2.6 inches, and an average peak rate of flow from the terraced watersheds of 0.9 inch per hour compared to 2.4 inches per hour from the unterraced watershed. This represents a 62 percent reduction in peak rates of flow.

In another paper covering the work in Wisconsin, Hayes et al. reported that the total runoff from the terraced watersheds represented 10.39 percent of the rainfall as compared to 7.49 percent for the unterraced watersheds. (7) Furthermore, they found the percentage of runoff varied greatly between storms, with one watershed producing more runoff in one storm, and another watershed producing more in another storm. At any rate this experiment represents a case where terraces increased the total runoff from a watershed by 38.5 percent.

On the Blacklands Experimental Watershed near Waco, Tex. studies have been made on fairly large areas. (2) Rainfall and runoff records were taken for a period of five years from two untreated watersheds, one containing 176 acres and the other 132 acres. At the end of the five years, a conservation program was started on the 176-acre watershed which included increased areas of grassland; the addition of legumes to the crop rotation of oats, corn, and cotton; and the construction of a large number of terraces. Rainfall and runoff records were then continued for more than 10 years. The results indicate that the peak runoff rates were reduced by about 0.48 inch per hour. That is, a peak rate of one inch per hour was reduced to 0.52 inch per hour, but a peak rate of 3.0 inches per hour was reduced only to 2.52 inches per hour. The runoff volumes were compared and it was found that when the watersheds were dry, both areas absorbed large amounts of precipitation, thereby greatly reducing the runoff from both watersheds. Under saturated conditions, most of the precipitation on either watershed was delivered as runoff. However, when the soil was partially wetted, the conservation practices caused a marked reduction in runoff volumes.

At Hastings, Nebr. experiments were conducted on still larger watersheds. (1) Rainfall and runoff records were collected from a 481-acre watershed and a 411-acre watershed. Two periods were selected for comparison. During the first period (1939-1947) both watersheds were farmed in straight rows. During the second period (1947-1952) 65 percent of the planned terraces and grassed waterways were built on the 411-acre watershed, and legumes were increased from about one percent to about 15 percent while the grassland was increased from about 17 percent to about 30 percent. The 481-acre watershed continued to be farmed in the original manner. During the first period, a close simlarity in runoff was observed between the two watersheds, but during the second period the treated watershed produced 30 percent lower volumes of runoff and 50 percent lower peak rates of runoff than did the untreated watershed.

It should be noted that in the latter two examples cited above, the cropping systems were improved on the terraced watersheds.

Stallings has summarized the experiments that have been conducted to determine the effects of terraces on volumes of runoff. (13) His summary shows that in 20 experiments in seven states, the average reduction in runoff volumes due to terracing for all the storms of record was 27 percent. In three of the experiments (covering short periods of time) runoff was completely eliminated by terraces. In five of the 20 cases the runoff volumes were increased by terraces.

DESCRIPTION OF THE BURGE BRANCH WATERSHED

Size and Location

The watershed is 216 acres in size. The north end of the watershed is about one-half mile south of Arrow Rock, Mo., on state highway 41. Most of the watershed is contained in a farm owned by O. L. Burge of Blackwater, Mo. William Burge assisted in collection of much of the data.

Climate

According to weather records from Boonville, Mo., the area of central Missouri in which this watershed is located has a mean annual temperature of 54.2° F, and monthly mean temperatures ranging from 29.1° F for January to 77.4° F for July. Yearly extreme temperatures in the area normally range from below 0° F to over 100° F. The mean annual precipitation is 40.18 inches. The mean monthly precipitation varies from 1.72 inches for January to 5.19 inches for September. Averages indicate that about 10 times each year, one inch or more of precipitation will fall in less than 24 hours. The average length of the growing season for the area is 190 days. (17)

Topography

A contour map of the Burge Branch Watershed is shown in Figure 1.* The area is composed of rolling upland, with slopes ranging from three to seven percent. The average slope of the watershed is five percent, assuming the average is equal to the total length of the contour lines shown in Figure 1 multiplied by the contour interval and divided by the area of the watershed. (5) The main channels on the watershed are shown in Figure 2. They are up to 10 feet deep and 15 feet wide and are very crooked.

Soils

Slightly eroded loessial soils are found on the watershed. Grundy soils are found on the ridges and Sharpsburg soils, on the slopes. Sharpsburg soils are permeable and well aerated, but Grundy soils have some restriction in subsoil drainage and are not as well aerated as are Sharpsburg soils. (11)

Land Use and Structures

Before 1959. In the virgin state, the Burge Branch Watershed was probably covered with timber. This timber was removed from the cropland long ago, however, and in recent years (prior to 1959) the cropland of the watershed has been planted primarily to pasture, hay, and small grain, with small acreages planted to row crops. (Figure 2). The areas adjacent to the main ditches remained in timber.

As can be seen in Figure 2, many terraces existed on the watershed prior to 1959. However, erosion had caused these terraces to become practically useless by 1959. The small ponds on the watershed were constructed in the late 1940s and early 1950s. Soil treatments other than liming had not been used extensively prior to 1959.

1959. Beginning in 1959, accurate records of the watershed's use were kept. During the 1959 crop year, 30 acres were planted to corn, 79 acres were planted to wheat and oats and 62 acres were in hay and pasture (Figure 3). The only soil treatment applied in 1959 was an

*See Appendix, pages 19-42, for figures.

application of 2.5 tons of lime per acre over an eight acre area along the terraces shown in Figure 3.

Water control structures built in 1959 are shown in Figure 3, and consist of 2000 feet of terraces, and a 500-foot terrace outlet.

1960. Crops grown in 1960 on the Burge Branch Watershed included 113 acres of corn, three acres of sorgo, 56 acres of grass and hay and three acres of wheat (Figure 4). Fertilizer applied to the areas in corn east of the highway was equivalent to 70 pounds of nitrogen per acre, 40 pounds of P_2O_5 per acre, and 40 pounds of K_2O per acre. No lime was applied in the 1960 crop year.

Comparison of Figure 3 with Figure 4 shows the water control structures built in 1960. Structures added in 1960 included 13,000 feet of terraces, 1,780 feet of terrace outlets, and 1,000 feet of diversion channel. The diversion channel serves as a spillway for the ponds located in the main channel.

About four acres of land were cleared of brush and timber in 1960. Most of the area cleared is located just below the ponds in the main channel.

1961. Figure 5 shows the watershed as it was in 1961. One hundred twenty-four acres were planted to corn, 15 acres were planted to small grain, and 38 acres were in hay and pasture. In 1961 most of the corn yielded between 90 and 100 bushels per acre, whereas, in the other years for which records were available, the corn yield was between 75 and 80 bushels per acre.

No lime was used on the watershed in 1961, and fertilizer was applied only to the areas in corn east of the highway. The fertilizer was applied in amounts equivalent to 80 pounds of nitrogen per acre, 40 pounds of P_2O_5 per acre, and 40 pounds of K_2O per acre.

The location of terraces built in 1961 can be determined by comparing Figures 4 and 5. The added terraces, primarily at the lower end of the watershed, have a total length of 10,500 feet. Note in Figure 5 that in 1961, two small areas of land were removed from the watershed by new terraces which did not drain into the main channel of the watershed. The area removed from the watershed was approximately three acres.

An area of about two acres was cleared and leveled in 1961. The area included a small ditch and was part of the area terraced in 1961. The exact location of the area can be determined by comparing the lower portion of the watershed shown in Figure 4 with that shown in Figure 5.

1962. The watershed as it was in 1962 is shown in Figure 6. Crops included 116 acres of corn, 53 acres of hay and pasture, about four acres of oats, and four acres of soybeans.

Fertilizer applications were made only to the areas in corn in 1962, and proved the equivalent of 100 pounds of nitrogen, 45 pounds of P_2O_5, and 40 pounds of K_2O per acre. No lime was applied.

Two terraces, totaling approximately 2,000 feet in length, were built in 1962. Comparing Figures 5 and 6, it can be seen that one of the added terraces is located near the center of the watershed, while the other terrace is located in the northeast corner of the watershed. The latter terrace removed approximately three acres of land from the watershed.

Only one small area of land was cleared in 1962. This area, about two acres, is located near the center of the watershed at the north end of one of the terraces built in 1962.

INSTRUMENTATION OF THE BURGE BRANCH WATERSHED

Instrumentation for this project was provided by the U. S. Geological Survey. It consists of a weir, water level recorder, and two recording rain gages. This equipment is located as shown in Figure 1.

The weir serves as a reference point for the watershed, located at Latitude 39° 02' 45", Longitude 92° 56' 35", in the SW 1/4 of the NE 1/4, Sec. 1, T49N, R19W. (14)

The water level recorder, an automatic and continuously operating Stevens A-35 model, is in a small metal house over a 42 inch corrugated metal pipe well (Figure 7) near the weir (Figure 1). This recorder records to the nearest 0.01 foot, and is adjusted to read the same as a reference enamel staff gage inside the well. Water enters the well through a three inch steel pipe about eight feet long. Mud is flushed from this intake pipe by releasing water from an elevated tank into the pipe.

One of the rain gages is a tipping bucket rain gage, located on the roof of the metal house described above, (Figure 7). This rain gage measures rainfall to the nearest 0.1 inch and records on the same graph paper as does the water level recorder.

The other rain gage is a continuous weighing type, located near the farmstead shown in Figure 1. This rain gage records to the nearest 0.01 inch.

Two V-notch weirs have been used on this project. The original V-notch weir, Figure 7, was a concrete wall about eight inches thick, with a road grader blade set on edge in the concrete to form a sharp crest. Each side of the original V-notch weir was 4.75 feet long and the two sides of the V-notch formed an angle of 130°. This weir provided a control accurate enough for the measurement of low flows to within 0.05 cfs, but did not extend high enough to provide an accurate control for the measurement of depths of flow of more than two feet. Above two feet, the stream bank provided the control, except at extreme depths where the bridge downstream acted as the control.

In December, 1961, the county road bridge just downstream from the weir was replaced by a five-foot diameter, corrugated metal culvert. During the installation of the culvert, brush was piled in the channel downstream (about 200 feet) from the road. This brush was not removed upon completion of construction and remained to provide a restriction to flow, which caused deposition of silt over the weir. To avoid this silt deposition and lack of accurate control at high flows, a new weir was constructed October 18, 1962.

The new V-notch weir (Figures 8, 9, and 10) also consists of a concrete wall, eight inches thick, with a V-shaped top, and with a road grader blade set on edge along the center of the concrete to form a sharp crest. Unlike the original weir, however, the new one spans the entire channel and provides an accurate control for all but extreme depths of water. At extreme depths the five-foot culvert in the county road just downstream acts as the control. Also unlike the original structure, the new one has a concrete apron over the five-foot distance between the new weir and the culvert (Figure 10). The sides of the new V-notch weir form a 155° angle and are of unequal length. The left end of the new weir is 1.09 feet higher than the right end. The crest of the new weir is 1.32 feet higher than the crest of the old weir.

Discharge measurements at various depths of flow were made by personnel of the U. S. Geological Survey. Extreme low flow measurements were made volumetrically. Other low flow measurements were made by wading and using a Price Current Meter. At medium and high stages, a Price Current Meter was used, and readings were taken from the bridge (above the weir) at two-foot intervals along the bridge.(14) These measurements were used to plot a rating curve for the recorder and weir combination. A rating curve for the new weir is being determined.

COLLECTION OF DATA

Sources of Data

A contour map of the Burge Branch Watershed (Figure 1) was plotted from data collected by a stadia survey.

Records of the various crops grown, of the lime and fertilizer treatments used, and of the structures constructed on the watershed were collected by Myron Bennett, associate county agent of Cooper County.

The U. S. Geological Survey assumes the responsibility for collecting rainfall and runoff data from the watershed, and for providing and maintaining this equipment.

Quantity and Quality of the Data

The rainfall records from the Burge Branch Watershed are continuous from October 8, 1959, when the equipment was installed, except for short periods when the records were lost or were not obtained due to mechanical failure of one of the rain gage recording mechanisms.

The rainfall records are of only fair quality. The tipping bucket rain gage records only tenths of an inch of rainfall (versus time). An hour of time is represented by only 0.2 inch of distance on the time scale of the recording graph paper of the tipping bucket rain gage. Also, tipping bucket rain gages generally do not keep up with very intense storms, and therefore, record less rainfall than is actually received.

Another problem adversely affecting the quality of the rainfall data from this watershed is that the two rain gages are too close together and insufficient in number to give a clear indication of variation of total rainfall or speed and direction of travel of a storm over the watershed. The two rain gages in use have generally failed to give any indication of the direction of travel of past storms because the timing mechanisms of the two rain gages were generally not carefully synchronized with each other.

The quality of runoff records from the Burge Branch Watershed is good for the periods when the deposition of silt did not occur at the intake to the recorder well or elsewhere near the weir. However, silt covered the intake to the recorder well, causing complete loss of runoff records, or accumulated near or on the weir causing loss of accurately calibrated records, during several storms between October 8, 1959. and September 30, 1961. Also, after the new culvert was placed in the road in the fall of 1961, sediment completely covered the intake to the recorder well and bottom of the weir, causing an almost complete loss of accurate records from October 1, 1961, to October 18, 1962. On October 18, 1962, the recorder intake was raised, and a new weir was installed, which eliminated the sediment problem.

An additional problem was that the original weir did not provide an accurate control for large flows. This problem has also been corrected by the installation of the new weir.

In summary, there are several gaps in the rainfall and runoff records from the Burge Branch Watershed, but the records that were collected are of fairly good quality. Runoff records collected in the future are expected to be of consistently better quality than past runoff records.

The crop, soil treatment, and conservation structure records are in detail, and are generally accurate.

DISCUSSION OF DATA

The collection of rainfall and runoff records from the Burge Branch Watershed began on October 8, 1959, and will continue indefinitely. This bulletin, covers records collected between October 8, 1959, and October 1, 1962. For convenience, the records used herein were divided into 1960, 1961, and 1962 water years. Each water year was assumed to begin on October 1, and end September 30.

Peak Rates of Runoff

The highest peak rates of runoff from a watershed result from those storms producing the most rainfall within a period of time approximately equal to the lag time for the watershed. The lag time has been between 30 and 50 minutes for most storms on the Burge Branch Watershed. Therefore, high peak rates of runoff from storms having high 30 to 50-minute rainfall intensities would be expected. The peak rate of runoff will also depend on the amount of storage available and the infiltration rate of the soil.

Between October 8, 1959, and October 1, 1962, the highest instantaneous peak rate of runoff was 134 cfs. This runoff rate (Figure 11) occurred on September 13, 1961 as the result of a storm associated with hurricane Carla. During the storm, high wind was observed, and a rainfall of 7.1 inches within a 20-hour period was recorded. The rainfall intensity of this storm began at less than 0.1 inch per hour, and gradually over a six-hour period increased to about 0.8 inch per hour. The rainfall intensity then increased to a peak rate of two inches per hour for about 30 minutes. The first two inches of very low intensity rainfall were omitted from Figure 11.

This storm was a 75-year frequency occurrence for a 12-hour duration storm. However, it was less than a two-year frequency occurrence for a 40-minute duration storm. (6) Only small amounts of rain had fallen during the 30 days preceding this storm. The infiltration rate of the soil was high and a large volume of storage was available in ponds and other depressions at the beginning of the storm. However, the peak intensity of this storm occurred after the storm had been in progress for 12 hours and had produced 3 inches of rainfall. For this reason, the watershed was probably nearly saturated during the peak rainfall and runoff event.

The second highest instantaneous peak rate of runoff from the Burge Branch Watershed for this period occurred on March 7, 1961 (Figure 12). The peak runoff rate was 112 cfs. The storm represented only 1.33 inches of rainfall, but began with a rainfall intensity of about 3.5 inches per hour for about five minutes and then dropped to 2.5 inches per hour for an additional 15 minutes. The 40-minute peak period of this storm produced about 0.9 inch of rain and had a frequency of occurrence of less than two years. (6) Large hail and high winds accompanied the earlier part of this storm. Since the soil was wet before the storm, and the soil contained some frost, the infiltration rate of the soil was very low even during the first part of the storm.

The third highest instantaneous peak flow in the 1960, 1961, and 1962 water years was measured on November 15, 1960, and amounted to 66.8 cfs (Figure 13). This peak flow was caused by a rain of approximately 1.57 inches. The rain had an intensity of about 1.2 inches per hour for about one hour. The 40-minute peak intensity for this storm had a frequency of occurrence of less than two years. (6) Only about 0.1 inch of rain had fallen in the 17 days prior to November 15, 1960, and less than normal rain had fallen during the four months prior to the date, indicating that pond and depression storage was available and the infiltration rate of the soil was high at the beginning of the storm.

Volume of Runoff

The largest volume of runoff for any 24-hour period resulted from the storm producing the highest peak flow for the records being considered. This storm, shown in Figure 11, has already been discussed. It occurred September 13, 1961, and produced about 2.34 inches of runoff from 7.1 inches of rain within a 24-hour period. The watershed was dry, initially, but probably became saturated before the storm was half over.

The second largest 24-hour volume of runoff resulted from a storm on March 20, 1962 (Figure 14). Runoff on this date amounted to 1.25 inches from the watershed in less than 24 hours. The rain amounted to 2.2 inches over a 16-hour period. The maximum rainfall intensity did not exceed 0.3 inch per hour. This large valume of runoff was caused in part by a low infiltration rate resulting from frost in the soil.

The third largest 24-hour volume of runoff occurred May 5, 1960; it amounted to approximately 0.80 inch of runoff from the watershed (Figure 15). The storm causing this runoff totaled 2.71 inches of rainfall in a 6-hour and 45-minute period. A maximum rainfall intensity of about 0.85 inch per hour occurred for about two-hours. Although no rain had fallen in the six days prior to May 5, 1960, rains totaling 1.8 inches fell between April 28, 1960, and April 30, 1960.

Runoff Frequency and Duration

Measurable runoff (more than 0.005 cfs) was recorded on 284 days during the 1960 and 1961 water years. Records for the 1962 water year were not accurate enough for these determinations. Measurable rainfall (more than 0.05 inch) occurred on 152 days of the 1960 and 1961 water years. In general, separate rains of less than 0.35 inch on fairly dry soil did not produce runoff, but large rains on wet soil sometimes produced small amounts of runoff for 10 or more days.

During the 1960 and 1961 water years, monthly runoff volumes ranged from no flow during four months to 2.7 inches during September, 1961.

Accumulated Rainfall and Runoff

The mass rainfall curves in Figure 16 indicate that the rainfall patterns for the 1960 and 1961 water years were similar from February 1 to July 1, but during the other months, much more rain was recorded in the 1961 water year than in the 1960 water year. Total rainfall for the 1961 water year was 50.4 inches and that for the 1960 water year, 25.6 inches.

The mass runoff curves shown in Figure 17 demonstrate how dissimilar the runoff volumes were for the two water years. The total volume of runoff for the 1960 water year was 3.18 inches and for the 1961 water year, 8.40 inches. The large difference in these runoff volumes is due to the occurrence of two more large storms in the 1961 water year than in the 1960 water year. In fact, the sum of the runoff volumes of only two days, September 13, 1961, and March 7, 1961, almost equals the total runoff for the entire 1960 water year.

The records for the 1962 water year were not accurate enough to be plotted as mass runoff curves. The 1962 water year was dry, and no very large storms occurred.

Analysis of Hydrographs

To determine the effects of soil conservation practices on runoff, it would have been desirable to compare records from storms before soil conservation practices were applied to the watershed with records from similar storms after the soil conservation practices were applied. However, appropriate groups of storms for this purpose are not yet available; in this bulletin, it was necessary to base the comparisons of hydrographs upon storms which were somewhat dissimilar.

A group of storms is presented in the Appendix to indicate the types of hydrographs obtained from the Burge Branch Watershed between October 8, 1959, and October 1, 1962. The storms are grouped by rainfall intensities and include only intense, abrupt rains that had a duration of less than the lag time for the watershed. These storms were chosen because they avoided complicating effects of intermittent and prolonged rains.

By studying the storm data collected thus far, it was possible to detect changes in the hydrograph peaks and lag times for this watershed. The changes apparently were due to the construction of terraces on the upper portion of the watershed (Figure 4). Most of these terraces were built in late May, 1960. The remainder of the terraces (the three lower terraces on the east side of the main channel, Figure 4) were completed in December, 1960.

The changes in hydrograph peaks apparently occurred about May 25, 1960, after the construction of most of the terraces on the upper portion of the watershed. Before May 25, 1960, the hydrographs collected generally had only one peak (examples: Figures 19, 22, 23, and 24). After May 25, 1960, the hydrographs from short intense storms generally had two peaks (examples: Figures 18, 20, 21, 25). For the longer storms after May 25, 1960--where all of the watershed contributed fully to the peak--only one hydrograph peak occurred (examples: Figures 11 and 12).

It is felt that the trend from single peak hydrographs to double peak hydrographs for short intense storms may be explained as follows. The terraces on the lower portions of the watershed carry runoff to points downstream from the points where the runoff originally entered the main channel of the watershed. On the other hand, most of the terraces built on the upper parts of the watershed carry runoff to points upstream from the points where it originally entered the main channel of the watershed. This arrangement of terraces may produce the hydrograph double peaks when, during short storms, the rain stops before all of the watershed contributes to flow. In such a case the terraces in the lower portion of the watershed may contribute their portion of the runoff soon after the beginning of rainfall, thus producing the first peak. Then, after the peak runoff rate from the lower portion of the watershed has passed, the terraces in the upper portion of the watershed contribute runoff, producing the second hydrograph peak. During longer storms runoff increases until all of the watershed contributes to one peak.

Changes in the lag time for the watershed apparently have resulted also from the terraces built in 1960. These changes probably resulted because the terraces built in 1960 were at the upper end of the watershed and runoff in these channels had to flow longer distances than did other runoff from the rest of the watershed.

The average lag time for 8 storms occurring prior to May 25, 1960, was 32 minutes. The range was from 27 minutes to 35 minutes. The shorter time resulted from a storm which occurred when the soil was wet and runoff was still occurring from a previous rain and the longer time resulted from a storm which occurred when the soil was dry.

The average lag time for 7 storms occurring between May 25 and December 31, 1960, was 42 minutes. The range was from 36 minutes to 48 minutes.

The average lag time for 7 storms occurring after December 31, 1960, was 50 minutes with a range from 40 minutes to 55 minutes.

SUMMARY

More information is needed concerning the relationships of rainfall to runoff on watersheds containing between five and 500 acres. To provide more information, the United States Geological Survey and the University of Missouri are conducting cooperative studies on the 216-acre Burge Branch Watershed located near Arrow Rock, Mo.

This watershed is composed of rolling upland with slopes ranging from three to seven percent. The drainage channels of the watershed are well defined. Soils on the watershed are Sharpsburg and Grundy. Instrumentation for this watershed was provided by the U. S. Geological Survey and consists of a weir, water level recorder, and two recording rain gages.

The collection of rainfall and runoff data was begun in 1959 and will continue indefinitely. This bulletin covers the records collected between October 8, 1959, and October 1, 1962. The records were divided into water years, each beginning October 1 and ending on September 30.

The three highest peak rates and volumes of runoff obtained during the three water years are presented. Both the highest peak rate and volume of runoff occurred during one storm. During this storm (September 13, 1961), 6.1 inches of rain fell within 12 hours, producing a peak flow of 134 cfs, and a volume of 1.34 inches of runoff. This storm had a frequency of occurrence of 75 years for a 12-hour duration, but less than a two-year frequency of occurrence for a 40-minute duration. The second highest peak rate of runoff (March 7, 1961) amounted to 112 cfs and resulted from a 1.33 inch rain over a one-hour period. The third highest peak rate of runoff (November 15, 1960) amounted to 66.8 cfs and resulted from a rain of about 1.2 inches over a one-hour period. The second highest volume of runoff (March 20, 1962) amounted to 1.25 inches from a 2.2 inch rain over a 16-hour period, and the

third highest volume of runoff (May 5, 1960) amounted to 0.80 inch of runoff, and resulted from a rain of 2.71 inches over a 6-hour and 45-minute period.

The mass rainfall and runoff curves for two water years were presented. Total rainfall for the 1960 water year was 25.6 inches and for the 1961 water year, 50.4 inches. Total runoff for the 1960 water year was 3.18 inches and for the 1961 water year, 8.40 inches.

In addition to the storms which produced maximum peak rates and/or volumes of runoff, an additional group of storms was presented to indicate the types of hydrographs collected from the Burge Branch Watershed. The storms are grouped by rainfall intensities and include only intense, abrupt rains that fell evenly over the watershed and had a duration of less than the 50-minute lag time for the watershed.

It was found that several of the collected hydrographs contained double peaks. All of the hydrographs from storms prior to May 25, 1960--when most of the terraces were built on the upper part of the watershed had only one peak. Hydrographs of short intense storms after this date had two peaks. The longer storms after May 25, 1960, continued to produce hydrographs with one peak. The double peaks were thought to result from delays of runoff by terraces in the upper portions of the watershed until after the peak from the lower portion of the watershed had passed. During longer storms all of the watershed contributed to one peak.

It was also found that the terraces built at the upper end of the watershed in 1960 caused a change in the lag time for the watershed. The average lag time for eight storms occurring prior to May 25, 1960, was 32 minutes; for seven storms occurring between May 25 and December 31, 1960, it was 42 minutes; and for seven storms occurring after December 31, 1960, 50 minutes.

APPENDIX

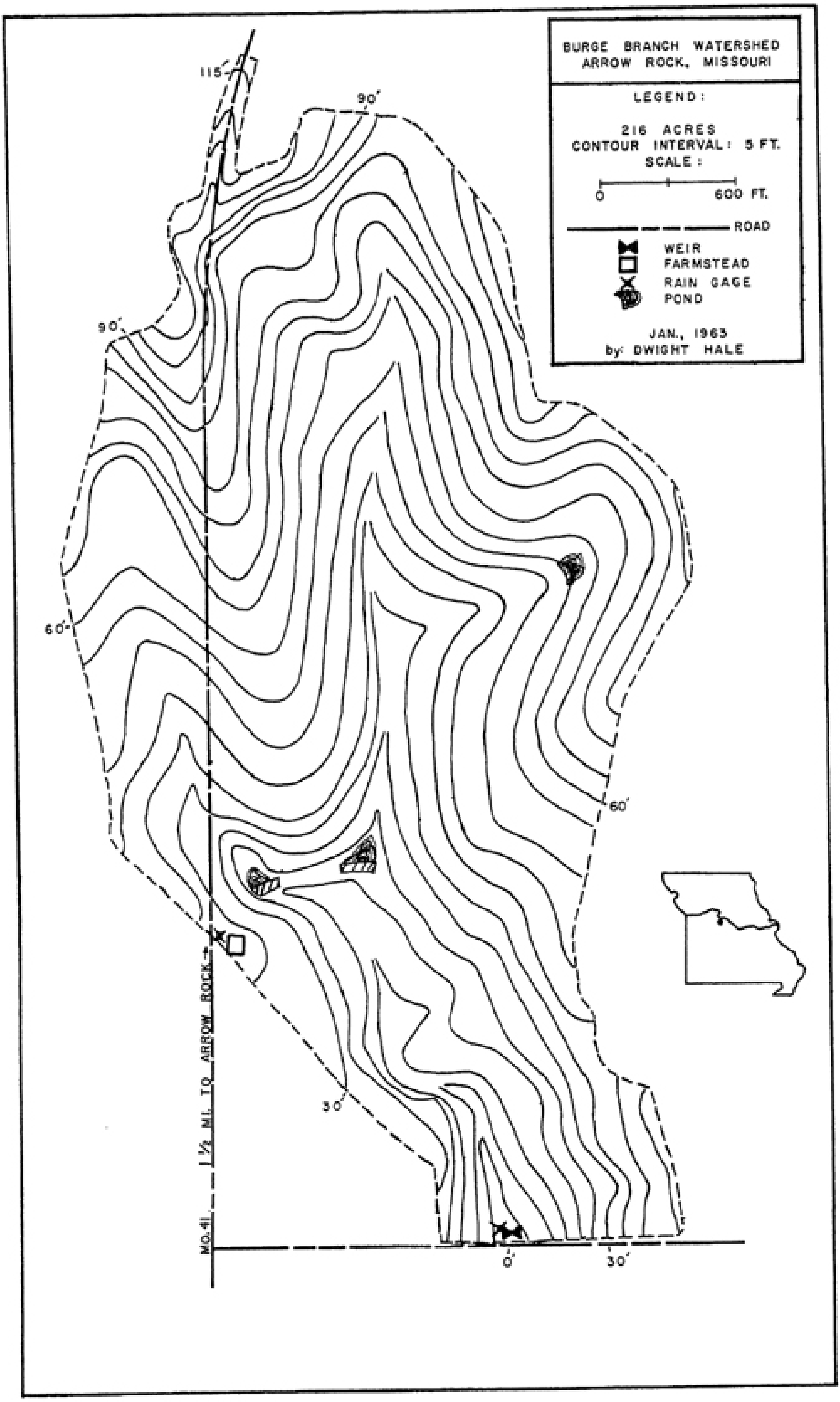

Fig. 1—Contour Map of Burge Branch Watershed.

Fig. 2—Aerial View of Burge Branch Watershed Before 1959. (Enclosed by dotted lines). Photo Courtesy A.S.C.S.

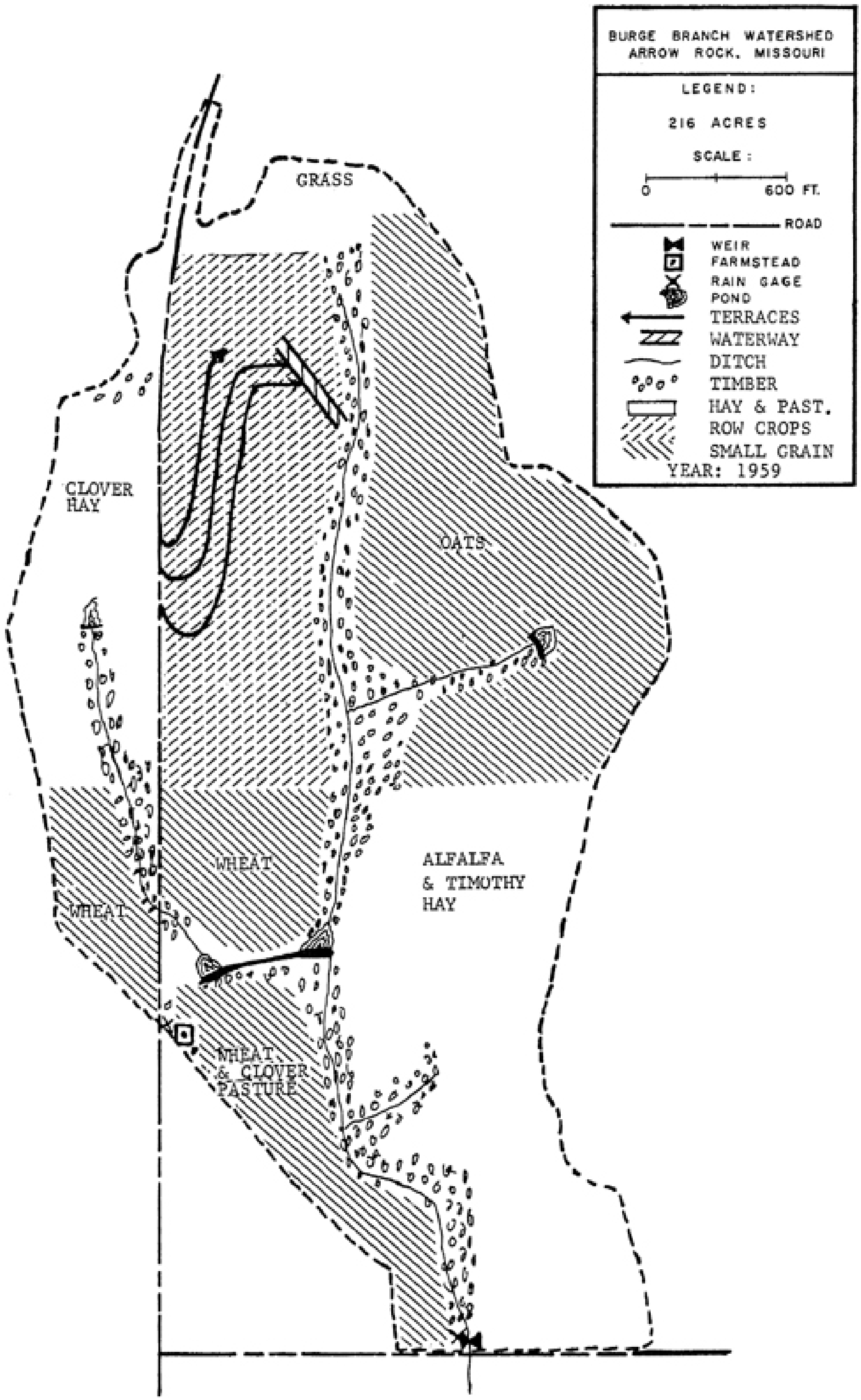

Fig. 3—Burge Branch Watershed 1959.

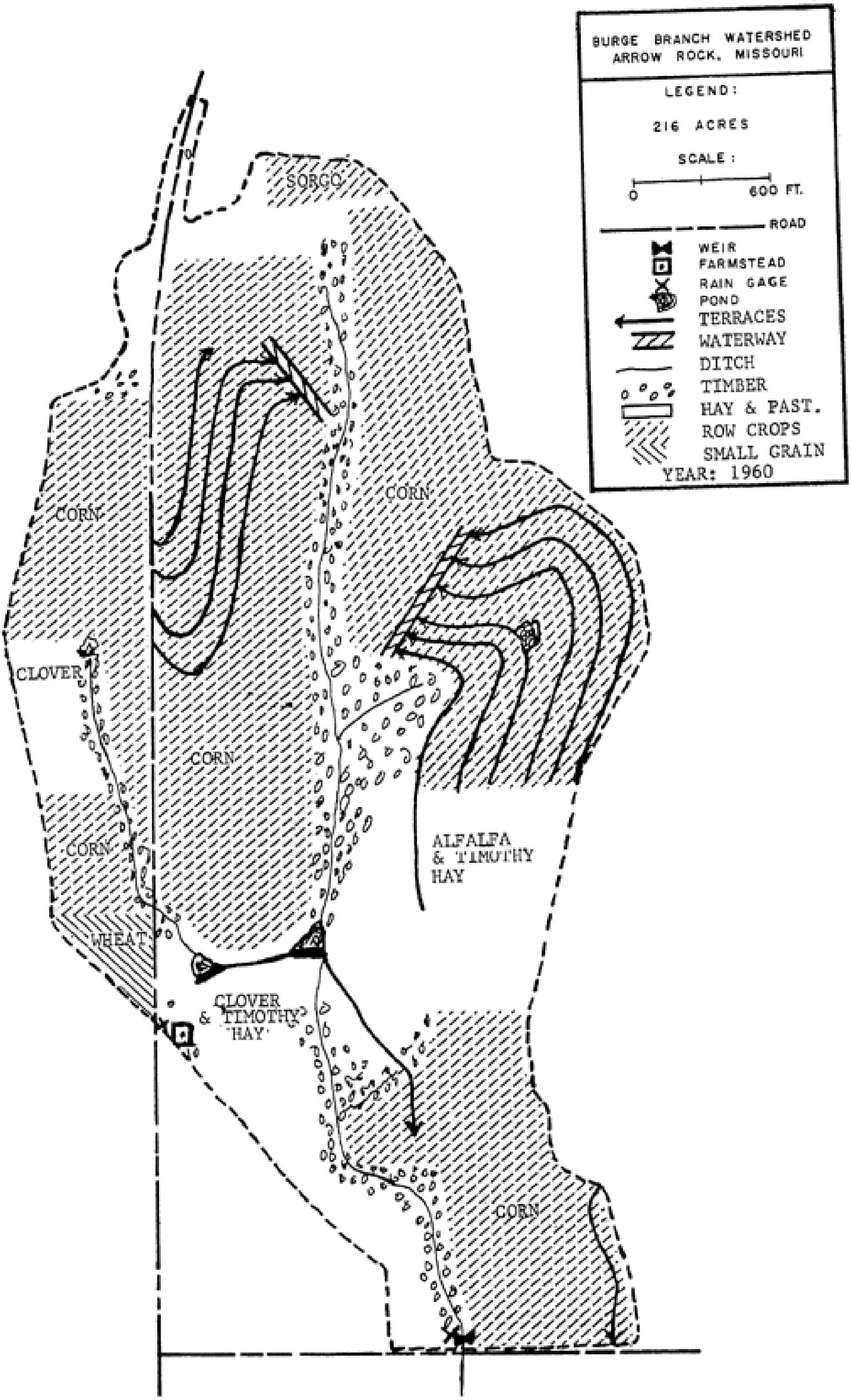

Fig. 4—Burge Branch Watershed, 1960.

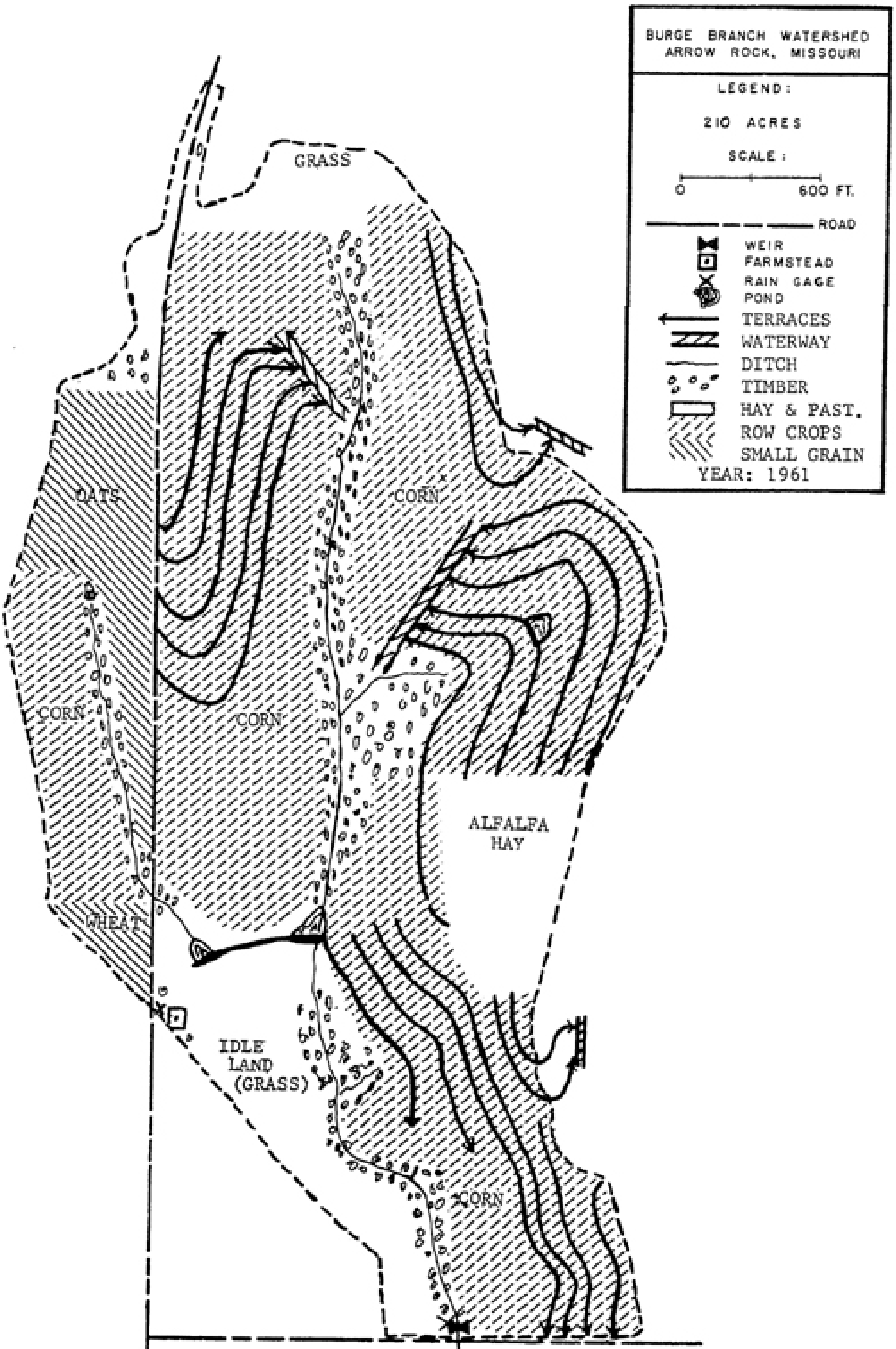

Fig. 5—Burge Branch Watershed, 1961.

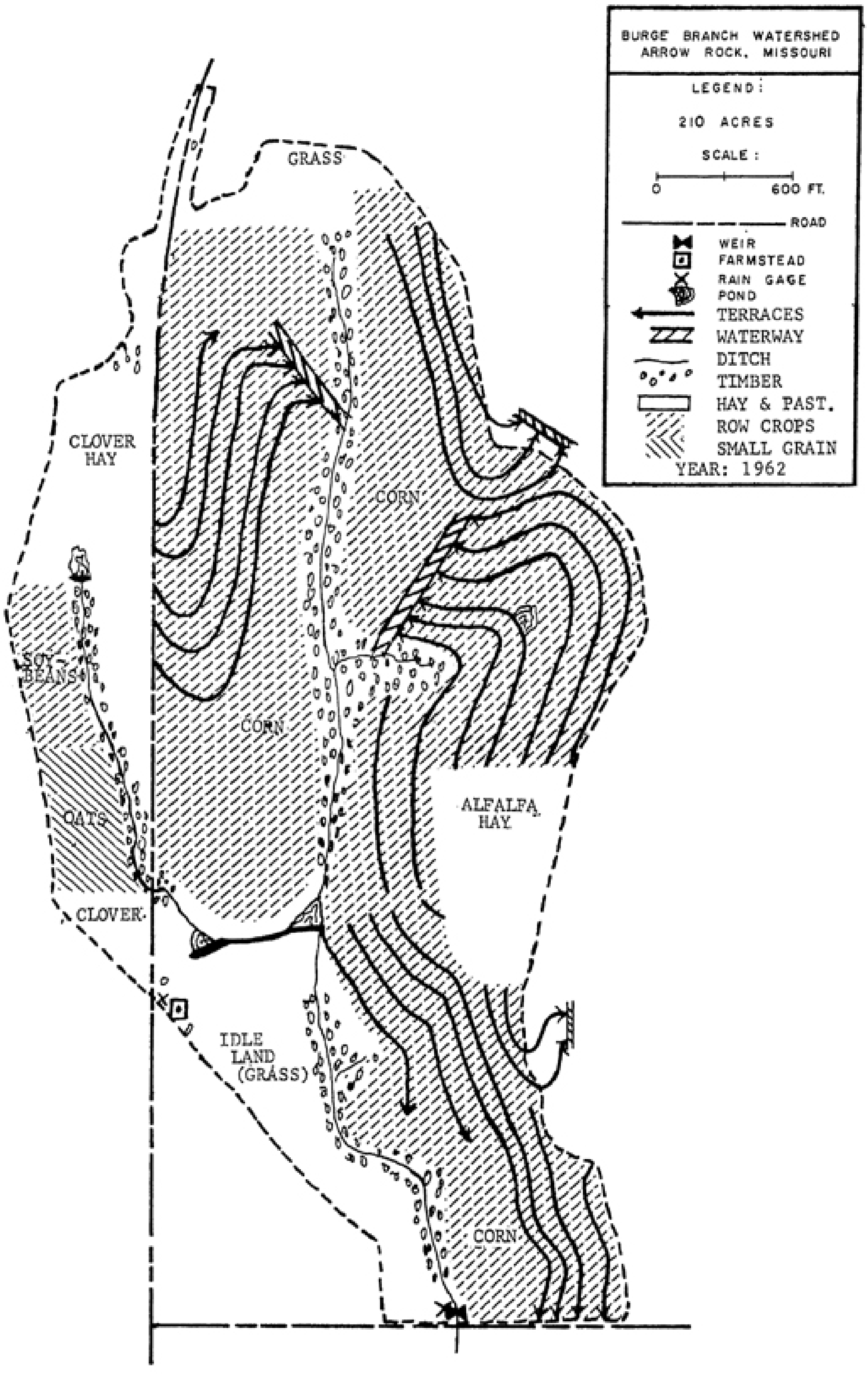

Fig. 6—Burge Branch Watershed, 1962.

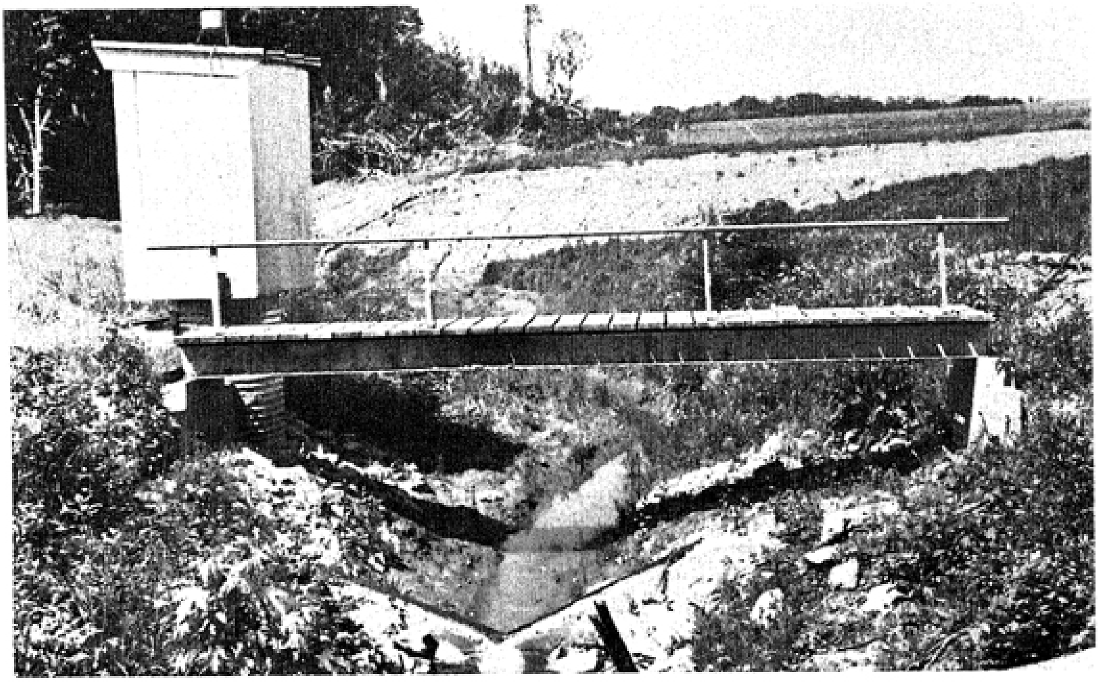

Fig. 7—Upstream view of the original weir.

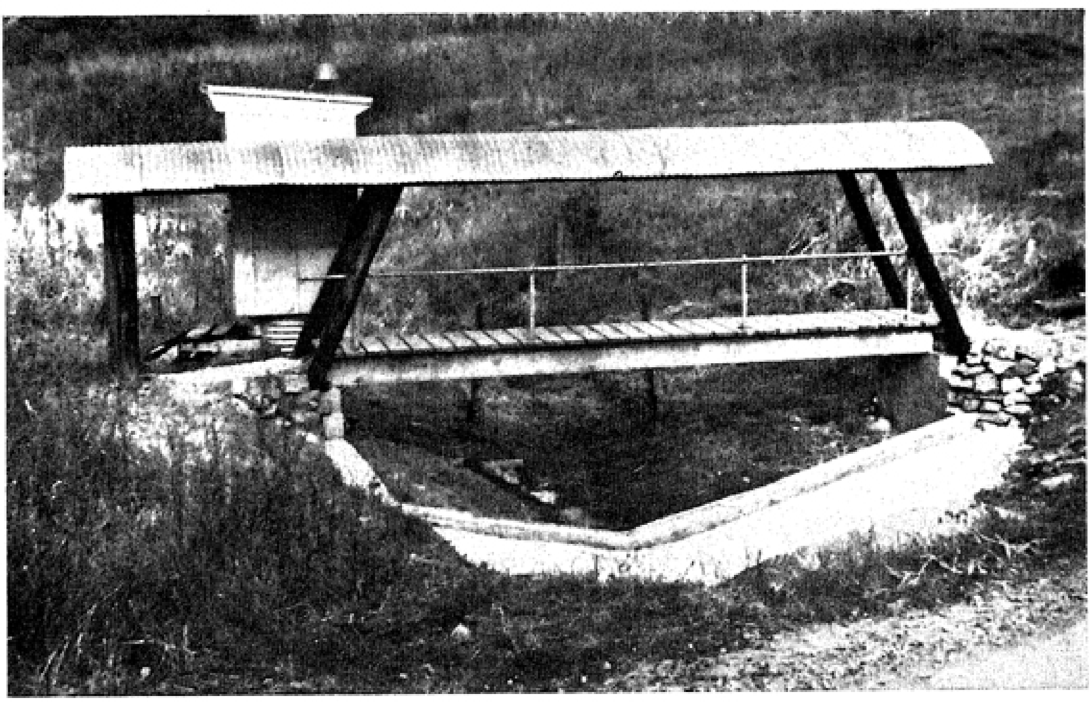

Fig. 8—Upstream view of the new weir.

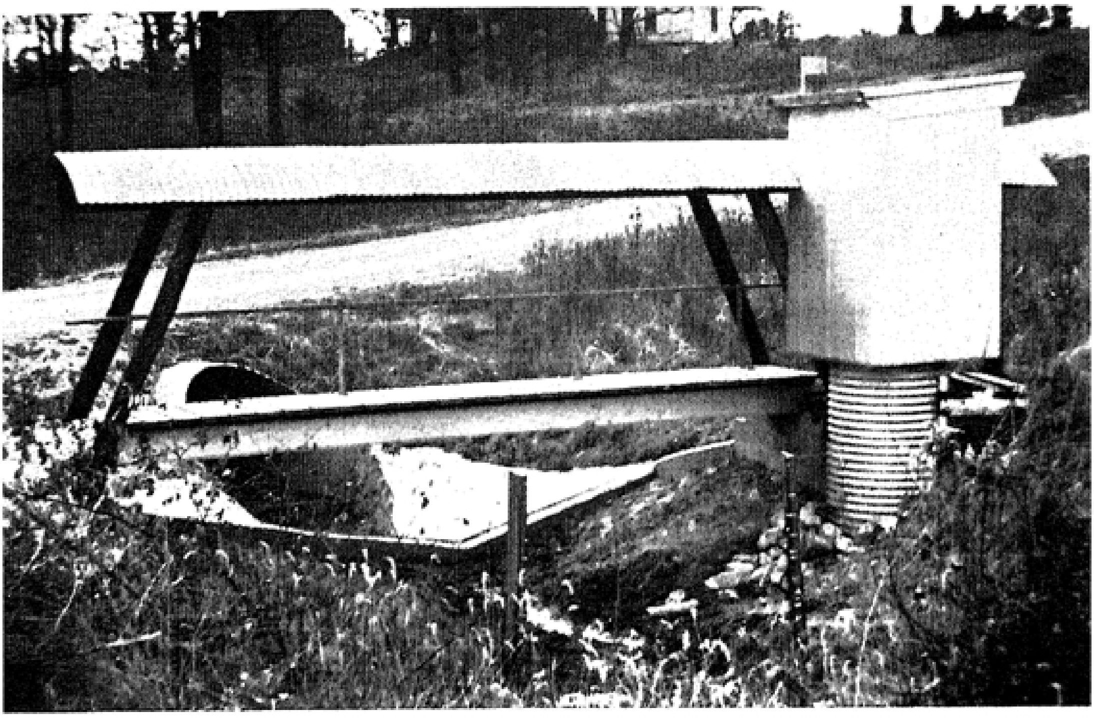

Fig. 9—Downstream view of the new weir.

Fig. 10—Side view of the new weir and associated apron.

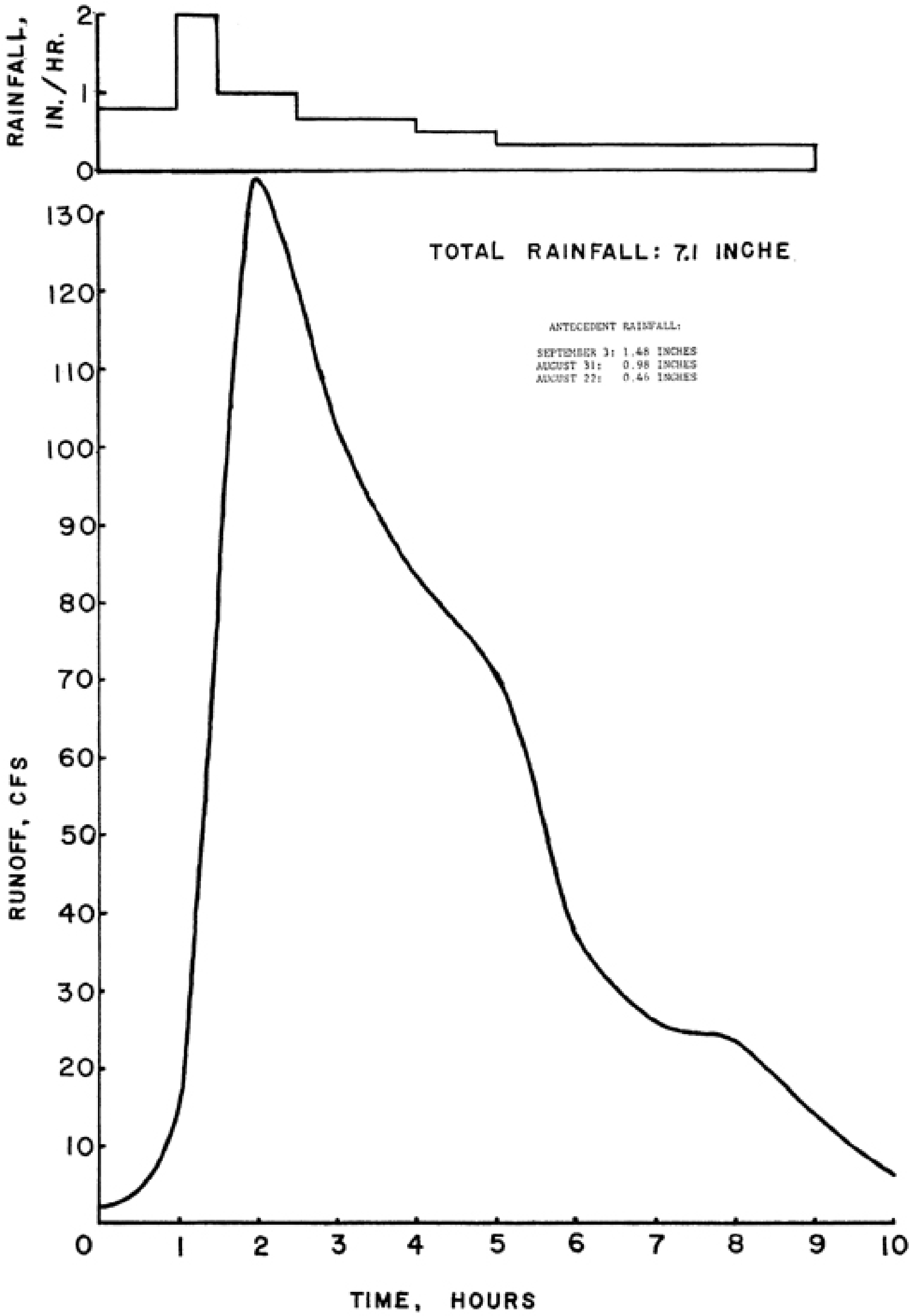

Fig. 11—Storm of September 13, 1961. The first 2 inches at low intensity rainfall is omitted.

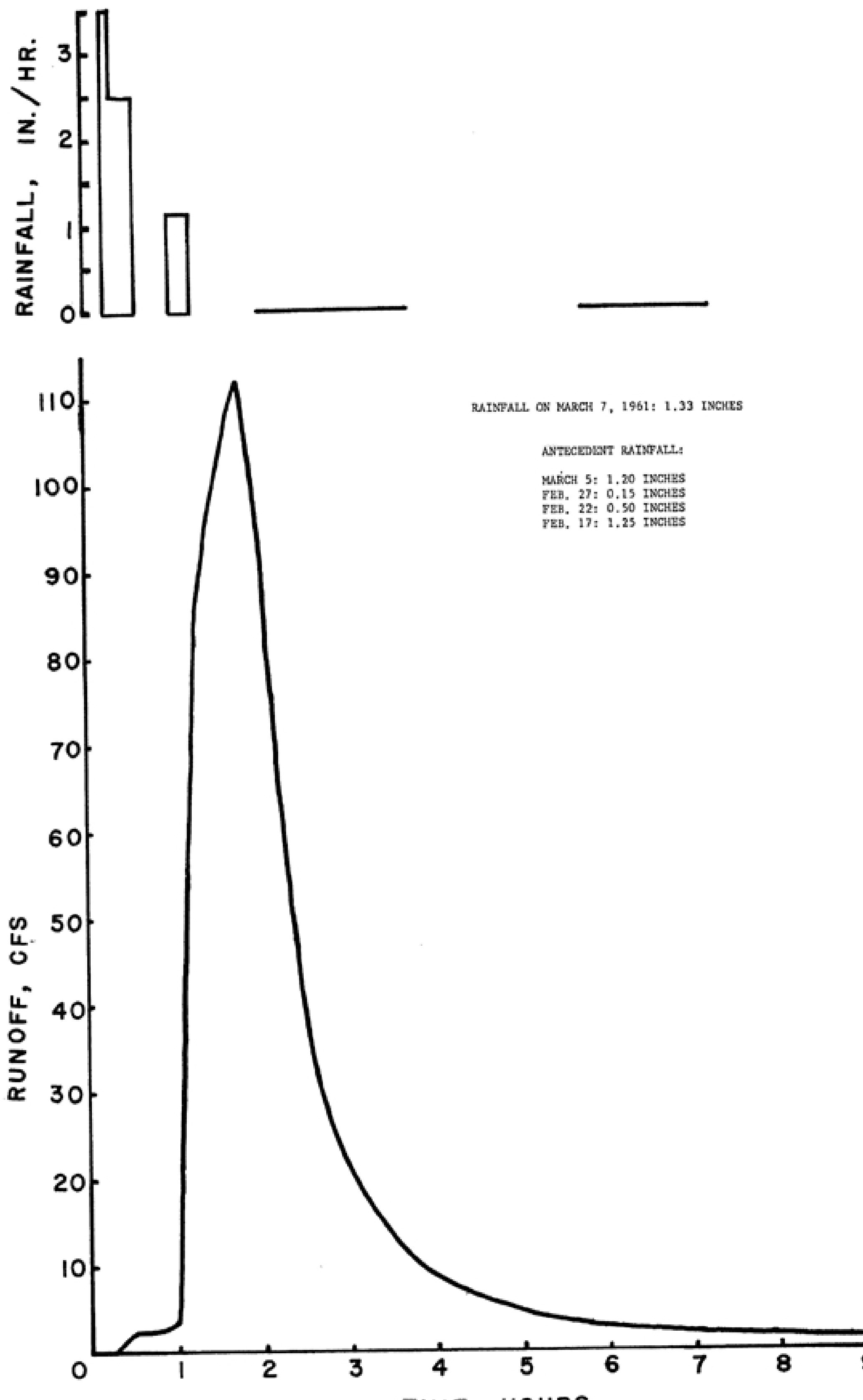

Fig. 12—Storm of March 7, 1961.

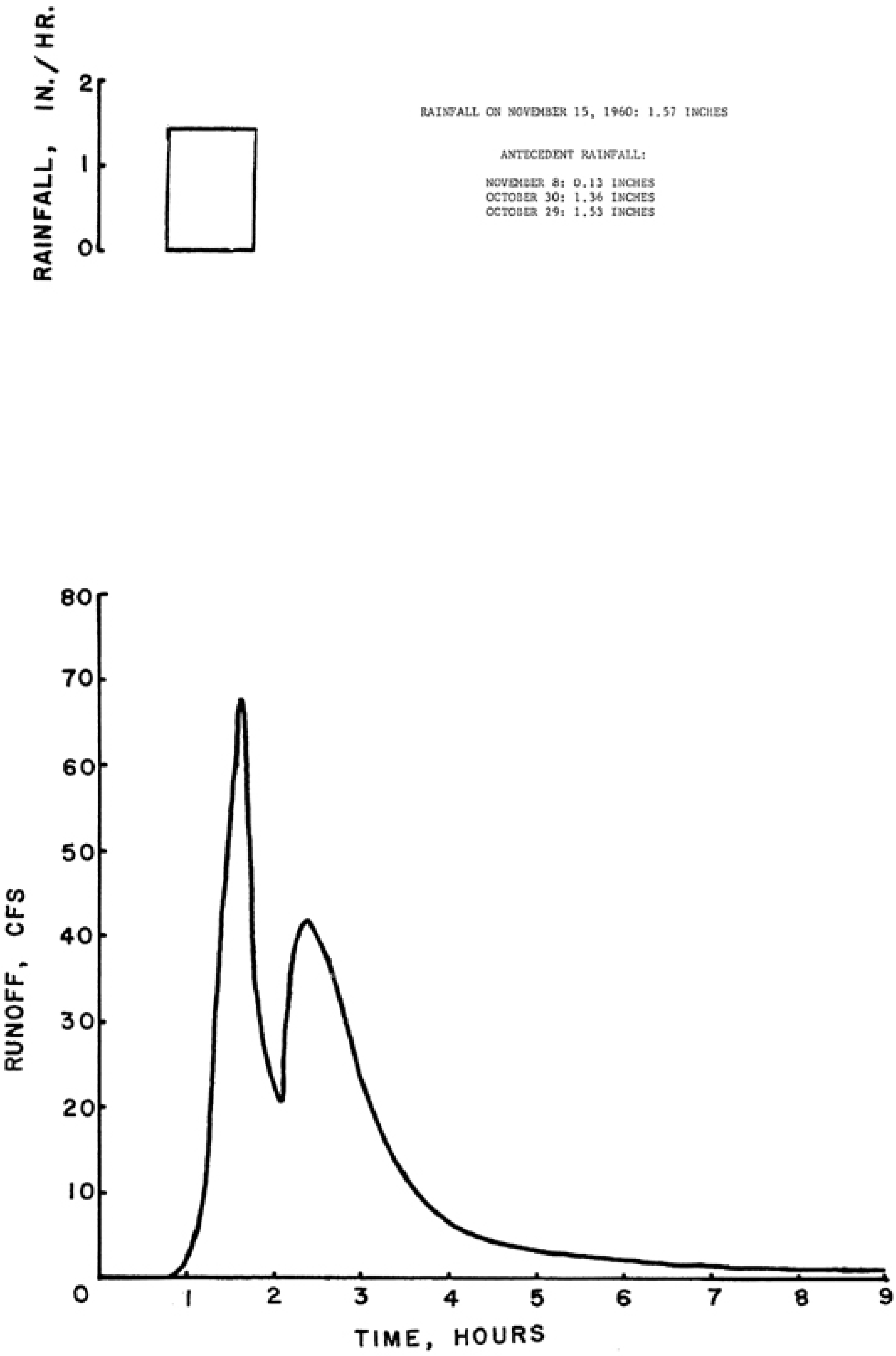

Fig. 13—Storm of November 15, 1960.

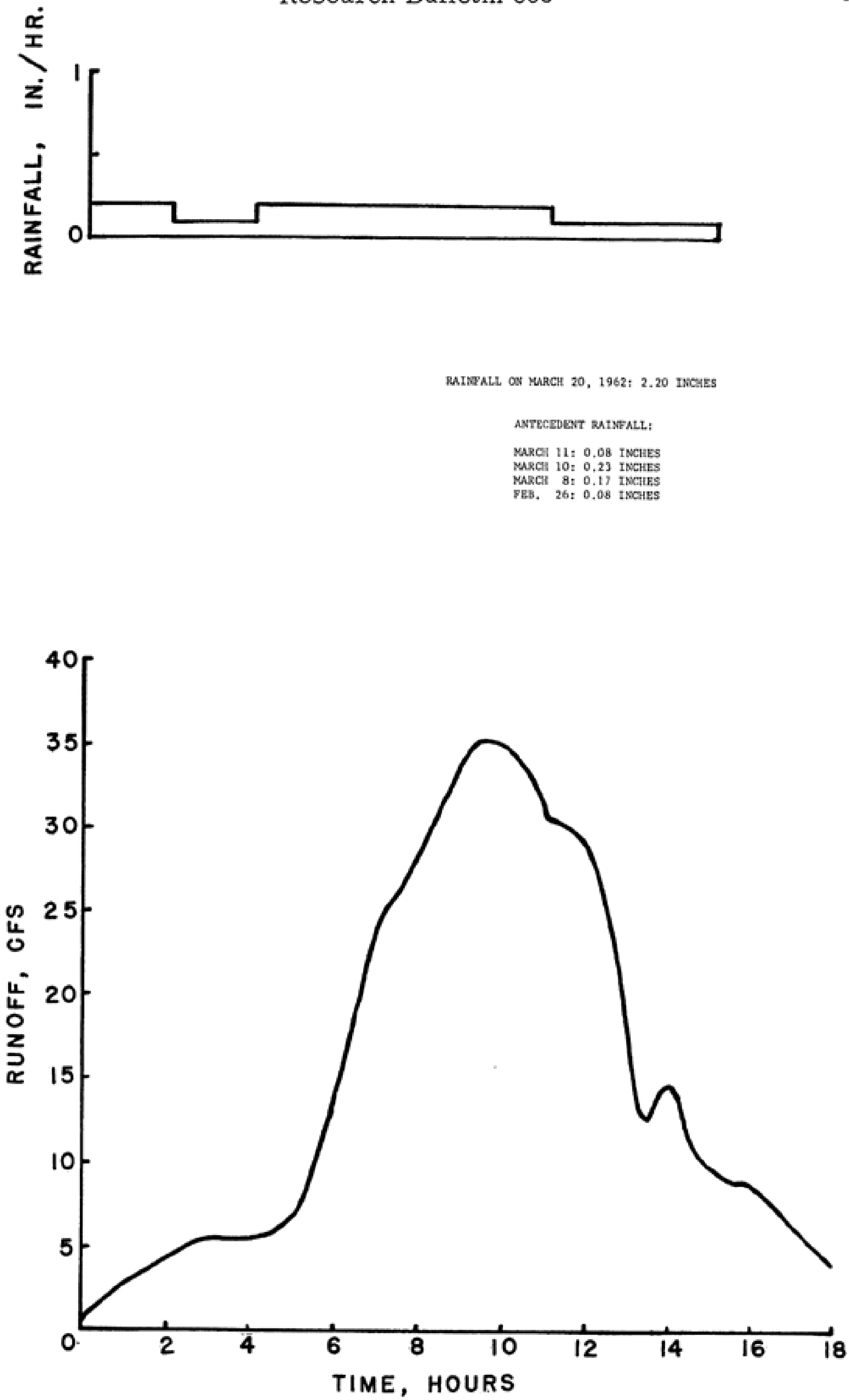

Fig. 14—Storm of March 20, 1962.

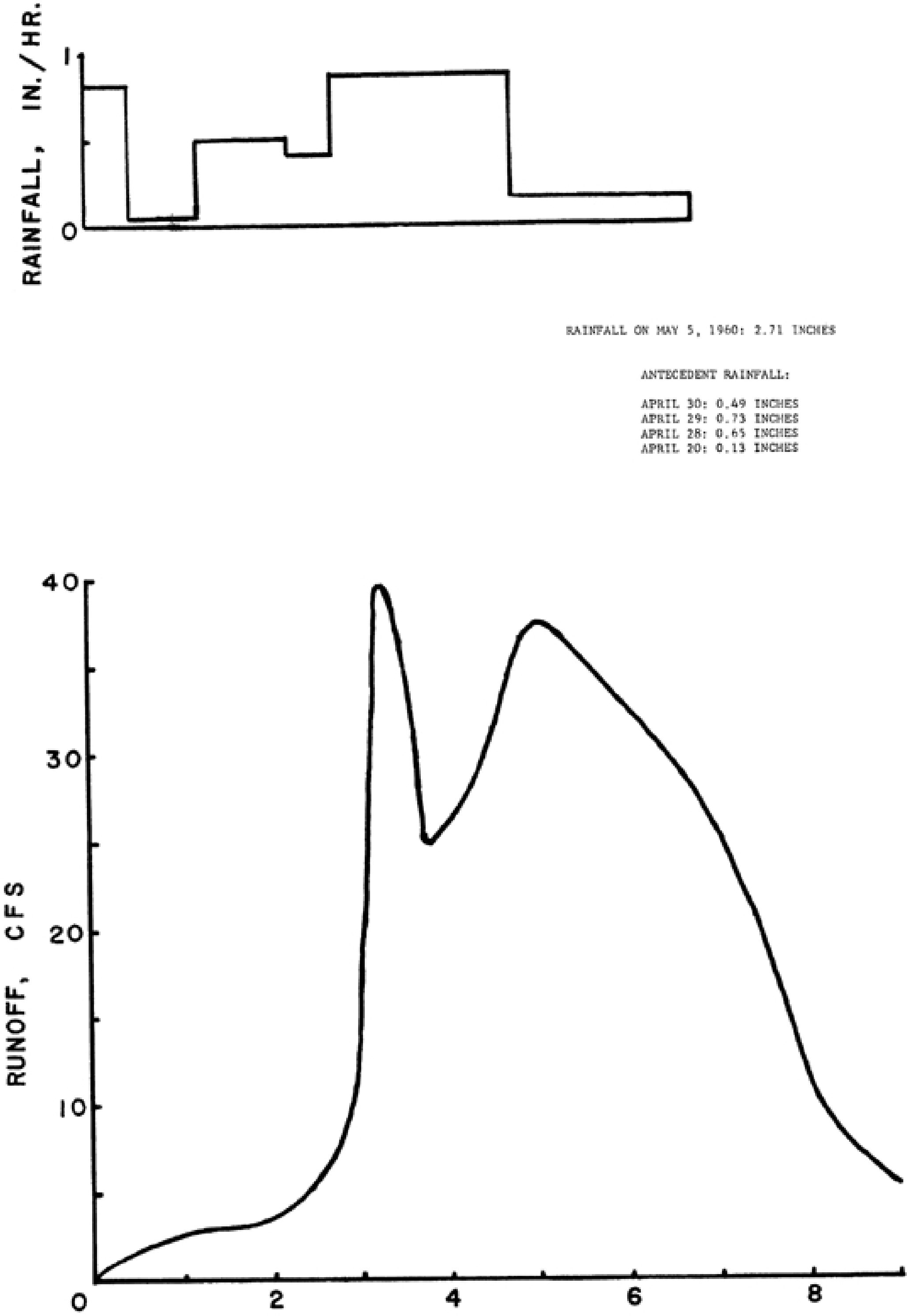

Fig. 15—Storm of May 5, 1960.

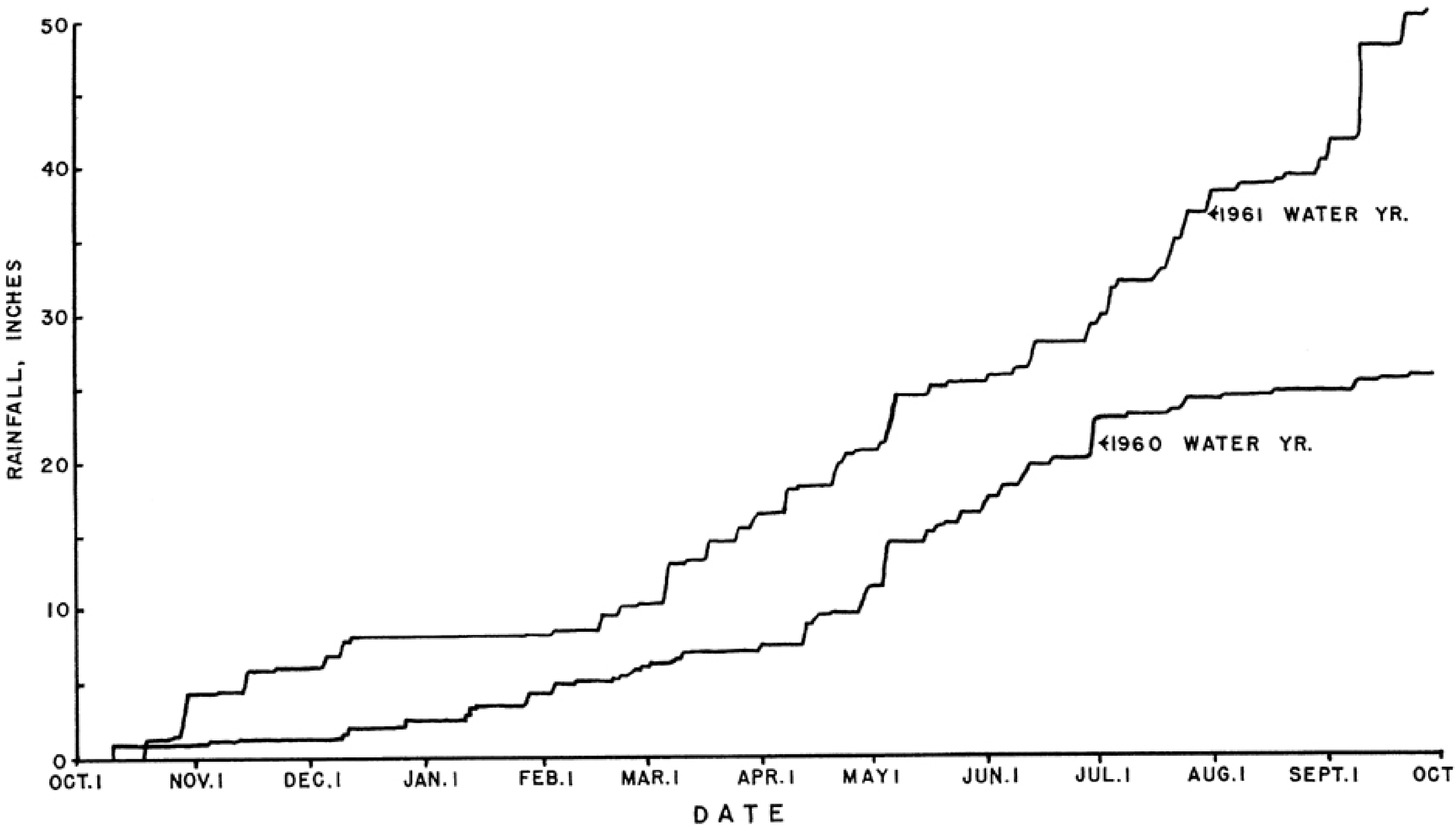

Fig. 16—Mass rainfall Curves.

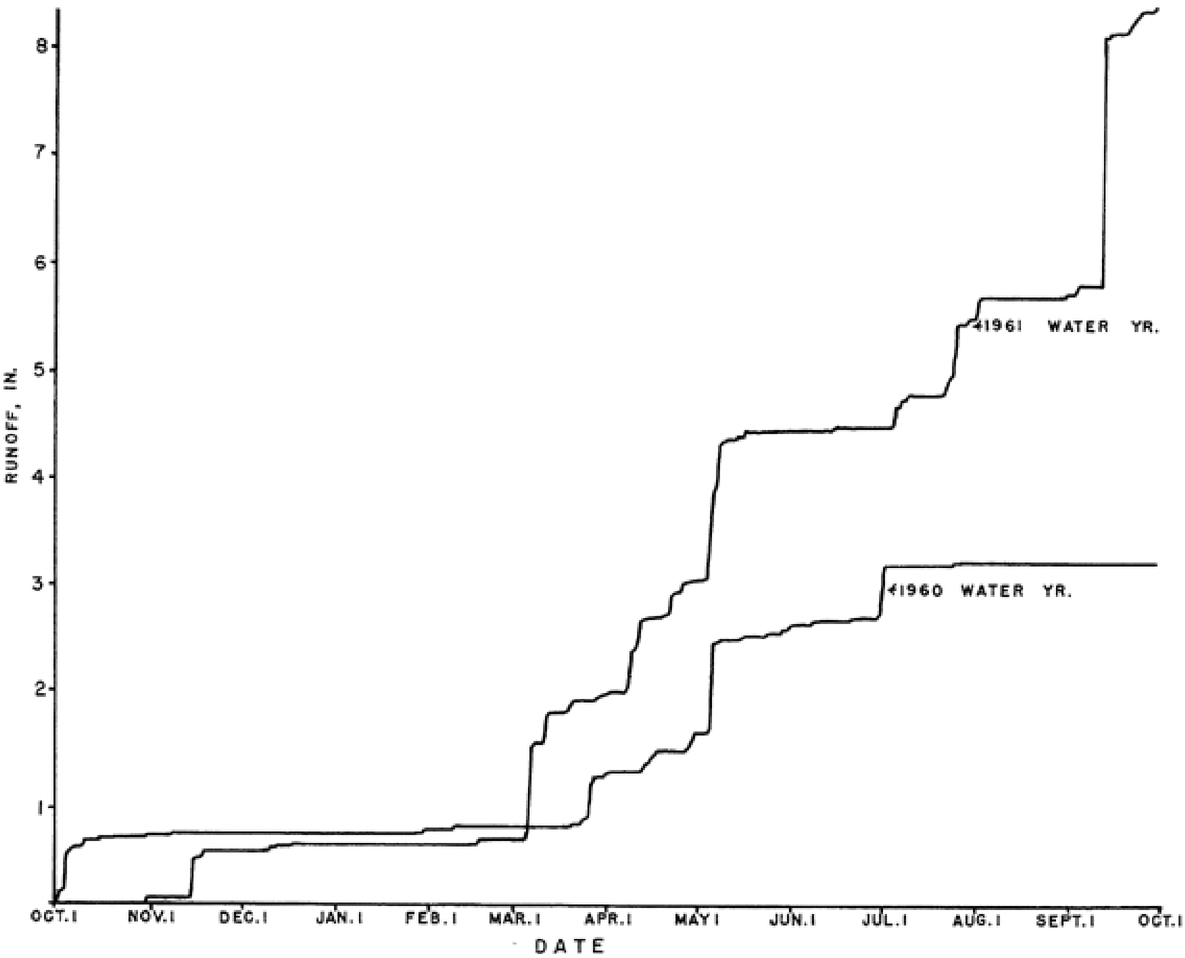

Fig. 17—Mass Runoff Curves.

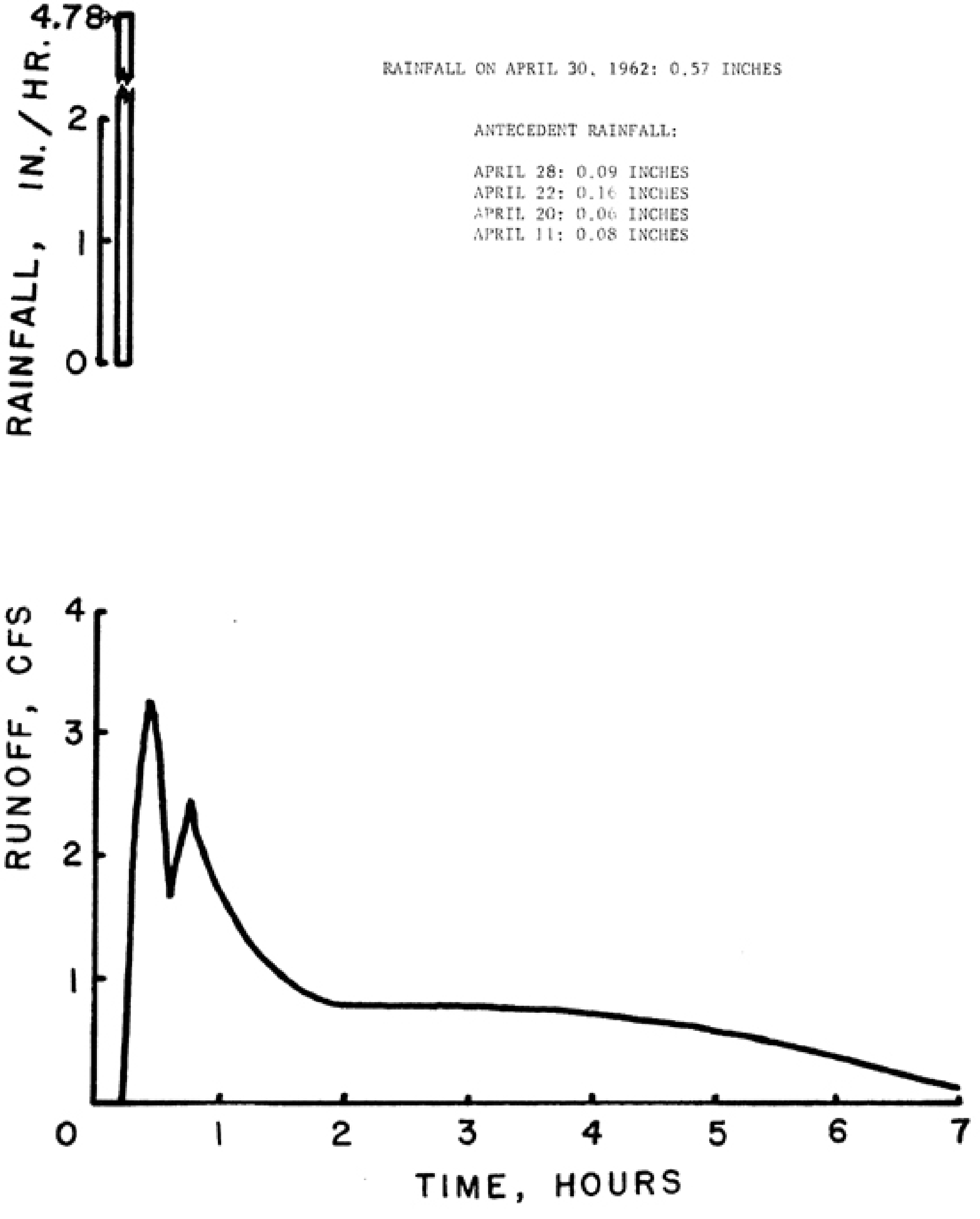

Fig. 18—Storm of April 30, 1962.

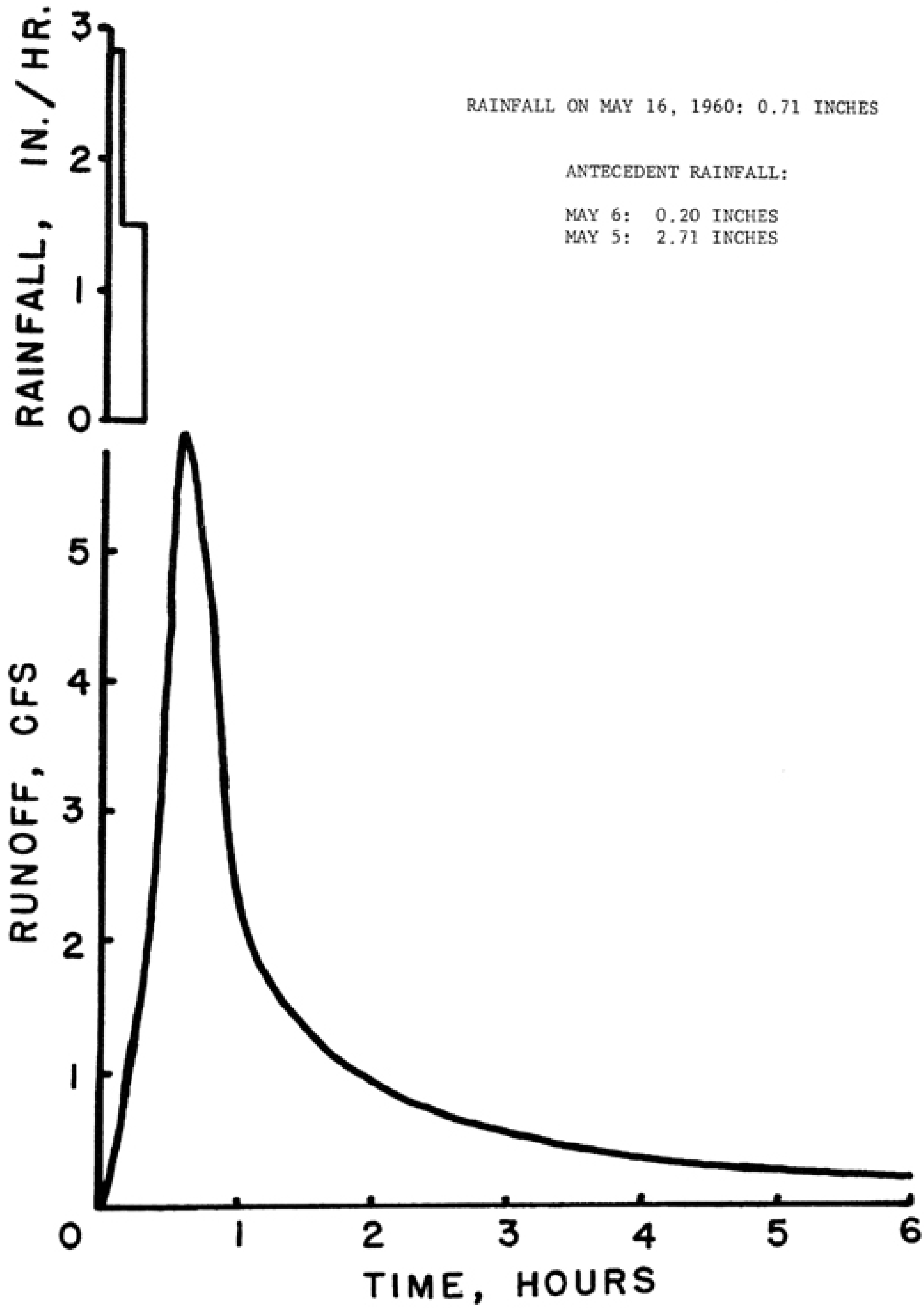

Fig. 19—Storm of May 16, 1960.

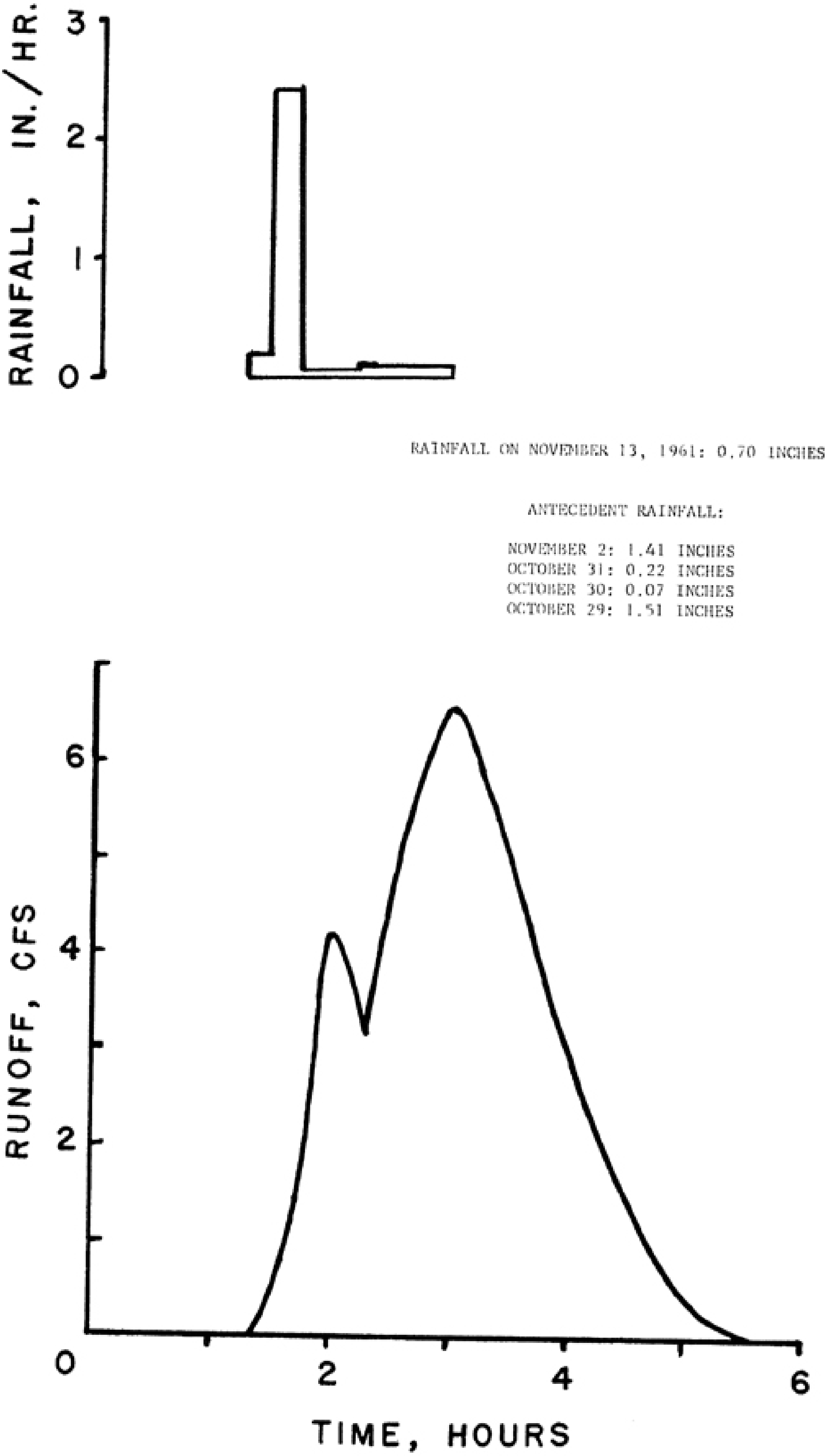

Fig. 20—Storm of November 13, 1961.

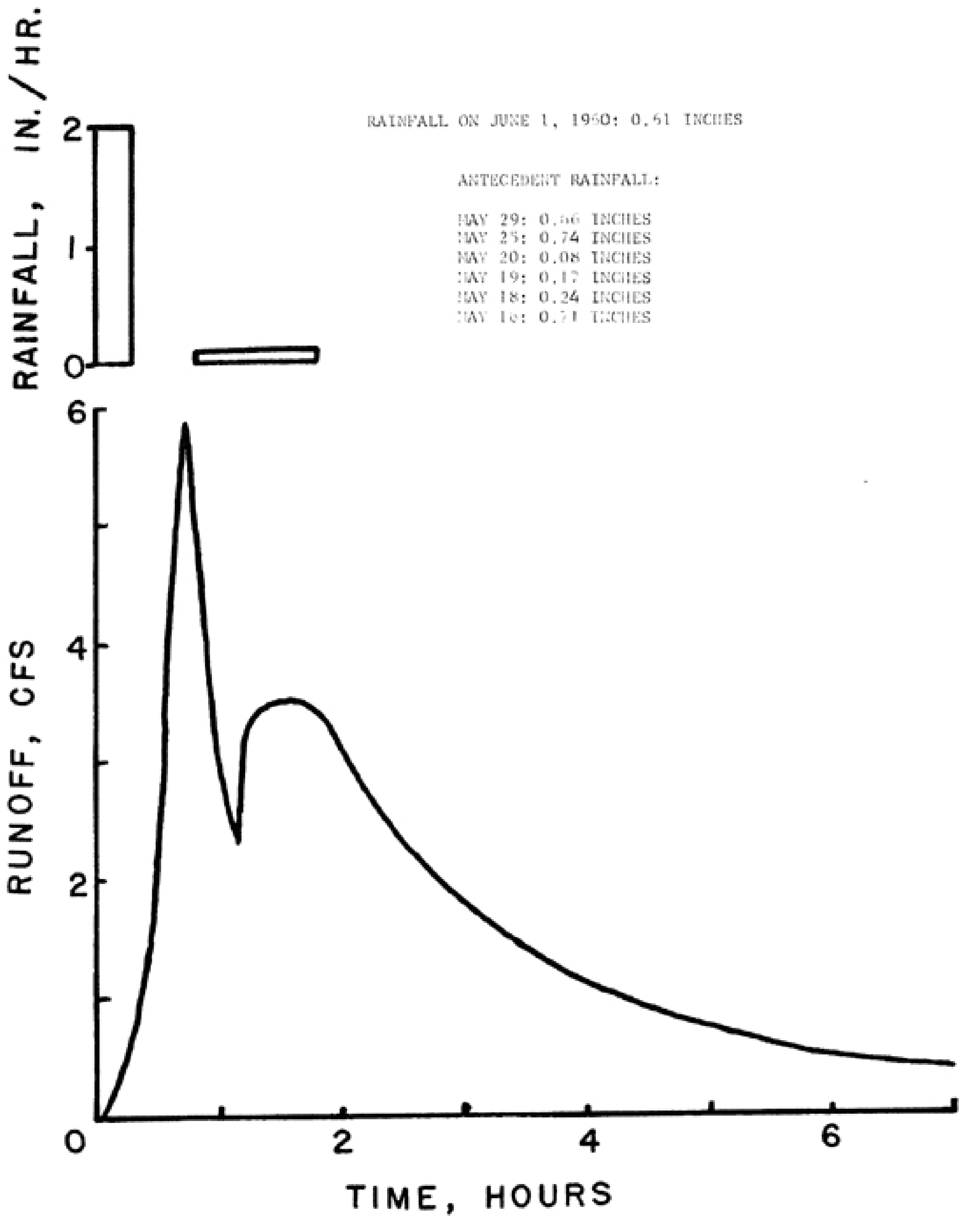

Fig. 21—Storm of June 1, 1960.

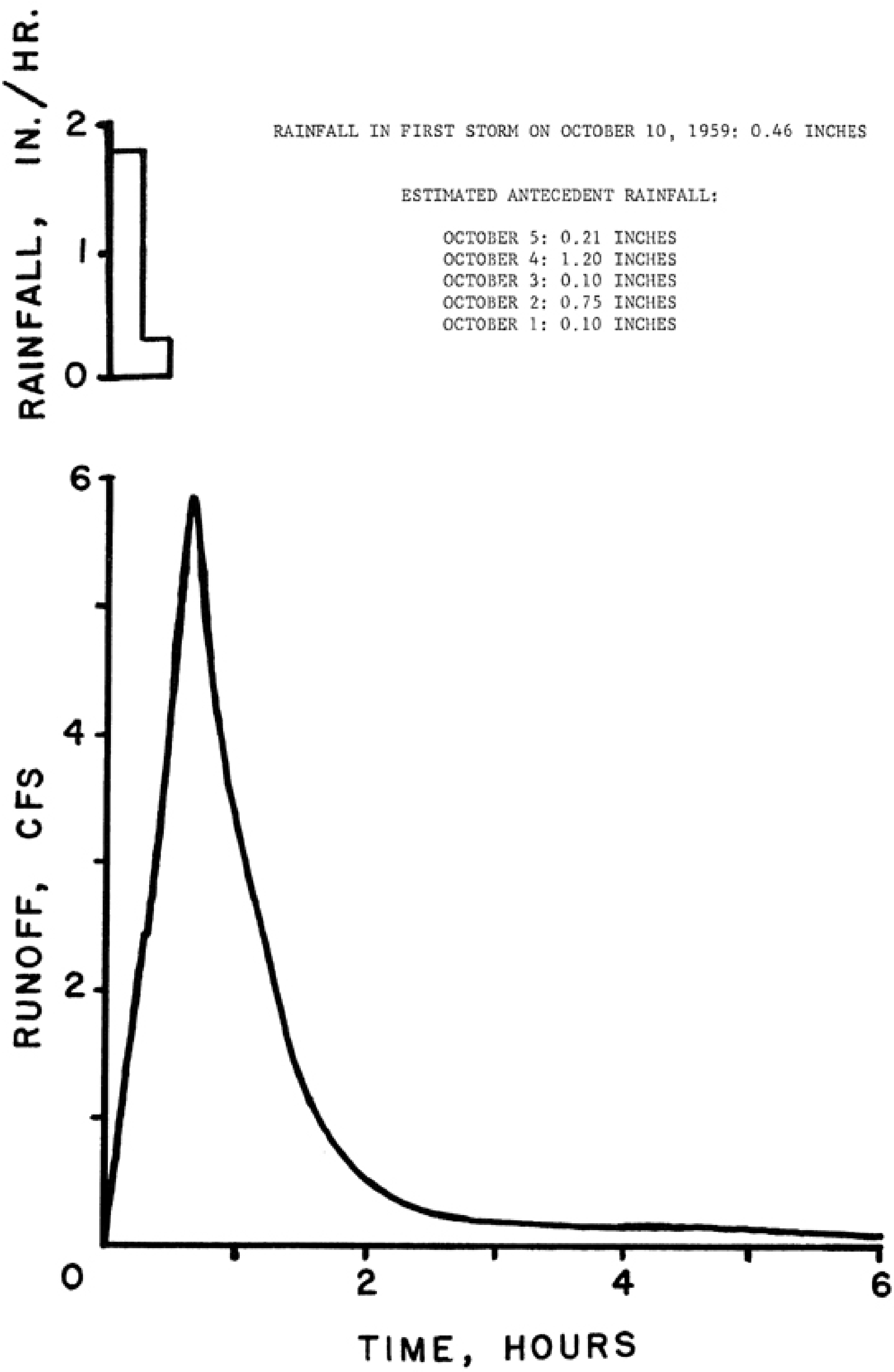

Fig. 22—First Storm of October 10, 1959.

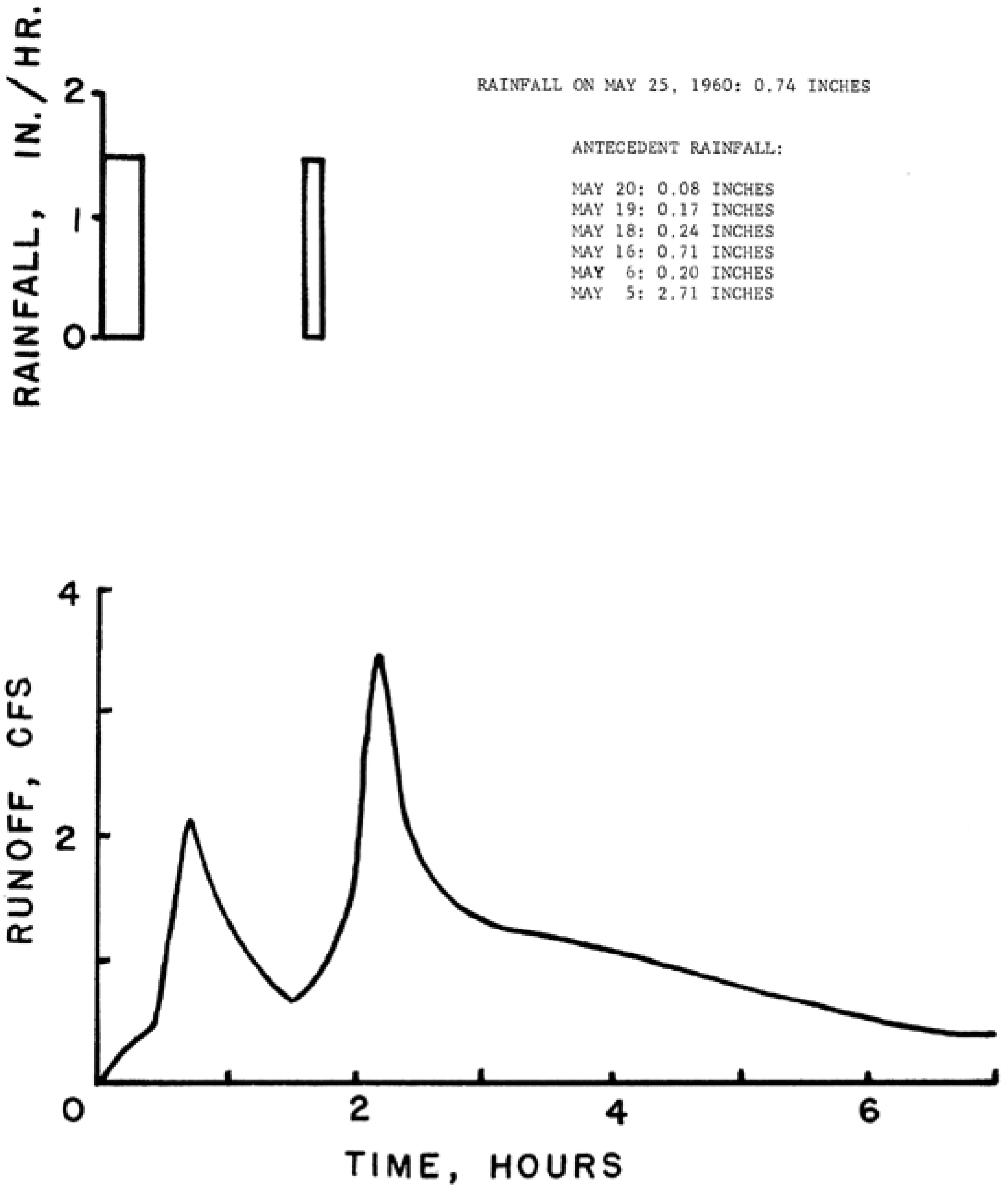

Fig. 23—Storm of May 25, 1960.

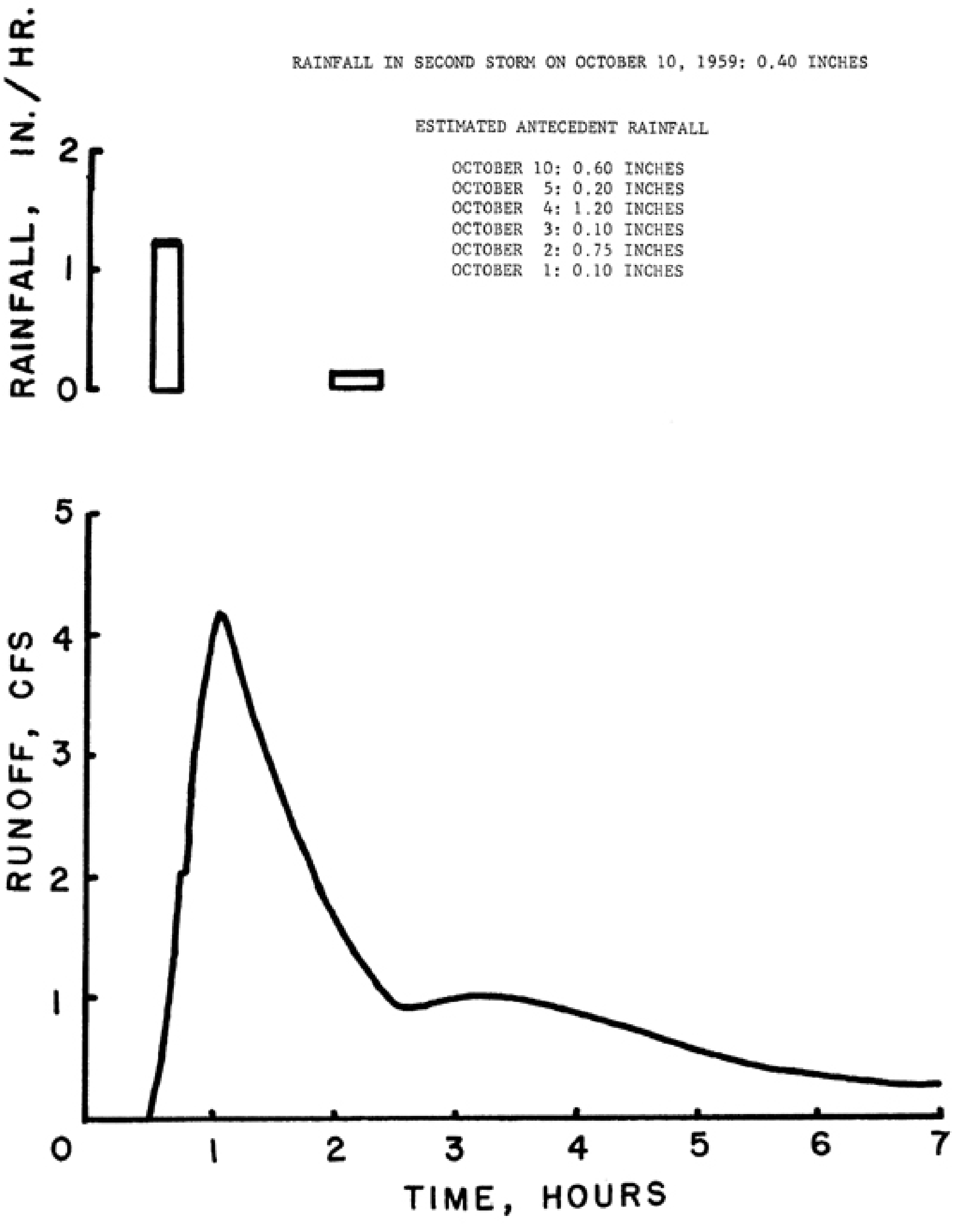

Fig. 24— Second Storm of October 10, 1959.

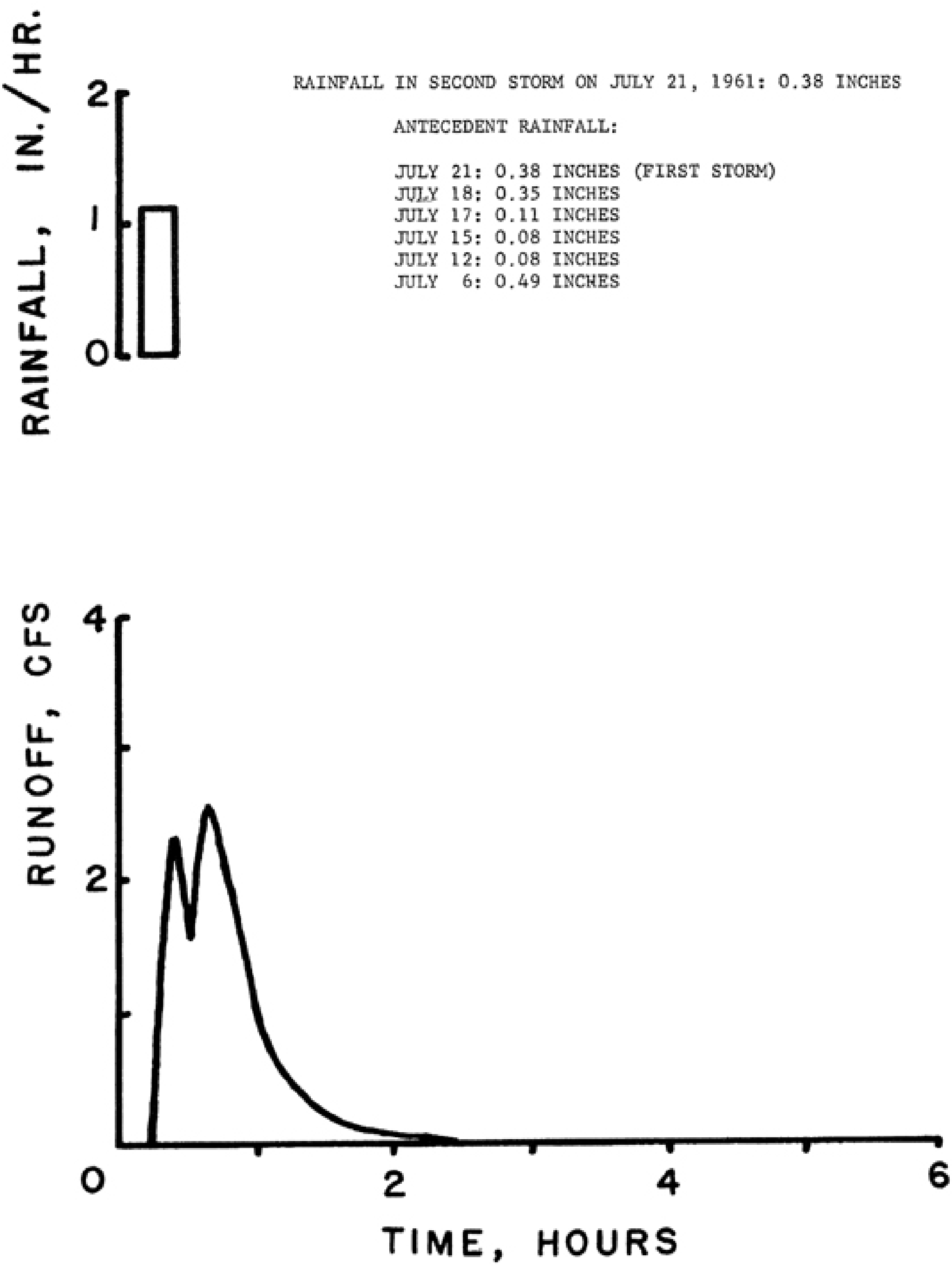

Fig. 25—Second Storm of July 21, 1961.

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