

FIGURE 1. - Location of report area and rainfall near Kelly Barnes Dam, November 2 - 6, 1977



FIGURE 2. - Lakebed and remains of Kelly Barnes Dam. (View downstream)



FIGURE 3. - Remains of rock crib dam and penstock pipe exposed by breach in Kelly Barnes Dam. Log in foreground was part of rock crib dam

INTRODUCTION

The Kelly Barnes Dam on Toccoa Creek near Toccoa, Ga., failed at approximately 1:30 a.m., November 6, 1977, after a period of intensive rain. Thirty-nine people were killed and damages were estimated at \$2.8 million by the Federal Disaster Assistance Administration and the U.S. Department of Housing and Urban Development (Roland Seratba and Carl Badger, oral commun., 1978).

Immediately after the flood, hydrologists of the U.S. Geological Survey obtained hydrologic information to document the disaster and to test the Survey's dam-break model procedures.

President Jimmy Carter, at the request of Governor George Busbee of Georgia, authorized the U.S. Army Corps of Engineers to make a technical assessment of the Kelly Barnes Dam failure with the assistance of other Federal agencies having appropriate expertise. The Corps of Engineers, the U.S. Geological Survey, the Soil Conservation Service, and the National Weather Service formed a technical Federal Investigative Board that conducted the technical assessment and published its evaluation as, "Report of Failure of Kelly Barnes Dam, Toccoa, Georgia," in December 1977. The history of the dam and meteorological and hydrologic findings of the Board are repeated herein to complement the additional detailed hydrologic and hydraulic data presented in this atlas.

Toccoa Creek Basin. Toccoa Creek lies immediately north of Toccoa, Ga., and flows in an easterly direction to Lake Hartwell (fig. 1). The drainage basin above the damsite has an area of 4.6 square miles and it is heavily wooded with pines and deciduous trees. The Toccoa Creek basin is in the Piedmont physiographic province and soils are of the Podzol-Wedowee-Chandler association, clay loam to loam subsoil. Stream channels are fairly steep and have slopes that generally exceed 100 feet per mile.

Between the dam and Toccoa Falls, the average low-water channel width of Toccoa Creek is 40 feet. Below the falls the low-water channel is about 50 feet wide and the flood plain ranges from 100 to 400 feet in width. The Toccoa Falls College trailer village was located on the flood plain where the width is approximately 350 feet. The flood plain expands downstream from the trailer village, but becomes restricted to a width of 200 feet upstream from Georgia Highway 17.

Kelly Barnes Dam and Lake. Kelly Barnes Dam was about 400 feet long, 20 feet wide at the crest, and 40 feet high at the maximum section. The dam was concave upstream. Figure 2 shows the lakebed and the broken dam.

The history of the dam as determined by the Federal Investigative Board (1977) is summarized as follows: The dam went through various stages of development, first as a rock crib dam and then with subsequent stages as an earth dam. The rock crib dam was completed about 1899 to impound water for a small hydroelectric plant located near the foot of the falls. About 1937, the Toccoa Falls Bible Institute, which later became Toccoa Falls College, was interested in developing a more dependable power source and decided to build an earth dam over the rock crib dam with equipment provided by a local manufacturer. Figure 3 shows part of the rock crib dam and the penstock pipe to the powerplant that was incorporated in the new dam.

After World War II, the earthfill was raised to a point where an earth spillway on the left side of the valley (facing downstream) could be utilized, and a low point on the rim on the right side away from the dam would serve as a secondary spillway during high flows. This installation served as a power source for the Toccoa Falls Bible Institute until 1957. At that time, power generation was stopped but the lake continued to be used for recreation.

The normal pool elevation for Kelly Barnes Lake was about 1,137 feet above NGVD (National Geodetic Vertical Datum of 1929). The lake had an impoundment of about 15 million cubic feet (410 acre-feet) and a surface area of about 42 acres. The maximum lake level reached before the dam failed was 1,141.6 feet, with an impoundment of about 27 million cubic feet (630 acre-feet). The elevation of the low point on the crest of the dam was approximately 1,147 feet, based on surveys of the remaining embankment after the failure.

The surface-area-elevation and volume-elevation curves for Kelly Barnes Lake are shown in figure 4. Bench marks used for topographic surveys, high-water profiles, and cross sections are listed in table 1 and shown in figures 9 and 10.

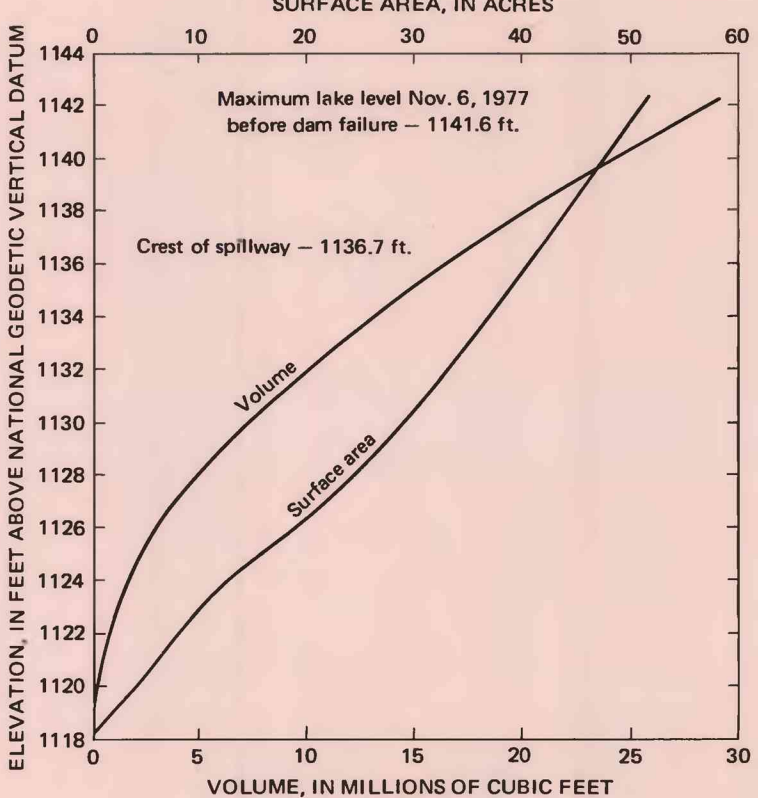


FIGURE 4. - Relation of elevation to volume and to surface area of Kelly Barnes Lake

TABLE 1. - Description of elevation bench marks

Bench Mark No.	Description of bench marks	Elevation above National Geodetic Vertical Datum of 1929 (ft)
1	Nail in power pole on upstream side of road and 175 ft left of Highway Road bridge over Toccoa Creek.	719.53
2	40-penny nail in twin poplar tree on left bank, 60 ft upstream from culvert under County Farm Road at Toccoa Creek.	783.53
3	40-penny nail in streamward side of telephone pole, 18 in. above ground, 150 ft right of Georgia Highway 17 bridge over Toccoa Creek on upstream side of road at a "T" road upstream.	821.15
4	Crestline of Georgia Highway 17 bridge over Toccoa Creek at right end of bridge deck.	814.23
5	40-penny nail in south side of poplar tree with basketball backboard attached 100 ft left of left bank, 300 ft southeast of Beechwood Circle bridge over Toccoa Creek and 1,100 ft west of Georgia Highway 17.	828.76
6	Chiseled square in southeast corner of granite gate entrance to Forrest Drive from Toccoa Falls Drive.	833.18
7	Chiseled square on boulder on right bank 180 ft downstream from Toccoa Falls and 1 ft upstream from most upstream rock bench beside nature trail.	865.52
8	40-penny nail in pine tree 1 ft above ground on left bank 30 ft upstream from lip of falls.	1,034.15
9	40-penny nail in a 24-inch oak tree 220 ft downstream from toe of falls just downstream from Kelly Barnes Dam and 90 ft left of Toccoa Creek.	1,073.23

Topographic maps of the lakebed and the dam were prepared immediately after the break by the U.S. Geological Survey (figs. 5 and 6). The earth spillway at the left end of the dam (facing downstream) apparently carried all normal lake overflow. The crest of the spillway was 1,136.7 feet above NGVD (596.2 feet above datum). A low area, minimum elevation 1,139.8 feet (599.3 feet above datum), in the approach road about 1,100 feet upstream on the right rim, served as a secondary spillway.

The Federal Investigative Board (1977) concluded that separate inlets for a low-water spillway and a welded steel penstock to the powerplant existed at the time of the dam failure (fig. 7). These facilities were described by the Board as follows: The low-level spillway had a rectangular shaped masonry inlet which could be shut off with stop logs or flashboards. The inlet for the welded steel penstock was also masonry and controlled with a slide gate at the upstream toe of the dam. *

Some historical witnesses remember the penstock slide gate but do not recall the masonry structure. After the failure, this gate was retrieved from below the damsite and found to be closed. The conduits for the spillway outlet and new penstock were both welded plate pipes approximately 30 inches in diameter. A historical witness stated that during placement of fill over the spillway conduit, the pipe began to cave in and had to be reinforced with metal struts. *

At this time, or during previous construction, the old spiral riveted penstock pipe had been abandoned, but not removed. Conflicting information suggests the possibility of a series of construction events during the 1940's. A 1954 Survey of Buildings, Roads, Streams, and Lakes of the Toccoa Falls Institute locates the overflow pipe (low-level spillway), 24-inch conduit (welded steel penstock), and the intake structures.

"Information available indicates that the fill was constructed to its final height in the late forties. However, a study of stereopairs of aerial photographs taken on January 17, 1955, shows the reservoir to be essentially empty at that time. The inlet structure, two earth spillways, and the pipe leading to the powerhouse are clearly visible. In later years a heavy growth of vegetation became established on both the upstream and downstream faces and apparently obliterated the masonry intakes from view. Again, information received from historical witnesses conflicts as to whether or not two structures existed at the time of failure. Judging from the debris found downstream and the remains of the welded steel penstock, it is the Board's opinion that both existed at the time of failure."

The Federal Investigative Board (1977) reported: "A number of observers informed the Board of seeing almost continual seepage on the downstream slope of the dam near the point of exit of the spillway pipe. Photographs obtained from one source, taken in 1973, show that a large embankment slide had occurred on the downstream face of the dam * * *. This 12-foot high, 30-foot wide slide of unknown depth, was observed on the lower one-third of the downstream slope in the area of the current failure section, which was the highest point of the dam. The slide left a two-foot, vertical, scarp face and partially exposed the end of a pipe. The slide, at the time of the photograph, was apparently not recent because of the existence of established vegetation on the slide area. The picture shows the pipe to be essentially clogged with silt and trash, but a very slight seepage was observed coming from the pipe. The area near the pipe contained water that was discolored by iron oxide, sulfur, or some other matter indicating little or no flow. The area adjacent to the recent dam failure was wet and spongy a week after the failure and seepage water was still coming from the toe near the right abutment (looking downstream) at that time."

The Board also stated, "The rock type at the site is a biotite gneiss of the Carolina gneiss series. * * * A layer of soft alluvium, from two to five feet thick (overlying solid bedrock) was observed in both faces of the breach of the dam. This material extends from the proximity of the old crib dam upstream - an undetermined distance. The layer appears to be quite extensive in the foundation of the earth dam. The lower six inches of the layer of the alluvium contains an extensive root mat. The alluvium appears to be composed principally of soft, plastic clay and (or) silt with some layers of fine silty sand."

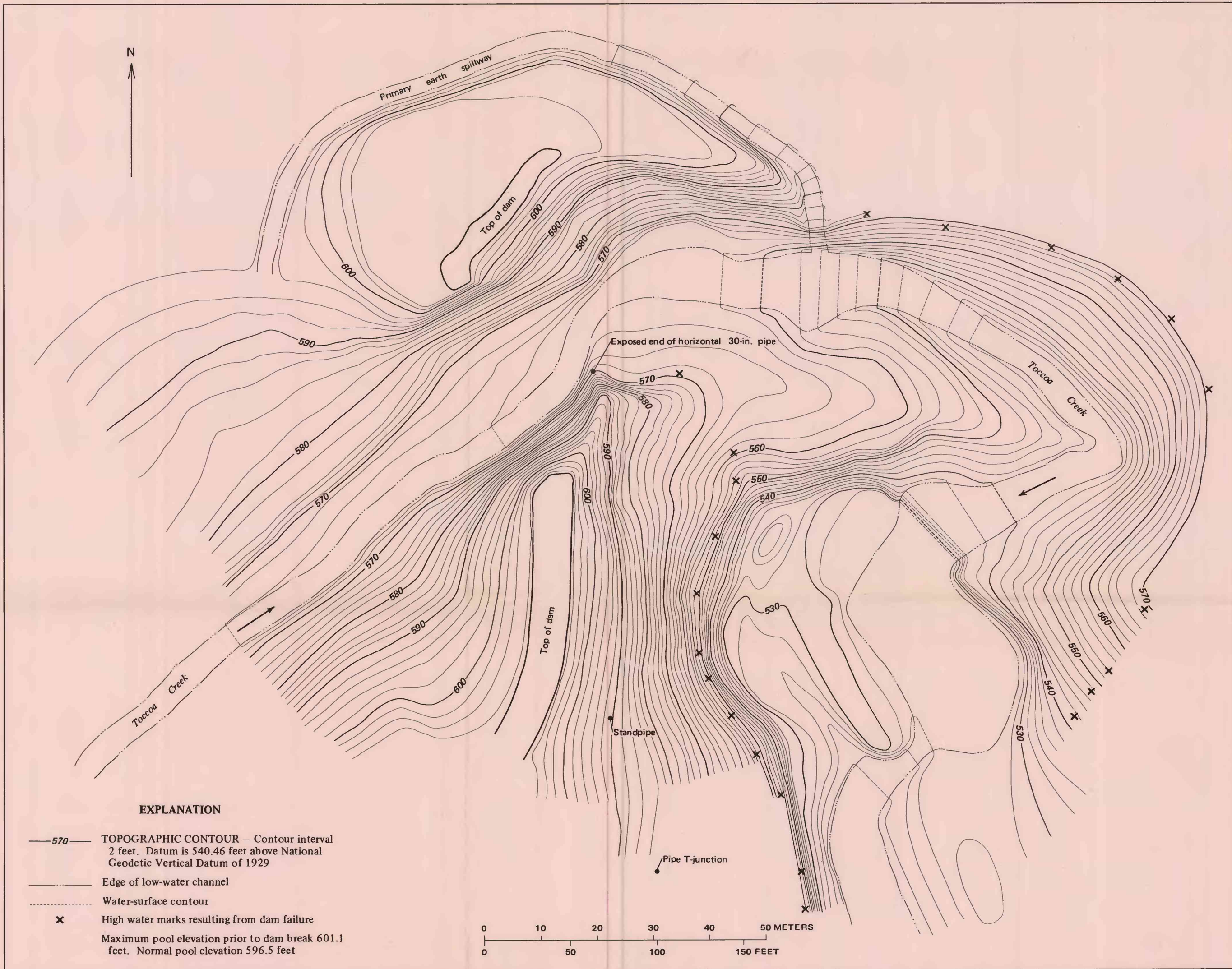


FIGURE 6. - Kelly Barnes Dam after failure

Meteorological conditions. - The NWS (National Weather Service) described meteorological conditions in the report by the Federal Investigative Board (1977) as follows: "Before rain began the ground was already wet from heavy rainfall of 3 1/2 to 4 1/2 inches, which fell on October 25 - 26. The rainfall began on Wednesday morning, November 2, and ended by midnight on Saturday, November 5. A strong high pressure area, centered over New England, was bringing Atlantic moisture into Georgia on Wednesday and this produced the rainfall at the beginning of the storm period. Meanwhile, a more important development was taking place in Texas where a strong low pressure area was developing at upper levels in the atmosphere. This intense upper level low was located near Shreveport, Louisiana, on Thursday morning, November 3; New Orleans, Louisiana, on Friday morning, November 4; Mobile, Alabama, on Saturday morning, November 5; Greenville, Alabama, on Sunday, November 6. As this slow-moving upper level storm moved closer to Georgia, more and more moisture was brought in on southerly winds from the Gulf of Mexico. Lifting of the air by the higher terrain of north Georgia accentuated the lifting processes provided by the at-

mospheric storm patterns. A plentiful supply of moisture, lifting of the air, and slow-moving storm system are the ingredients of a long, heavy rain event.

"Rainfall reports are received by the National Weather Service from radio stations WLET and WNEG in Toccoa. Since these stations are located some distance from the drainage area above Kelly Barnes Dam, a rainfall survey was made. Three additional storm total values were obtained * * *. [The location and storm totals of hourly and daily rainfall stations from the Federal Investigative Board (1977) and National Oceanic and Atmospheric Administration (1977) for the period November 2 - 6 are shown in fig. 1.] These measurements, interviews with local residents, radar echoes, and hourly values from nearby recording stations [at Burton Dam, Ga., and Long Creek, S.C.] were used in estimating the rainfall distribution for the drainage basin above Kelly Barnes Dam. [See fig. 8.] Although radar echoes indicated that the heaviest rainfall probably occurred between 6:30 p.m. and 7:30 p.m. on November 5, the estimated maximum 1-hour value is shown between 6:00 p.m. and 7:00 p.m. since points are plotted on the hour.

"The rainfall was light for the first two days with slightly over 1 inch falling in the Toccoa area by Friday morning, November 4. Rainfall intensity increased somewhat for the next 24 hours, with a storm total of approximately 2 1/2 inches by 8:00 a.m., Saturday morning, November 5. The storm total increased to approximately 3 1/2 inches by noon on Saturday and then the rainfall was apparently light until about 6:00 p.m., when showers moved into the area. From 6:30 p.m. to 7:30 p.m., radar echoes [from Athens, Ga.] indicated periods of torrential rainfall with frequent intense lightning and thunder. A small tornado apparently touched down about 5 miles southeast of Kelly Barnes Dam at approximately 8:00 p.m. The damage to trees was limited to only 100 yards in width and about one-fourth mile in length, but the tornado was indicative of the severity of the weather. After 8:00 p.m. the showers were less frequent and had practically ceased by midnight. Estimated basin rainfall for the entire period is about 7 inches, with almost 3 1/2 inches occurring between 6:00 p.m. and midnight on November 5." (See fig. 8.)



FIGURE 7. - Separate inlets for low-water spillway and welded steel penstock to power plant, photographed in 1949. (Photograph courtesy of Federal Investigative Board, Kelly Barnes Dam)

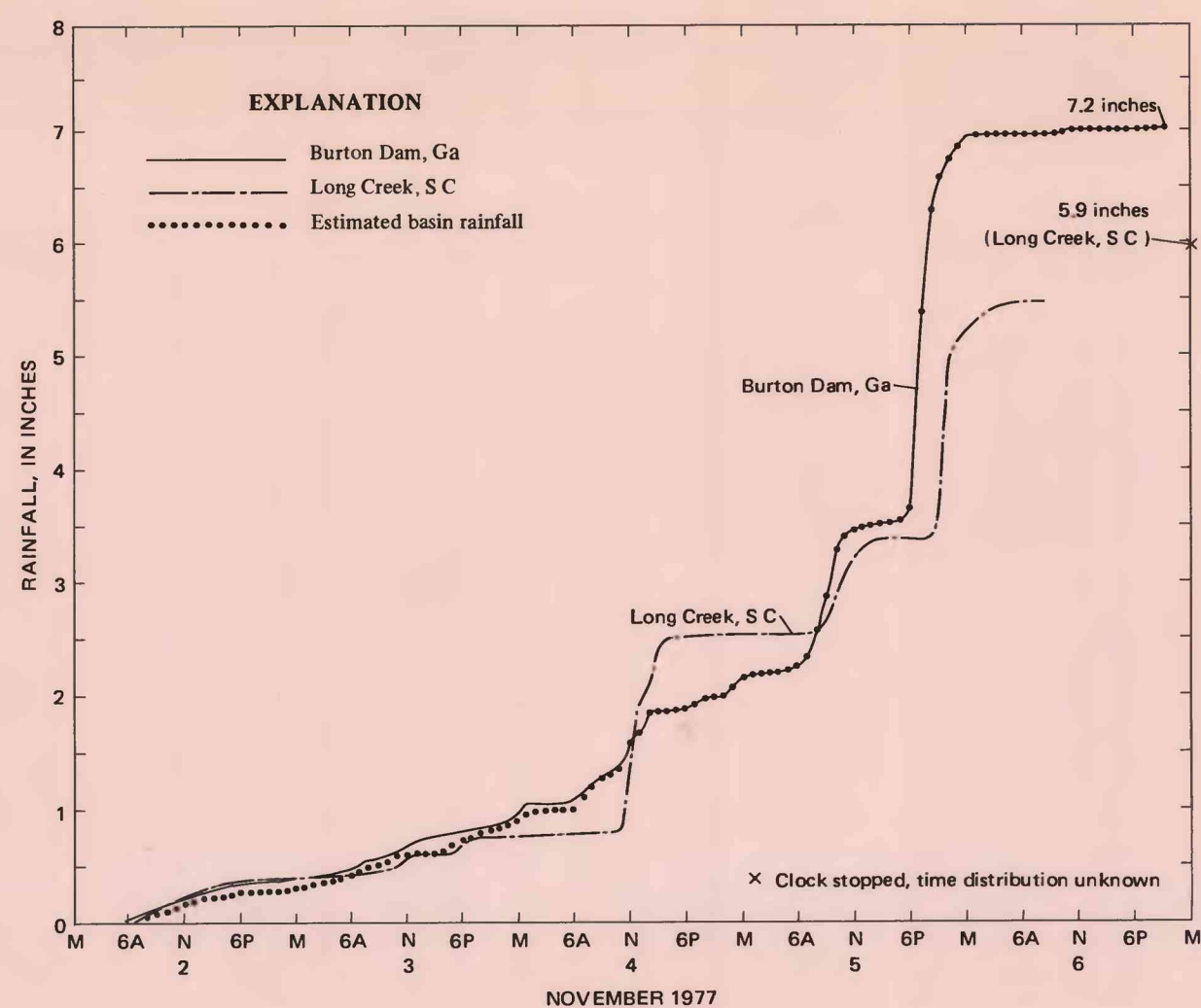


FIGURE 8. - Mass curves of rainfall at Burton Dam, Ga., and Long Creek, S.C., and estimated rainfall in upper basin of Toccoa Creek, November 2 - 6, 1977. (National Oceanic and Atmospheric Administration, 1977)

KELLY BARNES DAM FLOOD OF NOVEMBER 6, 1977, NEAR TOCCOA, GEORGIA

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