



Floods of September 6, 1960, in Eastern Puerto Rico

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By Harry H. Barnes, Jr., and Dean B. Bogart

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ABSTRACT

The floods of September 6, 1960, were the greatest known on many streams in eastern Puerto Rico. There were 117 lives lost, 30 persons missing, and 136 injured. Total damage was estimated in excess of \$7 million. Several thousand persons were forced from their homes by the floods as 484 houses were destroyed and more than 3,600 others were damaged. All main highways and most secondary roads were impassable for a short period during the floods and damage to them was heavy.

Following the passage of Hurricane Donna off the north-east coast, rains of very high intensity fell over parts of the eastern half of the island, beginning about 9 p.m. September 5. By dawn September 6, rains totaling more than 10 inches over a large area produced floods in every river basin from the Rio Grande de Manati eastward. Flood discharges on the Rio Humacao, Rio Turabo, and Rio Valenciano were the greatest known and rank high among the notable floods on streams that drain from 6 to 15 square miles.

An outstanding feature of the floods was the unusually high magnitude of peak discharges—9 of the 24 peak discharges determined had Myers ratings greater than 80 per cent.

INTRODUCTION

The floods of September 6, 1960, in the eastern half of Puerto Rico rank among the most disastrous floods ever experienced on the island.

The passage of Hurricane Donna off the north coast of Puerto Rico caused torrential rains over eastern Puerto Rico during the night of September 5-6, and produced destructive floods in all river systems from the Rio Grande de Manati eastward. Before dawn on September 6, more than 100 persons were dead and many others were injured as a result of the floods. Damage to highways and bridges, railroads, utilities, farmlands, livestock, and other public and private properties was in excess of \$7 million. Emergency housing, food, and water had to be provided for hundreds of the homeless in Humacao and San Lorenzo by the American Red Cross and Commonwealth authorities.

Rains of 10 inches or more fell over a large area of the eastern interior section of the island during a 6- to 8-hour period beginning about 9 p.m. on September 5. Maximum rainfall of record occurred at several stations. Residents of the area indicated the floods on many streams were the highest that could be recalled. Floods on the Rio Humacao, Rio Turabo, and Rio Valenciano were particularly outstanding.

The prompt dispatch of survey crews proved to be valuable as the pertinent flood-marks were deteriorating rapidly through the action of rains that fell almost daily for the remainder of September.

General descriptions of the storm and floods, peak stage and discharge for the September 1960 floods and for previous maximum floods at selected gaging stations, peak stage and discharge at miscellaneous sites, a discharge hydrograph and a table of discharge at selected times at three gaging stations, and a summary of flood damage are included in this report.

ACKNOWLEDGEMENTS

The documentation of basic streamflow records in Puerto Rico is a part of a continuous cooperative program with agencies of the Commonwealth of Puerto Rico. The preparation of this report is part of a supplemental investigation program financed through a special cooperative agreement between the U.S. Geological Survey and the Puerto Rico Water Resources Authority, Rafael V. Urrutia, executive director; the Puerto Rico Aqueduct and Sewer Authority, Juan Labadie Eurite, executive director; and the Puerto Rico Industrial Development Co., Carlos M. Pas-salacqua, president.

Because of the need to perform the fieldwork and office computations pertaining to flood-peak discharge as promptly as possible, 5 hydraulic engineers from the United States, and 5 engineers and engineering aids from the Puerto Rico Water Resources Authority were assigned to the San Juan district for a 30-day period after the floods. The fieldwork and office work of determining peak discharges by indirect methods were directed by Harry H. Barnes, Jr., flood specialist, Atlanta, Ga., under the general supervision of Tate Dalrymple, chief of the Floods Section, Water Resources Division.

The collection and compilation of the basic stage and discharge record as well as the associated analyses for the special flood investigations were under the direction of Dean B. Bogart, project hydrologist.

The U.S. Weather Bureau, the Office of Civil Defense, and other agencies provided information for the report.

THE STORM

On September 2, 1960, Hurricane Donna was located about 1,200 miles east-southeast of Puerto Rico. By the evening of September 5, Donna had moved through the northern Leeward Islands to a position about 100 miles north of San Juan. Beginning about 9 p.m. on September 5, and continuing until 3 or 4 a.m. September 6, rains of very high intensity fell over parts of eastern Puerto Rico. Light rains continued until daybreak.

Precipitation intensities were outstanding at many of the weather stations during the period of heavy rain. At Carite Dam, 25 miles south of San Juan, 6.10 inches was measured in 2 hours between 9 and 11 p.m. Gages in the eastern section of the island at El Yungue, Rio Blanco, and Fajardo recorded 3 inches in 1 hour during the night.

The largest rainfall total reported was 18.76 inches on the northeast slope of the Luquillo Mountains near Sabana. Naguabo and Cayey reported 24-hour totals of 14.60 and 14.07 inches, respectively. High-intensity rain amounting to 10 inches or more fell over an area about 15 by 40 miles extending from Barranquitas, in the central interior, to the east coast of the island.

An isohyetal map of the storm rainfall for September 5-7 is shown on figure 1. The isohyets are drawn through points of approximately equal values and caution is advised in interpolation of the lines. This is particularly true in the mountainous area between Cayey and Humacao where inconclusive reports suggest that the total rainfall during the storm period may have been considerably higher than that indicated by the map.

No hurricane-force winds were observed in Puerto Rico during the passage of Hurricane Donna, except for a brief flurry at Roosevelt Roads which may have been tornadic in character. Tides of 4 to 6 feet above normal were reported along the east and north coasts of the island.

THE FLOODS

Damaging floods were widespread on both large and small streams throughout the eastern half of Puerto Rico. At Humacao, near the southeast coast, 90 persons were drowned as floodwaters of the Rio Humacao swept through the low-lying areas of the city (figs. 2, 3) during the predawn hours of September 6. The rate at which the level of this unprecedented flood rose was so rapid that victims were unable to reach safety even after being warned of the danger. Residents at Ciales reported a bore on the Rio Grande de Manati, one of the largest rivers on the island.

Many landslides occurred on the cultivated slopes of the island's mountainous interior. Highways along the mountainsides were blocked in many places and dangerously undermined or destroyed in others. Large amounts of soil, rock, and bamboo were dumped into the streams by the landslides and channel erosion.

Bamboo is used rather extensively throughout the island to check roadside erosion and protect streambanks. The dislodged bamboo that was swept away by streams proved to be a menace to bridges and culverts. In many places bridge and culvert openings were completely blocked by the debris (fig. 4), forcing floodwaters over or around the structures, and resulting in large washouts.

In the upper reaches of the Rio Turabo, deposition of rock and gravel raised the

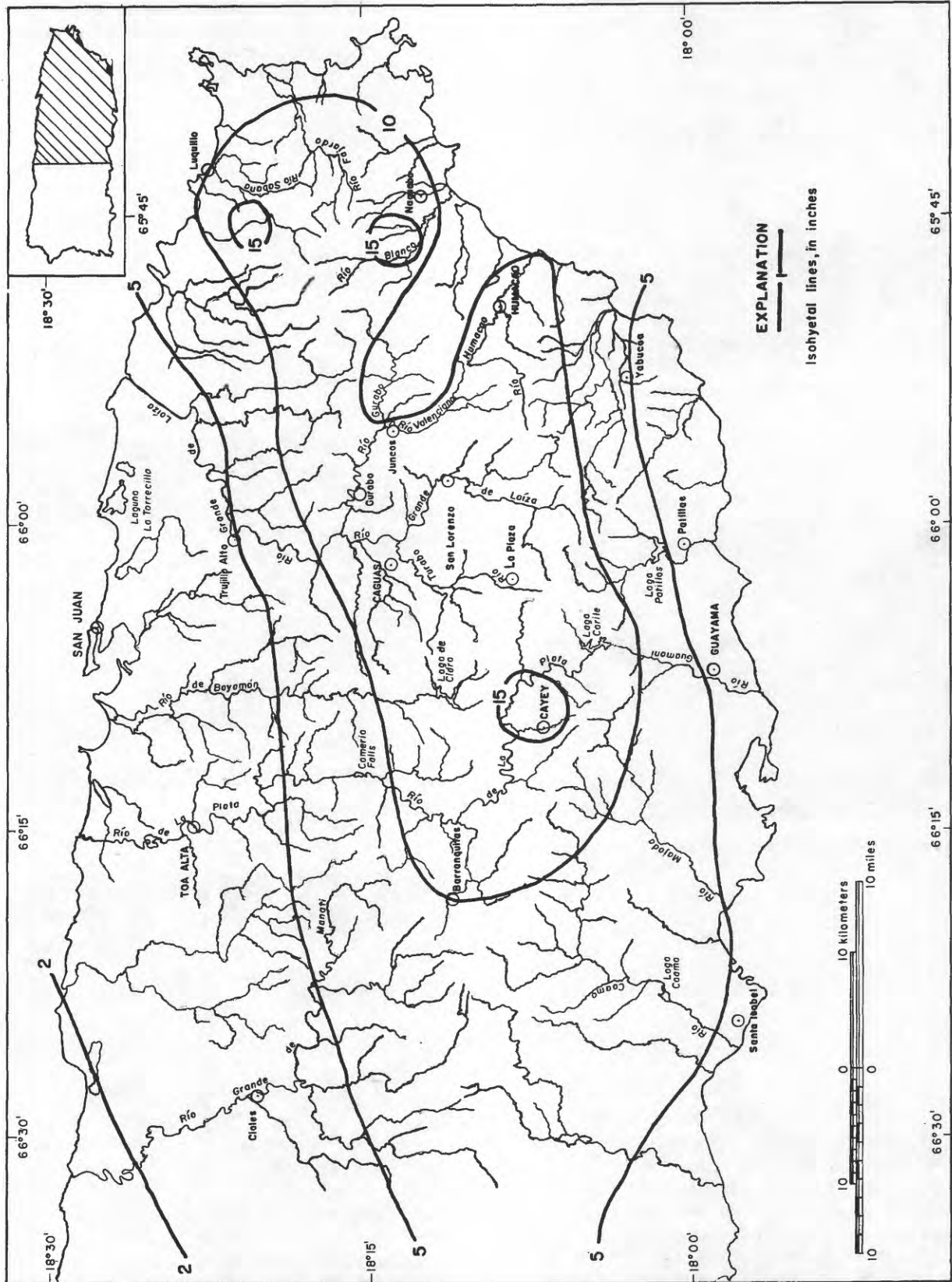


Figure 1. — Isohyetal map of eastern Puerto Rico showing storm rainfall, September 5–7.



Figure 2.—Flood debris in a street in Humacao.



Figure 3.—After the recession of the floodwaters at the northwest edge of Humacao. Note the man pointing to the high-water mark above his head.

riverbed above the highway and bridge level (fig. 5) at points between Caguas and La Plaza. Sharply angled fresh rock, in addition to the usual rounded and bleached-out boulders, was particularly noticeable in the channels. Several of the older citizens living along the Rio Turabo north of La Plaza indicated that the flood on September 6 was the greatest known.

Floods along the small tributaries in upper reaches of the Rio Grande de Manati were high, but were not particularly outstanding. However, downstream at Ciales the peak stage exceeded the previous maximum of record by 3 feet and destroyed the gaging station.

At Comerio Dam, the Rio de la Plata produced a peak discharge of 101,000 cfs (cubic feet per second) from its 140-square-mile drainage basin. The design head for the dam was exceeded by more than 3 feet and water poured over the abutments of the spillway. The generation of hydroelectric power was interrupted when the powerhouse was flooded prior to the peak. Farther downstream at the Toa Alta gaging station, the river rose 29.1 feet, of which 15 feet was in 1 hour.

Peak discharges or stages were determined at 25 sites on streams in eastern Puerto Rico (fig. 6).



Figure 4.—Bridge opening completely clogged, mostly by bamboo.



Figure 5.—View from downstream side of bridge on Rio Turabo near La Plaza. Note the rock-filled channel above the bridge.

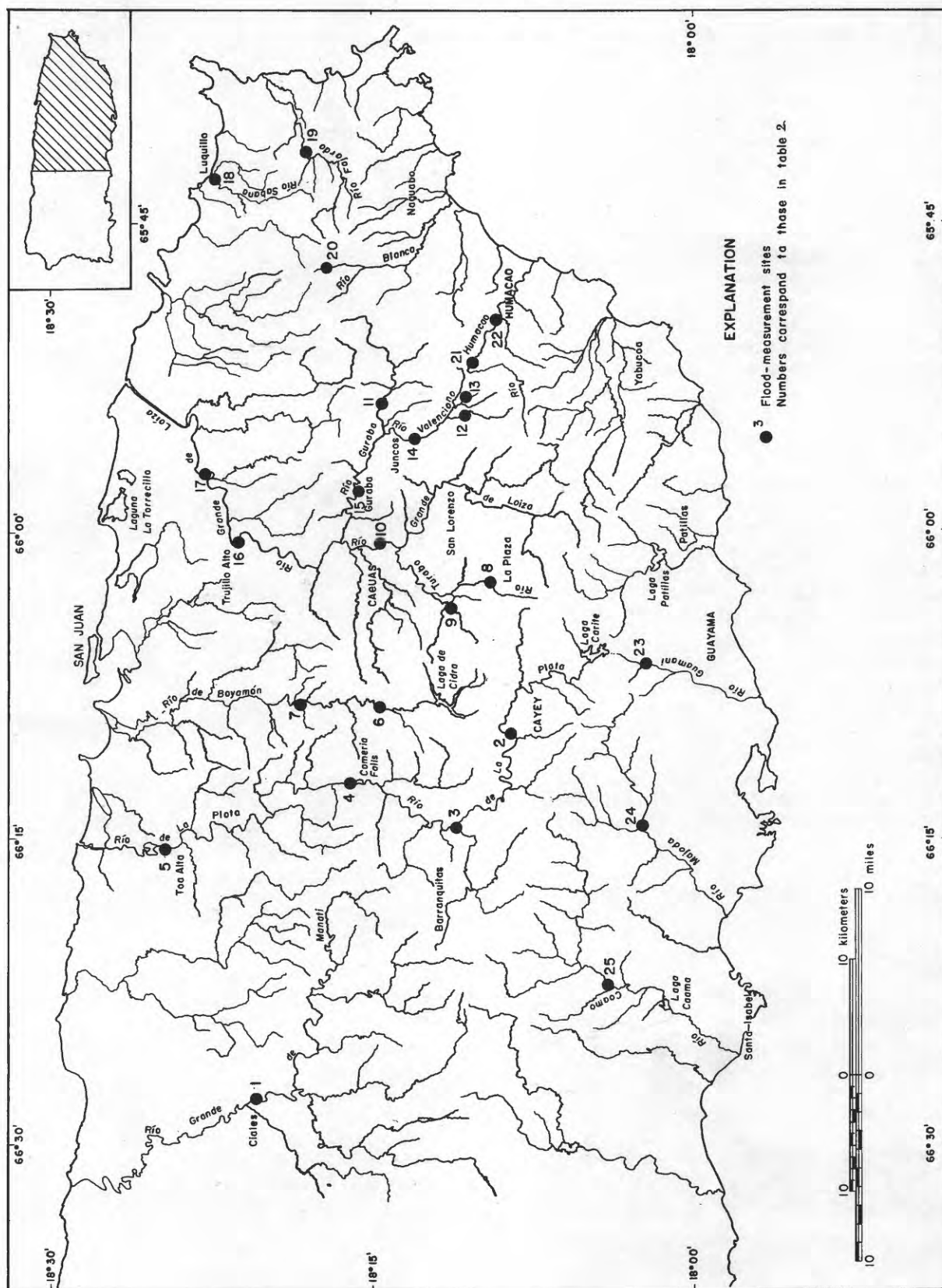


Figure 6. —Map of eastern Puerto Rico showing location of flood-measurement points; floods of September 6.

Peak discharges in the middle reaches of the Rio Valenciano rank among the highest known for streams that drain from 6 to 15 square miles. At Juncos, the floodwall protecting the city along the left bank of the river was overtopped and extensively damaged (fig. 7). Downstream from the mouth of Rio Valenciano, floodwaters of Rio Gurabo overtopped the bridge handrails at Highways 185 and 181, and washed out the bridge approaches. The gaging station at Gurabo was damaged and put out of action. The railroad bridge 1 mile downstream was destroyed.

At San Lorenzo the floodwaters of Rio Grande de Loiza destroyed practically all houses and buildings in its path (fig. 8). The only evidence left of previous habitation was partly exposed foundations along the boulder- and debris-littered banks.

The gaging station on the Rio Grande de Loiza at Highway 30 recorded a rise of 12 feet in 1 hour. Shortly after 5 a.m. September 6, the river crested at a stage of 31.2 feet on the gage. It was reported by local residents that the floodwaters rose 42 feet just below Loiza Dam at Trujillo Alto. At Carolina the peak discharge through the bridge on Highway 3 was 197,000 cfs from a contributing area of 239 square miles. Below this point floodwaters, in their rush to the sea, broke out of the Loiza's canalized main channel and found outlet through Laguna La Torrecilla about 8 miles to the west. Practically the entire coastal plain between Highway 3 and the low ridge at the Atlantic beach



Figure 7.—View showing damage to floodwall along left bank at Rio Valenciano in Juncos.



Figure 8.—Heavily eroded and redeposited bank of Rio Grande de Loiza at San Lorenzo. Several houses formerly occupied this area.



Figure 9.—Bridge on Rio Limones near Limones. Wingwall from left side was found intact about 50 feet downstream; the remains of the wingwall from the right side can be seen in the foreground.

became a large lake about 10 miles long. Highway 3 was under water at several places.

The Rio Sabana and the Rio Fajardo, draining the northern and eastern slopes of the Sierra de Luquillo, produced notable floods.

Along the coastal highway from Naguabo, at the eastern end of Puerto Rico, to Santa Isabel, on the south-central coast, practically every principal stream overtopped the highway (fig. 9). Floods on the Rio Blanco and Rio Guayanes were particularly destructive. According to interviews with residents along the coast northeast of Yabucoa, the magnitude

of flooding on streams of this area was less than that for the floods of 1928.

FLOOD DAMAGE

The damage caused by the floods of September 6 exceeded \$7 million. A summary of estimated damages is given in table 1.

Table 1.—Summary of flood damage, September 6

[Adapted from Civil Defense Corps data]

Public property:	
Department of Public Works (roads and bridges).....	\$3,201,000
Aqueduct and Sewer Authority.....	247,000
Land Authority.....	600,000
Water Resources Authority (power).....	104,000
Communication Authority.....	20,000
Total.....	4,172,000
Private property:	
Houses.....	1,496,000
Agriculture:	
Crops.....	924,000
Livestock and poultry.....	91,000
Facilities.....	298,000
Other.....	74,000
Utilities.....	26,000
Total.....	2,909,000
Total damage.....	\$7,081,000

Human suffering was great—there were 117 deaths, 30 persons missing, and 136 injured. Emergency housing, medical attention, food, and clothing were provided for thousands as 484 houses were destroyed and about 3,600 others damaged. The Civil Defense Corps and the American Red Cross assisted more than 30,000 persons in 33 towns.

Damage to agriculture was high as 8,300 acres of sugar cane, coffee, bananas, and other crops were damaged. Over 800 head of livestock were killed.

Total damage to roads and bridges exceeded \$3 million. During the floods, all main highways and most secondary roads were impassable for a short period. At Humacao, the highway bridge over Rio Humacao was destroyed and traffic was not restored for more than 3 weeks. It was reported that the temporary bridge over Rio Humacao was destroyed on December 1, 1960, by a somewhat lesser flood.

SUMMARY OF FLOOD DISCHARGES

Records of past floods in Puerto Rico are very scanty. Michael A. Quinones, former chief engineer, Puerto Rico Water Resources Authority, suggests in a study of major floods in Puerto Rico¹ that "the absence of record may be partly due to the fact that most of the major floods have occurred during hurricanes when most of the people are too busy looking for protection of their own lives, and partly to lack of curiosity in determining afterwards the magnitude of the floods."

Hydrologic information indicates that the floods of September 6, 1960, were the greatest known over much of eastern Puerto Rico. The only previous flood in the area with which they may be compared occurred September 13–14, 1928, during the San Felipe hurricane. Quinones' study of the 1928 flood at Comerio Falls Dam indicates that the peak discharge was slightly higher than that of the 1960 flood.

The peak discharges for the floods of September 6, 1960, were determined at 24 sites. Peak discharges, expressed in cubic feet per second per square mile, are plotted against drainage area on figure 10. Comparison of these floods with outstanding floods that have occurred in other places indicates that the floods on the Rio Humacao, Rio Valenciano, and Rio Turabo (drainage areas of from 6 to 15 square miles) rank among the highest known.

The peak discharge at 9 sites had a Myers rating in excess of 80 percent; the discharge at 4 of these sites exceeded 100 percent. Compilations of record peak discharges on streams in the United States and some foreign streams^{2,3} reveal only 14 known events (from drainage areas of less than 250 square miles) in which the Myers rating exceeded 80 percent.

¹Quinones, M. A., 1953, High intensity rainfall and major floods in Puerto Rico: Am. Soc. Civil Engineering Proc., v. 79, Separate 364.

²Lindsey, R. K., Kohler, M. A., and Paulhus, J. C. H., 1949, Applied hydrology: New York, McGraw-Hill Book Co., Inc., 689 p.

³Creager, W. P., Justin, J. D., and Hinds, J., 1954, Engineering for dams: New York, John Wiley and Sons, Inc., v. 1, 245 p.

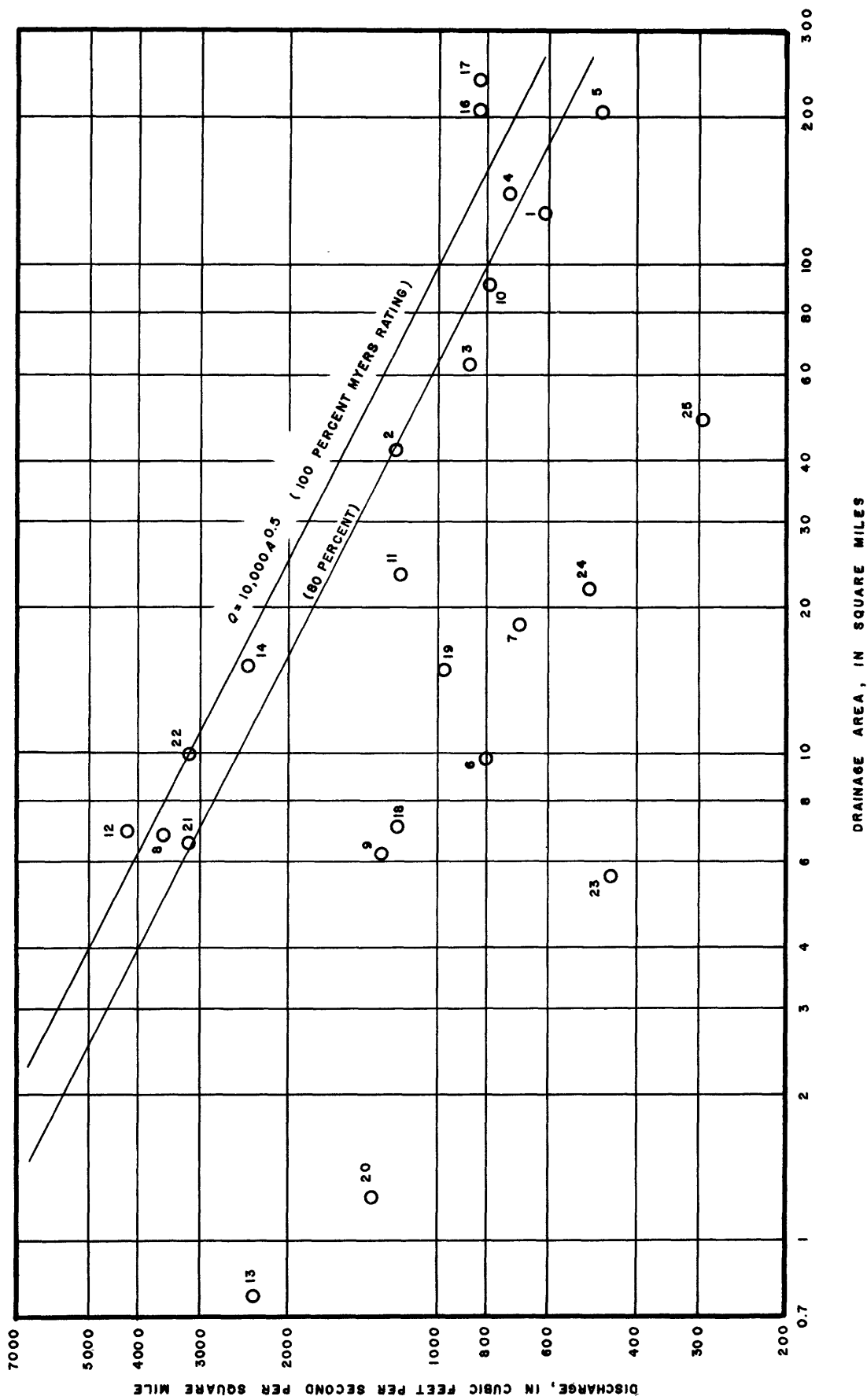


Figure 10.—Relation of unit discharge to drainage area; floods of September 6.

It is significant that each of the high-yield streams mentioned above head on the northern slope of the Sierra de Cayey between Cayey and Humacao. During the storm, Weather Bureau radar units tracked the northeastward movement of the most intense rainstorm over this area. The orographic influence of the mountain range that rises ab-

ruptly from the south coastal plain is shown by the rainfall pattern (fig. 1).

Peak discharges at stream-gaging stations and at other points in eastern Puerto Rico are summarized in table 2. The reference numbers in the table apply to figures 6 and 10.

Table 2.—Summary of flood stages and discharges in eastern Puerto Rico for flood of September 6

[Each station in this table has 1 or 2 entries listed under maximum floods; the first pertains to the flood being reported on, and the second pertains to the maximum flood previously known during the period of record]

No.	Stream and place of determination	Drainage area (sq mi)	Period of record	Maximum floods			
				Date	Gage height (feet)	Discharge	
						Cfs	Cfs per sq mi
1	Rio Grande de Manati at Ciales----	128	1946-60	Sept. 6, 1960	22.7	77,300	604
				Aug. 12, 1956	19.7	-----	-----
2	Rio de la Plata near Cayey-----	42.2	-----	Sept. 6, 1960	-----	51,000	1,210
3	Rio de la Plata at Proyecto La Plata.	63.1	1959-60	----do-----	30.5	54,500	864
				Aug. 14, 1960	10.0	-----	-----
4	Rio de la Plata at Comerio Dam----	140	1914-60	Sept. 6, 1960	-----	101,000	721
				Sept. 14, 1928	-----	116,000	829
5	Rio de la Plata at Toa Alta-----	204	1960	Sept. 6, 1960	35.8	95,500	468
				Aug. 14, 1960	22.4	9,800	481
6	Rio Bayamon near Aguas Buenas----	19.9	-----	Sept. 6, 1960	-----	28,000	808
7	Rio Bayamon Dam near Aguas Buenas.	18.5	-----	----do-----	-----	12,800	692
8	Rio Turabo near La Plaza-----	6.82	-----	----do-----	-----	24,000	3,520
9	Quebrada de las Quebradillas near Caguas.	6.25	-----	----do-----	-----	8,150	1,300
10	Rio Grande de Loiza at Caguas----	89.7	1960	----do-----	31.2	71,500	769
				Aug. 14, 1960	20.0	-----	-----
11	Rio Gurabo near Juncos-----	23.6	1960	Sept. 6, 1960	-----	28,000	1,190
12	Rio Valenciano near Las Piedras----	6.86	1960	----do-----	-----	28,800	4,200
13	Rio Valenciano tributary near Las Piedras.	.76	1960	----do-----	-----	1,770	2,330
14	Rio Valenciano at Juncos-----	15.3	1960	----do-----	-----	37,100	2,420
15	Rio Gurabo at Gurabo-----	59.6	1960	----do-----	27.7	-----	-----
				Aug. 21, 1960	13.75	6,600	111
16	Rio Grande de Loiza at Loiza Dam----	207	1960	Sept. 6, 1960	-----	170,000	822
17	Rio Grande de Loiza at Carolina----	239	1960	----do-----	-----	197,000	824
18	Rio Sabana at Luquillo-----	7.01	1960	----do-----	-----	8,500	1,210
19	Rio Fajardo near Fajardo-----	14.9	1960	----do-----	-----	14,500	974
20	Rio Hicaco near Naquabo-----	1.24	1945-54	----do-----	6.50	1,660	1,340
			1958-60	Oct. 25, 1953	8.1	2,560	2,060
21	Rio Humacao at Las Piedras-----	6.54	1960	Sept. 6, 1960	-----	20,800	3,180
22	Rio Humacao at Humacao-----	10.0	1960	----do-----	-----	31,600	3,160
23	Rio Guamani near Guayama-----	5.65	1960	----do-----	-----	2,580	457
24	Rio Majada near Salinas-----	22.0	1960	----do-----	-----	11,000	500
25	Rio Coamo at Coamo-----	48.4	1960	----do-----	-----	14,300	295

¹Drainage area above Cidra Dam not included.

²Estimated on basis of field survey.

FLOODS OF SEPTEMBER 6, 1960, IN EASTERN PUERTO RICO

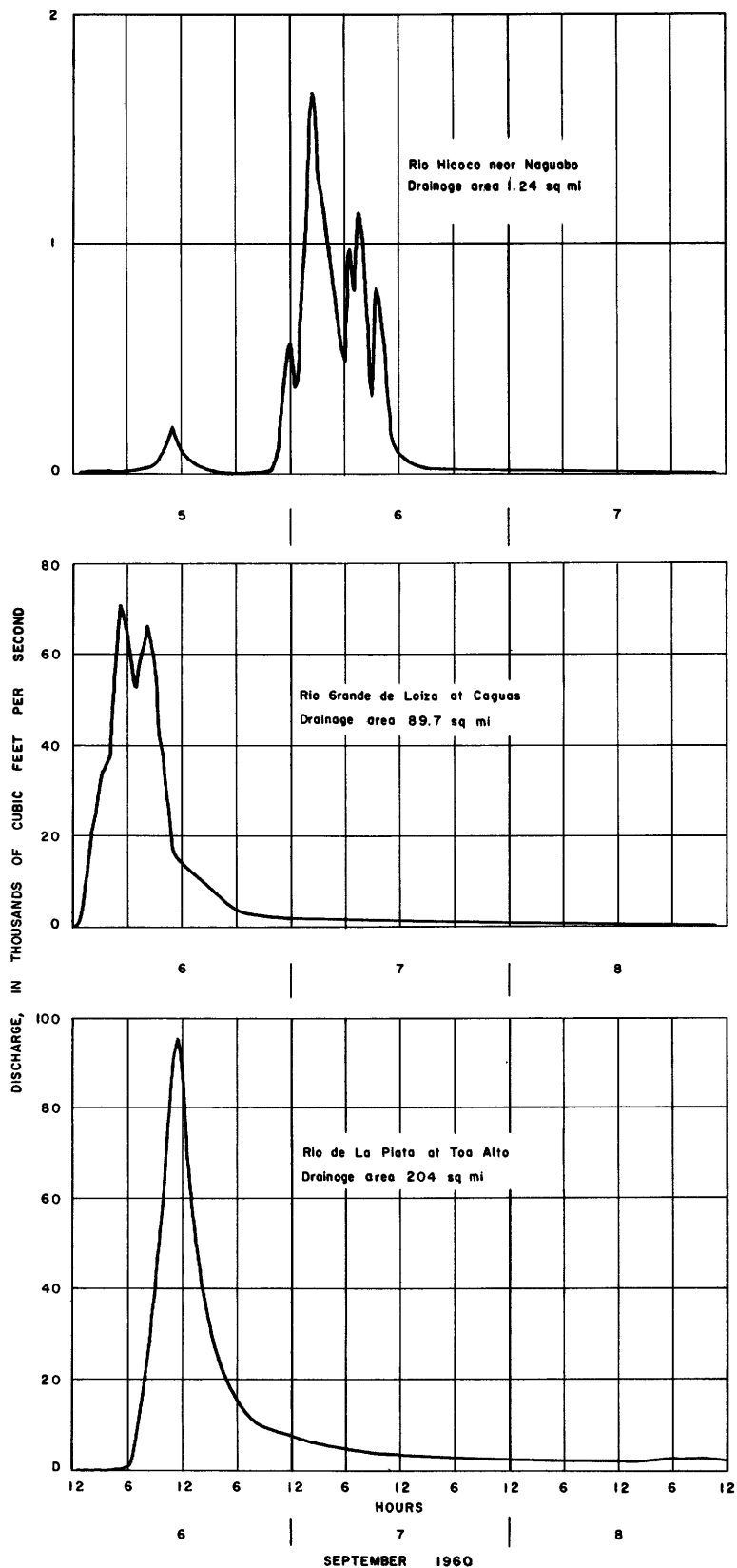


Figure 11.—Discharge hydrographs for selected gaging stations September 5—8.

Five gaging stations are operated by the Geological Survey in the flood area—4 recording gages and 1 nonrecording. During the flood the gaging station on Rio Grande de Manati at Ciales was completely destroyed. The station on Rio Gurabo at Gurabo was extensively damaged. The other two recording gages, both bubble type, had some damage to the intake system. The discharge hydro-

graphs for selected gaging stations are shown in figure 11; stages and discharges for selected time intervals are listed in tables 3, 4, and 5.

The discharge hydrograph for Loiza Dam is shown as figure 12. Discharge over the spillway was slightly regulated by the operation of taintor gates.

Table 3.—Record of stage and discharge, Rio de La Plata at Toa Alta

Date and time	Gage height (feet)	Discharge (cfs)
<i>Sept. 5</i>		
12 p. m. -----	6.65	230
<i>Sept. 6</i>		
5 a. m. -----	6.65	230
6 -----	7.50	462
6:30 -----	16.20	4,090
7 -----	22.00	10,900
7:30 -----	24.20	16,800
8 -----	26.10	23,900
9 -----	29.60	41,700*
10 -----	33.00	67,000
11 -----	35.40	92,500
11:30 -----	35.80	95,500
12 m -----	35.10	88,900
1 p. m. -----	31.80	57,300
2 -----	29.40	40,400
3 -----	27.50	30,300
4 -----	26.00	23,400
5 -----	24.80	18,700
7 -----	22.75	12,600
9 -----	21.30	9,490
11 p. m. -----	20.80	8,540
<i>Sept. 7</i>		
2 a. m. -----	19.20	6,240
4 -----	18.00	5,200
8 -----	16.90	4,450
12 m -----	15.10	3,600
4 p. m. -----	14.00	3,100
8 -----	13.15	2,720
12 p. m. -----	12.65	2,490
<i>Sept. 8</i>		
6 a. m. -----	12.15	2,270
2 p. m. -----	11.70	2,080
4 -----	12.20	2,290
6 -----	12.50	2,420
12 p. m. -----	12.30	2,340

Table 4.—Record of stage and discharge, Rio Grande de Loiza at Caguas

Date and time	Gage height (feet)	Discharge (cfs)
<i>Sept. 5</i>		
12 p. m. -----	7.31	200
<i>Sept. 6</i>		
1 a. m. -----	13.9	5,260
2 -----	20.6	20,100
3 -----	24.2	33,400
4 -----	25.1	37,400
5 -----	30.8	69,000
5:15 -----	31.2	71,500
6 -----	30.2	65,200
6:55 -----	28.2	52,900
7 -----	28.6	55,200
8 -----	30.0	63,900
8:10 -----	30.4	66,600
9 -----	29.0	57,600
10 -----	24.8	36,100
11 -----	19.3	16,300
12 m -----	18.5	14,100
1 p. m. -----	17.6	12,000
2 -----	16.8	10,200
4 -----	15.1	7,100
6 -----	12.3	3,240
9 -----	11.3	2,240
12 p. m. -----	11.0	1,970
<i>Sept. 7</i>		
6 a. m. -----	10.6	1,620
12 m -----	10.3	1,370
6 p. m. -----	10.0	1,230
12 p. m. -----	9.80	1,110
<i>Sept. 8</i>		
6 a. m. -----	9.60	994
12 m -----	9.40	886
6 p. m. -----	9.20	786
12 p. m. -----	9.10	735

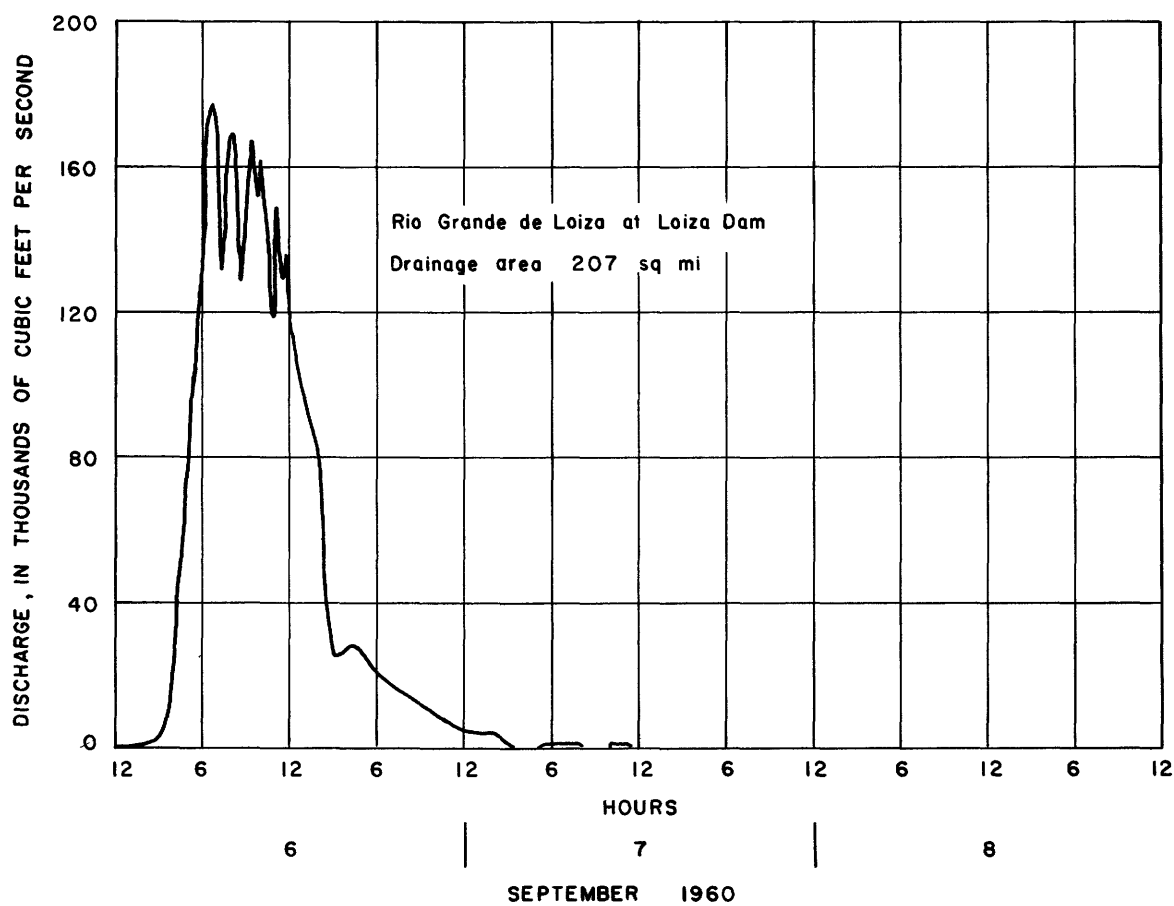


Figure 12.—Discharge hydrograph, Rio Grande de Loiza at Loiza Dam.

Table 5.—Record of stage and discharge, Rio Hicaco near Naguabo

Date and time	Gage height (feet)	Discharge (cfs)	Date and time	Gage height (feet)	Discharge (cfs)
<i>Sept. 4</i>			<i>Sept. 6—Continued</i>		
12 p. m.-----	0.23	7	3 p. m.-----	5.80	1,320
<i>Sept. 5</i>			4 -----	5.20	1,050
5 a. m.-----	.20	6	5 -----	4.35	743
6 -----	.23	7	6 -----	3.60	490
8 -----	.60	29	6:30 -----	4.95	981
9 -----	.60	29	7 -----	4.50	799
10 -----	1.40	102	7:30 -----	5.40	1,140
11 -----	2.20	206	8 -----	5.00	1,000
12 m.-----	1.30	91	9 -----	3.00	337
2 p. m.-----	.65	32	9:30 -----	4.52	806
6 -----	.32	12	10 -----	4.20	687
9 -----	.26	9	11 -----	2.00	177
10 -----	.29	10	12 m.-----	1.20	81
11 -----	2.90	320	1 p. m.-----	.82	46
12 p. m.-----	3.86	572	3 -----	.55	26
<i>Sept. 6</i>			6 -----	.40	16
12:30 a. m.-----	3.20	375	12 p. m.-----	.34	13
1 -----	4.00	618	<i>Sept. 7</i>		
2 -----	5.80	1,320	6 a. m.-----	.30	10
2:30 -----	6.50	1,660	12 m.-----	.27	9
			12 p. m.-----	.23	7