DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
DEPARTMENT OF NATURAL RESOURCES AND THE DEPARTMENT
OF PUBLIC WORKS, COMMONWEALTH OF PUERTO RICO

HYDROLOGIC INVESTIGATIONS
ATLAS HA-584

FLOODS IN THE NAGUABO AREA, EASTERN PUERTO RICO

This report provides factual and interpretive information on major floods in the Naguabo area. This information provides a technical basis on which the planner, engineer, administrator, or other interested persons can make decisions related to land use and development compatible with the degree of flood risk. Among the data presented are tabulations of flood discharge, flood profiles, and a map of the area inundated by the flood of 1960. The areas of inundation are specifically for conditions that existed at the time of the flood. Flood-frequency data are presented for selected sites.

This study is based principally on flood data obtained immediately after the floods of 1960 and 1970. Information was also obtained in interviews with residents in the study area.

A dual system of metric, "The International System of units (SI)," and English units are used in this publication. English units followed by (SI) units in parentheses are used throughout the report except in tables. The following conversion table shows the factors for converting English units to International System of units (SI):

Multiply English units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi²)	2.590	square kilometers (km²)
cubic feet per second (ft³/s)	.02832	cubic meters per second (m³/s)
cubic feet per second per square mile [(ft³/s)/mi²]	.01093	cubic meters per second per square kilometer [(m³/s)/km²]

Drainage Basins—The Naguabo study area (fig. 1) lies in the eastern part of Puerto Rico and encompasses about 70 mi² (181 km²) composed of coastal plain bordering the Mar Caribe and the mountains El Yunque area which is the eastern terminus of the Sierra de Luquillo.

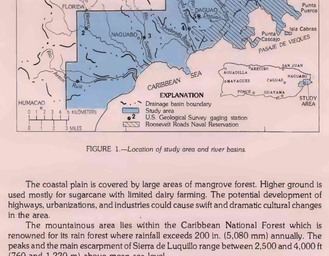


FIGURE 1.—*Location of study area and river basins.*

The coastal plain is covered by large areas of mangrove forest. Higher ground is used mostly for sugarcane with limited dairy farming. The potential development of highways, urbanizations, and industries could cause swift and dramatic cultural changes in the area.

The mountainous area lies within the Caribbean National Forest which is renowned for its rain forest where rainfall exceeds 200 in. (5,080 mm) annually. The peaks and the main escarpment of Sierra de Luquillo range between 2,500 and 4,000 ft (760 and 1,220 m) above mean sea level.

The eight rivers that contribute to flooding in the study area have their origin on the southern slopes of the Sierra de Luquillo and flow to the Mar Caribe with a combined drainage area of about 66 mi² (166 km²). Drainage areas of the streams are given in table 1.

Table 1.—*Drainage areas of streams*

River	Direction of flow	Drainage area				
		At gaging station			At mouth	
		Map number	mi²	km²	mi²	km²
Rio Anton Ruiz	east	1	4.3	11.2	8.0	20.7
Rio Blanco	southeast	2	11.0	28.5	27.2	70.5
Rio Santiago	south	3	5.0	13.0	7.1	18.4
Quebrada Botija	southeast		—	—	3.6	9.3
Quebrada Palma	southeast	4	4.86	12.5	6.0	15.5
Rio Daguao	southeast	5	2.26	5.85	7.2	18.6
Quebrada Aguas Claras	east	—	—	—	2.2	5.7
Quebrada Celba	east				2.8	7.3

The maximum distance from stream origin to the ocean is 10 mi (16 km). Channel slopes are very steep and stream velocities are extremely high in the mountains. The slopes become less steep from the foothills to the ocean.

Flood History—The flood of September 13, 1928 is the greatest known in the study area since 1899. The second largest known flood occurred on September 6, 1960; the third largest on record occurred on October 9, 1970 and the fourth largest on record occurred on August 12, 1956. All these floods are associated with hurricanes except the flood of October 9, 1970. The 1970 flood was caused by a slow moving tropical depression that stagnated about 300 mi (480 km) south of Puerto Rico. The earliest and largest flood for which definitive elevation data are available occurred on September 6, 1960. Major floods have occurred at least three times since 1960.

Floods that have inundated sizable areas since 1899 and for which some water-surface elevation data are available occurred in 1928, 1932, 1940, 1956, 1960, 1961, 1962, and 1970 but records are too fragmentary to determine accurate water-surface profiles for any flood except that of September 6, 1960.

Flood Discharge—Three peak discharge measurements made during the flood of October 9, 1970 are the only flood discharge data available in the study area. The results of these measurements are: (1) 14,900 ft³/s (422 m³/s) measured on Rio Blanco at the U.S. Geological Survey gaging station located at Florida (site 2 in fig. 1) where the drainage area is 11.0 mi² (28.5 km²). The ratio of discharge to drainage area at this site was 1,350 (ft³/s)/mi² [14.8 (m³/s)/km²]. (2) 2,300 ft³/s (65 m³/s) measured on Quebrada Palma at the U.S. Geological Survey gaging station located near Daguao (site 4 in fig. 1) where the drainage area is 4.84 mi² (12.5 km²). The ratio of discharge to drainage area at this site was 475 (ft³/s)/mi² [5.2 (m³/s)/km²]. (3) 2,600 ft³/s (74 m³/s) measured on Rio Daguao at the U.S. Geological Survey gaging station located at Daguao (site 5 in fig. 1) where the drainage area is 2.26 mi² (5.85 km²). The ratio of discharge to drainage area at this site was 1,150 (ft³/s)/mi² [12.6 (m³/s)/km²].

Flood Profiles—Profiles of Rio Anton Ruiz, Rio Blanco, Rio Santiago, Quebrada Botija, Quebrada Palma, Rio Daguao, Quebrada Aguas Claras tributary, Quebrada Aguas Claras, and Quebrada Ceiba for the flood of September 6, 1960 are shown in figures 2 through 9.

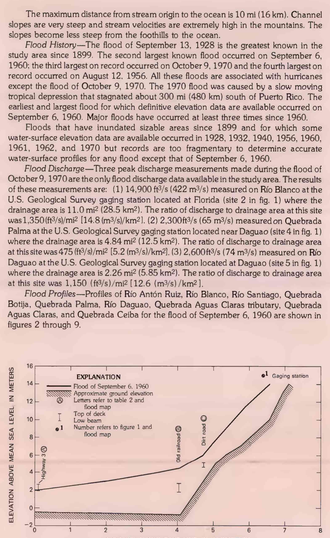


FIGURE 2.—*Profile of Rio Anton Ruiz, flood of September 6, 1960.*

FIGURE 3.—*Profile of Rio Blanco, flood of September 6, 1960.*

FIGURE 4.—*Profile of Rio Santiago, flood of September 6, 1960.*

FIGURE 5.—*Profile of Quebrada Botija, flood of September 6, 1960.*

FIGURE 6.—*Profile of Quebrada Palma, flood of September 6, 1960.*

FIGURE 7.—*Profile of Rio Daguao, flood of September 6, 1960.*

FIGURE 8.—*Profile of Quebrada Aguas Claras and Quebrada Aguas Claras Tributary, flood of September 6, 1960.*

FIGURE 9.—*Profile of Quebrada Ceiba, flood of September 6, 1960.*

Flood profiles are vertical sections showing the elevation of the water surface and the ground surface along the arbitrarily chosen base lines indicated on the flood map. The base line used to determine distances upstream from the mouth is not the thalweg of the stream but follows a smoother path along the valley and conforms to the general direction of flow during floods. The selected datum plane is mean sea level.

The land-surface profiles since they are taken along an arbitrarily chosen base line conforming to the general direction of flow during floods may or may not represent the ground elevation at the actual streambed.

The profiles represent the average of floodmark elevations and are somewhat smoothed. Abrupt changes in the profiles indicate the difference in water-surface elevations at the upstream and downstream sides of channel constrictions. The drop in water surface through constrictions during future floods may be different from that shown.

Forty-five bridges are in the flood area. Flooding in 1960 inundated 28 of the bridges and the water surface was above low beam on 10 others (table 2 and figs. 2 through 9).

Table 2.—*Bridge elevations in flood area*

Map symbol	Stationing along base line, in kilometers	Location of bridge	Elevation above mean sea level, in meters	
			Top of deck	Low beam
A	0.10	Boca Prieta, Highway 3	2.6	1.9
B	4.04	Rio Anton Ruiz, old railroad	2.7	1.7
C	4.73	Rio Anton Ruiz, dirt road	5.1	4.6
D	0.10	Rio Anton Ruiz, Highway 3	3.2	1.8
E	0.05	Rio Blanco, Highway 3	2.5	1.6
F	1.50	Rio Blanco, old railroad	2.8	2.1
G	1.92	Rio Blanco, old railroad	3.6	2.8
H	3.75	Rio Blanco, dirt road	4.7	3.8
I	6.80	Rio Blanco, Highway 31	14.9	13.9
J	1.94	Rio Blanco tributary, old railroad	3.5	2.8
K	3.00	Rio Blanco tributary, dirt road	5.3	4.4
M	3.20	Quebrada Massies, dirt road	4.7	3.8
N	5.60	Rio Blanco tributary, Highway 31	8.7	8.4
O	0.03	Rio Santiago, Highway 3	2.3	1.6
P	1.87	Rio Santiago, old railroad	8.9	8.2
Q	1.98	Rio Santiago, old railroad	10.4	9.4
R	2.50	Rio Santiago, Highway 192	16.0	15.2
S	3.20	Rio Santiago, Highway 31	22.0	21.7
T	4.15	Rio Santiago, old railroad	32.4	31.4
W	4.18	Rio Santiago, Highway 971	32.8	31.8
X	1.73	Quebrada Botija, old railroad	2.9	2.1
Y	2.58	Quebrada Botija, Highway 3	7.0	6.4
Z	2.77	Quebrada Botija, Highway 31	11.1	10.7

Table 2.—*Bridge elevations in flood area*—Continued

Map symbol	Stationing along base line, in kilometers	Location of bridge	Elevation above mean sea level, in meters	
			Top of deck	Low beam
A	1.63	Quebrada Palma, old railroad	4.1	3.5
B	2.50	Quebrada Palma, Highway 3	8.1	7.3
C	2.92	Quebrada Palma, old railroad	9.5	8.8
D	3.20	Quebrada Palma, old railroad	8.8	8.7
E	3.35	Quebrada Palma, old railroad	10.6	9.8
F	3.92	Quebrada Palma, dirt road	12.0	11.9
G	4.42	Quebrada Palma, Highway 973	16.8	16.1
H	4.11	Quebrada Platano, Highway 973	12.9	12.6
I	4.13	Quebrada Platano, old railroad	16.3	15.7
L	2.43	Rio Daguao, Highway 979	8.9	8.0
M	3.33	Rio Daguao, old railroad	15.2	14.6
N	3.45	Rio Daguao, Highway 3	16.7	15.8
P	4.27	Rio Daguao, Highway 974	23.0	22.5
Q	0.92	Quebrada Aguas Claras, Highway 979	5.9	5.6
R	1.13	Quebrada Aguas Claras tributary, Highway 3	9.0	8.1
T	1.96	Quebrada Aguas Claras tributary, Highway 3	19.1	18.4
U	0.60	Quebrada Ceiba, old railroad	3.3	2.7
V	0.65	Quebrada Ceiba, Highway 979	3.8	3.5
W	0.87	Quebrada Ceiba, dirt road	4.1	3.7
X	1.40	Quebrada Ceiba, Highway 3	9.1	8.1
Y	2.65	Quebrada Ceiba, Highway 975	22.9	22.5
Z	4.21	Quebrada Ceiba, Highway 975	52.9	52.6

Flood Frequency—It is not possible to predict when a flood of a specific magnitude will occur. However, the probable number of floods with a specific magnitude that will occur over a long period of time can be estimated. The frequency of occurrence (recurrence interval) is the average interval of time within which a given flood will be exceeded once. For example, a flood with a 25-year recurrence interval would have a 4-percent chance of being exceeded in any given year, or a flood with a 50-year recurrence interval would have a 2-percent chance of being exceeded in any given year.

The record of floods in the Naguabo area is fragmentary and not of sufficient length to determine a reliable flood-frequency relation. However, since the 1960 flood was the second highest during the period 1899–1972, it has an indicated frequency of 37 years. The flood of October 9, 1970 is the third highest of record and has an indicated recurrence interval of 25 years.

Flooded Areas—The areas inundated by the flood of September 6, 1960 on Rio Anton Ruiz, Rio Blanco, Rio Santiago, Quebrada Botija, Quebrada Palma, Rio Daguao, Quebrada Seca, Quebrada Aguas Claras, and Quebrada Ceiba have been delineated on the topographic map on the basis of flood-stage information furnished by local residents and observations in the field by U.S. Geological Survey personnel. The 1960 flood caused more inundation in these areas than any flood since at least 1928.

Flood boundaries were determined from water-surface profiles based on elevations of floodmarks, which were obtained from field surveys. The boundaries are well defined in densely populated areas and fairly well defined in agricultural and forest lands.

Cooperation and Acknowledgments—This report was initiated as part of the floods investigation authorized by a cooperative agreement between the Department of Public Works, Commonwealth of Puerto Rico and the U.S. Geological Survey. Administration of the cooperative program was placed under the Puerto Rico Department of Natural Resources in January 1973 and this report has been completed under their auspices.

Additional Information—Additional information relating to floods in the Naguabo area can be obtained from Water Resources Division of the U.S. Geological Survey, San Juan, Puerto Rico.

SELECTED REFERENCES

Lopez, M. A., 1967, Floods at Humacao, Puerto Rico: U.S. Geol. Survey Hydrol. Inv. Atlas HA–265.

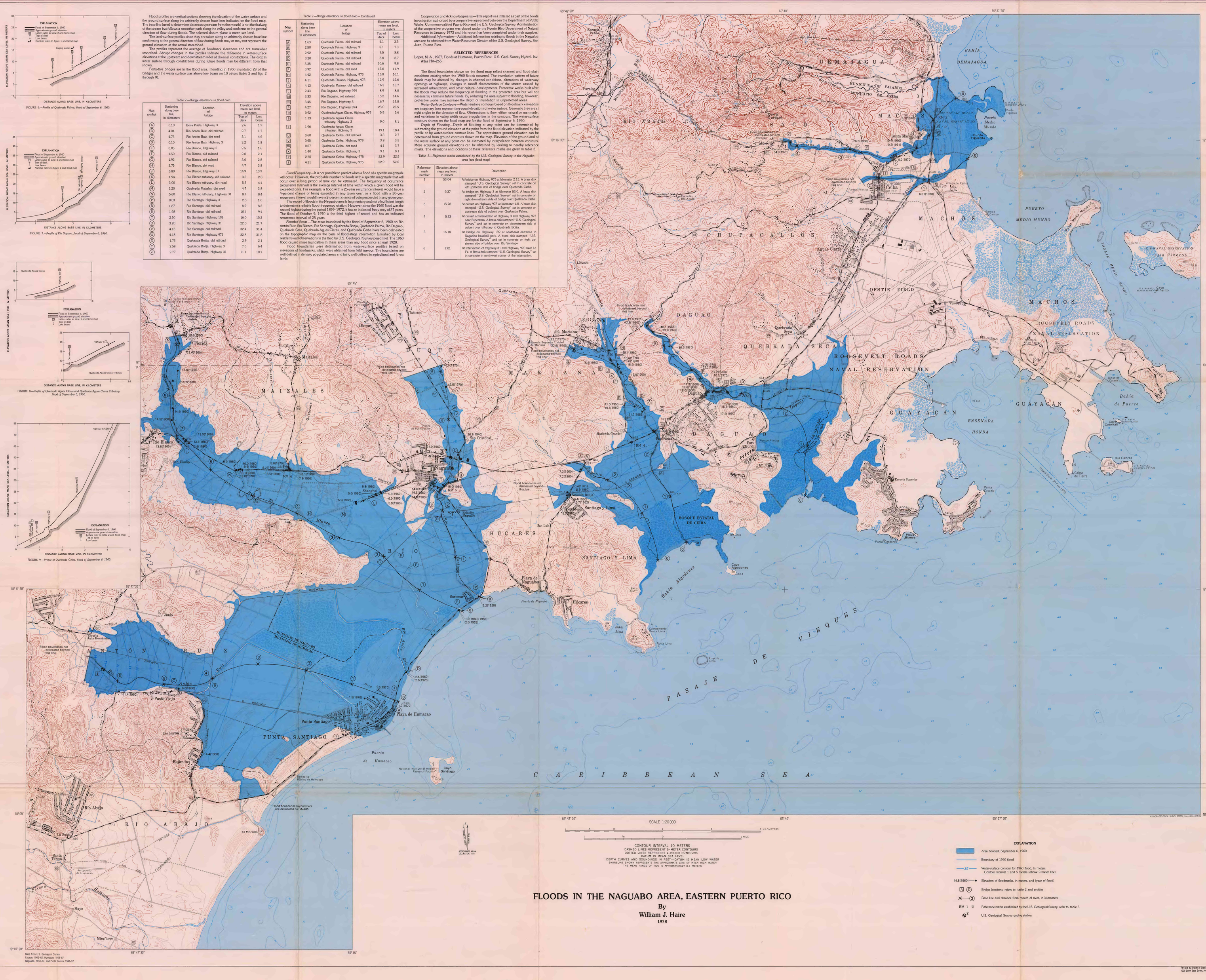
The flood boundaries shown on the flood map reflect channel and flood-plain conditions existing when the 1960 floods occurred. The inundation pattern of future floods may be affected by changes in channel conditions, alterations of waterway openings at highways, changes in runoff characteristics of the stream caused by increased urbanization, and other cultural developments. Protective works built after the floods may reduce the frequency of flooding in the protected area but will not necessarily eliminate future floods. By reducing the area subject to flooding, however, protective works may increase the depth of inundation in unprotected areas.

Water-Surface Contours—Water-surface contours based on floodmark elevations are imaginary lines representing equal elevations of water surface. Generally they are at right angles to the direction of flow. Obstructions to flow, either natural or manmade, and variations in valley width cause irregularities in the contours. The water-surface contours shown on the flood map are for the flood of September 6, 1960.

Depth of Flooding—Depth of flooding at any point can be determined by subtracting the ground elevation at the point from the flood elevation indicated by the profile or by water-surface contour lines. The approximate ground elevation can be determined from ground contours shown on the map. Elevation of the ground and of the water surface at any point can be estimated by interpolation between contours. More accurate ground elevations can be obtained by leveling to nearby reference marks. The elevations and locations of these reference marks are given in table 3.

Table 3.—*Reference marks established by the U.S. Geological Survey in the Naguabo area (see flood map)*

Reference mark number	Elevation above mean sea level, in meters	Description
1	53.04	At bridge on Highway 975 at kilometer 2.15. A brass disk stamped "U.S. Geological Survey," set in concrete on left upstream side of bridge over Quebrada Ceiba.
2	9.37	At bridge on Highway 3 at kilometer 53.0. A brass disk stamped "U.S. Geological Survey" set in concrete on right downstream side of bridge over Quebrada Ceiba.
3	15.78	At culvert on Highway 973 at kilometer 1.9. A brass disk stamped "U.S. Geological Survey" set in concrete on upstream side of culvert over Quebrada Palma.
4	5.33	At culvert at intersection of Highway 3 and Highway 973 near Esperanza. A brass disk stamped "U.S. Geological Survey" and set in concrete on downstream side of culvert over tributary to Quebrada Botija.
5	16.18	At bridge on Highway 192 at southeast entrance to Naguabo baseball park. A brass disk stamped "U.S. Geological Survey," and set in concrete on right upstream side of bridge over Rio Santiago.
6	7.01	At intersection of Highway 31 and Highway 970 near La Fe. A Brass disk stamped "U.S. Geological Survey" set in concrete in northwest corner of the intersection.



FLOODS IN THE NAGUABO AREA, EASTERN PUERTO RICO

By
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1978

EXPLANATION

- Area flooded, September 6, 1960
- Boundary of 1960 flood
- 25 — Water-surface contour for 1960 flood, in meters. Contour interval 1 and 5 meters (above 2-meter line)
- 14.8 (1960) — Elevation of floodmarks, in meters, and (year of flood)
- A, D — Bridge locations, refers to table 2 and profiles
- X, 3 — Base line and distance from mouth of river, in kilometers
- RM 1 — Reference marks established by the U.S. Geological Survey refer to table 3
- 2 — U.S. Geological Survey gaging station

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