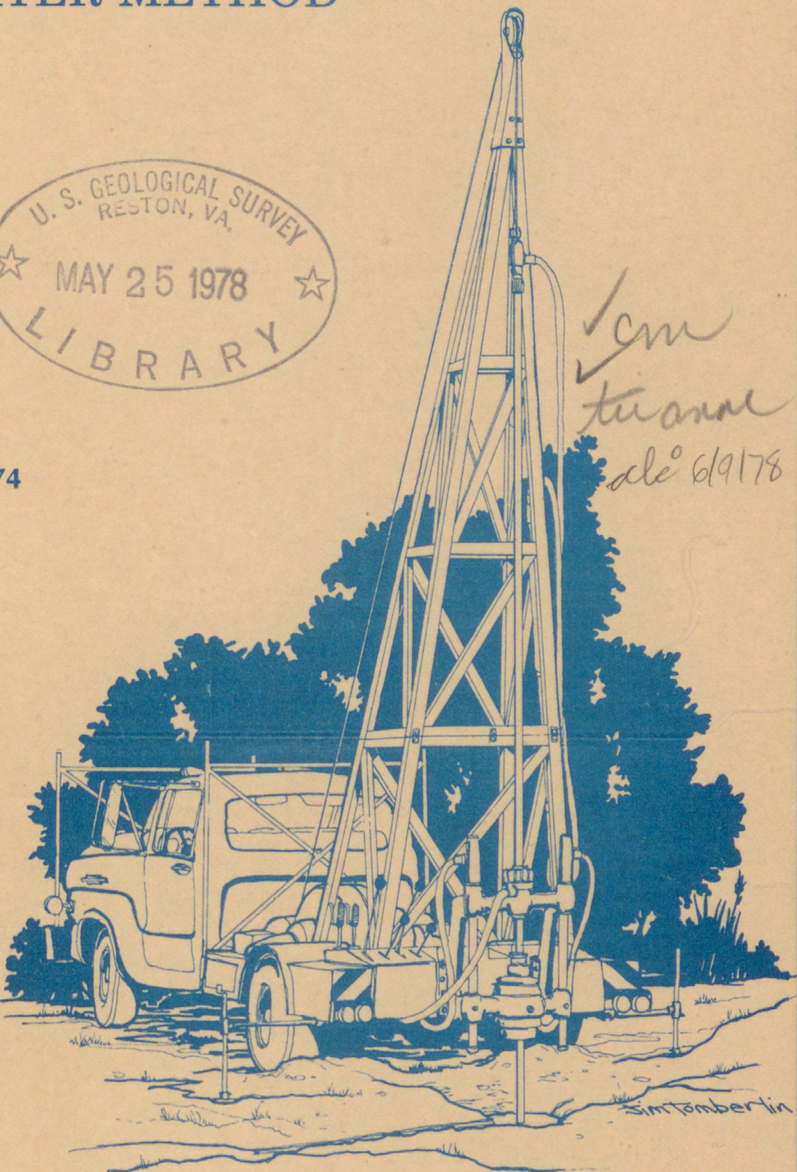
FLOOD PROFILES OF THE ALAFIA RIVER, WEST-CENTRAL FLORIDA, COMPUTED BY STEP-BACKWATER METHOD

U.S. GEOLOGICAL SURVEY

Water-Resources Investigation 77-74



Prepared in cooperation with the
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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March 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

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(Open-File Report)

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For readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet (ft^3)	.02832	cubic meters (m^3)

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INTRODUCTION

The Alafia River is a coastal stream in west-central Florida that extends about 23 mi from its mouth at Hillsborough Bay, eastward to the confluence of its two major tributaries, the North Prong Alafia River and South Prong Alafia River. The tributaries extend eastward and southeastward through Hillsborough County (fig. 1). The drainage area of the entire basin is 420 mi^2. Although the Alafia River basin is predominantly a rural area, urban residential areas are being developed near the coast.

The flood plains of these streams are subject to flooding, particularly during large regional storms and hurricanes. Inundation of these land areas in the event of a major storm could result in considerable destruction of property and peril to the inhabitants of the region. Recognizing the need to define areas that are subject to frequent or severe flooding, the Southwest Florida Water Management District entered into a cooperative agreement with the U. S. Geological Survey to determine theoretical flood profiles for the Alafia River and the North and South Prongs of the Alafia River.

Purpose and Scope

This report presents theoretical flood profiles for the Alafia River, North Prong Alafia River, and South Prong Alafia River, and describes how theoretical flood peak discharges and elevations were determined and flood profiles constructed. These flood profiles were determined for floods having recurrence intervals of 2.33, 5, 10, 25, 50, 100, and 200 years. Profiles are presented for 19.2 mi of the Alafia, 9.1 mi of the North Prong, and 9.8 mi of the South Prong.

Tidal floods can be significant in reaches 1 and part of 2 (fig. 1) near the coast. A satisfactory method for determination of flood profiles of streams affected by tidal influences is not feasible within the scope of this investigation.

Cross sections were selected for 151 sites. The cross-section geometry was determined from aerial photographic maps with contour intervals of 1 ft. The channel-bottom elevations were determined from sounding the streambed.

Description of Study Reaches

The Alafia River, including its two major tributaries, was divided into six reaches for convenience of computation of the flood profiles.

Reaches 1 and 2 (fig. 1) extend from the bridge at U. S. 41, the mouth of the river, upstream 10.2 mi to the bridge at Bell Shoals Road. Residential development along these reaches is considerable on this generally flat land. Streamflow in these reaches is influenced by tidal fluctuations in Hillsborough Bay. During low flow, the effects of tide changes can be observed within a few miles of the Bell Shoals Road bridge.

Reach 3 begins at the bridge at Bell Shoals Road and extends upstream 4.9 mi to the bridge at Pinecrest-Lithia Road, State Road 640. Although some residences are along this reach, it is generally rural and the flood plain is covered with dense vegetation.

Reach 4 begins at the bridge at State Road 640 and extends upstream 8.3 mi to the confluence of the two major tributaries, the North Prong and the South Prong Alafia Rivers. The area along this reach is also rural and the flood plain is heavily overgrown. At several locations in the reach the river has cut into limestone bedrock creating rapids during periods of low flow.

Reach 5 extends up the North Prong Alafia River 9.1 mi, and reach 6 extends up the South Prong Alafia River 9.8 mi. The flood plains in these reaches are broader than in reaches 3 and 4 and are generally heavily overgrown.

The cross sections used to compute flood profiles are numbered consecutively from the mouth of the river upstream through reach 4. Cross sections on the North Prong Alafia and South Prong Alafia are numbered consecutively upstream from the confluence of these two tributaries. Upstream distances were measured from the mouth of the Alafia River at U. S. 41 Bridge. Cross-section identification numbers and upstream distances in feet are given in table 1.

Streamflow Records

The U. S. Geological Survey maintains a gaging station (Alafia River at Lithia) on the main stem, and one each (North Prong Alafia River at Keysville and South Prong Alafia River near Lithia) on the two principal tributaries (fig. 1). Flow in the main stem has been measured since 1933, in the North Prong since 1950, and in the South Prong since 1963. The drainage area above the station on the main stem is about 335 mi^2. The drainage area above the station on the North Prong is about 135 mi^2; and on the South Prong, about 107 mi^2.

Stage-discharge relations for these stations have been developed (fig. 2) and were used to adjust the flood-profile computations.

Table 1. -- Cross-section numbers and upstream distances.

Reach 1			Reach 2		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
1-2B	0	US Hwy 41 Bridge	26	25,640	
3	250		27	27,540	
4	500		28	29,320	
5	1800	*High-water mark at elev. 5.5 ft	29	31,080	*High-water mark at elev. 9.6 ft
6	3300		30	32,220	
7	4200	*High-water mark at elev. 5.9 ft	31	33,900	Near Buckhorn Creek
8	5660		32	35,020	
9	6880		33	36,220	
10	8160		34	37,420	
11	9440		35	39,000	*High-water mark at elev. 17.6 ft
12	10,280		36	39,760	
13	11,400		37	41,120	
14	13,700		38	42,460	
15	14,940		39	43,410	
16	16,380		40	44,840	*High-water mark at elev. 18.9 ft

* 1960 high water marks.

Table 1. -- Cross-section numbers and upstream distances (continued).

Reach 1			Reach 2		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
17	17,560		41	45,940	
18	18,710		42	46,380	
19-20B	20,080	*US Hwy 301 Bridge high-water mark at elev. 6.1 ft	43	46,980	
21	20,400		44	47,680	
22	21,020		45	48,500	Near Bell Creek
23	21,580		46	49,420	
24	23,500	*High-water mark at elev. 6.2 ft	47	50,340	
25	24,900		48	51,160	
			49	52,140	
			50	52,925	*High-water mark at elev. 23.0 ft
			51-52B	53,460	Bell Shoals Road Bridge
			53	53,520	

Table 1. -- Cross-section numbers and upstream distances (continued).

Reach 3			Reach 4		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
53	53,520				
54	54,340		75	80,350	
55	55,210		76	81,400	
56	56,320		77	83,900	
57	57,720		78	87,100	
58	59,220		79	90,020	Near Turkey Creek
59	60,560		80	92,680	
60	61,640		81	95,460	
61	62,840		82	96,320	Railroad Bridge
62	64,060	Near Fishhawk Creek	83B	96,920	
63	65,400		84	97,520	
64	66,920		85	98,980	
65	68,760		86	101,520	
66	70,400	*High-water mark at elev. 29.4 ft	87	105,700	
67	71,600	Near Lithia Springs	88	108,160	
68	72,980		89	111,100	

Table 1. -- Cross-section numbers and upstream distances (continued).

Reach 3			Reach 4		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
69	74,480		90	114,160	Near McDonald Branch
70	76,020		91	115,860	
71	77,860		92	118,980	
72	78,920		93-94B	119,740	SR 39 Bridge
73	80,060		95	119,790	
74B	80,200	SR 640 Bridge USGS Gaging Station	96	120,990	
			Conf	123,000	Confluence at North and South

Table 1. -- Cross-section numbers and upstream distances (continued).

Reach 5			Reach 6		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
NPCN	123,000	North Prong at confluence	SPCN	123,000	South Prong at confluence
1	125,234		1	124,270	
2	126,694		2	125,730	
3	130,834		3	130,530	
4	133,234		4	132,270	
5-6B	135,214	Railroad Bridge	5	134,350	
7	135,264		6	136,210	
8	139,084		7-8B	137,110	SR 640 Bridge
9	142,484		9	137,160	
10-11B	144,444	Railroad Bridge	10	138,330	
12	144,494		11	140,130	
13	144,984		12	144,010	
14-15B	145,584	SR 676 Bridge USGS Gaging Station	13	145,910	
16	145,634		14	147,810	
17	147,994		15	150,450	
18	150,214		16	152,910	

Table 1. -- Cross-section numbers and upstream distances (continued).

Reach 5			Reach 6		
Cross section	Distance above mouth (ft)	Remarks	Cross section	Distance above mouth (ft)	Remarks
19	151,894		17	154,910	
20	154,334		18	157,010	
21	158,234		19	158,890	
22	164,394		20	161,870	
23	168,974		21	163,170	
24	171,134		22-23B	164,250	Jameson Rd. Bridge USGS Gaging Station
			24	164,300	
			25	166,600	
			26	168,320	
			27	169,820	
			28	171,280	
			29	172,680	
			30	172,680	

* 1960 high-water marks.

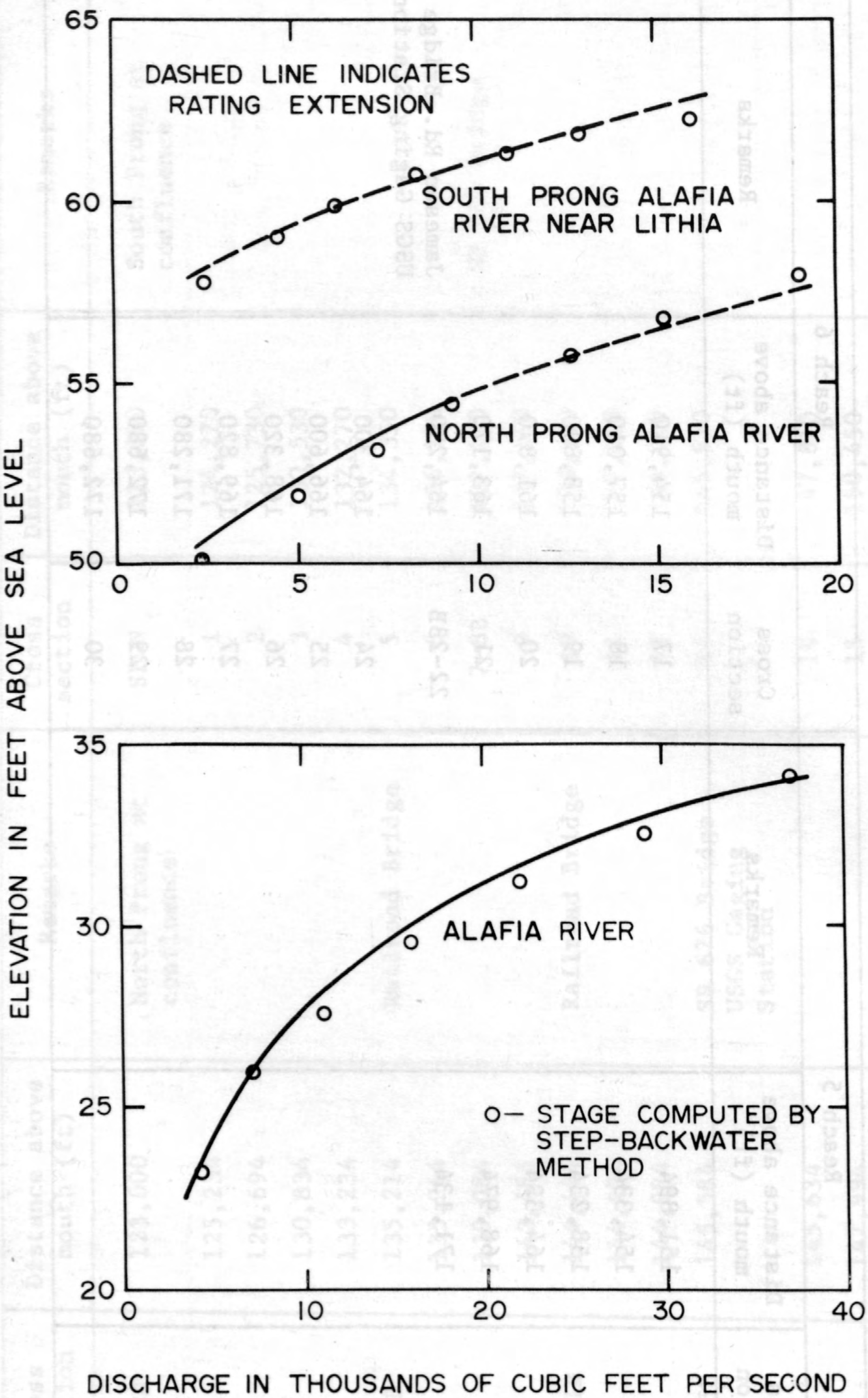

FIGURE 2.--Stage-discharge rating for the Alafia River at Lithia; North prong Alafia River at Keysville; South Prong Alafia River near Lithia.

Historic Floods

During 1960, Hurricane Donna passed over the west coast of Florida and caused one of the largest floods of recent history in the Alafia River basin. Data from this flood were used to check the theoretical profile computations. The peak discharge at the gaging station of the Alafia River at Lithia was 20,300 ft^3/s. The river reached stage of 30.98 ft above mean sea level.

In order to retrieve additional information about the flood levels, many local residents were interviewed. From their recollections, several high water marks were located. The elevations of the flood marks were determined and are given as remarks in table 1, and are shown on figures 5 and 6. All high water marks located were associated with the 1960 flood and many were in reaches 1 and 2 of the river where tides may affect flooding. Only one flood larger than the 1960 flood has been recorded in the Alafia River basin. That flood occurred in September 1933 and had a stage of 35.5 ft above mean sea level and a discharge of 45,900 ft^3/s at the gaging station, Alafia River at Lithia.

METHODS OF ANALYSIS

Flood Frequencies

Theoretical flood discharges and frequencies were determined from regional flood-frequency relations (Barnes and Golden, 1966) and from analyses of streamflow records of the gaging stations of the Alafia River and its two principal tributaries. Annual peak discharges for the period of record through 1965 have been published (U. S. Geological Survey, 1960, 1963, and 1970). Those discharges, along with those from 1965-72 (table 2), were analyzed using the log-Pearson Type III distribution (Hydrology Committee, 1967). These analyses were averaged graphically to determine the flood discharge estimates indicated for the Alafia River at Keysville in figure 3. The flood of September 1933 was not included in the frequency distribution analysis because it was anomalously high.

Table 2. -- Annual maximum discharges at three gaging stations in the Alafia River basin, 1966-72.

Water year	North Prong Alafia River at Keysville Gage Datum: 38.56 (msl)			South Prong Alafia River near Lithia Gage Datum: 50.00 (msl)			Alafia River at Lithia Gage Datum: 7.00 (msl)		
	Date	Discharge (ft^3/s)	Gage height (ft)	Date	Discharge (ft^3/s)	Gage height (ft)	Date	Discharge (ft^3/s)	Gage height (ft)
1966	1/24/66	945	9.65	10/ 1/75	512	5.53	1/27/66	1500	11.04
1967	8/14/67	2170	11.50	8/14/76	2600	7.88	8/15/67	5060	18.24
1968	9/14/68	1850	11.13	6/19/68	1660	6.72	9/15/68	2700	15.15
1969	3/17/69	1320	10.30	8/23/69	1360	6.69	3/19/69	1760	12.38
1970	10/ 3/69	2140	11.35	10/ 4/69	1250	6.47	10/ 4/69	2330	14.08
1971	9/14/71	590	8.80	9/15/71	1050	6.70	9/13/71	1730	12.28
1972	2/ 4/72	1280	10.25	2/ 3/72	917	6.38	2/ 5/72	2090	13.42

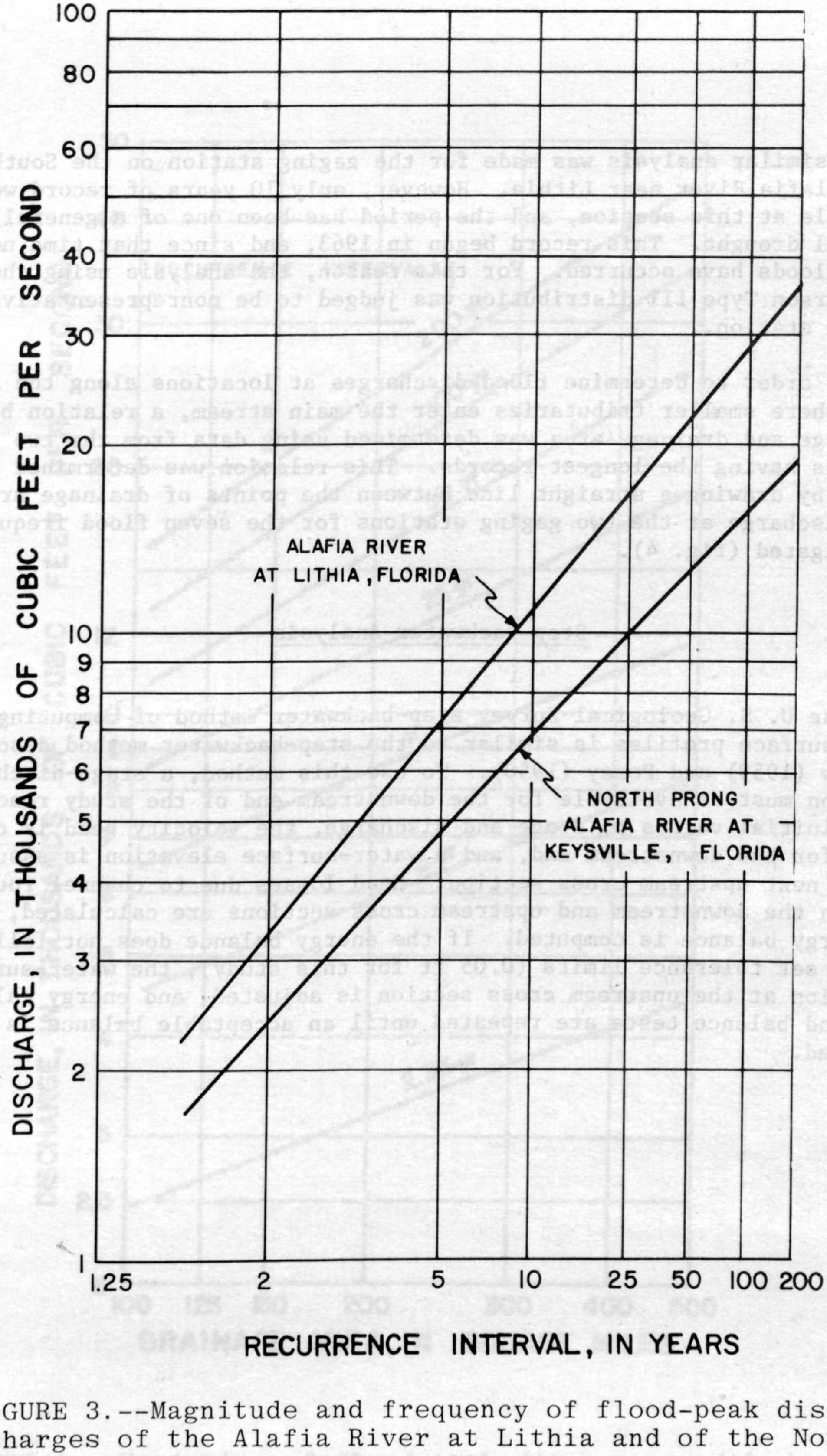

FIGURE 3.--Magnitude and frequency of flood-peak discharges of the Alafia River at Lithia and of the North Prong Alafia River at Keysville.

A similar analysis was made for the gaging station on the South Prong Alafia River near Lithia. However, only 10 years of record were available at this station, and the period has been one of a general regional drought. This record began in 1963, and since that time no major floods have occurred. For this reason, the analysis using the log-Pearson Type III distribution was judged to be nonrepresentative for the station.

In order to determine flood discharges at locations along the Alafia River where smaller tributaries enter the main stream, a relation between discharge and drainage area was determined using data from the two gaging stations having the longest records. This relation was determined graphically by drawing a straight line between the points of drainage area and peak discharge at the two gaging stations for the seven flood frequencies investigated (fig. 4).

Step-Backwater Analysis

The U. S. Geological Survey step-backwater method of computing water-surface profiles is similar to the step-backwater method described by Chow (1959) and Posey (1950). To use this method, a stage-discharge relation must be available for the downstream end of the study reach. Using initial values of stage and discharge, the velocity head is calculated for the downstream end, and a water-surface elevation is assumed at the next upstream cross section. Head losses due to channel roughness between the downstream and upstream cross sections are calculated, and an energy balance is computed. If the energy balance does not fall within set tolerance limits (0.05 ft for this study), the water-surface elevation at the upstream cross section is adjusted, and energy calculation and balance tests are repeated until an acceptable balance is achieved.

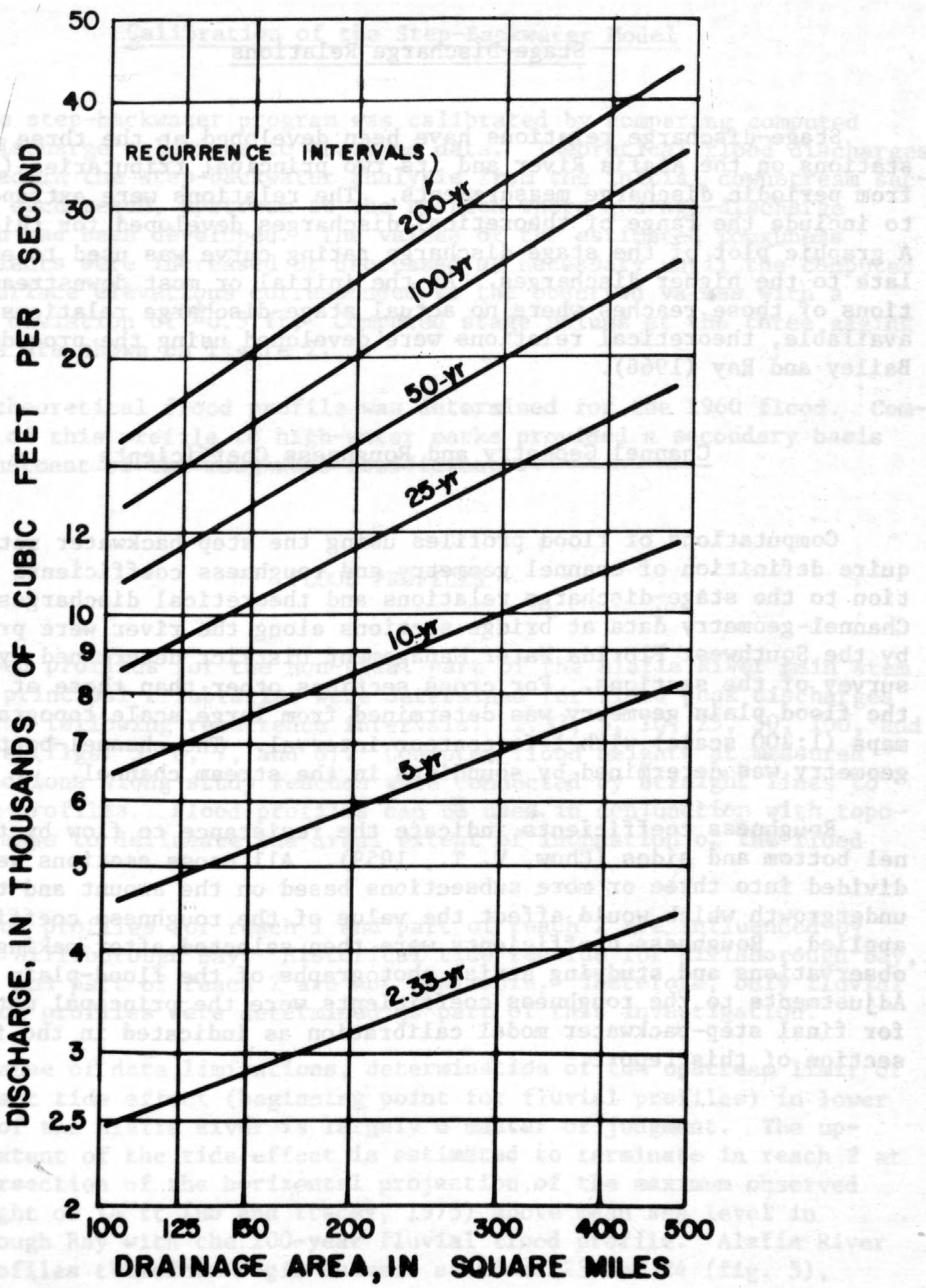

FIGURE 4.--Variation of flood-peak discharges with drainage area in the Alafia River basin.

Stage-Discharge Relations

Stage-discharge relations have been developed at the three gaging stations on the Alafia River and its two principal tributaries (fig. 2) from periodic discharge measurements. The relations were extrapolated to include the range of theoretical discharges developed for this study. A graphic plot of the stage-discharge rating curve was used to extrapolate to the higher discharges. At the initial or most downstream sections of those reaches where no actual stage-discharge relations were available, theoretical relations were developed using the procedures of Bailey and Ray (1966).

Channel Geometry and Roughness Coefficients

Computations of flood profiles using the step-backwater method require definition of channel geometry and roughness coefficients in addition to the stage-discharge relations and theoretical discharges. Channel-geometry data at bridge sections along the river were provided by the Southwest Florida Water Management District determined by direct survey of the sections. For cross sections other than those at bridges, the flood plain geometry was determined from large scale topographic maps (1:200 scale) with 1-ft contour interval. The channel-bottom geometry was determined by soundings in the stream channel.

Roughness coefficients indicate the resistance to flow by the channel bottom and sides (Chow, V. T., 1959). All cross sections were divided into three or more subsections based on the amount and type of undergrowth which would affect the value of the roughness coefficient applied. Roughness coefficients were then selected after making field observations and studying aerial photographs of the flood-plain area. Adjustments to the roughness coefficients were the principal method used for final step-backwater model calibration as indicated in the following section of this report.

Calibration of the Step-Backwater Model

The step-backwater program was calibrated by comparing computed stage-discharge relations to observed data. Theoretical flood discharges were used in the step-backwater analysis from the initial downstream section of each reach, upstream to the section where a stage-discharge relation had been developed. The values of the estimated roughness coefficients were increased or decreased as necessary until the computed water-surface elevations corresponded to the observed values with a maximum deviation of ±0.5 ft. Computed stage values at the three gaging stations are shown on figure 2.

A theoretical flood profile was determined for the 1960 flood. Comparison of this profile to high-water marks provided a secondary basis for adjustment of the roughness coefficients.

FLOOD PROFILES

Flood profiles for the non-tidal part of the Alafia River main stem and two principal triubtaries were determined for flood peak discharges having the following recurrence intervals: 2.33, 5, 10, 25, 50, 100, and 200 years (figs. 5, 6, 7, and 8). Computed flood heights at measured cross sections along study reaches were connected by straight lines to form the profiles. Flood profiles can be used in conjunction with topographic maps to delineate the areal extent of inundation of the flood plains.

Flood profiles for reach 1 and part of reach 2 are influenced by tides in Hillsborough Bay. Historical tide records for Hillsborough Bay, reach 1, and part of reach 2 are not available. Therefore, only fluvial area flood profiles were determined as part of this investigation.

Because of data limitations, determination of the upstream limit of significant tide effect (beginning point for fluvial profiles) in lower reaches of the Alafia River is largely a matter of judgment. The upstream extent of the tide effect is estimated to terminate in reach 2 at the intersection of the horizontal projection of the maximum observed tide height of 14 ft (Ho and Tracey, 1975) above mean sea level in Hillsborough Bay with the 200-year fluvial flood profile. Alafia River flood profiles therefore begin between sections 23 and 24 (fig. 5), 23,000 ft above the mouth.

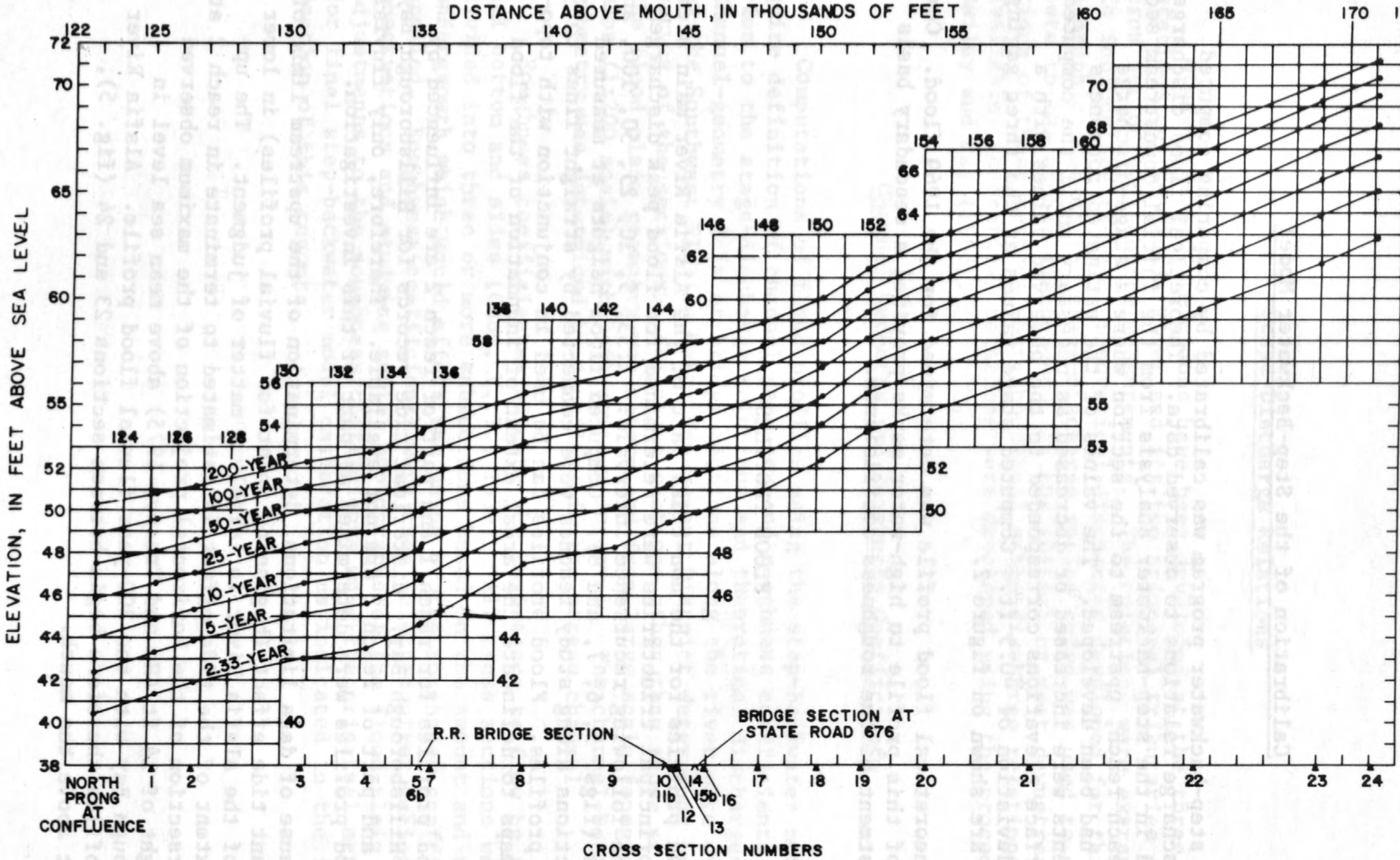

FIGURE 7.--Flood profiles of Reach 5 of the North Prong Alafia River

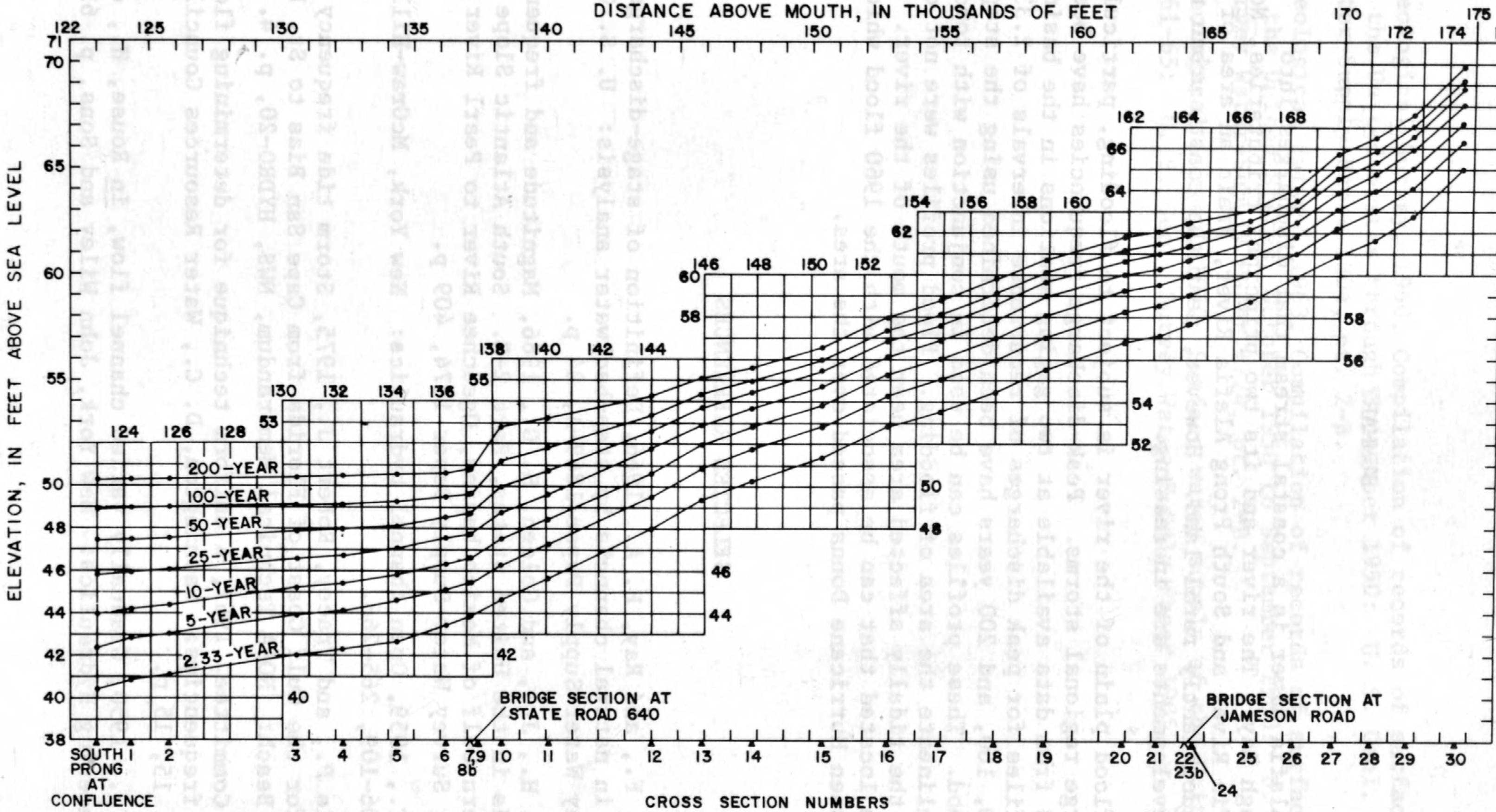

FIGURE 8.--Flood profiles of Reach 6 of the South Prong Alafia River.

SUMMARY

The Alafia River is a coastal stream that discharges into Hillsborough Bay. The river and its two principal tributaries, North Prong Alafia River and South Prong Alafia River, drain an area of 420 mi^2 of predominantly rural land. However, near the coast, urban residential developments are increasing.

The flood plain of the river is subject to flooding, particularly during large regional storms. Peak-discharge frequencies have been determined from data available at two gaging stations in the basin. The flood profiles for peak discharges of recurrence intervals of 2.33, 5, 10, 25, 50, 100, and 200 years have been determined using the step-backwater method. These profiles can be used in conjunction with topographic maps to delineate the area of flooding. Flood profiles were not determined for the tidally affected area near the mouth of the river. Flood marks were located that can be associated with the 1960 flood which occurred when Hurricane Donna passed over the area.

SELECTED REFERENCES

Bailey, J. F., and Ray, H. A., 1966, Definition of stage-discharge relation in natural channels by step-backwater analysis: U. S. Geol. Survey Water-Supply Paper 1869-A, 24 p.

Barnes, H. H., Jr., and Golden, H. G., 1966, Magnitude and frequency of floods in the United States, Part 2-B. South Atlantic Slope and Eastern Gulf of Mexico basins, Ogeechee River to Pearl River: U. S. Geol. Survey Water-Supply Paper 1674, 409 p.

Chow, V. T., 1959, Open channel hydraulics: New York, McGraw-Hill, p. 106-109, 265-268.

Ho, Francis P., and Tracey, Robert J., 1975, Storm tide frequency analysis for the Gulf Coast of Florida from Cape San Bias to St. Petersburg Beach: NOAA Technical Memorandum, NWS, HYDRO-20, p. 4.

Hydrology Committee, 1967, A uniform technique for determining flood flow frequencies: Washington, D. C., Water Resources Council Bull. 15, 15 p.

Posey, C. J., 1950, Gradually varied channel flow, _in_ Rouse, H., ed., Engineering Hydraulics: New York, John Wiley and Sons, p. 625-629.

U. S. Geological Survey, 1960, Compilation of records of surface waters of the United States through September 1950: U. S. Geol. Survey Water-Supply Paper 1304, pt. 2-B.

U. S. Geological Survey, 1963, Compilation of records of surface water of the United States, October 1950 to September 1960: U. S. Geol. Survey Water-Supply Paper 1724, pt. 2-B.

U. S. Geological Survey, 1970, Surface water supply of the United States 1961-65: U. S. Geol. Survey Water-Supply Paper 1905, v. 2, pt. 2.

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