

DRE-144

REPORT

On

**Tropical Storm Dennis
August 16 - 18, 1981**

June, 1982

REPORT ON
TROPICAL STORM DENNIS
August 16 - 18, 1981

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Water Resources Division
Resource Planning Department
South Florida Water Management Department

June 1982

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FOREWARD

Over the past twenty-five years the District has established the procedure of reporting on and analyzing unusual meteorological occurrences affecting the district area and District works. Several such reports have been prepared in the past, including the September 1960 report on Hurricane Donna and the report on the severe storm of April 24-25, 1979. The purpose of these reports is to document and record pertinent facts regarding these occurrences which might not be otherwise available from any single source.

TABLE OF CONTENTS

	<u>Page</u>
List of Tables	ii
List of Figures.....	iii
<u>I.</u> <u>Description of Tropical Storm Dennis</u>	1
<u>II.</u> <u>Rainfall Characteristics</u>	4
<u>III.</u> <u>Antecedent Conditions</u>	21
A. Rainfall Deficiency.....	21
B. Canal Stages Prior to the Storm.....	21
C. Groundwater Stages Prior to the Storm.....	22
<u>IV.</u> <u>Discussion of Project Performance</u>	24
A. Water Levels and Discharges.....	24
B. Flooded Areas.....	34
<u>V.</u> <u>Rainfall During August and September 1981</u>	36
A. Areal Distribution.....	36
B. Time Distribution.....	39
C. Return Frequency Distribution.....	39
<u>VI.</u> <u>Rainfall Comparisons with Hurricanes Donna, Betsy, and Tropical Storm Dennis</u>	52
<u>VII.</u> <u>Damage Estimates</u>	56
<u>VIII.</u> <u>Summary and Conclusions</u>	58

LIST OF TABLES

<u>Number</u>		<u>Page</u>
1.	Storm Dennis - Maximum Rainfall Intensity at Selected Stations.....	5
2.	Rainfall Analysis.....	7
2A.	Precipitation Recorded by Telemetry.....	10
2B.	Rainfall Analysis.....	16
3.	Rainfall Distribution Around Lake Okeechobee During Storm Dennis.....	17
4.	Rainfall Distribution Over the Lower Kissimmee Valley During Storm Dennis.....	18
5.	Stages at Selected Structures Prior to Tropical Storm Dennis.....	22
6.	Groundwater Stages at Selected Monitoring Wells, 1981.....	23
7.	Compilation of Operation, Stages, and Discharges During Tropical Storm Dennis.....	25
8.	Flow Measurements Made by USGS During Storm Dennis.....	27
9.	August 1981 Daily Rainfall over South Dade Area.....	41
10.	September 1981 Daily Rainfall over South Dade Area.....	44

LIST OF FIGURES

<u>Number</u>		<u>Page</u>
1	The formation and path of Storm Dennis.....	2
2	Map showing path and growth of Tropical Storm Dennis.....	3
3.	Maximum recorded one day rainfall during Storm Dennis.....	12
4.	Maximum recorded three days rainfall during Storm Dennis.....	13
5.	Total four days rainfall (August 16-19, 1981) during Storm Dennis.....	15
6.	Total five days rainfall (August 16-20, 1981) during Storm Dennis.....	16
7.	Daily stage hydrographs at S-20G, S-20F during Storm Dennis.....	28
8.	Daily stage hydrographs at S-176, S-18C during Storm Dennis.....	29
9.	Daily stage hydrographs at S-197, S-21A during Storm Dennis.....	30
10.	Daily stage hydrogrpahs at S-28, S-27 during Storm Dennis.....	31
11.	Daily stage hydrographs at S-29, S-26 during Storm Dennis.....	32
12.	Daily stage hydrographs at S-33, S-36 during Storm Dennis.....	33
13.	Flooded areas - Tropical Storm Dennis.....	37
14.	Area rainfall distribution in south Dade area during months of August and September 1981.....	38
15.	Area rainfall distribution in south Dade for Storm Dennis during August 16-20, 1981.....	40
15A.	Daily rainfall distribution at Selected Guages during August and September 1981.....	47
16.	Monthly rainfall data at Homestead Experimental Station.....	49
17.	Isohyetal map of rainfall resulting from Hurricane Donna.....	53

List of Figures Continued:

<u>Number</u>		<u>Page</u>
18.	Isohyetal map of rainfall resulting from Tropical Storm Florence.....	54
19.	Bar Graph Comparisons of Rainfall Intensities of Storm Dennis, etc.	55

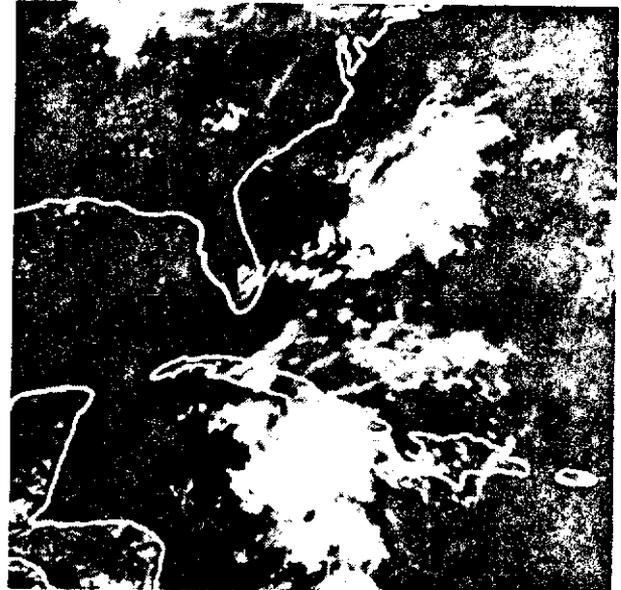
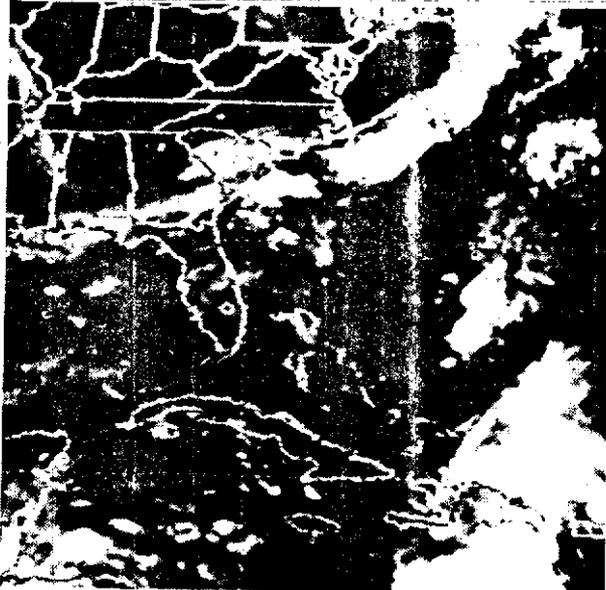
The passage of Tropical Storm Dennis brought local relief from a prolonged rainfall deficiency in the lower east coast area of south Florida. The water supply benefits of this storm, however, were overshadowed by the extensive flooding damages which resulted from the storm's rainfall.

In addition to the rainfall attributable to Dennis, the total rainfall recorded during August and September 1981 was 48.88 inches at the Homestead Agricultural Research and Education Center. The historical rainfall data for this station indicate that more than 20 inches of rain in any two months of the same year has never been previously recorded.

I. Description of Tropical Storm Dennis

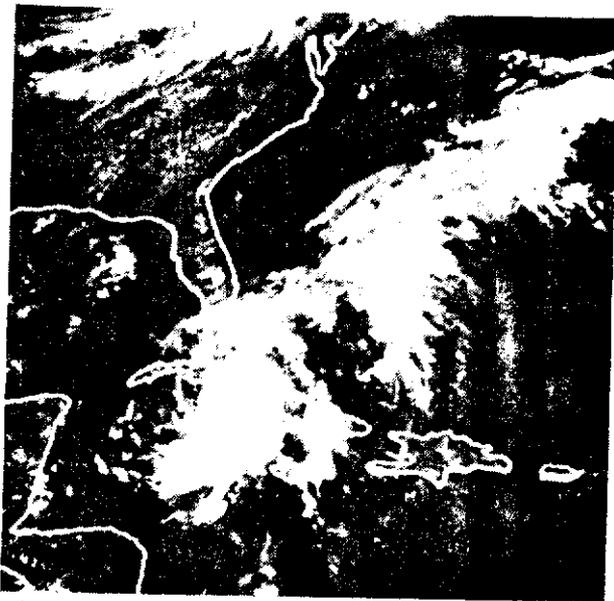
Tropical Storm Dennis began as a tropical depression near Puerto Rico on August 13, 1981. Figures 1 and 2 show the formation and path of this storm. It developed into a mid-size tropical storm by August 16, 1981, with its center over Florida Bay about 110 miles southwest of Miami. Maximum sustained winds were recorded at 55 miles per hour (mph), which is slightly below the intensity of a hurricane. The barometric pressure at the center of the eye was 29.56 inches of mercury. As the storm continued to move north across the Florida straits and over Big Pine Key, bands of rain lashed Marathon, Miami, and Fort Lauderdale. Tides two to four feet above normal were estimated along the Keys.

At 9PM, August 17, 1981, the broad center of the storm remained near latitude 26.8 N - longitude 81.2W (Figure 2), somewhere between Fort Myers and Palm Beach. Top winds were estimated to be about 50 mph, mainly along the southeast coast and the Keys. Dennis was moving north at a pace of 5 to 10 mph.



THE PATH OF DENNIS: Time-sequence photo series shows the stages in the formation and path of Tropical Storm Dennis, starting at 1 p.m. Thursday, left. Dennis was barely more

than a bluster, visible as a scattered cloud pattern in the right corner of the first satellite photo. Second from left, Dennis was more organized to the south of Cuba at 1 p.m. Friday.



In the third photo from the left, Dennis at 1 p.m. Saturday was much better organized, with its center to the south of Cuba. In the last photo, taken at 1 p.m. Sunday, the center of



Dennis had passed over Cuba and was headed for the Florida Keys and southern mainland.

UPI

FIGURE 1. The formation and path of Storm Dennis

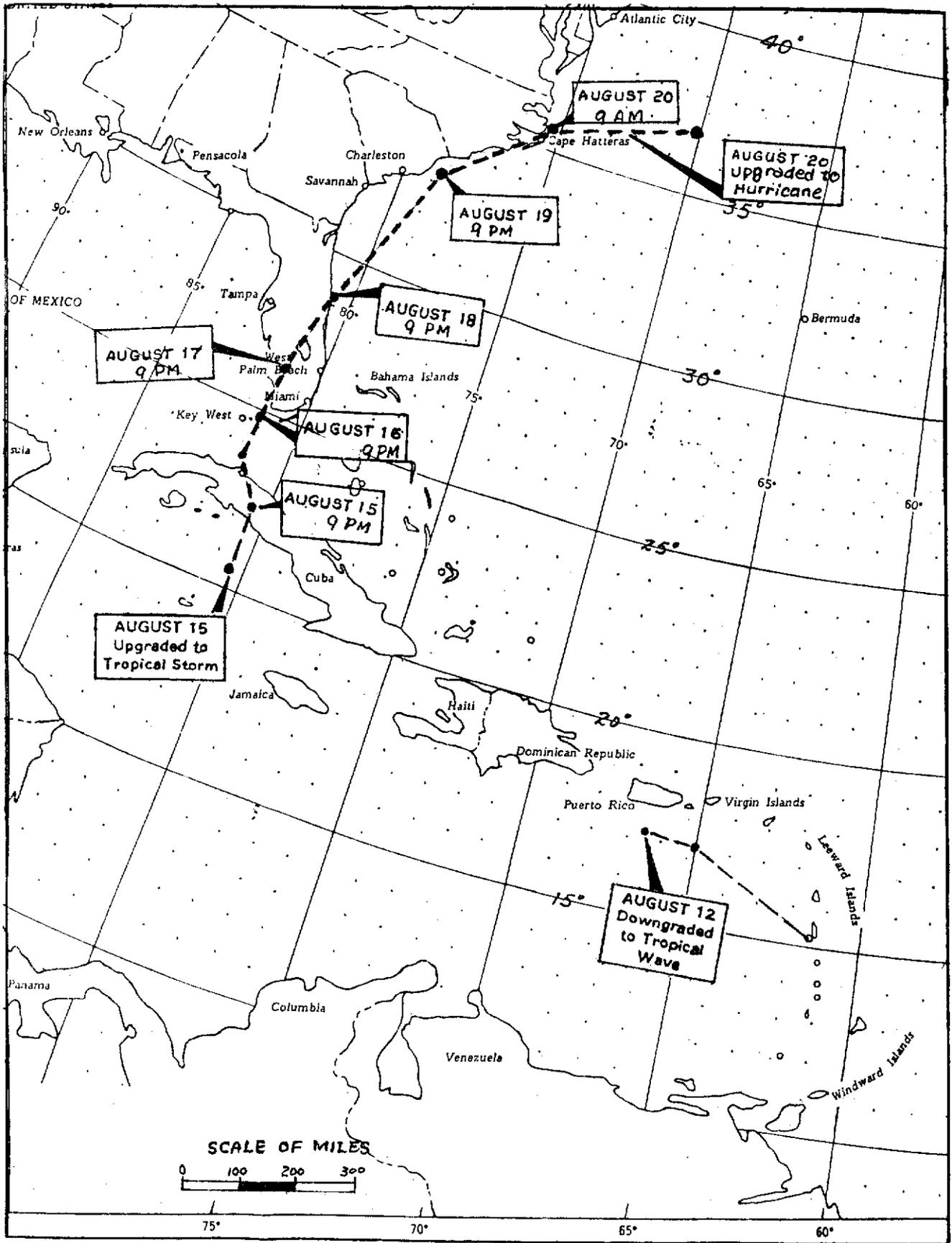


FIGURE 2. Map shows path and growth of Tropical Storm Dennis

At noon Tuesday, August 18, 1981, the National Hurricane Center in Miami issued Tropical Storm Dennis Advisory No. 40 which indicated that the broad center of Dennis remained nearly stationary near latitude 26.8N - longitude 81.2W. The advisory predicted that there would be very little movement of storm Dennis that afternoon. The advisory also reported extremely heavy rains, causing serious local flooding, in some areas of southeast Florida.

Storm Dennis drifted very slowly, and finally, by August 19, 1981 it passed over Lake Okeechobee to the northeast. The storm was over the Atlantic Ocean just northeast of Cape Canaveral after 9PM, August 19. Top winds were recorded at 55 mph, mainly in squalls. At 9AM, August 20th, the broad center of Storm Dennis was located near latitude 35.5N - longitude 75.5W about 25 miles north of Cape Hatteras. It gathered more strength over the Atlantic Ocean and became a hurricane on August 20, 1981.

II. Rainfall Characteristics

Light, scattered rainfall was reported on August 15, 1981 period to the arrival of Storm Dennis. Intensive rainfall started at 6:45AM, August 16 at Station S-18C and continued through 12 noon, August 16 when the storm center had just passed Cuba and headed for the Florida Keys. The rain stopped between 12 noon and 9PM, August 16. At this time the broad center of Storm Dennis was located over Florida Bay about 110 miles southwest of Miami. The most intensive period of rainfall occurred in the hours between 11:30PM, August 17 through 6:30AM, August 18. The rain then continued through 7AM, August 18 as recorded at rainfall station S-18C which is approximately 10 miles south of Homestead. Table 1 shows the intensive periods of Storm Dennis at various selected locations where continuous recording was available.

TABLE 1

STORM DENNIS - MAXIMUM RAINFALL INTENSITY AT SELECTED STATIONS

Location	Intensive Period Time and Date	Elapsed Time (Hours)	Inches of Rainfall
S-18C	6:45AM - 11:45AM, Aug. 16	5.00	1.40
	11:30PM Aug. 17 - 6:30AM Aug. 18	7.00	3.50
S-20	8:15AM - 10:30AM, Aug. 16	1.75	1.90
	9:00PM - 11:30PM, Aug. 16	2.50	2.00
	11:00PM Aug. 17 - 4:00PM Aug. 18	5.00	2.37
S-173	9:30AM - 10:30AM, Aug. 16	1.00	1.33
	8:30PM Aug. 17 - 2:30AM Aug. 18	6.00	8.50
S-9	1:30AM - 10:30AM, Aug. 18	9.00	5.35
WCA-3AW (near L-28)	11:30AM - Noon, Aug. 16	1.00	0.83
	3:00PM - 5:30PM, Aug. 17	2.50	2.40
	6:30AM - 10:00AM, Aug. 18	3.50	3.45
WCA-3A (South)	2:30PM - 4:45PM, Aug. 17	2.25	1.56
	4:00AM - 10:00AM, Aug. 18	6.00	4.03
WCA-3A (NE)	12:00AM - 1:15PM, Aug. 16	1.25	0.72
	6:30AM - 9:30AM, Aug. 18	3.00	1.75
WCA-3A (NW)	12:30PM - 2:00PM, Aug. 16	1.50	0.65
	3:30PM - 9:30PM, Aug. 18	6.00	1.95

Intensive rainfall occurred at station S-20 between 8AM and 10:30AM, August 16, and from 9PM August 16 continuously through 6:30AM, August 18 when rainfall stopped. At rainfall station S-173, approximately 10 miles north of Homestead, the rain began at 9:30AM, August 16, restarted at 9:30AM, August 16, and ended at 2:30AM, August 18 when further record was lost due to recorder pen jamming. Therefore, the major rain in the Homestead Area fell in the evening after 9PM, August 16 through about 6AM, August 18, as presented in Table 1.

Rainfall distribution at pumping station S-9 was slightly different from the previously mentioned stations. The rain did not begin until 9AM, August 16, was fairly consistent from 4PM, August 16 through 1:30AM, August 18, and then the intensity increased through 10:30AM, August 18 (see Table 1).

Rainfall at the station in Water Conservation Area 3A-West (WCA-3A) near L-28 tieback was of lesser intensity than the previous one described (see Table 1). Raingauges in WCA-3A South and WCA-3A Northwest had similar characteristics except in magnitude. The timing and magnitude of rainfall decreased as the storm center moved toward the northwest of WCA-3A.

To illustrate the areal distribution of rainfall, isohyetal maps were produced for maximum one day, three day, four day, and five day rainfalls. It is rather difficult to estimate an accurate daily rainfall due to the fact that the reading time for some of the rain gauges is different. For example, 2.76 inches of rain was reported at 8AM, August 18; this amount of rainfall actually occurred between the hours from 8:01AM August 17 through 8AM August 18. Some gauges were read randomly in the morning hours. Daily rainfall can be accurately estimated only with a recording gauge that records from 0 to 24 hours. Tables 2 through 2B present

TABLE 2 - RAINFALL ANALYSIS

Station Name	County	8/16	8/17	8/18	8/19	8/20	Read. Time	Maximum 3 Days Rainfall Inches	Total 8/16-8/19	Total 8/16-8/20
Boca Rd @ Powerline	(E.PBC)*	-	2.40A	2.76	1.88	0.01	8 AM	5.16	7.04	6.85
Mil.Tr1 & Lat.38	(E.PBC)	-	2.80A	2.20	1.84	0.01	8 AM	5.00	6.84	6.85
Rangeline & Lat.39	(E.PBC)	-	2.17A	3.17	3.04	0.01	8 AM	6.21	8.38	8.39
West Palm Beach AP	(E.PBC)	1.26	0.95	3.73	-	0.02	-	5.94	5.94	5.96
SR806 & SR7	(E.PBC)	-	2.88A	1.82	2.90	0.01	8 AM	4.72	7.60	7.61
Manatee Plant @ 6 Mi.Bend	(W.PBC)	0.00	1.10	3.50	0.90	0.00	8 AM	4.60	5.50	5.50
S-5A	(W.PBC)	0.68	0.31	6.05	0.00	0.09	24 PM	7.04	7.04	7.13
S-6	(W.PBC)	5.08	0.82	7.45	0.00	0.24	24 PM	13.35	13.35	13.59
S-2	(W.PBC)	1.00	0.20	2.25	0.00	0.35	24 PM	3.45	3.45	3.80
Clewiston	(W.PBC)	0.12	0.70	0.19	0.17	T	-	1.06	1.18	1.18
S-36	(E.Brwd)*	1.71	1.85	4.05	0.27	0.22	24 PM	7.61	7.88	8.10
Dixie Water Plant	(E.Brwd)	0.95	1.32	4.57	0.21	0.70	-	6.84	7.05	7.55
Gill Realty	(E.Brwd)	-	2.00A	6.40	0.94	0.19	8 AM	8.40	-	-
S-9	(E.Brwd)	1.84	2.34	7.47	0.00	0.05	24 PM	11.65	11.65	11.70
Ft.Laud.F/S	(E.Brwd)	-	2.00A	3.05	1.14	1.10	8 AM	5.05	6.19	7.29
Laud.Exp.Sta.	(E.Brwd)	1.25	1.40	4.01	-	-	-	6.66	-	-
Ft. Laud.Bch	(E.Brwd)	0.15	2.44	2.99	0.23	-	-	5.66	5.81	-
S-140	(W.Brwd)*	0.92	3.31	2.87	0.25	0.38	24 PM	7.10	7.35	7.73
Cons.Area 3A-NW	(W.Brwd)	1.29	0.43	2.73	0.15	0.59	24 PM	4.45	4.60	5.19
WCA 3A-NE	(W.Brwd)	1.33	0.58	3.90	0.13	0.08	24 PM	5.81	5.96	6.04
WCA 3A-South	(W.Brwd)	0.96	1.92	5.10	0.43	0.15	24 PM	7.98	8.41	8.56
S-7	(W.Brwd)	1.23	0.59	11.98	0.04	0.00	24 PM	13.80	13.80	13.80

TABLE 2 - RAINFALL ANALYSIS (Continued)

Station Name	County	8/16	8/17	8/18	8/19	8/20	Read Time	Maximum 3 Days Rainfall Inches	Total 8/16-8/19	Total 8/16-8/20
S-8	(W.Brwd)	1.34	0.99	1.92	0.11	0.62	24 PM	4.25	4.36	4.98
WCA 3A, (C/E Gage 3-26)	(W.Brwd)	2.32	3.66	5.27	0.00	0.00	24 PM	11.25	11.25	11.25
Miami F/S	(E.Dade)	-	2.70A	7.80	1.45	0.28	8 AM	10.50	11.95	12.23
Miami 12S. SW	(E.Dade)	2.49	1.16	5.30	0.46	0.33	-	8.95	9.41	9.74
Miami Bch	(E.Dade)	0.55	1.32	3.51	0.08	0.06	-	5.38	5.46	5.52
Miami AP	(E.Dade)	1.28	2.50	2.75	0.19	1.31	-	6.53	6.72	8.03
North Dade	(E.Dade)	1.03	1.76	4.77	0.00	-	-	7.56	7.56	-
Wheeler Frye	(E.Dade)	1.65	2.35	4.80	0.44	0.07	-	8.80	9.24	9.31
Clark	(E.Dade)	2.50	3.50	4.00	0.40	1.02	-	10.00	10.40	11.42
Sir Kin	(E.Dade)	1.60	2.07	5.60	0.30	0.16	8-9 AM	9.27	9.57	9.73
Opa-Locka AP	(E.Dade)	-	2.50	4.00	0.30	0.10	-	6.50	6.80	6.90
Office of Div.Forest	(E.Dade)	3.50	8.00	0.25	0.30	T	-	11.75	12.05	12.05
Homestead F/S	(S.Dade)	-	6.32A	9.75	0.29	0.34	-	16.07	16.36	16.70
S-20F	(S.Dade)	3.45	4.23	1.02	0.44	-	24 PM	8.70	9.14	9.14
S-20	(S.Dade)	4.41	3.68	2.19	0.05	0	24 PM	10.28	10.33	10.33
S-18C	(S.Dade)	2.19	2.12	3.03	0.00	0	24 PM	7.34	7.34	7.34
S-331	(S.Dade)	2.27	6.88	4.88	M	M	24 PM	14.03*	-	-
S-332	(S.Dade)	2.00	4.98	5.42	M	M	24 PM	12.40	-	-
Gold Isles	(S.Dade)	1.75	4.75	0.80	0.50	1.60	-	7.30	7.80	9.40
WCA 3A-SW	(W.Dade)	1.39	3.07	4.88	0.50	0.22	24 PM	9.34	9.84	10.06
S-336	(W.Dade)	1.52	12.20	M	M	0.18	24 PM	13.72	-	-
Tamiami Ranger Sta.	(W.Dade)	1.08	0.71	5.10	0.45	0.00	8 AM	6.89	7.34	7.34

TABLE 2 - RAINFALL ANALYSIS (Continued)

Station Name	County	8/16	8/17	8/18	8/19	8/20	Time	Maximum 3 Days Rainfall Inches	Total 8/16- 8/19	Total 8/16- 8/20
General Portland Cement	(W.Dade)	-	3.70A	12.40	0.73	0.63	8 AM	16.10	16.83	17.46
Royal Palm	(W.Dade)	1.42	4.75	7.75	0.00	0.33	-	13.92	13.92	14.25
Flamingo	(Monroe)	1.84	2.81	8.20	0.04	0.00	-	12.85	12.89	12.89
S-4	(Hend.)	0.00	0.87	0.20	0.20	0.00	8 AM	1.08	1.27	1.27
Hendry C.I. 1	(Hend.)	0.70	0.05	0.51	0.24	0.66	8 AM	1.75	1.50	2.16
Devil's Garden	(Hend.)	-	2.02A	0.17	0.24	0.10	7-8 AM	2.02	2.45	2.55
Jungle Larry	(Coll.)	0.20	0.03	0.12	2.02	1.07	8 AM	3.21	2.37	3.44
Corkscrew Sanctuary	(Coll.)	0.01	0.44	0.08	2.35	0.76	8 AM	3.19	2.88	3.64
Bay West Nursery	(Coll.)	0.56	0.04	2.38	1.13	1.42	8 AM	4.93	4.11	5.53
So.Florida Field Lab.	(Coll.)	0.13	0.47	0.02	1.30	0.98	8 AM	2.30	1.92	2.90
Copeland Tower	(Coll.)	1.80	0.00	0.00	3.50	0.50	8 AM	3.50	5.30	5.80
Naples Tower	(Coll.)	0.30	0.10	1.80	0.60	0.90	8 AM	2.50	2.80	3.70
Everglades City	(Coll.)	0.03	0.38	0.42	1.78	0.38	-	2.58	2.61	2.99
Oasis	(Coll.)	1.59	0.58	4.85	1.50	T	-	6.93	8.52	8.52

*E.PBC - East Palm Beach County; W.PBC - West Palm Beach County; E.Brwd - East Broward County, etc.

(A = Accumulated; M = Missing; T = Trace; + = Overflow)

TABLE 2A. PRECIPITATION RECORDED BY TELEMETRY - READING TIME 8:00AM EACH DAY

Station Name	County	Max. 3 Days Rainfall (Inches)						Total 8/16-8/20
		8/16	8/17	8/18	8/19	8/20	Total 8/16-8/19	
S-5A	(W. Palm Beach)	0.04	0.79	1.78	2.47	-	5.04	5.08
S-5AX	(W. Palm Beach)	0.01	0.02	0.76	1.28	0.05	2.09	2.12
S-6Z	(W. Palm Beach)	0.27	0.87	3.29	1.35	-	5.51	5.78
S-7Z	(W. Palm Beach)	0.08	0.65	1.58	1.10	-	3.33	3.41
S-8	(W. Palm Beach)	0.04	1.12	0.78	1.59	-	3.49	3.53
S-8Z	(W. Palm Beach)	0.64	0.62	0.46	0.74	0.01	1.82	2.47
S-44	(E. Palm Beach)	0.04	2.42	0.55	3.21	0.08	6.18	6.30
S-41	(E. Palm Beach)	0.12	0.78	1.28	2.54	-	4.60	4.72
S-39	(E. Palm Beach)	0.03	1.39	3.52	3.01	-	7.92	7.95
S-40	(E. Palm Beach)	0.22	1.42	1.61	1.40	-	4.43	4.65
S-37B	(E. Broward)	0.12	2.03	3.31	1.17	-	6.51	6.63
S-38	(E. Broward)	0.13	3.23	3.41	3.07	-	9.71	9.84
S-36	(E. Broward)	0.23	1.20	4.90	3.85	0.13	9.95	10.31
S-13A	(E. Broward)	0.47	1.88	5.92	1.13	0.42	8.93	9.82
S-29	(E. Dade)	0.44	1.18	3.62	0.44	0.74	5.24	5.42
S-27Z	(E. Dade)	0.35	2.25	9.35	2.05	0.17	13.65	14.17
S-28Z	(E. Dade)	0.76	3.14	11.15	3.71	0.06	18.00	18.82
S-27	(E. Dade)	0.15	0.70	3.21	0.57	-	4.48	4.63
S-26	(E. Dade)	0.29	0.83	5.34	0.40	0.51	6.57	7.37
S-21A	(S. Dade)	0.15	2.67	5.24	0.05	0.03	8.06	8.14
S-20G	(S. Dade)	0.40	3.67	2.36	-	0.33	6.43	6.76
S-20F	(S. Dade)	0.12	3.87	5.06	0.02	0.40	9.05	9.47
S-18C	(S. Dade)	0.51	2.68	5.26	0.01	-	8.45	8.46

TABLE 2B. RAINFALL ANALYSIS

Station Name	8/16	8/17	8/18	8/19	8/20	Reading Time	Max.3 Days Rainfall (Inches)	Total 8/16-8/19	Total 8/16-8/20
Homestead Exp.Sta.4F (So. Dade)	4.50	7.40	7.49	0.61	0.29	6:45AM	19.39	20.00	20.29
Homestead Exp.Sta.NHC (So. Dade)	0.27	8.76	10.02	T	-	-	19.05	19.05	-
West Kendall	1.12	6.45	12.52	0.10	-	-	20.09	20.19	-
Ira Ebersole	1.50	4.36	6.15	12.28	0.87	-	22.79	24.29	25.16
Homestead AP	0.15	3.35	14.63	0.28	0.78	7:00AM	18.26	18.41	19.19
Tamiami AP	2.05	7.64	11.46	0.36	0.46	12 Noon	21.15	21.51	21.97

T = Trace

all the available data for the rainfall stations in the affected area. The reading time is also indicated for the rainfall stations wherever available. Figure 3 shows the isohyetal map of the maximum 1-day rainfall during the event. Figure 4 shows the isohyetal map of the maximum 3-day rainfall. Figure 5 shows the isohyetal map of the rainfall amount for August 16 through August 19 (or 8:01AM August 15 through 8:00AM August 19) for most stations. Figure 6 shows the isohyetal map of the total rainfall of the event (August 16 through August 20, 1981).

The highest daily rainfall quantity due to the storm event was 25.16 inches reported at gauge number 95 (Ira Ebersole), a cooperative Dade County gauge about 3 miles north of Homestead (Table 2B). The area of approximately 100 square miles covering Homestead and Florida City up to West Kendall reported 20 inches or more of rainfall due to Storm Dennis as indicated in Table 2B. The next highest rainfall quantity was 18.82 inches reported by the District telemetry gauge in the area between Hialeah Gardens and Opa Locka Airport (S-28). Additional high rainfall quantities of 13.59 to 13.80 inches were reported in the area between S-6 and S-7.

The areas of highest rainfall intensity during Storm Dennis occurred in a 15 to 20 miles wide strip parallel to L-31 North and L-30. The area from Florida City to the Tamiami Canal reported 18 or more inches of rainfall within the storm period. The area north of Tamiami Canal to S-9 received about 11 to 18 inches of rainfall over a strip of land 10 to 20 miles in width along L-30 and L-33. Palm Beach County received 5 to 8 inches, Broward County east of Water Conservation Area 2A received 7 to 10 inches.

The lower west coast near Naples received 3 to 5 inches, while 1 to 5 inches fell over Lake Okeechobee (see Table 3), and 0.24 to 3.47 inches fell over the Kissimmee River Basin (see Table 4).

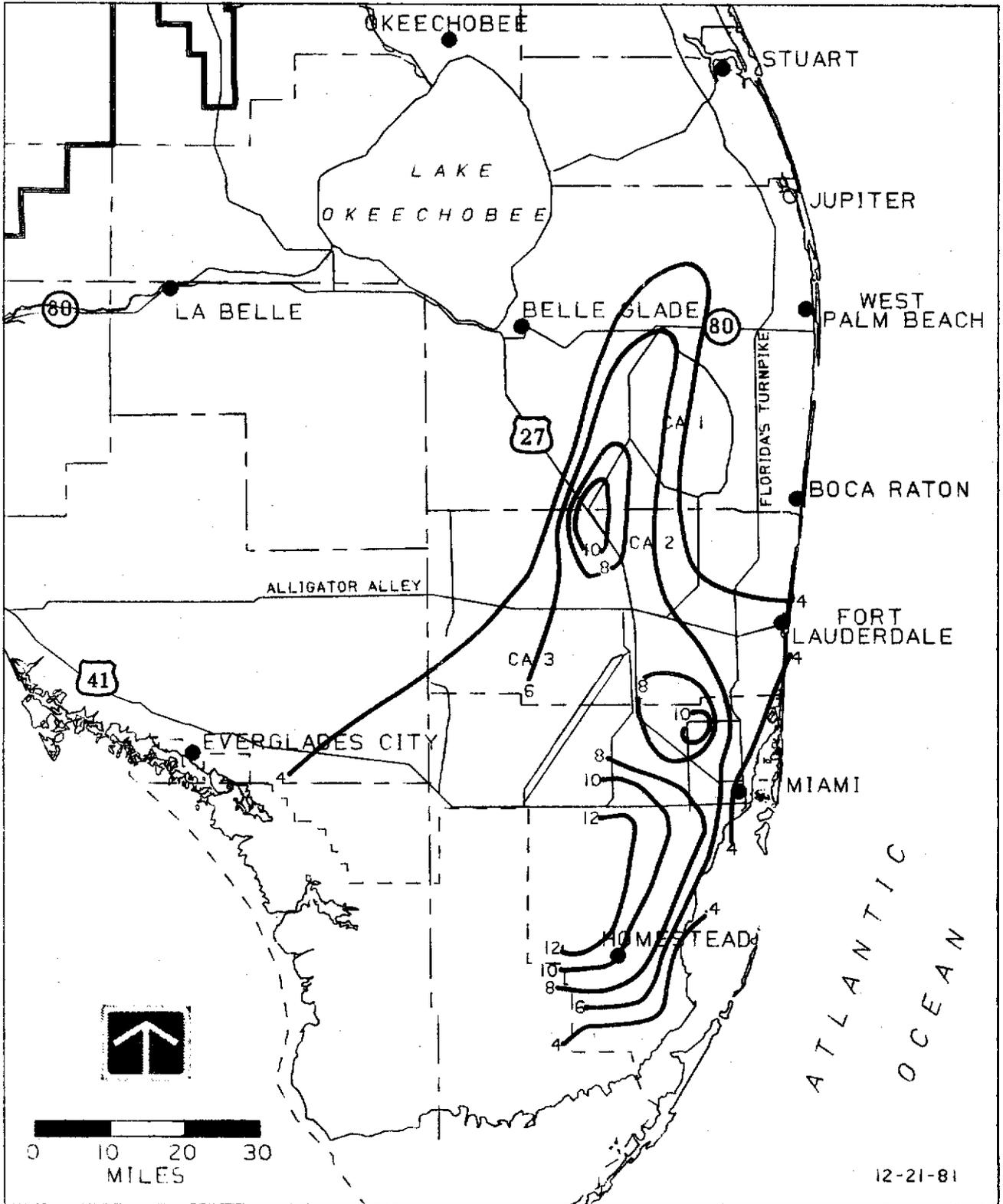


FIGURE 3.

MAXIMUM RECORDED ONE DAY RAINFALL
DURING STORM "DENNIS"

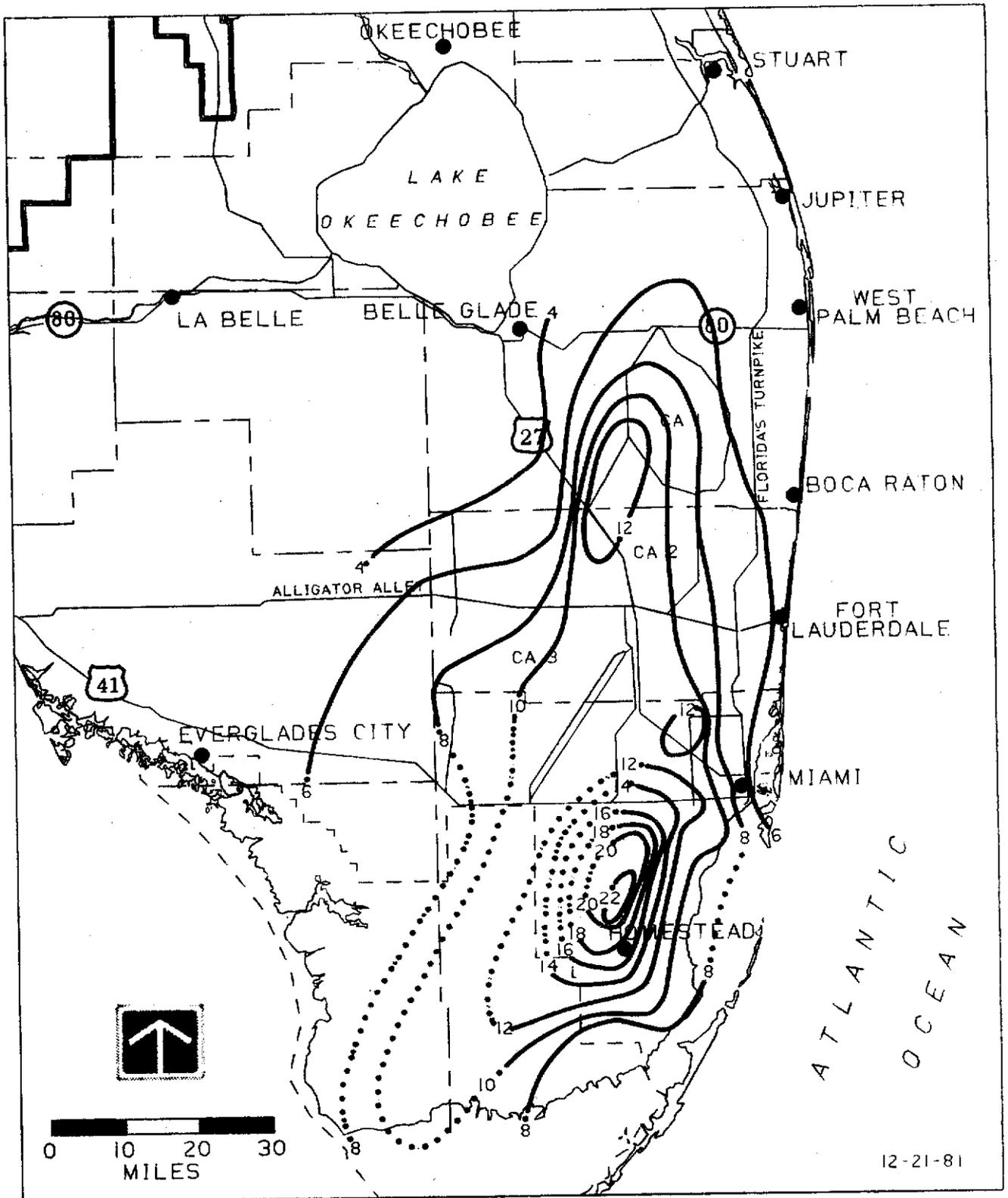


FIGURE 4.

MAXIMUM RECORDED THREE DAYS RAINFALL
DURING STORM "DENNIS"

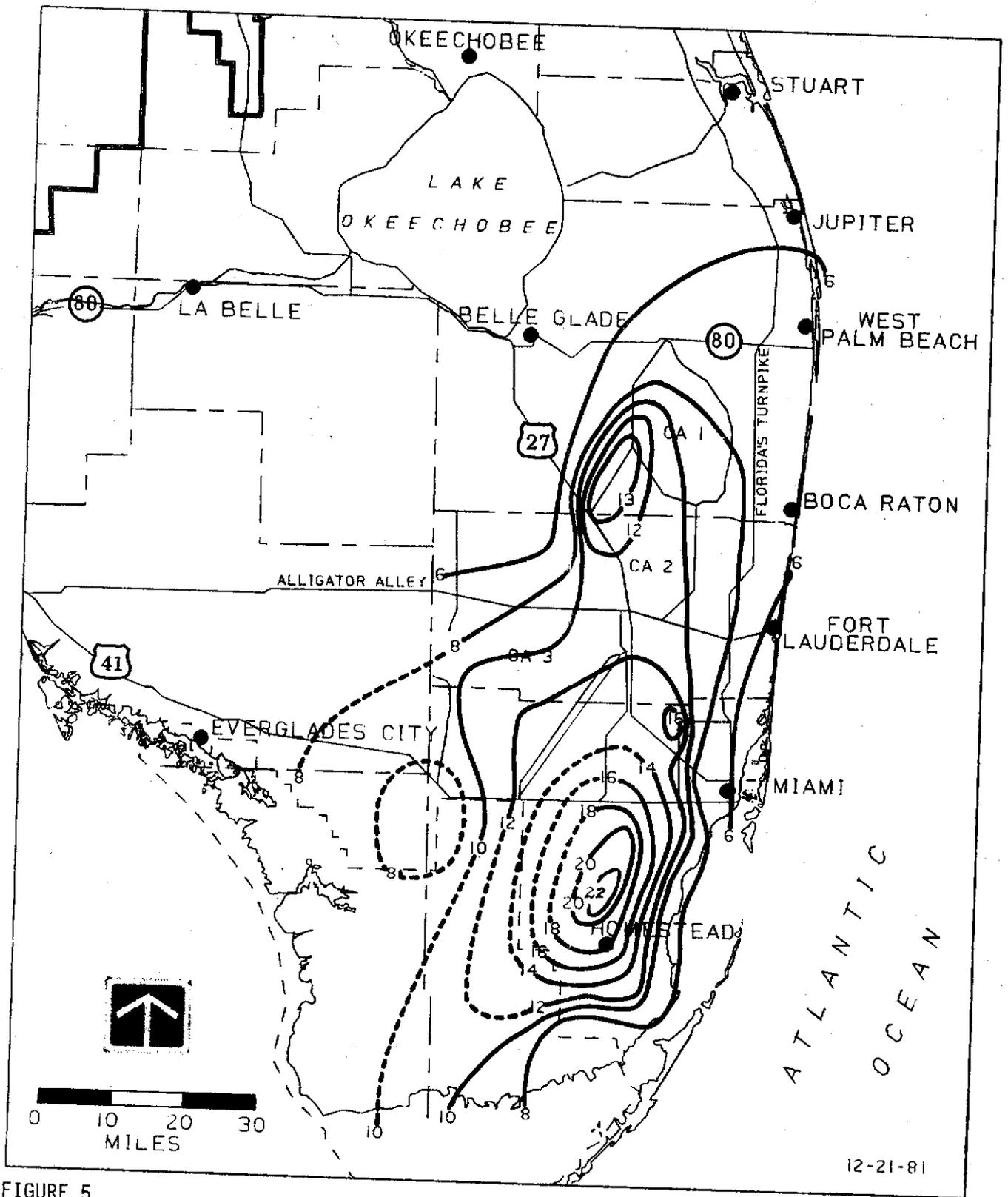


FIGURE 5.
 TOTAL FOUR DAYS RAINFALL (AUGUST 16-19, 1981)
 DURING STORM "DENNIS"

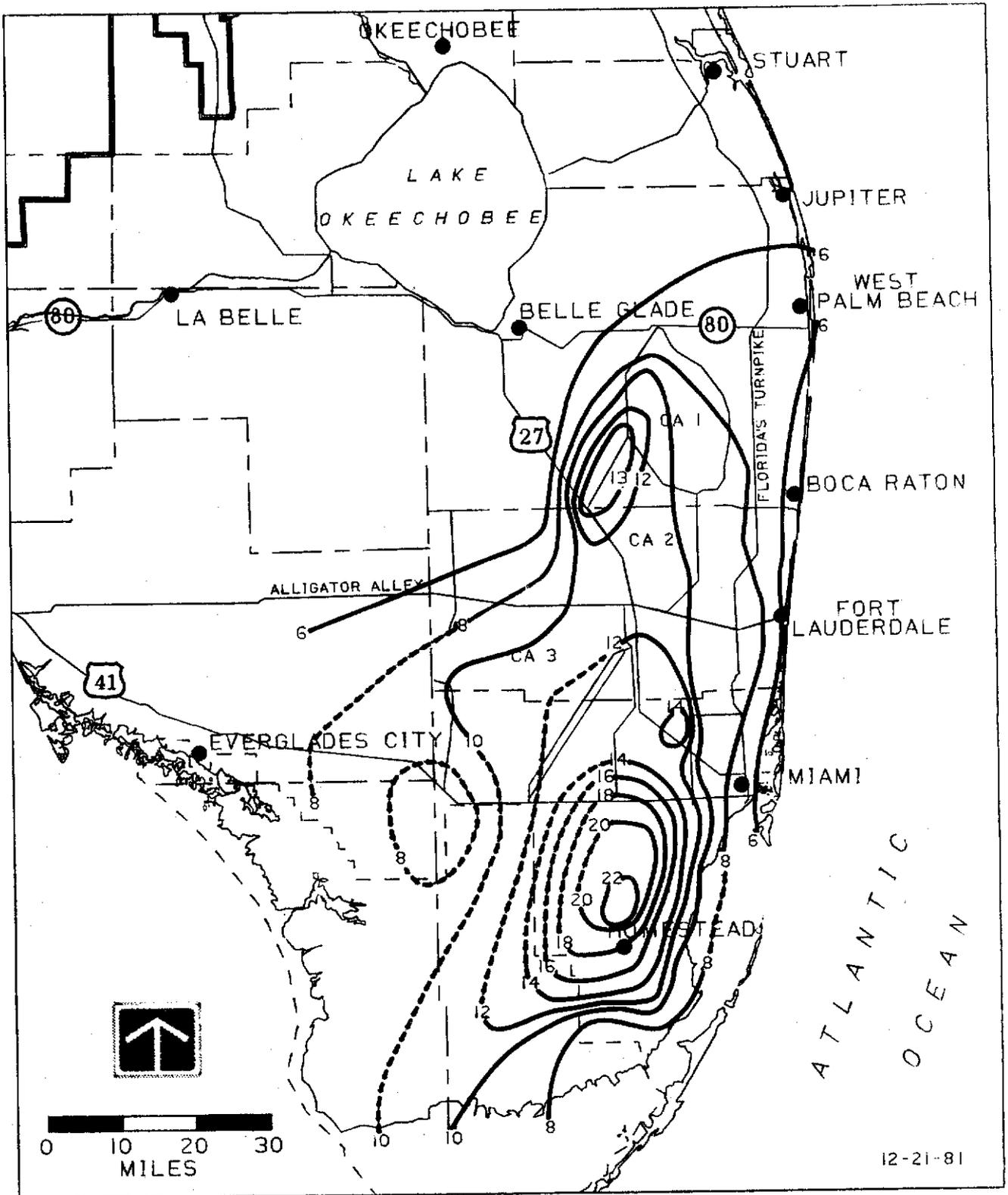


FIGURE 6.
 TOTAL FIVE DAYS RAINFALL (AUGUST 16-20, 1981)
 DURING STORM "DENNIS"

TABLE 3.

RAINFALL DISTRIBUTION AROUND LAKE OKEECHOBEE DURING STORM DENNIS

Station	<u>Rainfall - Inches</u>								
	8/14	8/15	8/16	8/17*	8/18	8/19	8/20	8/21	8/24*
S-2	0.04			2.30	1.05	1.25	0	0.35	0.35
S-3	0.03			2.44	0.28	0.28	0	0.64	1.32
S-4	0.04			0.87	0.20	0.20	0	0.27	1.10
S-127	0			0.28	0.09	0.80	0.03	0.13	0
S-129	0			0.87	0.09	1.42	0	0.15	0.23
S-131	0			1.70	0.15	1.65	0	0.20	0.45
S-133	0			0.53	0.06	1.13	0.07	0.56	0.32
S-135	0			0.58	0.07	2.95	0	0.12	0.35
HGS-5	0.05			1.50	0.55	1.95	T	0.45	0.95
Clewiston	0.03			1.23	0.18	0.30	0.01	0.34	1.36
Okeechobee	0.61			0.69	0.06	1.05	0.18	0.42	0.36
S-65E	0			0.50	0.05	1.30	0	0.95	0.10

*Rainfall accumulated over the weekend.

T = Trace

TABLE 4.

RAINFALL DISTRIBUTION OVER THE LOWER KISSIMMEE VALLEY DURING TROPICAL STORM

DENNIS

<u>Station</u>	<u>Rainfall - Inches</u>						
	<u>8/15</u>	<u>8/16</u>	<u>8/17*</u>	<u>8/18</u>	<u>8/19</u>	<u>8/20</u>	<u>8/21</u>
Okeechobee			0.69	0.06	1.05	0.18	0.42
S-65			0.05	0.15	0.27	0.35	2.55
S-65A			0	0.18	0.28	0.94	2.07
S-65B			0	0.05	0.10	0.25	1.00
S-65C			0.06	0.08	0.11	0	0.58
S-65D			0.05	0.02	0.05	0	0.12
S-65E			0.50	0.05	1.30	0	0.95
S-68			0.45	0	0.07	0	1.60

*Rainfall accumulated over the weekend

Most farmers in the Everglades Agricultural areas began backpumping on Monday night (August 16). Lake Okeechobee's stage rose from 9.95 ft msl on August 14 to 10.08 ft msl on August 17. There was a significant water level rise in the three water conservation areas due to Storm Dennis. For example, the stages in the water conservation areas at 8AM August 14 were 11.35 ft msl at gauge 1-8C (WCA 1), 9.83 ft msl at S-38 (WCA 2A), and 8.58 ft msl at gauge 63 (WCA 3A). By August 20 the water level rose to 15.72 ft msl at gauge 1-8C (WCA 1), 11.83 ft msl at S-38 (WCA 2A), and 9.64 ft msl at gauge 63 (WCA 3A). Major water control structures such as S-5A, S-6, S-7, S-8, S-9, S-10, S-11, etc., produced significant amounts of flow during and after the storm.

To evaluate the return frequency of the rainfall associated with this storm event, the maximum one-day, three-day, and five-day rainfall map series presented in the "Frequency Analysis of Rainfall Maximums for Central and South Florida", District Technical Publication 81-3, were used for comparison. Even though that report covers rainfall data only up to 1977, the addition of the major storm events of April 24-25, 1979 and the one in this report did not significantly change the statistical analysis of the one day rainfall presented in that report. A slight change (within 7%) for the three-day and five-day rainfall occurred in some locations. Since the distribution of rainfall for this storm event varied over south Florida, the return-frequency of the measured rainfall also varied. The areas with particularly intense rainfall are identified as follows:

A. One-day rainfall:

1. Rainfall in the area of Florida City, Homestead, Tamiami Airport, West Kendall, L-31N, and the area near S-7 slightly exceeded the 1-in-100 year return frequency.

2. Rainfall in the area of Hialeah Gardens and Opa Locka Airport was on the order of about 1-in-50 years.

3. Rainfall in the area near S-9 was on the order of 1-in-25 years.

4. Rainfall in the city of South Miami up to S-22 was approximately 1-in-10 years.

B. Three-day rainfall:

1. Rainfall in the area of Florida City, Homestead, Tamiami Airport, West Kendall, and L-31N was more than 5 inches in excess of the 1-in-100 years.

2. Rainfall in the area of Opa Locka Airport was similar to 1-in-100 years.

3. Rainfall in the area near S-7 and S-6 was in the vicinity of 1-in-50 years.

4. Rainfall in the area of S-9 was in the order of 1-in-25 years.

5. Rainfall in the area of the city of South Miami was also close to 1-in-25 years.

C. Five-day rainfall:

1. Rainfall in the area of Florida City, Homestead, Tamiami Airport, West Kendall, and L-31N was 4 to 5 inches in excess of the 1-in-100 year return frequency.

2. Rainfall in the area of Opa Locka Airport was in the order of 1-in-100 years.

3. Rainfall in the S-7 area was estimated at 1-in-100 years.

4. Rainfall in the S-6 area was approximately 1-in-50 years.

5. Rainfall in the S-9 area was close to 1-in-25 years.

6. Rainfall in the area southwest of Coral Gables and South Miami was near 1-in-10 years.

III. Antecedent Conditions

A. Rainfall Deficiency

Prior to the passage of Tropical Storm Dennis, the wet season of 1981 had produced abnormally low rainfall. Average rainfall for the months of June and July in the lower east coast area is 16.22 inches. Actual rainfall during June and July 1981 was 10.69 inches, which is 66% of normal. The June 1980 to June 1981 rainfall in the Lower East Coast Area was 78% of normal, and has a return interval of about 25 years.

On a District-wide basis, rainfall deficiencies were more extreme in the interior of the peninsula than in the coastal areas. Between June 1980 and August 1981 the interior areas received about 65% of normal rainfall, which led to a record low stage of 9.75 ft. MSL in Lake Okeechobee on July 29, 1981.

Rainfall conditions prior to Tropical Storm Dennis were substantially below normal throughout the District. The wet season rainfall pattern which normally characterizes the months of June and July was poorly developed and as a result, regional water storage levels were low.

B. Canal Stages Prior to the Storm

Due to low water levels in the water conservation areas and the lack of normal wet season rainfall prior to the storm, canal stages were being maintained at or where possible somewhat above optimum, to conserve water and to prevent further saltwater intrusion. No controllable discharges were being made to tidewater and with the exception of S-335, S-336, and S-173. which were operating in a water supply mode, all structures were closed. Table 5 shows the relationship of actual stages prior to the storm (August 14, 1981) and optimum headwater stages.

Table 5. STAGES AT SELECTED STRUCTURES PRIOR TO TROPICAL STORM DENNIS

Structure	Headwater Stage	Optimum Headwater
	ft MSL	ft MSL
S-20F	2.20	2.20
S-20G	2.29	2.00
S-21A	2.25	2.00
S-21	2.48	2.00
S-25	2.15	2.00
S-25B	3.07	2.80
S-26	2.65	2.70
S-27	2.37	2.00
S-28	2.38	2.00
S-18C	2.11	2.30
S-173	4.00	5.00
S-176	3.67	5.50
S-197	1.50	1.50
S-177	3.19	4.50
S-332	3.45	4.50

C. Groundwater Stages Prior to the Storm

In contrast to the low groundwater stages which preceded the severe storm of April 1979, groundwater stages prior to Tropical Storm Dennis were about one foot below normal in the south Dade area as shown in Table 6. Ground storage was not nearly as important in reducing flood stages as it was during the April 1979 storm.

TABLE 6. GROUNDWATER STAGES AT SELECTED MONITORING WELLS, 1981

Well No.	End of July '81	Normal
	Stage	Level
596	3.96	5.64
613	2.03	2.43
614	2.31	3.70
757	3.04	4.57
858	2.86	4.22
860	2.05	2.59
864	2.18	2.88
1183	2.04	2.30
358	2.09	2.91
196	2.71	3.19

IV. Discussion of Project Performance

Due to the need to closely monitor water level conditions associated with the water shortage, operational personnel had been manning the control center in West Palm Beach on a twenty-four hour basis since July 13, 1981. With the approach of Tropical Storm Dennis on Friday August 14, 1981, stand-by crews were established to be called in over the weekend (August 15 and 16), if necessary. Homestead Field Station personnel were called in on Sunday August 16, 1981 to monitor water levels and structure operations. Late Sunday afternoon water levels were under control and the station was secured for the night. From 0700 hours, Monday, August 17 through the next several weeks, the Homestead Field Station was manned on a continuous twenty-four hour basis.

A. Water Levels and Discharges

Table 7 presents the data on structure operations, peak stages, and discharges.

These data show that for the most critical structures, peak stages occurred (generally 12 or more hours) after the structures were opened. Peak stages were sufficient to bypass the ridge and divide structures and were a result of rainfall quantities exceeding design by a large margin.

Structure S-197 was opened full at 0501 on August 18. The earthen plug was removed in accord with Corps criteria at 2330 on August 18.

Data indicate that the rainfall quantities associated with Tropical Storm Dennis greatly exceeded the quantities of water that the system was designed to accommodate. Design discharges were exceeded at all control structures, as were design stages.

The heaviest rainfall occurred in the evening of Monday, August 17 and the morning hours of Tuesday, August 18. S-20F, the coastal control

STRUCTURE	LOCATION	MODE OF OPERATION	GATE OPEN FULL TIME	DATE	PEAK STAGE (FT.)		DATE	DESIGN STAGE		DESIGN DISCHARGE (C.F.S.)	FLOOD DISCHARGE (C.F.S.)		REMARKS
					H.W.	T.W.		H.W.	T.W.		MM. DAILY MAX.	MM. DAILY MAX.	
S-21A	C-102	Automatic	2330	8/17/81	2.70	2.21	2345	1.9	1.4	1300		2454	
S-165	C-102	Automatic	2330	8/17/81	7.55	6.11	1305	5.6	4.6	450		666	
S-194	C-102	Manual	0201	8/18/81	9.23	9.15	1230	5.5 (opt.)	--	--		124	Divide Structure
S-195	C-102N	Manual	0140	8/18/81	7.1	6.4	0410	5.6	4.8	180		--	400 Peak Stage Est.
S-20F	C-103	Automatic	0145	8/18/81	3.05	0.50	1940	1.9	1.4	2900		5780	
S-179	C-103	Automatic	1024	8/17/81	4.94	3.82	0700	4.9	3.8	1920		2680	
S-166	C-103	Automatic	0114	8/18/81	6.84	5.90	1330	5.2	4.6	420		653	
S-167	C-103	Automatic	0130	8/18/81	7.68	5.50	0130	5.6	4.8	380		410	
S-196	C-103	Manual	0030	8/18/81	8.75	--	0940	5.5 (opt.)	--	--		60	Divide Structure
S-197	C-111	Manual	0501	8/18/81	2.74	0.78	1800	1.4	0.6	550 2400 (Plug)		779	Plug removed 2330 8/18/81
S-18C	C-111	Automatic	1240	8/17/81	3.20	2.92	1817	3.3	2.8	2100		1950	2170
S-177	C-111	Automatic	1420	8/17/81	4.95	4.25	0850	4.7	4.2	1400		1695	
S-176	C-111	Automatic	1245	8/17/81	7.53	7.05	1200	6.3	5.9	630		888	
S-173	L-31N	Manual	--	--	8.02	8.25	0210	5.5 (opt.)	--	--		--	Divide Structure Remained Closed
S-174	L-31W	Automatic	1100	8/17/81	7.56	7.18	1202	6.0	5.5	500		550	600
S-175	L-31W	Manual	0339	8/18/81	5.84	4.00	0338	5.0	4.5	500		534	600
S-332	L-31W	Manual	--	--	5.93	5.89	0820	--	5.8	165		--	140

TABLE 7. COMPILATION OF OPERATION, STAGES, AND DISCHARGES DURING TROPICAL STORM DENNIS

Pumps on 2107 8/17/81 to 1553 8/18/81 - turned off as water 100 ft. high.

structure for the C-103 canal system, was operated at 0630 hours, August 17. A record level of 3.19 ft MSL was reached at the headwater of this structure at 1900 hours August 17, approximately twelve hours later.

The discharge at S-20F exceeded the standard project flood (SPF) discharge of 4900 cfs. The peak stage, 3.05 ft MSL, at S-20F also exceeded the SPF stage of 3.0 ft. MSL.

S-18C, which controls the western portion of the south Dade system, was opened full at noon August 17. The peak headwater stage occurred about 18 hours later.

Peak discharges at S-18C exceeded the SPF discharge of 2100 cfs.

Discharge measurements were made at S-20F and S-18C and discharges were calculated by the U.S. Geological Survey. These are presented in the following table.

AVERAGE DAILY DISCHARGE AT S-20F and S-18C

<u>Structure</u>	<u>Date</u>	<u>Discharge-cfs-Day*</u>
S-20F	8/17	5000
	8/18	5780
	8/19	4390
	8/20	3490
S-18C	8/17	908
	8/18	1740
	8/19	1950

*Discharge computed by USGS

A summary of discharge measurements is presented in Table 8.

Figures 7 through 12 show the average daily water level at S-20G, S-20F, S-176, S-18C, S-197, S-21A, S-28, S-27, S-29, S-26, S-33, and S-36. The highest downstream stages occurred at S-27, S-28, and S-197.

TABLE 8. FLOW MEASUREMENTS MADE BY USGS DURING STORM DENNIS

<u>Location</u>	<u>Date</u>	<u>Headwater</u>	<u>Discharge,cfs</u>
Tamiami Canal	8/20	8.64	4360
40 Mile Bend, Monroe	8/19	8.80	2340
S-18C	8/19	3.08	2170
S-197	8/19	1.86	3430
S-27	8/18	2.32	918
S-28	8/18	2.36	822
Snake Creek, N. 67th Ave.	8/18	3.85	1340
S-29	8/18	1.78	3040
Snapper Creek (S-22)	8/18	2.45	2110
Coral Gables Canal	8/18	5.73	933
	8/18	4.56	627
Maimi Canal (NW 36th)	8/19	2.63	796
	8/20	2.53	775
	8/22	2.70	745
Taylor Slough (Homestead)	8/14	2.68	6
	8/18	4.86	531
	8/20	5.34	819*
-	8/24	5.09	590
Black Creek (S-21)	8/20	0.76	1730
S-20F	8/20	0.11	3610
Tamiami Canal, L-29 & L-67A	8/19	7.94	74.8
	8/22	7.86	50.2
Taylor Slough (at Context Road)	8/19	6.95	882

*Maximum of Record

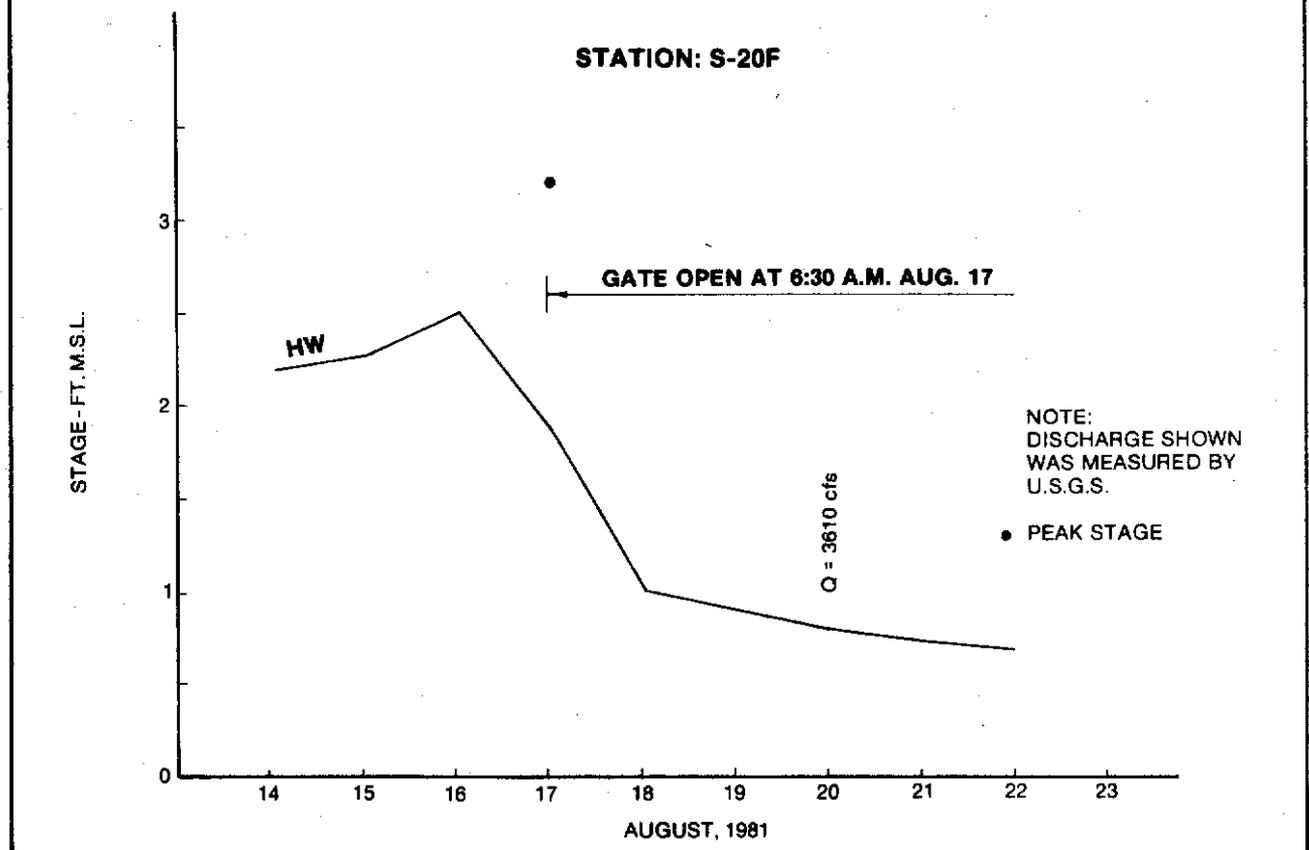
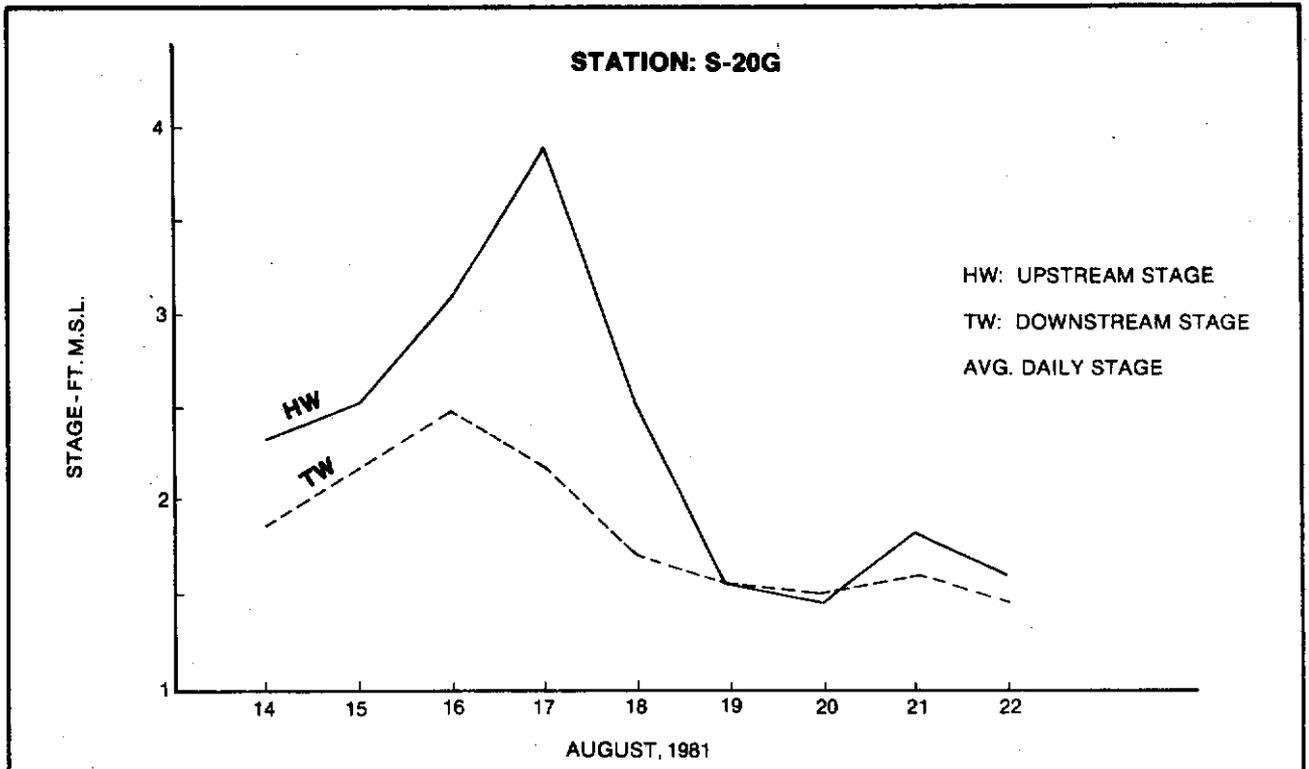


Figure 7 DAILY STAGE HYDROGRAPHS AT S-20G, S-20F DURING STORM DENNIS

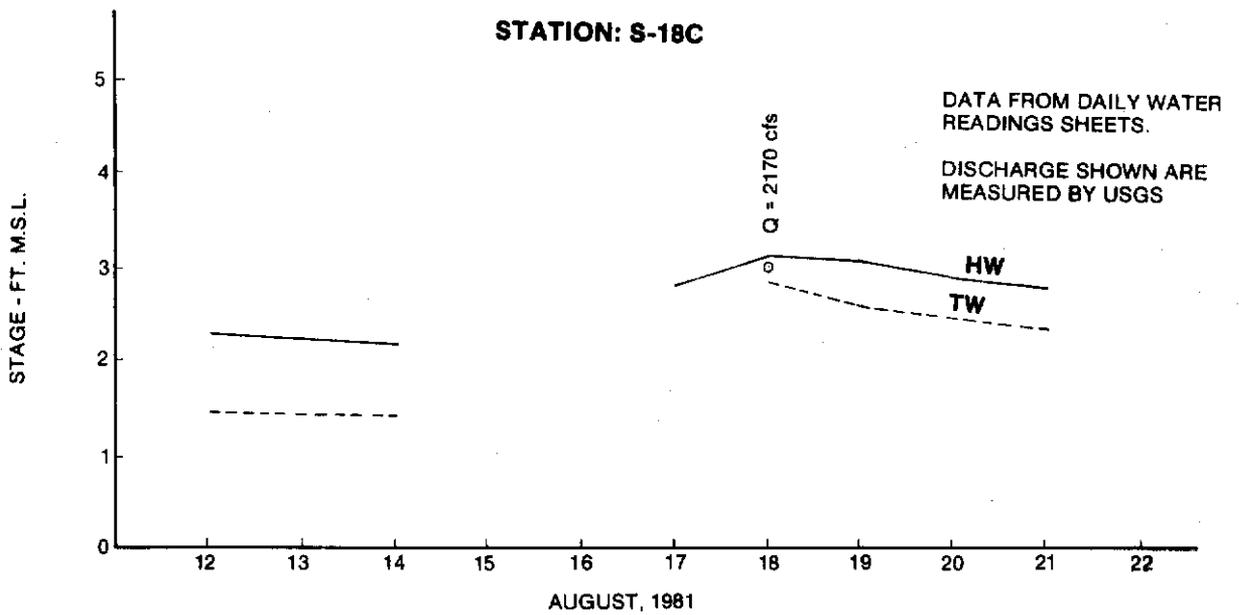
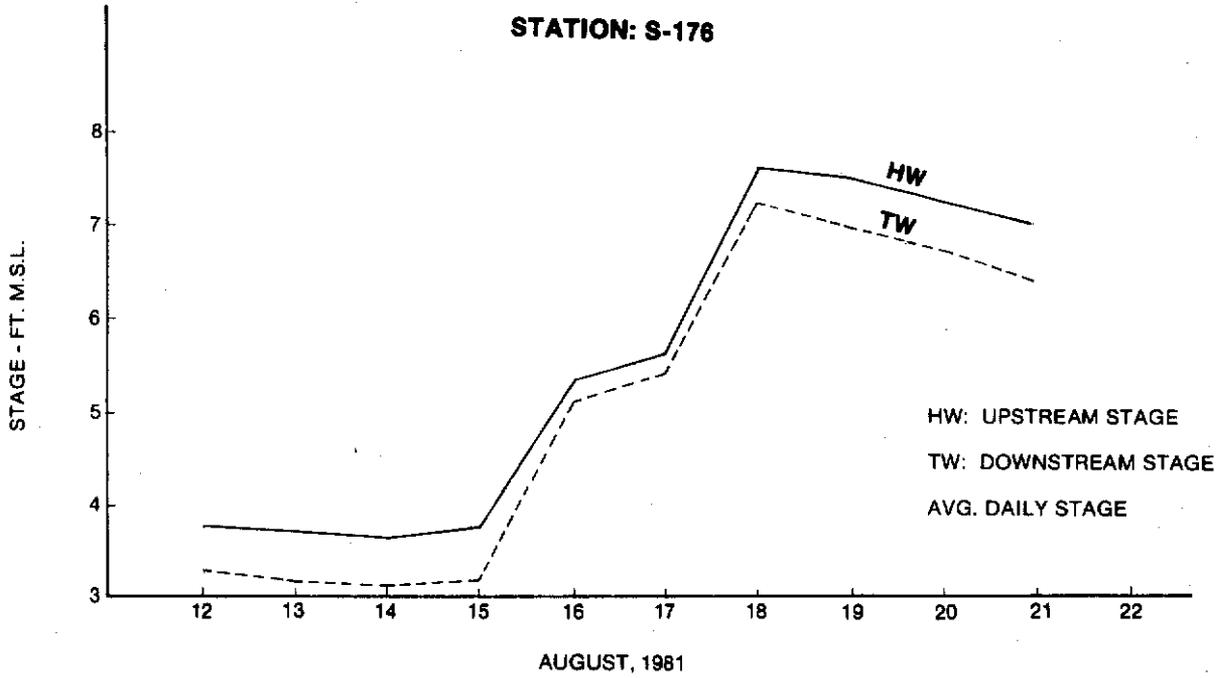


Figure 8 DAILY STAGE HYDROGRAPHS AT S-176, S-18C DURING STORM DENNIS

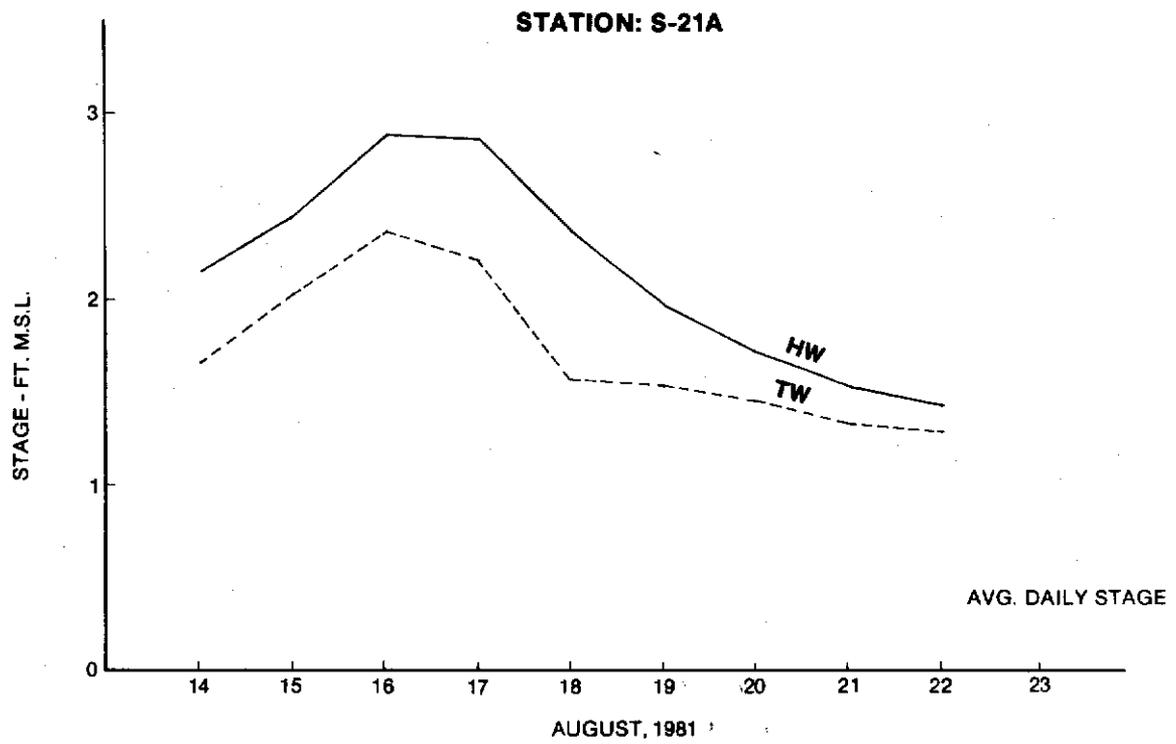
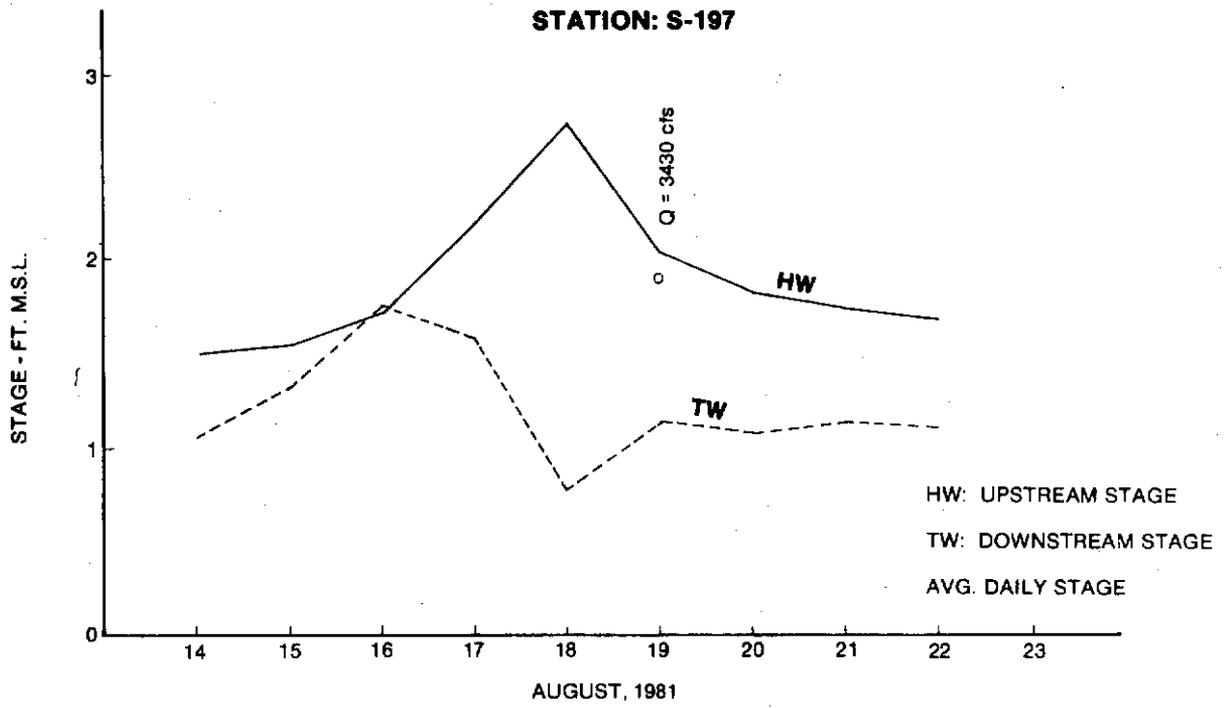


Figure 9

DAILY STAGE HYDROGRAPHS AT S-197, S-21A DURING STORM DENNIS

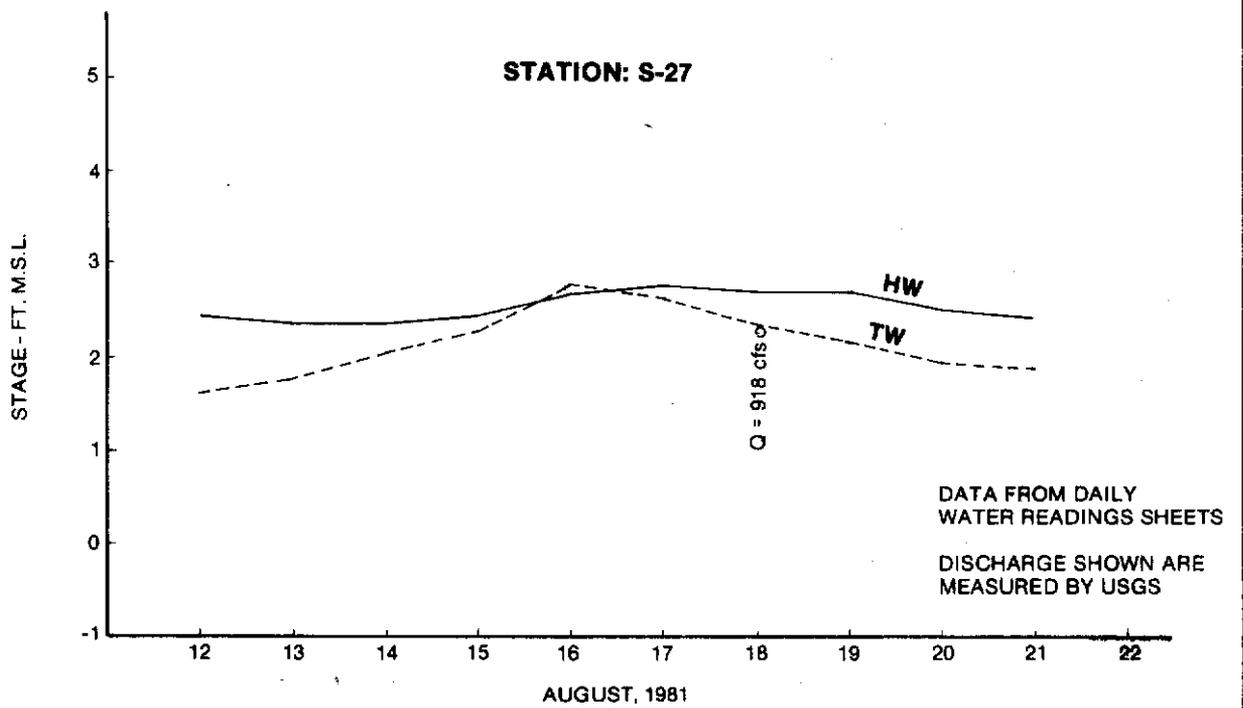
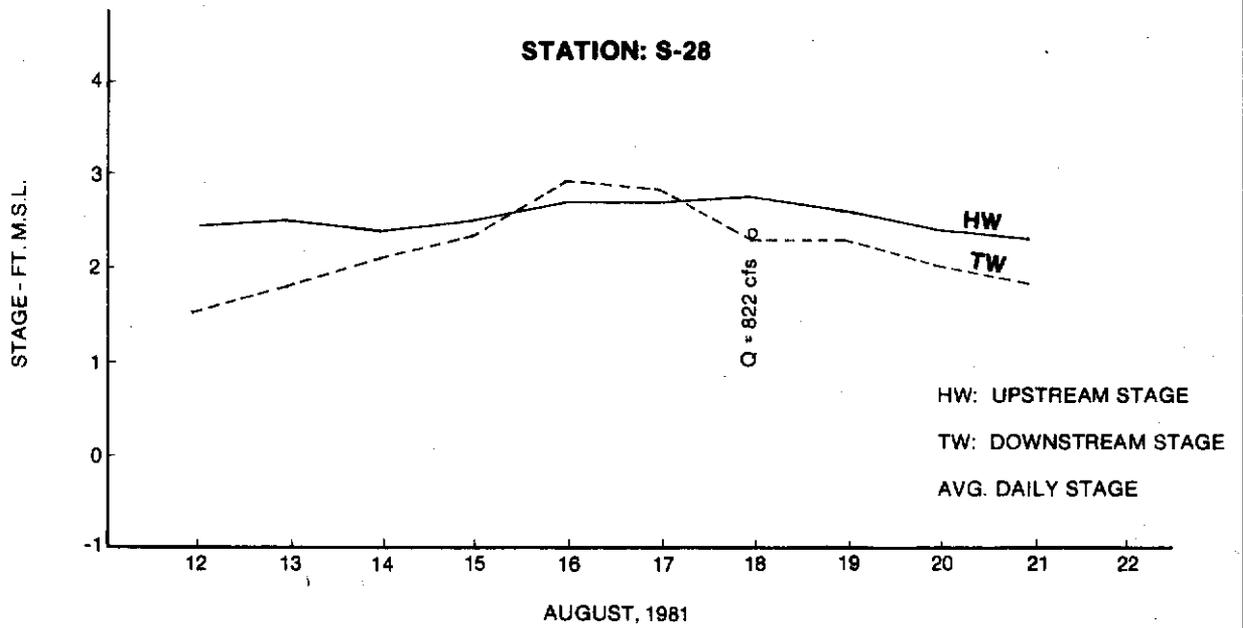


Figure 10

DAILY STAGE HYDROGRAPHS AT S-28, S-27 DURING STORM DENNIS

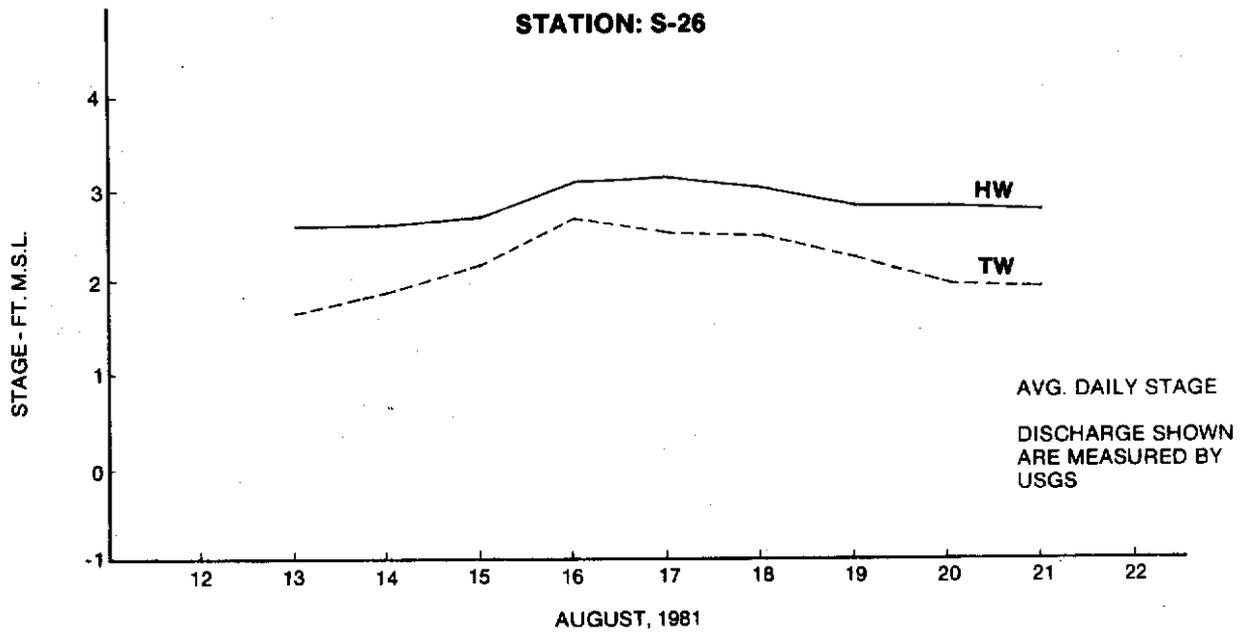
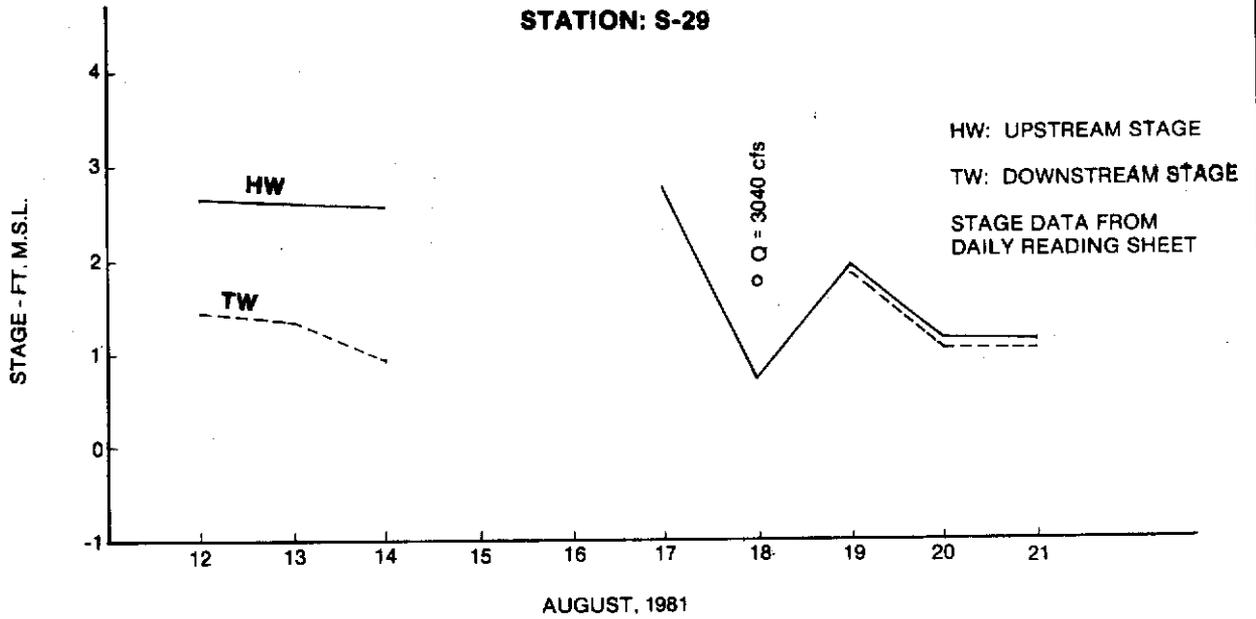


Figure 11 DAILY STAGE HYDROGRAPHS AT S-29, S-26 DURING STORM DENNIS

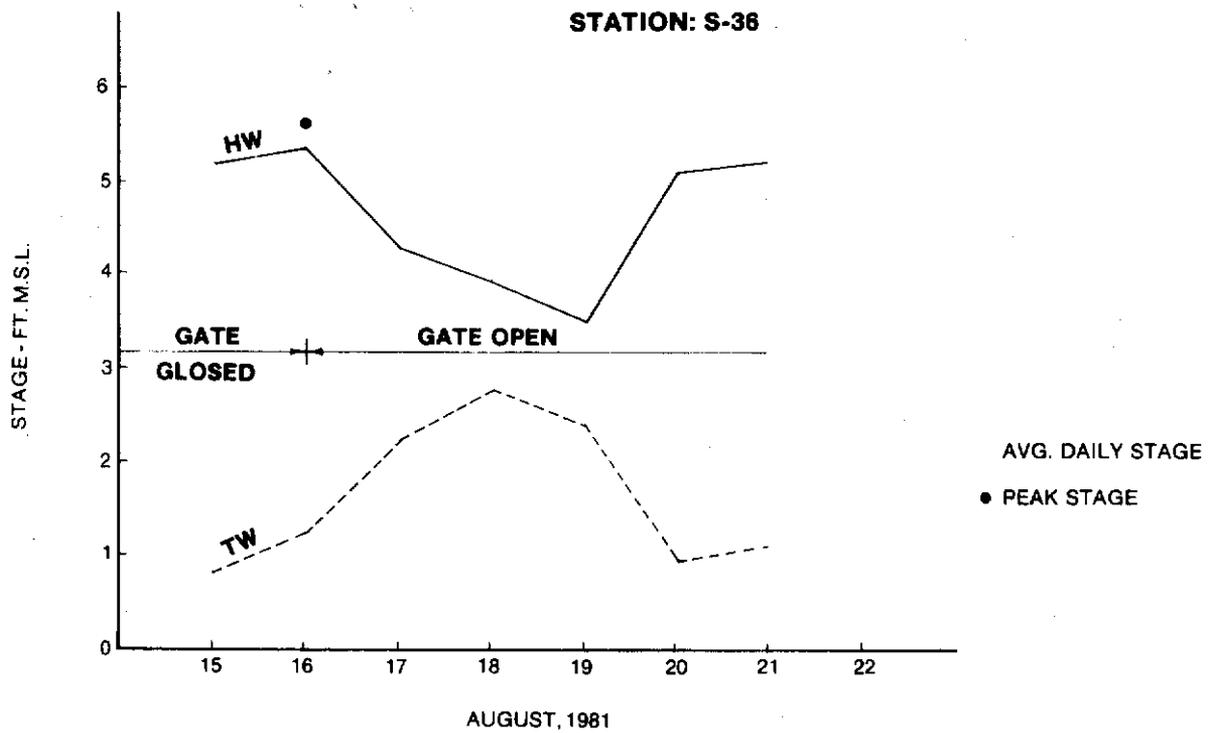
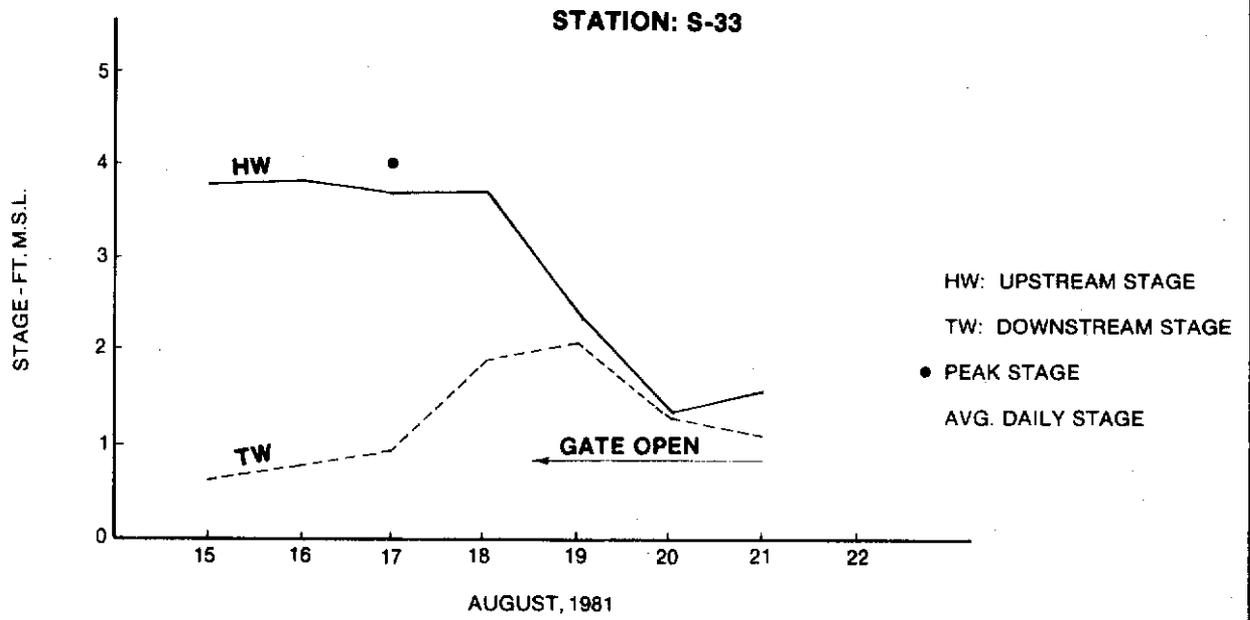


Figure 12 DAILY STAGE HYDROGRAPHS AT S-33, S-36 DURING STORM DENNIS

B. Flooded Areas

In several areas of Broward and Dade Counties, the high rainfall intensities and large rainfall quantities exceeded the capacity of secondary and tertiary drainage systems and, in the case of south Dade, the capacity of the primary flood control systems.

The problem areas covered in this report include areas which had either street flooding that lasted three days or more, or house flooding. This information was compiled from all available sources.

Palm Beach County; There were no flooding problems reported except in portions of South Indian River Drainage District.

Broward County: The west Broward area had flooding in isolated areas. In Lauderhill, Sunrise, Plantation, Plantation Acres subdivision, and Sunshine Ranches subdivision, isolated flooding of homes and extensive street flooding was reported.

Davie area - Flooding was reported in the 500 block of SW 130th Terrace in a mobile home community; about 2 feet of water in spots.

Pompano Beach - The northbound lane of Dixie Highway was under water; one foot at the crest of the road to about 3 feet on the sides. This occurred during the heaviest rainfall period of the event.

Plantation Acres - Many streets were flooded and houses became islands after two days of rain. Many side roads leading to houses in Plantation Acres were covered with several inches of water. The canals were at capacity

C-11 Basin - Minor flooding was observed at several locations. Lawns, swales, open and undeveloped areas were flooded, but only minor street flooding was observed and no house pads were endangered.

North Lauderdale area (C-12 Basin) - Extensive localized street flooding at SW 81st Avenue and SW 5th Street was observed from sidewalk

to sidewalk 6 to 8 inches deep at centerline of the road. At the local subdivision canal adjacent to Highland Park playground, and in the vicinity of SW 78th Terrace, the water was out of banks and up to fences along property lines and onto recreational fields.

Kimberly Boulevard (C-14 Basin) - SW 80th Avenue was flooded 6 to 8 inches deep from Kimberly south to Tam-o-shanter. SW 10th Street was flooded from SW 80th Avenue east. SW 10th Court was flooded from SW 80th Avenue east. Tam-o-shanter was completely flooded east and west from SW 80th Avenue, 7 to 8 inches deep at waterline. SW 78th Avenue was flooded from Tam-o-shanter north. East of SW 78th Avenue there was water 10 inches deep on the centerline of Tam-o-shanter.

Fountains of Tam-o-shanter (C-14 Basin) - Street flooding was much less than in other areas.

Inverrary and Environs Area (C-13 Basin) - NW 44th Street -substantial areas were flooded with about 6 inches of water overflowing into some adjacent backyards, close to homes, patios, and porches.

Dade County: Dade County, especially in the south Dade area, received most of the rainfall during this storm. From just below South Miami to the southern tip of the Florida Peninsula, water covered most of the 20 mile long stretch between the Black Creek Canal and the State's southern tip. Numerous homes that were built on large tracts of land had standing water inside. Flood waters lapped at the doors of most homes. The flooding was described as a "solid sheet of water from Kendall Drive all the way south".

Florida City - Most of the streets in southwest Florida City were closed. Water as deep as 4 feet spread across front lawns and into some homes.

The agricultural area between Homestead and Everglades National Park had canal waters rising above the banks.

The areas in south Dade County which experienced flooding as a result of Tropical Storm Dennis are shown in Figure 13.

A comparison of flooding from Hurricane Donna in 1960 and Tropical Storm Dennis is in preparation by the U. S. Geological Survey.

V. Rainfall During August and September 1981

A month subsequent to the passage of Tropical Storm Dennis, a new rainfall record was set in some portions of south Dade. A new record high of 48.88 inches of rainfall over August and September 1981 was recorded at Homestead Experimental Station. A great portion of south Dade, especially the Homestead area, was flooded for a period of more than two months due to Storm Dennis and subsequent heavy storms during the month of September. This amount of rainfall far exceeded the project design of the flood control system for the area. The areal extent of rainfall distribution in August and September, its characteristics, and return frequency estimation are covered in this section of the report.

A. Areal Distribution

The rainfall amounts in Palm Beach County, Broward County, Everglades Agricultural Area, Lower West Coast Area, and north Dade County were on the order of 25 inches or less for August and September. It is not unusual to have these quantities of rainfall during these months in south Florida; however, the available data indicate that much heavier rainfall occurred in south Dade, especially at Homestead. Figure 14 shows the area rainfall distribution for this two month period. The areal rainfall which was 40 inches or more covered almost 100 square miles which included north Florida City, Homestead, the West Princeton area, and the south campus of the University of Miami. The peak rainfall amount was observed at the Homestead

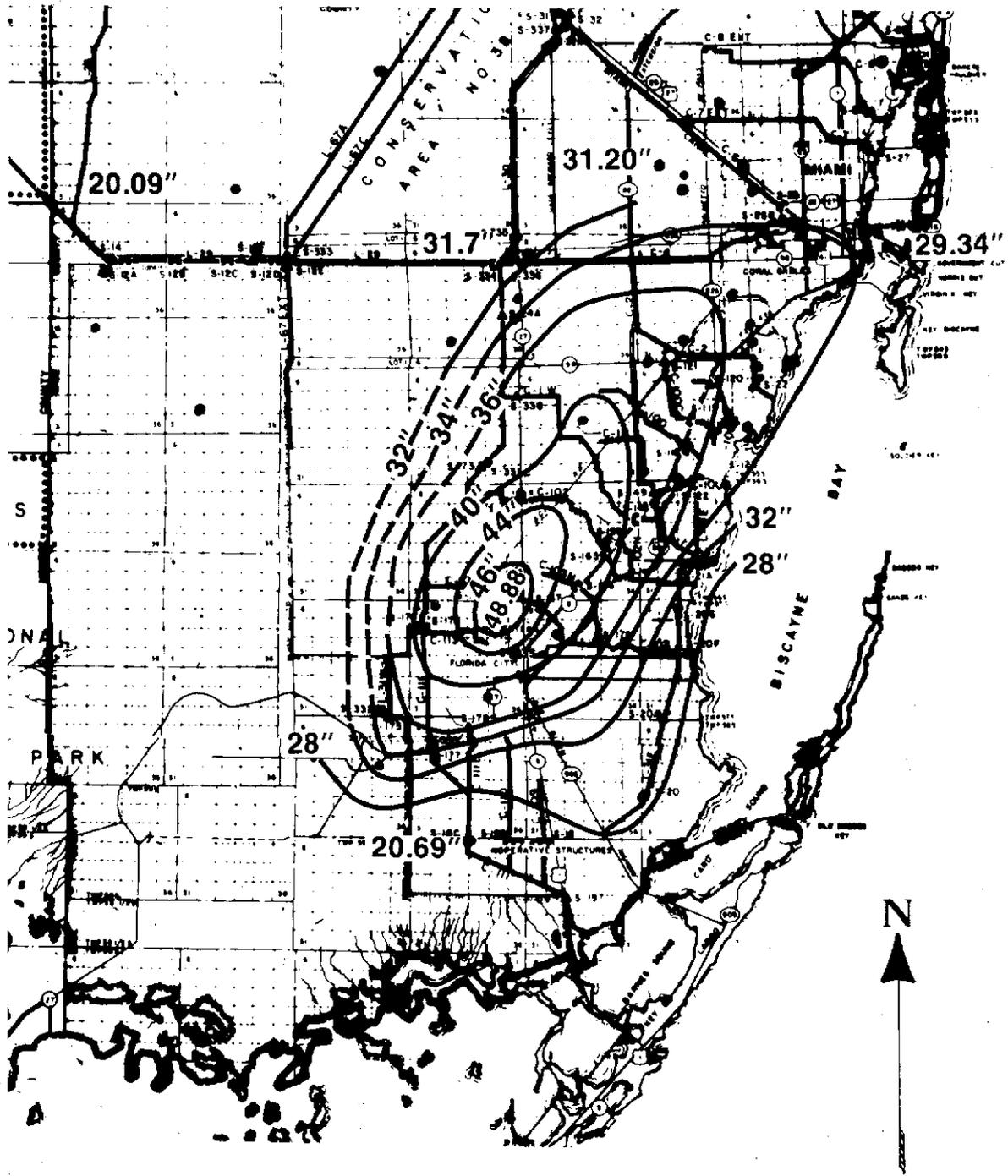


Figure 14: Area Rainfall Distribution in South Dade Area During Months of August and September 1981.

Experimental Station, was significantly lower toward the south, west, and east of Homestead to 20.69 inches at the station at S-18C, and 28 inches at Royal Palm Ranger Station and the station at S-20. The gradient is less pronounced in the northeastern direction. In general, the areal rainfall distribution under Storm Dennis is shown in Figure 15.

B. Time Distribution

The time distribution analysis of rainfall for this two month period was based on the daily recorded rainfall from the raingauges presented in Tables 9 and 10. The major rainfall event during August was Storm Dennis which has been discussed in the previous sections of this report. There were several additional major storm events which occurred during September; however, all these events were typical convective type storms. Some stations recorded two major events during that period - one in the first half of September and the second on the last 10 days of September. Most stations in south Dade recorded one major event during September 24 through 27 with intensive rainfall occurring on September 26. The intensity was higher near the coastal area of Biscayne Bay and gradually reduced in strength inland (see Figure 15A). For example, rainfall amounts for the four day period (September 24 - 27) were 9.82 inches at S-20, 12.24 inches at Miami 12S SW, 8.79 inches at Homestead Experimental Station, and 3.74 inches at Royal Palm Ranger Station. Therefore, the distribution of these events during September was much different from the Storm Dennis event in areal and intensity distributions. The antecedent conditions and the additional rainfall in September did prolong the flooding situation of the area.

C. Return Frequency Estimation

A design memorandum on rainfall frequency estimates for the District area was developed by the Corps of Engineers as part of the Central and Southern Florida Flood Control Project. This report was published in 1953.

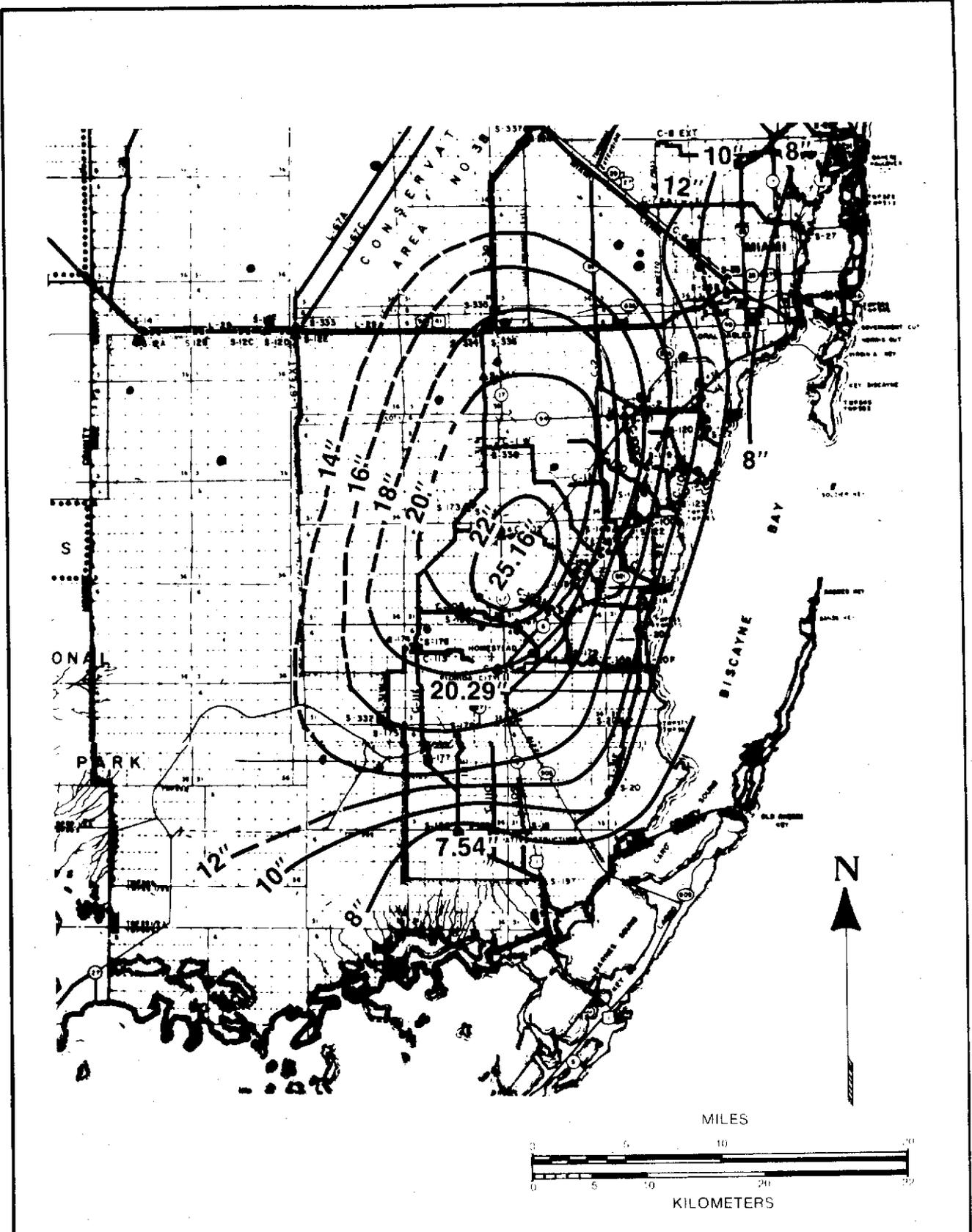


Figure 15: Area Rainfall Distribution in South Dade for Storm Dennis During August 16-20, 1981.

YEAR 1961 MONTH AUGUST

TABLE 9
DAY

STATIONS

NUMERICAL FIELD STA	S-20	S-180	S-207	S-331	S-332	S-336	GOLD ISLES	CLARK
1	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
2	1.27	1.03	1.46	1.33	1.02	0.57	1.30	1.72
3	0.00	1.02	0.00	0.20	1.25	0.45	0.25	0.40
4	0.00	0.00	0.11	0.10	0.74	0.42	0.80	0.91
5	0.00	1.15	0.00	0.02	0.00	0.02	0.00	0.14
6	0.00	0.07	0.00	0.00	0.00	0.00	0.40	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
10	0.17	0.04	0.10	0.03	0.51	0.19	0.40	0.20
11	0.00	0.00	0.20	0.07	0.00	0.00	0.00	0.21
12	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
13	0.14	0.00	0.00	0.17	0.00	0.45	0.00	0.00
14	0.43	0.02	0.00	0.02	0.72	0.00	0.00	0.55
15	0.60	0.40	0.37	0.27	0.23	0.16	0.40	0.50
16	4.41	2.19	3.45	2.27	2.02	1.47	1.75	2.50
17	3.00	2.12	4.23	0.88	4.96	12.20	4.75	3.50
18	0.27	3.03	1.02	4.88	5.42	0.00	0.80	4.00
19	0.34	0.00	0.44	0.00	0.00	0.00	0.50	0.40
20	0.01	0.00	0.00	0.00	0.00	0.18	1.60	1.02
21	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.55
22	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0	0.58
24	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
25	0.00	0.26	0.00	0.00	0.92	0.12	0.40	0.70
26	0.12	0.14	0.23	0.02	0.48	0.32	0.60	0.50
27	0.34	0.02	0.02	0.04	0.03	0.01	0	0.38
28	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
30	0.00	0.00	0.30	0.00	0.00	0.00	0	0.00
31	0.00	0.00	0.05	0.02	0.00	0.88	0.60	0.30
TOTAL	7.30	11.50	12.02	15.64	16.32	17.44	15.30	15.16

TABLE 9 (continued)
DAY

STATIONS

	HUMESTEAD EXP. STA.	ROYAL PALM RANGER	MIAMI 125 SW	MIAMI A P.	HIALEAH	TAMIAMI 40MI. BU	UASIS
1	0.00	0.00	0.00	0.17	0.00	0.00	0.06
2	1.27	0.91	3.20	1.78	0.08	0.45	0.08
3	0.10	0.45	0.30	0.17	1.95	0.02	0.00
4	0.45	0.80	0.55	0.04	0.26	0.15	0.00
5	0.04	0.16	0.12	T	0.10	0.00	0.05
6	0.00	0.00	0.00	0.00	0.04	0.00	0.00
7	0.00	0.00	0.00	0.07	0.00	0.00	0.15
8	0.00	0.00	0.00	0.00	0.00	0.00	0.08
9	0.20	0.00	0.00	T	0.00	0.25	0.00
10	0.32	0.54	0.32	0.01	0.11	0.04	0.00
11	0.45	0.10	0.00	T	0.04	0.15	0.32
12	0.00	0.00	0.00	T	0.00	0.00	0.00
13	0.14	0.00	0.00	T	0.47	X	0.80
14	0.00	0.00	0.00	T	0.14	X	0.24
15	0.22	1.04	0.33	0.45	0.09	0.75A	1.08
16	4.50	1.42	2.45	1.26	0.07	1.08	1.24
17	7.40	4.70	1.10	2.20	0.70	0.71	0.58
18	7.44	7.70	5.30	2.75	7.30	5.10	4.85
19	0.01	0.00	0.46	0.14	0.53	0.45	1.50
20	0.24	0.32	0.33	0.31	0.18	0	T
21	0.00	0.00	0.02	0.10	0.00	0.00	0.19
22	0.00	0.00	0.01	0.00	0.12	0.74	0.50
23	0.00	0.00	0.15	0.04	0.00	0.29	0.04
24	0.00	0.00	0.09	0.00	0.00	0.03	0.00
25	5.03	0.30	0.00	0.70	0.00	0.07	0.02
26	0.14	1.12	0.25	0.23	0.26	0.22	0.60
27	0.01	0.38	0.20	0.14	0.70	0.34	0.25
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.11	0.00	0.00	0.21	0.00	0.00	0.00
31	0.14	0.00	0.04	T	0.00	0.00	0.16
TOTAL	27.92	20.44	19.07	14.05	15.13	11.44	13.64

YEAR- 1901 MONTH- AUGUST

TABLE 9 (continued)

DAY	MIAMI F S	S-T	MIAMI BCH	S-140	W P B A P	TAVERNIER	FLAMINGO
1	0.00	0.00	0.00	0.00	0.00	0.02	0.22
2	0.00	0.34	2.99	0.00	0.31	0.25	0.01
3	1.40	0.30	0.56	0.08	T	0.19	2.01
4	0.79	0.20	0.12	0.00	0.00	0.22	0.15
5	0.15	0.00	0.00	0.00	T	0.05	0.51
6	0.05	0.00	T	0.00	0.00	0.12	0.00
7	0.00	0.15	0.00	0.40	0.68	0.00	0.00
8	X	0.00	0.00	0.00	0.00	0.00	0.00
9	X	0.00	0.12	0.00	0.00	0.21	0.00
10	0.17A	0.07	0.14	1.25	0.18	0.02	0.17
11	0.12	0.00	0.08	0.27	0.01	0.16	0.09
12	0.00	1.25	0.11	0.67	0.00	0.07	0.09
13	0.15	0.08	0.00	0.20	T	0.07	0.03
14	0.05	1.00	0.16	0.00	0.02	0.02	0.00
15	X	0.00	0.21	0.00	0.26	1.14	0.43
16	X	1.84	0.55	0.92	1.26	1.66	1.84
17	2.70A	2.34	1.52	3.31	0.95	4.13	2.81
18	7.60	7.47	3.51	2.67	5.73	1.62	6.20
19	1.45	0.00	0.08	M	0.00	0.00	0.04
20	0.26	0.05	0.06	M	0.02	0.03	0.00
21	0.35	0.08	0.55	M	1.86	0.00	0.00
22	X	0.00	0.00	0.00	0.00	0.03	0.00
23	X	0.00	0.02	0.00	0.02	0.00	0.00
24	0.70A	0.63	0.00	0.00	T	0.00	0.00
25	0.00	0.04	0.14	0.62	0.07	0.01	0.00
26	1.40	0.25	0.20	0.18	0.83	0.40	0.21
27	0.45	0.10	0.20	0.16	0.01	0.22	0.03
28	0.00	0.08	0.00	0.35	0.02	0.00	0.48
29	X	0.00	0.00	0.00	0.00	0.00	0.00
30	X	0.55	0.25	1.92	0.09	0.00	0.00
31	0.35A	0.05	0.55	1.08	0.00	0.00	0.00
TOTAL	18.52	17.05	12.25	14.46M	10.33	10.64	17.32

YEAR- 1901 MONTH- SEPTEMBER

TABLE 10

DAY STATIONS

DAY	HUMESTEAD EXP. STA.	KUJAL PALM KANGER	MIAMI 125 SW	MIAMI A P	HIALEAH	MIAMI 40MI. BU	LASIS
1	0.01	0.00	1.18	0.00	0.01	0.00	0.88
2	0.22	0.37	1.03	I	0.00	0.40	0.38
3	1.17	0.75	0.00	0.04	0.00	0.50	0.00
4	2.45	0.00	0.00	0.01	0.08	0.00	0.00
5	I	0.00	0.04	0.04	0.00	0.00	0.00
6	0.02	0.00	0.16	0.04	0.15	0.00	1.85
7	0.10	0.30	0.47	2.35	0.88	1.32	1.10
8	0.65	0.00	0.16	0.03	1.95	0.00	0.09
9	1.04	0.25	0.21	2.04	0.06	0.00	0.13
10	0.04	2.60	0.60	0.17	1.95	0.14	0.00
11	0.85	0.37	0.10	0.11	0.46	0.01	0.04
12	0.00	0.00	0.04	0.02	0.04	0.00	0.00
13	0.01	1.76	0.00	0.05	0.07	0.03	0.90
14	0.35	0.00	0.00	I	0.02	0.00	0.00
15	0.11	0.15	0.00	0.06	0.27	0.00	0.18
16	0.04	0.00	0.34	0.74	0.04	0.14	0.00
17	0.22	0.10	0.33	0.14	0.95	0.10	0.00
18	0.60	0.00	0.00	0.01	0.08	2.77	0.00
19	0.00	0.00	0.00	0.00	0.60	0.01	0.00
20	0.00	0.00	0.05	1.01	1.20	0.00	0.00
21	2.05	0.71	0.08	0.01	0.00	0.00	0.00
22	1.22	0.20	0.00	1.20	0.04	0.00	0.13
23	0.00	0.50	0.60	I	0.18	0.98	2.35
24	I	0.02	0.00	0.00	0.00	0.00	0.00
25	0.50	1.24	0.28	0.00	0.37	1.35	0.05
26	0.52	0.91	0.66	0.15	4.45	0.30	0.25
27	1.71	1.52	0.70	1.45	0.10	0.05	0.00
28	0.00	0.00	0.00	I	0.10	0.00	0.00
29	1.50	0.12	0.00	0.03	0.00	0.00	0.00
30	0.00	0.97	1.07	0.00	0.00	0.51	0.90
TOTAL	21.57	15.04	14.95	14.75	15.70	6.65	9.23

YEAR- 1961 MONTH- SEPTEMBER

TABLE 10 (continued)

DAY	HUNDREDS FILL STA	S-20	S-100	S-20F	S-331	S-332	S-336	6CLD ISLES	CLARK
1	0.11	0.01	0.00	0.00	0.00	0.04	0.96	0.30	0.00
2	1.14	0.00	0.02	0.00	0.37	0.80	0.00	0.00	0.00
3	0.00	0.00	0.02	0.00	0.93	0.03	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
5	X	0.00	0.12	0.00	0.00	0.08	0.00	0.52	0.00
6	X	0.00	0.06	0.00	0.04	0.24	0.00	0.26	0.11
7	X	1.10	0.00	0.00	0.50	0.71	0.34	0.90	1.60
8	2.21A	0.00	0.20	0.00	0.93	0.00	0.61	0.00	0.11
9	0.44	0.00	0.35	0.00	0.15	0.79	0.23	0.48	1.20
10	0.07	0.00	0.12	0.00	0.38	1.80	0.00	2.00	0.00
11	0.68	0.75	0.65	0.65	4.97	0.11	1.31	0.00	0.14
12	X	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.10
13	X	0.00	0.35	0.00	1.45	0.16	0.00	0.00	0.11
14	2.54A	0.00	0.00	0.00	1.21	0.00	0.12	0.00	0.00
15	0.00	0.04	0.00	0.00	0.08	0.00	0.04	0.00	0.09
16	0.21	0.13	0.00	0.00	1.99	0.00	0.61	0.90	1.66
17	0.12	0.00	0.00	0.00	0.14	0.00	0.20	0.00	2.30
18	0.11	0.00	0.00	0.00	0.00	0.00	0.45	0.12	0.00
19	X	0.10	0.00	0.00	0.00	0.00	0.00	3.75	0.00
20	X	0.10	0.20	0.00	0.00	0.00	0.25	0.00	1.60
21	0.63A	0.98	1.10	0.00	0.11	0.10	0.04	0.00	0.00
22	0.27	0.15	1.06	1.06	0.05	0.70	0.20	0.30	0.70
23	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	1.33	0.00	0.00	0.07	0.00	0.00	0.00	0.00
25	0.11	1.00	1.30	1.30	1.50	0.80	1.25	2.55	3.48
26	7.20	1.00	5.45	5.45	4.75	2.27	4.10	0.33	3.48
27	2.08	1.82	0.20	0.20	0.00	1.23	0.00	0.40	1.00
28	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.31	1.00	1.00	2.19	1.07	1.23	2.25	0.00	0.00
30	1.80	0.21	0.40	0.05	0.02	0.32	0.00	0.68	0.18
TOTAL	23.00	17.87	7.17	12.20	21.00	11.01	13.43	13.01	15.26

YEAR- 1981 MONTH- SEPTEMBER

TABLE 10 (continued)

DAY	STATIONS									
	MIAMI F S	S-9	MIAMI BUR	S-140	* F B A P	IAVERNER	FLAMINGO			
1	0.00	0.00	0.00	0.42	0.02	0.00	M			
2	0.18	0.00	0.00	0.37	0.00	0.08	M			
3	0.00	0.00	0.19	0.02	0.02	0.00	M			
4	0.03	0.03	0.10	X	0.05	0.00	M			
5	. X	0.00	0.00	. X	0.01	0.02	M			
6	. X	1.74	0.48	. X	0.00	0.03	M			
7	. X	0.07	3.43	. X	0.60	1.30	M			
8	2.06A	0.11	0.09	. X	0.08	0.65	M			
9	0.09	0.08	. I	. X	2.12	0.23	M			
10	2.02	0.00	0.88	. X	0.20	0.06	M			
11	0.45	0.00	0.72	0.85A	0.07	0.05	M			
12	. X	0.00	0.02	0.39	0.00	0.14	M			
13	. X	0.00	0.00	0.00	0.00	0.00	M			
14	0.00A	0.00	0.00	0.00	0.03	0.00	M			
15	0.52	0.00	0.17	0.72	0.89	0.52	M			
16	0.02	0.00	0.00	0.08	0.28	0.07	M			
17	1.23	0.00	0.07	0.82	. I	0.01	M			
18	0.32	0.23	0.05	0.08	0.37	0.10	M			
19	. X	0.00	0.00	0.00	0.00	0.00	M			
20	. X	0.00	1.61	0.00	0.12	1.39	M			
21	0.32A	0.20	0.48	0.10	1.04	1.22	M			
22	0.07	0.06	. I	0.09	0.18	0.82	M			
23	0.00	0.00	0.70	0.00	. I	0.71	M			
24	0.00	0.00	0.00	0.00	0.00	1.31	M			
25	0.00	0.00	4.20	0.00	0.18	2.46	M			
26	. X	0.00	0.79	0.05	0.00	0.47	M			
27	. X	0.00	2.82	0.00	0.00	0.29	M			
28	4.05A	0.00	0.00	0.00	0.00	0.00	M			
29	0.08	0.00	. I	0.09	0.00	0.18	M			
30	0.02	0.00	0.01	0.00	0.00	0.87	M			
TOTAL	11.89	3.32	17.09	9.14	7.30	12.78	M			

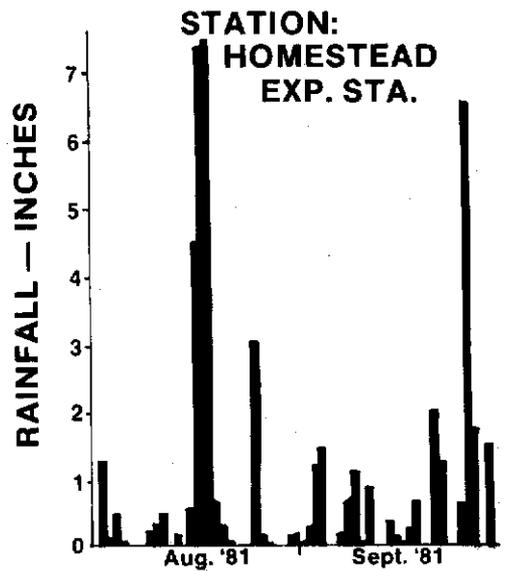
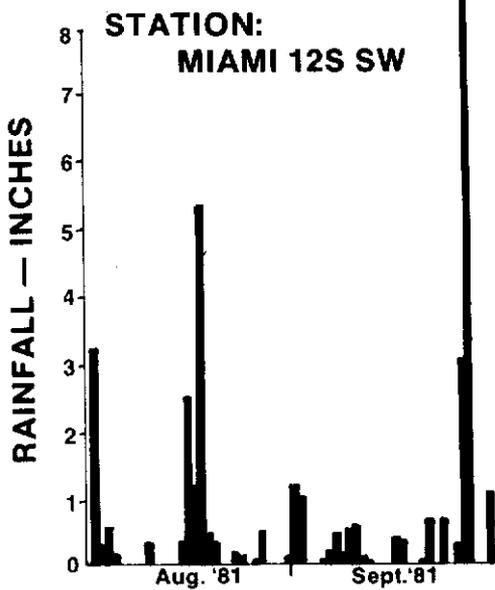
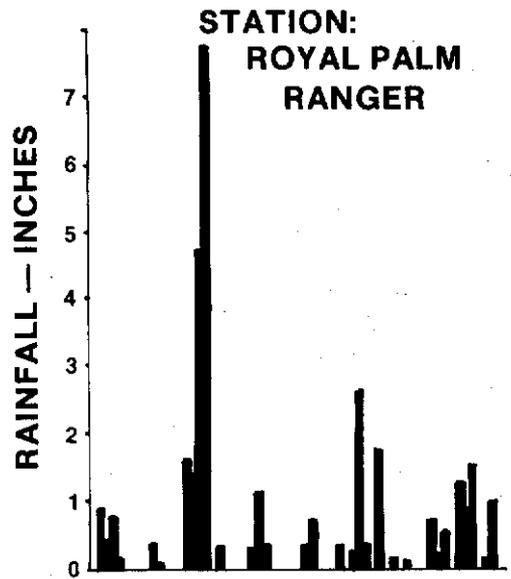
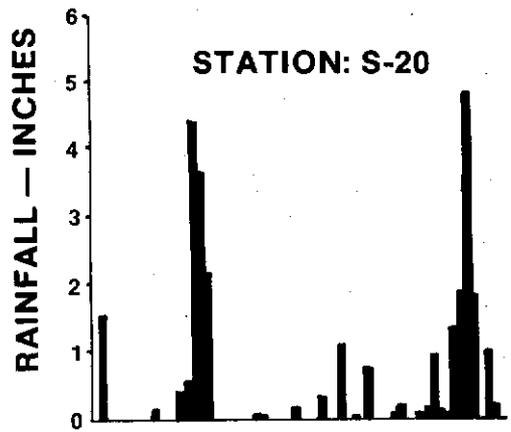
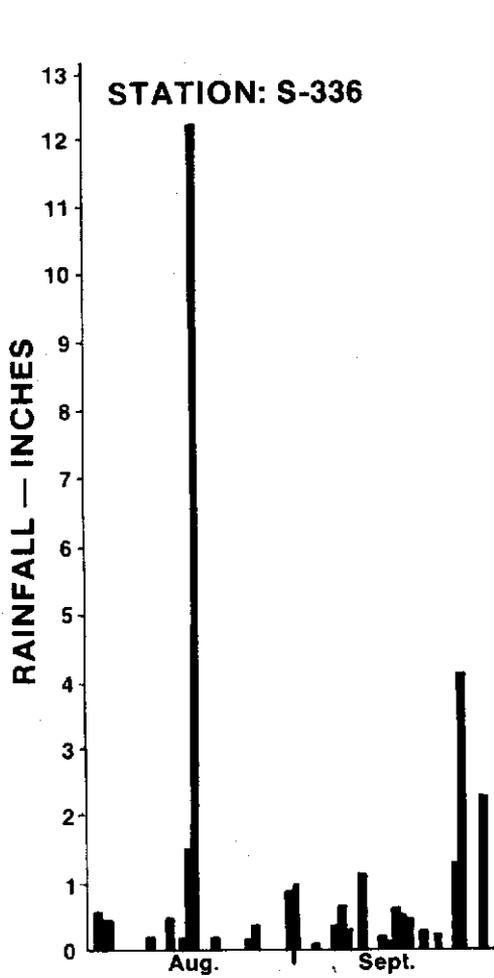


Figure 15A:

During August and September 1981

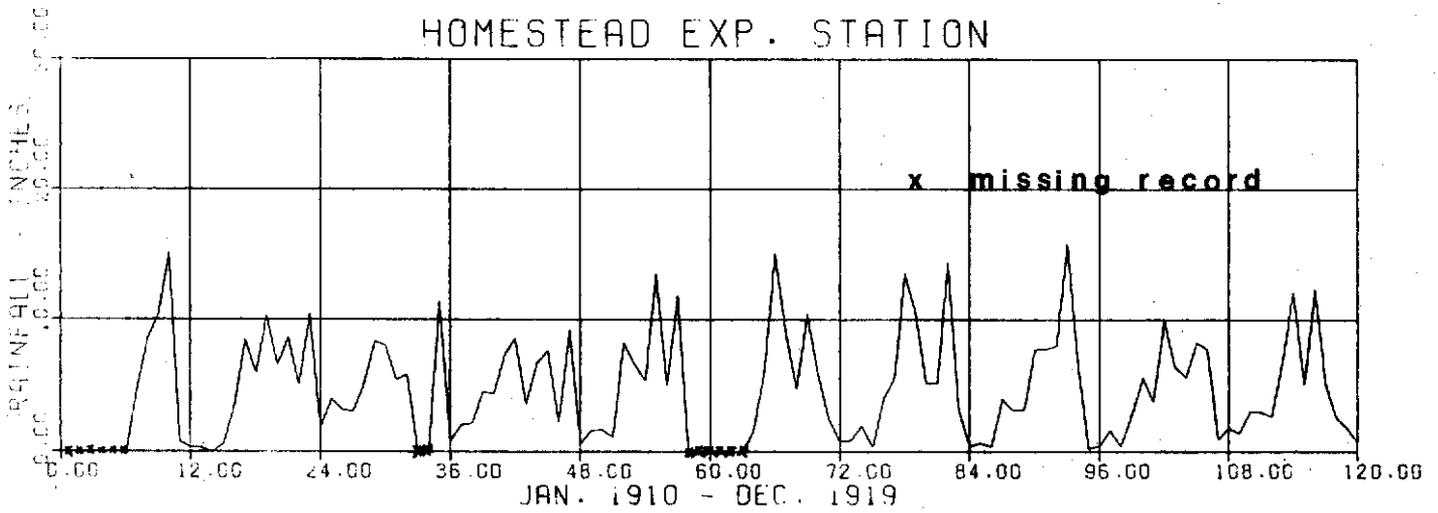
The study encompassed durations from one day to one year and return periods from 2 to 100 years. Rainfall data through 1952 were used as the basis of this analysis. An updated analysis performed by the District and published in a report entitled "Frequency Analysis of Rainfall Maximums for Central and South Florida", dated May 1981 considered rainfall data through December 1977. In order to investigate the possible changes in return frequency due to the major storm events of April 24-25, 1979 and Storm Dennis, an analysis of two months rainfall was performed. A frequency analysis based on the Gumbel extreme theory, as recommended in that report, was applied to the Homestead Experimental Station. Figure 16 shows the monthly rainfall distribution at the Homestead Experimental Station throughout the record period (January 1910 through September 1981). The results of the return frequency estimates for 1 day, 3 days, 1 month, and 2 months duration at the station as shown in the table below.

RETURN FREQUENCIES, ADDING RECENT STORM EVENTS

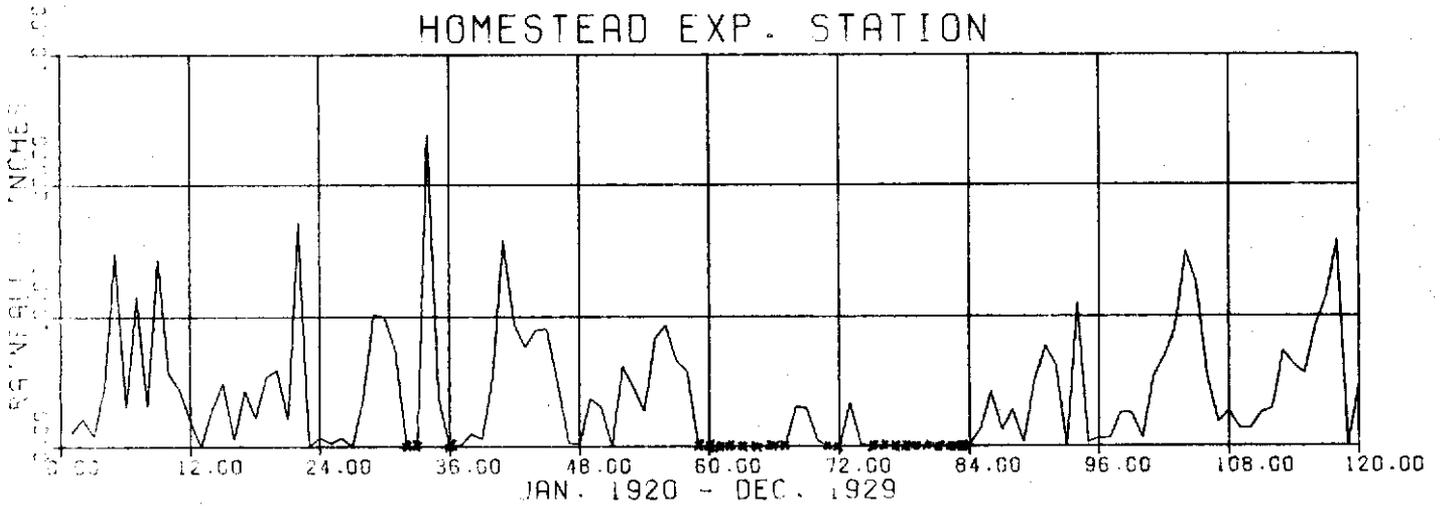
Return Frequency Years	Rainfall Depth - Inches			
	1 day	3 days	1 month	2 months
100	10.70	15.75	27.40	41.00
50	9.60	14.25	25.40	38.40
25	8.50	12.70	23.30	35.70
10	7.05	10.55	20.50	32.20
5	6.05	8.90	18.25	29.50

Comparing this result with the previously mentioned reports, indicates that there are no significant differences. Therefore, the results of the District Technical Report 81-3 were used in the analysis.

HOMESTEAD EXP. STATION



HOMESTEAD EXP. STATION



HOMESTEAD EXP. STATION

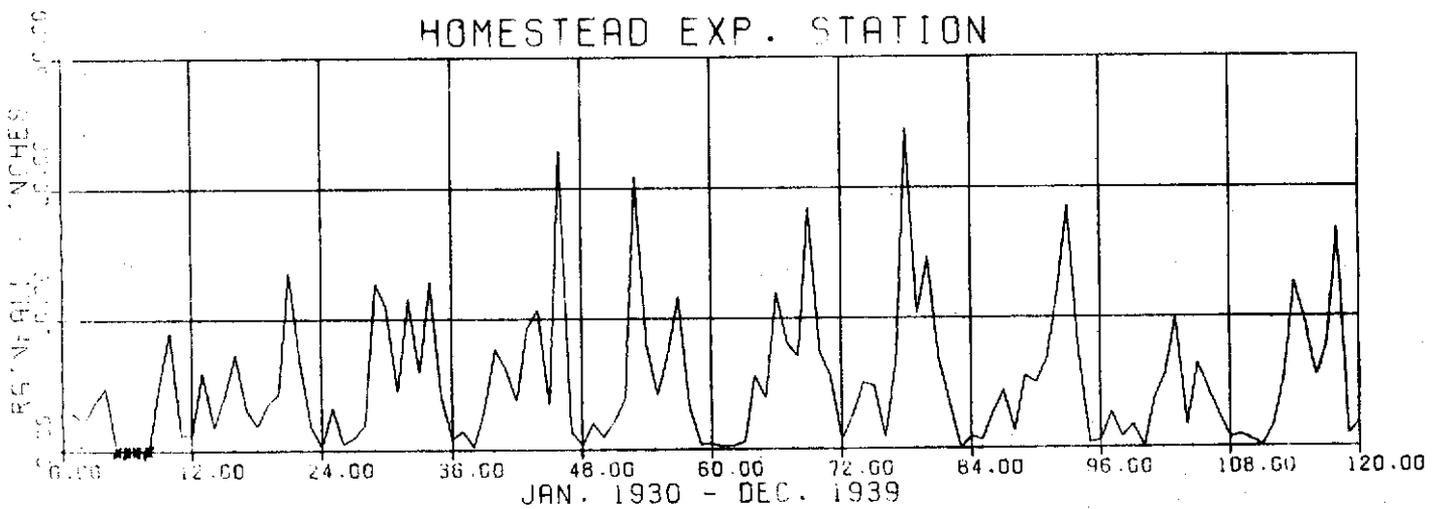


FIGURE 16. MONTHLY RAINFALL DATA AT HOMESTEAD EXPERIMENTAL STATION

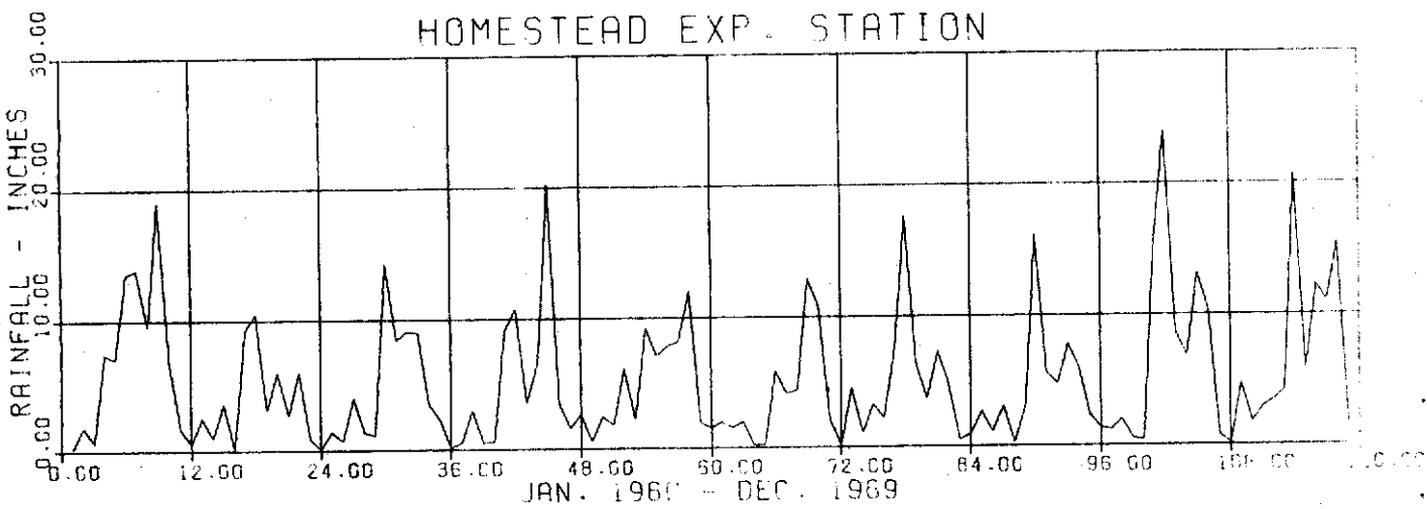
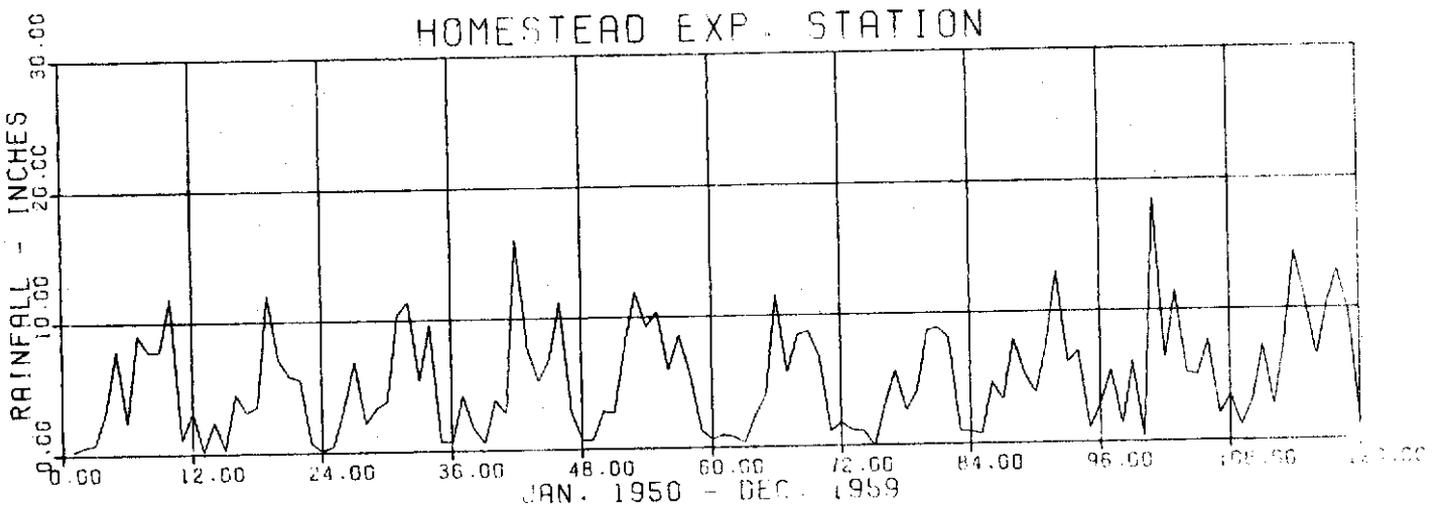
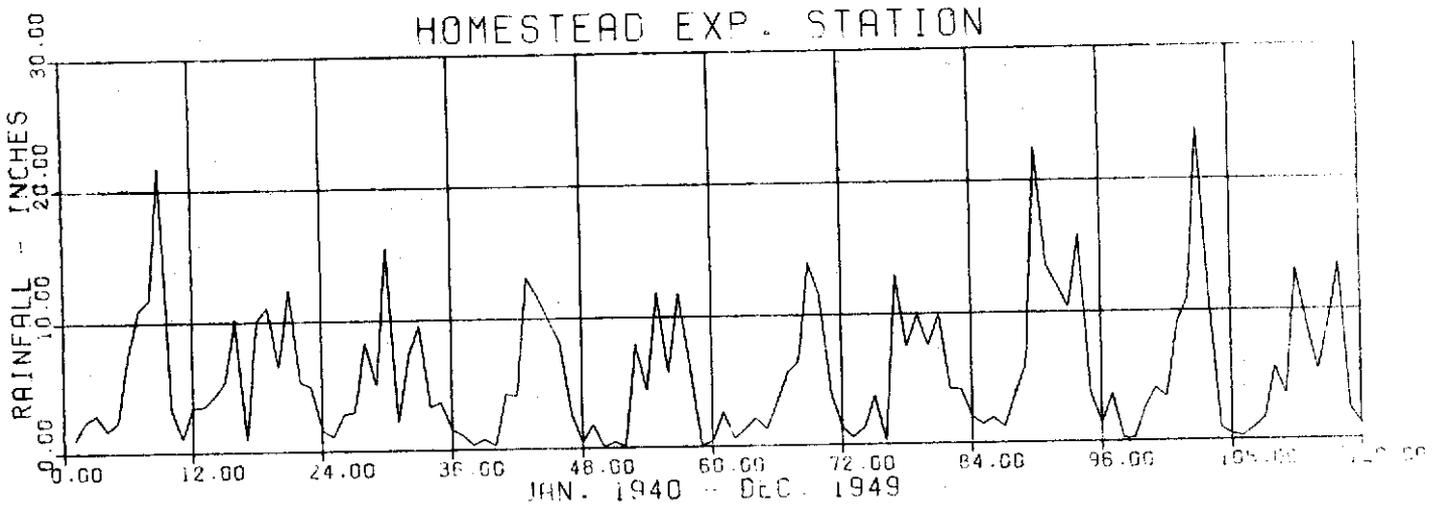


FIGURE 16 (continued)

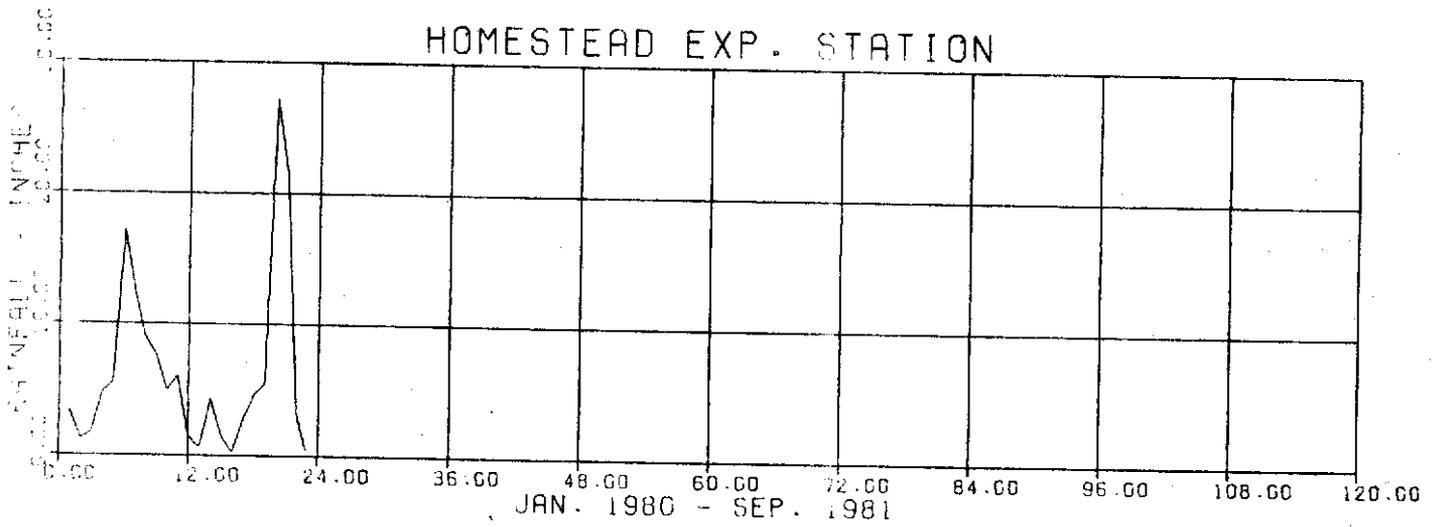
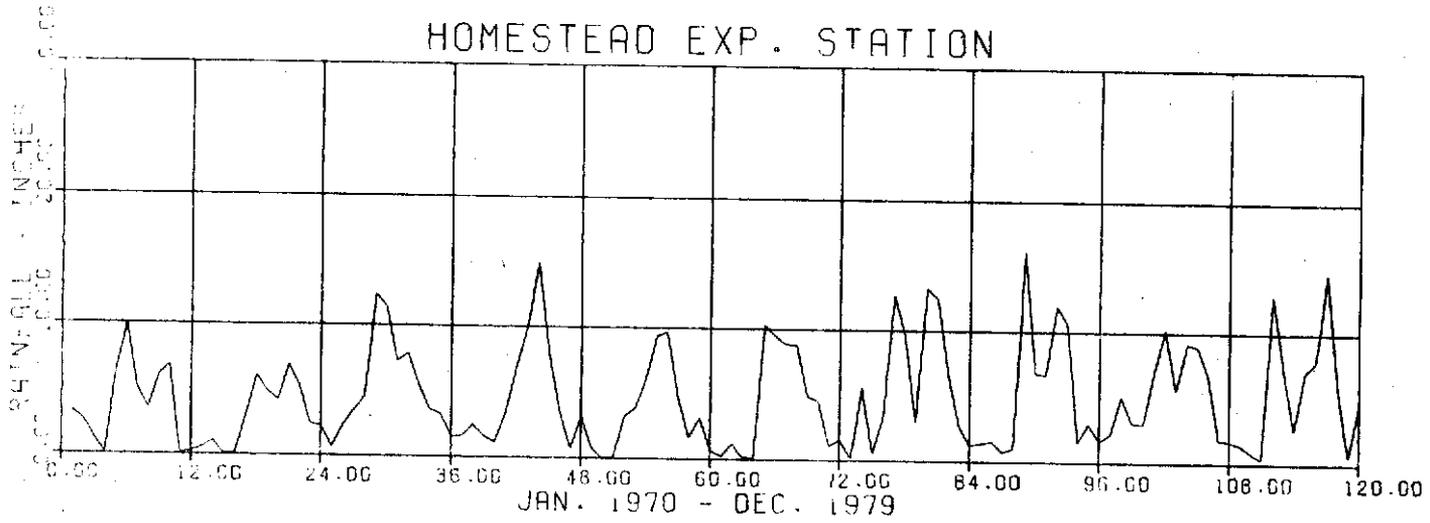


FIGURE 16 (continued)

VI. Rainfall Comparisons with Hurricanes Donna, Betsy, and Tropical Storm Florence

Rainfall records indicate that this storm event was equivalent to and in certain areas (south Dade), greater than storm events originated from Hurricanes Donna, Betsy, Tropical Storm Florence, and the April 24-25, 1979 storm. The most heavily concentrated rainfall associated with Hurricane Donna occurred south of Miami in the vicinity of Black Creek (C-1) where over 15 inches were recorded during the period of September 9-11, 1960. Rainfall on the coastal areas decreased from Miami northward to Jupiter where the rainfall approximated 1 inch. Rainfall on the remaining portion of the District averaged from 5 to 6 inches as a result of Hurricane Donna. There were 10 to 12 inches of rainfall in the areas of South Miami and Coral Gables and the central portion of the Everglades National Park (see Figure 17). A subsequent storm, Florence, from September 21-25, 1960 also produced 8 to 12 inches of rainfall in the areas of South Miami and Homestead with the highest rainfall intensity concentrated along the coast. The rainfall pattern of this storm showed a gradual decrease in the inland regions; only 2 inches were recorded along the west side of the water conservation area. The rainfall decreased gradually to about 6 inches in the West Palm Beach area and increased gradually to 15 inches in Indian River County (see Figure 18). The rainfall pattern of Florence, which was opposite that of Hurricane Donna and Tropical Storm Dennis, showed a rather uniform decrease from the coast to the western boundary of the District. Storm Florence, however, was similar to the abnormal rainfall subsequent to Dennis on September 24-27, 1981 which was a typical tropical convection-type storm. Comparing Storm Dennis with Hurricane Betsy, September 7-9 1965, (Figure 19) it can easily be seen that Storm Dennis produced two to three times more rainfall in both Broward and Dade Counties. Rainfall

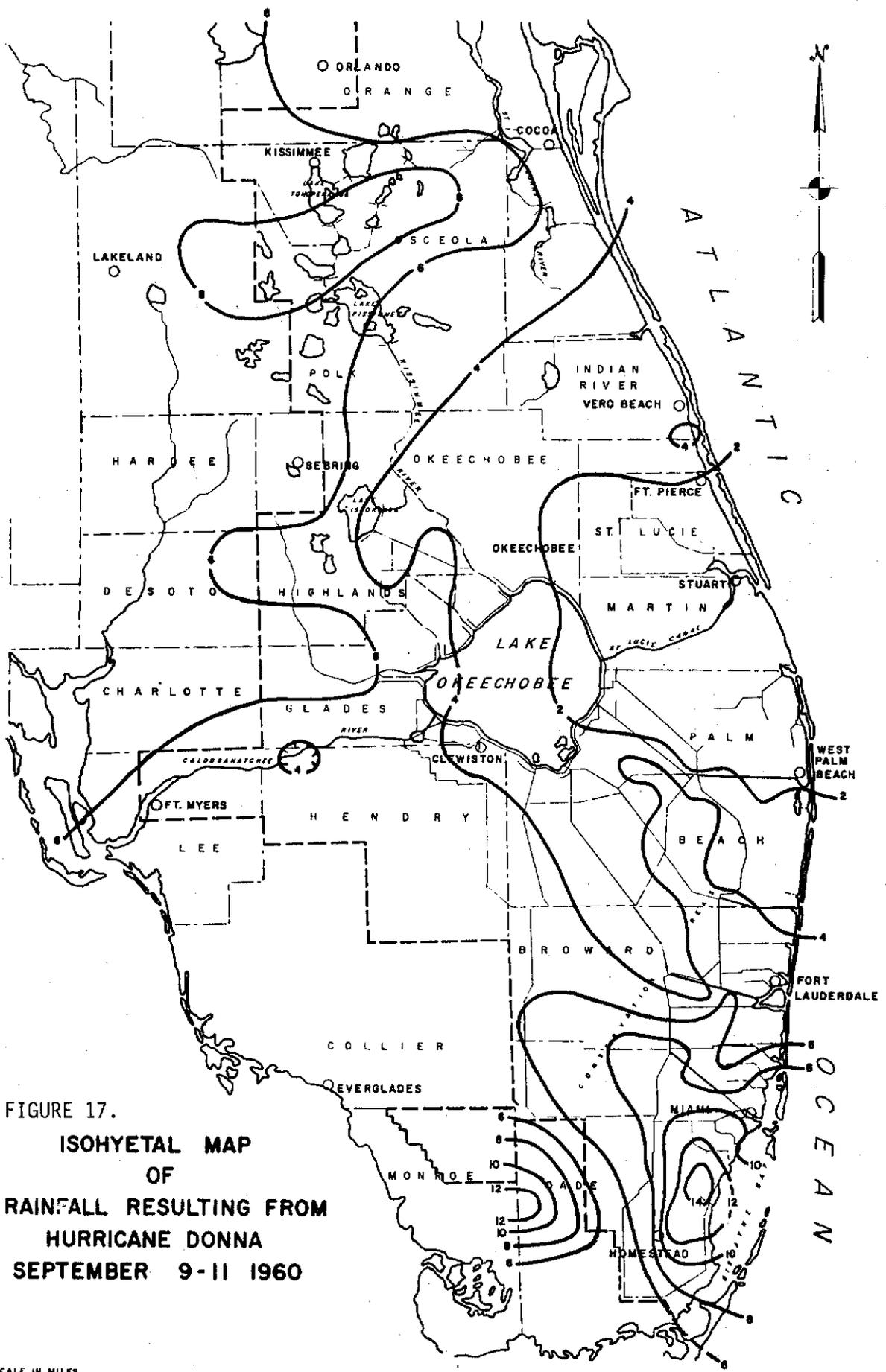
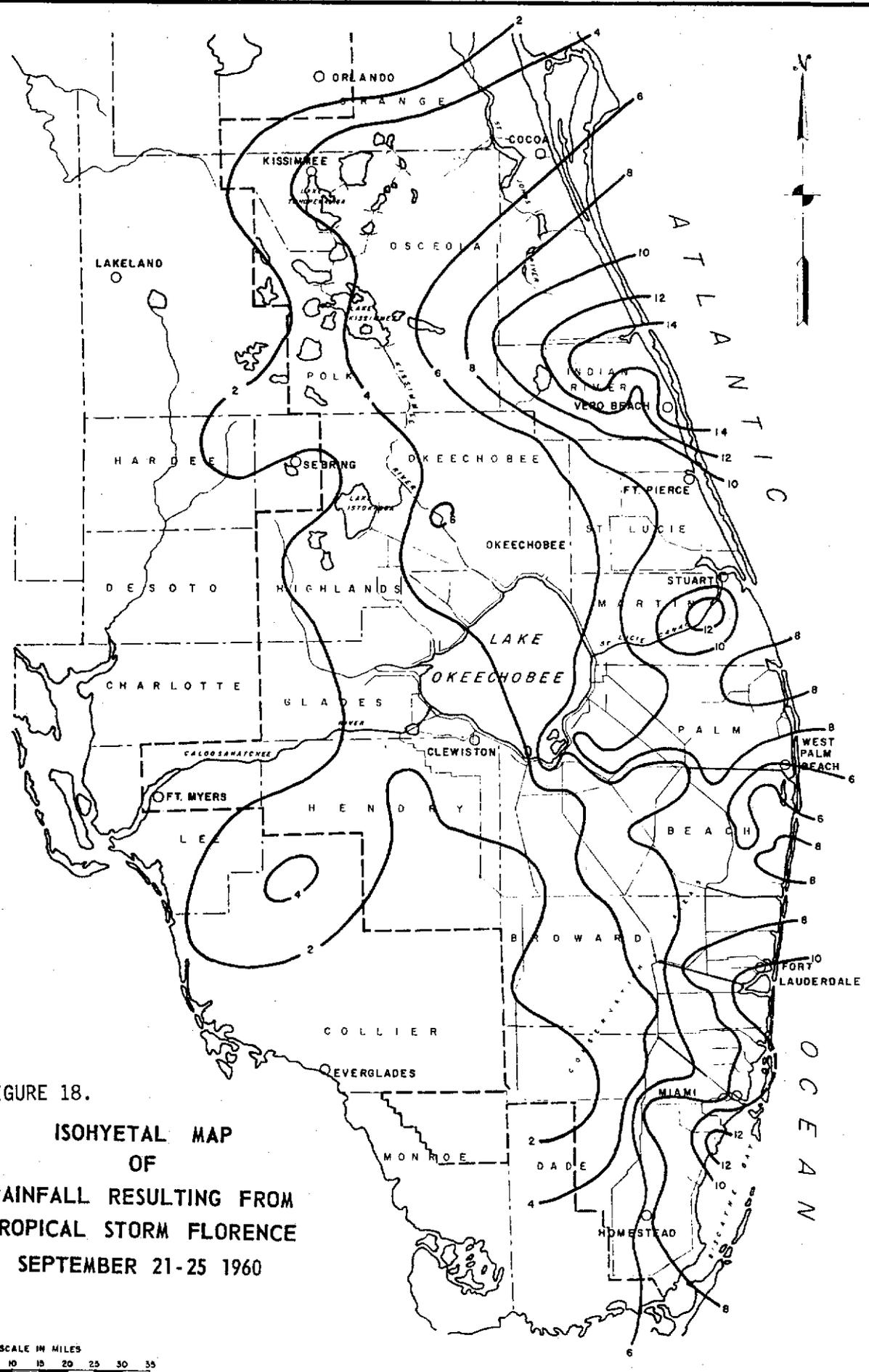


FIGURE 17.
ISOHYETAL MAP
OF
RAINFALL RESULTING FROM
HURRICANE DONNA
SEPTEMBER 9-11 1960

SCALE IN MILES
 0 5 10 15 20 25 30 35

FIGURE 18.
 ISOHYETAL MAP
 OF
 RAINFALL RESULTING FROM
 TROPICAL STORM FLORENCE
 SEPTEMBER 21-25 1960



SCALE IN MILES
 0 5 10 15 20 25 30 35

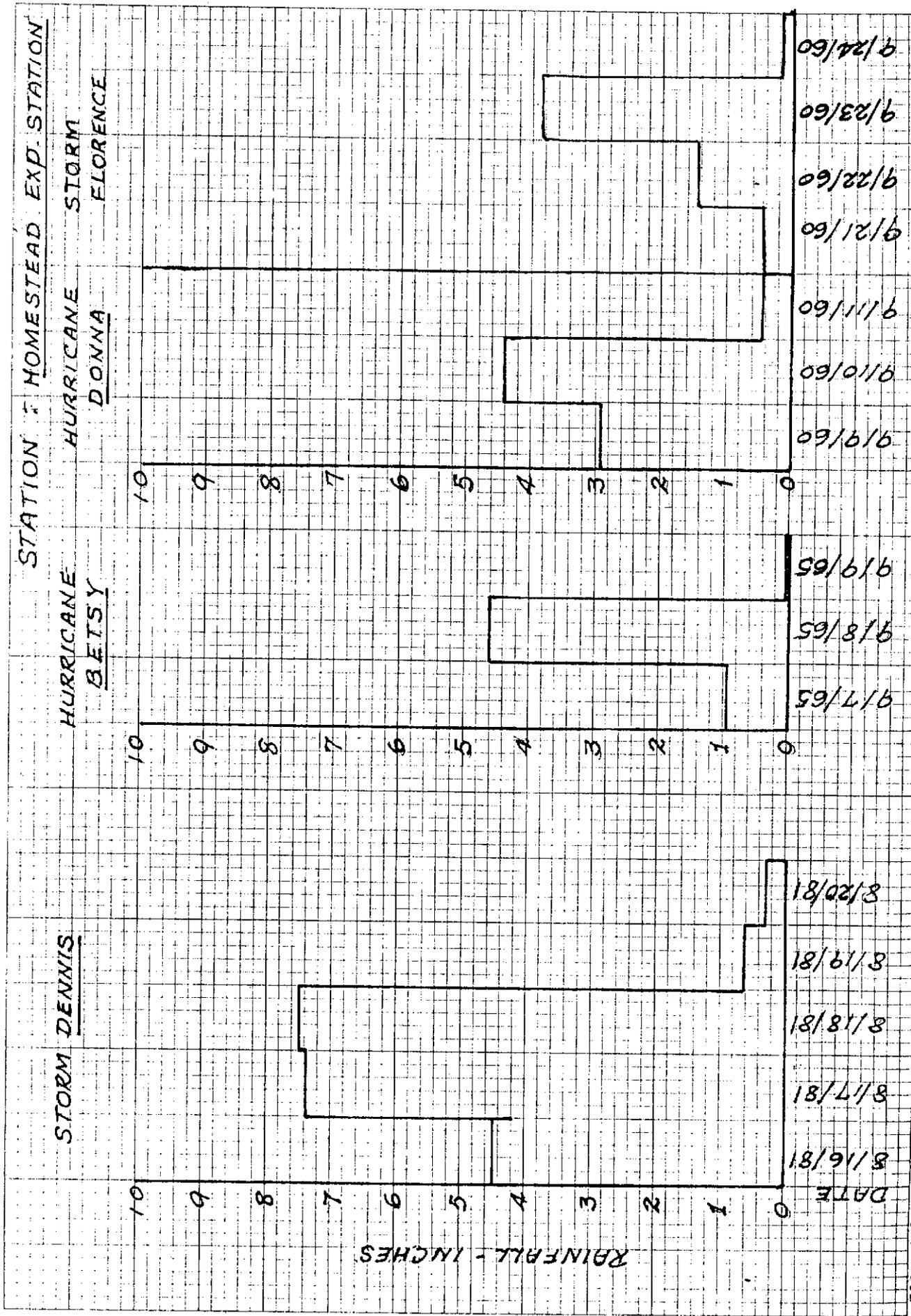


FIGURE 19 - Bar-Graph Comparisons of Rainfall Intensities of Storm Dennis and Other Storms Such As Betsy, Donna, and Florence at Homestead Experimental Station

produced by Betsy covered all of Dade County in depths ranging from 4 to 7 inches with a maximum of 10.89 inches recorded at the rainfall station near Homestead Air Force Base; 9.3 inches at Royal Palm Ranger Station; and 2.91 inches at Everglades City. The area of tidal flooding resulting from Betsy was extensive in the areas east and south of Homestead Air Force Base (a foot or so of water over many of the paved streets). The area west of US#1 was similarly flooded northward to within three miles or less of Florida City. Flooding on the upper Keys was extensive with water levels reaching several feet in depth in many areas.

In comparing Tropical Storm Dennis to the April 24-25, 1979 storm, the areas of rainfall intensities were different. The highest intensity of rainfall occurred in the area near Delray Beach (16-18 inches), Miami International Airport (12-16 inches), and Homestead (8-10 inches), while Storm Dennis produced the most rainfall in the vicinities of Homestead, Florida City, and West Kendall.

VII. Damage Estimates

Based upon the 1807 claims paid by the FEMA Claims Office, residential damages associated with Tropical Storm Dennis exceeded \$983,130.93. An additional sum of \$247,894 resulted from evacuation and road repair costs.

Agricultural damage estimates, covering August-September 1981, have been prepared by the U. S. Department of Agriculture and are presented below:

ORNAMENTAL NURSERIES: Estimated loss \$4.5 million.

FRUIT CROPS:

Avocados: While some trees are showing signs of resprouting, others are showing signs of stress. The decline and recovery pattern appears

balanced at this time. (11/20/81)

350 acres of young trees were lost - representing \$297,500. Approximately 300 acres of old trees were lost - representing \$1,500,000. Over 100,000 boxes of fruit were lost with an estimated value of \$511,200. Potential crop loss over the next 3 years, or so, is unknown. The cost of removing and disposing of dead trees by cutting and shredding will be about \$450,000. To move and transplant mature trees and restore production represents \$750,000.

Total assessment = \$3,508,700.

Limes: Approximately 1000 trees were lost - representing \$100,000.

Papayas: 175 acres lost - representing \$503,125.

Mamey: Loss to 20 acres would run about \$100,000.

VEGETABLES:

Tropical Vegetables: Production loss on 4500 acres of Boniato, Yucca, Calabaza, Malanga, etc., represents \$5,108,192.

Tomatoes: Estimated loss on 135 acres is \$494,893.

Pole Beans: On 100 acres \$234,040 was lost.

Bush Beans: 250 acres were lost - representing \$304,790.

FIELD CROPS:

Corn: 60% loss on 1045 acres totaled \$691,128.

Seed Corn: Approximately 1000 acres lost - representing \$2,760,000.

Grain Sorghum: The damage on 200 acres represents \$189,000.

Total Damage Assessment = \$18,493,868.

VIII. Summary and Conclusions

1. The passage of Tropical Storm Dennis during the week of August 16, 1981 brought local relief to a prolonged rainfall deficiency, but resulted in the most extensive flooding in south Dade since 1960. Maximum recorded rainfall (5-day) from the storm was 25.16 inches about three miles north of Homestead. Rainfall amounts in excess of 18 inches were reported over a several hundred square mile area along L-31N. More than 12 inches of rainfall were recorded in most of Dade County and in portions of Broward and Palm Beach Counties.
2. The return frequency for rainfall in the Florida City, Homestead, Tamiami Airport, West Kendall, and L-31N areas was 4 to 5 inches in excess of the 1 in 100 year storm. Rainfall in the area of the Opa Locka Airport was on the order of 1 in 100 years, as was that near the S-7 pump station.
3. Design rainfall amounts, structure discharge rates, and stages were exceeded without system failure. In some cases calculated Standard Project Flood (SPF) stages and discharges were exceeded. The capacity of the south Dade facilities to remove runoff was greatly exceeded by the rainfall and associated runoff from Tropical Storm Dennis. The system was operated and performed in accord with design. Peak stages occurred generally 12 or more hours after the structures were open.
4. Extensive flooding of agricultural, residential, and commercial property occurred in the area west to southwest of Black Creek (C-1), west of U.S.#1 in Dade County. More localized flooding occurred in the S-119 basin and West Miami areas. Localized flooding also occurred in portions of Broward and Palm Beach Counties.
5. Water levels in the water conservation areas increased from nearly dry to the regulation schedules as a result of rainfall associated with

Tropical Storm Dennis. However, rainfall amounts over Lake Okeechobee were between 1 and 5 inches, while only between 0.24 and 3.47 inches were recorded in the Kissimmee River Basin.

6. The rainfall which occurred during August and September 1981 in the south Dade area was the most intense general rainfall since the inception of the C&SF project in the area. Total rainfall in August and September was 48.88 inches at the Homestead Experimental Station and exceeded the prior 2 month maximum record.
7. The rainfall associated with Tropical Storm Dennis and subsequent late August and September storms surpassed in intensity and magnitude that of Hurricanes Betsy and Donna and Tropical Storm Florence.
8. Flood damages associated with Tropical Storm Dennis and subsequent storms were conservatively estimated at about \$20 million. Residential damages approached \$1 million, and the balance of damages was agricultural - primarily avocados and tropical vegetables.