

**REPORT OF
TROPICAL STORM BOB
JULY 22-24, 1985**

DRE-209
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**South Florida Water Management District
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Our appreciation is extended to all who worked so diligently to produce this report.

I. Description of Tropical Storm Bob

The system which became Tropical Storm Bob developed when the remnants of a weak surface trough of low pressure merged with an upper low to form a tropical depression in the southeast Gulf of Mexico on the afternoon of July 21. Despite unfavorable atmospheric conditions, the depression reached tropical storm strength on the afternoon of the 22nd, and was christened "Bob".

The storm moved eastward, reaching its maximum intensity of 50 miles per hour (mph) with gusts of 70 mph just before moving inland near Fort Myers on the morning of July 23. Figure 1 illustrates the path of tropical storm Bob. The broad, disorganized center crossed the peninsula, emerging into the Atlantic in the Stuart-Jupiter area during the late evening of the 23rd, after which it turned northward moving out of the area. The storm received a short-lived hurricane status after gaining strength over the Atlantic and producing 75 mph winds with gusts up to 92 mph.

The storm was noteworthy in that the southeast quadrant of the storm was very wet, while the northern half was virtually rain-free. This was due to the fact that the storm's low level inflow was confined to the southern section off the Gulf of Mexico. The southern section was the area of strongest convergence in the storm, and consequently had the most rain. Rather strong high level winds from the northwest also contributed to keeping the majority of the convection on the south side of the center.

In addition to the asymmetry of the rainfall pattern, Bob was also rather unusual for the track it followed (refer to Figure 2). In nearly 100 years of data, no storms have been observed to move eastward across

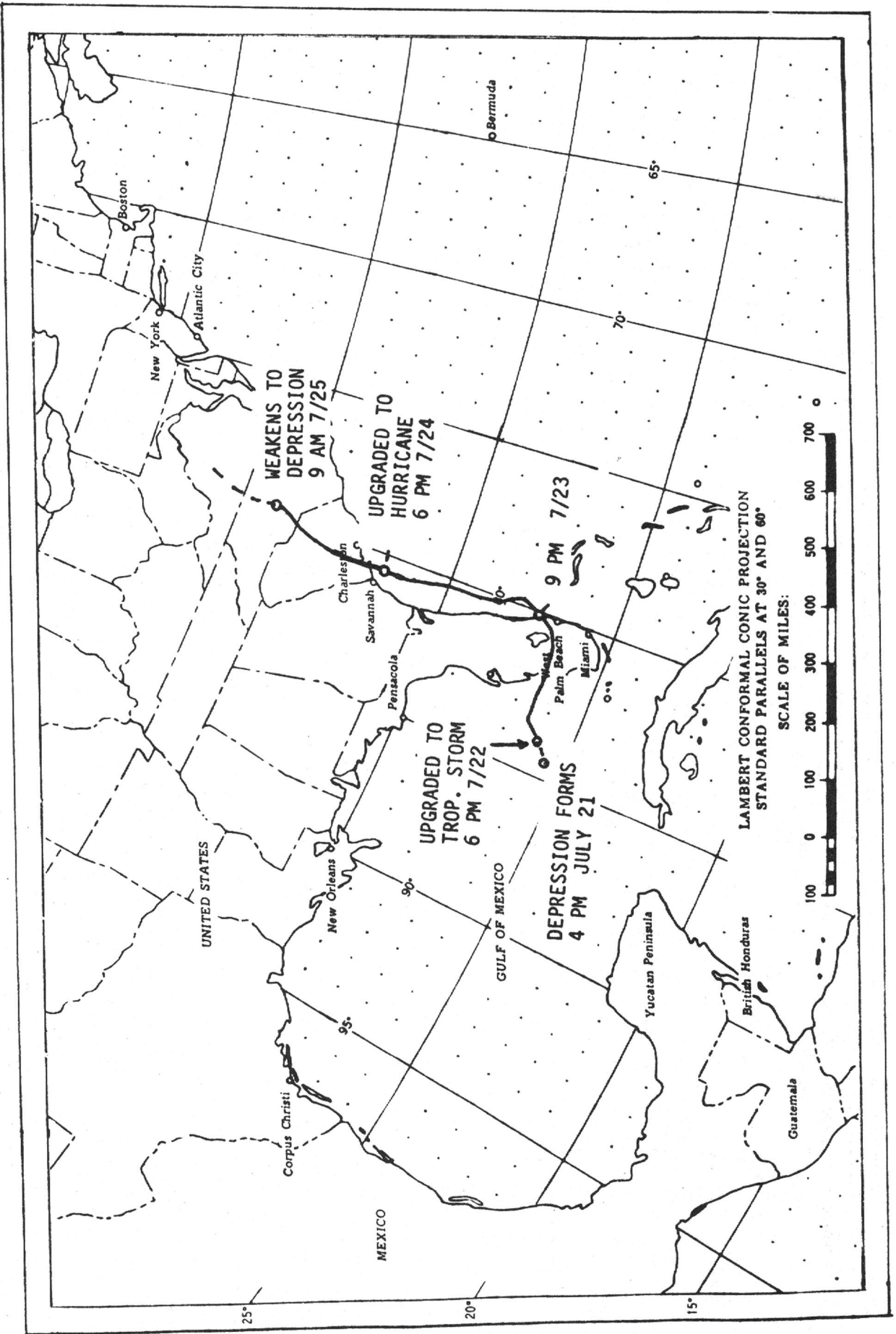
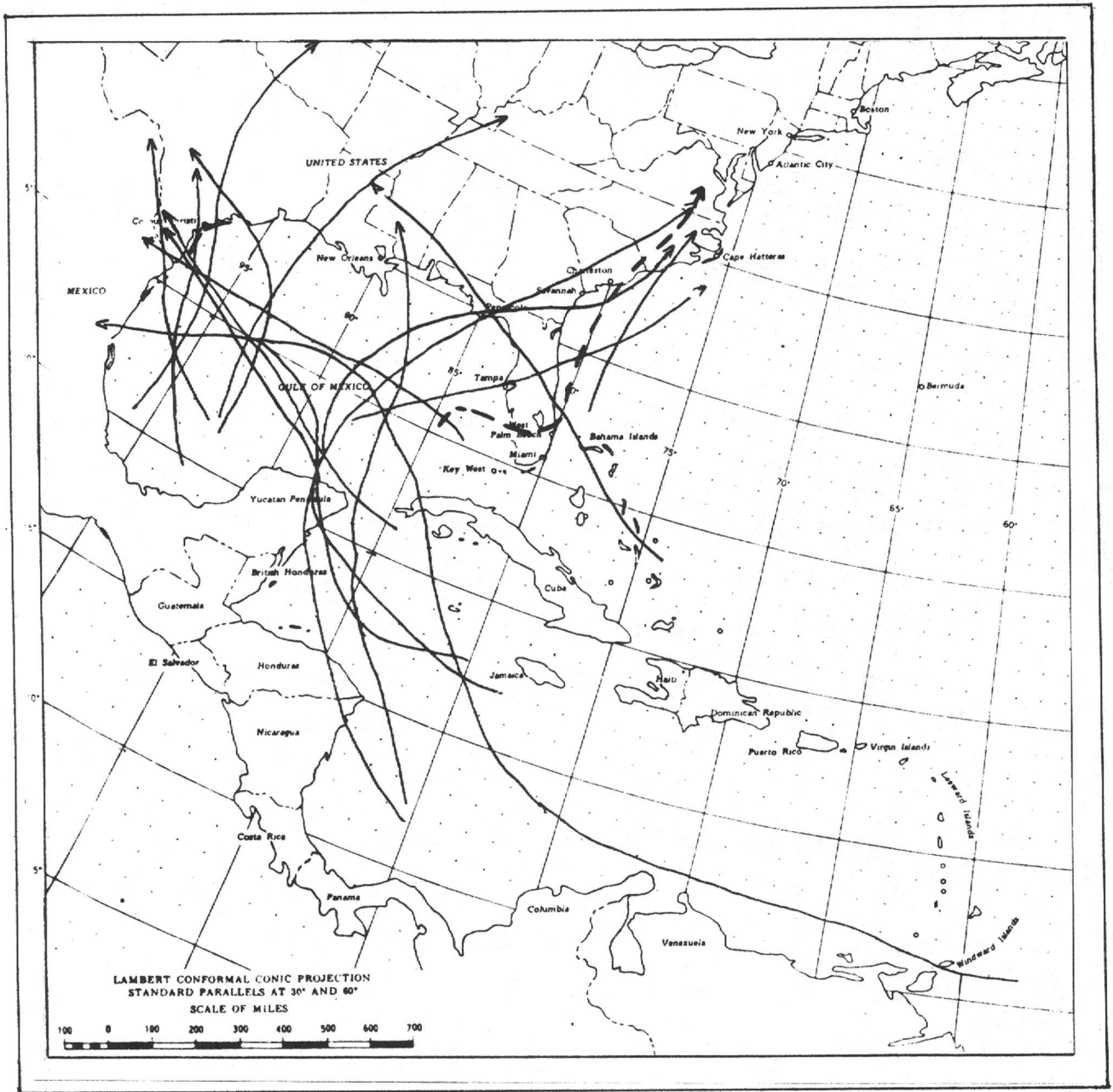


FIGURE 1. PATH OF TROPICAL STORM BOB (1985)



——— TROPICAL CYCLONES FORMED BETWEEN
 JULY 21 AND JULY 31 (1886-1984)
 - - - TROPICAL STORM BOB (1985)

FIGURE 2. TROPICAL CYCLONES FORMED BETWEEN JULY 21 AND JULY 31

south Florida in late July; a motion far more common in very early season or very late season storms. The motion was due to a temporary suppression of the Atlantic high far enough south to allow upper level westerlies to develop across south Florida. In fact, this invasion of the westerlies was the major mechanism responsible for initiating the disturbance which eventually became Tropical Storm Bob, and also was a factor in the storm's unusual structure.

Tropical Storm Bob's intense rains and gusting winds affected the southwest coast of Florida the most. Many of the areas from Fort Myers to Everglades City reported flooded streets, downed power lines, and closed businesses. The most common property damage reports were limited to screened porches, car ports, and roofs.

The Sanibel Island causeway was closed for four hours during the storm due to heavy rain and winds gusting up to 60-65 mph. Extensive street flooding and an estimated \$250,000 damage to the Sanibel Arms West condominiums were also reported.

In Naples, heavy rain and 65-70 mph winds resulted in widespread flooding and some sunken boats. Two pilings of the Naples pier were washed out by the surf. After the storm, the Florida Marine Patrol monitored erosion along the Gulf Coast and reported that damage was the worst in Naples and on Lido Beach in Sarasota. Sanibel, Captiva, and Marco Islands, as well as Bonita Beach also reported varying degrees of beach erosion.

Much of Marco Island was covered with a foot of water after 10.5 inches of rain fell in the area. Water was also reportedly lapping at the steps of the city hall in Everglades City. Fort Myers Beach reported 3 feet above-normal tides.

Palm Beach and Broward Counties received heavy rainfall and 40-50 mph winds. Many streets were flooded, but there were no reports of flooded homes. Gusting winds at the Butler Aviation compound at Palm Beach International Airport overturned three small planes. Florida Power and Light representatives estimated that 75,000 customers were temporarily without power.

Thunderstorms with high winds dropped several inches of rain and caused power failures in the Miami area. Two confirmed tornadoes were sighted in the Miami-Fort Lauderdale area, but did little damage. Eight Miami families received emergency shelter after the roof of their apartment building collapsed from the rain. Beach erosion at Miami Beach and Key Biscayne was severe enough that renourishment may be required.

Tropical Storm Bob caused minimal damage compared to the June 1982 unnamed storm that hit the southwest coast (causing at least \$100,000 damage in Collier County and \$3 million damage in Lee County, mostly to condominiums along Bonita Beach).

The storm brought local relief to some of the areas of south Florida which had been experiencing a severe rainfall deficiency, although most of south Florida continued to have below-normal rainfall for the year.

II. Rainfall Characteristics

A. Distribution

The poorly-defined center of Tropical Storm Bob passed over the west coast of Florida during the early morning hours of July 23 and reached the Atlantic Ocean by that evening. Rainfall associated with the storm lasted through parts of July 24 for some areas of Florida's east coast. The daily rainfall readings for the storm event were taken at various stations throughout south Florida.

Figure 3 illustrates the locations of the rainfall stations that were used in this report. The daily rainfall values recorded at these stations were used in developing Figures 4, 5, and 6, and are tabulated in Appendix B.

Figure 4 shows the isohyetal map of the total three-day rainfall accumulated from July 22 to July 24. Collier and Monroe Counties received the highest rainfall amounts ranging between 2 and 20 inches during this period. The highest three-day total of 21.5 inches was recorded at the rainfall station near Everglades City (MRF6048). Rainfall station MRF370 in Royal Hammock State Park recorded 15.3 inches during the storm. Hendry County received between 1 and 4 inches, while Palm Beach County received from 1 to 6 inches. The highest rainfall amounts along the east coast occurred between the areas surrounding Boca Raton and Fort Lauderdale. These areas received 4 to 6 inches with a maximum of 7.8 inches recorded at Lake Worth station MRF213. Dade County received between 2 and 4 inches. Areas north of Lake Okeechobee received the lowest rainfall amounts--ranging from 0 to 2 inches. Martin and St. Lucie Counties

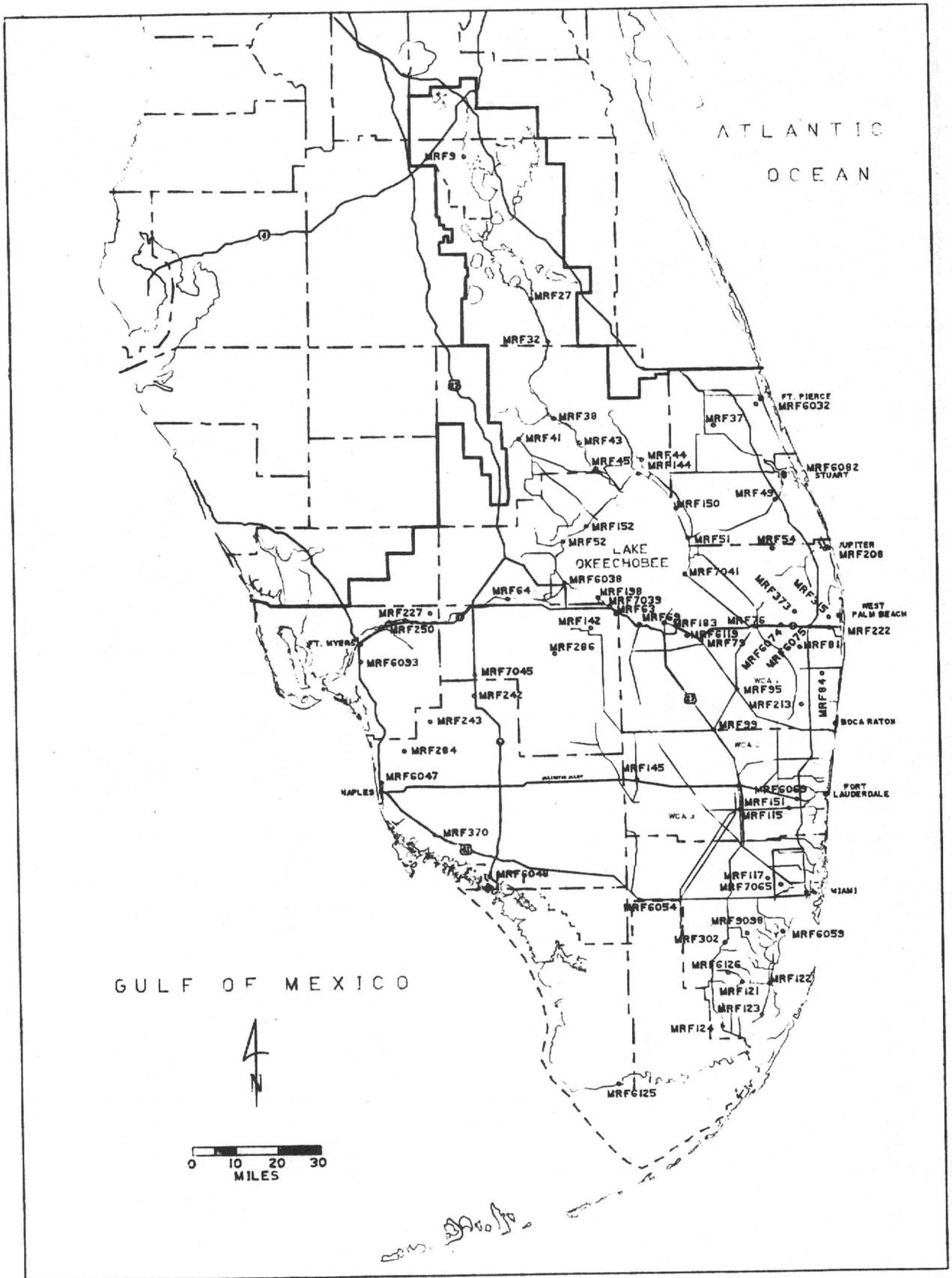


FIGURE 3 LOCATION MAP FOR RAINFALL GAGES

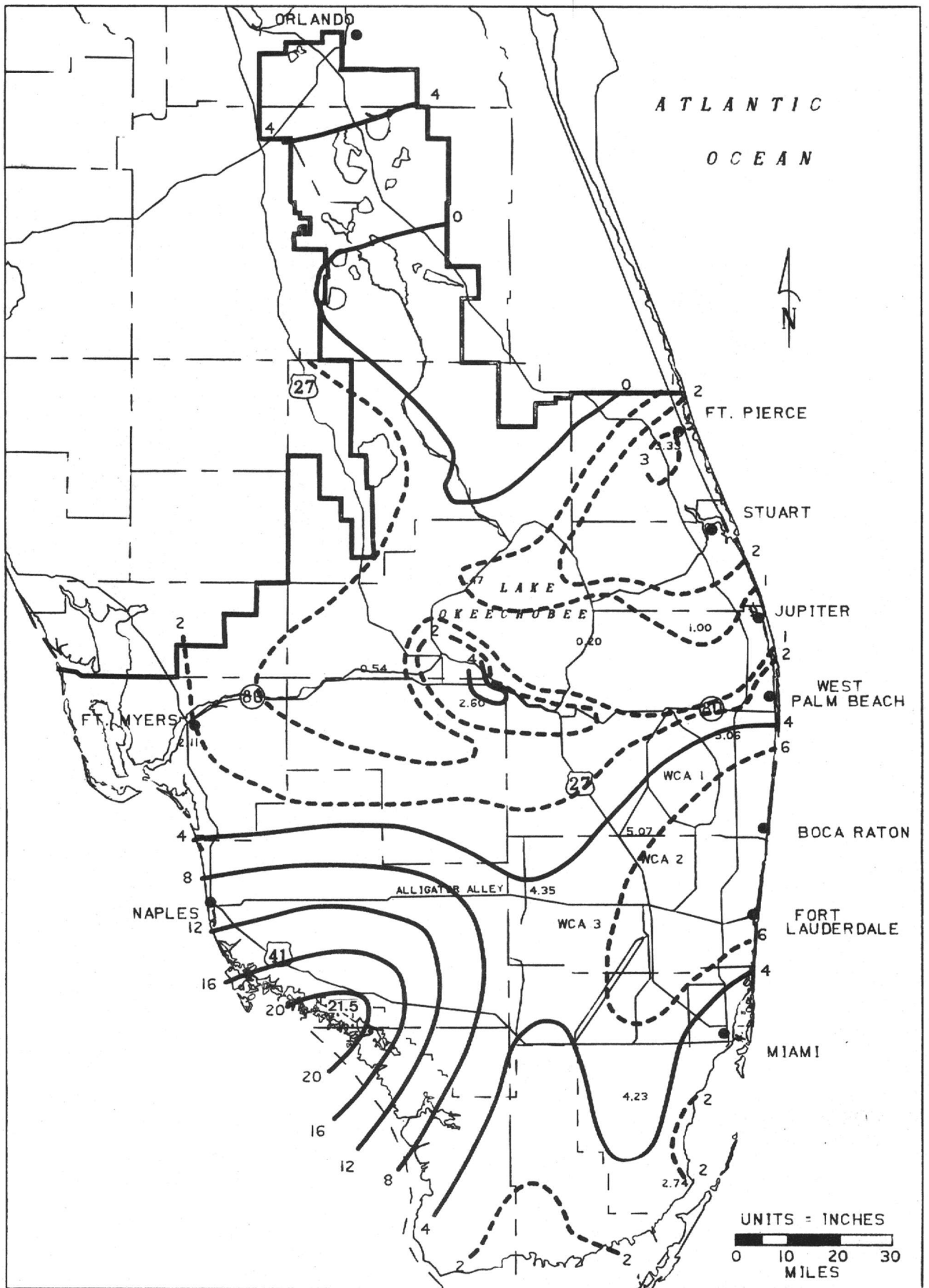


FIGURE 4. TOTAL THREE-DAY RAINFALL DURING TROPICAL STORM BOB (JULY 22-24, 1985)

received about 2 inches, with a small area near Fort Pierce receiving 3 inches.

Since it is difficult to accurately estimate daily rainfall distribution over a large area due to the fact that reading times for the gages vary, isohyetal maps of one-day and two-day maximum rainfall were constructed. Figure 5 illustrates the maximum recorded one-day rainfall that occurred between July 22 and July 24. The largest one-day maximum rainfall amount was 14.5 inches which was recorded near Everglades City on July 22. Figure 6 shows the maximum recorded two-day rainfall that occurred between July 22 and July 24. The largest two-day maximum rainfall was 21.5 inches which was also recorded near Everglades City between July 22 and July 23. Figures 5 and 6 resemble Figure 4 with respect to the areal distribution of the storm. These isohyetal maps all illustrate that the lower west coast received the largest rainfall amounts during the storm. The return periods associated with the maximum one- and two-day rainfall amounts for various locations are discussed at the end of this section.

The occurrence of Tropical Storm Bob brought many areas of south Florida from a monthly rainfall deficiency to a monthly surplus; however, some areas remained below the normal July totals. Figure 7 shows the isohyetal map of total rainfall for July 1985. Figure 8 illustrates the isohyetal map of the normal July rainfall. Comparison of these two figures indicates that most of the areas south of Lake Okeechobee received rainfall in excess of normal. Some areas of northwest Palm Beach County and central Hendry County received near-normal rainfall; while most of the areas

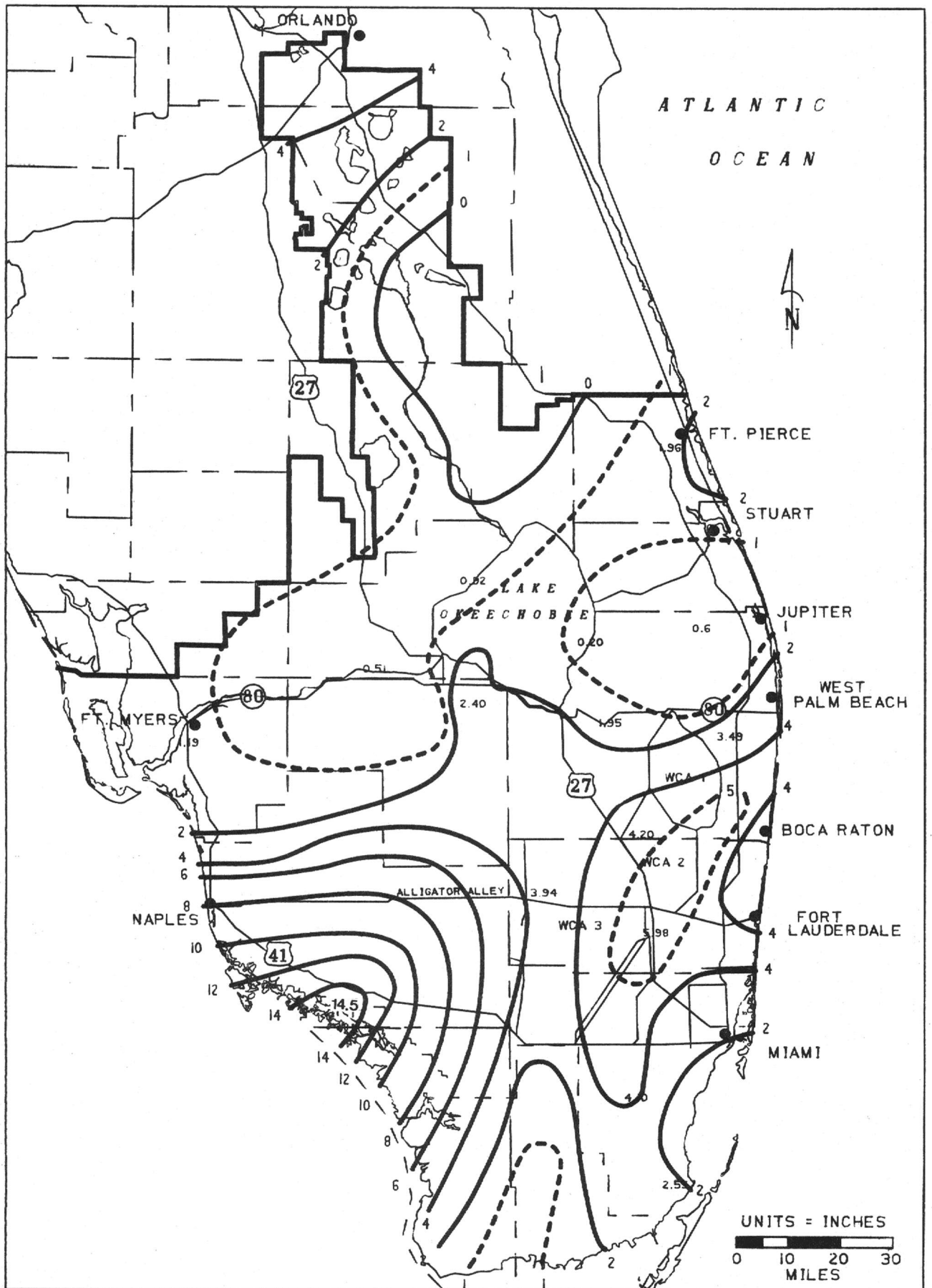


FIGURE 5. MAXIMUM RECORDED ONE-DAY RAINFALL DURING TROPICAL STORM BOB

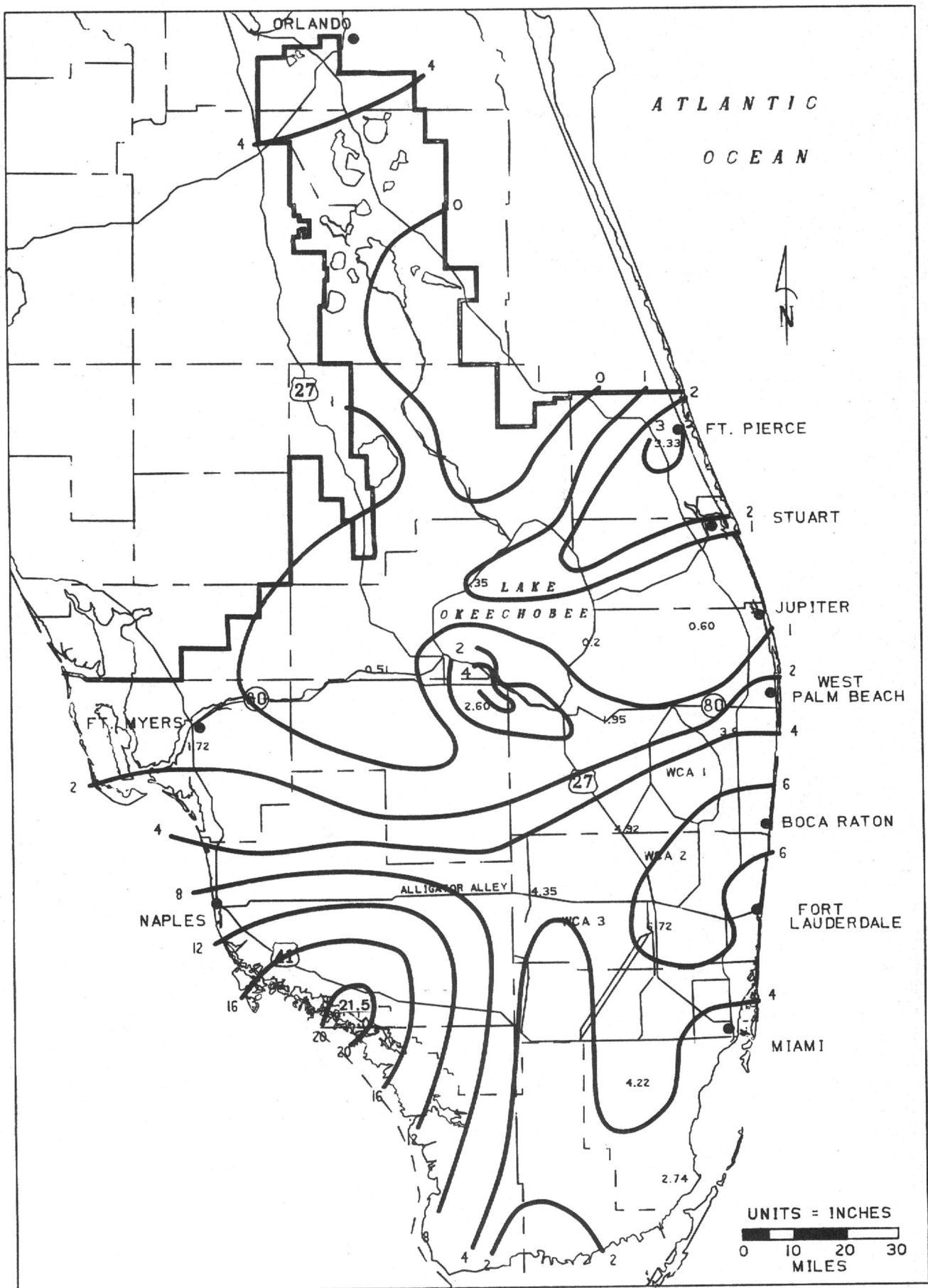


FIGURE 6. MAXIMUM RECORDED TWO-DAY RAINFALL DURING TROPICAL STORM BOB

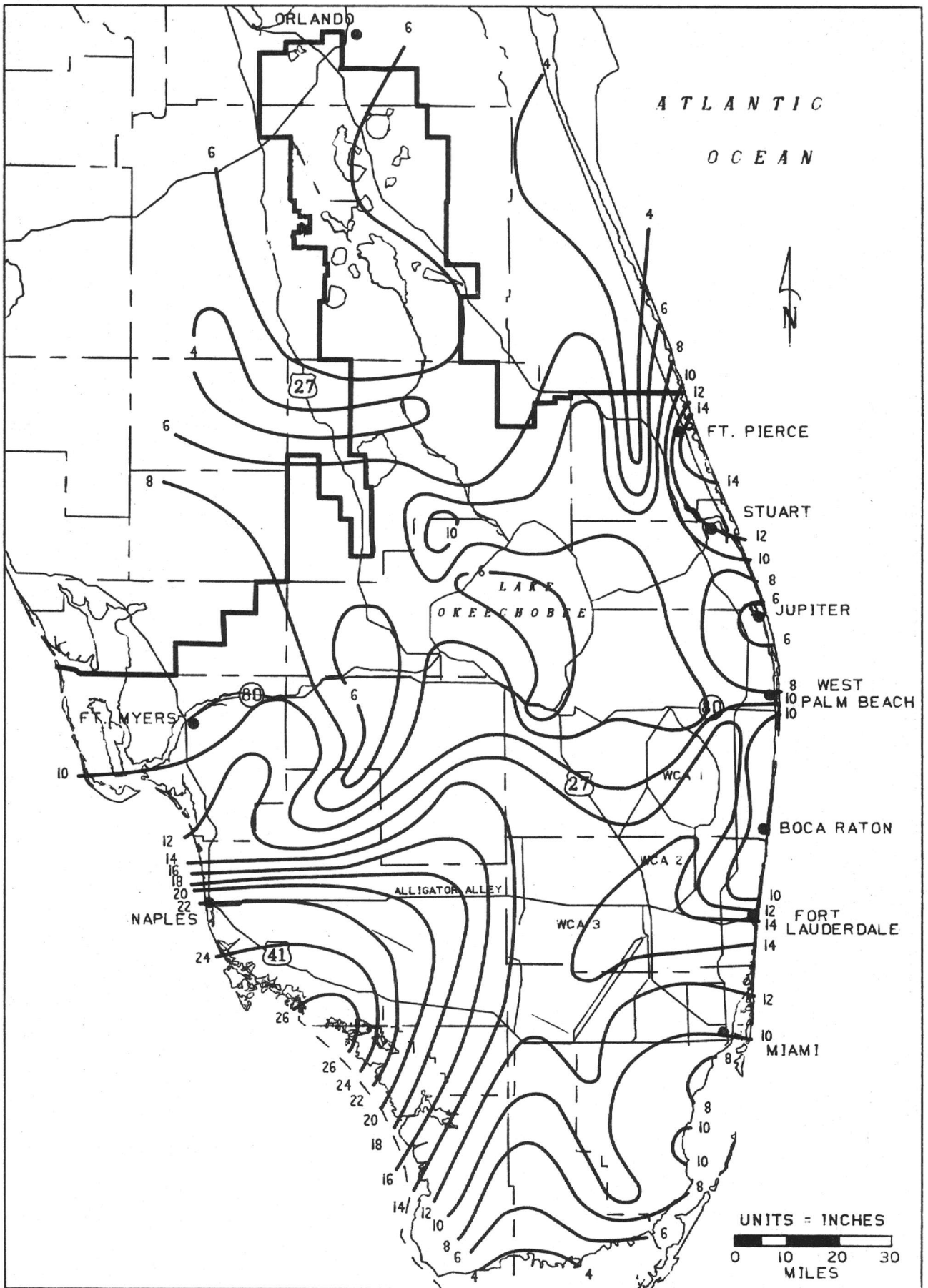


FIGURE 7. ISOHYETAL MAP OF TOTAL RAINFALL (JULY, 1985)

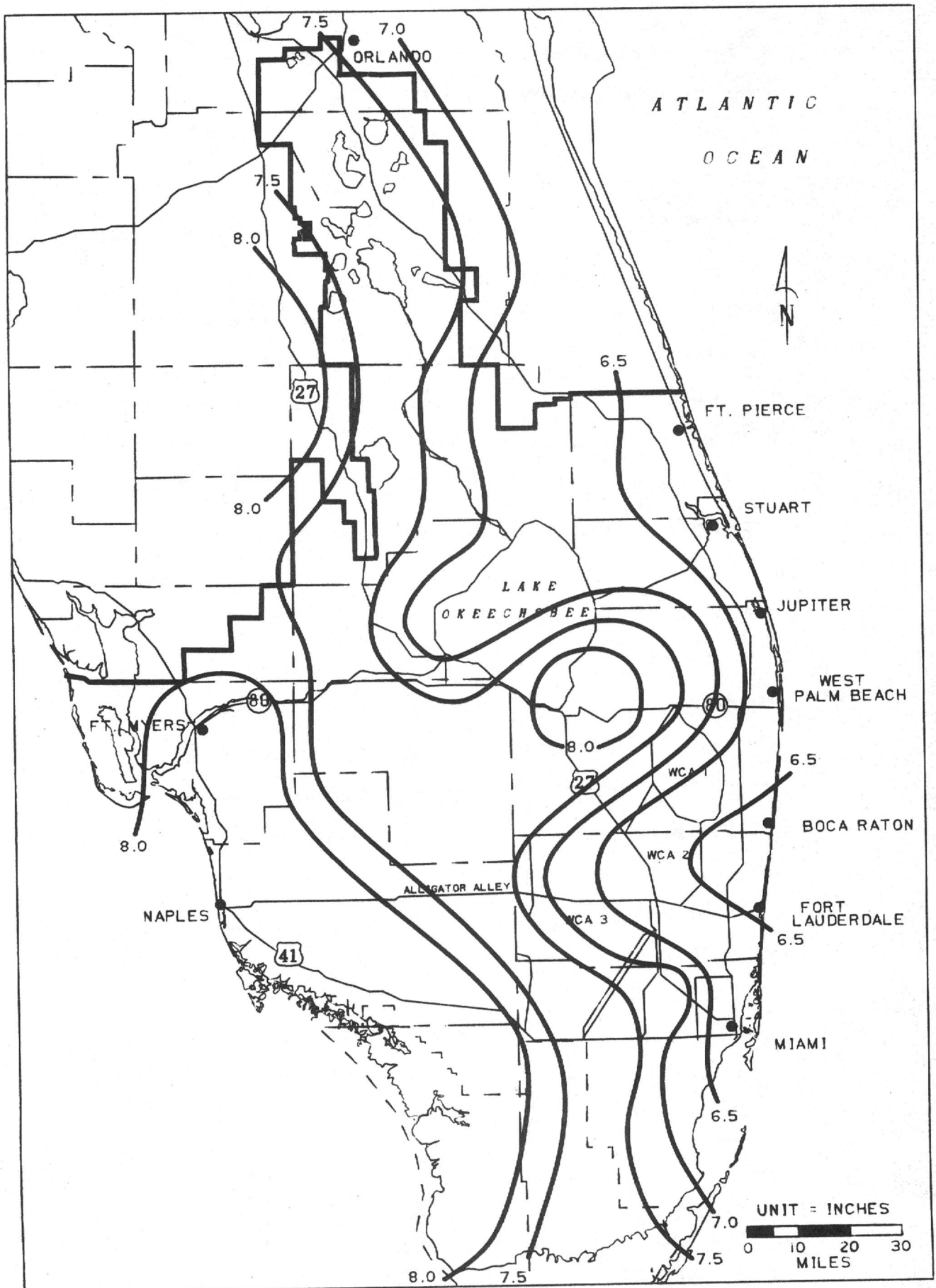


FIGURE 8. NORMAL RAINFALL (JULY)

north of Lake Okeechobee had below-normal July rainfall. These areas received little or no rainfall from Tropical Storm Bob.

Figure 15 illustrates the contribution that Tropical Storm Bob made to the cumulative 1985 rainfall. Rainfall in excess of 10 inches at Naples raised the cumulative rainfall to about 4 inches above normal. Precipitation at S-6 near Water Conservation Area 1 brought the cumulative rainfall to near-normal levels; however, the precipitation at S-131 on the northwestern shore of Lake Okeechobee was minimal, providing little relief to the existing rainfall deficiency in the area.

Figures 9, 10, 11, and 12 illustrate the hourly rainfall distributions (hyetographs) for areas near Naples, Homestead, WCA-3, and Lake Okeechobee, respectively. These areas were selected in order to illustrate the hourly distribution of Tropical Storm Bob for different locations in south Florida. Comparison of Figure 9 with Figures 10, 11, and 12 shows that the area near Naples received more rainfall than the Homestead, WCA-3A, and Lake Okeechobee areas. Comparison of Figure 11 with Figure 12 shows that the areas near WCA-3A received much more rainfall than the areas surrounding Lake Okeechobee.

Table 1 lists the maximum hourly rainfall intensities for the Naples, Homestead, WCA-3A, and Lake Okeechobee areas.

LOCATION: ROYAL HAMMOCK STATE PARK

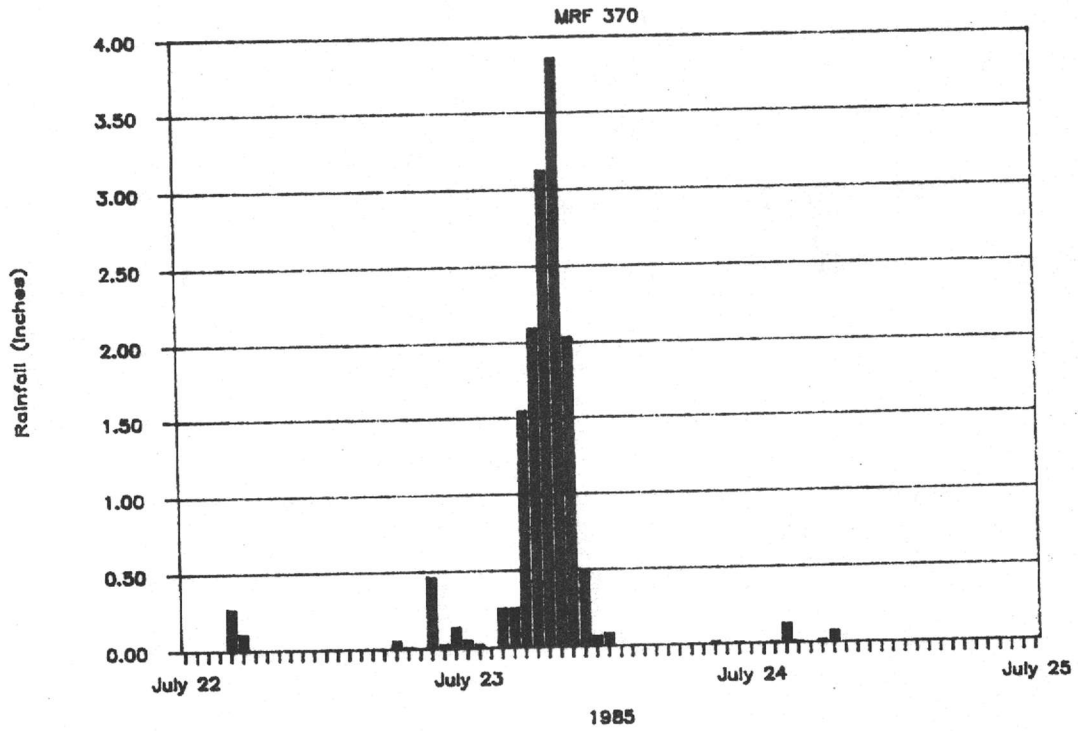


FIGURE 9. HOURLY RAINFALL DISTRIBUTION NEAR NAPLES

LOCATION: S-332

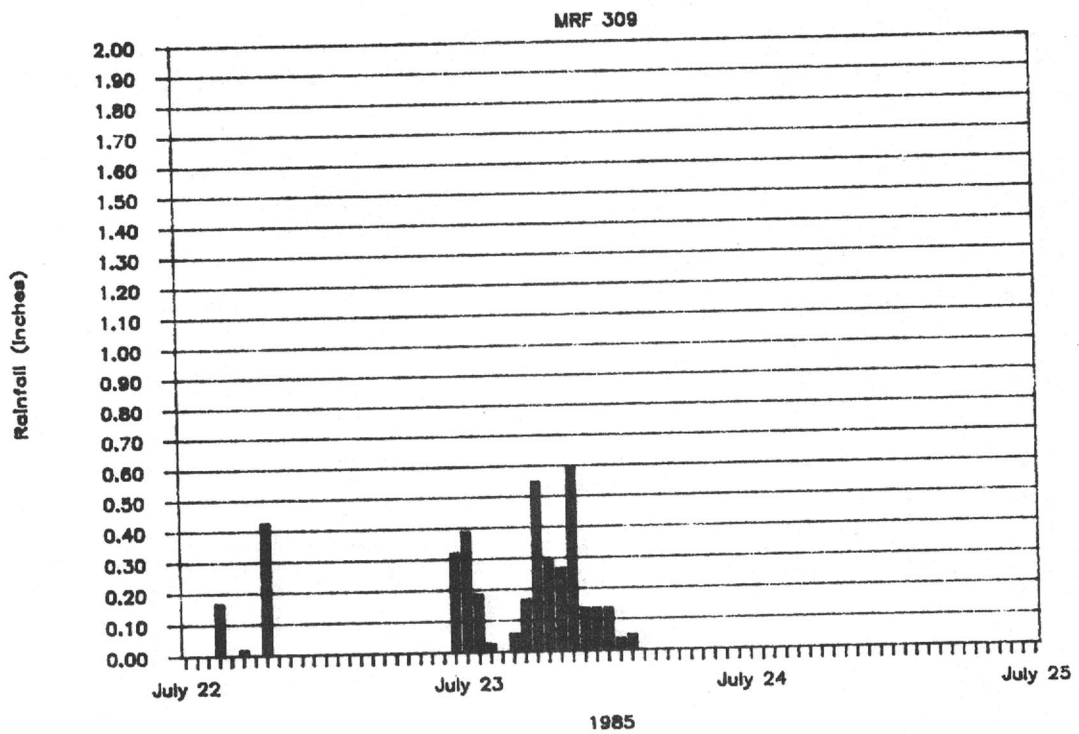
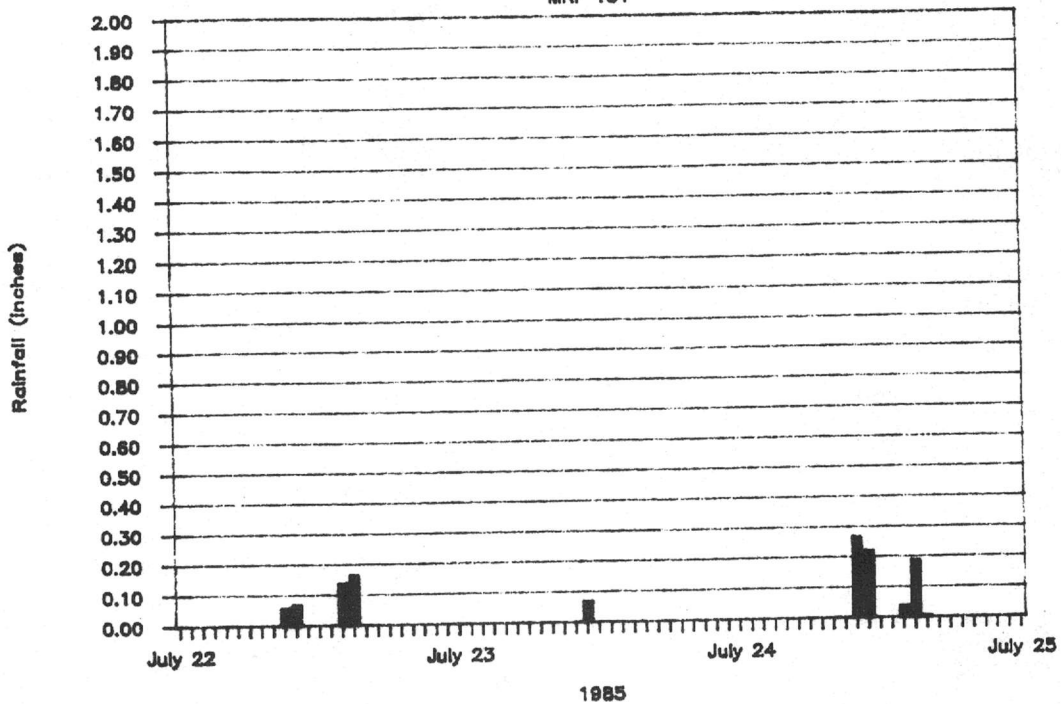


FIGURE 10. HOURLY RAINFALL DISTRIBUTION NEAR HOMESTEAD

LOCATION: PELICAN LAKE

MRF 131



LOCATION: S-131

MRF 52

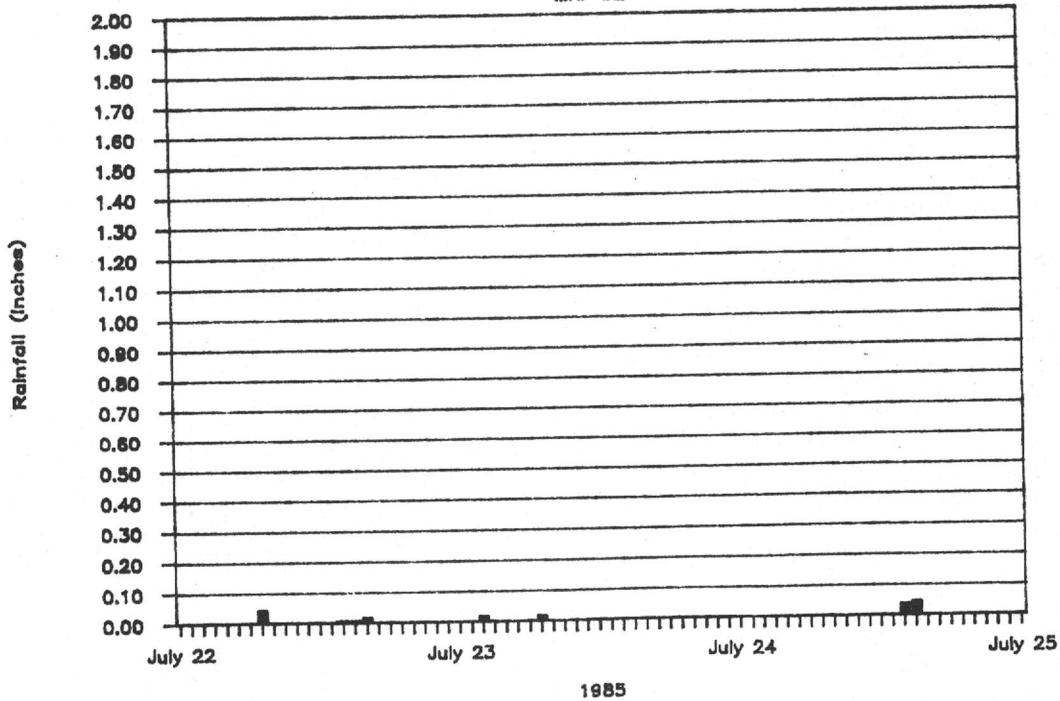


FIGURE 12. HOURLY RAINFALL DISTRIBUTION NEAR LAKE OKEECHOBEE

Table 1. Maximum Hourly Rainfall Intensities
at Selected Stations

<u>Location</u>	<u>Most Intensive Time and Date</u>	<u>Rainfall Intensity (in/hr)</u>
<u>Near Naples</u>		
Royal Hammock State Park (MRF370)	8 a.m.-9 a.m., July 23	3.86*
<u>Near Homestead</u>		
S-332 (MRF309)	9 a.m.-10 a.m., July 23	0.60
<u>Near WCA-3A</u>		
WCA 3-36 (MRF106)	Noon-1 p.m., July 23	0.69
S-9 (MRF115)	1 p.m.-2 p.m., July 23	1.94
S-140 (MRF145)	1 p.m.-2 p.m., July 23	0.75
<u>Near Lake Okeechobee</u>		
Pelican Lake (MRF131)	10 a.m.-11 a.m., July 24	0.27
S-131 (MRF52)		0.05

*MRF6048 near Everglades City is not an hourly station, but the magnitude of the daily values indicate that the hourly rainfall intensity at that station might equal or exceed the intensities recorded at the Royal Hammock State Park.

The temporal distribution of the storm can be seen by noting that the higher rainfall intensities occurred at different times. Comparing the maximum intensity near Royal Hammock State Park with the maximum intensities of the other stations indicates that the area near Naples received the most intense part of the storm 1 to 4 hours before the areas near Homestead and WCA-3A, respectively. Comparing the maximum intensity near Homestead to those of WCA 3-36, S-9, and S-140 shows that the Homestead area felt the most intense part of the storm about 3 hours before the area near WCA-3A.

B. Return Period Estimation

As stated previously, the coastal areas of Collier and Monroe Counties received the greatest amounts of rainfall from Tropical Storm Bob. The reader may feel more comfortable expressing these large amounts in terms of their return period (i.e., the n-year rainfall). For example, the 100-year rainfall is defined as the rainfall that is equalled or exceeded on the average once in 100 years. Using District Technical Publication 81-3, "Frequency Analysis of Rainfall for Central and Southern Florida", return periods for various locations were determined for 1-day and 2-day maximum rainfall amounts. The 14.5 inches recorded at Everglades City in one day has a return period greater than 100 years. The two-day rainfall of 21.5 inches recorded at Everglades City also has a return period greater than 100 years. (The one- and two-day, 100-year rainfall amounts at Everglades City are approximately 11 and 16 inches, respectively.)

Figures 13 and 14 illustrate the return periods for the maximum one- and two- day rainfall resulting from Tropical Storm Bob.

The maximum one- and two-day rainfall amounts exceeded the 100-year events in parts of Collier and Monroe Counties surrounding Everglades City. They did not, however, exceed the 2-year events outside Collier and Monroe Counties, with the exception of the Water Conservation Areas. Portions of WCA-2A experienced a 3-year event.

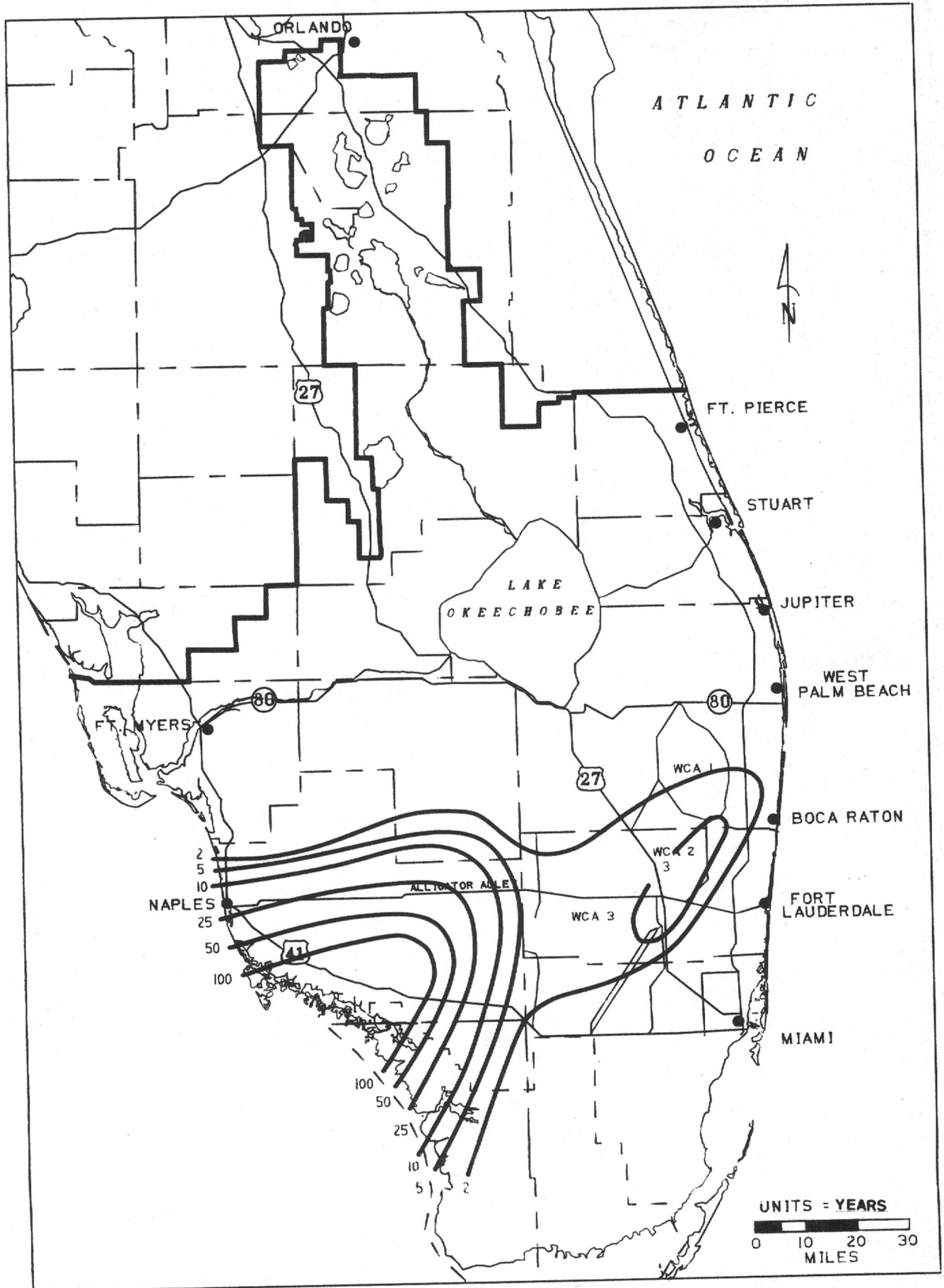


FIGURE 13. MAXIMUM ONE-DAY STORM RETURN PERIODS

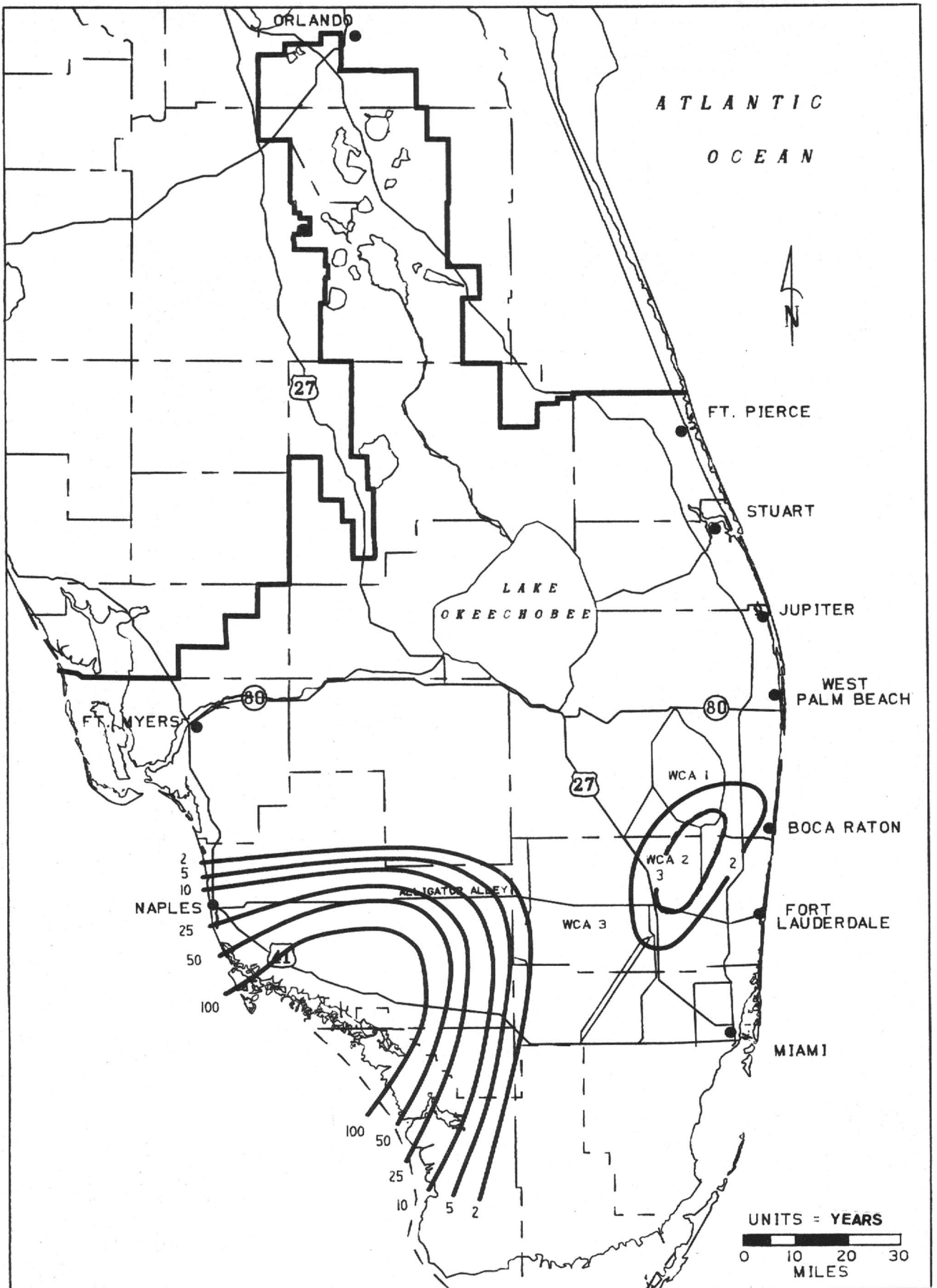


FIGURE 14. MAXIMUM TWO-DAY STORM RETURN PERIODS

III. Antecedent Conditions

A. Rainfall

Most of the SFWMD areas had received below-normal rainfall in 1985 prior to Tropical Storm Bob. Phase I restrictions were imposed in Lee and Collier Counties in early June primarily due to the regional rainfall deficiency. Figure 15 shows 1985 cumulative monthly rainfall for three locations in the District compared with their respective historical average values. These average values are site-specific and contain at least 20 years of record. From Figure 15 Naples, S-6 (near WCA-1), and S-131 (on the northwest shore of Lake Okeechobee) all had received below-normal rainfall prior to Tropical Storm Bob, with deficiencies ranging from 4 to 7 inches.

B. Canal Stages

Figures 16 and 17 show daily stage hydrographs at four selected sites from July 1 to July 21, reflecting conditions prior to the tropical storm. Also shown are the optimum stage for S-197 and the automatic settings for S-18C. The reader is referred to the maps in Figures 21-23 to locate these and all other structures referenced in this report.

C. Groundwater Stages

Figure 18 shows the location map for the surficial aquifer groundwater wells that are referenced in this section. Figures 19 and 20 illustrate the groundwater levels before and after the storm for selected wells in Lee, Collier, Palm Beach, and Broward Counties. The before-and after-storm reading dates for the wells in

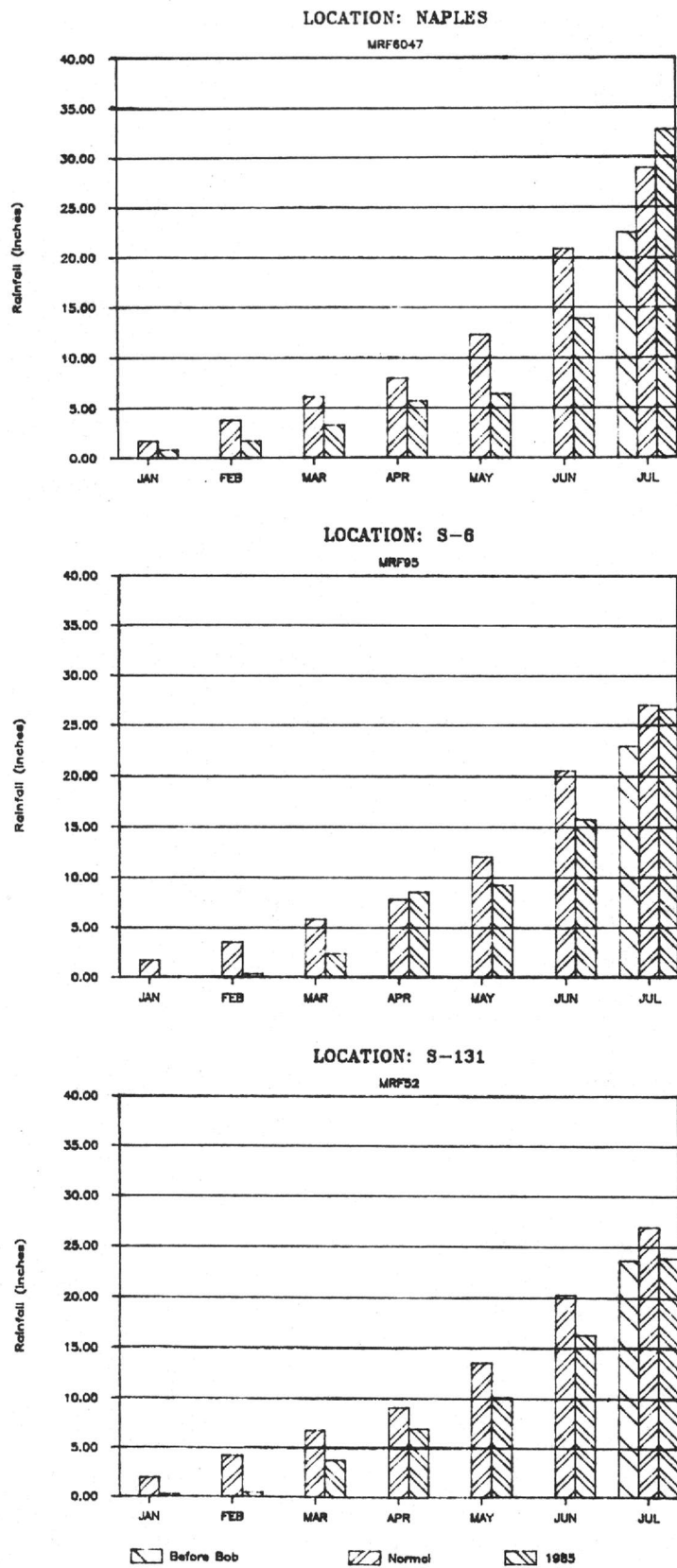


FIGURE 15. CUMULATIVE MONTHLY RAINFALL FOR SELECTED LOCATIONS

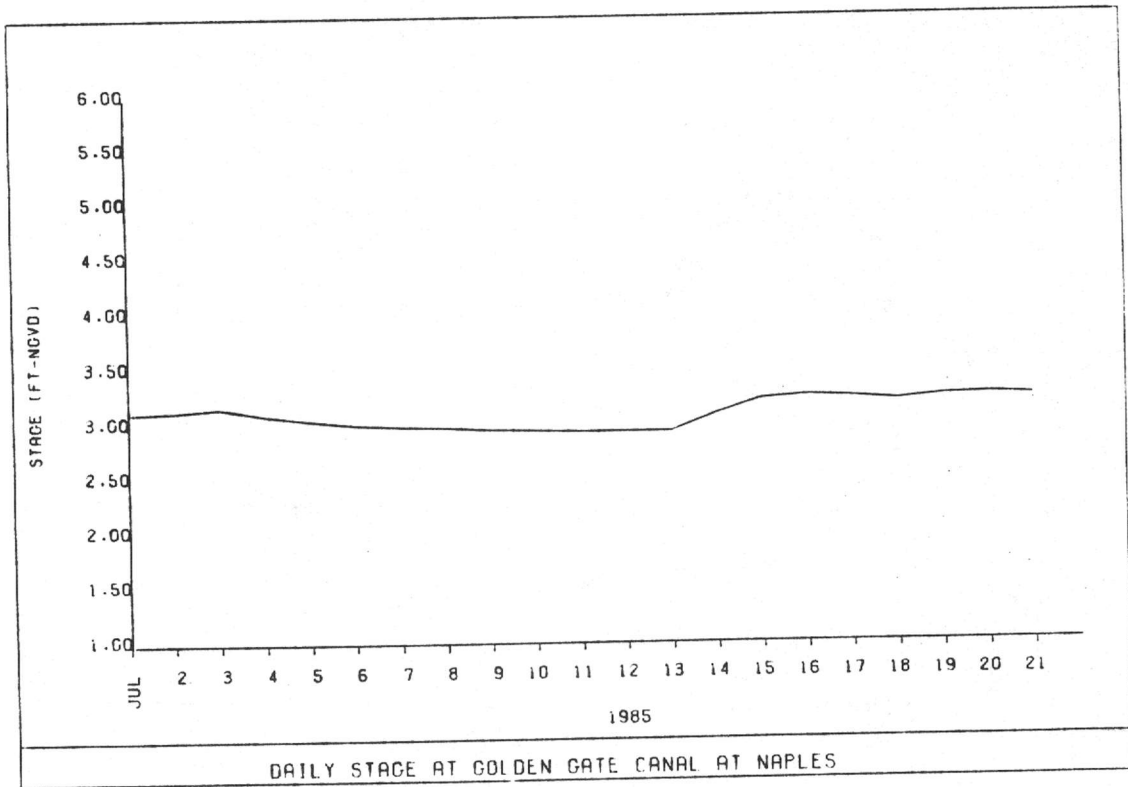
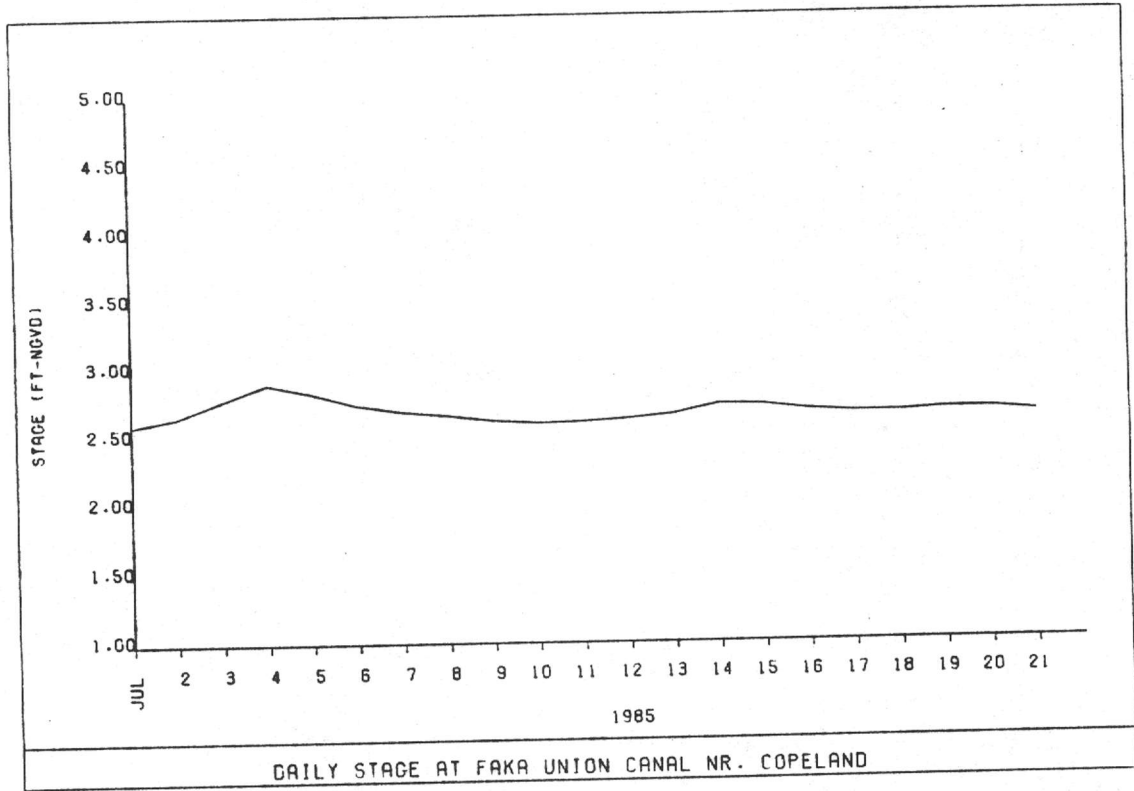


FIGURE 16. DAILY STAGE AT FAKA UNION AND GOLDEN GATE PRIOR TO TROPICAL STORM BOB

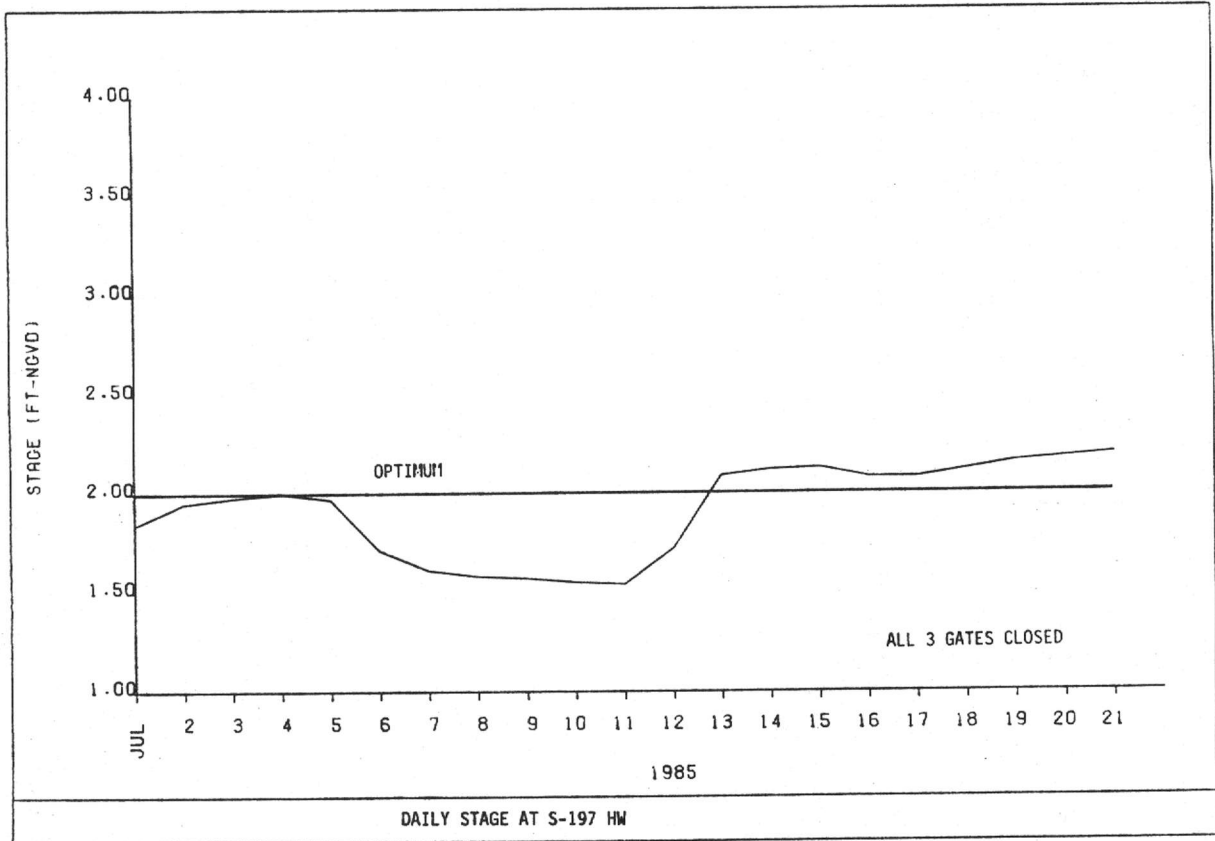
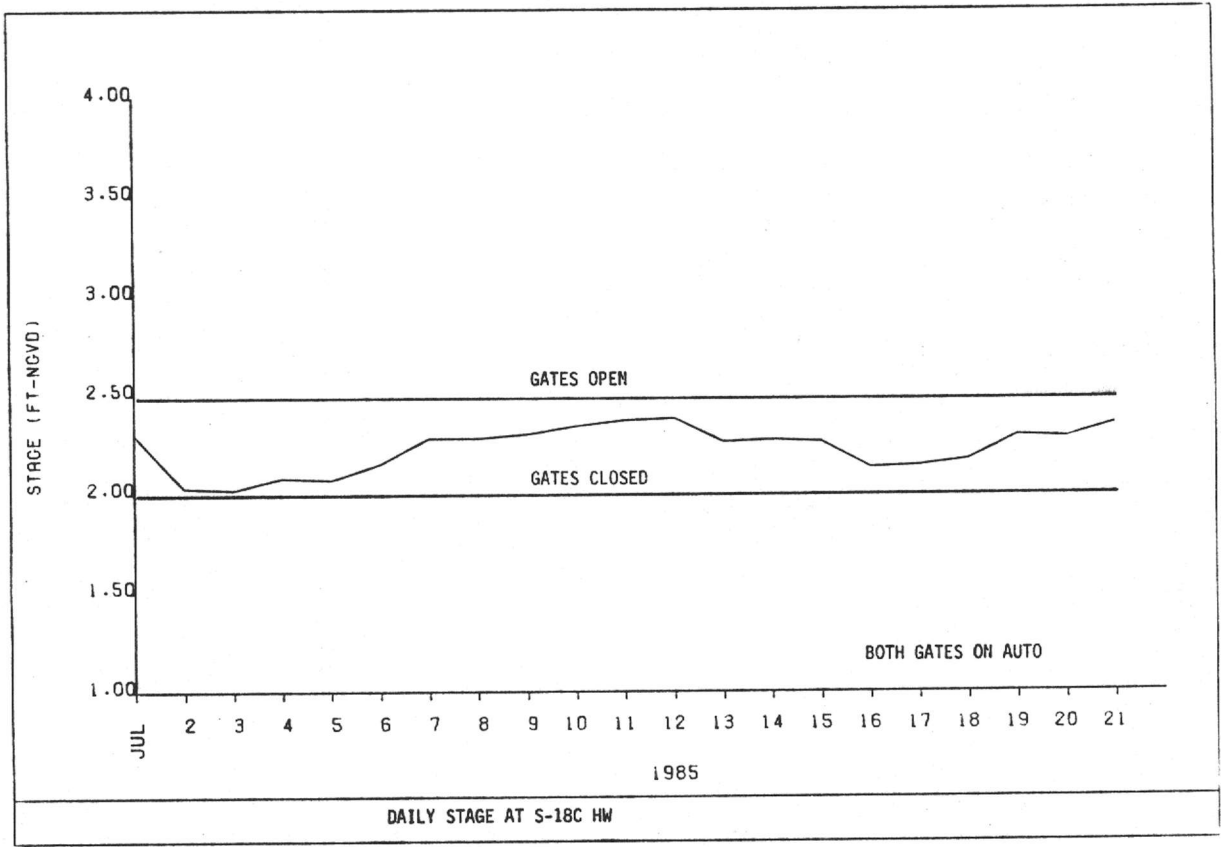


FIGURE 17. DAILY STAGE AT S-18C AND S-197 PRIOR TO TROPICAL STORM BOB

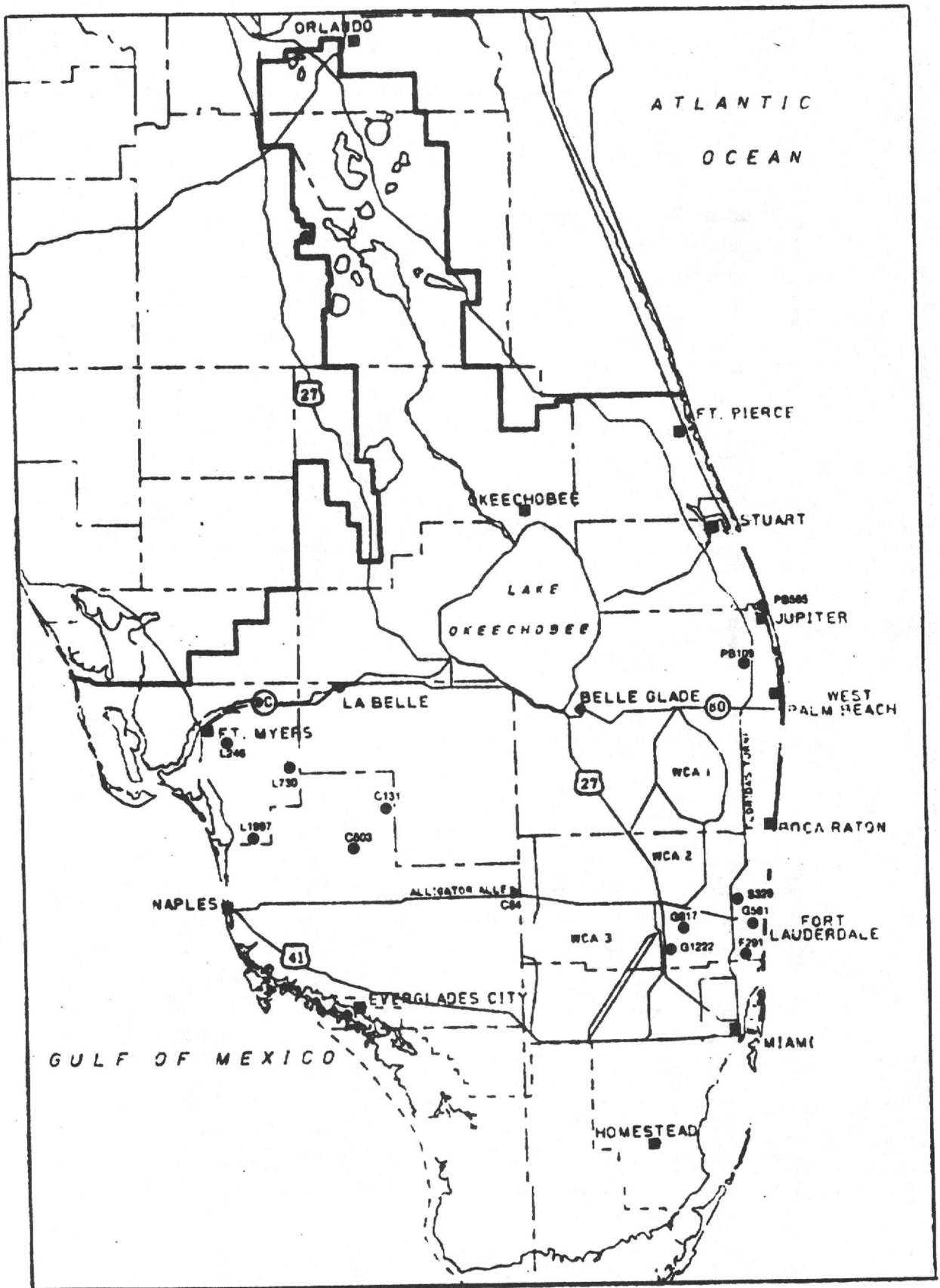
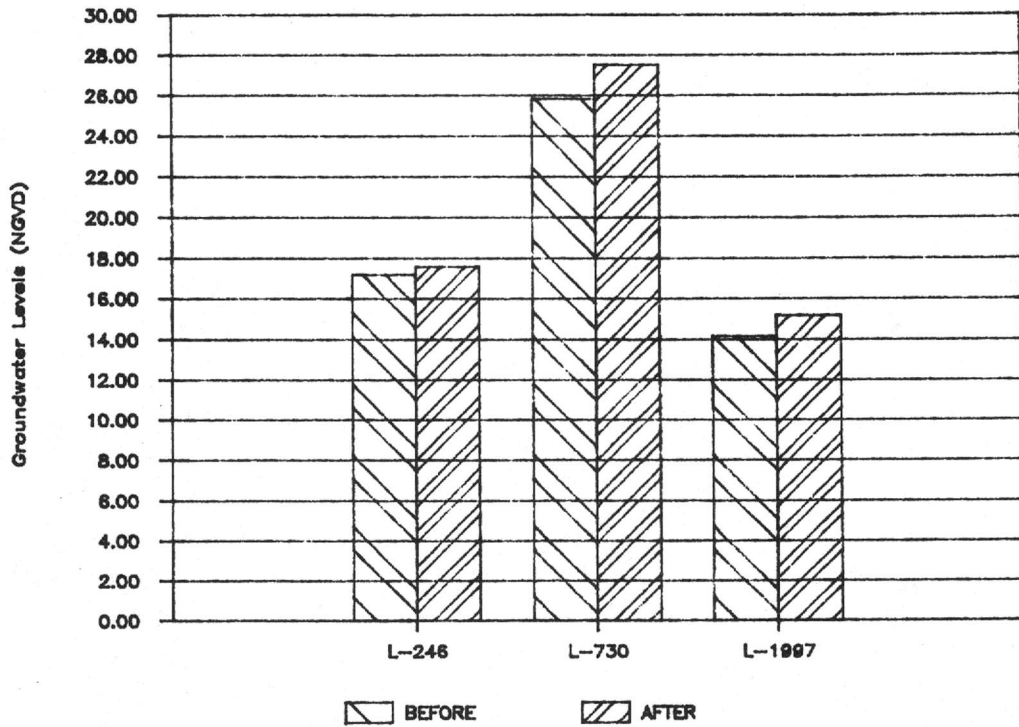


FIGURE 18. LOCATION MAP FOR GROUNDWATER WELLS

LEE COUNTY



COLLIER COUNTY

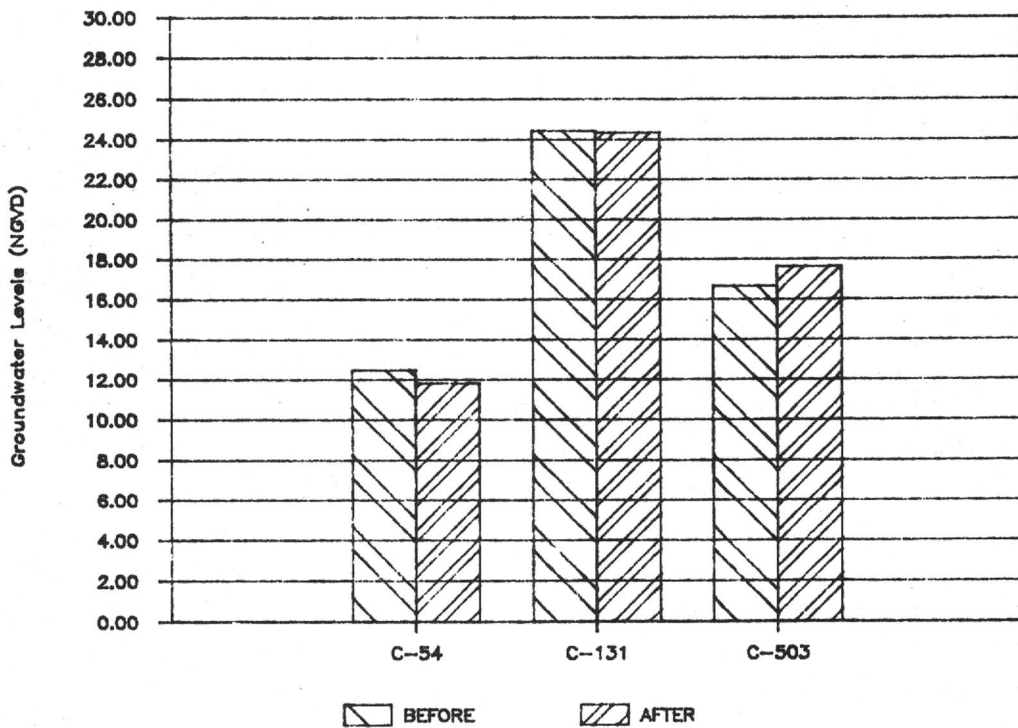
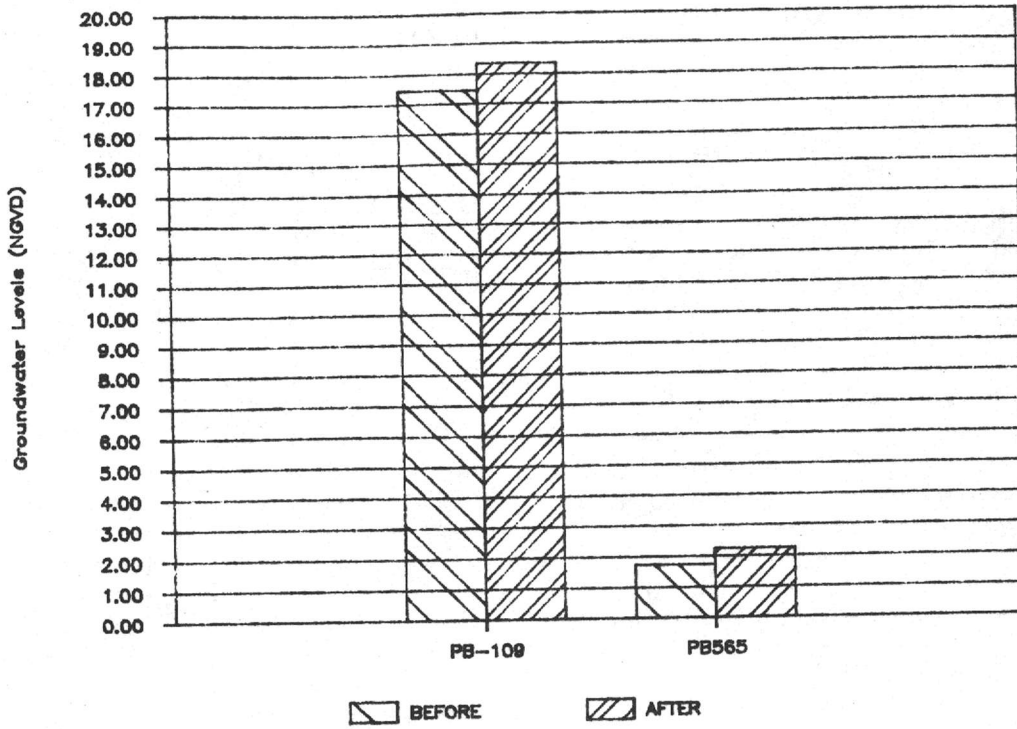


FIGURE 19. GROUNDWATER LEVELS FOR SELECTED WELLS IN LEE AND COLLIER COUNTIES

PALM BEACH COUNTY



BROWARD COUNTY

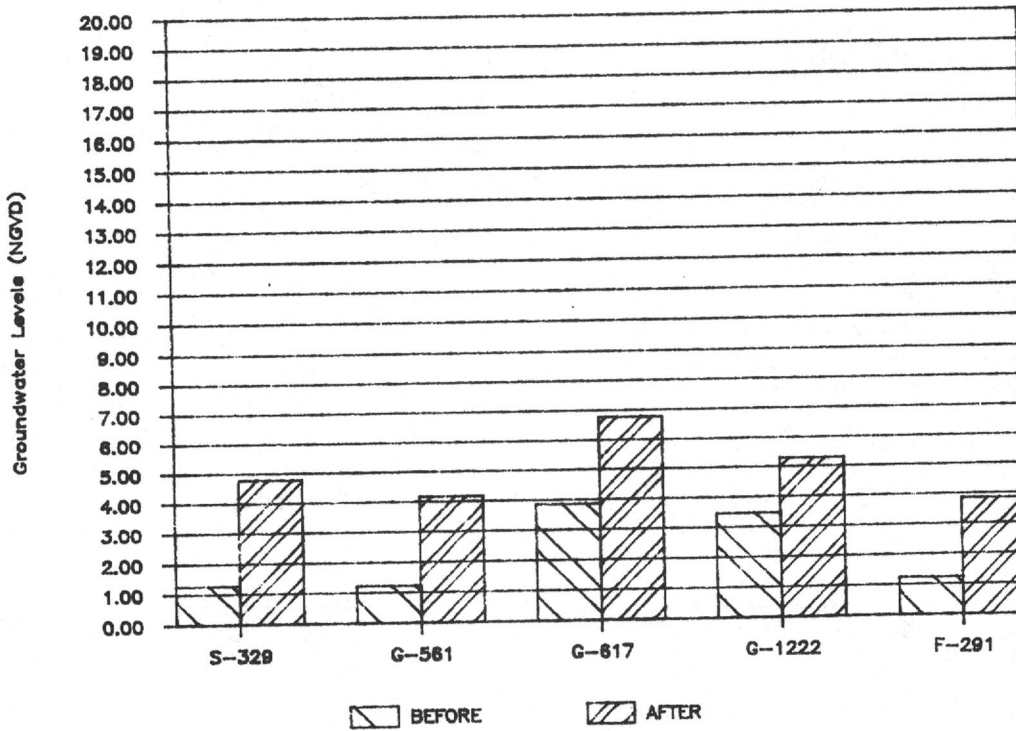


FIGURE 20. GROUNDWATER LEVELS FOR SELECTED WELLS IN PALM BEACH AND BROWARD COUNTIES

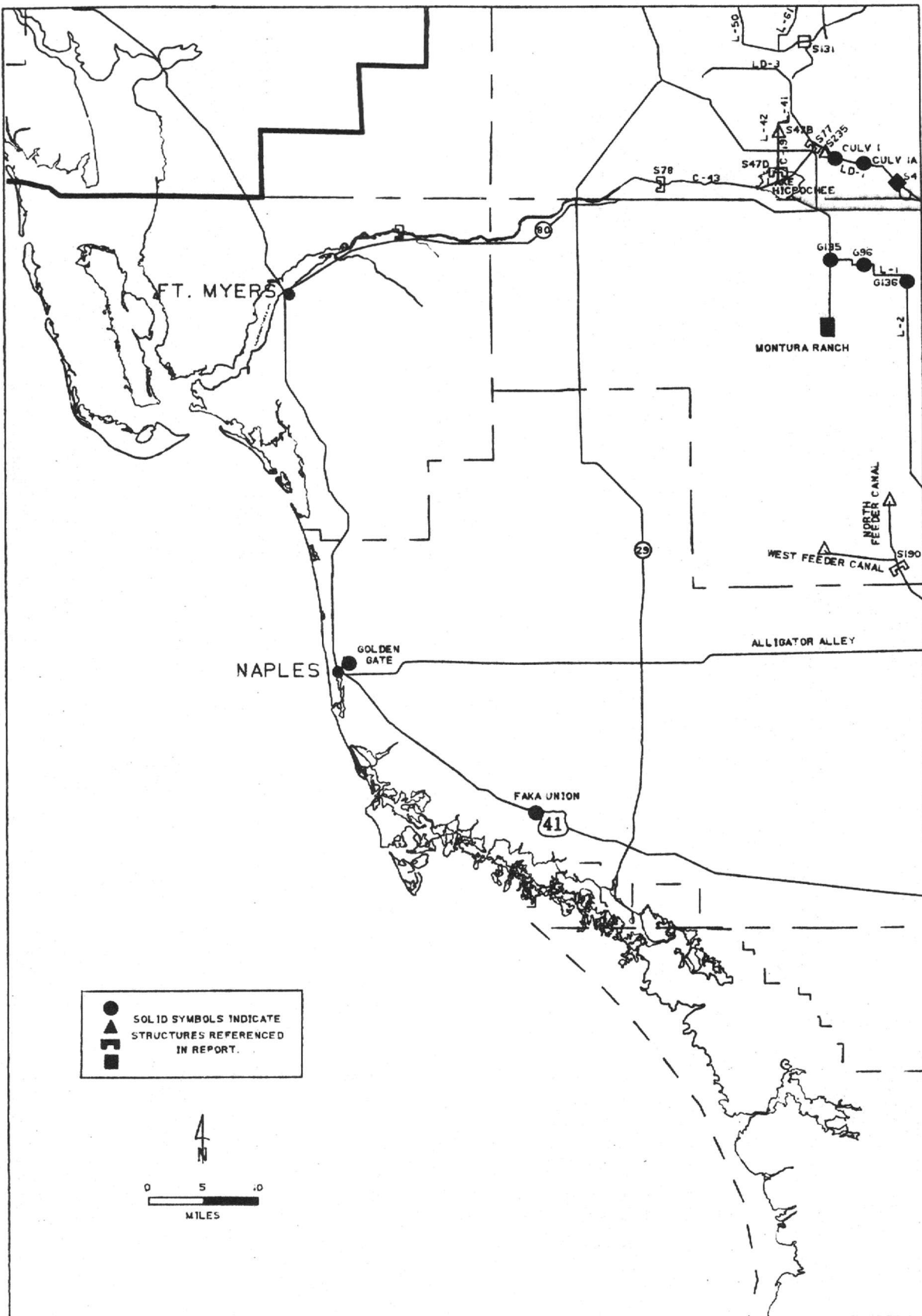


FIGURE 21. STRUCTURE LOCATION MAP FOR THE LOWER WEST COAST

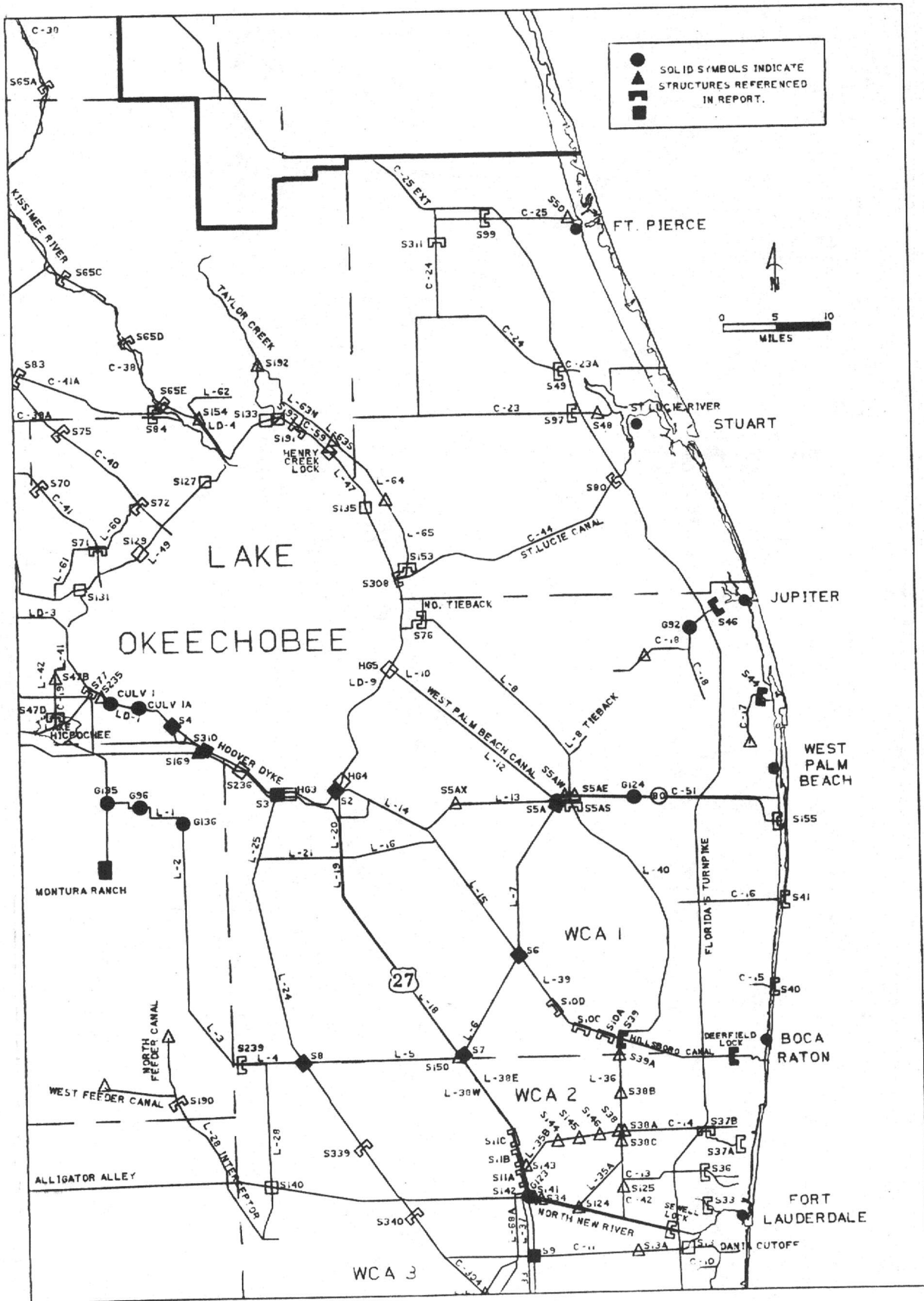


FIGURE 22. STRUCTURE LOCATION MAP FOR LOWER AND UPPER EAST COAST

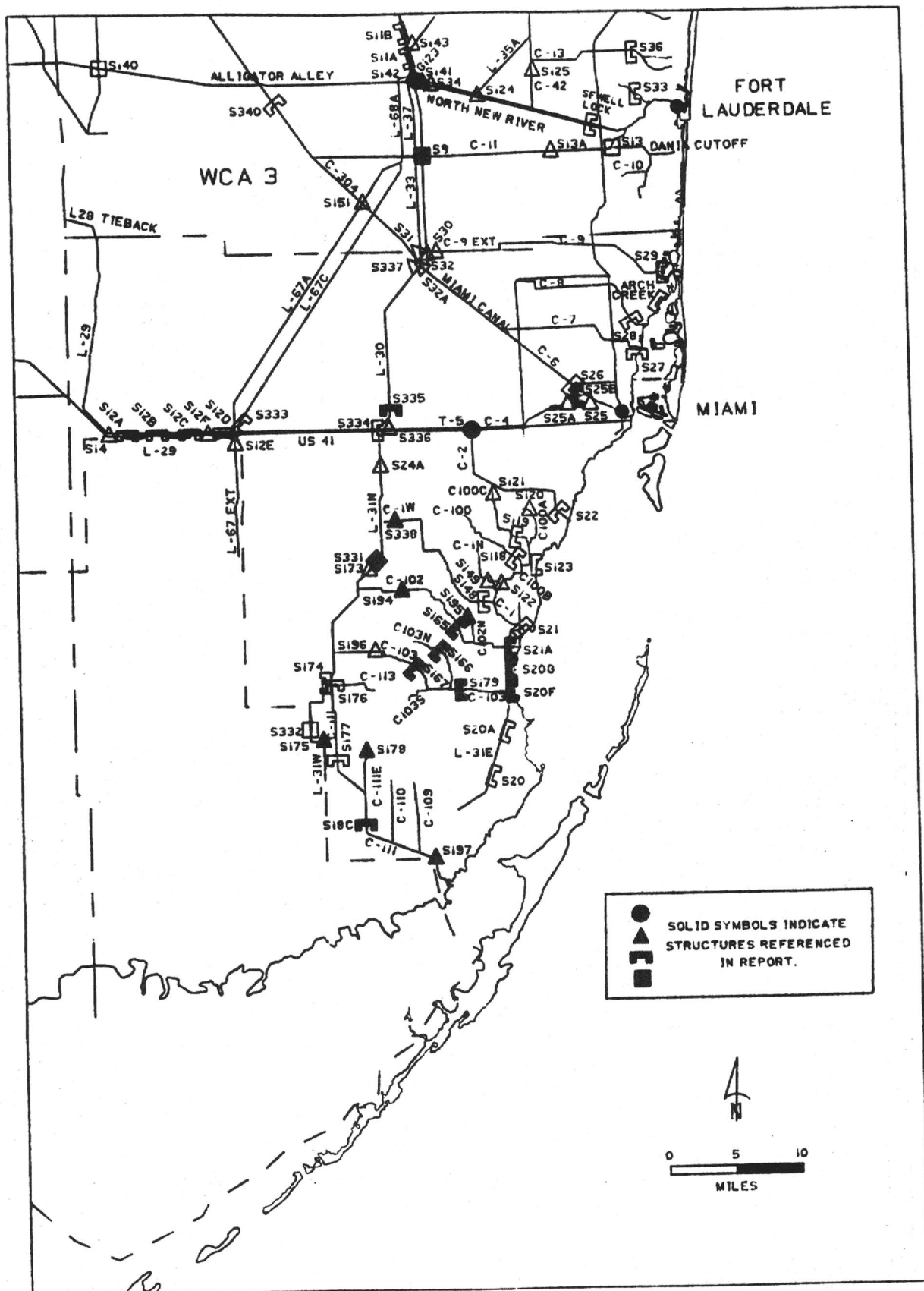


FIGURE 23. STRUCTURE LOCATION MAP FOR SOUTH DADE

Lee County were July 18 and July 31. Collier County wells C-54 and C-51 were read on July 18 and July 29. Well C-503 was read on July 15 and July 30. All of the Broward County wells were read on July 11 and July 25. Both Palm Beach County wells were read on July 12 and July 26. Most of these selected wells show an increase in water levels after the occurrence of the storm. The exceptions are wells C-54 and C-131 in Collier County which show a slight decrease. These wells are located in eastern and northern Collier County areas which did not receive the major rainfall from the storm.

IV. Operation of the System

A. Field Inspection of Affected Areas

Prior to the storm, rainfall in the general Marco Island/Naples area was less than normal. As a result, lakes, canals, ditches, and the ground itself had ample storage for Tropical Storm Bob. By mid-morning, all lakes, canals, and ditches were overflowing. The unpermitted areas and roads were inundated. Permitted projects, however, had standing water in low areas only. For example, the old unpermitted portions of Lely Estates (roads, low areas, golf courses, etc.) were inundated, whereas the permitted portions held water in low areas but roads were not inundated.

In the entire Marco Island/Naples area no adverse impact such as home flooding was observed. The major drainage system in the county and permitted projects functioned without incident. Within a period of 24 hours the inundated area had receded because of two factors; the dry season prior to Tropical Storm Bob provided ample storage, and the outfall structures helped the system to drain rapidly except during periods of high tides. Farmers in the area detained the runoff from the storm in their fields for beneficial purposes such as killing nematodes and increasing percolation.

The Collier County Water Management Department along with the Big Cypress Basin Board had made adequate preparation for a storm event and were very pleased with the results of the preparation.

No flooding complaints were received in relationship to Tropical Storm Bob from North Palm Beach County or Martin County. Minor street flooding was observed and served as an inconvenience during and immediately after the storm. Runoff and percolation was

rapid with the passing of the storm and this was attributed to the unusually dry spring and winter. Low areas in Martin County did have standing water for a few days, but it had no major effect on residential areas. Wetlands which had been reasonably dry benefitted greatly from this particular storm.

B. Hydrologic Conditions During the Storm

Coastal Collier County

Figure 24 illustrates the hourly stage hydrograph at Golden Gate Canal at Naples. A peak stage of 5.45 feet NGVD was reached at 0900 hours July 24 and lasted about 3 hours. A gage height at 7.14 feet on September 14, 1971 was the highest recorded stage in 18 years of record. No peak discharge estimate was available.

Figure 25 shows the hourly stage hydrograph at Faka Union Canal near Copeland during the storm. This gage is located five miles west of the hourly rainfall station at Royal Hammock State Park (see Figure 9). Figures 9 and 25 show the peak stage of 4.65 feet NGVD at 1000 hours July 23 was reached one to two hours after the most intense part of the storm. The maximum peak discharge at this location was 3200 cfs on September 15, 1971 with a corresponding gage height of 4.77 feet NGVD. The estimated peak discharge during Tropical Storm Bob was 3200 cfs, based on an October 1981 rating.

Montura Ranch Area

Pumping into the Montura Reservoir began early during the storm, although not all the pumps were operational. Maximum permissible discharge was made to the east through structures G-96 and G-136 to the Miami Canal, and via L-1, L-2, and L-3 borrow

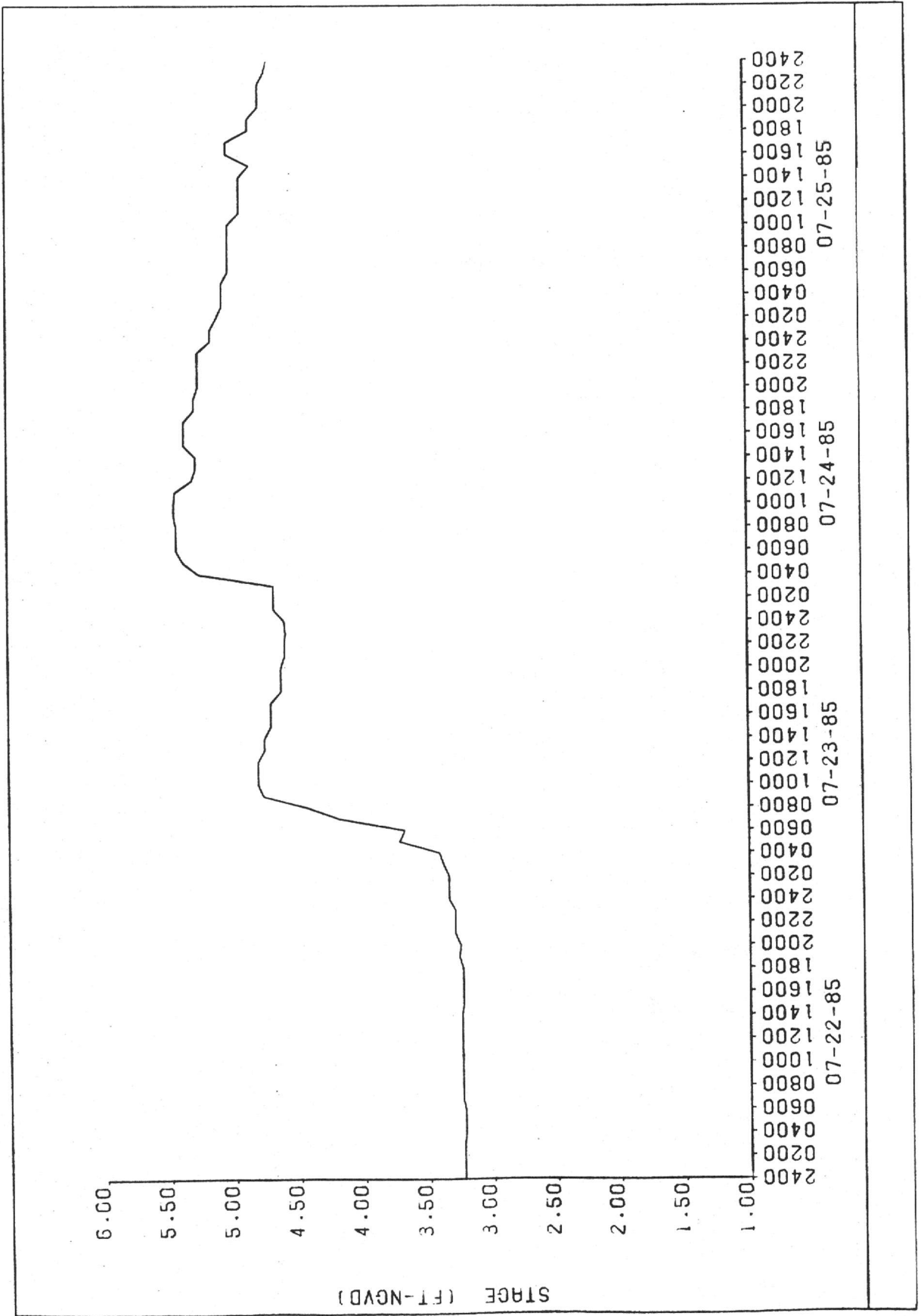


FIGURE 24. HOURLY STAGE AT GOLDEN GATE CANAL AT NAPLES

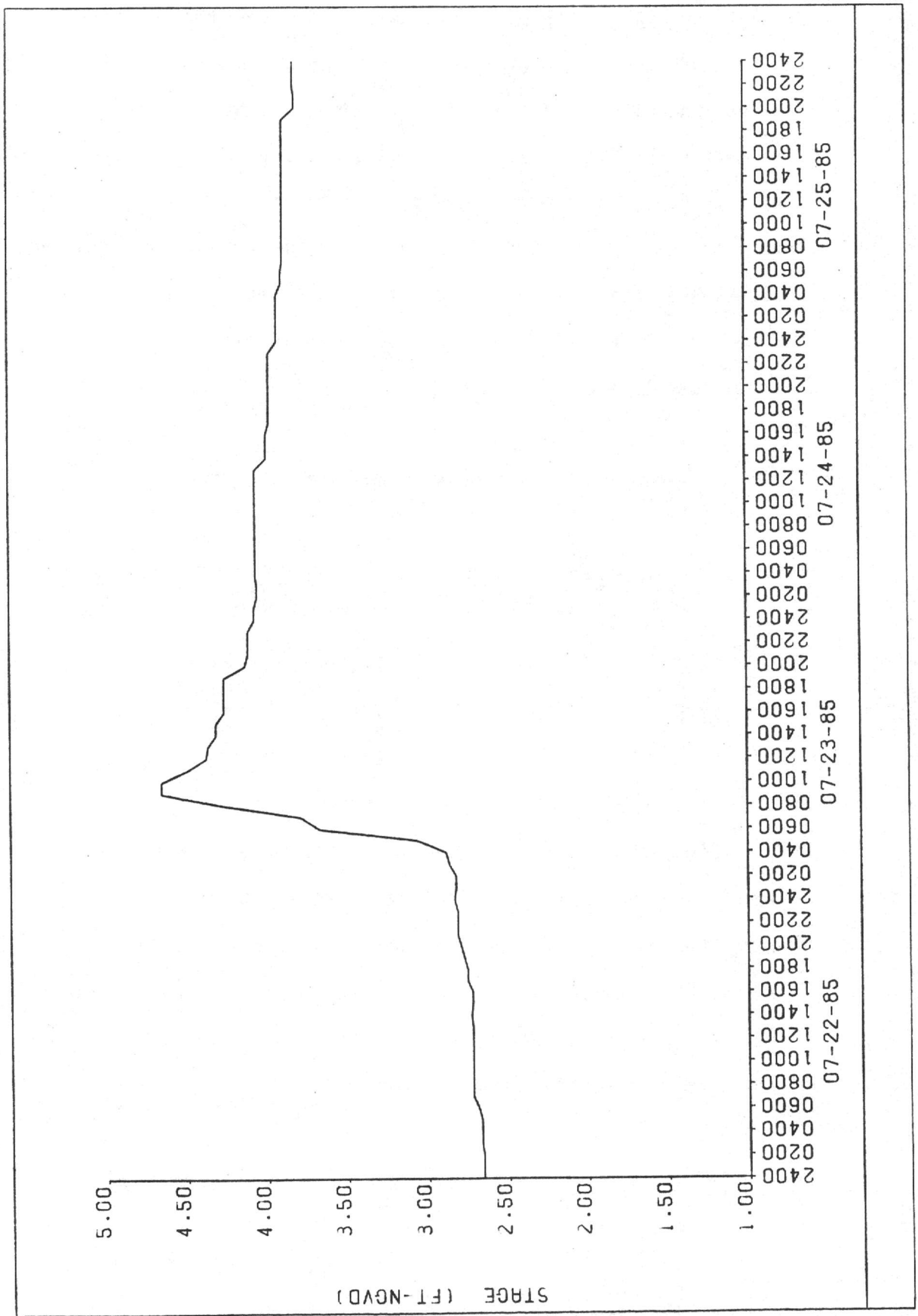


FIGURE 25. HOURLY STAGE AT FAKA UNION CANAL NEAR COPELAND

canals to WCA-3A. On July 22 discharge was made through structure G-135 into the Flaghole Drainage District (FDD) canal, but the FDD forced the closure of that structure on the 23rd, allowing it to be opened on the 24th. The FDD again forced the closure on the morning of the 25th. As a result, the pumps into the reservoir were not able to keep up with the rising water in the residential areas which experienced considerable street and yard flooding, but no house flooding. Since no discharge could be made from the reservoir, the level rose as shown in Table 2.

Table 2. Daily Levels at Montura Reservoir

<u>Date</u>	<u>Reservoir Level (feet NGVD)</u>	<u>Date</u>	<u>Reservoir Level (feet NGVD)</u>
7/22	22.98	7/26	23.42
7/23	23.12	7/27	23.48
7/24	23.32	7/28	23.52
7/25	23.36	7/29	23.55
		7/30	23.56
		7/31	23.56
		8/1	23.38

Since the lowest point in the reservoir perimeter dike was about 24.8 feet NGVD, the SFWMD had instructed the Central County Water Control District to terminate pumping when the reservoir reached a stage of 24.0 feet. Fortunately, this stage was not reached as a result of the storm, though it did continue to rise until well after the storm, peaking at 23.56 feet on July 31.

Everglades Agricultural Area (EAA)

Runoff was pumped continuously at S-2 and S-3 at near-maximum rates into Lake Okeechobee beginning from the week before Tropical Storm Bob through the entire storm. Figure 26 illustrates daily stages and storages of Lake Okeechobee for July. In addition, water was pumped into the Water Conservation Areas (WCA) in a similar manner beginning before the storm at S-5A, on the evening of July 22 at S-6, S-7, and S-8, and continuing through the storm period at these four pump stations. No difficulty was experienced in holding stages in these canal basins between 10.0 feet and 11.0 feet NGVD.

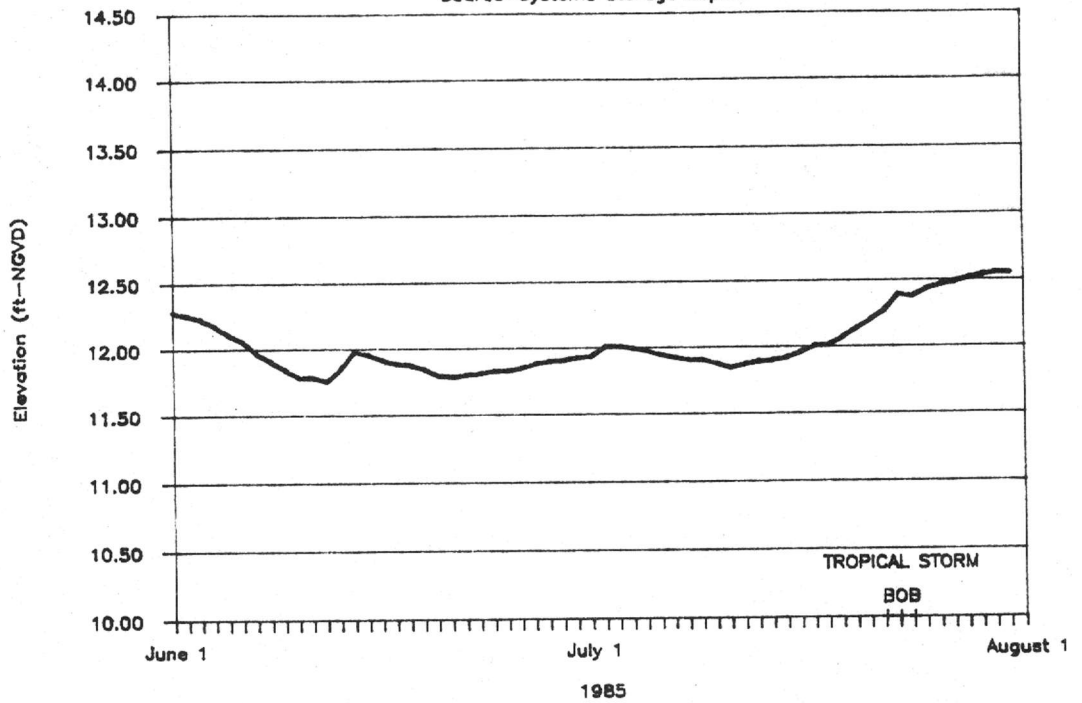
Pump station S-4 was not used during the storm. Runoff from the basin flowed by gravity into Lake Okeechobee through lake culverts 1 and 1A, and eastward through S-169, C-21, and Industrial Canal into Lake Okeechobee via the open S-310 lock chamber. The normal operating range of the canals in the S-4 basin remained in the normal operating range of 12.0 feet to 12.5 feet NGVD.

Water Conservation Areas (WCA)

Direct rainfall was heavy in all three water conservation areas. This, coupled with continuous pumping at all pump stations, brought the stages up sharply in all three areas. Figures 27 through 29 show the July stages and storages for WCA-1, 2A, and 3A respectively. WCA-1 rose above schedule and all S-10 structures were opened fully. The control structures for WCA-2A were already open fully as part of the three year drawdown program. The control structures for WCA-3A were open only slightly in accordance with the experimental program to link discharge into Everglades National

LAKE OKEECHOBEE

Source=Systems Storage Report



LAKE OKEECHOBEE AVAILABLE STORAGE

Source=System Storage Report

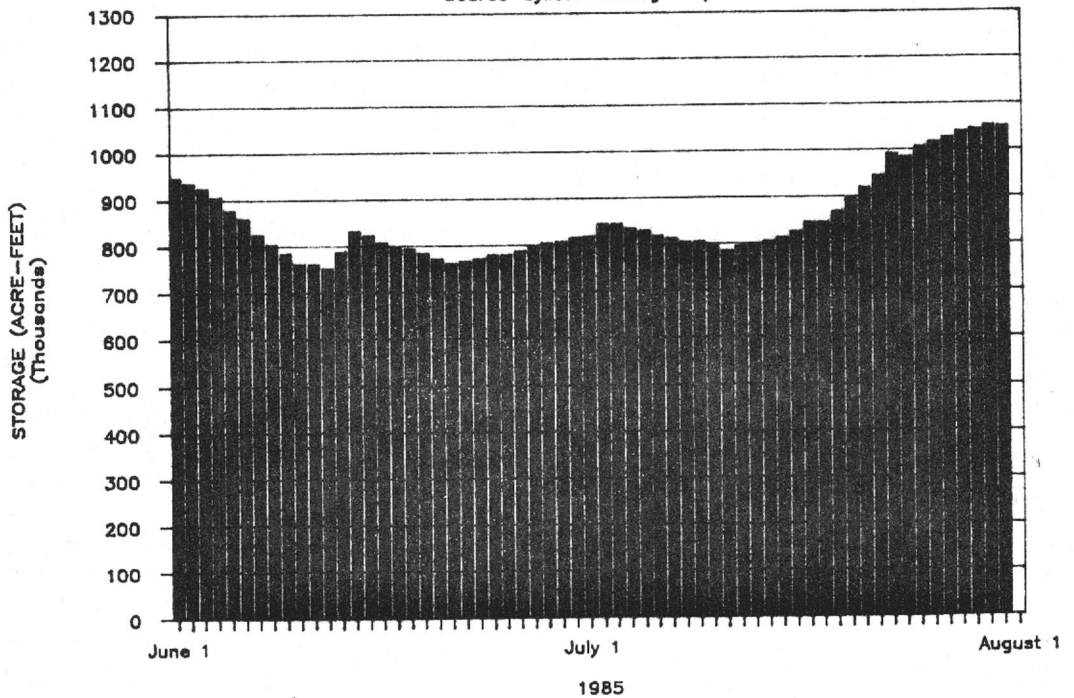
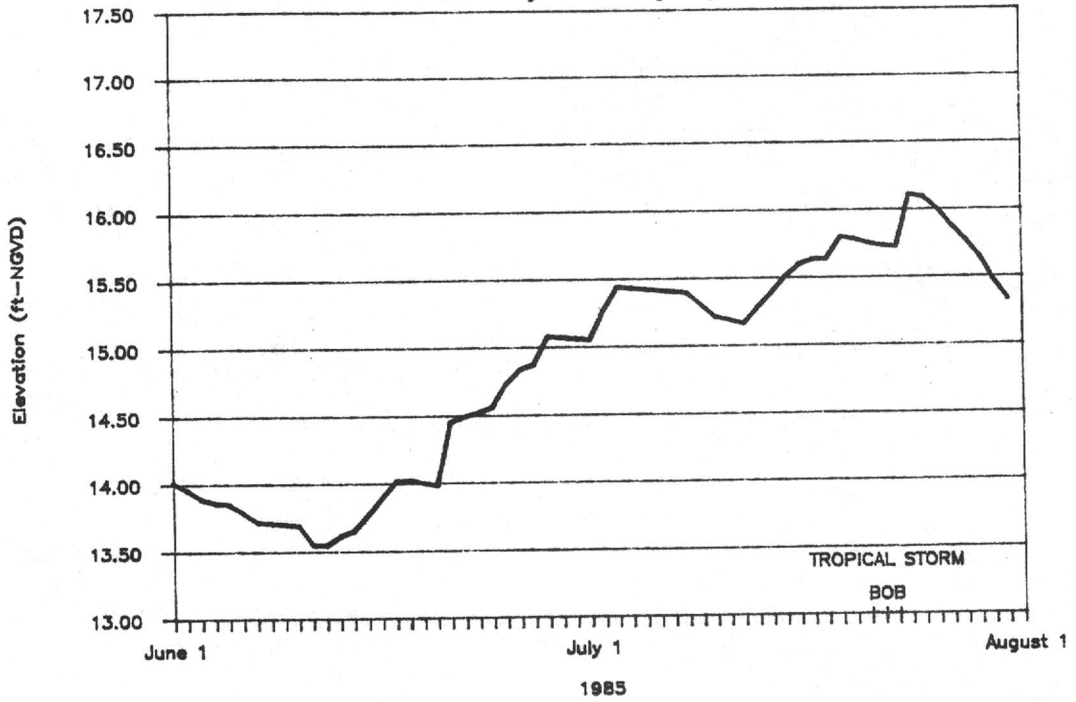


FIGURE 26. DAILY STAGE AND STORAGE: LAKE OKEECHOBEE

WATER CONSERVATION AREA 1

Source=Systems Storage Report



WCA1 AVAILABLE STORAGE

Source=System Storage Report

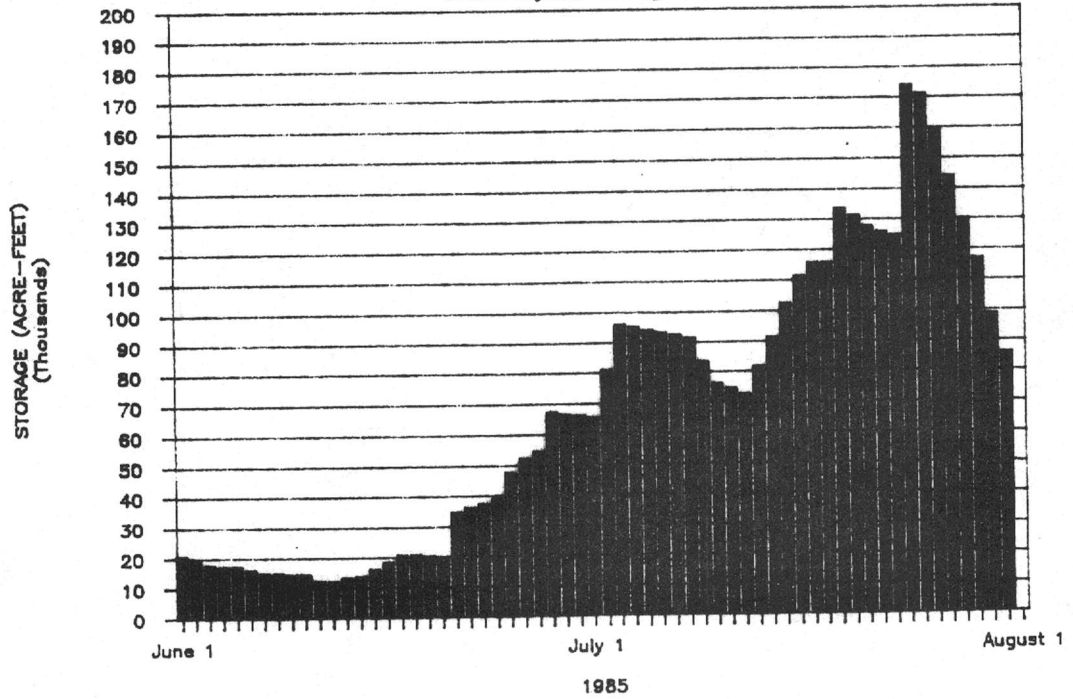
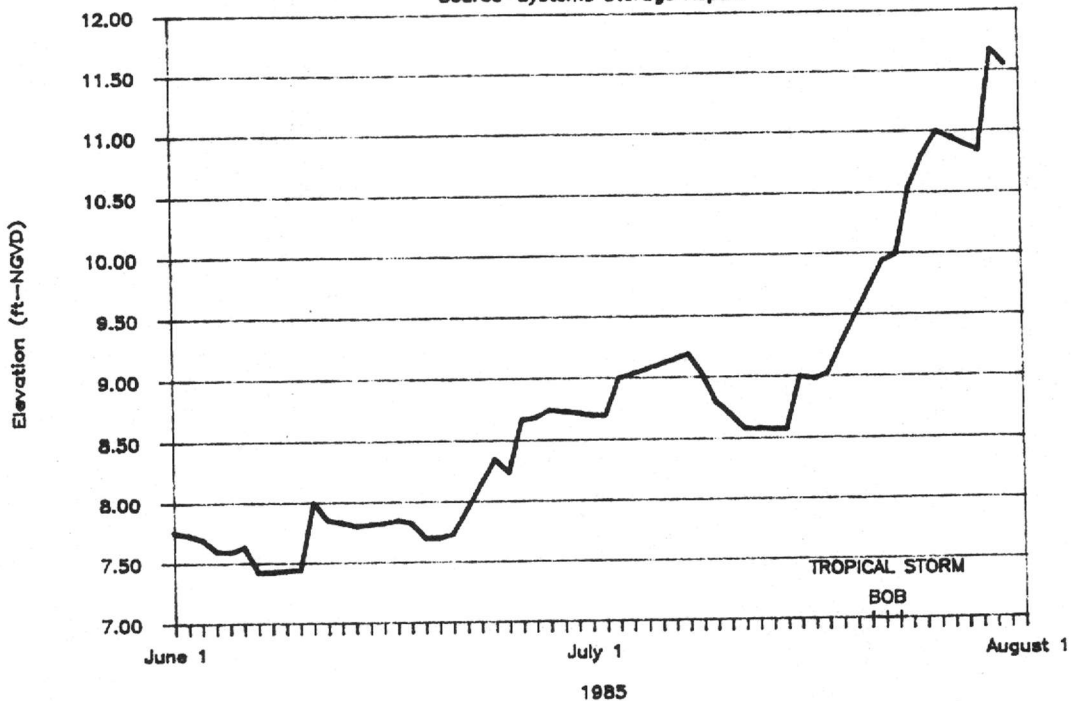


FIGURE 27. DAILY STAGE AND STORAGE: WCA-1

WATER CONSERVATION AREA 2A

Source=Systems Storage Report



WCA2A AVAILABLE STORAGE

Source=System Storage Report

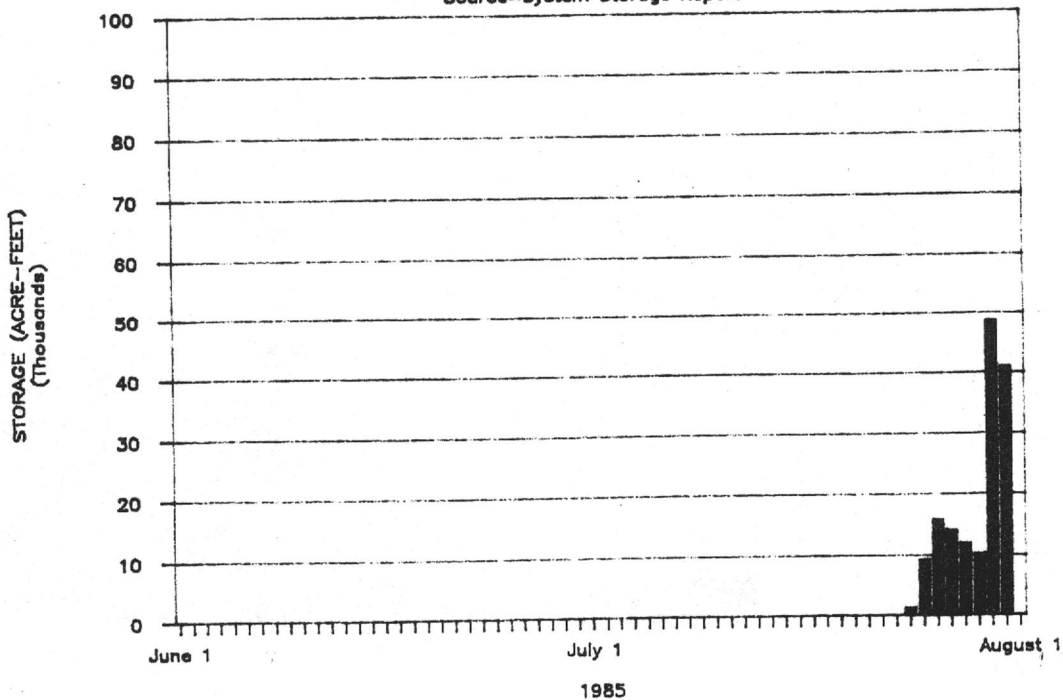
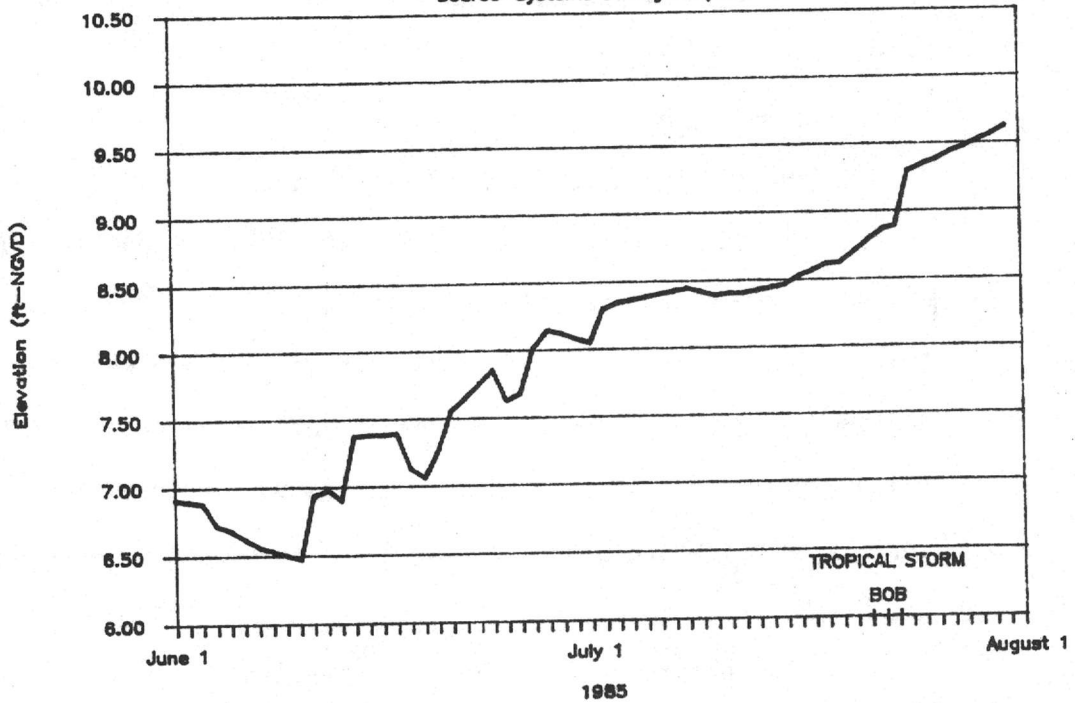


FIGURE 28. DAILY STAGE AND STORAGE: WCA-2A

WATER CONSERVATION AREA 3A

Source—Systems Storage Report



WCA3A AVAILABLE STORAGE

Source—System Storage Report

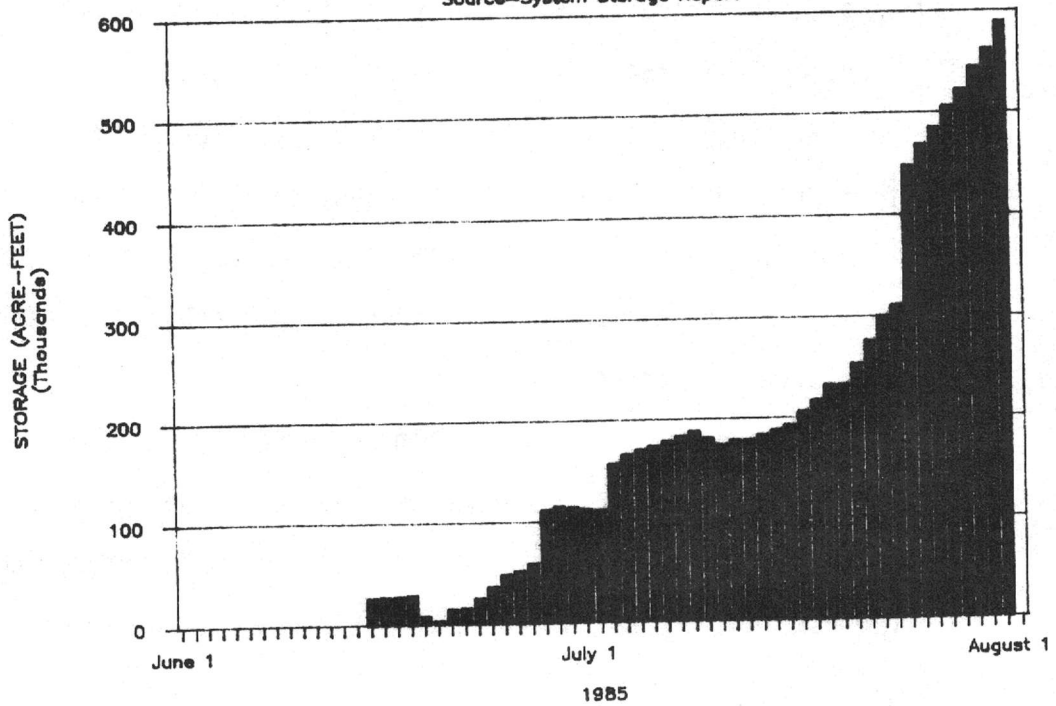


FIGURE 29. DAILY STAGE AND STORAGE: WCA-3A

Park to a rain driven model. The stage in WCA-3A increased 0.5 feet from July 22-24 which brought an additional 170 thousand acre-feet of available storage to the area.

Coastal Palm Beach County

On the evening of July 22, coastal control structures S-155, S-41, and S-40 (on canals C-51, C-16, and C-15, respectively) were placed on low range, thus lowering the canal stages about 1.0 foot. This action provided limited extra storage in the lakes and canals, and increased the gradient and capacity of the secondary system. The divide culvert in C-51 (G-124) had already been closed and inflows in the western part of the basin were passed through S-5AE and S-5AW, and pumped into WCA-1 throughout the storm.

On the morning of July 23, the control structure S-44 on the C-17 canal was opened by the Communications & Control System (C&CS), and the stage was lowered almost 2.0 feet until after the storm. For a brief period during intense rainfall, the gates were opened at structure S-155 on the C-51 canal between 1800 hours and 1925 hours. The C-51 stage east of divide structure G-124 peaked at an elevation of about 10.0 feet NGVD around midnight on July 23, and west of G-124 at an elevation of 11.25 feet NGVD a few hours earlier. On the morning of July 25 all structures were restored to their high range automatic operation.

The rainfall in northern Palm Beach County was light and the control structure S-46 remained on the high range automatic mode, but never opened. Increased discharges were made through the G-92 culverts into the northwest fork of the Loxahatchee River.

Coastal Broward County

Coastal control structures were fully opened on the evening of July 23. These structures, except G-56 (Deerfield Lock), were returned to automatic operation late July 24, or early July 25. Two pump stations on the C-11 canal (S-9 at the west end, and S-13 at the east end) pumped continuously during the entire storm. S-9 had been pumping the weekend before the storm; S-13 began pumping late July 22, and both were still pumping through the night of July 28.

In spite of the maximum gate openings, canal stages were very high at the west end of C-14, C-13, and Hillsboro Canal, reaching 8.0 feet, 6.6 feet, and 9.9 feet respectively. Flood levels are considered to be 8.2 feet, 6.0 feet, and 9.0 feet respectively. Stages on the west and east sides of the divide structure on the C-11 canal reached 4.6 feet and 2.5 feet respectively. Peak stages were reached very early July 24.

In an effort to reduce the very high stage at the west end of the C-13 canal, structure S-124 was opened and pump station G-123 was activated. This operation was limited because of water quality considerations caused by construction of the Sawgrass Expressway. During the storm, however, the turbidity was less than it was the week before. This operation was terminated late July 25 when the stage in C-13 was lowered.

The limited capacity of the west end of the Hillsboro Canal was confirmed by this storm. The S-39 tailwater stage peaked almost one foot above flood level at 1130 hours July 24. The gate at the Deerfield Lock (G-56) control structure was open fully since 1500 hours July 23 (see Figure 30). Because of the high stage, all the

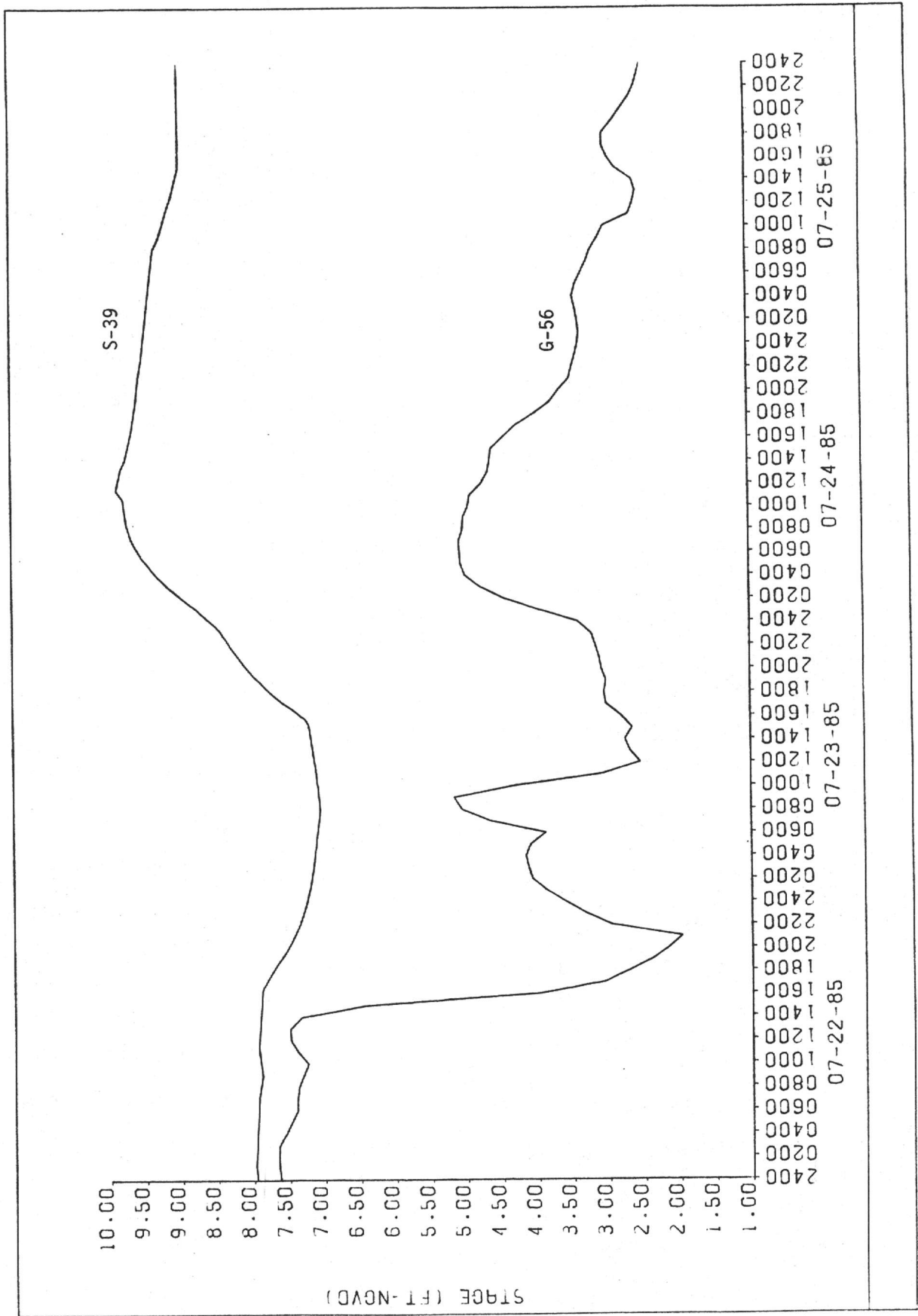


FIGURE 30. HOURLY STAGE AT DEERFIELD LOCK (G-56) AND S-39 TW

boards were removed from the spillway at about 0800 hours July 24. By 1600 hours July 25 the stage at the west end was still at the 9.0 feet flood level, and was falling very slowly.

North Dade County

This area experienced few problems. Most coastal structures remained on normal operating settings, and frequent gate operations controlled water levels in the safe range. As an example, the west end of the Miami Canal (C-6) peaked at 4.07 feet NGVD early July 24 compared with a flood level of 5.3 feet. The only problem area was in west Miami where inadequate secondary drainage facilities frequently cause problems. To counter this problem S-25B, the coastal control structure on the Tamiami Canal (C-4), was placed on flood range automatic at 1200 hours July 23. The control structure S-22 on C-2 canal was opened 4.0 feet at 1400 hours the same day. This canal intersects C-4 at the Telemark recorder (T-5) where the flood level is 4.5 feet. The control structure G-97, on the Coral Gables Canal, was opened at 0900 hours July 23 and remained open for the duration of the storm. This canal intersects C-4 between C-2 and S-25B. These actions quickly lowered the east end of C-4 and C-2 close to the tidal level through the storm. Nevertheless, the stage at T-5 rose above 4.5 feet NGVD at 1600 hours July 23, peaked at 4.88 NGVD feet at 2100 hours the same day, dropping gradually to 4.5 feet at 1800 hours July 24, and to 4.0 feet at 1500 hours July 25.

South Dade County

On the evening of July 22 the coastal control structures S-20F, S-20G, and S-21A were all placed on low range automatic, lowering the east ends of the canals in that area close to the tidal level where they remained throughout the storm. At the same time, the ridge structures S-195, S-164, S-166, and S-167, as well as S-175 and S-178, were all opened fully for the duration of the storm. The divide structures on C-103 and C-102 canals were also opened fully for the duration of the storm. The latter action was of little effect as these canals flattened and virtually no flow occurred during the storm as shown in Table 3.

Table 3. Daily Discharges through S-194 and S-196

<u>Date</u>	<u>Flow in CFS</u>	
	<u>S-194</u>	<u>S-196</u>
7/22	0	0
7/23	90	80
7/24	60	30
7/25	120	65

On the main stem of L-31N to C-111 canal system the operation during July 22 had been following the terms of an agreement which resulted from an action in Federal District Court. This agreement required pumping at station S-331, with the structures S-176, S-177, and S-18C on automatic operation. Because of the storm on the evening of July 22, pumping was terminated at S-331, structures S-176, S-174 S-177, S-18C, and the culverts at S-197 were opened fully. The stage hydrographs for S-18C and S-197 are shown in Figures 31 and 32 respectively.

The divide structure S-338 on the C-1 canal also was opened fully in an attempt to remove some of the water from borrow canal L-31N north of S-331 which had no other discharge during the storm.

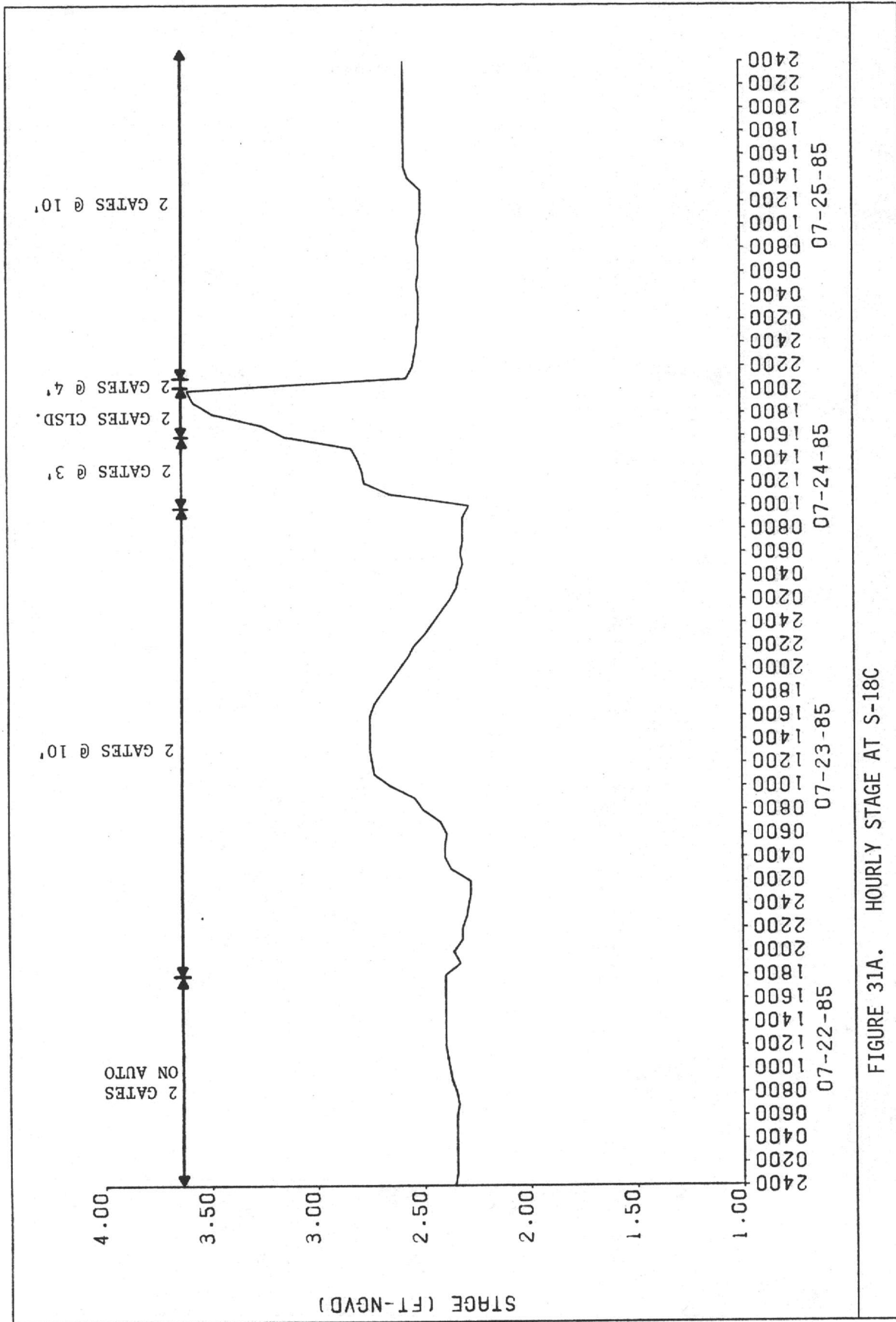


FIGURE 31A. HOURLY STAGE AT S-18C

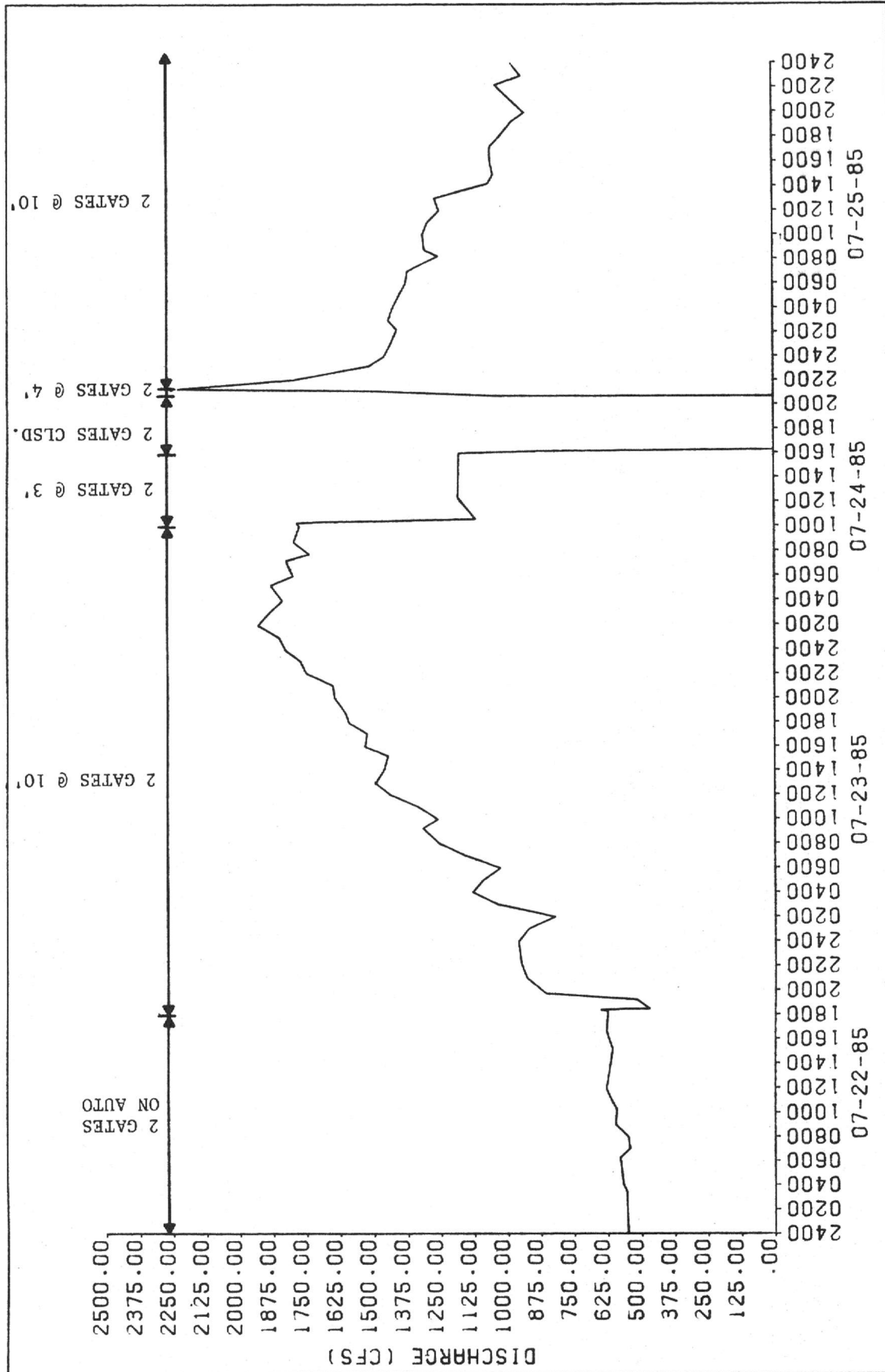


FIGURE 31B. HOURLY DISCHARGE AT S-18C

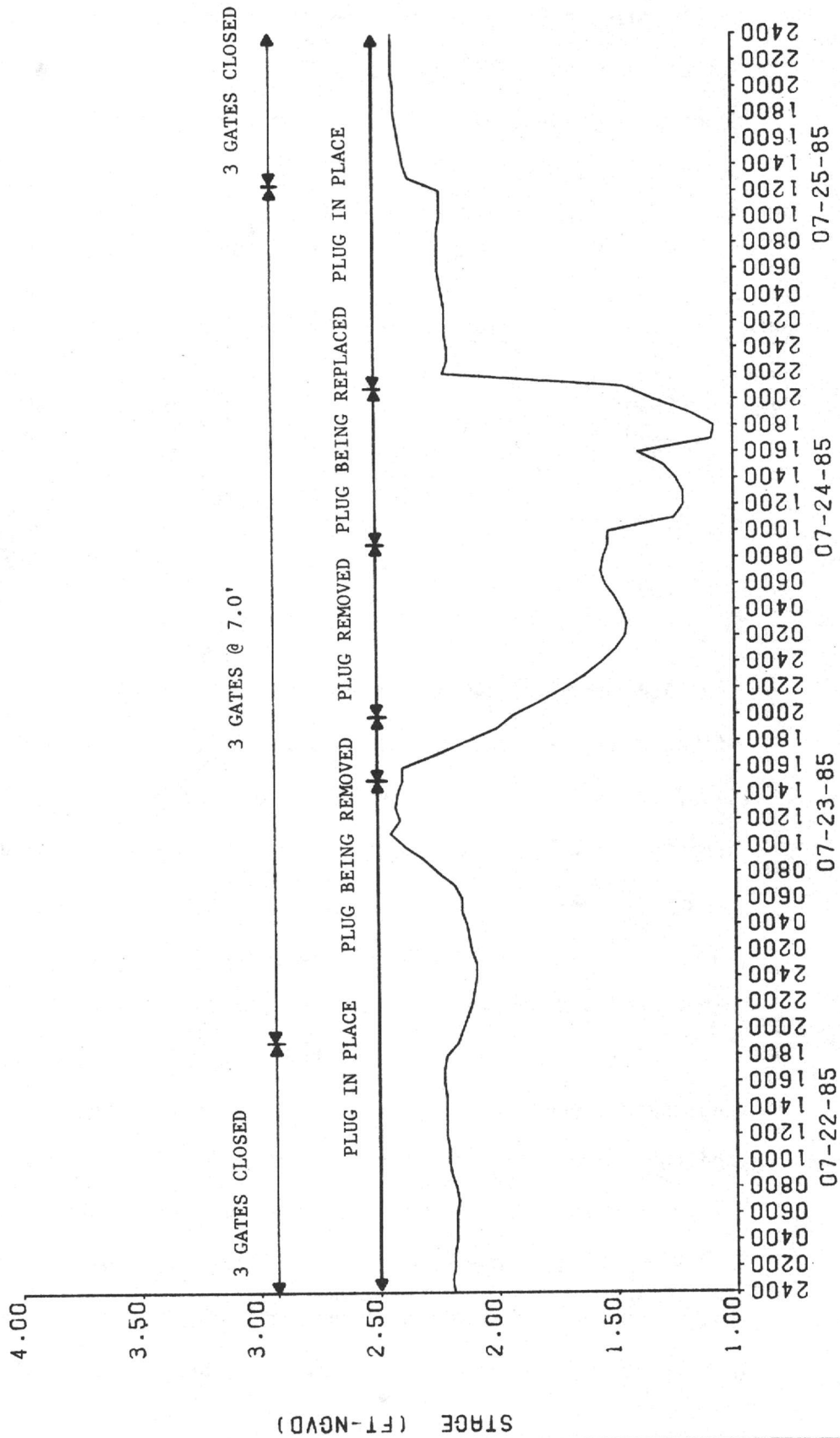


FIGURE 32. HOURLY STAGE AT S-197

As a result of the above actions, the stage north of S-331 rose to 5.1 at 0900 hours July 23 and to 5.9 at 0800 hours July 24. The downstream stages fell initially, but rose as a result of the storm as shown in Table 4.

Table 4. C-111 Stages

<u>Date</u>	<u>Time</u>	<u>S-331 Tailwater (in feet NGVD)</u>	<u>S-177 Headwater (in feet NGVD)</u>	<u>Comment</u>
7/22	1600	5.50	4.21	Pumping secured
7/23	0100	4.39	3.29	No pumping
	1100	5.31	4.21	No pumping
	1300	5.58	4.35	No pumping
	1800	5.71	4.30	No pumping, plug removed
	2400	5.56	4.10	Plug out, no pumping
7/24	0800	5.34	3.89	Plug out, no pumping

According to the operational criteria established by the Corps of Engineers, the earthen plug at the lower end of C-111 canal near S-197 was to have been removed whenever the headwater stage at structure S-177 reached 4.3 feet NGVD, the design stage at that structure. As shown in Table 4, the critical level was reached by 1300 hours July 23. Since the storm was still southwest of Lake Okeechobee and moving east, and the stage at S-177 was still rising, the decision was made to remove the plug. The Army Corps of Engineers concurred with this decision. After the plug was removed and the rains subsided, the canal began to fall as shown in Table 4.

Since the storm appeared to have passed and the canal stages in L-31N and C-111 had receded, the decision was made to replace the plug, and the operation was begun early on July 24. Considerable difficulty was experienced in replacing the plug because of the

strong flow. Consequently, S-18C was closed for some time, from about 1600 to 2000 hours (see Figures 31A, 31B, and 32). Naturally, the canal stages above S-18C rose during this time; the headwater at S-177 reached 4.17 at 2000 hours. After the plug had been replaced, the agreement resulting from the Federal District Court was again followed and the pumping resumed at S-331.

The U. S. Geological Survey measured the flow in C-111 at U. S. Highway No. 1 above S-197. The preliminary estimates of the flow are shown in Table 5.

Table 5. S-197 Discharge Measurements (July 24)

<u>Time</u>	<u>Average Water Level Above S-197</u>	<u>Average Velocity (ft/sec)</u>	<u>Discharge (cfs)</u>
11:05-11:40	0.58	1.73	2160
11:40-Noon	0.59	1.77	2200
12:50-1:30	0.48	1.68	2090

The Northern Portion of the SFWMD

The portions of the District north of Lake Okeechobee received virtually no rainfall from Tropical Storm Bob, hence no operational actions were required. All lakes north of Lake Okeechobee were near or below flood regulation levels and no action was needed. Kissimmee River inflow was small due to the small quantity of rainfall that basin received from the storm.

V. Summary

Tropical Storm Bob brought local relief to some of the areas of the SFWMD, such as the Lower West Coast, which had been experiencing a severe rainfall deficiency. However, most of the areas near and to the north of Lake Okeechobee continued to have below-normal rainfall for the year.

The storm passed over south Florida during the major part of July 23 with accompanying rain and winds lasting through July 24. The storm's eastward movement was anomalous for late July tropical cyclones. Tropical Storm Bob's intense rain and gusting winds affected the southwest coast of Florida the most. Flooding, property damage, and varying degrees of beach erosion were reported from Fort Myers Beach to Everglades City; however, damage was minor compared to the June 1982 unnamed storm that affected the southwest coast. Many streets were flooded in Palm Beach and Broward Counties but there were no reports of flooded homes. Two tornadoes were sighted near the Miami-Fort Lauderdale area, but did little damage.

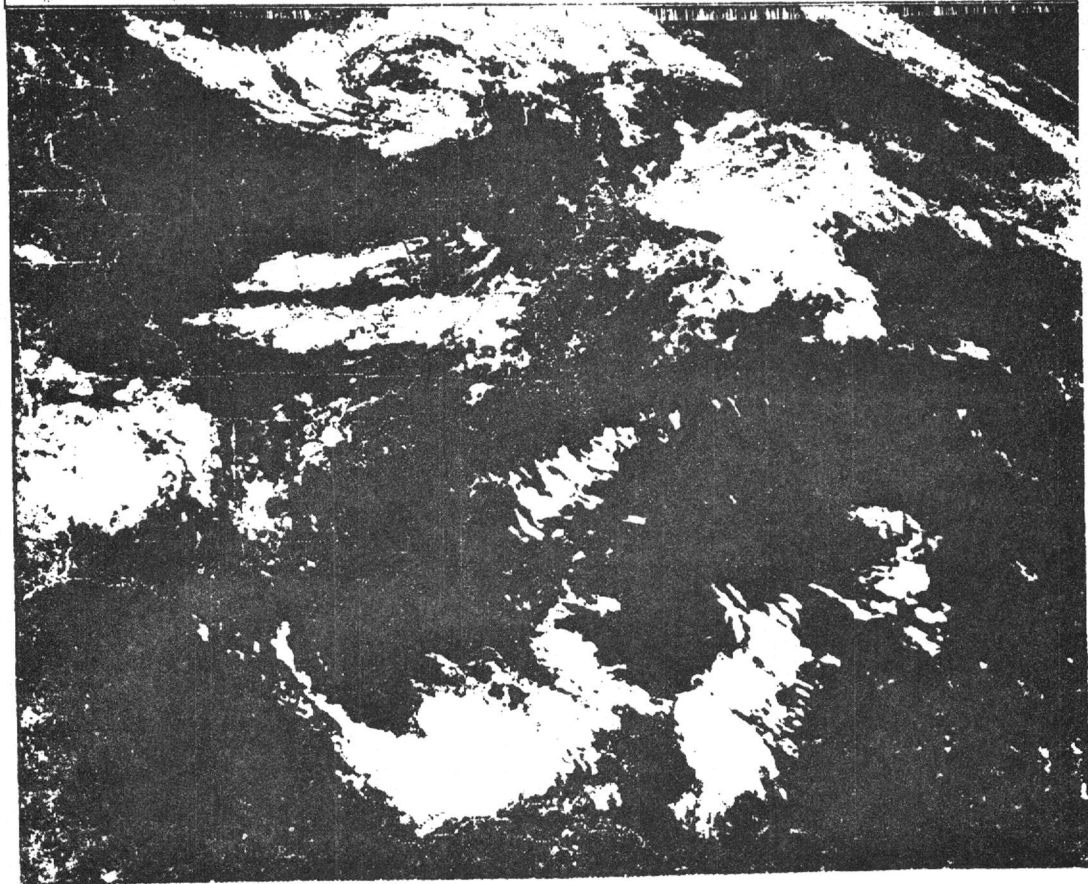
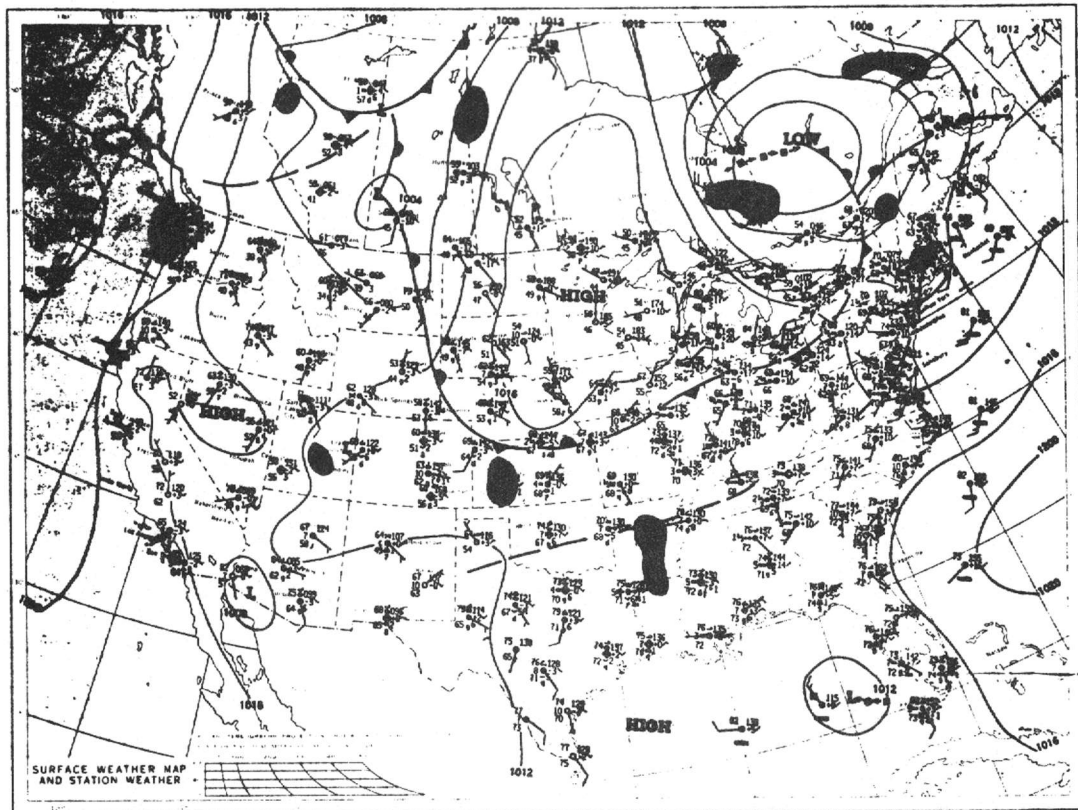
In a 48-hour period near Everglades City more than 21 inches of rain was recorded. The one- and two-day maximum rainfall at Everglades City exceeded the 100-year event. Rainfall exceeding the 2-year event was confined to Collier and Monroe Counties, with the exception of the Water Conservation Areas. The areas of the District surrounding and to the north of Lake Okeechobee received little or no rainfall from the storm.

Most of the SFWMD had received below-normal rainfall in 1985 prior to Tropical Storm Bob; flooding in these areas was consequently less severe due to the dry antecedent conditions.

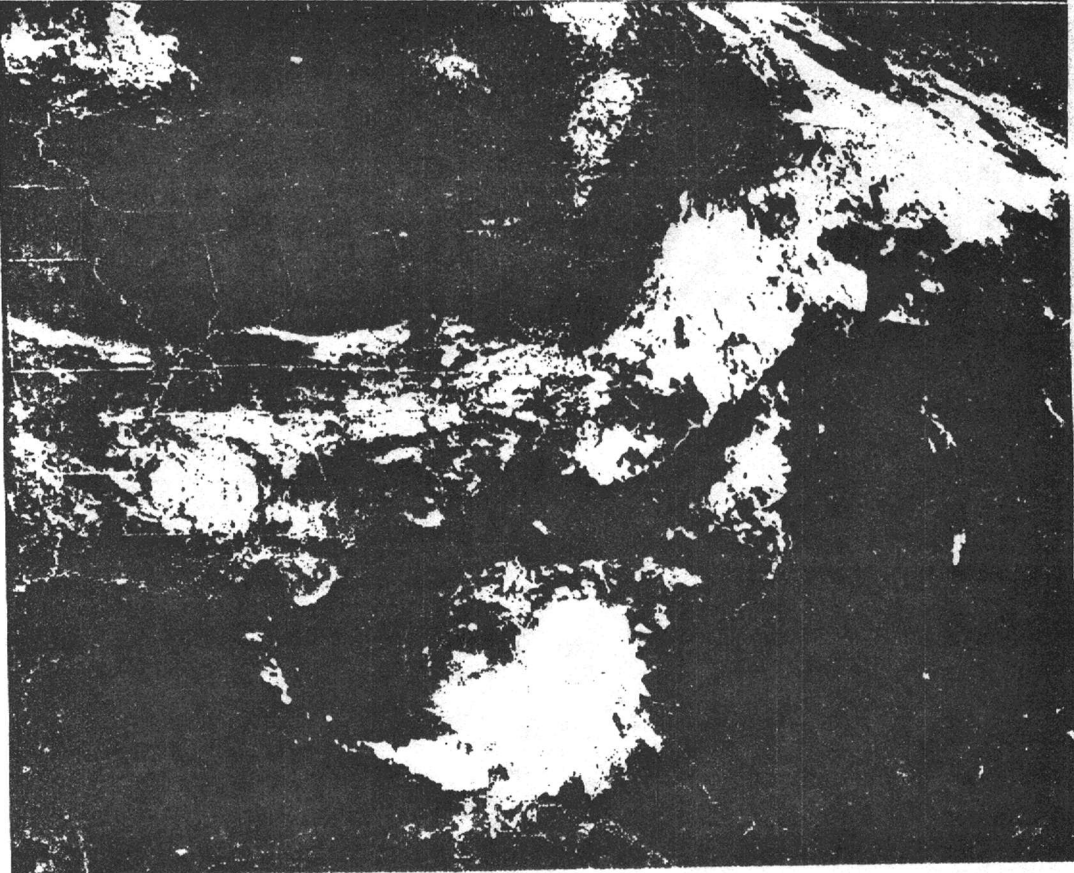
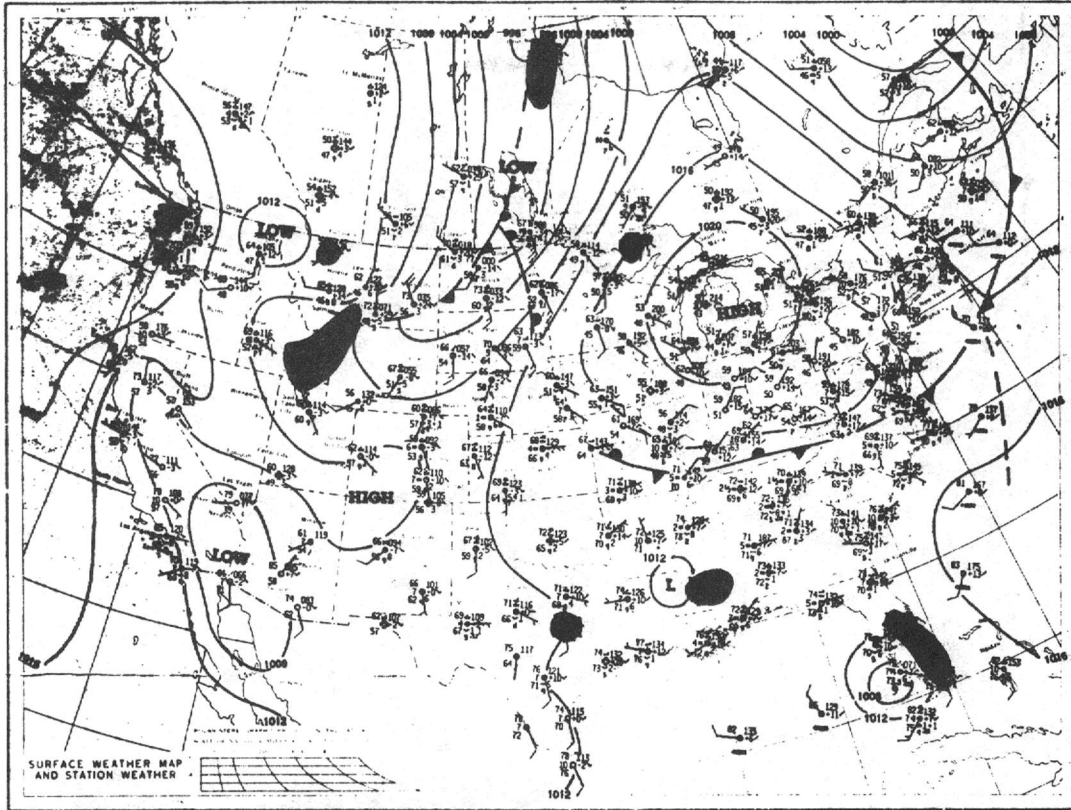
A review of the operation of the system during the storm indicated there were no serious problems encountered. The earthen plug at S-197 was removed during the storm according to criteria established by the Army Corps of Engineers. S-18C was closed for about 4 hours to facilitate the replacement of the plug.

Synoptic Maps and Satellite Photographs

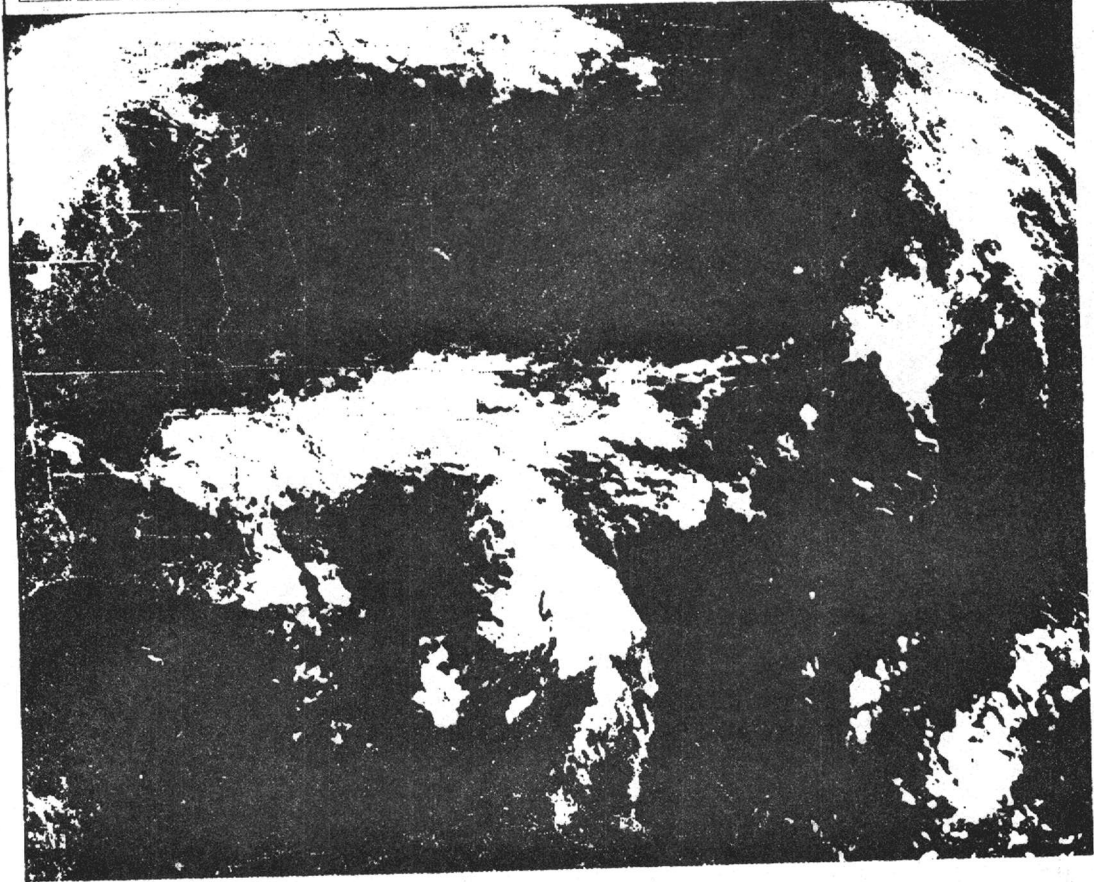
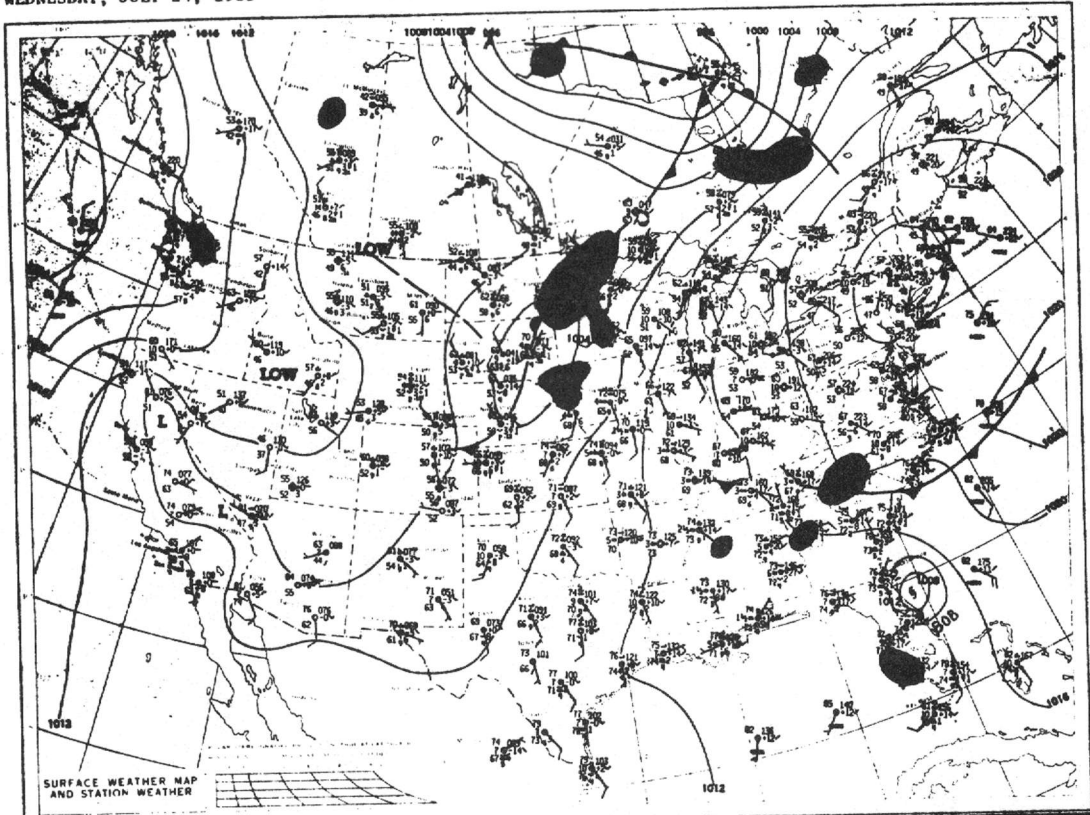
MONDAY, JULY 22, 1985



TUESDAY, JULY 23, 1985



WEDNESDAY, JULY 24, 1985



APPENDIX B

Daily Rainfall Values at Various Locations During Tropical Storm Bob

MRF	Station Name	County	7/22	7/23	7/24	Time	Total
227	S-79 Franklin Lock	Lee	0.15	0.60	0.40	8:00 a	1.15
250	Alva Farms	Lee	0.22	0.50	0.03	8:00 a	0.75
6093	Ft. Myers	Lee	0.53	1.49	0.09	8:00 p	2.11
6047	Naples	Collier	0.69	7.66	2.06	4:00 p	10.41
370	Royal Hammock State Park	Collier	1.10	13.98	0.25	Midnight	15.33
242	So. Fla. Field Lab-USDA Immok.	Collier	1.20	0.50	0.54	4:00 p	2.24
284	Bay West Nursery	Collier	1.10	2.00	2.97	8:00 a	6.07
6048	Everglades City	Collier	7.00	14.50	0.00	8:00 a	21.50
243	Corkscrew Sanctuary	Collier	0.90	1.30	0.80	8:00 a	3.00
7045	Felda	Hendry	0.31	0.80	0.25	8:00 a	1.36
63	Clewiston Field Station	Hendry	2.43	1.98	0.05	Midnight	4.46
142	3R Ranch	Hendry	2.40	0.20	0.00	8:00 a	2.60
7039	Clewiston Corps of Engineers (HGS2)	Hendry	0.03	1.91	0.03	8:00 a	1.97
286	Devil's Garden	Hendry	0.00	0.70	T	8:00 a	0.70
6038	Moore Haven Lock 1	Glades	1.27	0.66	0.11	8:00 a	2.04
52	S-131	Glades	0.09	0.04	0.09	Midnight	0.22
198	S-4	Glades	2.41	1.93	0.05	"	4.39
152	S-129	Glades	0.92	0.47	0.08	"	1.47
64	Ortona Lock	Glades	0.03	0.51	0.00	8:00 a	0.54
6032	Ft. Pierce	St. Lucie	0.13	2.60	0.05	9:00 a	2.78
37	Ft. Pierce Field Station	St. Lucie	1.96	1.37	0.00	Midnight	3.33
6082	Stuart IN	Martin	1.40	0.51	0.73	4:30 p	2.64
49	St. Lucie Lock	Martin	0.00	0.45	0.06	8:00 a	0.51
51	Port Mayaca Lock (COE)	Martin	0.00	0.50	0.05	8:00 a	0.55
150	S-135	Martin	1.05	1.36	0.02	Midnight	2.43

Appendix B - continued

<u>MRF</u>	<u>Station Name</u>	<u>County</u>	<u>7/22</u>	<u>7/23</u>	<u>7/24</u>	<u>Time</u>	<u>Total</u>
6075	West Palm Beach Airport	Palm Beach	0.32	2.17	1.07	Midnight	3.56
6074	Loxahatchee	Palm Beach	0.00	0.96	0.06	5:00 p	1.02
373	374 LaMancha Av., Royal Palm Beach	Palm Beach	0.09	0.20	0.19	6:00 a	0.48
315	419 Sequoia Dr., WPB	Palm Beach	0.24	0.53	2.07	7:30 a	2.84
183	S-2	Palm Beach	1.52	0.05	0.40	Midnight	1.97
69	S-3	Palm Beach	2.71	0.05	0.20	Midnight	2.96
54	Pratt & Whitney	Palm Beach	0.40	0.00	0.60	Midnight	1.00
79	Manatee Plantation	Palm Beach	0.00	0.00	1.95	8:00 a	1.95
208	Jupiter Fire Station	Palm Beach	0.65	0.00	T	8:00 a	0.65
81	Lake Worth Rd & E1 (LWDD)	Palm Beach	1.27	0.30	3.49	Before noon	5.06
84	Boynton Rd & Military Tr (LWDD)	Palm Beach	1.08	0.83	4.15	Before noon	6.06
213	Rangeline & Lateral 39 (LWDD)	Palm Beach	1.09	0.80	5.92	Before noon	7.81
6119	Belle Glade Experiment Sta.	Palm Beach	0.78	1.08	0.55	8:00 a	2.41
7041	Canal Point @ Hurricane Gate 5	Palm Beach	0.00	0.00	0.20	8:00 a	0.20
222	West Palm Beach Field Station	Palm Beach	0.11	2.09	1.03	Midnight	3.23
76	S5A	Palm Beach	0.30	0.25	0.00	Midnight	0.55
95	S-6	Palm Beach	1.12A	2.35	0.23	Midnight	3.70
151	Ft. Lauderdale Field Station	Broward	0.51	1.49	4.54	"	6.54
99	S-7	Broward	0.15	4.20	0.72	"	5.07
115	S-9	Broward	0.74	5.98	0.40	"	7.12
6069	Ft. Lauderdale	Broward	1.60	3.83	1.70	5:00 p	7.13
145	S-140	Broward	0.00	3.94	0.41	Midnight	4.35
6126	Homestead Experimental Station	Dade	0.01	2.86	1.26	8:00 a	4.13
7065	Miami WB Airport	Dade	0.64	2.40	0.34	8:00 p	3.38
9098	Tamiami Airport	Dade	0.45	3.10	1.20	Noon	4.75
6059	125 S.W., Miami	Dade	0.10	1.78	1.47	8:00 a	3.35
117	Miami Field Station	Dade	0.02	1.98	3.35	Midnight	5.35
121	Homestead Field Station	Dade	1.58	0.64	2.09	"	4.31
6054	Tamiami Canal @ 40 Mile Bend	Dade	0.20	0.88	2.45	8:00 a	3.53
124	S-18C	Dade	0.07	3.30	0.00	Midnight	3.37
122	S-20F	Dade	0.43	1.75	0.00	"	2.18
123	S-20	Dade	0.19	2.55	0.00	"	2.74
302	S-331	Dade	0.12	4.10	0.01	"	4.23

Appendix B - continued

<u>MRF</u>	<u>Station Name</u>	<u>County</u>	<u>7/22</u>	<u>7/23</u>	<u>7/24</u>	<u>Time</u>	<u>Total</u>
6125	Flamingo	Monroe	0.03	0.90	0.89	8:00 a	1.82
41	S-68	Highlands	1.35	0.00	0.00	"	1.35
44	Okeechobee Field Station	Okeechobee	0.17	0.00	0.07	Midnight	0.24
38	S-65C	Okeechobee	0.08	0.05	0.00	"	0.13
45	S-65E	Okeechobee	0.05	0.13	0.02	"	0.20
43	S-65D	Okeechobee	0.00	0.00	0.00	"	0.00
144	S-133	Okeechobee	0.11	0.07	0.00	"	0.18
27	S-65	Polk	0.00	0.00	0.00	"	0.00
32	S-65A	Osceola	0.00	0.00	0.00	"	0.00
9	Kissimmee Field Station	Osceola	4.00	0.00	0.00	"	4.00

Notes: A = Accumulation
T = Trace