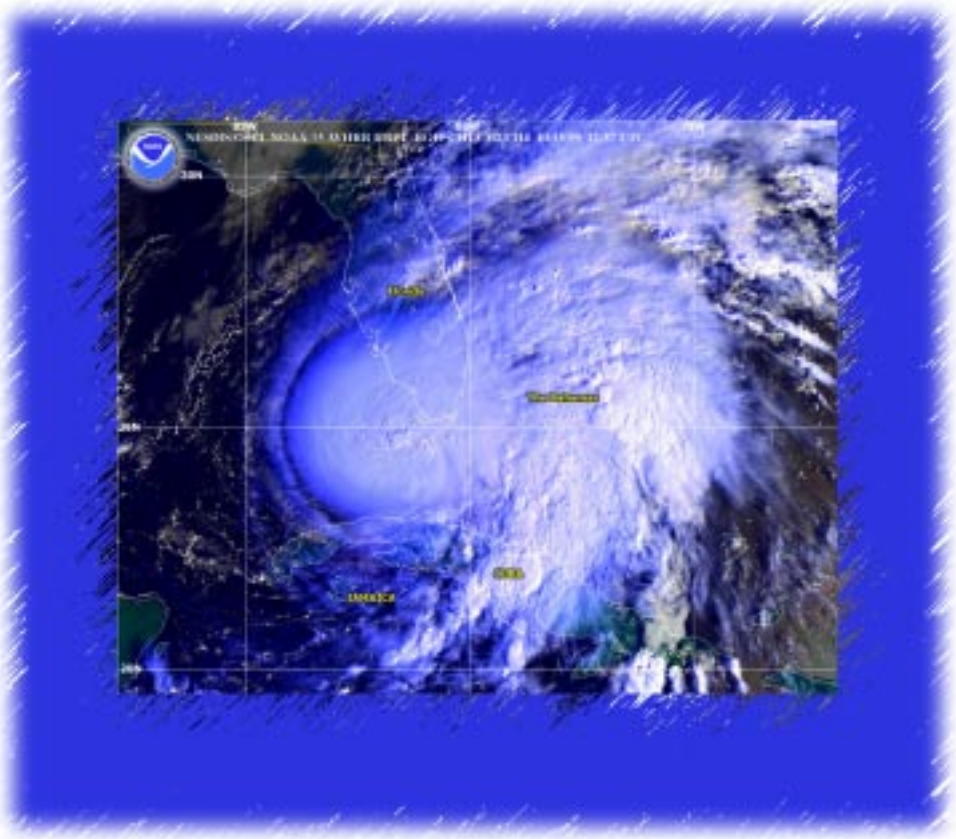
Hurricane Irene



South Florida Water Management District
AFTER-ACTION ASSESSMENT
December 9, 1999

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COVER PHOTO: Hurricane Irene as it makes landfall near Flamingo, Florida on October 15, 1999.

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1. Introduction

By memorandum dated October 26, 1999 (see Appendix A), the Executive Director requested an internal, after-action assessment of District operations during Hurricane Irene. Two major areas were requested to be focused on: District Operations, and Operating Criteria.

Five questions were posed regarding District operations:

1. Did we operate according to our approved criteria?
2. Did our infrastructure perform as intended?
3. Did our workforce perform as intended?
4. Did we react early enough?
5. Could we have done anything better?

Two questions were posed regarding operating criteria:

1. Have we found significant shortcomings in the criteria?
2. Are there modifications we might recommend for better system performance?

Objective, Scope, & Methodology

The principal purpose of the assessment was to "identify possible system improvements."

The Inspector General was requested to provide support during the course of the review.

The report that follows addresses the pertinent issues surrounding the District's performance prior to, during, and following Hurricane Irene. While this effort is primarily an engineering assessment, it is beyond the scope of the report to evaluate the return frequency of the rainfall associated with the event or to assess operations of federally controlled structures. However, the magnitude of Hurricane Irene can be judged by the fact that on October 15, 1999, it dropped over nine inches of rainfall, on average, across Palm Beach, Broward, and Miami-Dade Counties, and that the three-day rainfall totals at specific measuring sites throughout this area ranged between 10.88 and 17.47 inches.

Also, in the interest of time and practicality, this assessment has been largely confined to District water control facilities within those populated or agricultural areas that experienced the most significant impacts from the storm. This includes locations within the counties mentioned above, plus Martin and St. Lucie Counties. However, it does not include an assessment of the impacts to the water conservation areas and Lake Okeechobee, which have been subjected to great stress due to all too often high water conditions brought about by excess rainfall and the environmental shortcomings of the

Central and Southern Florida Flood Control (C&SF) Project (see Appendix C). The Central and Southern Florida Project Comprehensive Review Study (The Restudy) addresses these issues.

In order to accomplish the assigned tasking and be responsive to the questions posed, the following activities were undertaken:

- Interviews were conducted with District field and pump station personnel, District service center personnel, District water managers, the District emergency manager, and District water resource regulation personnel.
- Discussions were held with representatives of certain secondary drainage districts and the United States Army Corps of Engineeers (USACE) water operations staff.
- Attended various forums addressing Hurricane Irene impacts and concerns.
- Flew over impacted areas in Miami-Dade County and visited various water control structures.
- Reviewed operating criteria and operating data for selected structures.
- Reviewed meteorological data and forecasts leading up to Hurricane Irene.

Due to time constraints, the operations of every District water control structure and the performance of every waterway could not be reviewed. Our efforts were, therefore, concentrated within basins that experienced the more severe impacts from Hurricane Irene. This included L-31N/L-31W/C-111 (South Dade Conveyance System), C-2, C-3, C-4, C-9, C-11, C-16, C-51, L-8, C-17, C-23, and structures located in the EAA.

Those water control structures selected were deemed to be the most critical and representative within the basin. In determining whether the District complied with the criteria for the selected structures, the criteria were first obtained from the Structure Books located on the District internal web site, or, in the case of the South Dade Conveyance System, Test Iteration 7 of the Experimental Water Deliveries Program. Next, relevant operating data were obtained and reviewed. Due to time constraints, we did not corroborate or validate this data. We also conducted several discussions with District water managers regarding structure operations. Finally, a judgment was made as to whether we complied with the operating criteria.

In assessing the performance of our workforce and our reaction time, we considered the input of key field and office staff. Working hours and conditions were reviewed with an eye toward the factors of safety and fatigue.

Based on the findings, conclusions were reached and recommendations made. It is important to note that the conclusions and recommendations set forth in this report are not only the result of this review and assessment, but represent over thirty years of experience in system design, construction and operation. Moreover, the support of the Inspector General provided an independent focus that stimulated objectivity and helped honor the critique and corrective action format that is the convention of the auditing profession. However, it should be noted that this report is not an audit conducted in accordance with generally accepted government audit standards.

It is hoped that the product of this work will help bring better balance to our water resources mission.

Executive Summary 2.

District Operations

1. Did we operate according to our approved criteria?

For the most part, we found that the structures that we reviewed were operated in accordance with the criteria based on our understanding and interpretation of that criteria. The operating data for twenty-three structures was examined starting on October 12, approximately three days prior to Hurricane Irene making landfall in South Florida, through the end of the month. Based on our review we have concluded that all of the structures reviewed, with the exception of three, were operated in accordance with the criteria. The exceptions being S-331, S-197 and S-44.

S-331 had an average daily water level upstream of the structure that minimally exceeded the target range on two days. S-197 was closed prematurely one day and reopened the following day. Finally, after Hurricane Irene had passed we noted that S-44 was being operated at a setting lower than the specified low setting per the criteria. We were told that this was done to allow the secondary system to make emergency discharges.

2. Did our infrastructure perform as intended?

Our interviews with field personnel indicated that the infrastructure performed as intended. Even though the system was pushed to its limits, and in some cases beyond, with maximum rainfall in some areas exceeding 17 inches, we received few reports of infrastructure breakdowns. Instances where there were problems reported included S-332D, which experienced problems with two of its five pumps. Additionally, at S-13 minor problems were also encountered with vegetation blocking the intake bays, requiring manual removal under hazardous conditions. At S-7, one of the three pump units was inoperable throughout the storm period due to a pump bearing failure on September 22. A number of recommendations to improve flood control conditions in the C-51 and L-8 areas are detailed in the recommendations.

3. Did our workforce perform as intended?

It was found that the workforce as a whole performed in accordance with the job requirements and the needs of the District. In many cases, individual and crew performance was commendable. There were no reports received of any problems encountered with the workforce. On the contrary, many individuals worked long hard hours in order to relieve the flooding left behind by Hurricane Irene. In this regard, we did find some evidence of an over-extended workforce and an increased exposure to accidents due to employee fatigue.

4. Did we react early enough?

The information collected and analyzed clearly establishes that we took the appropriate action at the appropriate time. We did find, however, that in the handling of the South Dade Conveyance System flood control demands we should have elevated the decision-making to the Executive Director level. We should also note that flood control, as with the other District mission elements, is important year round not just two days prior to a heavy rainfall event or just before the start of the wet season. Flood control, as a mission element, should be elevated to the same relative importance as our other mission elements and should include planning considerations leading to system improvements.

5. Could we have done anything better?

During our interviews, many observations and ideas for improvement were suggested. Some of those ideas are mentioned here and detailed in the report. Some suggestions involved straight-forward infrastructure improvements such as improving canal conveyance capacity, adding a trash rake to pump station S-13, considering partial automation of S-197, or reevaluating the frequency of levee mowing. However, most of the recommendations contained in this report involve moving forward with major initiatives and projects, such as the Modified Water Deliveries and C-111 Improvement projects.

OPERATING CRITERIA

1. Have we found significant shortcomings in the criteria?

The only area where we noted any significant shortcomings in the criteria was in the South Dade Conveyance System that is governed by Test 7. These criteria do not allow for adequate flexibility in operating the system during emergency conditions.

2. Are there modifications we might recommend for better system performance?

Modifications to the flood control criteria covering the South Dade Conveyance System, the feasibility of providing pumping assistance measures in the C-4 and C-9 Canals, and adhering to our current canal cleanout schedules are covered in the report and are aimed at bettering system performance.

3. Background

The South Florida Water Management District operates and maintains the primary flood control and water supply system within its sixteen county area of jurisdiction. The major portion of that system includes the federally designed and constructed Central and Southern Florida Flood Control Project, hereinafter referred to as the C&SF Project (see Appendix C). The District is responsible for all C&SF Project facilities, other than those certain facilities on the perimeter of and providing the primary outlet for Lake Okeechobee, and those structures within the three water conservation areas, which remain under the jurisdiction of the U. S. Army Corps of Engineers (USACE).

Most of the originally authorized C&SF Project facilities were constructed during the period 1950-1972. While this construction timeframe may tempt observers and practitioners to refer to these facilities as "antiquated", it is, in many instances, a misnomer when applied to the flood control features that currently exist. Incomplete or under-designed may be more appropriate. However, it must be recognized that system improvements and efficiencies that help exploit full capacity utilizations have been implemented, including (a) the addition of a communication and control system that provides real time hydro-meteorological data and automated remote operational capabilities over most of the Project; (b) round-the-clock operational monitoring and control; (c) the repowering of major pumping stations at S-6, S-9, and S-13; (d) the ongoing mechanical and electrical system upgrades at our major water control structures; and (e) the overall waterway and structure gate maintenance programs of the District.

In addition to the C&SF Project, the District operates and maintains numerous other water control facilities including (1) those canals, levees, and water control structures in eastern Hendry County, built in 1982-83, that are not part of the C&SF Project, but provide for primary flood control within that service area, and (2) those Everglades Drainage District (EDD) facilities that have primary flood control features, but are also not part of the C&SF Project. The Big Cypress Basin (BCB) (see map page 52), a sub-basin to the District, also operates and maintains a network of canals and water control structures that are not a part of the C&SF Project.

Counties impacted by Hurricane Irene.

Focus of the Report

This after-action assessment requires us to focus on those units that carry out the water control and field operations tasking of the District. They reside within the executive domain of Water Resources Operations and are comprised of 585 personnel representing managers, supervisors, engineers, scientists, technicians, craftworkers and administrators.

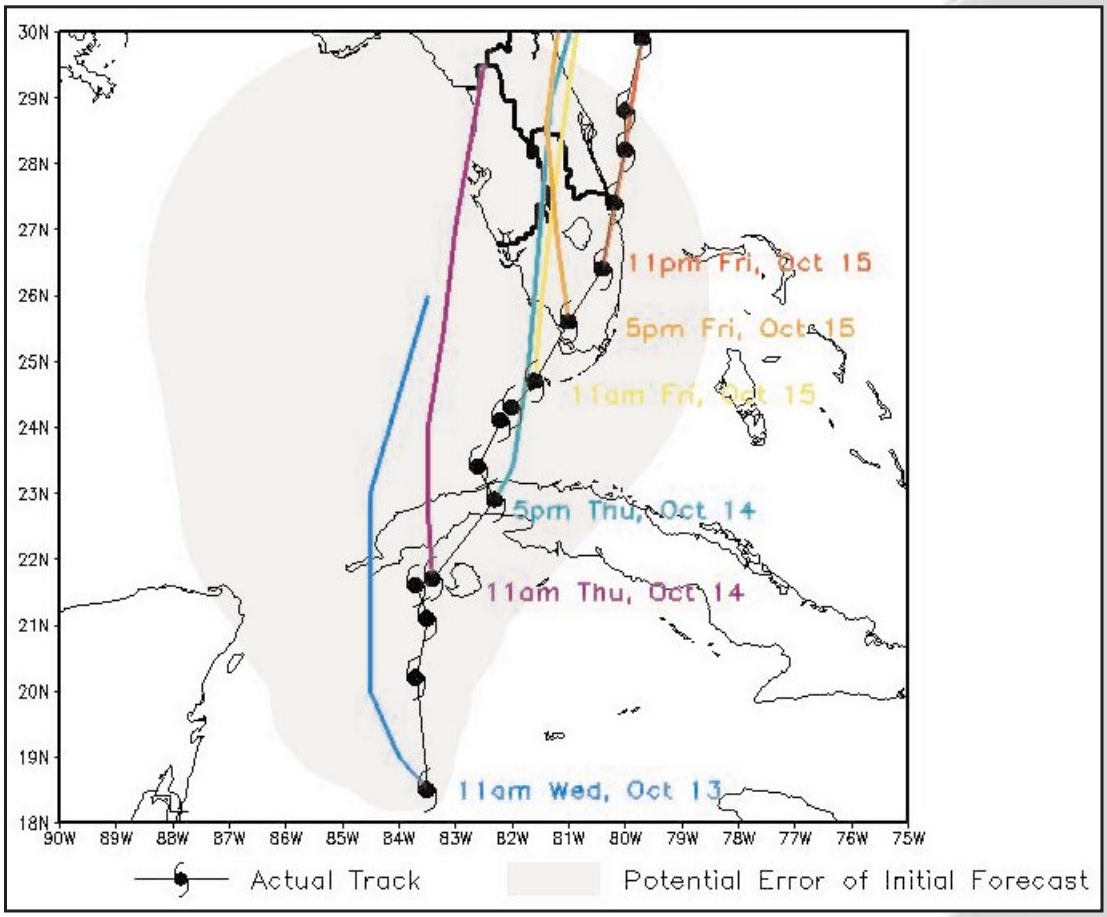
The Water Control Operations Department is an integral unit within Water Resources Operations. It consists of an Operations Control Center, a Water Operations Management section, a Meteorological Analysis section, and an Environmental Operations section. The unit provides monitoring and control of the C&SF Project, which today includes 1,800 miles of canals and levees, 25 major pumping stations and about 200 primary water control structures. Monitoring and control of this primary flood control and water supply network requires a coordinated decision-making process with the USACE and with other District departments and executives. Liaison and coordination with certain other local, state, and federal agencies and certain stakeholders also represent a tasking of this unit. With the exception of the BCB, all other non-C&SF Project systems are also monitored and controlled by the Water Control Operations Department. Local monitoring and control of the BCB water control system by the Basin Administrator is the most effective method of operations, since the BCB system does not interconnect to the other systems of the District. However, communications and information transfer prior to, during, and following a storm event remain a vital activity between the District and the BCB.

Field Operations North, Central, and South represent the three department level units within Water Resources Operations that are assigned the responsibility of carrying out all field activities necessary for the operation and maintenance of the District's primary flood control and water supply systems. This critical activity involves the work of seven field stations strategically located throughout the District to carry out field and pumping station tasking. An eighth field station located in Naples carries out a similar tasking under the BCB Administrator and the field station Superintendent.

Another function within Water Resources Operations that is critical to our water control activities is the System Control and Data Acquisition (SCADA) section. This unit provides the technical skills and wherewithal to ensure the operational readiness of the District's communications and control system.

THE EVENT

The developments leading up to Hurricane Irene demanded a high degree of water management skill in (1) grasping the effects of antecedent conditions; (2) understanding the capabilities and operating criteria of the primary flood control system; (3) assessing the rainfall threat; (4) preparing for impact; and (5) taking the necessary pre-storm, storm, and post-storm actions in a coordinated and timely fashion. This review will address these items within the areas of greatest impact.



The evolution of the National Hurricane Center forecast tracks. The lightly shaded area shows the potential error of the initial forecast. Irene struck well within the predicted cone of error.

CHRONOLOGY OF FORECASTS & ACTIONS

Monday, October 11

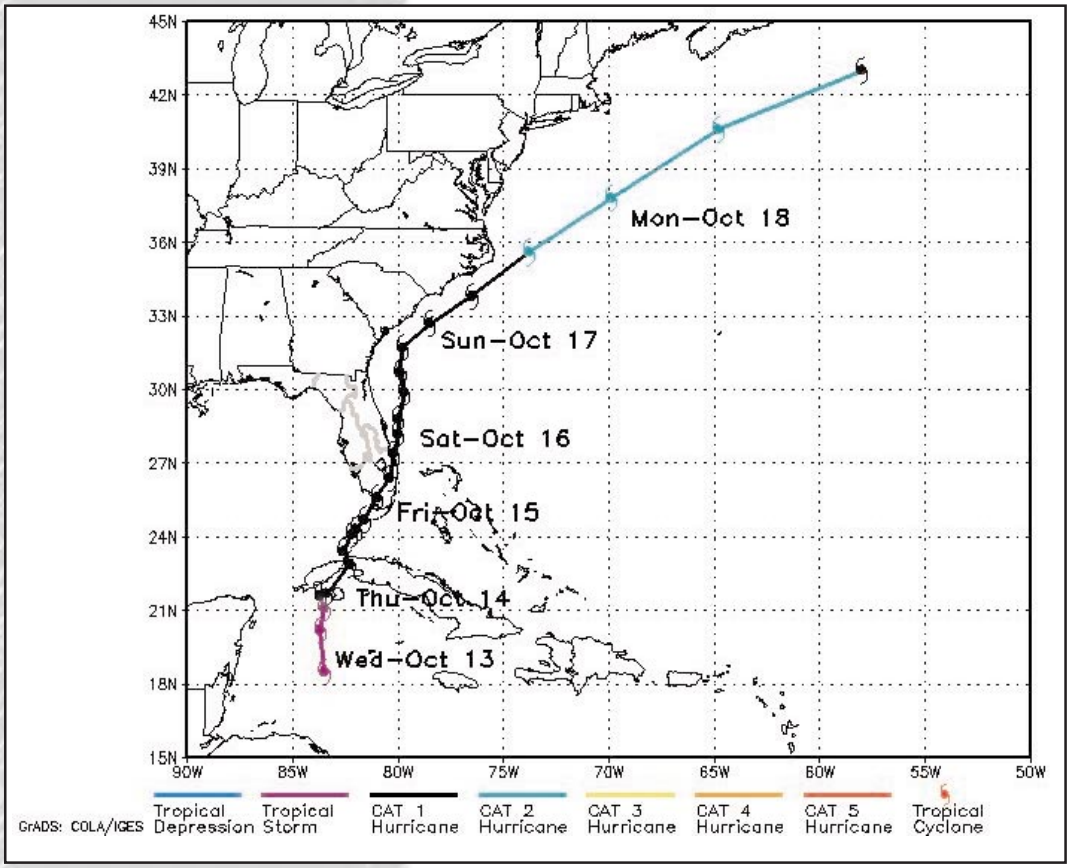
District Tropical Conditions Report first mentions a large area of disturbed weather over the southwest Caribbean. This disturbed area will become Irene.

Tuesday, October 12

The District Tropical Conditions Report states that conditions are favorable for slow development over the next couple of days, as this system drifts toward the northwest. While direct impacts to the District from any development are uncertain, District forecasters expect increases in winds and rains over south Florida this week.

The rainfall forecast is for scattered showers and thunderstorms on Friday and Saturday.

On Tuesday afternoon, the District's Emergency Manager issues



Actual storm track of Irene from October 13-18, as it progressed from a Tropical Storm to a Category 2 hurricane after leaving the east coast of Florida.

Emergency Bulletin #1, stating that the area of disturbed weather is likely to develop into the next tropical depression. The District was put on Increased Readiness.

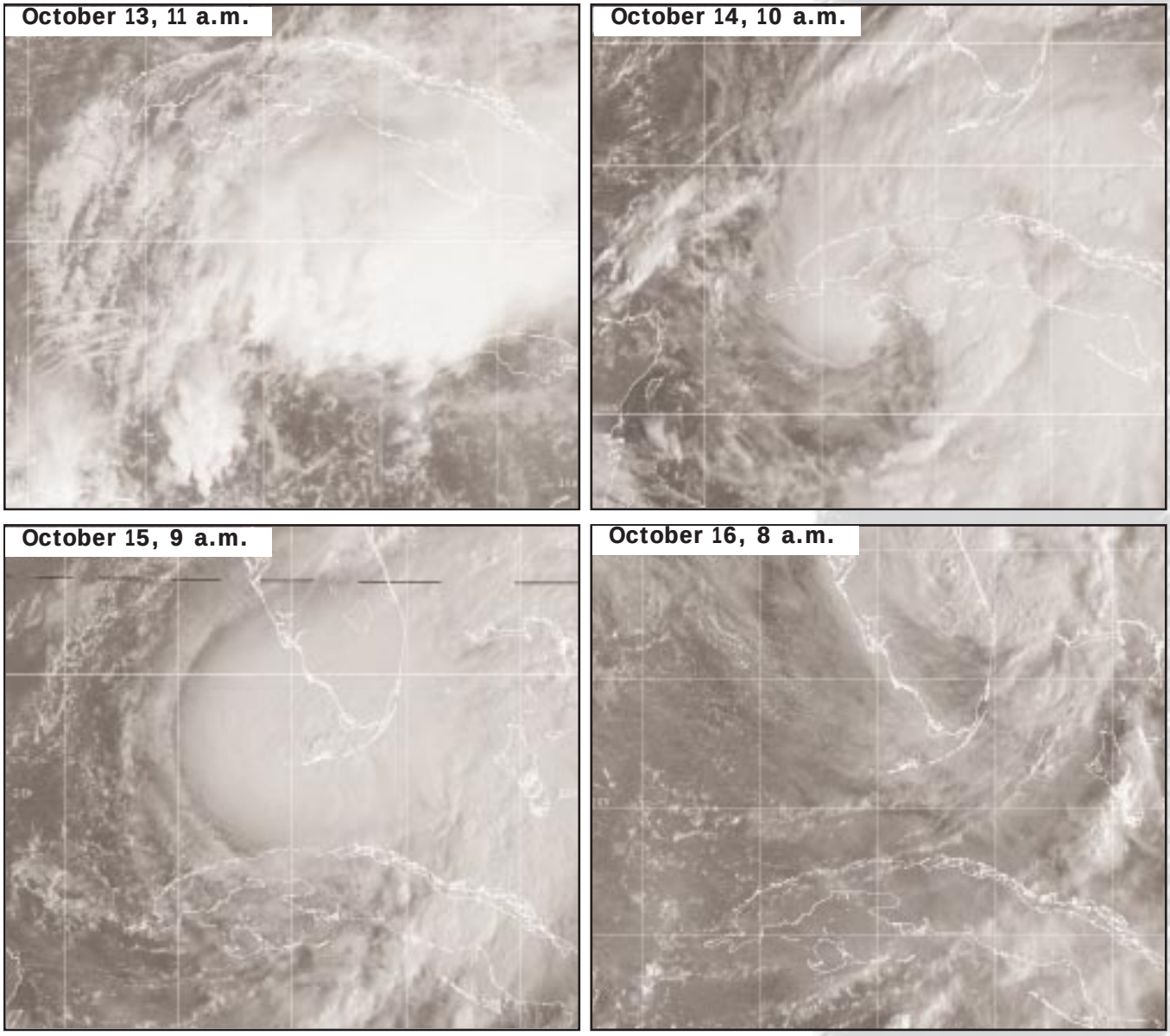
The District began 24-hour monitoring – activating Emergency Management and the Water Control Operations Department. Individual contacts were made with the Chapter 298 water control districts within the region. The District also began daily teleconferencing with the emergency management personnel of counties most likely to be affected, based on the predicted track of the storm.

Wednesday, October 13, 1999

District meteorologists predict that conditions are favorable for continued development to the next tropical depression or tropical storm as early as this morning. They further predicted that the system is likely to head into the southern Gulf of Mexico by Friday, with the possibility of a turn toward the Florida peninsula by the weekend, which will result in widespread heavy to excessive rainfall over a large portion of south Florida.

Later in the morning, the National Weather Service issued a Special Tropical Disturbance Statement indicating that the area of low pressure in the northwestern Caribbean Sea has become better organized and that a Tropical Depression is forming.

At 11:00 a.m. the National Weather Service issues Tropical Storm Irene Advisory #1. The District predicts heavy to excessive rainfall beginning in the Keys Wednesday evening, and spreading northward Thursday and through the weekend.



Satellite images depicting Hurricane Irene's track.

The District issues Emergency Bulletin #2 for Tropical Storm Irene. This bulletin put the District in Condition 4. The bulletin emphasized that, because this is a late season Gulf of Mexico storm (which tend to be highly unpredictable), forecast errors could be large, in terms of both timing and location. The bulletin noted that departments should be prepared for rapid and/or unexpected changes in future forecasts.

The afternoon of October 13, the National Weather Service issues

Tropical Storm Irene Intermediate Advisory #1A – advising that all interests in Florida, especially South Florida and the Keys, monitor the progress of Irene. District meteorologists predict that District-wide average rainfall of 6" is possible over the period.

The National Weather Service issues Tropical Storm Irene Intermediate Advisory #2 at 5:00 p.m. This report says Irene may reach western Cuba as a hurricane, and also may pose a threat to Florida. Additionally, a Hurricane Watch was issued for the lower and middle Florida Keys west of Craig Key. District meteorologists predicted that under the current forecast track, heavy to excessive rainfall remains the biggest threat to the District – beginning in the Keys in the evening and spreading northward Thursday through the weekend.

District Emergency Bulletin #3 for Tropical Storm Irene is issued placing the Keys in Condition 3, with the rest of the District remaining in Condition 4. Heavy rains of 6-12" were expected along the path of Irene. At this point, the District's Emergency Operations Center (EOC) was at Level 1 activation.

With the Level One Activation of the District's EOC, the District began teleconferencing with its field stations throughout the region, and Big Cypress Basin. A governmental liaison was also deployed to the Okeechobee County EOC, because this was the area forecast by the National Weather Service to be hardest hit.

Based on the day's forecasts, the District initiated a pre-storm draw-down of the coastal canal network, Everglades Agricultural Area (EAA) and the major lakes in the Kissimmee Upper Chain of Lakes. (This system-wide draw-down was conducted based on forecasts that predict a system-wide impact.) Structures located on the coastal ridge in south Miami-Dade County were opened, and pumping stations (throughout the 16-county system) were staffed in preparation for the storm.

At 8:00 p.m. the National Weather Service issued Tropical Storm Irene Intermediate Advisory #2A, indicating that Irene is strengthening.

Thursday, October 14, 1999

At 5:00 a.m. Irene becomes a Hurricane with the issuance of Hurricane Irene Advisory # 4 by the National Weather Service. The Hurricane Watch remains in effect for the lower and middle Florida Keys.

Under this scenario, District meteorologists expect heavy to excessive rainfall continuing to be the biggest threat to the District, with the potential of 5-6" falling District-wide from Thursday through Saturday.

National Weather Service issues Hurricane Irene Intermediate Advisory # 4A at 8 a.m.; and #5 at 11 a.m. stating that a Hurricane Watch remains in

effect for the lower and middle Florida Keys, and it is expected that a Tropical Storm Warning will still be required later in the morning. In addition, a Hurricane Watch was issued for the west coast of Florida, from Flamingo to Boca Grande. District meteorologists reiterate that under the current scenario, heavy to excessive rainfall remains the biggest threat to the District.

Shortly after noon, the District issues Emergency Bulletin #4 and and later in the day, #5. Most of the District remains in Condition 3, except the Florida Keys, which are in Condition 2. The phone bank has been activated and the District's EOC remains at a Level 1, monitoring. Tropical Storm force winds can be expected in the Keys and the west coast on Friday, and the Kissimmee Valley on Saturday. Heavy to excessive rains will continue throughout the District through Sunday.

Hurricane Irene Intermediate Advisory #5A is issued at 2 p.m. by the National Weather Service. Irene makes first landfall over the Isle of Youth, Cuba. The District local maximum rainfall for eastern Miami-Dade, Broward and Palm Beach Counties is forecast to be 8", 6", and 6", respectively – up 2-4" from earlier District forecasts.

The 5:00 p.m. Hurricane Irene Advisory #6 establishes that the Hurricane Warning for the Dry Tortugas is extended to south of Florida City, including the Keys. A Tropical Storm Warning and a Hurricane Watch are issued from Florida City to Jupiter Inlet and for Lake Okeechobee. Heavy rains of 10-20", with locally higher amounts are associated with Irene, the Weather Service says. The District predicts heavy to excessive rainfall, especially over eastern sections, with the potential of 12-15" falling through Saturday night. Additionally, hurricane force winds are predicted south through west of Lake Okeechobee with a storm surge of 3-6' on the southwest coast late Friday. Rainfall remains the biggest threat over eastern sections of the District.

District Emergency Bulletin #6 is issued at 7:11 p.m. District operations in the Keys are now in Condition 1 – in preparation for the onslaught of Category 1 Hurricane force winds. District operations in Broward, Charlotte, Collier, Dade, Glades, Hendry, Highlands, Lee, Martin and Palm Beach Counties are now in Condition 2 for hurricane force winds. District operations in Orange, Osceola, Polk, St. Lucie and Okeechobee Counties remain in Condition 3. This bulletin stresses the fact that the hurricane's track was, and is highly uncertain. Effective Friday morning at 7:30 a.m., the District's EOC will be at a Level 2 activation.

The 11:00 p.m. National Weather Service Intermediate Advisory # 7 states that conditions are expected to deteriorate over south Florida on Friday. A Hurricane Warning is extended, with a forecast for heavy rains of 10-15" and locally higher amounts. The District reiterates watches and

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
HURRICANE IRENE RAINFALL FORECASTS

DAY	FORECAST (Thursday through Sunday) District-wide	Area Averages	Local Maxima	Focus
Tuesday	2"+	---	---	Heavy Southeast by Friday
Wednesday	6"	---	---	Widespread Heavy to Excessive - Heaviest East
Thursday	5-6"	10-15"	20"	Heavy to Excessive District-wide
Friday Morning	7"	12-15"	20"	Widespread Heavy to Excessive - Heaviest West Coast
Friday Afternoon	4-5"	---	---	Widespread Heavy to Excessive - Heaviest South and East
Saturday	4"	---	---	---
Observed	4.18"	9.15" (Lower East Coast)	17.47"	Heavy to Excessive South and East

warnings, again emphasizes the forecast for heavy to excessive rainfall, especially to the east, and cautions against hurricane force winds forecast to impact Lee and Charlotte Counties, with a storm surge of 4-6' predawn Saturday. Again, 12-15" of rain are forecast through Saturday night. District Emergency Bulletin #7 stresses the uncertainty of the track.

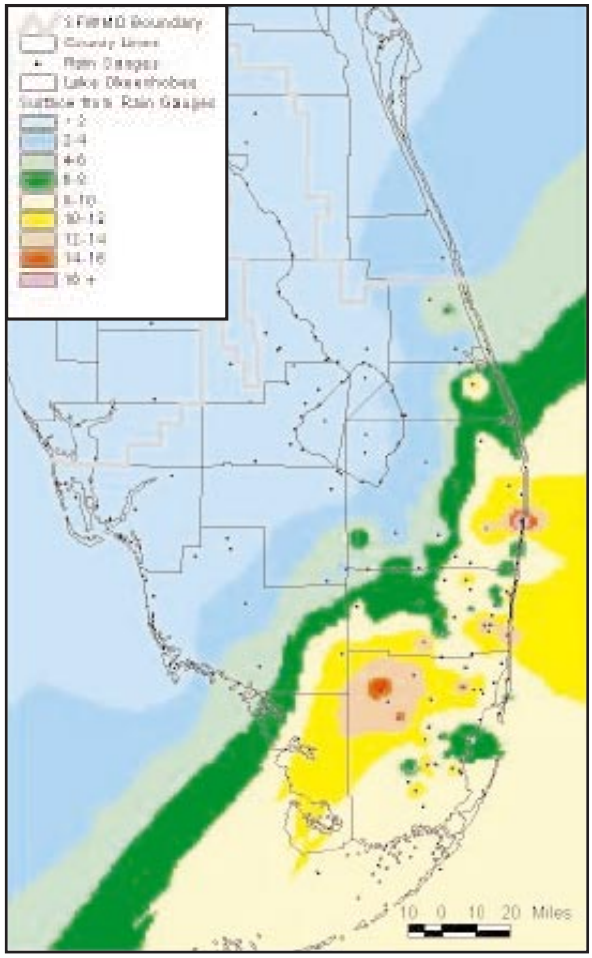
Other actions taken during the day Thursday, October 14, to prepare for the forecast excessive rainfall include:

- Activation and continued operation of the Citizen Emergency Information Phone Bank.
- Issuance by Governor Bush of Executive Order 99-258 declaring a State of Emergency.
- Deployment of governmental liaisons to Miami-Dade County EOC.
- Teleconferencing with secondary water control districts.
- Commissioning of two District pumps for the City of Sweetwater in Miami-Dade County by the State EOC.
- Continuing to lower canal stages in the Upper East coast and Palm Beach County – in advance of the expected rainfall.
- Operating coastal structures in Miami-Dade and Broward Counties to maximum capacity.
- Staffing of pump stations with night shifts, and continued lowering the system in preparation for heavy rains.
- Obtained Emergency Authorizations from the Florida Department of Environmental Protection (FDEP) for use of the recently constructed S-332D Pump Station on L-31W in south Miami-Dade County, and STA-5 in the western Everglades Agricultural Area.

Friday, October 15, 1999

Hurricane Irene Makes Florida Landfall

Intermediate Advisory # 7A issued at 2 a.m. and #8 issued at 5 a.m. by the National Weather Service, noting that the center of Irene is re-forming farther to the east and resumes northward motion. Tropical Storm Warnings and hurricane watches are extended northward along Florida's east coast, with a forecast of heavy rains of 10-15", and the risk of isolated tornadoes over portions of south Florida and the Keys.



Rainfall Distribution – October 14-16, 1999

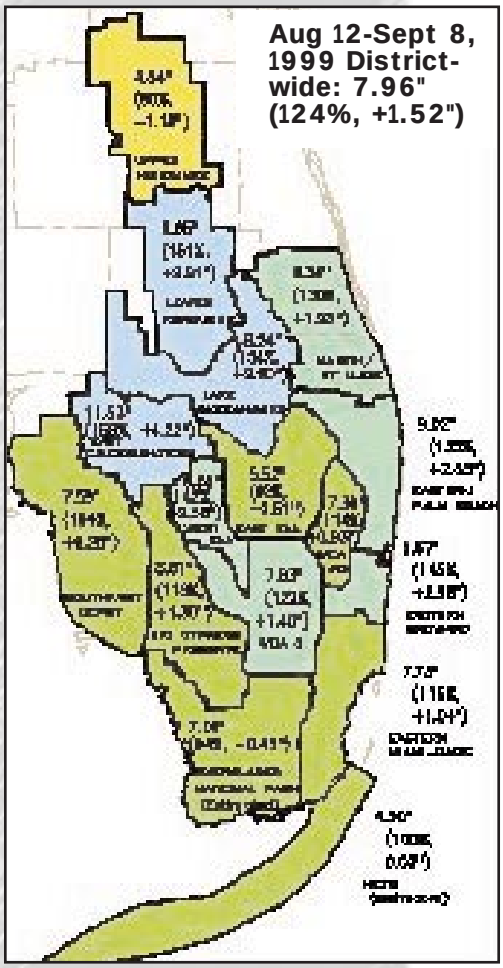
District Emergency Bulletin # 8 is issued. Operations in the Keys are now in Condition 0 for sustained tropical storm force winds. Operations in Dade, Broward, Palm Beach, mainland Monroe, Collier, Hendry, Lee, Charlotte, and Glades Counties are now in Condition 1. Operations in Highlands, Okeechobee, Martin, St. Lucie, Polk, Osceola, and Orange Counties are in Condition 2. This is the last Emergency Bulletin due to full activation of the District EOC at 7:30 am.

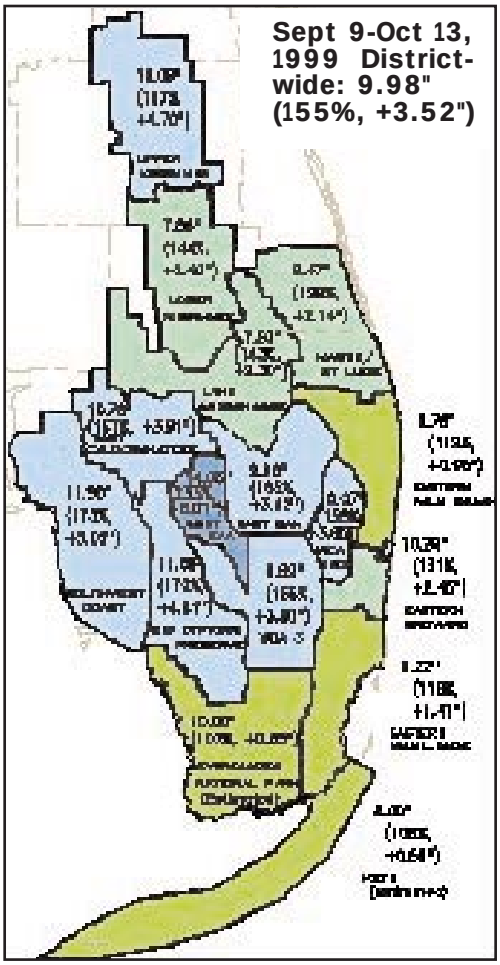
National Weather Service Advisory #9 and #10 state that all watches and warnings remain in effect, with 10-15"of rain and isolated tornadoes expected. At 11 a.m., the center of Irene is over Key West.

At 2:00 p.m., the National Weather Service Intermediate Advisory #10A indicates that Irene is approaching the southwest Florida coast. Tropical storm conditions with gusts up to hurricane force are spreading through Dade and Broward County. All warnings and watches remain in effect. Heavy rains and isolated tornadoes are a threat.

PRELIMINARY RAINFALL TOTALS FROM OCTOBER 14-16, 1999

MIAMI-DADE COUNTY	INCHES
Sweetwater	11.88
Miami International	10.99
Miami Field Station	13.93
East Everglades (S-331)	11.04
Homestead Field Station	13.50
Homestead Air Force Base	11.05
BROWARD COUNTY	
Pompano (S-37A)	13.20
Fort Lauderdale Field Station	14.08
Coral Springs	11.23
Coopertown	15.17
Hollywood	13.13
West Miramar	13.45
PALM BEACH COUNTY	
Boynton Beach(S-41)	17.47
Delray Beach	12.20
Palm Beach International	10.88
West Palm Beach Field Station	14.50





Heavy rainfall prior to Hurricane Irene made for wet antecedent conditions. Irene's rainfall contributed to make the 1999 wet season the third wettest since 1960 – only 1995 was wetter.

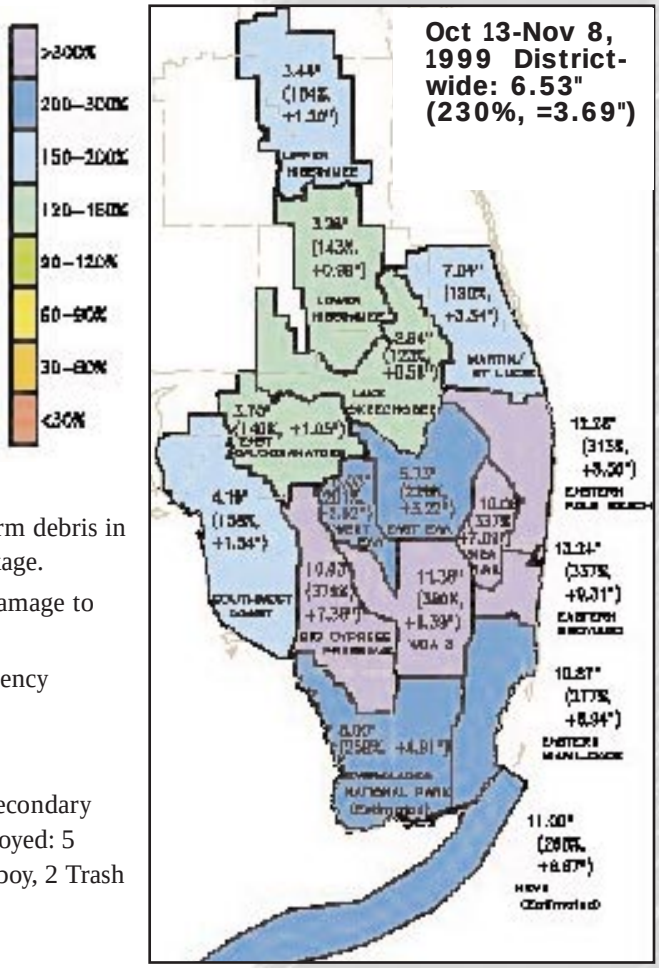
The 5:00 p.m. Advisory #11 states that the hurricane warning north of Bonita Beach to the Anclote Keys has been downgraded to a Tropical Storm warning. At the same time, a Tropical Storm Warning is extended northward, and is in effect from Florida City to Fernandina Beach, and for Lake Okeechobee.

At 11:00 p.m., Irene is located about 25 miles southwest of West Palm Beach, moving north-northeast. Irene is expected to continue in this general direction and move offshore into the Atlantic, and away from the District during the predawn hours. Very heavy to excessive rains and strong tropical storm force winds will continue east of Lake Okeechobee for the next few hours, but conditions will vastly improve District-wide by sunrise. The center of Irene moved off-shore near Jupiter just prior to midnight.

Other Actions taken on Friday, October 15 include:

- More frequent (twice daily) teleconferencing with the secondary drainage districts.
- A District liaison and hydrologist were deployed to the State EOC.
- Governmental liaisons were deployed to Broward and Martin County EOCs.
- USACE representation was in the District's EOC.
- The state commissioned one pump for the City of West Miami.
- Nine (9) Community Assessment Teams deployed to Miami-Dade, Broward, Palm Beach, Martin and St. Lucie Counties.
- Coastal water control structures remained configured to make maximum discharges.
- Pumping stations were operated 24-hours per day at maximum possible discharge.

SFWMD ACTIONS AFTER THE STORM



Saturday, October 16, 1999

- Aerial reconnaissance conducted for the Governor's Office to view impacted areas in South Florida.
- Aerial reconnaissance for Homestead and Miami, Broward and Palm Beach to assess flooding and related damage to impacted canals, structures and facilities.
- Once tropical storm force winds subsided, coastal water control structures were exceeding design flows in various locations along the lower east coast. Pumping stations continued to operate on a 24-hour per day basis at maximum possible discharge.

Monday, October 18

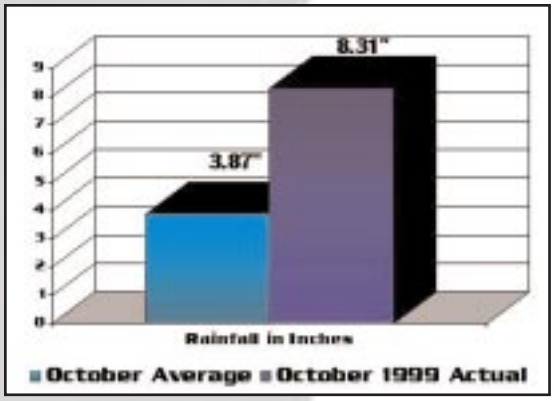
- State commissions District to remove trees and other storm debris in the C-3 Canal for City of Coral Gables to alleviate blockage.
- Aerial reconnaissance conducted to assess flooding and damage to impacted canals, structures and facilities.
- Provided GIS flood maps to State Department of Emergency Management.

Tuesday, October 19

- State commissions the District with debris clearance in secondary canals in Miami-Dade County. Equipment & Staff Deployed: 5 cranes with operators, 2 Towboats with operators, 1 Lowboy, 2 Trash Trucks, 14 Chainsaws with operators.
  Approximate cost of mission - $122,000
- State commissions the District to prepare computer modeling of sewage spill (sewage outflow, estuary model) for Intracoastal Waterway.
- Provided GIS flood maps to counties and FPL.

Wednesday, October 20, 1999

- President Clinton declares a Major Disaster (under the Robert T. Stafford Disaster Relief and Emergency Assistance Act,) for the State of Florida beginning on October 14, 1999, for the following counties: Broward, Miami-Dade, Martin, Monroe, Palm Beach, Okeechobee and St. Lucie, and for the contiguous counties of Collier, Hendry, Glades, Highlands, Polk, Osceola and Orange – due to heavy rains from Irene and antecedent conditions from previous events.
- 6-hour inspections on a daily basis of the L-8 levee.
- USACE/District teams inspect structures in southern Palm Beach County, northern Broward County, and the L-8 canal in the vicinity of the Lake Okeechobee Dike.
- State requests ten (10) District engineers be placed on standby to assist the State of Florida and local government with damage assessment as a



Average normal vs. actual rainfall totals for the month of October

part of State Response Team.

Thursday, October 21, 199

- Assess Corbett Wildlife Management Area overflow conditions at Indian Trail Reservoir discharge canal into the Corbett/Moss property.
- Provide GIS flood maps to Palm Beach County Planning and Zoning.

Friday, October 22, 1999

- EOC deactivates. Recovery operations continue, including: District will participate in FEMA's interagency meeting for levee repair; Preliminary damage assessment for State of Florida – $178 million; District damage assessment teams continue to inspect structures and canals for damages. Expect damage in areas/ with equipment that exceeded designed capacity.
- FEMA, State DCA, and the District to meet and identify flood mitigation projects within secondary and community systems.

METEOROLOGICAL CONDITIONS

Antecedent conditions contributed to the severity of Irene's impact. Rainfall for the period of August 12-September 8, 1999, was slightly above average at 7.96" or 124% of average. Heavy rains from September 9-October 13 resulted in a rainfall total of 9.98", or 155% of average, prior to rainfall from Hurricane Irene.

South Florida was inundated with rain when Hurricane Irene struck the peninsula on October 15. District-wide rainfall averaged over four inches. While the easterly track of Irene prevented excessive rains over and around Lake Okeechobee, more than 9" of rainfall on average, fell across eastern Palm Beach, Broward and Miami-Dade Counties.

Normal average rainfall for the month of October is 3.87". Actual rainfall total for October 1999 was 8.31" or 215% of average. Irene contributed to make the 1999 wet season the third wettest since 1960 – only 1995 was wetter.

4. Findings, Conclusions & Recommendations

Overall, the District's performance prior to, during, and following Hurricane Irene reflected favorably upon the experienced hands that are charged with operating and maintaining the primary flood control system complex. To be sure, this assessment found areas within the system and within our operational practices that need attention. These are more fully spelled out in the pages that follow and represent opportunities for improvement. In certain instances, other agencies are a part of the solution.

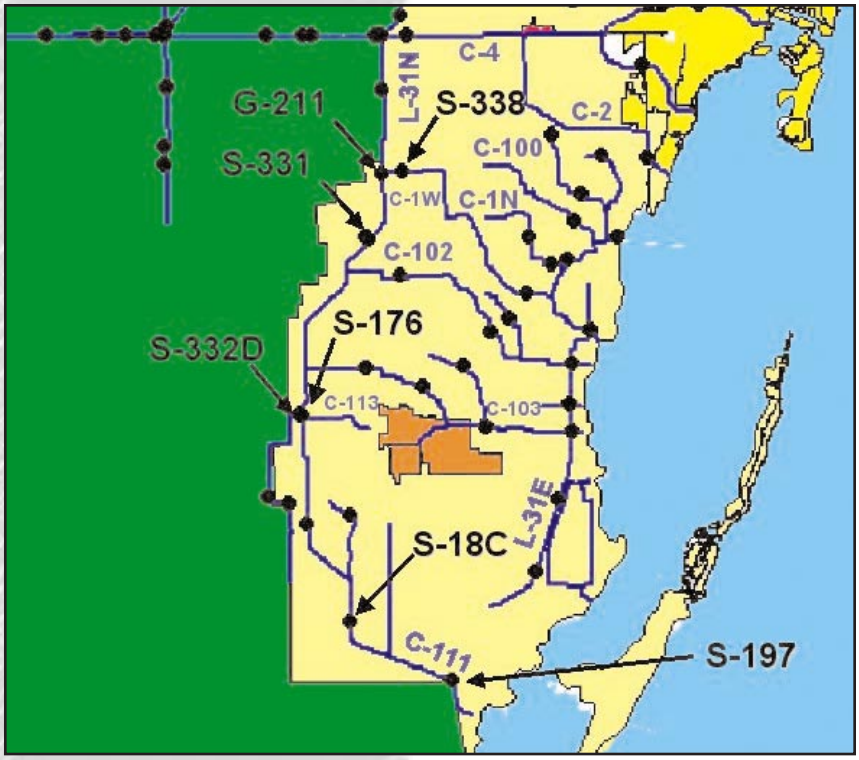
Miami-Dade County

South Dade Conveyance System

The operation of the South Dade Conveyance System is governed by Test Iteration 7 (Test 7) of the Congressionally authorized Experimental Program of Water Deliveries (EWD) to Everglades National Park (ENP). In addition, the C-111 General Reevaluation Report recommended project modifications designed to maintain existing flood protection and other C&SF project purposes in developed areas east of C-111 while restoring natural hydrologic conditions in the Taylor Slough and eastern panhandle areas of ENP. To date, only the S-332D pump station and the C-111 spoil mound removal features have been completed as part of the C-111 project.

The operating criteria for the South Dade Conveyance System are spelled out in a three-party agreement (the "Agreement") between the ENP, the United States Army Corps of Engineers (USACE), and the South Florida Water Management District (the "District") for test iteration 7 of the EWD. The test objectives are to evaluate methods to restore a more natural hydroperiod to ecosystems within ENP including Northeast Shark River Slough (NESRS) and Taylor Slough, enhance flow to Florida Bay via Taylor Slough, as well as reduce large freshwater discharges through S-197 into Manatee Bay and Barnes Sound.

The Agreement also states that one of the ultimate objectives is to "deliver water to NESRS and Taylor Slough in consonance with rainfall to the degree possible without compromising the flood control function." It also indicates that the specific flood control criteria described [within the agreement] would override normal operations during storm events, and points out that the criteria may be used at the discretion of the District's Director of Operations. The Agreement requires that the Director "shall obtain concurrence" from specifically named personnel in the USACE and ENP upon the next business day following the action taken. It is quite apparent that the operational criteria associated with Test 7, under the Experimental Program of Water Deliveries to Everglades National Park, created a special challenge to District water managers, given the wet antecedent conditions and the



South Dade Conveyance System

uncertainty of what would be the final track of Hurricane Irene.

It is important to note that the October 1995 *Environmental Assessment and Finding of No Significant Impact for Test 7* (EA) stipulated that a monitoring program be developed "to detect any significant adverse effects that would be cause to consider changes in the test, or termination of it." A monitoring schedule was established (EA, page 13 of Appendix D) and called for annual hydrological and ecological assessments with reports due on March 31 of each year beginning in 1997. Only the 1997 report was produced. No reports were prepared for 1998 and 1999. This is unfortunate since the very nature of this effort may have addressed some of the flood control issues now being debated following Hurricane Irene. For example, in the Flood Damage Assessment of Agricultural Crops in south Dade County, prepared by the Institute of Food and Agricultural Sciences, University of Florida, dated June 1997, the following statement is made: Flooding in the agricultural area "has intensified in frequency, duration and depth. The flooding events have corresponded with the EWD Iteration 6 and 7 and overall changes in water management in South Dade County instituted by the USACE and SFWMD. The lack of documentation concerning the negative impact of the EWD has hindered progress by the USACE and SFWMD to address these concerns."

Five water control structures within this system were evaluated for adherence to operational criteria. The data that was used to determine structure operations is provisional data contained in the Operations Database. The structures and our assessments are noted below:

G-211

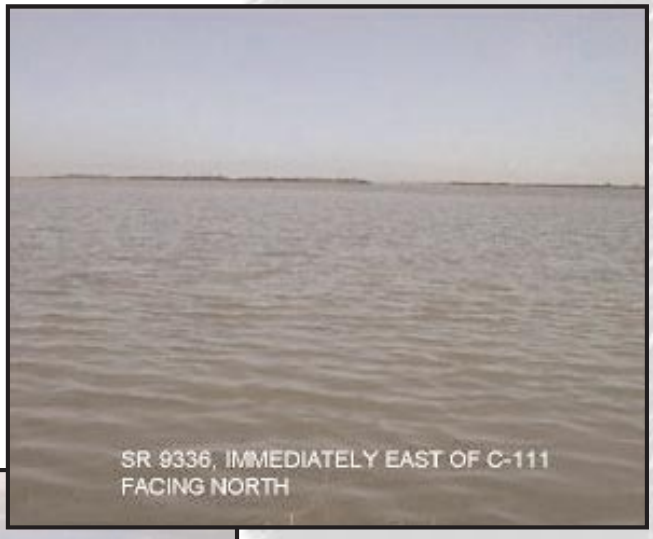
This structure is a six-barreled corrugated metal pipe culvert, located south of the point where the L-31N Canal joins C-1W Canal. The control is effected by six manually operated sluice gates on the upstream end of the structure.

The goal is to keep headwater stages at G-211 generally between 5.5 feet[1] and 6.0 feet, insofar as practicable. The criteria for opening the struc-

[1]**Elevations shown throughout this report refer to the National Geodetic Vertical Datum of 1929 (NGVD 29).**

ture is when the headwater stage reaches 6.0 feet. On Monday, October 12, the first day that we reviewed operating data, the headwater was 6.25 feet and three of the six gates were open in excess of one foot (two at 1.08 feet and one at 1.14 feet).

Data provided by Operations Management indicates that the headwater stage at G-211 was greater than 6.0 feet for several months prior to this, primarily because of the conveyance limitations that exist downstream at S-176. This condition was exacerbated by the high seepage inflows from the Water Conservation Areas to the north and the above average rainfall experienced in the region during the wet season. If additional water was moved south from the reach of L-31N upstream of G-211, to the reach of L-31N downstream of S-331 (see page 20 for commentary on the S-331 structure), it would have required increased pumping at S-331 that could have raised the tailwater elevation to intolerable levels, even with S-176 (see page 20 for commentary on the S-176 structure) being open. Furthermore, increased flows through S-176 could have triggered the opening of S-197 (see page 21 for commentary on the S-197 structure). This could be expected because the wet conditions that existed through most of the wet season required that S-18C remain open to its maximum capacity.



South Dade Agricultural Lands

The criteria for the G-211 structure state that during flood control operations or when making water supply deliveries, stages outside the 5.5 to 6 foot range, either high or low, may occur for extended periods of time. At approximately noon on October 15, the three gates were closed due to worsening downstream water level conditions. The headwater at G-211 at the time of closing was 7.53 feet. The structure remained closed until October 28, when the downstream water levels had improved to allow a reopening. At that time, the upstream stage was 6.82 feet and three gates were opened approximately one foot. The criteria appear to provide for this flexibility with regards to the operation of the structure and as such it appears that the

structure was operated in accordance with the operating criteria.

S-338

This structure is a double-barreled, corrugated metal pipe culvert, located at the point where C-1 crosses Krome Avenue, about 12 miles north of Homestead. Control is effected by electric gear driven sluice gates mounted on a steel frame erected on the upstream end of the structure. This structure provides a means of making water supply releases during dry periods. It also provides flood control releases from the area between Krome Avenue and L-31N, and north of S-331.

The criteria require that S-338 be opened when the headwater stage at S-211 exceeds 5.8 feet. The operating data indicate that the structure was open during this time, therefore, it appears that the structure was operated in accordance with the criteria. It should also be noted, however, that the diversion of L-31N flow into the C-1W and C-1 system, due to the extended closure of G-211, most likely served to add further stress to that system.

S-331

This structure is a three-unit pumping plant located in L-31N borrow canal about nine miles north of Homestead, Florida. It consists of a reinforced concrete and concrete block masonry superstructure. The pumping station is equipped with three vertical axial flow pumps, each rated for 387 cubic feet per second (cfs) at 3.0 foot static head. Each pump is driven by a 250 horsepower diesel engine. This is a water supply pumping station, but for the purpose of Test 7, it serves to control the level in L-31N, north of S-331, as a function of the water levels in the Rocky Glades residential area.

The criteria require that the average daily headwater stage be maintained between 4.0 and 4.5 feet when Angels Well, a groundwater monitoring well located in the southwestern section of the 8 1/2 Square Mile Area, is above 6.0 feet. Except for two days when the average daily water level upstream from the structure minimally exceeded the target range (4.53 on Oct. 12 and 4.57 on Oct. 14), the structure appears to have been operated in accordance with the criteria.

S-176

This structure is a reinforced concrete, single-gated spillway with discharge controlled by a cable operated, vertical lift gate. Operation of the gate is automatically controlled so that the gate hydraulic operating system opens or closes the gate in accordance with the operational criteria. The structure is located on C- 111 about 5 miles west of Homestead. Under Test 7 criteria, this structure, together with S-174, maintains a normal water control stage between 5.0 feet and 4.75 feet upstream in L-31N, and is intended to pass the design flood (40% of the Standard Project Flood) without exceeding

upstream flood design stage. It also serves to restrict downstream flood stages and discharge velocities to non-damaging levels.

There are two sets of criteria for operation of this structure, normal conditions criteria and flood conditions criteria. The normal conditions criteria require that the gates begin to open when the headwater is at 5.0 feet and begin to close when the headwater drops to 4.75 feet. The flood conditions criteria require that the gates begin to open when the headwater is 5.0 feet and begin to close when the headwater drops to 4.6 feet.

Florida City & Homestead

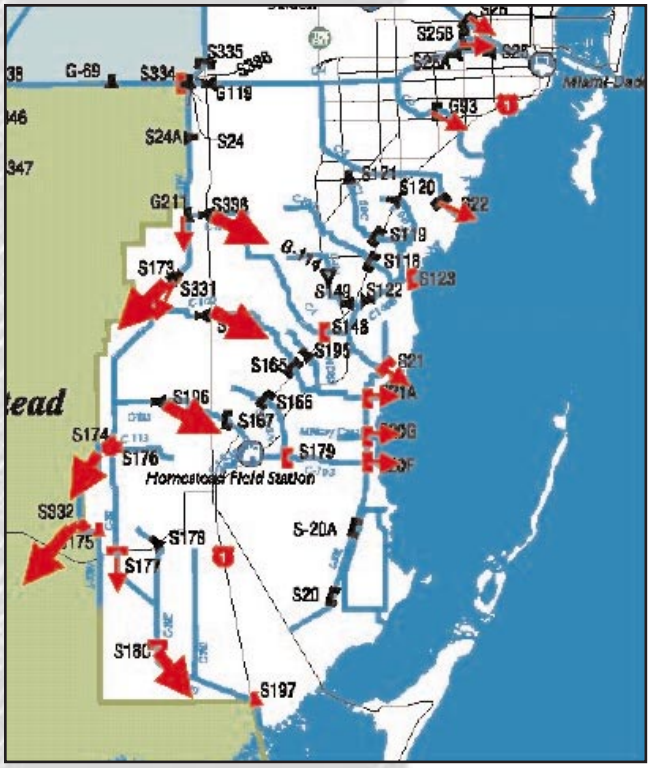
The flood conditions criteria may be used at the discretion of the Director of Operations at South Florida Water Management District. However, upon the next business day, the Director is required to obtain concurrence from the USACE and ENP.

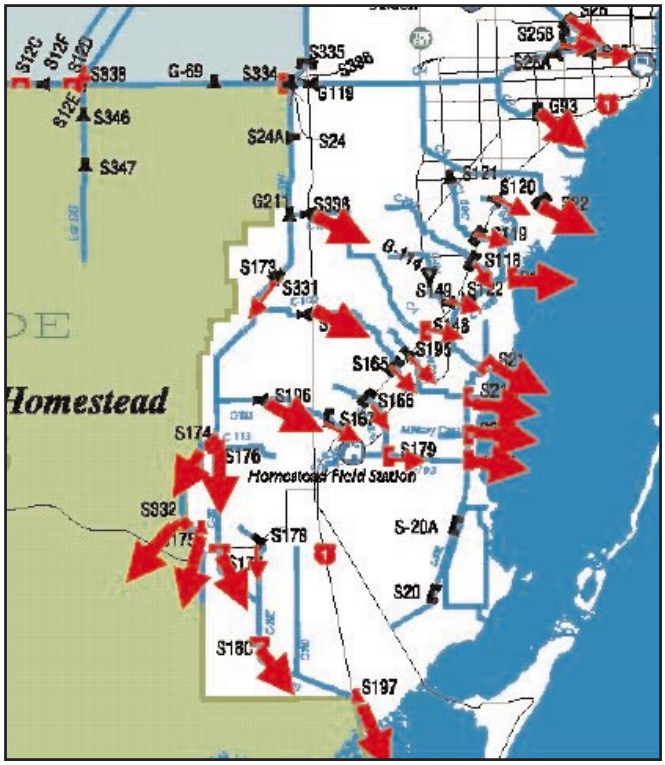
The operating data indicated that the gate started opening when the headwater stage reached 5.0 feet and started closing when the headwater stage reached 4.6 feet (flood close). Based on this it appears that the structure was operated in accordance with the flood operating criteria. It should be noted, however, that this structure is viewed by our operational managers as a “bottleneck” due to its limited capacity compared to the carrying capacity of the downstream reaches of C-111.

S-197

S-197 is a thirteen-barreled corrugated metal pipe culvert, located near the mouth of C-111 about 3 miles from the shore of Manatee Bay and 750 feet east of U.S. Highway 1. Three of the gates are screw gates and the remaining ten require the use of heavy equipment to manually operate the structure. This structure maintains an optimum upstream water control stage in C-111 and prevents saline intrusion during high tides. Most of the time S-197 remains closed and helps to divert discharge from S-18C as spillover along the south bank of C-111 and into sheetflow through the panhandle area of ENP towards Florida Bay. S-197 releases water only during major floods according to the established guidelines.

During high tides. Most of the time S-197 remains closed and helps to





Left – Structures discharging one week prior to Hurricane Irene.

Right – Structures discharging during Hurricane Irene (Oct. 15, 1999). Most structures were opened one-two days prior in anticipation of high rainfall.

divert discharge from S-18.

The opening of S-197 culverts will begin when water levels exceed specified levels at the referenced structures:

- S-177 HW > 4.10 after gates have been opened full or S-18C HW > 2.80: open 3 culverts.
- S-177 HW > 4.20 for 24 hours or S-18C HW > 3.10: open 7 culverts
- S-177 HW > 4.30 or S-18C HW > 3.30: open 13 culverts

Closing of the culverts at S-197 will begin after the following conditions have been met:

1) When the headwater canal stage at S-176 has declined below 5.2 feet and headwater stage at S-177 has declined below 4.2 feet. Stage levels above 5.2 feet and 4.2 feet, respectively, at these structures trigger mandatory flood control releases. A declining trend in water levels below this stage would indicate the peak of the storm event has passed.

2) Position of the storm has moved away from the basin.

3) Once conditions 1 and 2 above have been met, only the number of S-197 culverts required to match the residual discharge volume flowing through S-176 will remain open. This is intended to prevent unnecessary

over-drainage of the panhandle region by restricting the amount discharged through S-197 to equal the amount of inflow from the upper basin. All culverts will be closed once the S-177 headwater stage declines below 4.1 ft and the above conditions are satisfied.

Our review of the operation of S-197 indicated that a considerable period of time elapsed between meeting the opening criteria and opening the structure. The criteria for opening the first 3 gates occurred at 2345 Thursday, October 14, however, the gates weren't fully open until almost 8 hours later at 0728 on Friday. This happened because S-197 is a manually operated structure and gate changes there are normally made during normal work hours, to the extent possible. The required gate opening was ordered at approximately 0530 on October 15, in accordance with these guidelines. The Homestead field station crew dispatched to open the first set of gates were able to carryout their assignment without the need for heavy equipment since the three gates involved are manually operated screw gates. These gates were opened at approximately 0728 on October 15.

The criteria to open 4 more gates and the remaining 6 gates were both met at approximately 0410 on Friday, October 15. However, these gates weren't opened until 2318 that same day. This occurred because these remaining 10 gates require heavy equipment and specially trained personnel for opening operations. Special safety restrictions for moving heavy equipment along the road and operating it come into play. The heavy equipment was dispatched at 0830 when lighting, road conditions, and wind conditions permitted. The crew was instructed to open 4 of the remaining gates as soon as wind conditions permitted. Verbal communications with the Homestead field station later that morning indicated that the combination of wind and high tides did not allow opening the gates at that time. They were instructed to open all of the remaining gates when conditions allowed rather than the original four noted in the original order. After the field supervisor noted that tide and wind conditions were not improving rapidly, the equipment was protected from damage and secured at the S-197 site for rapid deployment when conditions permitted. The crew then returned to the field office to perform other storm duties. Although the tide conditions improved in the late afternoon, the wind did not subside sufficiently (there is a 35 mph limitation) to allow operation of the crane until late evening. When the wind began to subside, the crew was again dispatched to the S-197 site where they finished opening the remaining gates just before midnight on October 15.

While there were delays involved between meeting the opening criteria at various stages, the operation was consistent with the limitations imposed by the state of automation of the structure, coupled with the wind and tide constraints. Had the structure been fully automated so that control could be accomplished from the central control room, the first 3 screw gates would

have been opened about 8 hours sooner and the remaining gates about 7 hours sooner. The impacts of these delays on the upstream performance of the system is not known, but, given the system's improved capability for spillover discharge along the south bank of C-111 and sheet flow within the panhandle area of ENP, the backwater increase should have been minimal.

With regards to gate closings, approximately 11 hours elapsed after the criteria for gate closing was met at which time all but 3 of the gates were actually closed. Then, our review indicates that the remaining 3 gates were closed prematurely, on October 25, when the headwater at S-18C was 2.89 feet. This is only 0.09 feet higher than the stage which requires those 3 culverts to be closed.

The criteria to begin closing S-197 was met on the morning of October 22. Three conditions are explicit before closing is to begin: 1. The storm has passed and water levels are declining (this condition was met October 17); 2. S-177 must be below 4.2 feet (this condition was met on the evening of October 21); and 3. S-176 must be below 5.2 feet (this didn't occur until 0800 on October 22).

A fourth condition, which is not explicit, must also be met in practice. This implicit condition relates to stages at S-18C. Although a stage criteria at S-18C is not formally noted in the closing criteria, it does not make sense to close S-197 and immediately reopen in response to water levels at S-18C. In practice, this is implemented by estimating the effect that the computed S-197 closing will have on S-18C stages and adjusting (or deferring closure) on this basis.

The closing of the structure takes place in the reverse order of its opening. There are three phases 1) close six gates, 2) close four more gates, and 3) close the remaining three gates. When the criteria to begin closing S-197 was met, the flow at S-176 was approximately 800 cfs and falling rapidly. Since 7 culverts at S-197 will pass far more than 800 cfs, the decision was made to close 10 of the gates at this time, leaving only 3 gates open. This were acceptable when conditions at S-18C were considered. The discharge capabilities with this partial closure at S-197(10 gates closed, 3 gates open) made it unlikely that the stage at S-18C would increase from 2.8 to 3.1 feet, which would trigger a reopening of 4 gates (for a total of 7 gates open). The developing closing mode condition was recognized early in the morning, but the heavy equipment required to close the gates was being utilized for debris removal in Miami thus it took several hours to mobilize for the S-197 operation. Nevertheless, the structure was closed on October 22, before the crews went home for the evening.

Given the conditions for partial closure and no flow through S-176 the explicit criterion for complete closure of S-197 is when S-177 declines to 4.1 feet. The S-177 condition was met during the early morning hours of

October 22 (before all of the criteria to initiate closure were satisfied) and S-176 was closed (no flow) early on October 24. The implicit S-18C criteria were then the only impediment to closing S-197.

Early on the morning of October 25 the on-duty water manager dialed in and misinterpreted the S-18C water level to be below 2.80 feet (it was 2.89 feet). On that basis, he ordered all gates at S-197 closed. The error was not detected until late in the day and since S-18C water levels were still above the opening criteria, three gates had to be reopened the following morning, October 26. On the basis of experience gained from extensive monitoring during similar previous events, the environmental and flood relief impacts of this error are considered to be very minor.

Typically, after S-197 gates are closed, water levels at S-18C rise somewhere between 0.10 to 0.20 feet within several hours if there is significant flow through S-18C or S-177. The S-18C water level fell to 2.8 feet on the morning of October 27. However, given the expected water level rise following a S-197 closure, it was deemed inappropriate to close S-197 at that time. The following day, October 28, the water level at S-18C had fallen between 2.75 and 2.70 feet, but, given the amount of flow through S-177 and S-18C, it was again was judged too high to be able to effectuate total closure at S-197. Finally, on the morning of October 29, all gates at S-197 were closed since flow through S-177 had largely subsided.

Except for the mistake made on October 25, the operation of S-197 was consistent with the criteria if consideration is given to the structure's lack of automation and the intensive manpower and heavy equipment required to effectuate multiple openings and closings.

It should be noted that extensive monitoring during past events indicate very few environmental problems with the current water control methodology at S-197 following the addition of 10 culverts in September 1990 to eliminate the very cumbersome requirement of removing the earthen plug during severe storms.

In summary, given the nature of the structure with its manual gates and remote location, and the weather and tide conditions that were occurring as a result of Irene, it appears that the structure was opened as soon as practicable. With regards to the closing of S-197, it appears that the structure was closed prematurely, reopened, and then allowed to stay open longer than the criteria directed.

S-332D

On October 15, 1999, the District obtained a pre-storm emergency authorization to operate pump station S-332D from the Florida Department of Environmental Protection. S-332D discharges into ENP and is located in the L-31W canal, adjacent to the S-174 gravity water control structure and

immediately west of a confluence with the L-31N canal. The pump station has been in place since December 1997, but the start up of S-332D has been delayed due to permitting issues associated with operational criteria and concerns in several key areas such as endangered species impacts, increased risk of flooding to agriculture, and unknown water quality impacts. Obtaining this authorization was a commendatory action indicative of alert water managers anticipating flood conditions and seeking avenues of relief.

It is noteworthy and instructional that during the course of the storm two of the five pump units at this station were deemed inoperable. One experienced overheating problems and the other was down due to warranty work on the gear box. Allowing pumping equipment to stand idle for an extended period of time begets reliability problems. In this case 31% of the pump station capacity, or 176 cfs, remained off line during the passing of Hurricane Irene. Nevertheless, the use of this facility allowed for removal of approximately 18,740 acre-feet of runoff from the service area.

After sorting through much of the water management complexities in this area, we must say that our operational performance was dutiful, but clouded by the three-party agreement that offers an entry point for the application of flood control criteria that does not fully exploit system capabilities prior to and during events of Hurricane Irene proportions. The Agreement also places middle managers in the unenviable position of deciding when to initiate the restrictive flood control criteria. It is noteworthy that the criteria were not sensitive to the G-211 structure headwater stage being above elevation 6.0 ft. for an extended period of time prior to the storm, nor the S-176 structure having limited capacity.

Accordingly, we recommend the following:

- **Call for an assessment of the benefits of preparing the Test 7 final report stipulated in the October 1995 Environmental Assessment. This would be a comprehensive report, covering the period from November 1, 1995 to October 31, 1999. This report would make definitive hydrologic and ecological conclusions about Test 7, and recommend any possible improvements. A report written jointly between the three parties would not be required, but cooperation between the three parties and other government agencies in writing this report is encouraged.**

- **Propose revisiting the operating criteria, in the context of the USACE proposed Interim Operating Plan[2], to consider (a) stipulating the involvement of the USACE Jacksonville, District Engineer; the Superintendent, ENR; and the District's Executive Director, along with their water managers/hydrologists, when critical flood control decisions are to be addressed prior to the onslaught of a major storm, and (b) flood**

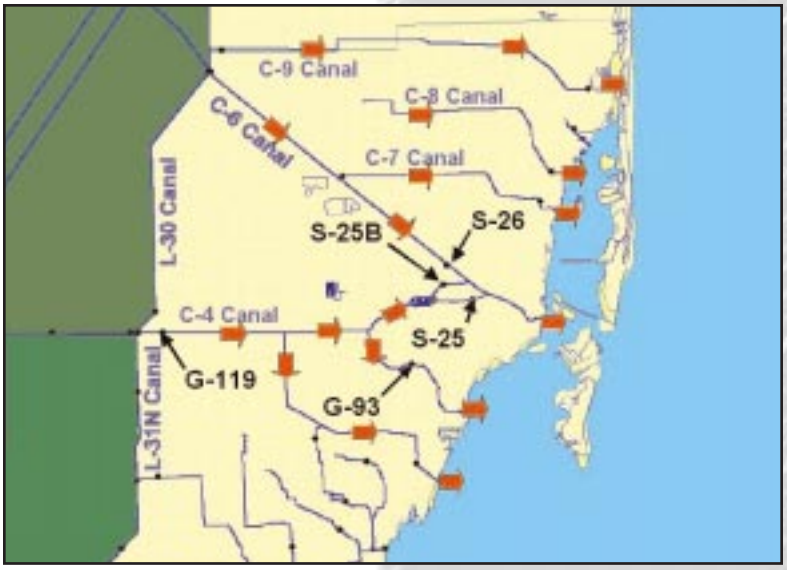
[2]An Interim Operating Plan is being prepared by the USACE to address the Cape Sable Seaside Sparrow nesting requirements.

control criteria modifications.

- **Weigh the benefits attained through automation of the three screw-gated culverts at S-197. Recognizing the remote nature of this site, infrequent operation, and vandal prone nature may make the automation effort expensive in relation to the benefit received, but it should be looked at.**

- **Encourage full participation of affected interests in the operational plan development under way and an acceleration of the ultimate plan of improvement for the Modified Water Deliveries and C-111 projects (see Appendix D).** [Note: When finally designed and constructed, the Modified Water Deliveries Project and the C-111 project modifications will: (a) enable water deliveries for the restoration of more natural hydrologic conditions in ENP; (b) maintain existing flood protection for developed areas east of the project; and (c) increase freshwater flows to Florida Bay, thereby improving conditions in that waterbody.] With respect to flood control, it is also important to recognize that while these projects will provide for overall system improvement compared to the present condition, they will not prevent flooding from an event like Hurricane Irene.

- **The warranty work on the S-332D pump station should be completed as soon as possible in order to improve the operational readiness of the pump station.**

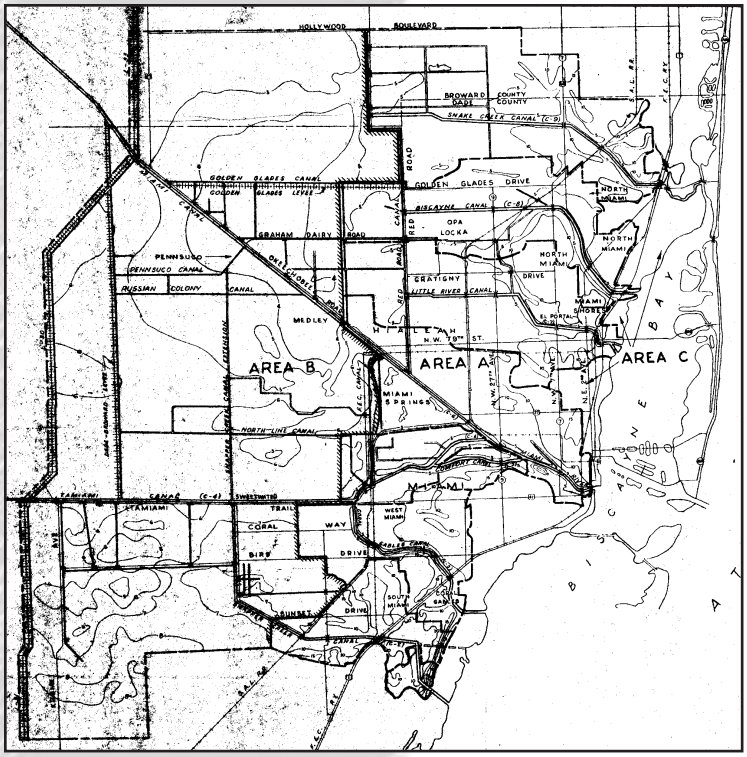


Coastal Miami-Dade Conveyance System

SNAPPER CREEK CANAL (C-2), CORAL GABLES CANAL (C-3) AND TAMIAMI CANAL (C-4) BASINS

The criteria used to evaluate these structures, as well as all other structures that follow, is the criteria posted on the District's internal web site. We were told that this is the same information as contained in the USACE's Master Water Control Manuals. It should also be noted that the criteria appear to provide for some flexibility in the operation of the system with regards to flood operations. The Master Water Control Manuals for East Coast Canals, section 7.04, Flood Control Operations, incorporates by reference the District's Major Storm Procedures dated August 1990[3] which allows the District to make pre-storm draw-downs prior to the impact of a storm. These pre-storm draw-downs generally lower water levels substantially below the stated criteria for normal structure operations. We discussed this interpretation with USACE staff who concur with the District's interpretation. As such, in all instances where pre-storm draw-down settings were in

[3] **These procedures have been superceded by the Operations Division's (now Water Control Operations Department) Suggested Operation Procedures (SOP's), which also provide for pre-storm draw-downs.**



Greater Miami Area Drainage Areas as defined by the Corps of Engineers, dated March 23, 1954

effect, we concluded that the structure was operated in accordance with the criteria, although outside of the normal operating criteria.

Three water control structures within these basins were evaluated for adherence to operational criteria. The structures and our assessments are noted below:

S-22

This structure is a reinforced concrete, gated spillway, with discharge controlled by two cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gate system opens or closes the gates in accordance with the seasonal operational criteria. The structure is located near the mouth of C- 2 about 7,000 feet from the shore of Biscayne Bay and maintains optimum water control stages upstream in C- 2; without exceeding upstream flood design stage. Further it restricts downstream flood stages and discharge velocities to non-damaging levels and prevents saline intrusion during periods of high flood tides.

The criteria indicate that the gates are to open when the headwater elevation rises to 3.5 feet, and will close when headwater elevation falls to 2.5 feet.

Our review indicated that the structure was operated at a low setting (pre-storm setting) between 2.5 feet and 1.5 feet as opposed to the 3.5 feet and 2.5 feet as stipulated in the criteria. Because the criteria appear to provide for pre-storm draw-downs, we have concluded that the structure was operated in accordance with the criteria.

G-93

This structure is a reinforced concrete, gated spillway on the Coral Gables Canal (C-3) at Red Road in the City of Miami. Discharge is controlled by two vertical lift gates. Operation of the gates is manually controlled. An automatic device has not been installed due to the possibility of injury to manatees. The structure replacement was completed in January 1990.

This structure maintains optimum upstream water control stages; plus a small discharge from the C-4 basin, without exceeding the upstream flood design stage and restricts downstream flood stages and discharge velocities to

City of Sweetwater

non-damaging levels; and it prevents saline intrusion during periods of high flood tides.

The criteria require that this structure be opened during storm events. Our review indicated that the structure was opened before, during, and after Hurricane Irene. This appears to be consistent with the flood control criteria.

S-25B

This structure is a reinforced concrete, gated spillway, with discharge controlled by two cable operated, vertical lift gates. Operation of the gates is automatically controlled. The structure is located in the City of Miami immediately downstream of the Le Jeune Road crossing of the Tamiami Canal, C-4. This structure maintains optimum water control stages upstream in C-4; it passes the design flood (the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saline intrusion during periods of high flood tides.

There are two sets of criteria for operating this structure, normal and high flow. Normal operating criteria range between 3.0 feet and 2.0 feet. High flow operating criteria is between 2.0 feet and 1.5 feet but is to be used only when the stage at the junction of C-4 and C-2 (also known as T-5) exceeds 4.0 feet.

The high flow setting was initiated on October 13, prior to the criteria

City of West Miami

being met for this setting. This was done as a part of the "pre-storm" activities in order to make capacity available in the system. Based on this it appears that this structure was operated in accordance with the operating criteria.

Our review indicates that the primary system located within these basins was operated in responsible fashion and maximum discharges were generated in keeping with the constraints of a gravity system interfacing with tidal waters during passage of a tropical storm. The flooding that occurred was widespread and most serious in those low-lying areas where secondary and tertiary drainage is the least efficient (West Miami and Sweetwater, for example). This flooding was the result of excessive rainfall (10.99 inches at Miami International Airport and 11.88 inches in Sweetwater, for example) that far exceeded the design capacity of the primary facilities. To fully appreciate the magnitude of this event, one must recognize that the 3-day rainfall totals represent about 20% of the area's average annual rainfall. For more commentary on the performance of District structures (S-25B, for one) during critical storm events in West Miami, see Technical Publication #DRE-158, *Performance of District Structures during Critical Storm Events in West Miami, and Proposed Alternatives to Reduce Flooding*. (Revised October 1982).

In analyzing primary flood control system performance in these basins it is important to gain an understanding of Area B. Likewise, it is also important to understand that Area A lies to the east of Area B and represents the area where primary system design was intended to accommodate urban development. The Area A reach of Tamiami Canal (C-4) is therefore designed to remove urban runoff from the Area A sub-basin and only service the Area B sub-basin after stages in Area A begin to recede. In other words, backwater conditions in the less efficient westerly portion of C-4 will worsen while the more efficient eastern portion of C-4 handles storm runoff from

its sub-basin.

The following is quoted from *A Report on Area B*, prepared jointly by the Central and Southern Florida Flood Control District and Metropolitan Dade County in 1959:

> *Area B, an arm of the Everglades basin, originally drained eastward to Biscayne Bay through the Miami River and other small streams which cut through the coastal ridge from Snake Creek on the north to Snapper Creek on the south. The area consists of approximately 235 square miles of poorly drained glades land lying between the coastal ridge and Levees 33, 30 and 31 of the Central and Southern Florida Project. The area situated north of Tamiami Canal is generally below elevation 6 feet. South of Tamiami Canal land elevations rise to a maximum of 10 feet. The lowest lands of the area are centered about the Miami Canal.*

The problem is that development has extended well into the Area B portion of C-4 thereby exacerbating our primary flood control mission. Moreover, the runoff generated by this westward expansion stacks up the backwater and creates an added burden on the eastern reaches of the Canal. This has been the case now for some time. Also, the City of Sweetwater is located in Area B and is one of the oldest developments in that reach of C-4. It is also one of the most flood prone. Surrounding developments have not helped Sweetwater's plight.

Since our operational criteria at S-25B have been fine-tuned to move as much water as possible through the structure without risking salinity intrusion, physical modifications to better system performance are in order.

There are at least five options: (1) backpump into a detention area in Area B, (2) pump forward to tide at S-25B, (3) hook up to an Aquifer Storage and Recovery (ASR) unit, (4) use deepwell injection without recovery, and (5) status quo. The backpump plan for a 1/2 to 3/4 inch per day pumping unit would require a sizable detention area in the undeveloped section of Area B, but would provide the most protection of all options. The forward pumping plan would provide a remotely operated, storm hardened, dual pump unit having an approximate total capacity of 300cfs. The pump would be located on the south side of the existing S-25B gravity structure and would serve to maintain the eastern flow dynamic of the C-4 canal during storm surge or extreme high tide conditions when gravity discharges have to be cut back or entirely curtailed. The pump could also be used to augment gravity discharges. The ASR and deep-well injection options would probably be the most costly in terms of dollars per acre feet.

Based on the foregoing and as a first step in the search for a system

betterment solution, we recommend that a feasibility study be undertaken to consider the practicability of the options as follows: (1) backpump into a detention area in Area B, (2) pump forward to tide at S-25B, (3) hook up to an ASR unit, or (4) use deepwell injection without recovery.

SNAKE CREEK CANAL (C-9) BASIN

One coastal structure within this region was evaluated for adherence to operational criteria. The structure and our assessment are noted below.

S-29

This structure is a reinforced concrete, gated spillway, with discharge controlled by four cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gates open or close in accordance with the seasonal operational criteria. The structure is located in the City of North Miami Beach near the mouth of C-9 (Snake Creek Canal) and about 500 feet from the shore of Maule Lake. This structure maintains optimum water control stages upstream in C-9; it passes the design flood (100 percent of the Standard Project Flood) without exceeding upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; and it prevents saline intrusion during periods of high flood tides.

Prior to the storm, the structure was operated within the normal operating range between 2.5 feet and 1.5 feet. On October 14, the S-30[4] tailwater exceeded 3.3 feet. According to the criteria, when this condition occurs releases at S-29 are made at the discretion of the Chief of Operations. As of October 31, the last day for which operating data was analyzed, stages were still sufficiently high so as allow for discretionary releases. Based on this, it appears that S-29 was operated in accordance with the operating criteria.

We found no evidence of flawed infrastructure performance or operational criteria problems within C-9. It should be noted, however, that the level of service provided to the western portions of this basin is beset by the same constraints as that previously outlined for C-4. That is, a portion of C-9 lies in Area B. Therefore, similar to C-4, water will stack up to the west when excess rainfall occurs. Not surprisingly, that is what occurred during Hurricane Irene, thereby bringing about area flooding.

Accordingly, as a means to better system performance, we recommend that the feasibility study proposed for the C-4 canal also consider the same set of options for C-9. In this instance, backpumping to a water storage area may be more in keeping with the District's long range water conservation plans. [Note: Another option would be to request that the USACE perform a reconnaissance study to consider the feasibility of utilizing

[4]The S-30 water control structure is located near the western extremity of C-9 at US Highway 27.

backpumping as a flood control measure within Area B.]

Coastal Broward Conveyance System

Broward County

SOUTH NEW RIVER CANAL (C-11) BASIN

Two pumping stations (one with a gated spillway), and one culverted divide structure within this basin were evaluated for adherence to operational criteria. The structures and our assessments are noted below.

S-9

This structure is a three unit pumping plant located in Broward County, at the west end of C-11 in the alignment of Levee 37, about 0.5 miles west of U.S. Highway 27 and about 20 miles west of Hollywood, and consists of reinforced concrete and concrete block masonry superstructure. The purpose of the structure is to pump runoff from the tributary drainage area west of S13-A into Water Conservation Area 3A via the South New River Canal at the rate of 3/4 inch per day. The pump station is also designed to handle the return of seepage from the water conservation area.

The criteria require that the pumping station be operated whenever the water level in the South New River Canal at S-13A exceeds 4.0 feet. There are no stopping criteria other than that the water surface should not be drawn down below 0.0 feet at the pumping station. Drawing down the canal below this elevation places the pump units at risk due to cavitation. It is also important to note that seepage alone may require that pumping occur 8 hours a day. On the morning of the October 13, pumping began as usual, however, instead of ceasing after 8 hours, pumping continued 24 hours a day until approximately noon on October 28. Normal 8 hour pumping resumed on October 29. At no time did the headwater drop so that pumping had to be halted. Based on this it appears as though the station was operated in accordance with the criteria.

S-13A

This structure is a four-barreled, corrugated metal pipe culvert, located on C-11 (the South New River Canal) about 5 miles upstream from Pump

Station S-13. Control is affected by manually operated sluice gates mounted on a steel frame head structure on each culvert. This structure maintains optimum upstream water control stages in C-11 and it passes dry season releases to the area east of the structure. This structure is operated during flood conditions to supplement S-9 pumping when capacity is available in C-11 east of S-13A. It is operated during dry conditions to maintain the optimum stage of 2.2 feet at S-13. Our review indicated that this structure was operated in accordance with the criteria.

S-13

This structure is a pumping station with a gated spillway, which can control flows which bypass the pumps. The structure is located in C-11 (South New River Canal) about 300 feet west of U.S. Highway 441 and 5 1/2 miles southwest of Fort Lauderdale and is a reinforced concrete structure with concrete block superstructure. The purpose of the structure is to release flood runoff from, prevent over-drainage of, and saltwater intrusion into the area served by C-11 (South New River Canal) west of the structure. The purpose of the pumping units in the structure is to pump surplus water from the area west of the structure within the tributary drainage area, so as to keep the water level in the canal west of the structure at an optimum elevation of 2.2 feet, insofar as practicable. The purpose of the gated spillway in the structure is to release runoff from, prevent over-drainage of, and prevent intrusion of salt water into the area west of the structure.

Gate operations were such that an attempt was made to match gate discharges with tidal stages. This appears reasonable given that high tailwater stages caused by tides could result in water entering the system. Additionally, pumping began before the criteria were met in anticipation of the storm and continued for days after the storm passed and stages were relatively low. As previously indicated, the criteria allow flexibility in operating the structure when potential flooding events are imminent. As such, the structure appears to have been operated in accordance with the criteria.

In our judgement, performance of the C-11 facilities was nearly flawless. We believe this to be a positive testimony of the District's maintenance program and the skills of their operators, especially considering the quantity of machinery at the two pumping stations and the reliability of the two water control structures. While there is no question that high water stages in the canal and flooding in certain parts of the service area prevailed during the course of the storm, excess rainfall (14.08 inches at the nearby field station) was the culprit, not primary system failures. The C-11 system performed as it was designed.

In terms of better system performance, there are a couple of areas that

need to be mentioned, as follows:

- In the first case, personnel at Pump Station S-13 had to pull trash and weeds at the pump intake bays using potato rakes. This work is necessary in order to keep the pump units operating at full efficiency, but it is difficult, labor intensive, and unsafe. **Accordingly, we recommend that this pump station be equipped with an automatic trash rake like all the other District primary pump stations. A state-of-the-art unit similar to that recently provided at the Everglades Construction Project's Pump Station G-337 is suggested.**

- **In the second case, the addition of a remotely operated, electrically powered pump unit designed to handle water conservation area seepage is a good economical step to take at Pump Station S-9.** Having such a pumping unit eliminates the need to operate one of the large diesel units just for seepage, thereby cutting labor and fuel costs at the station. Moreover, automation facilitates nighttime operation and places the station in a more favorable readiness condition for storm events. The unit could be installed immediately north of the existing diesel powered station and take advantage of existing 42-inch pump tubes already in place through the levee. It is encouraging to note that a seepage pump station at S-9 is one of the USACE's critical projects under the Restudy. This unit, when in place, will represent a system improvement.

Palm Beach County

BOYNTON CANAL (C-16) BASIN

One coastal water control structure within this portion of the county was evaluated for adherence to operational criteria. The structure and our assessment are noted below.

S-41

This structure is a reinforced concrete, gated spillway with discharge controlled by two cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gate operating system opens or closes the gates in accordance with the operational criteria. The structure is located on Canal 16 and 300 feet east of U.S. Highway No. 1.

This structure maintains optimum upstream water control stages in Canal 16; it passes the design flood (60% of the Standard Project Flood) without exceeding the upstream flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels; it also prevents saline intrusion.

This structure has two sets of operating criteria, one for normal condi-

Palm Beach County water control facilities

tions and one for flood conditions. During normal operations the gates begin to open when the headwater reaches 8.5 feet, and close when the headwater falls to 7.9 feet.

During heavy flood periods, a temporary lower automatic operation is utilized. When the headwater elevation rises to 8.0 feet, the gates begin to open and when the headwater elevation falls to 7.3 feet, the gates begin to close. Additionally the criteria provide that during heavy storm events, the headwater may be lowered significantly below normal.

On October 12 and 13, it appears that the structure was being operated within the normal operating criteria for the most part. However, on October 14, the structure was being operated to maintain headwater stages substantially below normal stages. This continued until October 25, when the gates closed completely and normal operations resumed. Because the criteria allow the headwaters to be lowered significantly below normal during heavy storm events, we concluded that the structure was operated in accordance with the criteria.

It is noteworthy that during Hurricane Irene our highest recorded 3-day rainfall total (17.47 inches) occurred at water control structure S-41. This quantity of rainfall generated runoff well in excess of the design storm (about 12.3 inches of rainfall), which is 60% of the standard project flood. Obviously, this event created great stress on the primary and secondary systems, but as noted previously the District's coastal structure was operated in accordance with the established criteria. During this event, maximum discharge at this structure reached approximately 5,000 cfs. at 0130 on

October 16. As a comparison, the design discharge is 4,600 cfs and represents 60% of the standard project flood. Also, actual discharge at the structure exceeded design for a period of about 23 hours.

A hydrographic survey of the C-16 waterway indicates that shoaling exists. The degree to which that shoaling impacted flow is unknown and beyond the scope of this report. However, based on the available flow data, it appears that the canal performed satisfactorily in delivering design or above design flows to the structure during the peak demand period. Nevertheless, in addressing the C-16 shoaling, **it is recommended that the prioritized District canal clean-out schedule[5] under the canal conveyance capacity program be strictly followed**.

WEST PALM BEACH CANAL (C-51) AND LEVEE L-8 FACILITIES

One corrugated metal pipe culverted structure and one multi-gated spillway were evaluated for adherence to operational criteria. The structures and our assessments are noted below.

G-124

This structure is a 7-barreled, corrugated metal pipe culvert located in the West Palm Beach Canal (C-51) about 3 1/2 miles west of State Road 7. Control is effected by manually operated slide gates on 2 of the culverts and by stop logs in riser pipes on each of the other culverts. This structure was provided to act as a water control point and facilitate water conservation and irrigation for areas to the west. It also has a flow through capability to accommodate storm generated discharges to the west or water supply needs to the east.

Normally, the gates are closed and the stop logs are set to a crest elevation of 10.0 feet. The slide gates are opened to help maintain an optimum stage at S-155 of 8.0 feet during the dry season. During the wet season, the gates and the stop-logged culverts are operated to mitigate upstream (west of the structure) flooding, by holding a maximum stage of 13.0 feet. During Hurricane Irene the structure was completely open until October 29 in order to provide for maximum discharge. Based on this it appears that this structure was operated in accordance with the criteria.

S-155

This structure is a reinforced concrete, gated spillway with discharge controlled by three cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gate operating system opens or closes the gates in accordance with the operational criteria. The structure is located on C-51 at U.S. Highway No. 1.

This structure maintains optimum upstream water control stages in C-

[5] **See Operations and Maintenance Department (now Water Resources Operations) Canal Conveyance Cleanout Report dated March 27, 1998.**

51; it passes the design flood (60% of the Standard Project Flood) without exceeding the upstream flood design stage; restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents saline intrusion.

The criteria give considerable operating flexibility for this structure, anywhere between 7.0 and 8.3 feet, depending on whether operations are conducted in the normal or flood mode. Additionally, the criteria allow for the lowering of the headwaters significantly below the normal operating range during a heavy storm event. Given the latitude that the criteria provides it appears that the structure was operated in accordance with the operating criteria.

Although review of data pertaining to our water control structures within the C-51 canal indicates that the proper operational criteria were adhered to during Hurricane Irene, there are a number of related issues associated with the effective management of this canal that need to be discussed.

Point One: It is noteworthy that peak discharges at the S-155 coastal structure reached a point at or near standard project flood proportions (8,000 cfs). Actually, discharges at the structure exceeded 4,800 cfs design (60% SPF urban and 30% SPF agriculture) for over a 50-hour period (1930 on 10/15 to 0030 on 10/18). These kind of flows were generated by basin runoff resulting from a 3-day rainfall total of 9.18 inches at S-155, 10.88 inches at Palm Beach International Airport, 14.50 inches at the West Palm Beach Field Station, and 6.35 inches at Pump Station S-5A. In terms of achieving maximum discharges, District water managers handled their C-51 assignments well.

Point Two: Managing the basin is made more complicated by reason of the fact that the western reaches of C-51 (or C-51W) lying west of State Road 7 have yet to be improved. Currently, all runoff entering C-51W must be discharged up to twenty miles east to tide at S-155. The flow inefficiencies of C-51W are most challenging to both primary and secondary system water managers. All agree that the sooner the improvements are completed the better.

Point Three: The plan of improvement for C-51W is a congressionally authorized part of the C&SF Project. Design and construction responsibilities reside with the USACE. The primary features of the plan provide for canal enlargement and the construction of a pump station and a divide structure. The pump station will be located at the west end of the project to backpump canal flow into a stormwater treatment area (STA 1 East), also to be built by the USACE. The divide structure will be located just west of State Road 7 and serve to separate the east and west parts of the C-51 basin. The USACE has completed a preliminary schedule for all facilities, with anticipated construction to begin in May of 2000, (S-319) and be completed

in July 2003 (STA-1E).

Point Four: Managing the eastern basin of C-51 also has its complications. For example, District water managers must be sensitive to such items as (a) the drainage needs of Palm Beach International Airport which is under pump; (b) the seawalls along the lower reaches of the primary canal and tributary secondary canals when in a draw-down mode; (c) the flooding potential of low-lying Waterview Mobile Home Park; (d) the needs of Lake Worth Drainage District (LWDD); (e) the impacts to Lake Worth Lagoon; and (f) the drainage needs of the City of West Palm Beach, and the Towns of Glen Ridge, Cloud Lake, Lake Clarke Shores, and Haverhill.

Point Five: Managing the western basin also has its complications due to the previously mentioned inefficient condition of unimproved C-51W. Wellington and Royal Palm Beach have pumps and gravity connections, respectively. There are also connections to the primary canal from rural and agricultural areas composed of both gravity and pumped units. These inflows place great stress on the canal during events like Irene. Backwater conditions progressively worsen to the point where the high stage will threaten to breach the raised berm south of the canal within about a two-mile reach east of the S-5A East structure. In the case of Hurricane Irene, a breach did indeed occur spilling water out into the area that will eventually be occupied by STA 1 East. District forces from the West Palm Beach Field Station responded and had the breach repaired 19 hours after it was reported.

There are two other complications that present challenges to water managers when in a flood flow mode. They are discussed in points six and seven.

Point Six: The Indian Trail Improvement District (ITID) is located to the north of C-51W and Royal Palm Beach. This secondary drainage district is not included within the service area of C-51W, but has arranged, by agreement with the District, to make discharges from their service area into our primary canal when stages are favorable. This can occur in both pre-storm and post-storm conditions. The pre-storm condition allows for ITID to draw-down their system utilizing available capacity in our primary canal. The post-storm condition provides for ITID to gain discharge access to our primary canal when C-51W peak flow stages are receding and capacity exists. This is governed by certain triggering canal stage elevations cited in the agreement. In practice, the post-storm criteria are very difficult to manage, primarily because of canal flow dynamics and the inexact science of determining when canal capacity exists to accommodate ITID inflows. Hurricane Irene was no exception.

Point Seven: Water Control Structure G-124 is a divide structure constructed by the District under emergency drought conditions in the early part of 1982. The structure consists of a stabilized fill embankment containing seven CMP culverts.[6] The structure was established at a strategic loca-

[6] **Refer to 10/22/97 District drawing entitled "As-Built Survey of G-124 Structure."**

tion, immediately downstream of the Blue Trace bridge, in a manner that would facilitate bringing irrigation water into the western agricultural service area of C-51W without having to "fill up" the entire twenty mile reach of canal from S-5A East to S-155. To capture the essence of the time the following is quoted: "We were in the throes of a record setting drought and water supply from our main reservoir (Lake Okeechobee)[7] was under unprecedented restrictions. Continuing to follow past practice in providing irrigation water to permitted users in the western basin would have placed us in the worst category of water supply abusers."[8]

The structure was permitted by the DER without removal requirements and by the USACE as a temporary structure to "be removed following the resumption of normal rainfall in the area." On August 23, 1982, the District requested that the USACE "give consideration to waiving or deleting the Permit's Special Condition and allow the Structure to remain on a year to year basis." The USACE replied on November 17, 1982 and said in part: "The permit is hereby modified in accordance with your request." Additional permit authorizations for this structure were received from DEP and USACE on April 14, 1998 and May 28, 1999, respectively.

During the October 9, 1997 Governing Board meeting, Staff presented the Board members with a review of the functions and utility of the G-124 water control structure for purposes of forming a plan of action to maintain the structure in its present form, improve the structure, or remove the structure. Certain members of the public also spoke both for and against the structure's existence.

The following G-124 headwater/tailwater relationships existed during the course of Hurricane Irene:

- 1330 on 10/14 – HW10.52/TW10.22
- 0615 on 10/15 – HW12.65/TW12.20
- 0130 on 10/16 – HW17.40/TW17.00
- 0800 on 10/16 – HW17.37/TW16.96
- 1800 on 10/17 – HW16.52/TW15.60
- 0730 on 10/18 – HW16.08/TW15.02
- 1000 on 10/21 – HW14.40/TW13.46

The main issues surrounding this structure are:

- It has served successfully to conserve water during the dry season by providing an effective control point that avoids the need to stage up the entire twenty-mile stretch of canal to facilitate irrigation in the western section.

[7]Lake Okeechobee dropped to a record setting low stage of 9.75 feet in August 1981.
[8]E-mail dated 8/7/97 from J. Schweigart to K. Loftin.

▪ Flood flows create a headloss of varying height at the structure thereby increasing backwater stages to the west. During Hurricane Irene the headloss peaked around 12 inches. This backwater effect has an impact on the triggering stage for ITID releases to C-51W.

▪ Its water conservation functions will be replaced when S-155A is constructed. Based on the USACE's current schedule, the completion date of S-155A is January 2002.

Based on the foregoing, the following recommendations are made:

▪ Completion of the C-51W Plan of Improvement should stay on schedule.

▪ Opportunities should be explored for improving eastern basin flood control management. The District should work with local governments and the LWDD to identify areas of improvement and avenues of approach.

▪ The Deputy Director of Water Resources Operations (WRO) and the Director of Water Control Operations should clarify and strengthen the District's decision making protocol with respect to the ITID agreement and revisit the criteria to ensure clarity, fairness, and manageability.

▪ Prior to such time as the USACE gets construction underway at C-51W and STA 1 East, the West Palm Beach Field Station, with the support of the WRO Staff civil engineer, should conduct an earthen stability inspection of the raised south berm to help identify other weak or low spots and make corrections in an effort to help prevent another breach event.

▪ The removal of G-124 should be reevaluated each year prior to hurricane season. Climatological, meteorological, hydrological, and length of time remaining prior to the completion of S-155A should be considered. The Governing Board should approve any forthcoming Staff recommendation to remove. Removal of the structure should not be attempted under high flow conditions.

LEVEE L-8

The L-8 Basin encompasses approximately 170 square miles in central and northwestern Palm Beach County (168 square miles) and southwestern Martin County (2 square miles). Of the total basin area of 170 square miles, the Upper L-8 Basin contains approximately 87 square miles tributary to the L-8 borrow canal upstream (north) of the Indian Trail Improvement District (ITID) outlet canal, M-0. This area includes 47 square miles in the J.W. Corbett Wildlife Management Area, and 29 square miles in the adjacent Dupuis Reserve; both publicly owned and managed for wildlife and environmental restoration values. The remaining 11 square miles consists of agri-

cultural lands. The lower L-8 Basin contains approximately 83 square miles downstream (south) of M-0. This area includes 30 square miles of ITID service area, 12 square miles of agricultural and rural residential, and 41 square miles considered to be ineffectively drained and not contributing to L-8 Basin runoff.

Under certain conditions, the L-8 borrow canal can flow north to Lake Okeechobee (via Culvert 10A); south to Water Conservation Area 1 (via the S-5A South Spillway, or the S-5A West box culvert and the S-5A pump station), and/or east to Lake Worth (via the S-5A East water supply box culvert and C-51). Nevertheless, under the best set of flow conditions, the L-8 borrow canal remains an inefficient flow-way. During the Hurricane Irene event, conditions were not favorable for meaningful flow in any direction. In this case; (a) Lake Okeechobee was high and L-8 flow through Culvert 10A to Lake Okeechobee was minimal or non existent; (b) during much of the time, Water Conservation Area 1 was too high to effectively utilize the S-5A South gravity spillway; (c) Pump Station S-5A was occupied with serving its defined basin, and S-5A West had to be kept closed to keep from adversely impacting the primary S-5A service area; and (d) C-51 was unavailable to accept L-8 flows due to the demands of its own service area and, therefore, S-5A East had to be kept closed. When these conditions prevail, the L-8 right of way between the levees essentially becomes a flood detention area. Stacking water within this area places stress on the levees, especially in those areas where agricultural drainage exists and farm ditches are being drawn down. Seepage will occur under such conditions and piping is also a possibility. During the Hurricane Irene event, piping occurred at some of the same locations as those impacted in October 1995. Emergency crews from the West Palm Beach Field Station, under the direction of a staff civil engineer, took corrective action that helped reduce the pressure. The USACE also sent in an inspection team to the site to investigate levee integrity. It should be noted that difficulty in finding the piping locations was hampered by high grass along the right of way. (See Right of Way Maintenance recommendation on page 54.)

Originally, in the Lower Basin the properties located east and north of L-8 were in agriculture. However, during the last 25 years land use has gradually changed to rural residential, single family homes on 5-acre tracts, or to more intensive agricultural uses such as nurseries and equestrian centers. Residential buildings are built on housepads required to be at the 100-year storm elevation. Many of the lots are 10 acres or less, or have been subdivided into individual 5-acre lots. The drainage system serving these areas is minimal and flooding in yards, barns, fields, and roads is all too common following a storm event. Hurricane Irene caused severe flooding in these areas and the near static flow condition of the L-8 borrow canal resulted in an extended flood duration.

It is encouraging that the USACE is planning to put together a Scope of Work for preparation of a General Reevaluation Report (GRR) covering the L-8 Basin Study. The proposed purpose of the study (it is still in the draft stage) is to determine the feasibility of making structural and operational modifications to the C&SF Project in the interest of flood damage reduction, environmental quality, water supply, and other project purposes. The study will develop a regional plan to address multiple opportunities to include: flood control; environmental restoration of areas adversely impacted by the L-8 system; as well as urban and agricultural water supply, and recreation. The development of an L-8 Basin GRR takes on an added measure of importance when it is recognized that the necessary diversion of runoff (average annual quantity = 70,140 ac-ft) from the lower portion of the L-8 basin is not addressed in the Everglades Construction Project (ECP).

Based on the foregoing, we recommend that the District work closely with the USACE, local governments, and the ITID in swiftly moving the GRR for the L-8 Basin along. This represents a first step in helping to find ways to better system performance.

EARMAN RIVER (C-17) BASIN ISSUES[9]

S-44

This structure is a reinforced concrete, gated spillway with discharge controlled by two stem operated, vertical lift gates. Operation of the gates is automatically controlled remotely or on-site. In the latter case, the gate operating system opens or closes the gates in accordance with the established operational criteria. The structure is located on C-17, about 250 feet downstream of U.S. Highway A1A bridge.

This structure maintains optimum upstream water control stages in C-17; it passes the design flood (60% of the Standard Project Flood) without exceeding the upstream flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents saline intrusion.

S-44 structure normally operates automatically to maintain an optimum headwater elevation which varies seasonally from a low of 6.6 feet during the flood season to 7.1 feet during the dry season, when sufficient water is available. The criteria specify two operating ranges depending on the conditions. The low range, which is between 6.8 feet and 6.2 feet, and the high range which is between 7.3 feet and 6.8 feet.

Normally, the site is operated at high range. The automatic operation can be changed to low range temporarily if basin conditions require.

Our review of the operating data revealed that prior to the storm the structure was being operated in the high range between 6.8 feet and 7.3 feet.

[9] **For more details on this canal, refer to the June 1998 Technical Memorandum entitled: *An Atlas of Eastern Palm Beach County Surface Water Management Basins*.**

On October 14, both gates of the structure were opened to 4 feet as a part of the pre-storm activities. By midnight on October 15, the gates were opened to 6 feet. This occurred until October 22, when headwater stages had dropped to below 6 feet and the structure was then operated within a range between 5.5 feet and 6.1 feet. This setting is below that contained in the criteria for the low range. We were told that this structure was operated at this range so as to allow the secondary system to make emergency releases into C-17. On October 25, the structure was set to operate at the low range as specified in the criteria, 6.8-6.2 feet.

Except for October 22 through October 25, the period in which the structure was being operated between 5.5 feet and 6.1 feet so as to allow secondary systems to make emergency discharges, the structure was operated in accordance with the criteria.

After the storm, a situation arose that merits mention. On October 31, the City of Palm Beach Gardens received heavy rains as a result of a cold front that moved through the area. At 1540, a call came in from a citizen of Palm Beach Gardens expressing concern about the heavy rainfall. The control room personnel then verified that the structure was being operated in the low range, which is appropriate for such an event. At 1730 a call was received from the Palm Beach Gardens Utility Director who reported that the gates were closed and water was flowing over the top. The control room was receiving data from a remote monitoring device that indicated that the headwater stage at the structure was 6.58 feet, which is within the low operating range. With this, the on duty water manager was contacted and approximately 10 minutes later, the remote control was canceled and the gates were opened to 3 feet. It was suspected that the problem was with the headwater float in the stilling well. An electrician was dispatched to the structure. By 1800, the headwater still hadn't dropped and by 1850, both the District electrician and the Palm Beach Gardens Utility Director were at the structure. A test of the gates was performed and the gates were closed. This allowed the electrician to determine that the problem was a plugged stilling well. At 1910 the gates were opened to 4 feet and five minutes later they were opened full. This situation highlights the need for a greater level of redundancy required for monitoring water levels upstream of S-44. The City of Palm Beach Gardens and the District are currently working together to establish another monitoring site which would be useful in joint operations between the Northern Water Control District, the City of Palm Beach Gardens, and the District.

The C-17 basin has an area of approximately 33.0 square miles and is located in northeast Palm Beach County. The upstream end of this C&SF Project canal begins just south of 45th Street and east of I-95, and is a continuation of a canal belonging to the City of West Palm Beach. Flow in the

canal is to the north and then to the east through the S-44 coastal spillway, entering tidal waters and the Intracoastal Waterway just north of Singer Island.

C-17 was originally designed to pass the runoff from a 1 in 30 year storm. In 1955, when the USACE completed its General Design Memorandum (GDM) for C-17, most land in the basin was unimproved or in agricultural production, with some urbanization located within the easternmost region of the basin. The GDM predicted that by the year 2005 the population in the basin would increase to 19,000. Not surprisingly, that population was exceeded by 1970. Today, the population is approximately 82,000.

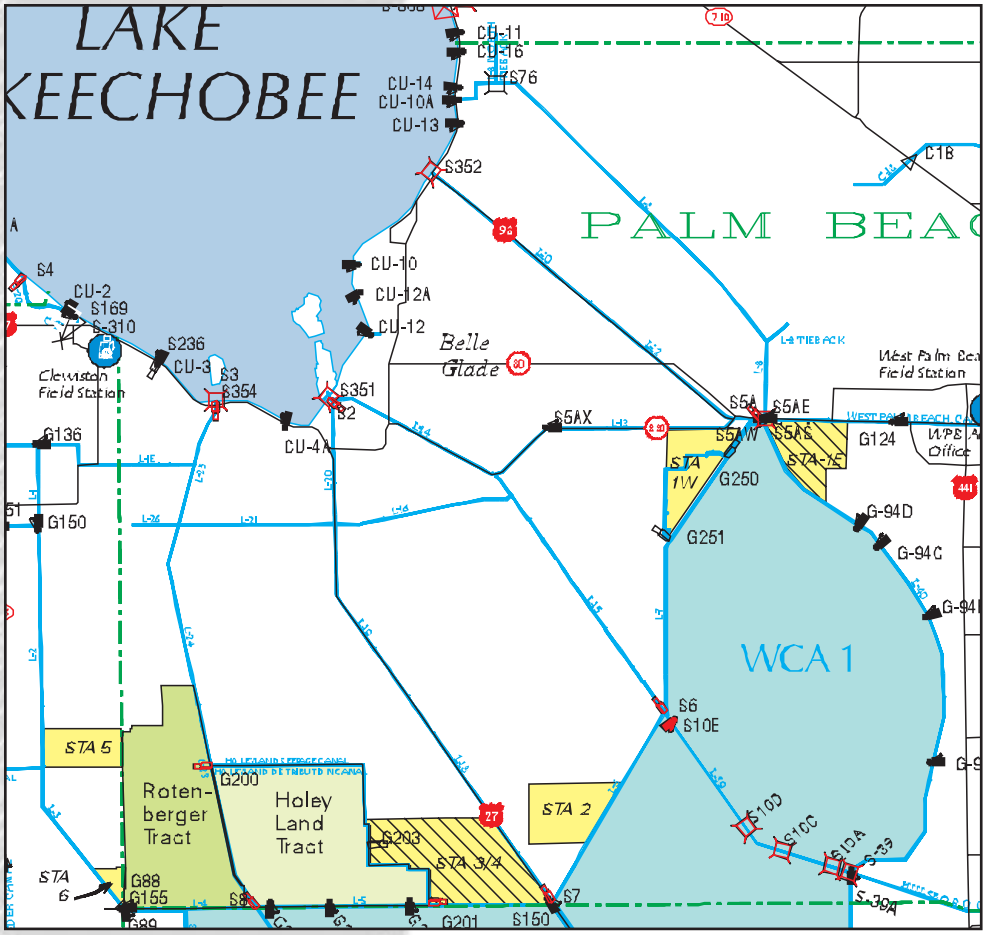
A Survey Review Study completed by the USACE in 1975 found that the design discharge for the basin should be for a 1 in 30 year urban area storm rather than the originally assumed agricultural area. This storm increases the design discharge at S-44 from 2,070 cfs to 3,700 cfs. The Study also considered a proposal to enlarge certain reaches[10] of the C-17 canal and add one vertical lift gate to the S-44 spillway to accommodate the higher discharge, but determined that the benefit-cost ratio was less than 1.0, thereby eliminating the possibility of federal participation under the C&SF Project.

Currently, a C-17 basin study group partnership with the Northern Palm Beach Water Control District has been formed to review basin water resources issues, including flood control, operational, and system improvement matters. Due to new organizational assignments of certain personnel, it is not now clear who the District's representative is on this study group.

At 0830 on October 16, flows at the S-44 spillway attributable to Hurricane Irene peaked at about 2,337 cfs. Actually, the design discharge of 2,070 cfs at the spillway was exceeded during this event for over 11 hours. This was generated by runoff resulting from a 3-day rainfall total of 7.56 inches at S-44, and 11.0 inches at Northlake Boulevard and the Turnpike. As noted elsewhere in this section, gate operations at the structure have been modified to facilitate secondary system demands. Moreover, during this event emergency releases were attempted to be accommodated when the primary system had the capacity to do so. (Also, see page 54 for Emergency Structure Program comments.)

Based on the foregoing, it is recommended that the District identify the person who will take the lead for us on the previously mentioned C-17 basin study group. This group may need to pull in further participants from local governments, but it appears to be an excellent forum to review system improvement issues.

[10]Some reaches of the C-17 Canal were previously enlarged to the ultimate section by agreement between the District and others to provide fill for area development.



Everglades Agricultural Area water control facilities

Everglades Agricultural Area (EAA) Basin

Six pumping stations within this basin were evaluated for adherence to operational criteria. The stations and our assessments are noted below. The 3-day rainfall total at each pump station is noted in parentheses.

S-5A (6.35 inches)

This structure is a six unit pumping plant located on the south side of U.S. Highway 441 and C-51 (West Palm Beach Canal) between the canal and the borrow canals of Levees 7 and 40, about 20 miles west of West Palm Beach. The primary purpose of the pumping station is to pump surplus water from the L-10, L-12 basin, and the S-5A agricultural area northwesterly of the pumping station into Conservation Area No. 1. The station has two additional functions, when these will not interfere with its primary purpose. This station is also employed to remove excess flows from the L-8 and C-51 basins and to remove excess water from Lake Okeechobee when it is above its regulation schedule.

The criteria state that the structure be operated to maintain optimum stages of 11.5 and 10.5 irrigation and drainage phases, respectively.

The data indicate that during Irene this structure was used to maintain stages at least a foot below optimum for drainage. This is consistent with pre-storm draw-downs and as such the structure appears to have been operated in accordance with the criteria.

S-6 (4.47 inches)

This structure is a three unit pumping plant located in the alignment of

the Hillsboro Canal, at its intersection by Levee 6 and Levee 7, about 20 miles southeast of the town of Belle Glade in the South-Central section of Palm Beach County. The purpose of the pumping station is to pump surplus water via the Hillsboro Canal from Lake Okeechobee and the agricultural area northwesterly of the pumping station into Conservation Area 1, at the rate of 3/4 inch per day from the 146 sq. mile tributary drainage area.

The criteria require that the pumping station be operated whenever the water level in the Hillsboro Canal exceeds the optimum level of 12.5 feet. The criteria do not state when pumping should stop.

The data indicate that pumping was done continuously with stages maintained substantially below 12.5 feet as a part of the pre-storm draw-down activities. Based on this, it appears that the structure was operated in accordance with the criteria.

S-7 (4.98 inches)

This structure is a pumping plant with a gated spillway which controls flows which bypass the pumps. This structure is located in the alignment of North New River Canal, at its intersection by Levees 5, 6, and 18, about 26 miles south of the town of Belle Glade and just east of U.S. Highway No. 27 at the Palm Beach-Broward County line. The purpose of the pumping station is to discharge drainage water via the North New River Canal from the agricultural area northwesterly of the pumping station into Conservation Area No. 2.

The criteria require the pumping station to be operated whenever the water level in the North New River Canal within the agricultural area tributary to the pumping station exceeds 12.5 feet.

The data indicate that pumping started when the headwater was at 11.37 feet as opposed to the 12.5 feet contained in the criteria. This is consistent with pre-storm draw-down activities and as such the structure appears to have been operated in accordance with the criteria.

S-8 (6.45 inches)

This structure is a pumping station with a gated spillway which can control flows which bypass the pumps. The structure is located in the alignment of the Miami Canal at its intersection by Levees 4, 5, and 23, about 30 miles southwest of the town of Belle Glade and 15 miles west of U.S. Highway 27 at the Palm Beach-Broward County line. The purpose of the structure is to discharge excess drainage water via the Miami Canal, from the agricultural area north of the pumping station, into Conservation Area No. 3 at the rate of 3/4 inch per day from the 208 sq. mile tributary drainage area.

The pumping station is operated whenever the water level in the Miami Canal within the agricultural area tributary to the pumping station exceeds

12.5 feet, unless the water level in the conservation area is low enough to permit gravity discharge at a satisfactory rate through the adjacent spillway gate.

As early as October 12, the pump station was being operated to keep headwater levels substantially below the 12.5 foot pumping criteria. This is consistent with pre-storm draw-down activities and as such the structure appears to have been operated in accordance with the criteria.

S-2 (2.57 inches)

S-3 (2.22 inches)

The purpose of these structures is to backpump surplus water into Lake Okeechobee. S-2 has four pumps and S-3 has three pumps. These structures are operated in accordance with the Everglades Agricultural Area Interim Action Plan. Under this plan, various factors are considered and points assigned based on the conditions. For example, one factor is average canal level. If less than 11 feet, –1 point is assigned; if between 11 and 11.5 feet, 1 point is assigned; if between 11.5 and 12 feet, 3 points are assigned. There are a total of 10 factors that are considered. If the sum of the points is between 21 and 34, then the decision is made to backpump to Lake Okeechobee and the Water Conservation Areas. Total points assigned to S-2 and S-3 were 25 and 22, respectively, on October 16. This resulted in the decision to pump. Based on this it appears as though these two structures were operated in accordance with the criteria.

With one exception, all pumping units at the six pump stations reviewed operated satisfactorily during this event. The exception was at Pump Station S-7 where one of the three pump units was down for repairs. Therefore, 1/3 of the pump station capacity (or 830 cfs) was not available to support pumping operations during the storm period. The unit went down on September 22, due to a pump bearing failure and was returned to service on November 1. In this instance, awaiting the delivery of repair parts aggravated our ability to return the pump station to full service sooner than November 1. The degree to which this reduction in pumping capacity influenced an earlier backpumping requirement at pumping station S-2 is unknown and beyond the scope of this assessment.

As noted elsewhere in this report, backpumping at S-2 and S-3 was required during this event to control rising stages in the northern portion of the EAA. S-2 and S-3 began pumping at 1:15 am on October 16th and 11:30 am on October 16th, respectively. Backpumping shutdown occurred at 6:15 am on October 18th for S-3 and at 10:30 pm on October 22nd for S-2. The total quantity of water backpumped amounted to approximately 34,888 acre-feet.

The Everglades Construction Project (ECP) is bringing about some

major changes in the handling of runoff from the EAA. For example, in terms of quantity, (a) the secondary systems located along the southern rim of Lake Okeechobee currently backpump totally into the Lake, but under a fully completed ECP, will divert 80% of their discharge to the south and into stormwater treatment areas (STAs); (b) a portion of the runoff now being handled by S-5A will be diverted to S-6 and into STA 2; and (c) the runoff from the C-139 basin located in eastern Hendry County and outside the EAA will be handled by S-8 and one augment pump station (G-404). Consequently, the triggers we now use for backpumping may soon need to be revisited.

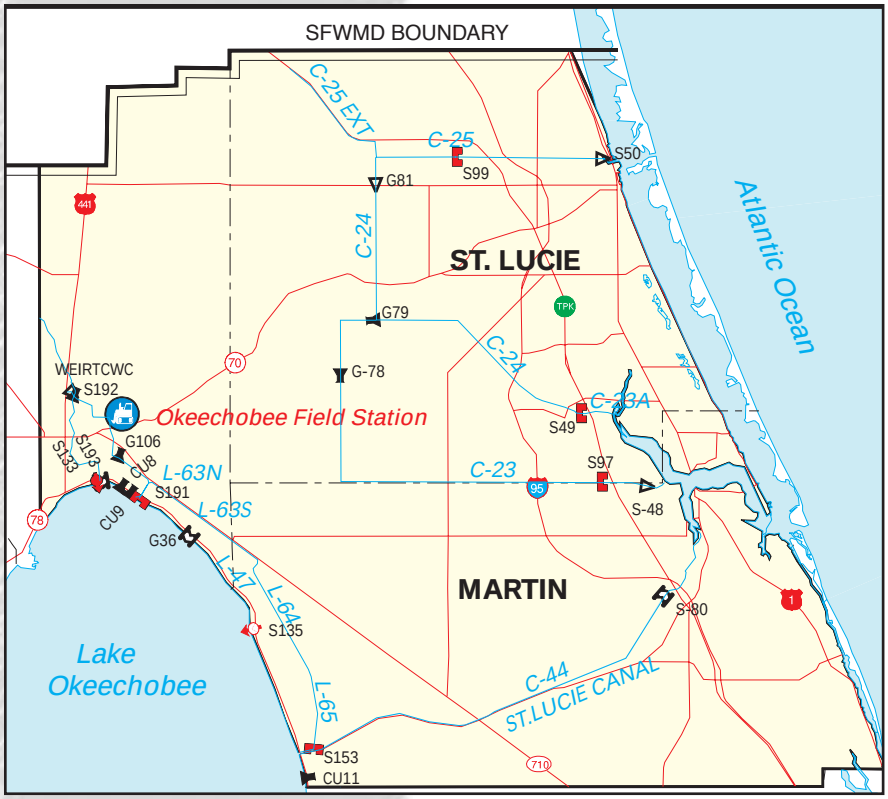
Another location that could be a positive influence on balancing operations in the EAA is the old Everglades Drainage District (EDD) Bolles and Cross canals. These canals represent an interconnected artery running generally in an east-west direction, about 5 to 7 miles south of Lake Okeechobee at Belle Glade, and intersecting the Hillsboro, North New River, and Miami canals along the way. At one time, the USACE was looking at the merits of improving this waterway. Currently, both canals are totally inefficient and cannot be effectively utilized to transfer water between the sub-basins. During rainfall events, such a transfer capability would allow movement of water towards the least stressed sub-basin, thereby helping to minimize backpumping.

Based on the foregoing, we recommend the following:

- **Water Resources Operations (WRO) should review their repair parts and shelf life policy for pumping stations to ensure that adequate parts are being stocked to facilitate repairs and, within all practicality, minimize downtime.**

- **In consonance with the Department of Environmental Protection's work on the Lake Okeechobee operating permit, the District should consider carrying out a reevaluation of the EAA backpumping operational criteria given the changing hydrology within the EAA.**

- **The District should encourage the USACE to revitalize the Bolles and Cross Canals study, given the operational sub-basin transfer features that would come into affect with an improved east-west artery at this location. This work should be given a higher priority than now given in the Restudy.**



St. Lucie and Martin Counties water control facilities

Martin/St. Lucie Counties

COUNTY LINE CANAL (C-23 BASIN[11])

One water control structure within this basin was evaluated for adherence to operational criteria. The structure and our assessment are noted below.

S-97

This structure is a reinforced concrete, gated spillway with discharge controlled by two cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gate operating system opens or closes the gates in accordance with the seasonal operational criteria. The structure is located on C-23, 3,300 feet west of the Sunshine State Parkway, and about 2 1/2 miles west of S-48.

This structure maintains optimum upstream water control stages in C-23; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels.

This structure is operated under either high or low ranges depending on basin conditions. The low range requires that the gates be opened when the headwater elevation rises to 22.2 feet and closed when the headwater elevation falls to 20.5 feet.

The high range requires that the gates be opened when the headwater elevation rises to 23.2 feet, and closed when the headwater elevation falls to 22.2 feet.

Our review indicated that this structure was operated to maintain stages well below the low range of the normal operating criteria. This is consistent with pre-storm draw-down activities and as such the structure appears to have been operated in accordance with the criteria.

The C-23 basin is approximately 167.7 square miles in area and is located in southwest St Lucie County (82.7 square miles), eastern Okeechobee

[11] **For more details on this canal, refer to the November 1988 Technical Memorandum entitled: An Atlas of St. Lucie County Surface Water Management Basins.**

County (14.0 square miles), and northern Martin County (71.0 square miles).

There are three Project structures controlling flow in the C-23 canal: S-48, S-97, and G-78. The S-97 structure is the focus of this review. The 3-day rainfall total for this event at this structure was 3.78 inches.

During Hurricane Irene discharge at S-97 peaked at 4,590 cfs. This compares to the design discharge of 5,035 cfs, which represents 30% of the standard project flood. Achieving maximum discharge has always been problematic at this structure due to an inability to develop a tailwater as contemplated in the original design. Consequently, full gate openings are not possible without risking structure stability. Both the USACE and the District have given this problem some attention, but a permanent fix has not yet been forthcoming.

It should be noted that failure of a local agricultural reservoir resulted in large uncontrollable inflows to C-23 in combination with energy dissipation problems at S-97 created a very serious concern for the integrity of S-97.

A hydrographic survey of the C-23 canal indicates that shoaling exists. The degree to which this shoaling impacted flow is unknown and beyond the scope of this report.

Based on the foregoing, we recommend the following:

- **Water Resources Operations should work closely and quickly with the USACE in determining a permanent fix for the tailwater problem at S-97. The corrective measures agreed to should be implemented as soon as possible.**

- **The prioritized District canal cleanout schedule[12] under the canal conveyance capacity program, which includes the C-23 canal, should be strictly followed.**

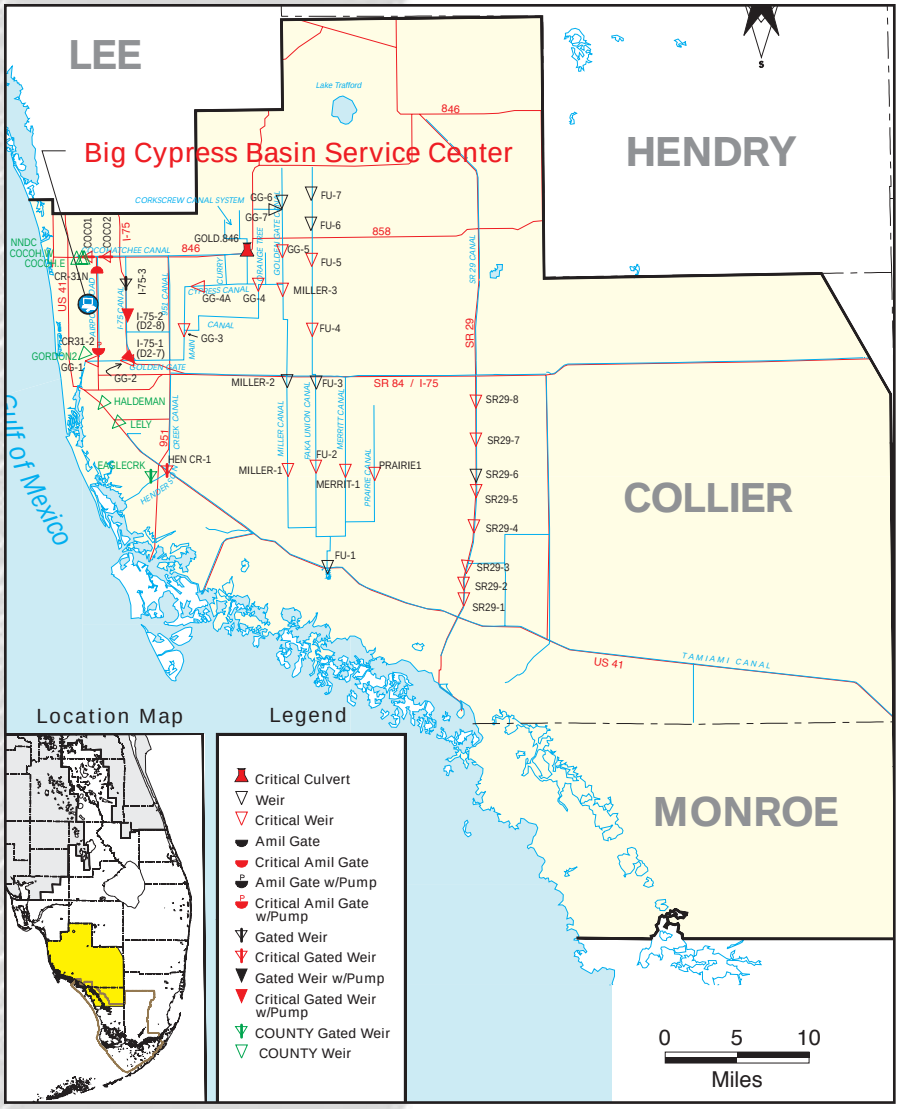
[12] See Operations and Maintenance Department (now Water Resources Operations) canal conveyance cleanout report dated March 27, 1998.

Other Comments, Observations & Recommendations

Following are observations that were made during interviews and discussions. While they are outside the scope of the report, they are noteworthy, merit mention, and perhaps further action.

BIG CYPRESS BASIN

Due to Irene's initial projected track, initial forecasts for the Big Cypress Basin area were for rainfall of approximately 5 1/2 inches, with some areas forecast to receive between 12-15 inches for Thursday and Friday. As a result of the forecast, all coastal structures in the Big Cypress Basin were opened to



Big Cypress Basin water control facilities

maximum capacity in order to lower the system in anticipation of heavy to excessive rainfall.

The Big Cypress Basin has no water supply storage capacity – it's basically a "ditch and drain" system. As a result, when the system is drained in preparation for storm events, it must rely on subsequent rainfall to replenish the system. This is particularly an issue with late season storms due to the fact that the dry season is fast approaching. The water lost in preparation for Hurricane Irene is not likely to be replenished with rainfall, which may lead to more severe drought conditions.

The preparation of a Basin Watershed Model is in progress to determine if there are water storage/supply opportunities available in the Big Cypress Basin. **It is recommended that the Big Cypress Basin Watershed Model be moved forward as quickly as possible.**

LAKE ISTOKPOGA

In Highlands County near the Lake Istokpoga area, reports were received stating that some agricultural concerns in the area were using unpermitted pumps to drain fields. This could result in decreased capacity in the District's primary canal systems. **It is recommended that monitoring efforts be increased in the Lake Istokpoga area to ensure compliance.**

FIELD STATION PERSONNEL RESPONSIBILITIES

It was noted during an interview that field station personnel are required to be on 24-hour call when storm events occur. They are also asked to volunteer for phone bank duty, resulting in potential overtaxing of critical field personnel. **It is recommended that field station personnel's services for phone bank duty not be requested due to critical responsibilities at our field sites.**

MANNING OF NAVIGATIONAL LOCKS

Navigational locks at S-193 and S-310 are manned and operated by personnel contracted through the District. When a hurricane is approaching, the USACE assumes responsibility for operation of the locks within 12-24 hours of the storm's arrival. Their responsibility ends when the threat of the storm has passed. When the USACE assumes responsibility, the locks are no longer operated for navigational purposes, but solely on an emergency situation basis. There is little coordination or clear communication regarding the transition of staffing for the locks between the EOC and the USACE, which could potentially result in the locks being unmanned for a period of time. A potentially dangerous situation exists, because people trying to evacuate boats from the affected area may be left on the lake during a dangerous storm event. **The recommendation is to create a clear communication process between the USACE, the District's EOC and locktenders so no lapse in coverage is experienced.**

EMERGENCY STRUCTURE PROGRAM

The Emergency Structure Program was developed and implemented as a result of the October 1995 wet season storms. It allows the secondary districts flexibility in operating structures that alleviate flooding in the secondary systems. Currently, approximately half a dozen agreements of this nature exist – primarily with secondary districts located in Northern Palm Beach and Martin-St. Lucie Counties. It is important to note that the secondary districts are not permitted to make discharges without communicating, coordinating, and obtaining District consent.

The program has obvious benefits and some drawbacks, as well. Benefits include allowing secondary systems to increase their drainage capacity with minimal downstream impacts. It is also contributes to improved relationships, coordination, and cooperation with the secondary districts. Some drawbacks are: it is very difficult to monitor discharges and can result in decreased capacity in and lack of control of the District's primary canal system. It is also very labor and time intensive because of the coordination and constant communication needs, particularly during storm events when resources are already stretched.

It is recommended that Water Resource Operations and Regulation continue to carefully investigate the merits of implementing the Emergency Structure Program keeping in mind the inherent risks and resource requirements associated with the program. Furthermore, some information received indicated the existence of post-storm communication difficulties between the EOC, District Control Room and secondary districts. **Therefore, it is also recommended that a clearly understood communication process/protocol be established between the EOC, Control**

Room, and secondary districts that will enable responsive, effective decision-making. It is further recommended that a representative from the Regulation Department be present in the Control Room during EOC activation in order to coordinate requests dictated through permits.

PRE-WET SEASON WORKSHOP

Currently, no forum exists for all of the various agencies with water control responsibilities to discuss the state of their systems and preparedness prior to entering into the wet/hurricane season. This is true primarily because flood control matters typically are a low priority until a storm event is approaching. Such a forum could serve to bring flood control issues to the forefront and also allow for the coordination of efforts and sharing of resources in advance of the Hurricane season. It could also serve as an opportunity to strategize pre-storm actions in order to alleviate flooding in vulnerable areas and would include addressing the maintenance of the secondary canal systems. We should work hard with local governments to help alleviate the kind of condition immediately following Hurricane Irene that resulted in our District's having to commit manpower and equipment to assist in cleaning out secondary canals in Miami-Dade County. This was at the expense of our other needs within our own project.

We recommend that, at a minimum, an annual pre-wet/hurricane season workshop be held county by county prior to the wet/hurricane season that includes representatives from the primary and secondary systems.

RIGHT OF WAY MAINTENANCE

In certain areas within the District, vegetation can grow 8-10 feet between mowing. The frequency rate of mowing is currently 120 days. This impedes after storm damage assessments. For example, post-Irene inspection crews were dispatched and piping was discovered only because they were able to hear it. The area of inspection was completely overgrown with Brazilian Pepper and not visible.

It is recommended that the District revisit the frequency of mowing, particularly during hurricane season.

EMERGENCY OPERATIONS CENTER STANDARD OPERATING PROCEDURES

Throughout the interviews conducted for the development of this report, many individuals commented that the EOC operated in a very effective and efficient manner. Communications between the EOC, field stations, service centers, area offices, and external agencies were said to be outstanding.

A potential area for improvement would be in the Suggested Operating Procedures (SOP's) and communications regarding deployment of field

crews. Under the SOP's, certain criteria must be met before the EOC gives the order to deploy field crews. This could mean that weather conditions have degraded substantially and could pose a potential risk to field crews. **We recommend that the Emergency Manager reevaluate the process used for ordering field crew deployment with an eye towards allowing field managers more on site flexibility to take advantage of the moment.**

STORM ASSESSMENT REPORTS

In the past after each storm event and/or wet season the District prepared a Storm Report. These reports provided information on the storm or wet season's environmental impact, water quality, rainfall analysis, meteorological description and system operation. **It is recommended that the District resume and assign responsibility for the preparation of storm assessment reports after each storm event or wet season, depending on the level of activity. It is also suggested that the District commit the resources needed to move forward with the recommendations brought forth in each assessment.**

Workforce Performance

In response to this Hurricane event and within the units identified, we found no evidence that our workforce did not perform as intended. In other words, we found that the workforce as a whole performed in accordance with job requirements and the needs of the District. In many cases, individual and crew performance was commendable.

However, we did note that several personnel worked consecutive hours in excess of that recommended by the risk management profession.[13] The element of fatigue within the workforce introduce an increased exposure to accidents and an environment for poor decision making. Fortunately, there were no lost time injuries or evidence of any poor decision making during the course of this event.

This storm, as a Category 1 hurricane, was more of a rainfall event than a windstorm event. Consequently, the demands on our workforce were not as intensive as they might have been with a higher category storm, which creates both flood and major waterway debris problems. Moreover, such a storm would have occupied our workforce over a much longer duration under emergency conditions.

Accordingly, we recommend that the Deputy Executive Director of Water Resources Operations review his field staffing capabilities to sustain recovery operations for that period of time between the passage of a design storm (say, wet category 3 hurricane) and the arrival of pre-contracted, emergency recovery, augment forces from the private sector. The Beck Study[14] is a good reference source for this purpose. We also recom-

[13] There were 71 occurrences where employees recorded over 16 hours worked during a work day.

[14] Beck, R.W., *Emergency Response Resource Model*, Operations and Maintenance Department, South Florida Water Management District, July 1995

mend that our pre-contracting arrangements with local contractors be examined for reliability and response time provisions.

DID WE REACT EARLY ENOUGH?

The chronology located in the Background section of this report (page 7) clearly establishes that overall, during Hurricane Irene, we took the appropriate action at the appropriate time. With the arrival of each advisory from the National Weather Service, communications were quickly disseminated and the necessary preparation and actions were completed. Furthermore, actions were taken as soon as practicable after the storm had passed.

In the case of the South Dade Conveyance System, the question is: Would we have reacted differently if the three-party agreement had been more flexible and sensitive to the flood control needs that existed prior to the storm? The answer to this questions is –Yes. However, if there was a lapse by us on this matter, it was that we didn't independently choose to elevate this critical issue up to our Executive Director and he, in turn, confer with the USACE Jacksonville, District Engineer and the Superintendent of ENP about the flood potential and further actions that might be taken outside of the bounds on the agreement.

While the chronology indicates that appropriate actions were taken during the storm event, flood control planning should not begin two days prior to a storm. Flood control is one of our primary mission elements but it does not always receive adequate weight, or priority, when the Agency's funding decisions are being made. While considerable resources are devoted to the repair and maintenance of infrastructure, flood control should also include planning considerations for system improvement. For example, one area that flood control planning could address initially is the basin level of service question. That is: Does an adequate flood control level of service exist within the key basins of the District? **Accordingly, we recommend that a District program be established to (a) address such a question, (b) consider system upgrade options where level of service is deem substandard, and (c) explore cost share options with the involved local governments and USACE, as applicable.**

5. Appendices

Appendix A: Memorandum entitled "Hurricane Irene After Action Assessment," dated October 26, 1999

CON 34

MEMORANDUM

TO: Joseph A. Schweigart, Director, Everglades Construction Project

FROM: Frank R. Finch, P.E., Executive Director

DATE: October 26, 1999

SUBJECT: Hurricane Irene After-Action Assessment

I would like you to lead an evaluation of District operations during Hurricane Irene. I have asked our Auditor General to provide support to you for this review. By copy of this memo, I am alerting our District leadership to provide you additional assistance, as needed.

Please focus on two major areas:

1. District operations
   - Did we operate according to our approved criteria?
   - Did our infrastructure perform as intended?
   - Did our workforce perform as intended?
   - Did we react early enough?
   - Could we have done anything better?
2. Operating Criteria
   - Have we found significant shortcomings in the criteria?
   - Are there modifications we might recommend for better system performance?

I would like a report of your findings by Thursday, November 18, 1999. Your evaluation should be unconstrained and objective. The principal purpose is to identify possible system improvements.

FRF/lcs

c: James Blount
John Fumero
Jeannie Hall
Bill Malone
Jock Merriam
Mike Slayton
Charlotte Taylor
Allen Vann

APPENDIX B: SUMMARY OF RECOMMENDATIONS

Miami-Dade County

SOUTH DADE CONVEYANCE SYSTEM

1. The District should call for an assessment of the benefits of preparing the Test 7 final report stipulated in the October 1995 Environmental Assessment. This would be a comprehensive report, covering the period from November 1, 1995 to October 31, 1999. This report would make definitive hydrologic and ecological conclusions about Test 7, and recommend any possible improvements. A report written jointly between the three parties would not be required, but cooperation between the three parties and other government agencies in writing this report would be encouraged.

2. The District should propose revisiting the operating criteria, in the context of the USACE proposed Interim Operating Plan, to consider (a) stipulating the involvement of the USACE Jacksonville, District Engineer; the Superintendent, ENR; and the District's Executive Director, along with their water managers/hydrologists, when critical flood control decisions are to be addressed prior to the onslaught of a major storm, and (b) flood control criteria modifications. Parallel to this Test 7 process, an Interim Operating Plan is being prepared by the USACE to address the sparrow nesting requirements.

3. The District should weigh the benefits attained through automation of the three screw-gated culverts at S-197, recognizing the remote nature of this site, infrequent operation, and vandal prone nature may make the automation effort expensive in relation to the benefit received.

4. Encourage full participation of affected interests in the operational plan development under way should be encouraged and an acceleration of the ultimate plan of improvement for the Modified Water Deliveries and C-111 projects.

5. The warranty work on the S-332D pump station should be completed as soon as possible in order to improve the operational readiness of the pump station.

SNAPPER CREEK CANAL (C-2), CORAL GABLES CANAL (C-3) AND TAMIAMI CANAL (C-4) BASINS

6. As a first step in the search for a system betterment solution, we recommend that a feasibility study be undertaken to consider the practicability of the options as follows: (1) backpump into a detention area in Area B, (2) pump forward to tide at S-25B, (3) hook up to an ASR unit, and (4) use deepwell injection without recovery.

SNAKE CREEK CANAL (C-9) BASIN

7. As a means to better system performance, we recommend that the feasibility study proposed for the C-4 canal also consider the same set of options for C-9. In this instance, backpumping to a water storage area may be more in keeping with the District's long range water conservation plans. Another option would be to request the that USACE perform a reconnaissance study covering Area B backpumping.

Broward County

SOUTH NEW RIVER CANAL (C-11) BASIN

8. The S-13 pump station should be equipped with an automatic trash rake like all the other District primary pump stations. A state-of-the-art unit similar to that recently provided at the Everglades Construction Project's Pump Station G-337 is suggested.

9. Add a remotely operated, electrically powered pump unit designed to only handle water conservation area seepage at Pump Station S-9. [Note: The seepage pump concept has already been identified by the Restudy and is designated as a critical project.]

Palm Beach County

BOYNTON CANAL (C-16) BASIN

10. The prioritized District canal clean-out schedule under the canal conveyance capacity program should be strictly followed.

WEST PALM BEACH CANAL (C-51) AND LEVEE L-8 FACILITIES

11. Completion of the C-51W Plan of Improvement should stay on schedule.

12. Opportunities should be explored for improving eastern basin flood control management. The District should work with local governments and the Lake Worth Drainage District to identify areas of improvement and avenues of approach.

13. The Deputy Director of Water Resources Operations (WRO) and the Director of Water Control Operations should clarify and strengthen the District's decision making protocol with respect to the Indian Trails Improvement District agreement and revisit the criteria to ensure clarity, fairness, and manageability.

14. Prior to such time as the USACE gets construction underway at C-51W and STA 1 East, the West Palm Beach Field Station, with the support of the WRO Staff civil engineer, should conduct an earthen stability inspection of the raised south berm to help identify other weak or low spots and make corrections in an effort to help prevent another breach event.

15. The removal of G-124 should be reevaluated each year prior to hurricane season. Climatological, meteorological, hydrological, and length of time remaining prior to the completion of S-155A should be considered. The Governing Board should approve any forthcoming Staff recommendation to remove. Removal of the structure should not be attempted under high flow conditions.

16. The District should work closely with the USACE, local governments, and the Indian Trails Improvement District in swiftly moving the GRR for the L-8 Basin along. This represents a first step in helping to find ways to better system performance.

EARMAN RIVER (C-17) BASIN ISSUES

17. The District should identify the person who will take the lead for us on the C-17 basin study group. This group may need to pull in further participants from local governments, but it appears to be an excellent forum to review system improvement issues.

Everglades Agricultural Area (EAA) Basin

18. Water Resources Operations (WRO) should review their repair parts and shelf life policy for pumping stations to ensure that adequate parts are being stocked to facilitate repairs and, within all practicality, minimize downtime.

19. In consonance with the Department of Environmental Protection's work on the Lake Okeechobee operating permit, the District should consider carrying out a reevaluation of the EAA backpumping operational criteria given the changing hydrology within the EAA.

20. The District should encourage the USACE to revitalize the Bolles and Cross Canals study, given the operational sub-basin transfer features that would come into affect with an improved east-west artery at this location. This work should be given a higher priority than now given in the Restudy.

Martin/St. Lucie Counties

COUNTY LINE CANAL (C-23 BASIN)

21. Water Resources Operations should work closely and quickly with the USACE in determining a permanent fix for the tailwater problem at S-97. The corrective measures agreed to should be implemented as soon as possible.

22. The prioritized District canal cleanout schedule under the canal conveyance capacity program, which includes the C-23 canal, should be strictly followed.

Other Comments, Observations & Recommendations

23. The Big Cypress Basin Watershed Model should be moved forward as quickly as possible.

24. Monitoring efforts should be increased in the Lake Istokpoga area to ensure compliance with permits.

25. Field station personnel's services should not be requested for phone bank duty due to critical responsibilities at our field sites.

26. A clear communication process should be created between the USACE, the District's EOC, and locktenders so no lapse is coverage in experienced.

27. Water Resource Operations and Regulation should continue to carefully investigate the merits of implementing the Emergency Structure Program keeping in mind the inherent risks and resource requirements associated with the program.

28. It is recommended that a clearly understood communication process/protocol be established between the EOC, Control Room and secondary systems that will enable responsive, effective decision making.

29. A representative from the Regulation Department should be present in the Control Room during EOC activation in order to coordinate requests dictated through permits.

30. At a minimum, an annual pre-wet/hurricane season workshop should be held, county by county, prior to the wet/hurricane season, that includes representatives from the primary and systems.

31. The District should revisit the frequency of levee mowing, particularly during hurricane season.

32. The Emergency Manager should reevaluate the process used for ordering field crew deployment with an eye towards allowing field managers more on site flexibility to take advantage of the moment.

33. The District should resume and assign responsibility for the preparation of assessment reports after each storm event or wet season, depending on the level of activity. It is also suggested that the District commit the resources needed to move forward with the recommendations brought forth in each assessment.

34. The Deputy Executive Director of Water Resources Operations should review his field staffing capabilities to sustain recovery operations for that period of time between the passage of a design storm (say, wet category 3 hurricane) and the arrival of pre-contracted, emergency recovery, augment forces from the private sector. The Beck Study is a good reference source for this purpose.

35. We also recommend that our pre-contracting arrangements with local contractors be examined for reliability and response time provisions.

36. A District program should be established to (a) address the level of flood control service within key basins, (b) consider system upgrade options where level of service is deem substandard, and (c) explore cost share options with the involved local governments and USACE, as applicable.