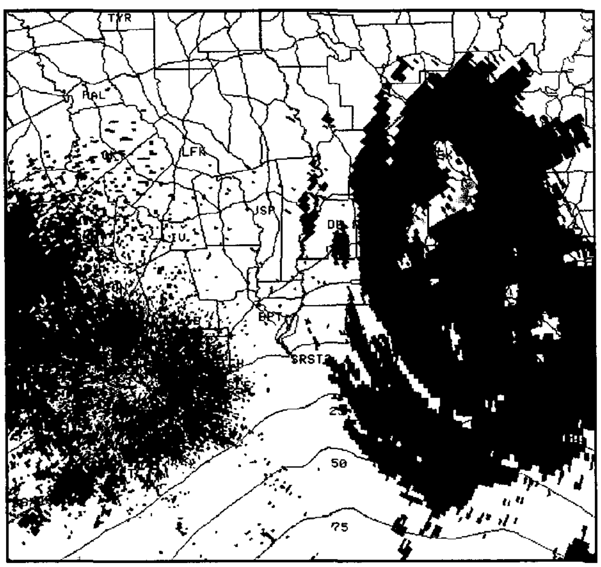
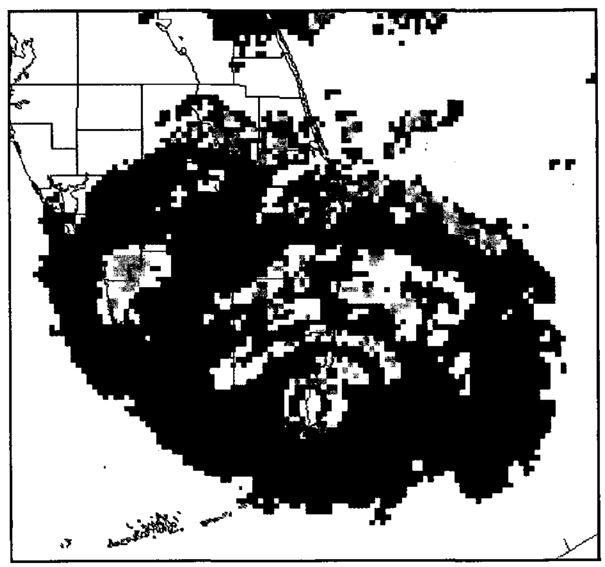
Natural Disaster Survey Report

Hurricane Andrew: South Florida and Louisiana August 23-26, 1992





U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service, Silver Spring, Maryland

Cover: Left photograph—Houston's WSR-88D, 0107 UTC, August 26, 1992; Right photograph—Melbourne's WSR-88D, 0106 UTC, August 24, 1992.

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Hurricane Andrew: South Florida and Louisiana August 23-26, 1992

November 1993

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

National Oceanic and Atmospheric Administration
D. James Baker, Administrator

National Weather Service
Dr. Elbert W. Friday, Jr., Assistant Administrator

ACKNOWLEDGMENTS

The outstanding efforts of our National Oceanic and Atmospheric Administration (NOAA) employees ensured the safety of millions of citizens in the path of this country's most destructive storm. The National Weather Service (NWS) staff throughout south Florida, and later in Louisiana, worked long hours under physically and emotionally stressful conditions. I am deeply moved by the dedication of those most affected, specifically those in and around south Dade County. Many of our people lost all or part of their homes and their personal belongings, and some were displaced for months after the storm. Yet they, as well as other Federal, state, and local employees, remained at their post in the worst of conditions, putting the public welfare ahead of their own safety.

Once again, I congratulate those who made NOAA's response to this powerful storm a success story. You are an inspiration to us all.

Dr. Elbert W. Friday, Jr.

November 1993

PREFACE

The primary purpose of this disaster survey has been to evaluate the performance of the NWS in fulfilling its mission of providing timely warnings and accurate forecasts for Hurricane Andrew. The responsibilities of NOAA, the parent agency of the NWS, are broader. The NWS' products and services are key to severe storm preparedness and the mitigation of its impact: its SLOSH (Sea, Lake, and Overland Surges from Hurricanes) models are used by emergency evacuation planners; its wind speed measurements are used to develop building codes and to design buildings; and its warnings and forecasts are instrumental to placing a timetable on implementing preparedness actions and response efforts. But NOAA's partnership role with states in managing the Nation's coastal zone, NOAA's trustee responsibility for marine resources, and other agencywide concerns compel NOAA to step outside of the traditional NWS format in this preface to comment on Hurricane Andrew's consequences in south Florida and Louisiana.

NOAA and the NWS are dedicated to a continuing improvement in warnings and forecasts, thereby allowing emergency management officials lead time to take lifesaving action. But, if disastrous consequences are to be mitigated, the coastal zone and other areas at risk must be managed in recognition of the awful threat to life and property that hurricanes pose.

Hurricanes, of course, are natural meteorological events. In the absence of people and their property, hurricanes expend their force against marine and terrestrial ecosystems that adapt to the storm's destruction. People and their property, unfortunately, are not as resilient as damaged ecosystems. Hurricanes frequently have caused significant loss of life and massive damage to property and natural resources at tremendous cost both to public and private sectors. Until the past 30 years, however, areas vulnerable to hurricanes have been relatively undeveloped; vacation beach houses were "beach shacks" or "cottages," easily rebuilt after a storm. Urban and suburban development was confined to relatively few areas, often limited in its landward spread by wetlands.

The rush to the sun belt in the 1960s, 1970s, and 1980s fundamentally changed Coastal Plains demographics. Beach cottages were replaced by million dollar dwellings, and suburban and urban development became more extensive along the coast and extended much further inland. Hurricanes Hugo and Andrew have been the most costly storms in history <u>largely</u> because there is now more development in place to damage and destroy. Given current development patterns and trends along the coast, we can anticipate both damages and costs to increase with future storms. We would do well to heed the warnings that population growth and land use practice in the Nation's Coastal Plains have set a stage for a series of hurricane disasters and associated economic consequences of unprecedented proportions. For example:

- Populations have grown explosively in coastal areas over the past 30 years. This growth has created the obvious logistical problems associated with warning and safely transporting ever-increasing numbers of residents out of harm's way or to adequate shelters. This inordinate burden is leading to evacuation times in some areas of the country that are double the effective warning times that the National Hurricane Center (NHC) can provide. There are other difficulties as well: there are significant coastal populations which have not experienced a hurricane and may be less able to prepare for one and respond properly before, during, and after the event. In urban and suburban areas, even the best organized government response may be unable to meet needs for shelter, food, and water.

- Development has been concentrated on barrier islands and in coastal flood plains. Such development almost never relates to natural geographic or geomorphic limits of areas vulnerable to hurricanes. In most places, infrastructure is designed and subdivisions are approved without reference to the need to evacuate low-lying areas quickly. Coastal construction setbacks, where they exist, often are inadequate to accommodate the storm surge of a major hurricane. Structures employ architectural designs, materials, and techniques that cannot withstand hurricanes. In booming communities vulnerable to hurricanes, local building departments often are unable or unwilling to keep pace with code enforcement—even if there is an adequate code to enforce.

- These problems are exacerbated by continued destruction of and interference with natural protective features: beaches, dunes, tidal wetlands, mangroves, and the like. Many state and local planners and emergency managers now understand the importance of a healthy beach/dune system and maintaining it by limiting so-called "hard" erosion control structures and following regular maintenance programs; many others do not.

Hurricane Hugo

In 1989, Hurricane Hugo foreshadowed the scale of hurricane disasters yet to come. After dealing a serious blow to the Caribbean, including Puerto Rico and the Virgin Islands, the major force of the storm hit the mainland United States at Cape Romain National Wildlife Refuge, then Francis Marion National Forest before wreaking havoc for many miles inland. Despite heavy damage to Charleston and its environs, the city largely was spared—at least compared to the devastation it would have suffered had Hugo's eye come ashore 20 miles further south. The sight of once beautiful vacation homes reduced to wind and water-borne debris along Charleston County's barrier islands obscured the fact that Hugo's wind effects could have been far more significant had they struck a more populated area.

In the wind damage along the South Carolina coast, Hugo also provided a glimpse of building code and engineering issues. Myrtle Beach was well north and east of the storm's major effects, but structures there that had been designed to withstand winds significantly greater than those actually experienced performed poorly. Other areas suffered because South Carolina had no statewide building code or hurricane resistance standards (and does not to this day) or because local building codes were not enforced adequately. The almost complete destruction of mobile homes in the path of the storm served notice once more that mobile homes are no place to be during severe weather.

Hurricane Andrew

Andrew defines the current problem: the majority of the damage was inland, outside of the primary storm surge areas where emergency preparedness and response officials usually focus their attention. Much of the coastal development in the past 30 years has been outside hurricane surge zones but well within wind zones.

Although Andrew caused significant flooding damage immediately adjacent to the coast, wind damage caused most of the devastation. Water, in the form of storm surge and flooding, still poses the greatest threat to public health and safety as local authorities must be able to evacuate the population at risk in time. After all, had the topography of Cutler Ridge not impeded the storm surge, it would have affected areas much further inland. Still, Andrew likely will prove the norm for future storms rather than the exception: winds will pose a very significant threat to life and safety and cause a major percentage of property damage.

In densely populated areas, it is all but impossible to evacuate for wind. Forecasters cannot yet predict wind fields accurately, and the large numbers of residents that would need to be evacuated to ensure an adequate margin of safety would overwhelm roads and shelters almost immediately. On the other hand, given extensive development in vulnerable areas inland, no longer can public officials afford to perceive hurricanes as merely flood/storm surge events. Instead, emergency preparedness officials and land use planners must consider hurricanes as much broader "wind/flood/storm surge" events affecting areas many miles inland. New approaches and building codes must be developed to protect the public. All of Florida, for example, must be considered vulnerable to the effects of hurricanes, regardless of how far from the coast. All of its communities should implement hurricane preparedness and mitigation policies.

Land Use Management

Advances in technology may improve long-range forecasting, and Weather Surveillance Radar-1988 Doppler (WSR-88D) is helping to improve short-term warning and forecasting, but it is unlikely that lead times can be increased significantly in the near future. Current lead times cannot provide enough warning in many heavily populated areas to evacuate threatened residents effectively.

NWS warning capabilities are only one side of the equation for reducing threats both to public health and safety and to property. The other side is state and local government actions that control development in hurricane-prone areas and plan for and carry out evacuations. Redefined as wind/flood/storm surge events, hurricanes present state and local planners with five areas of focus in addition to ongoing efforts.

- Emergency planners' primary priority must be to evacuate residents at risk from storm surge and other types of flooding, regardless of the extent of a hurricane's potential wind damage. These residents remain the most vulnerable to hurricanes. Planners must continue to reduce evacuation times in areas vulnerable to flooding from storm surge. In regions where development densities and patterns have outstripped the capacity of the area's infrastructure to handle evacuations, the best that can be hoped for is to minimize the number of residents in surge areas when the storm hits and to provide refuges of last resort.

- Officials need to ensure that adequate building codes are in place and that they are vigorously enforced. Building codes in coastal areas nationwide should be revised based on the Andrew experience. Because many structures were destroyed when door or window failures allowed wind pressure to demolish roofs from the interior, codes need to emphasize appropriate door and window storm covers. Even areas well inland must have hurricane resistance codes. Such codes should be enforced throughout the State of Florida.

- Regulations should be promulgated to require that new structures contain "hardened" interior rooms to provide in-place hurricane shelters and require that, at a minimum, mobile home parks have hardened sheltering for all residents.

- State and local officials need to devise programs to retrofit existing buildings to provide in-place hardened sheltering and to bring substandard housing into compliance with a hurricane-resistant code.

- State and local officials need to revise land use planning, subdivision approval, and permitting processes to consider the potential effects of severe storms.

Hurricane Andrew has given lessons to NOAA, too. For its part, in addition to continuing to improve NWS warning and forecasting capabilities, NOAA will continue to work to make Federal hurricane preparation and mitigation programs consistent. NOAA programs, with relevance to coastal hazards mitigation, must work together more closely to provide better services to state and other Federal agencies. As a beginning, the National Ocean Service (NOS) currently is working to develop a response plan to provide needed immediate and longer term products and services to states after coastal disasters. NOS also is developing new protocols consistent with the Federal Response Plan. Finally, NOAA will seek improvements both in its support for state coastal management programs and in the programs themselves.

To address the frightening potential consequences of increased hurricane activity, NOAA seeks a new partnership with states. State and local governments, through natural resource agencies, boards, and building inspectors, must work in collaboration with insurance companies, building industries, and other private sector groups to minimize the general population's exposure to the threats of hurricanes.

FOREWORD

This report on Hurricane Andrew was prepared by the DST after weeks of interviews and visits to the damaged areas with Federal, state, and local officials in Florida and Louisiana. Significant input also was provided by citizens in the affected areas.

The DST is particularly grateful to the NOAA employees in the affected areas for their assistance, despite the extreme hardship endured by so many of the NOAA family. We are grateful to the state and local officials and representatives of relief agencies who took time from urgent duties to provide their impressions of the events during and after the storm's onslaught. We deeply appreciate the willingness of many citizens who shared their experiences with the DST, despite the complete devastation of all their worldly possessions.

We commend the dedication and professionalism displayed by the NOAA staff as well as other Federal, state, and local employees who remained at their post under the most extreme of conditions, putting the public welfare ahead of their own safety. While this document is not intended to chronicle the entire history of the storm and its aftermath, it assesses NOAA's performance and recommends where improvements are needed.

We acknowledge, with admiration and gratitude, the many people whose individual and collective efforts saved the lives of their fellow human beings. To all whose participation made the response to Hurricane Andrew an overwhelming success, thank you.

The Disaster Survey Team

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PART II: LOUISIANA

APPENDICES

ACRONYMS

AFB	Air Force Base
AFOS	Automation of Field Operations and Services
AOC	Aircraft Operations Center
AOML	Atlantic Oceanographic and Meteorological Laboratory
AP	Associated Press
ASOS	Automated Surface Observing System
AVN	Aviation Model
AWIPS	Advanced Weather Interactive Processing System
BAM	Beta Advection Model
BMS	Bahamas Meteorological Service
CARCAH	Chief Aerial Reconnaissance Coordination for all Hurricanes
CDT	Central Daylight Time
CLIPER	CLImatology-PERsistence hurricane tracking model
CPA	Closest Point of Approach
CPCS	Common Program Control Station
CWA	County Warning Area
DEM	Division of Emergency Management
DIFAX	Digital Facsimile
DMSP	Defense Military Satellite Program
DST	Disaster Survey Team
EBS	Emergency Broadcast System
EDT	Eastern Daylight Time
EM	Emergency Management
EOC	Emergency Operations Center
ET	Electronics Technician
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
ft	Feet
FTS	Federal Telephone System
GDS	Graphic Decision System
GOES	Geostationary Operational Environmental Satellite
GOES-Next	GOES-Next Generation Satellite
HF	High Frequency
HLS	Hurricane Local Statement
HPP	Hurricane Preparedness Program
HRD	Hurricane Research Division
ICCOH	Interagency Coordinating Committee on Hurricanes
kts	Knots
LALETS	Louisiana Law Enforcement Telecommunications System
LMRFC	Lower Mississippi River Forecast Center
MARS	Military Affiliate Radio System
mb	Millibars
MEOW	Maximum Envelope of Water
Meteosat	Meteorological Operations Satellite

MIC	Meteorologist in Charge
MOU/A	Memorandum of Understanding/Agreement
mph	Miles per hour
MSL	Mean Sea Level
NAWAS	National Warning System
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar
NFD	National Forecast Division
NGVD	National Geodetic Vertical Datum
NGWLMS	Next Generation Water Level Measurement System
NHC	National Hurricane Center
NHC90	NHC 1990 Hurricane Computer Forecasting Program
NLETS	National Law Enforcement Telecommunications System
nm	Nautical miles
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center
NWR	NOAA Weather Radio
NOS	National Ocean Service
NWS	National Weather Service
NWSO	NEXRAD Weather Service Office
NWWS	NOAA Weather Wire Service
OEM	Office of Emergency Management
OES	Office of Ocean and Earth Sciences
OIC	Official in Charge
OSF	Operational Support Facility
PC	Personal Computer
PUP	Principal User Processor
QLM	Quasi-Lagrangian Model
Rmax	Radius of Maximum Wind
RFC	River Forecast Center
RTA	Remote Terminal to AFOS
SAB	Synoptic Analysis Branch
SELS	Severe Local Storms Branch of NSSFC
SHIFOR	Statistical Hurricane Intensity Forecasting Model
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SRH	Southern Region Headquarters
SWIS	Satellite Weather Information System
SWODY1	Severe Weather Outlook—Day 1
SWODY2	Severe Weather Outlook—Day 2
SWOMCD	Severe Weather Outlook—Mesoscale Convective Discussion
TCD	Tropical Cyclone Discussion
TCM	Tropical Cyclone Marine Advisory
TCP	Tropical Cyclone Public Advisory
TCU	Tropical Cyclone Update
TDL	Techniques Development Laboratory
TROPAN	Tropical Regional Analysis Facsimile Circuit
TSAF	Tropical Satellite Analysis and Forecast

UGC	Universal Generic Code
UPI	United Press International
UPS	Uninterruptable Power Supply
USACE	U.S. Army Corps of Engineers
USAFR	U.S. Air Force Reserve
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
VHF	Very High Frequency
WCM	Warning Coordination Meteorologist
WMO	World Meteorological Organization
WPM	Warning Preparedness Meteorologist
WSFO	Weather Service Forecast Office
WSO	Weather Service Office
WSR-57	Weather Surveillance Radar-1957
WSR-74(C,S)	Weather Surveillance Radar-1974 (C-band, S-band)
WSR-88D	Weather Surveillance Radar-1988 Doppler
WWAMKC	SELS Severe Local Storm Watch Status Report

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EXECUTIVE SUMMARY

The tropical disturbance that grew into Hurricane Andrew developed in the central tropical Atlantic Ocean on August 16, 1992. Eventually a category 4 storm on the Saffir-Simpson Scale, Andrew went on to inflict more dollar damage than any natural disaster in United States history. Upon its Florida landfall at 5 AM Eastern Daylight Time (EDT) on August 24, wind from Andrew was a sustained 145 mph with gusts over 175 mph. Over a narrow area, the storm surge reached more than 14 feet, with storm tides attaining nearly 17 feet (storm tides comprise the sum of storm surge and astronomical tides).

Andrew traversed south Florida and entered the Gulf of Mexico just 4 hours after impacting the east coast of Florida. After weakening to a category 3 over land, the storm quickly reintensified to a category 4 as it moved across the gulf. Prior to its landfall in Louisiana at 4:30 AM EDT on August 26, Andrew again weakened to a category 3. Its maximum sustained winds in Louisiana were estimated at 120 mph with higher gusts.

The devastation left in Andrew's wake over south Florida was immense. Total damage estimates of about $25 billion cannot convey the profound impact of the storm. According to insurance industry leaders, the total economic impact of Andrew will reach $35-40 billion by 1995. Moreover, the fabric of organized society was shredded in south Dade County, Florida. A total of 126,000 houses were destroyed or damaged and 9,000 mobile homes were destroyed. Andrew left at least 160,000 people homeless in Dade County alone. Perhaps years will be required to rebuild the original infrastructure. The municipal electric power grid in Homestead and Florida City was destroyed. Banking, and therefore much of society's ability to function, came to a halt. Businesses were unable to reopen because their employees were homeless and struggling to shelter, clothe, and feed themselves and their families. A total of 86,000 people lost their jobs. The National Guard provided tent cities and the essentials to live, but many chose to remain in what was left of their homes for fear of looting.

The damage from Andrew across Louisiana was overshadowed by what occurred in south Florida, but the storm still had a profound effect. Damages from Andrew in Louisiana are estimated to exceed $1 billion. Some small businesses were lost and many suffered some damage. Much of the estimated losses were insured: about 3,300 single family, multifamily, and mobile homes were destroyed. Over 18,000 units received some damage. As in south Florida, the National Guard quickly took control, protecting the hardest hit areas from looting. The storm's effect on Louisiana public utilities was minimal. Quick action by local and Louisiana state officials promoted both a rapid response to the disaster and immediate launching of a coordinated recovery effort.

Despite the severe physical damages and crippling monetary losses, human casualties were surprisingly few. In Florida, 15 deaths were directly attributed to the storm, with another 29 fatalities indirectly related. Those indirect fatalities were caused by electrocutions, cleanup accidents, fires, and other incidents associated with recovery. In Louisiana, 8 direct and 9 indirect fatalities occurred. Indirect fatality totals depend on the broadness of definition and vary greatly. For example, one major newspaper reported 85 indirect south

Florida fatalities. Those numbers include persons killed in motor vehicle accidents where a stop sign was down due to Andrew. The number of indirect fatalities the disaster survey team uses (29 in south Florida and 9 in Louisiana) are those for which the county medical examiner or parish coroner determined the storm to be a contributing factor.

Even before the Presidential Declaration of Disaster, NOAA/NWS assembled a Disaster Survey Team. The DST was responsible for assessing the performance of NOAA and the hazards community prior to and during the hurricane. The hazards community consists of all Federal, state, and local governmental entities, as well as the mass media and volunteer organizations, involved in the distribution and dissemination of weather information for the protection of life and property. Following the assessment, the DST was responsible for providing any necessary recommendations for improvements.

The DST found that NOAA performed exceptionally well both prior to and during Hurricane Andrew. The hurricane forecast track error was 30 percent less than average. Lead times on hurricane watches and warnings were 3 to 6 hours better than average. Hurricane watches were issued with 36 hours of lead time in south Florida and 43 hours in Louisiana. Hurricane warnings were issued with 21 hours lead time in south Florida and 36 hours in Louisiana. Throughout the event, NWS personnel, despite enormous personal hardship, supplied timely, high quality information to the public via NOAA Weather Radio (NWR), NOAA Weather Wire Service (NWWS), direct links with emergency management, and the mass media. To assure this flow of vital information, contingency plans were activated for backup of the NHC and for the Weather Service Forecast Office (WSFO) at Miami should they have become unable to function. Those plans were not needed for the NHC, but WSFO Atlanta and Weather Service Offices (WSO) at Tampa Bay and West Palm Beach provided forecasting issuance and backup warnings, respectively, for WSFO Miami.

State, county/parish, and local emergency management agencies, working in concert with law enforcement and based on information supplied by the NWS, coordinated some of the largest evacuations in United States history. In south Florida, as well as Louisiana, literally hundreds of thousands of people left their homes.

The DST found that the collection and dissemination of information, through appropriate warnings and statements, need improvement. In particular, hurricane local statements (HLS) need to be shortened and reorganized to provide more timely and specific information pertaining to the local area. The DST found also that WSOs and WSFOs need to address storm-scale events occurring within hurricanes by using appropriate severe weather warnings and statements, including tornado warnings. Additionally, Andrew re-emphasized the need for improvement in hurricane intensity forecasting. Finally, the DST found that wind, not storm surge, was the major cause of direct deaths in Andrew. Still, these statistics need to be kept in perspective: 12 of the 15 deaths directly attributed to Andrew in Florida were caused by wind as compared to the potential for hundreds of fatalities that could have occurred from storm surge. The reality is that evacuation from wind would involve far too many people to be accomplished; alternative shelter may be necessary.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

PART I

Chapter I.B

Finding I.B.1: The NHC is charged with a national focus on hurricane readiness, but it dominates the NWS hurricane preparedness program in south Florida.

Recommendation I.B.1: The NWS should staff WSFO Miami with a Warning Coordination Meteorologist (WCM) as soon as possible to enhance the WSFO's preparedness/hazard awareness program.

Finding I.B.2: This was the first time that the NHC (and the collocated WSFO Miami) facility had been directly affected by a major hurricane. The impact of Andrew proved the vulnerability of NHC to the effects of extreme wind.

Recommendation I.B.2: Better protected, self-contained facilities should be provided to the NHC and all NWS coastal offices. This is even more critical to National Centers, such as NHC, for which full backup procedures are extremely difficult to implement.

Finding I.B.3: Hurricane Andrew was characterized by devastating effects of strong inland winds in addition to powerful storm surges. The devastation that eventually occurred over south Florida heightened the awareness in other vulnerable areas to the significant inland wind damage which can accompany a hurricane.

Recommendation I.B.3: The NWS should provide technical assistance for a much more concerted preparedness and awareness effort by state and local emergency management and such other cognizant organizations as state coastal zone management agencies in areas of high vulnerability.

Finding I.B.4: Since the lead time for evacuation may be no more than 24 hours, it may not be practical or even possible to evacuate all inland residents in the path of a hurricane eyewall.

Recommendation I.B.4: The NWS should work with FEMA, state, and local emergency planners in exploring the potential of developing a "refuge of last resort" methodology, as appropriate, for occasions when critical saturation points are reached in the flow of evacuation traffic.

Chapter I.C

Finding I.C.1: The detailing of two hurricane specialists to the National Meteorological Center (NMC) is not sufficient to provide adequate continuous backup to NHC operations.

Recommendation I.C.1: The NWS should adopt a plan that would increase the number of forecasters capable of acting as hurricane specialists during an emergency brought on by a hurricane threatening NHC. There must be adequate staffing at both NHC and the backup site. One plan would be to provide hurricane forecast training to a select group of forecasters, possibly from NMC, who could fly to NHC as replacements for hurricane specialists dispatched to staff the backup center.

Finding I.C.2: When NHC staff is drawn down to implement the backup at NMC, insufficient staff remains at NHC to handle advisories of multiple tropical cyclones properly.

Recommendation I.C.2: See Recommendation I.C.1.

Finding I.C.3: Facilities for interacting with the media are very limited at NMC.

Recommendation I.C.3: The NMC should formulate a plan for handling the extensive interactions with the media that are required when a hurricane is threatening the United States coastline. Since NMC is the logical site for the backup forecast center, plans should be made to accommodate the large number of media personnel who will descend upon the backup center, especially if it is required to take over the primary forecast mission.

Chapter I.D

Finding I.D.1: NHC watch and warning lead times during Hurricane Andrew were longer than average for landfalling hurricanes. That extra margin of safety was at least partially responsible for allowing hundreds of thousands of people to evacuate safely from south Florida.

Recommendation I.D.1: NOAA and the NWS should work toward increasing watch/warning lead times by supporting efforts to enhance our understanding of tropical systems, improving numerical models, providing greater data availability to feed the models, and enhancing operational forecast methodologies. A significant step in this direction would be the collocation of the Environmental Research Laboratory's Hurricane Research Division (HRD) with NHC to allow for the synergism of research and operations.

Finding I.D.2: HLSs from WSO/WSFOs tend to be too lengthy, too infrequent, tend to reiterate NHC advisories too much, and tend not to include enough specific information about local conditions.

Recommendation I.D.2: The NWS should explore options to make HLSs more effective. This should include use of the "Short Term Forecast" concept and its relationship to HLSs and hurricane advisories. Furthermore, coastal offices should re-evaluate the manner in which data are collected and used to create HLS products. Emphasis should be made on use of on-station software, emergency management information, and remote sensing data to create a highly specific, current product.

Chapter I.E

Finding I.E.1: Concern was expressed by two emergency managers over the tone set by NHC on Friday afternoon when a "Have a good weekend...tune back in on Sunday or Monday" message was given to emergency management. Some officials felt that message could have promoted a less-than-serious attitude and that it could have caused them not to pay close attention to storm information during the weekend.

Recommendation I.E.1: Although NHC is extremely concerned about how information is presented, care must continue to be exercised not to send unintended messages.

Finding I.E.2: Many coastal emergency managers do not understand the scientific reasoning involved in designating hurricane watch and warning areas. They want to evacuate either all or none of their coastal surge vulnerable area rather than parts of counties.

Recommendation I.E.2: There needs to be better dialogue between NHC and emergency management involving the designation of hurricane watch and warning areas. Conference calls following or preceding a watch or warning issuance always should contain a thorough explanation for the choice of the end points of the areas. NHC also should explore the feasibility of including this information in the tropical cyclone discussions. Courses offered at NHC for emergency managers should include a segment on the subject of designating watch and warning areas.

Finding I.E.3: One critical aspect of hurricane forecasting—the intensification of storms—lags far behind the balance of the science. SHIFOR, the computer model used to forecast hurricane intensification, is old and ineffective. It does a poor job of handling rapid intensification.

Recommendation I.E.3: NHC, NMC, and HRD should redouble their efforts to develop models and operational techniques to forecast tropical cyclone intensity changes more effectively. In turn, NOAA should support research efforts at understanding and predicting cyclone intensity changes.

Finding I.E.4: Some emergency managers could have made greater use of hurricane strike probabilities and personal computer (PC) software in their decision-making process.

Recommendation I.E.4: Emergency management needs to use all the tools available to them to provide information for their decision-making processes, including PC-based software specifically designed for that purpose. The NWS should work with FEMA to support more workshops for coastal emergency managers. This should include instructions on how to use these tools effectively.

Finding I.E.5: As a result of increased anxiety caused by Hurricane Andrew, many south Florida residents indicated they would evacuate for future major hurricanes. Indeed, if this was the case, evacuation times for a category 4 or 5 hurricane striking the Florida Keys would increase from the pre-Andrew level of 37 hours to 70-80 hours, depending on the percentage of residents evacuating.

Recommendation I.E.5: NWS and FEMA should work in concert to develop response options as outlined in Recommendations I.B.4 and I.F.2.

Finding I.E.6: The link between the NWS, emergency management, and the broadcast media is critical to any community warning system. A partnership developed to coordinate NHC information through a broadcast "pool" enabled a large number of media outlets to receive broadcast footage from NHC without crowding the facility and compromising the operational setting.

Recommendation I.E.6: NWS should support development of similar broadcast pools at local offices along the hurricane-prone coasts, as well as at NMC, should backup for NHC be required.

Finding I.E.7: Television meteorologists were instrumental in encouraging evacuation from the threatened areas. Many of the television broadcasts were simulcast on AM and FM radio. This was particularly useful since many residents received lifesaving advice through their battery-operated radios when television transmitters were knocked off the air.

Recommendation I.E.7: NWS offices along hurricane-threatened areas should continue to encourage proactive, weather-conscious media who will provide that essential link with the public to convey lifesaving information.

Finding I.E.8: Efforts of the NWS, in conjunction with state and local emergency management and the news media, resulted in clear and motivating messages to the general public. Those messages resulted in a superb public response, except for some residents of Miami Beach, and may have saved countless lives.

Recommendation I.E.8: NHC and WSFO Miami should work with the local media to target those populations in Miami Beach where the response was deficient.

Chapter I.F

Finding I.F.1: NHC and NWS representatives, when making a case for refuges of last resort, may have contributed unintentionally to the problem of public resistance to evacuation by stressing the danger of being caught trying to evacuate.

Recommendation I.F.1: NWS and NHC representatives need to stress to the public the importance of referring to appropriate state and local emergency management directives about evacuation orders.

Finding I.F.2: If residents of the hard hit Naranja Lakes area had not evacuated because of the storm surge threat, more deaths likely would have resulted from the effects of wind.

Recommendation I.F.2: Since in many cases evacuation is not a viable option, the NWS and the Federal Emergency Management Agency (FEMA) should work together to encourage the concept of engineered in-residence shelters to protect from severe wind without invoking evacuation procedures.

Finding I.F.3: Many residents whose houses began to disintegrate during the storm followed "tornado safety rules" and went to the interior part of their house away from windows and outside walls.

Recommendation I.F.3: NWS and emergency management agencies should make "tornado safety rules" a standard component of hurricane awareness efforts, especially for strong storms. The public also should be better educated about the kinds of construction and building designs which are most vulnerable in strong hurricanes.

Chapter I.G

Finding I.G.1: Small errors in the track forecast produced by the Aviation Model were impressive for this small sample of forecasts.

Recommendation I.G.1: NOAA should continue to support development of such models. In order to use these models most effectively, methods need to be explored to gather better data in and around tropical cyclones. The Omega dropwinsonde experiment should be conducted to evaluate the potential of this capability.

Finding I.G.2: The storm surge impacted a relatively small area of coastline, but the SLOSH model accurately depicted the surge in south Florida.

Recommendation I.G.2: Refinements to the SLOSH model should continue. Also, training of NWS offices and emergency managers in its use should be emphasized. The SLOSH model should be validated in cooperation with the NOS/Office of Ocean and Earth Sciences (OES) and others to further continued improvements in the model. A greater effort should be made to document its physics and the validation efforts that justify its use. NOS should assist with such a documentation.

Finding I.G.3: On-station computers at WSOs and WSFOs are inadequate to run storm surge and applications programs.

Recommendation I.G.3: Coastal NWS offices should be provided sufficient PC hardware and software to display SLOSH MEOW (Maximum Envelop of Water) data as well as to run surge applications and hurricane decision-making programs. The Advanced Weather Interactive Processing System (AWIPS), under development for future NWS Weather Forecast Offices, should be able to support these programs.

Chapter I.H

Finding I.H.1: Despite the extensive commercial media coverage of Andrew, both the NWWS and NWR were well received and were utilized as official and timely sources of NWS information regarding the event.

Recommendation I.H.1: The NWS should continue strong encouragement of the widespread use of NWWS and NWR as official sources of NWS information. High priority should be placed on planned NWR upgrades and more wind-resistant transmitters, featuring voice synthesis, to improve the quality and efficiency of NWR dissemination during major weather events. The NWS should develop partnerships with FEMA and other organizations to increase NWR coverage as well as the broadcasting of critical pre- and post-event information.

Finding I.H.2: NHC made effective use of the Florida National Warning System (NAWAS) circuit to communicate with Florida emergency managers and Florida WSOs on important hurricane information.

Recommendation I.H.2: FEMA, NWS, and state emergency management offices should develop procedures to use the national NAWAS circuit for multistate conference calls so that NHC can brief all appropriate emergency management officials on the network during a hurricane threat.

Finding I.H.3: Excessive heat build-up contributed to the failure of the IBM mainframe computer at the NHC during the hurricane. This was the most serious communications failure at NHC because of the IBM's role in driving the McIDAS VDUC, a principal source of interactive satellite data for the NHC staff. In addition, other important circuits failed which depended on the IBM.

Recommendation I.H.3: The NWS should install a stand-alone air-conditioning system for the NHC independent of leased commercial facilities. This would greatly minimize the heating problem of critical communications and computer equipment.

Chapter I.I

Finding I.I.1: Satellite imagery is the only source of information over data-sparse oceans, except for ships which generally avoid rough weather.

Recommendation I.I.1: NOAA must make every effort to ensure that the GOES-Next (Geostationary Operational Environmental Satellite-Next Generation Satellite) program remains on schedule. Meanwhile, No-GOES plans need to be tested routinely.

Finding I.I.2: Aircraft reconnaissance is a necessary and vital tool for measuring storm intensity, for defining wind fields, and for calibrating satellite estimates of storm intensity. However, the current airframes are aging and provide limited range and performance characteristics.

Recommendation I.I.2: Aircraft reconnaissance of tropical cyclones must continue. In order to provide high quality data on the storm and its environment, NOAA should explore cost-effective options on future sensors and airframes. This must be done now if we are to make effective use of next generation models for tropical cyclone intensity and track forecasting.

Finding I.I.3: The precision, range, and refinement offered by the WSR-88D allowed for precise location not only of the eye but also, long before landfall, of stronger elements in the spiral bands. The ability of the WSO at Melbourne to observe and report on these small but significant features enabled them to allay public fears about a potentially approaching hurricane.

Recommendation I.I.3: Efforts by the NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DOD) to deploy the WSR-88D nationwide must continue. In addition, NOAA needs to assure staffing of its NWS Doppler radar equipped offices with properly trained personnel in order to take best advantage of this powerful data source.

Finding I.I.4: Wind observations are taken at varying heights and with different sampling strategies, making the determination of winds during a severe storm difficult to assess.

Recommendation I.I.4: The Office of the Federal Coordinator for Meteorology should continue to work with the various Federal agencies to ensure that wind observation adjustments are standardized for height and sampling interval variations to ensure consistency of data.

Finding I.I.5: Many wind observation sites failed not because of a failure of the instrument but because of the manner in which the support hardware was constructed and assembled.

Recommendation I.I.5: The NWS and FAA need to inventory their F420 anemometer installations in hurricane-threatened areas. The NWS and FAA should consider retrofitting suspect F420 sites with a locking cross arm prior to the 1994 hurricane season. Furthermore, the NWS Automatic Surface Observing System (ASOS) program office should investigate the potential for failures in the ASOS wind mast and sensors during high wind episodes.

Finding I.I.6: Valuable wind and pressure observations were lost when the data-gathering systems were powered down or removed before Andrew's landfall.

Recommendation I.I.6: Agencies with meteorological data-gathering equipment in the path of a hurricane should be encouraged to continue the data collection process throughout the event.

PART II

Chapter II.B

Finding II.B.1: There is an insufficient supply of safety and preparedness materials in support of NWS field offices, local emergency preparedness officials, and the public.

Recommendation II.B.1: NOAA and the Department of Commerce should increase their support for developing, printing, and distributing high quality preparedness and awareness materials. Present cooperative efforts with other agencies and the private sector to develop and distribute awareness and preparedness materials should be increased.

Finding II.B.2: The local print media is more reactive in community preparedness than proactive. Historically, in south Louisiana, the print media has not actively participated in preseason hurricane preparedness efforts, such as awareness campaigns. On the other hand, during the 72 hours prior to Andrew, they were extremely effective in providing their readership with detailed preparedness information.

Recommendation II.B.2: NWS offices in south Louisiana need to develop stronger cooperative relationships with the print media to enhance their involvement in the hazards awareness and mitigation program.

Finding II.B.3: Local emergency managers in south Louisiana were very proactive, taking the early initiative in dealing with Hurricane Andrew.

Recommendation II.B.3: The NWS must continue working closely with local emergency managers to ensure that together they promote a unified awareness program which elicits the desired public response.

Chapter II.D

Finding II.D.1: Users of NWS products would like more specific, technical information to assist them in their decision-making process.

Recommendation II.D.1: The NHC should work with users to define what additional information is required and to develop a means of communicating that information to them.

Finding II.D.2: Hurricane local statements were too closely tied to the issuance of hurricane advisories. As a result, the dissemination of critical information concerning tornadic events was delayed.

Recommendation II.D.2: The issuance of hurricane local statements should be event driven, rather than tied exclusively to routine NHC issuances.

Finding II.D.3: During the peak period of tornado activity, several reports of tornadoes were highlighted in the HLSs. One of these reports proved to be erroneous. Rather than issue a corrected HLS, the WSFO issued a special weather statement to acknowledge the error. This could have caused confusion and loss of precious time for users during a period of rapidly changing events.

Recommendation II.D.3: NWS field offices should follow established NWS formats for issuing corrections.

Chapter II.E

Finding II.E.1: FEMA/NWS-sponsored Hurricane Response and Decision-making Workshops are conducted only a few times each year. These workshops are incapable of reaching sufficient numbers of emergency officials. This limits the effectiveness of the hurricane preparedness program.

Recommendation II.E.1: FEMA and the NWS should increase the number of annual hurricane workshops to train coastal emergency management officials.

Finding II.E.2: Due to the close proximity of the WSFO, an agreement with the city allows for a dedicated meteorologist to be dispatched from the WSFO to the local Emergency Operations Center (EOC) during hurricane events which may threaten the city.

Recommendation II.E.2: Appropriate NWS staff should be dedicated to work with emergency management officials during major hazardous weather events.

Finding II.E.3: Formal evacuation clearance studies for southwest Louisiana have yet to be completed.

Recommendation II.E.3: FEMA and the USACE, with NWS support, should accelerate their efforts to complete evacuation studies for all hurricane-prone coastal areas.

Finding II.E.4: In general, coastal residents know that they have a potential storm surge problem. However, in some highly populated areas, such as Greater New Orleans, there are preliminary evacuation studies but no proven orderly plan for the safe and timely evacuation of the entire metropolitan area. Furthermore, the scope of these studies does not address regional complications which can compromise orderly evacuation.

Recommendation II.E.4: FEMA, in concert with the NWS, should ensure the completion of local evacuation studies and integrate them into a comprehensive regional evacuation plan.

Finding II.E.5: The emergency management community of southeast Louisiana felt strongly that the fear of looting was partially responsible for a smaller than expected number of evacuees.

Recommendation II.E.5: Local governments, with NWS and FEMA assistance, need to educate residents to alleviate these inaccurate perceptions.

Finding II.E.6: There were a few instances where one local television station presented forecast track scenarios that conflicted with official NHC forecasts. That caused some problems for local parish and NWS officials.

Recommendation II.E.6: The local NWS offices in Louisiana should make a renewed effort to impress upon the local media that providing consistent information to the public is critical during emergency situations.

Chapter II.F

Finding II.F.1: Many southeast Louisiana residents did not understand the full extent of danger from storm surge.

Recommendation II.F.1: The NWS needs to work more closely with FEMA, as well as state and local officials, to develop more effective preparedness information about storm surge. Presentations tailored to local areas could provide information about situations to which residents could better relate.

Finding II.F.2: Some south Louisiana residents interviewed commented that they had evacuated highly vulnerable areas only to find themselves threatened by other hurricane dangers.

Recommendation II.F.2: The NWS, in concert with local emergency management officials, should ensure that evacuation studies are up to date and accurate. Given widespread distribution, the results of these studies can direct the public to appropriate shelter.

Finding II.F.3: Despite the efforts of the NWS and state and local emergency managers, not all residents heeded the various evacuation requests even though their lives may have been in jeopardy had the storm made landfall further east along the Louisiana coast.

Recommendation II.F.3: The NWS and FEMA need to increase their efforts to educate and train the public. Each agency needs to consider expanding their training capabilities to overcome the public's denial of the threat from hurricanes.

Finding II.F.4: Some residents of Greater New Orleans who evacuated and later returned to their homes felt that local officials overreacted in their evacuation recommendations, especially since Andrew made landfall further west than projected.

Recommendation II.F.4: The NWS needs to work closely with the emergency management community in convincing this most skeptical segment of the population that the advantages of evacuating far outweigh the disadvantages of remaining in place.

Chapter II.G

Finding II.G.1: WSFO Slidell, being collocated with the Lower Mississippi River Forecast Center (LMRFC), had access to RFC PCs and was able to run SLOSH MEOW and other hurricane decision-making applications.

Recommendation II.G.1: See Recommendation I.G.3.

Chapter II.H

Finding II.H.1: The Universal Generic Codes (UGC) were incorrectly entered in several of the products disseminated by south Louisiana offices.

Recommendation II.H.1: NWS offices should perform more on-the-spot quality control of products prior to their public release. The use of software, such as version 6.0 of SRWarn, would help eliminate many of these errors.

Finding II.H.2: Currently, not all coastal WSOs have access to the hurricane hotline.

Recommendation II.H.2: NOAA needs to expand the hurricane hotline to all coastal WSOs in hurricane vulnerable areas.

Finding II.H.3: The use of Army MARS (Military Affiliate Radio System) within the Louisiana emergency communications system was very successful.

Recommendation II.H.3: The NWS and FEMA need to coordinate with Army MARS to ensure that these capabilities can be extended to other locations.

Finding II.H.4: The State of Louisiana, Division of Emergency Management, currently does not have a fully automated information redistribution system.

Recommendation II.H.4: The NWS and FEMA should encourage the State of Louisiana to explore options for providing a fully automated communications system to law enforcement agencies and local emergency operating centers. Once in place, the NWS should arrange to link with that system allowing two-way communication of critical warning information between the NWS and the emergency management community.

Chapter II.I

Finding II.I.1: The U.S. Coast Guard (USCG) has decided to remove all large navigational buoys and replace them with other, smaller types of buoys. The replacement buoys are too small to be fitted with meteorological instruments. Loss of the current buoys, in the near future, will mean the loss of hourly data from stations along the Atlantic and Gulf of Mexico coasts.

Recommendation II.I.1: The NWS, through its National Data Buoy Center, should ensure that sufficient capabilities are present to maintain hourly observations along the Atlantic and Gulf of Mexico coastal waters.

Finding II.I.2: The implementation of service maintenance fees has resulted in the removal of meteorological equipment from gulf oil platforms, and a significant loss of data has occurred.

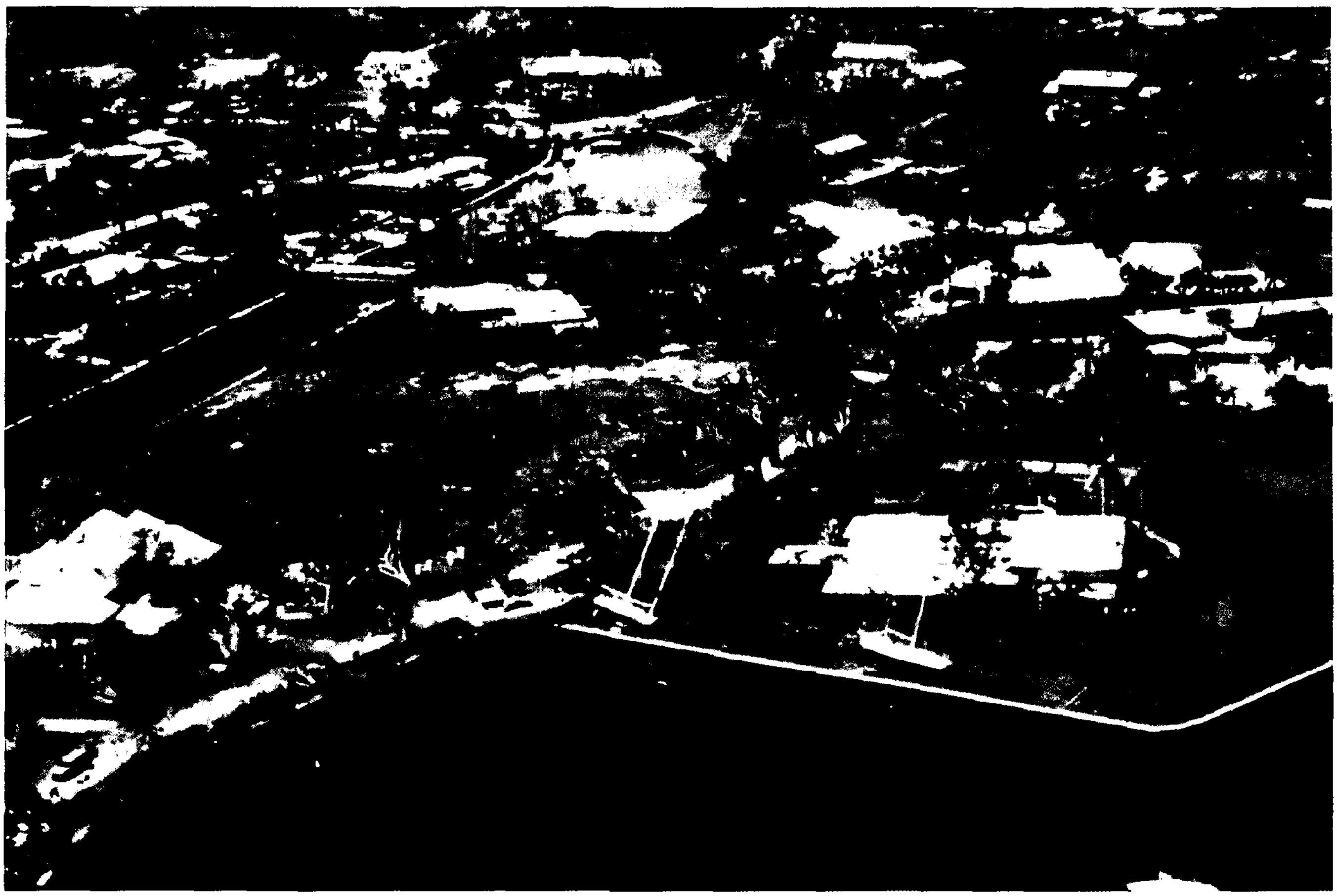
Recommendation II.I.2: NOAA must review its position on charging oil platforms a service fee to maintain meteorological equipment.

Finding II.I.3: Although Andrew did not move into WSO Houston's effective Doppler range, the WSR-88D radar did provide extremely detailed reflectivity data on the storm.

Recommendation II.I.3: See Recommendation I.I.3.

This tranquil scene was taken at Sewell Park in Florida located on the mouth of the Miami River on a normal day.

This is Sewell Park just after daybreak on August 24—water is still elevated.



Aerial photo of the marina "Gables by the Sea" located near Gables Estates, Florida. Numerous boats were forced ashore by the 9- to 16-ft storm surge.

HURRICANE ANDREW: THE EVENT AND ITS IMPACT

The intense winds accompanying Hurricane Andrew caused massive damage in southern Dade County and rendered it the costliest storm in United States history. The mind-numbing statistics of Andrew include 126,000 single family houses destroyed or damaged and 9,000 mobile homes destroyed. Officials ordered entire complexes bulldozed because there were no salvageable structures. Mobile home parks were cleared to make room for temporary housing. Andrew left 160,000 people homeless in Dade County alone. A total of 86,000 residents lost jobs, many permanently. Still, Florida was spared from an even larger disaster. Andrew was a compact, fast-moving, relatively dry storm. Had it been larger, slower, or carried more rain, its consequences would have been even more devastating. Further, and more significantly, Andrew's track **minimized** the damage to Dade County. Had the eye of the storm crossed the coast just 10 miles further to the north, it would have devastated downtown Miami, probably causing greater loss of life and tens of billions of dollars more in property damage. Andrew would have affected not only south Florida but the global economy since Miami is a very prominent world banking center.

Andrew was the third strongest landfalling hurricane in the United States this century. The estimated central pressure at landfall in Florida was 922 millibars (mb). The storm was classified at the upper threshold of category 4 on the Saffir-Simpson intensity scale (see appendix G). After raking Dade County, Andrew continued rapidly westward across south Florida and remained an intense storm as it traversed the Gulf of Mexico. Coincident with its landfall in Louisiana, it caused further significant damage. Although lives were lost both in Florida and Louisiana, the number of deaths was small considering the magnitude of destruction to property. That low number of fatalities was due partially to accurate forecasts and effective preparations and partially to the limited effect of storm surge. In Florida, 15 deaths are directly attributable to Andrew (29 indirect, including post-event electrocutions, cleanup accidents, heart attacks, and the like). In Louisiana, 8 fatalities are directly related to the storm and another 9 indirect.

In Louisiana, preliminary data for the 36-parish disaster area indicated that 3,301 single, multifamily, and mobile homes were destroyed, and 18,247 units received major or minor damages. Data compiled by a consortium of state agencies and groups with specific responsibilities in agriculture indicated that estimated agricultural losses would exceed $288 million. Sugarcane yield losses were estimated at $128.4 million, cotton losses at $68.2 million, and forestry-related losses at $38.6 million. The consortium also estimated losses of $13.2 million for the soybean crop, $12.7 million for corn, and $9.1 million for rice.

History of the Storm

Andrew formed from a tropical wave that moved off the African coast on August 14, 1992. The "best track" analysis of the storm's track is shown in figure 1. ("Best track" is a term used by the NHC to describe the closest post-event approximation possible on the track of a

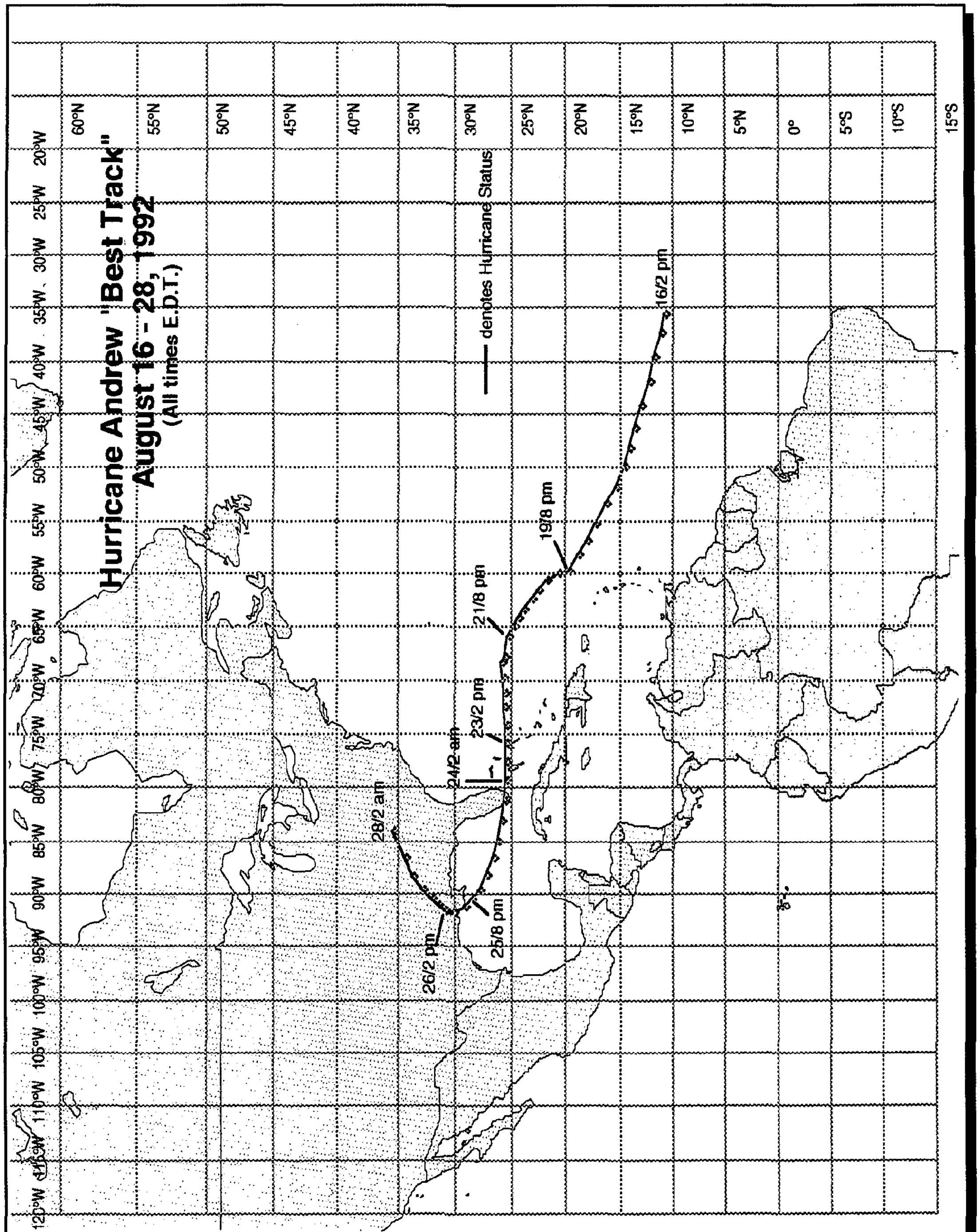


Figure 1 — Best track positions for Hurricane Andrew.

tropical system, based on satellite imagery, surface and ship observations, and any other data available.) Since the system was still outside of air reconnaissance range, satellite imagery was used exclusively to monitor the movement and structural changes to the developing system. By 2 PM EDT on August 16, the system had developed spiral cloud bands with wind speed estimated at 30 knots (34 miles per hour [mph]). The best track analysis indicates that the storm became a tropical depression at about that time.

On August 17, Andrew was classified as a tropical storm. It moved along a west-northwesterly track until August 22. The storm formed and intensified in an environment of weak easterly vertical wind shear. Large-scale processes that lead to tropical cyclogenesis are not well understood, but both observational and numerical modelling studies consistently show that cyclones can form and intensify readily in conditions of weak vertical shear, or sometimes in regions of moderate easterly shear. However, significant westerly shear over the top of a tropical cyclone is usually unfavorable for intensification or even maintenance of the storm.

During August 19-20, Andrew moved into a region with strong upper-level southwesterly winds associated with an upper-level low pressure system situated northwest of the storm. The resulting vertical shear is the probable cause of the observed filling of the central pressure to about 1015 mb. During this period, aircraft reconnaissance found that the storm circulation at lower levels was poorly organized, and satellite imagery showed only intermittent deep convection in the core region.

During August 21, the upper level low moved away from the storm, and Andrew was once again in an environment with vertical shears favoring intensification. It also turned west and accelerated to about 18 mph as high pressure north of the storm intensified, strengthening the easterly flow within which Andrew was embedded. The storm then followed an almost due westward track until it crossed Florida. Andrew rapidly deepened and reached hurricane intensity by 8 AM EDT on August 22. By 2 PM EDT on August 23, Andrew possessed a central pressure of 922 mb. It was at the upper end of category 4 strength (on the Saffir-Simpson scale) when its eye passed over the northern part of Eleuthera Island in the Bahamas on August 23 and the southern Berry Islands on August 24. Extensive damage occurred in these regions. Eleuthera experienced a high-water level (storm surge and waves) of 25 feet (ft) at the town of The Current.

Andrew weakened briefly on August 24, then rapidly reintensified. Once again, it deepened to have a minimum central pressure of 922 mb as it crossed the coast near Homestead Air Force Base (AFB), Florida, at 5:05 AM EDT, August 24. That pressure estimate was substantiated by pressure readings from barometers near the landfall, several of which were pressure chamber tested for accuracy following Andrew.

The storm was unusually compact. An aircraft penetration less than an hour before landfall showed that hurricane-force winds were confined to a region approximately 30 nautical miles (nm) in radius, with peak observed winds of 162 knots (kts) (186 mph) at a flight level of 10,000 ft (figure 2). The maximum sustained 1-minute surface (10-meter elevation) winds over southern Florida were approximately 125 kts (144 mph).

The most severe damage occurred along the swath of the eye and in the surrounding eyewall. Unofficial estimates of the pressure gradient in the eyewall on the north side of the storm

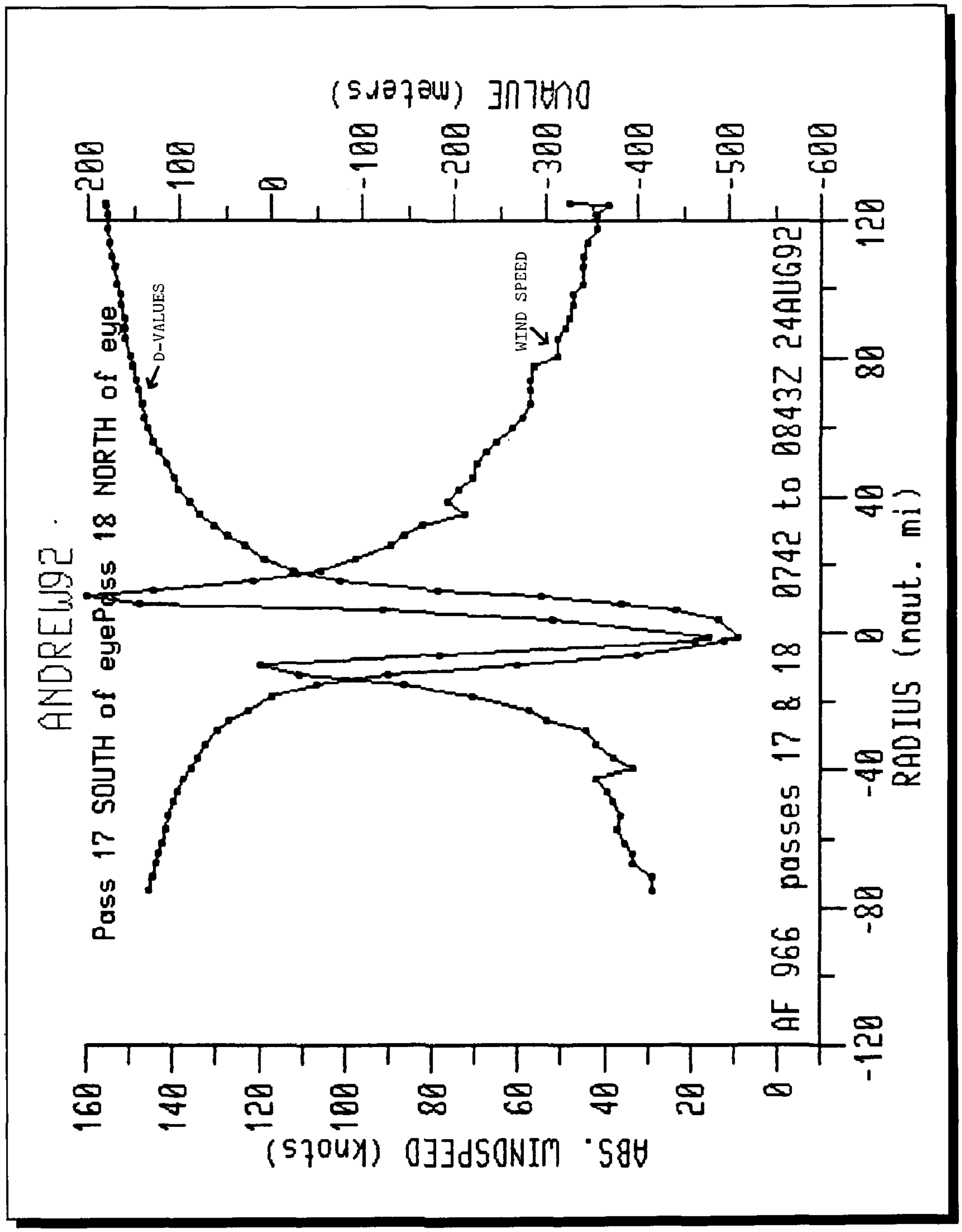


Figure 2 — Winds and D-values (variations in the height of a constant pressure surface, i.e., 700 mb) taken from the last aircraft pass, south to north, through Hurricane Andrew before it made landfall in Florida.

indicate that it may have been as large as 10 mb per nm. This is indicative of the extreme winds largely responsible for the tremendous damage.

Andrew was by far the most expensive natural disaster in United States history in terms of property loss (approximately $25 billion). In defiance of the conventional wisdom on hurricane effects in the United States, most of the damage was caused by the severe winds rather than the storm surge. The damage in Louisiana was substantial, over $1 billion, with about $300 million agricultural impact. The tornado at La Place was by far the most damaging Andrew-related element to manmade structures in Louisiana.

Hurricane Andrew continued westward across the southern tip of the Florida peninsula and exited on the west coast about 4 hours after it made landfall. The storm remained intense as it crossed the Gulf of Mexico, with surface pressure filling only to about 950 mb. During the 48 hours prior to landfall in Louisiana, two cycles of reintensification occurred, both the result of interactions between high pressure to the northeast and a mid-latitude trough to the northwest. As the high weakened, the influence of the mid-latitude trough became dominant. Steering winds across the northern gulf were altered; Andrew turned to the west-northwest and slowed its forward motion to 10 mph.

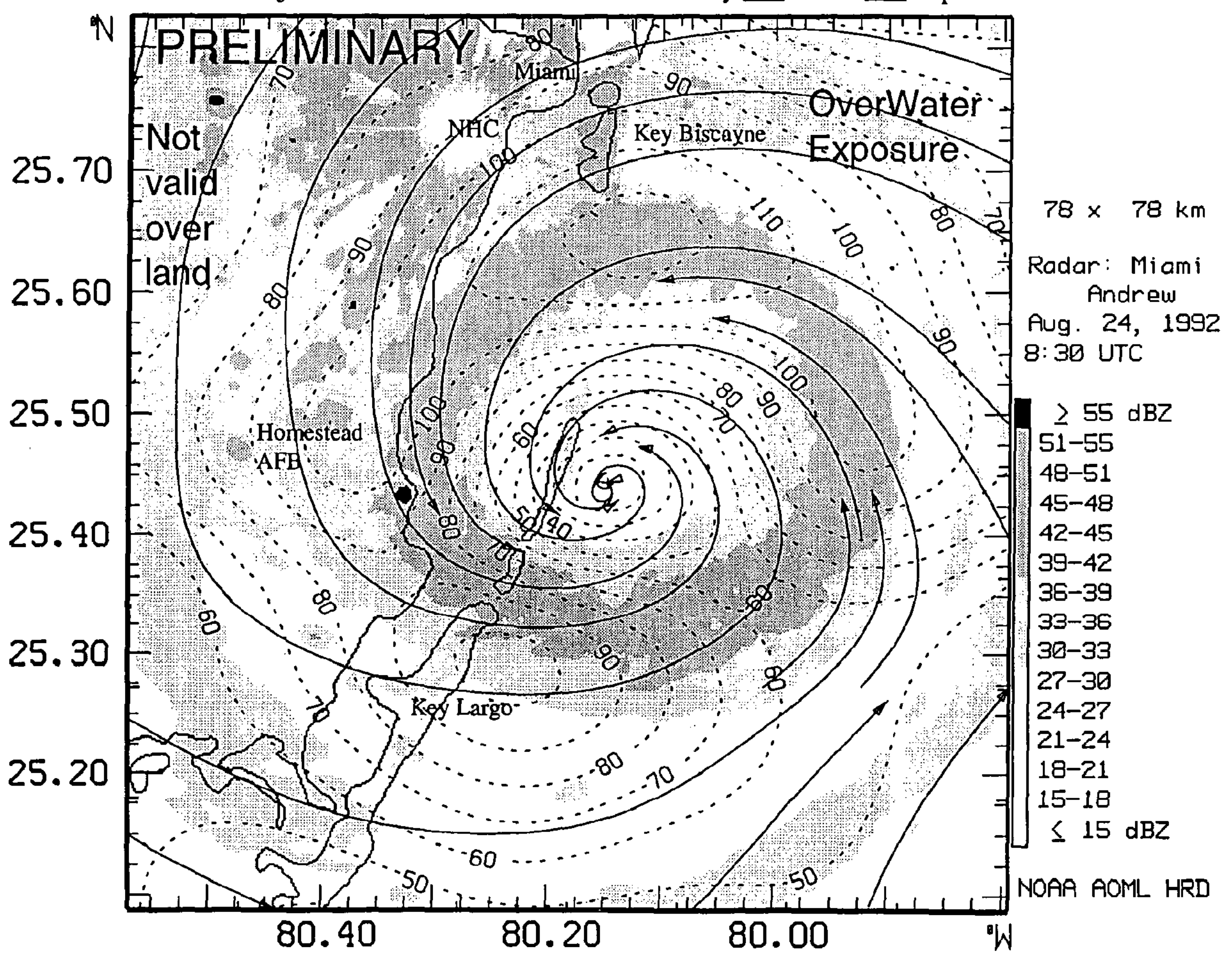
Andrew weakened prior to landfall, skirting Louisiana's coastline for about 10 hours before coming ashore near Point Chevreuil, about 20 nm west-southwest of Morgan City, Louisiana. The storm made landfall at 4:30 AM EDT on August 26. With an estimated landfall central pressure of 956 mb and sustained winds of 120 mph, Andrew struck the sparsely populated portion of south-central Louisiana as a category 3 hurricane. It filled very rapidly, weakening to tropical storm strength by early afternoon and to a depression by evening. On August 28, the remnants of Andrew merged with a cold front and were no longer considered a tropical weather system.

Wind Distribution

Intense, compact storms, such as Andrew, are infrequent but not rare. They are characterized by extremely strong pressure gradients and resulting intense winds in and near the eyewall. Figure 3a is a preliminary analysis of surface winds of Hurricane Andrew OVER WATER near the time of landfall. The wind analyses at flight level were reconstructed from available data sources and empirically adjusted to estimate surface values over water, using correction factors appropriate for over-water conditions. Sustained winds over land are typically weaker than surface winds over water, but surface winds over land tend to have larger gust factors than over-water surface winds. Superimposed on the wind estimates of figure 3a is a map of the region of southern Florida where Andrew made landfall, to give the scale of the storm and of the likely regions of intense winds. Note that the strongest winds were ahead and to the right side, with respect to storm motion, of the storm and, therefore, approximately coincided with the regions of maximum damage discussed elsewhere in this report. It is possible that the radius of maximum winds might have been a few miles smaller at the surface than is shown in these analyses since the analyses do not take into account outward sloping of the eyewall with height.

Figure 3b is a preliminary estimate of the over-water surface winds at the approximate time that Andrew made landfall on the coast of Louisiana. A map of the region is overlaid for

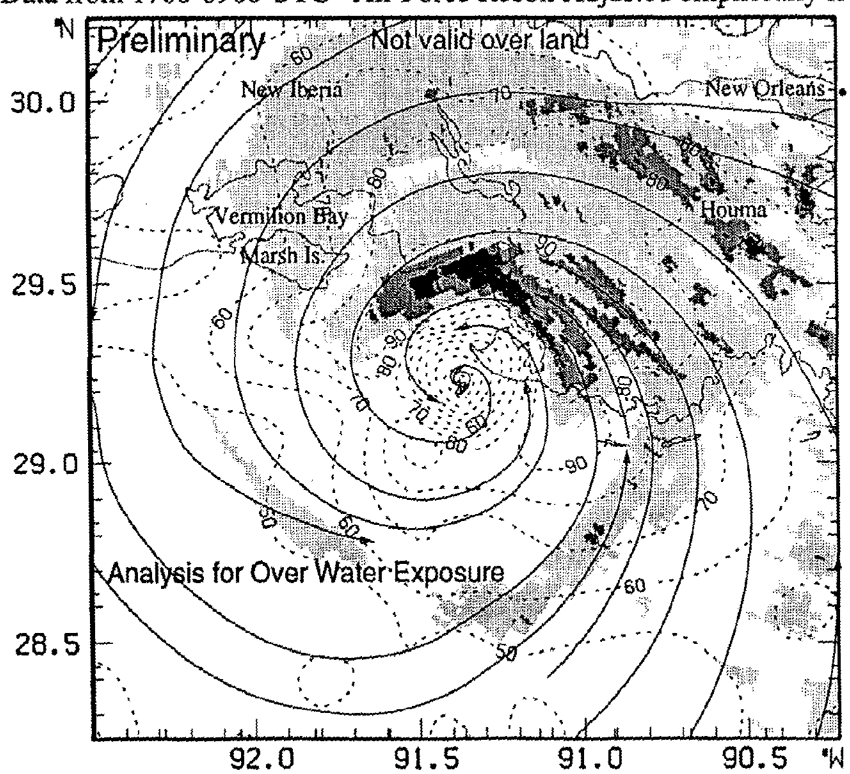
NOAA Hurricane Research Division Surface Wind Analysis
Hurricane Andrew 0831 UTC 24 August, 1992, data from 0410 - 1300 UTC
Recon adjusted to sfc. from 3000 m altitude by ___PBL or ✓ empirical



Maximum 1-min Sustained Winds
(Contour Interval= 10 kts)

Figure 3a — Preliminary estimate of the surface winds OVER WATER just before Hurricane Andrew made landfall in Florida. These winds are estimated empirically from flight level analyses using correction factors appropriate for over-water conditions only. A map of southern Florida is superimposed for reference. (M. Powell, personal communication)

Hurricane Research Division Surface Wind Analysis
Hurricane Andrew 0624 August 26 1992
Data from 1700-0900 UTC Air Force Recon Adjusted empirically from 10,000 ft.



Max 1 min
wind 109 kt
in N. eyewall

Maximum 1 min sustained suurface winds
contours in knots

Figure 3b — As in figure 3a but for landfall in Louisiana. (M. Powell, personal communication) scaling reference. Note that figures 3a and 3b are drawn on different scales. Once again, it is emphasized that the wind values shown are not valid over land: hurricane surface winds over land vary from those over water due to a variety of factors, including orography, surface roughness, and stability of the boundary layer.

Hurricane-spawned Tornadoes

There were no confirmed sightings of tornadoes over either the Bahamas or Florida. A few unconfirmed funnel clouds were reported in western Florida after sunrise. There were 14 confirmed tornadoes in association with Andrew's landfall on the Louisiana coast, including one that killed two persons at La Place, Louisiana. In Mississippi, 27 tornadoes were confirmed, and at least two damage-producing tornadoes were confirmed over Alabama. Damaging tornadoes in Georgia on August 27 and in Delaware and Maryland on August 27 and 28 may have been associated with the remnants of Andrew.

In south Louisiana, tornadoes ranged from F-0 to F-3 on the Fujita tornado intensity scale (figure 4). A tornado of F-3 intensity touched down near the subdivision of Belle Pointe, near the city of Reserve located in St. John the Baptist Parish. The tornado skipped along a 9- to 10-mile path between Reserve and La Place on the evening of August 25. The best estimate of tornado inflicted damage is in excess of $20 million. Table E.1, appendix E, provides a breakdown of the tornado damage inflicted upon St. John the Baptist Parish.

MAX WINDS (MPH)	PATH LENGTH (MI)	PATH WIDTH (YDS)	PATH WIDTH (MI)
F-0 < 73	PL0 < 1.0	PW0<18	<.01
F-1 73-112	PL1 1.0-3.1	PW1 18-55	.01-.03
F-2 113-157	PL2 3.2-9.9	PW2 56-175	.03-.09
F-3 158-206	PL3 10 - 31	PW3 176-556	.10-.29
F-4 207-260	PL4 32 - 99	PW4 557-1584	.30-.90

Figure 4 — Fujita tornado intensity scale.

Rainfall and Flooding

The hydrologic impact of Hurricane Andrew, throughout the entire life of the system, was generally minimal. While copious amounts of rain fell at some locations, there were no reports of major flooding.

As Hurricane Andrew passed over the Bahamas and Florida, the storm was compact and moved relatively rapidly. This movement limited the duration and amount of rainfall. Heaviest observed rainfall in Florida occurred inland across northwestern Dade and southwestern Broward Counties, where amounts ranged up to 8 inches (all rainfall amounts are storm totals; see appendix A, tables A.1 and A.2, for rainfall observations). Virtually no river flooding was reported across Florida in association with Andrew's rains, mainly due to the fact that the heaviest rains fell to the south and east of west-central Florida's river basins and instead occurred over the marshlands of the Everglades region. Some localized urban-type flooding did occur at several locations across south Florida.

In Louisiana, Hurricane Andrew's rainfall pattern was actually quite similar to past hurricanes striking the central gulf coast region—that of Hurricane Betsy (Louisiana, September 1965) and Hurricane Camille (Mississippi, August 1969). In the cases of Hurricanes Betsy and Camille, the heaviest rains were generally along and to the east of the paths of the hurricanes. Likewise, based on preliminary data, the heaviest rainfall associated with Hurricane Andrew was also along and to the right of the path of the hurricane although the rainfall pattern with Hurricane Andrew was somewhat more widespread than with Betsy and Camille. Additionally, maximum observed rainfall amounts were also similar for all three hurricanes. The maximum observed single rainfall from Hurricane Andrew occurred at Hammond, Louisiana, located in Tangipahoa Parish in east-central Louisiana, where 11.92 inches fell (see appendix E, figure E.2, for Louisiana rainfall analysis). Also, 9.30 inches of rain was recorded near Sumrall, Mississippi, located in south-central Mississippi, near Hattiesburg.

Still, despite the heavy rainfall, very little in the way of significant flooding developed in Louisiana and surrounding states. This was primarily due to the fact that hydrologic conditions prior to Hurricane Andrew's arrival were quite dry. Most rivers were at their low, mid-summer stages, and soils across much of the Lower Mississippi Valley were very dry. As an indication of the dry conditions, several calculations were done at the NWS's LMRFC which compared the volume of rainfall with runoff passing forecast points in both Louisiana and Mississippi. Those calculations indicated that only 25 percent or less of the volume of rain that fell actually move into the rivers as runoff. The remaining 75 percent was absorbed by dry soils or plants or it evaporated. Minor to moderate flooding did develop along portions of several Louisiana and Mississippi rivers, including the Tangipahoa, Bogue, Tickfaw, Tchefunta, Pearl, Little Tallahatchie and Tombigbee Rivers. The most spectacular river rise occurred along the Tangipahoa River at Robert, Louisiana, where a rise of 11 feet in the river stage occurred, resulting in a crest of 18.8 feet, or 3.8 feet above flood stage. This rise resulted from a concentrated 8 to 11-inch rainfall associated with one of Andrew's feeder bands moving across the Tangipahoa Basin. The flooding inundated some river camps, recreational areas, and adjacent flood plain farmland, but damages were generally minor. In general, the flooding across Louisiana and Mississippi could be described as small stream and urban type, causing the closure of some nearby roads.

As the remnants of Hurricane Andrew continued inland and headed northeast, there was considerable concern within the NWS that copious amounts of rainfall would be deposited across portions of the Appalachians due to orographic effects. Similar situations have occurred with other decaying tropical systems, including Camille (1969) and Agnes (1972), the result being widespread and devastating flooding, coupled with deadly mudslides. However, once the remnants of Hurricane Andrew made the turn towards the northeast, the system again accelerated its forward motion, thus limiting the duration of and amount of rainfall. The system tracked across the Tennessee River Valley, the southern and central Appalachians, and then through the mid-Atlantic region. While moderate-to-heavy rainfall amounts of generally 2 to 5-inches did fall, flooding was minimal and limited to stream and urban-type flooding.

Along the entire length of the inland path of the remnants of Hurricane Andrew, NWS offices were sufficiently prepared for a much larger hydrologic impact than actually occurred. NWS offices were very aggressive in their treatment of the decaying tropical system and were very cognizant of the potential for excessive rainfall and subsequent flooding.

Storm Surge

In Florida, Andrew caused a storm tide that reached a maximum of 16.9 feet a few miles north of Homestead AFB, a record for storms in southeastern Florida. Fortunately, the maximum surge hit a portion of the coastline not as heavily populated as numerous nearby communities. Also, Cutler Ridge, a topographic rise of between 8 and 24 feet mean sea level (MSL) caused by an ancient coral reef, blocked inland progression of the storm surge.

In Louisiana, the highest storm surge mark was recorded at Luke's Landing along East Cote Blanche Bay, where 8.2 feet was observed at a U.S. Army Corps of Engineers (USACE) water level gauge. Several other gauges recorded surge heights over 6 feet during Andrew. Lake Pontchartrain was raised to a level of approximately 4.5 feet NGVD (National Geodetic Vertical Datum). Fortunately, these surge heights occurred shortly before the occurrence of normal (astronomical) high tide. In the area impacted by Andrew, this would have added about 1 foot to the observed readings. Tidal traces indicate that prior to Andrew's landfall, water was being forced away from the coastline by offshore winds, resulting in depressed water levels (below MSL). As the eye passed and the winds shifted to onshore, water levels rose rapidly and reached their observed peaks.

Impact on Fisheries and Wildlife

Louisiana's legendary fisheries received a severe blow when Andrew slid along the Louisiana coast before making landfall. While the numbers of marine fishes killed did not expect to impact greatly the coastal recreational fishing, biologists estimate conservatively that the coastal sports industry will have suffered a loss of $12 million during September and October of 1992. Louisiana's marine recreational fishing industry depends on the accessibility to coastal waters and the availability of marine facilities. These have both suffered greatly due to the effects of Andrew. (Specific details can be found in appendix E.)

Impact on the Petroleum Industry

The petroleum industry plays a large role in the economy of Louisiana. The gulf coast from Texas to Mississippi is dotted by numerous submerged wells and oil well structures (platforms), including appurtenances, such as satellite wells and oil pipes. The largest concentration of oil platforms, satellites, and drilling rigs are located off the Louisiana coast. The total number of oil platforms and satellites is approximately 3,800, with about 150 oil drilling rigs. These facilities are extremely vulnerable to hurricanes. Their destruction poses a major threat to the ecology of the gulf.

Best estimates bring the total losses from the repair of damaged equipment, replacement of equipment, and clean-up costs to exceed $250 million.

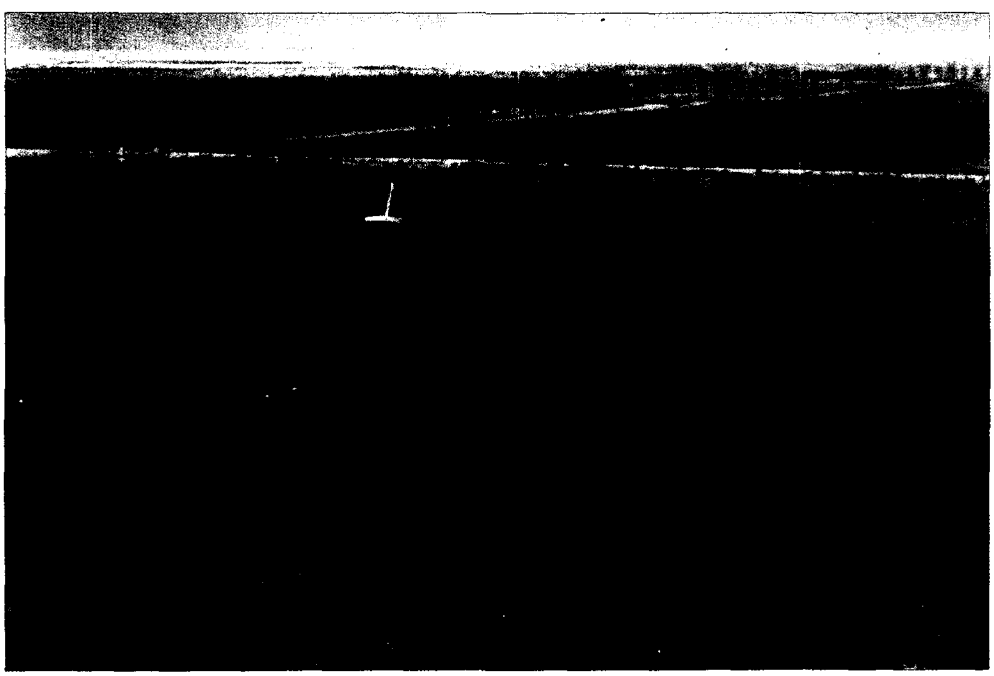
Commercial and Recreational Boating

In Florida, the ferocity of Andrew from Dinner Key to Coconut Grove south was such that when boats landed they were sunk, holed, or left full of oil, mud, or seaweed. Estimates are that one third of the 45,000 registered boats in Dade County, Florida, were damaged. Nearly 20 percent of these were total losses. Damage estimates to boats are as high as $250 million, more than twice the dollar losses from Hurricanes Bob and Hugo combined, and could reach $500 million. Hardest hit areas were Key Biscayne and Coral Gables. On Florida's west coast, minor damage was reported, except for two marinas on Marco Island that were hit hard as Andrew exited into the gulf.

Andrew affected an unknown number of commercial ships, recreational vessels, and barges throughout the Mississippi basin and the northern gulf coast. Documentation as provided by U.S. Coast Guard, District Eight, revealed that a number of ships were lost, and rescue efforts had to be conducted.

Louisiana fared much better than south Florida since Andrew missed the major boating areas north and east of New Orleans. Many boat owners also had enough advance warning and moved their vessels out of the path of the storm up into one of Louisiana's many bayous, where they had more protection. To date, no formal estimate of monetary loss has been computed for commercial and recreational marine interests as the result of Hurricane Andrew.

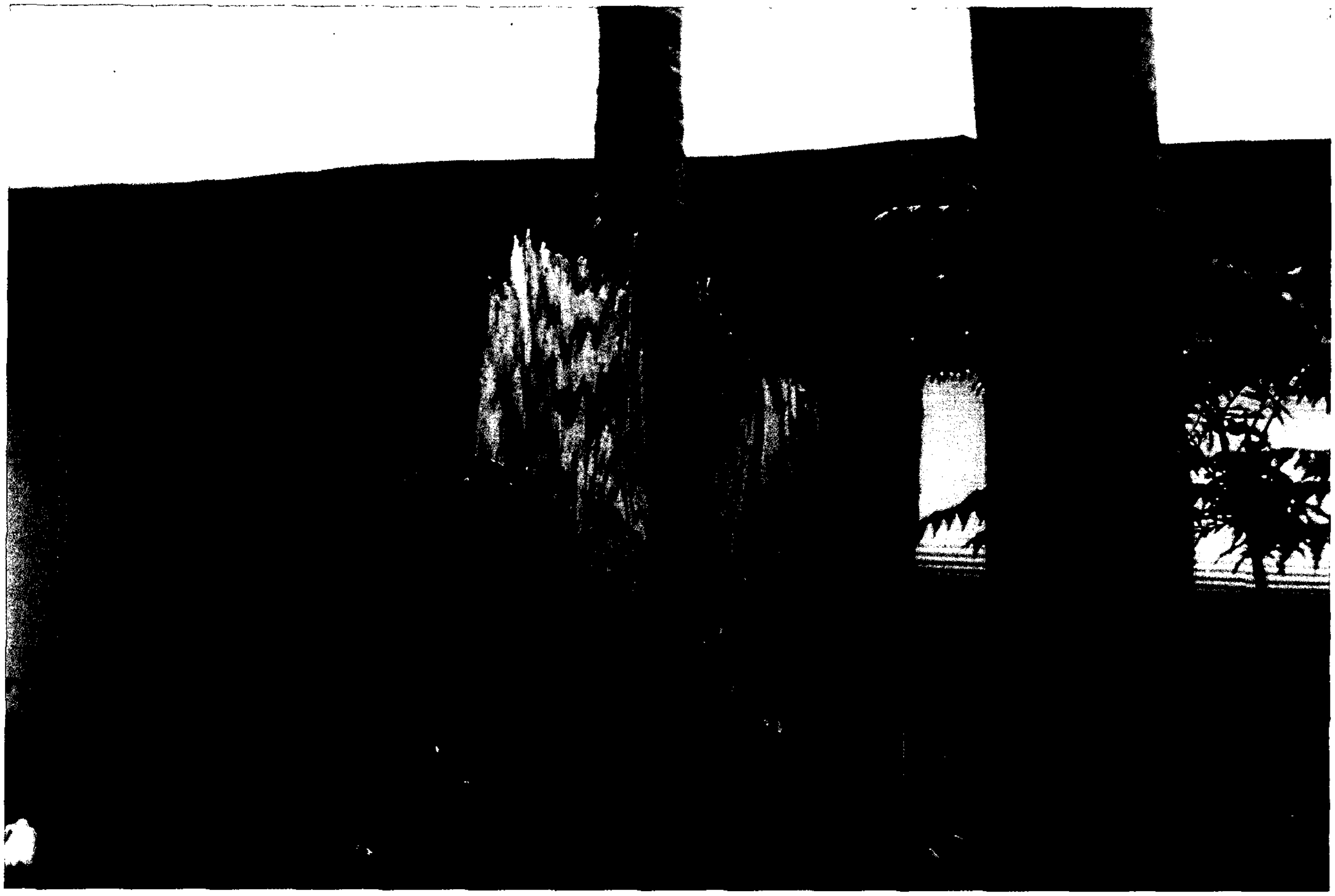
Naranja Lakes homes destroyed by Andrew's devastating winds.



A combination of hurricane-force winds and storm surge dragged this sailboat well inland. This photo was taken south of Homestead AFB.

PART I:

SOUTH FLORIDA



A piece of wind-driven plywood piercing the trunk of a royal palm near Homestead, Florida.

CHAPTER I.A

BACKGROUND

Description of the Disaster Area

Florida is largely a lowland peninsula comprising 54,100 square miles of surface area bounded on three sides by the Atlantic Ocean and the Gulf of Mexico. Numerous shallow lakes account for approximately 4,400 square miles of additional inland water area. No point in the state is more than 70 miles from salt water, and the highest natural land elevation is only 345 feet above sea level. Elevations in south Florida are even lower; natural elevations over 20 feet are rare. Coastal areas are low and flat and are indented by many small bays and inlets. Countless barrier islands are scattered along Florida's shoreline.

The region most affected by the passage of Hurricane Andrew was located in the extreme southern section of the state. The counties most affected were Broward, Dade, Monroe, and Collier. This "tip of Florida" includes the Everglades National Park, a sparsely populated region to the southwest, and the more populated areas to the east. The chain of islands, known as the Florida Keys, extends along the eastern seaboard from Miami southwest to Key West. The four counties affected encompass the Florida Keys, the Everglades National Park, the Big Cypress National Preserve, Biscayne National Park, John Pennekamp Coral Reef State Park, Bill Baggs Cape Florida State Park, the Miccosukee Indian Reservation, a portion of the Big Cypress Seminole Indian Reservation, and the cities of Naples, Fort Lauderdale, Miami, Homestead, and Florida City.

Population

The State of Florida has experienced tremendous population growth over the past 4 decades. With 12.9 million persons in the state in 1990, Florida has grown from the Nation's 20th most populated state in 1950 to the fourth most populated state. Dade County, where Hurricane Andrew struck the hardest, is Florida's most populated county. In 1980, the population of Dade County exceeded that of sixteen states and the District of Columbia. The sheer number of residents, coupled with the annual summer influx of tourists, enhance the potential for disaster.

Climate

The climate of south Florida is characterized as subtropical marine in Broward, Collier, Dade, and mainland Monroe Counties, and tropical maritime in the Keys. The region is strongly influenced by the adjacent marine environment. The Florida current, which becomes the Gulf Stream, affects the climate of the region. The Gulf Stream runs parallel to the east coast at an average distance of 3 miles, helping to maintain the tropical and subtropical regimes.

South Florida experiences two seasons—rainy from May to October and dry from November to April. During the rainy season, precipitation averages 6.24 inches a month. The dry season averages 1.97 inches a month. The rainy season coincides with the hurricane season.

Topography

The region is essentially a flat, low-lying limestone plain. Elevations are typically highest along the coastal ridge, which extends in a north-south direction several miles inland from the Atlantic Ocean and the Gulf of Mexico. The highest point in the region is 53 ft. above MSL. To the west of the coastal ridge, elevations gradually decrease to just slightly above sea level in the Everglades Basin. To the east of the ridge, elevations decrease as well, sloping down gradually to Biscayne Bay and other estuaries. Because of its low elevations, south Florida is particularly vulnerable to the hurricane threat.

The Intracoastal Waterway traverses the length of Dade and Broward Counties as a series of bays and channels. A continuous series of barrier islands east of the Intracoastal Waterway separates much of the mainland peninsula from the Atlantic Ocean. The coastal barrier islands are typically long and narrow with low elevations. The Florida Keys are an archipelago that sweeps for more than 100 miles in a southwesterly direction from Dade County. The islands of the Keys are composed of fossilized coral and limestone foundations. Elevations in the Florida Keys are rarely greater than 10 feet above MSL.

Hurricane Vulnerability

Hurricane activity in the southern peninsula of Florida has a long and varied history. Based on information gathered from NHC, the first hurricane to affect this area this century was a category 1, making landfall on September 11, 1903. In the intervening years, an additional 27 hurricanes have affected the south Florida region. Hurricane Andrew, the most costly of all natural disasters in United States history (approximately $25 billion) is the 28th hurricane.

While Hurricane Andrew has had a profound effect on south Florida, the same was said of a number of past hurricanes. The hurricane of 1928, a category 4, made landfall around Palm Beach and then moved across Lake Okeechobee, driving all the water to one side of the lake. This, in combination with normal storm precipitation, resulted in flooding which took 1,836 lives. This 1928 hurricane is considered the most catastrophic for Florida in regard to total lives lost. A dike was constructed around the lake as a result of this hurricane, protecting nearby communities from all but the most intense hurricanes.

The Labor Day Hurricane of 1935, a category 5 that struck the Florida Keys, resulted in the loss of 408 lives and $50 million in damage. The storm surge with that hurricane piled water to a height of 20 feet in some portions of the Keys.

In September of 1960, Hurricane Donna crossed the Florida Keys and then moved northeastward across the state from the Fort Myers area to near Daytona Beach. Although not the deadliest, it is thought to be financially the most destructive hurricane ever experienced in south Florida prior to Andrew, causing an estimated $305 million in damages. Donna claimed 13 lives in Florida.

The vulnerability of the state to hurricanes varies with the progress of the hurricane season. Early and late in the season (June and October) hurricane activity predominates in the Gulf of Mexico and the western Caribbean. Most of those systems that affect Florida approach the state from the south or southwest, entering the Keys or along the west coast. Mid-season (August and most of September) tropical cyclones normally approach the state from the east or southeast.

Other relevant statistics which reflect Florida's hurricane vulnerability and disaster history have been collected by NHC.

- More than one in three of this century's major United States landfalling hurricanes, those with winds above 110 mph (categories 3, 4, and 5), have struck Florida.

- Florida's hurricanes are among the most intense—of the 17 United States landfalling category 4 and 5 hurricanes since 1900, 5 of the 7 most intense affected Florida.

- September has been Florida's cruelest month. Twenty-three storms, 41 percent of the total Florida landfalls, have struck during the month. Fourteen struck during the first 2 weeks of September alone. October trails with 17 landfalls. The Atlantic and Gulf of Mexico reach their warmest temperatures during September and October, providing more moisture and energy to power developing storms.

- Nearly half of all Florida hurricanes this century have struck between 1920 and 1950. In the 1940s, Florida recorded ten hurricanes. The last major hurricane to strike south Florida before Andrew was Hurricane Betsy—27 years ago. Only seven have struck since 1970. The last, Hurricane Floyd, was a mild storm that struck the Florida Keys in 1987.

The extent to which Florida coastal areas have been developed, coupled with the frequency with which hurricanes have impacted, suggests that a disaster of unprecedented magnitude was inevitable.

Levitz furniture warehouse, west of Whispering Pines, Florida, shows extensive wind damage.

CHAPTER I.B

SUMMARY OF PREPAREDNESS ACTIONS

To assure timely and appropriate public response to hazardous weather events, a community-wide hazardous weather preparedness program is necessary. Such a program requires years to develop. Foundations of communication, understanding, education, and skills development are necessary for interagency coordination. The focal point of that effort usually is the NWS local office. The NWS office generally is the instigator of coordination and communication among Federal, state, local, and volunteer organizations involved directly with distribution and dissemination of weather information. The NWS is responsible for assuring that people involved in that process, including the public, possess an appropriate knowledge of weather hazards. To be successful, all involved agencies must provide continued support to the effort. The following summarizes that level of involvement among the principal members of the hazards community.

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

WSO Melbourne

The WCM at WSO Melbourne has spearheaded comprehensive preparedness and educational programs with major emphasis on hurricanes and the modern technologies to deal with them. These programs touched a wide variety of weather information users in the Melbourne area of responsibility. For example, the WCM gave a hurricane awareness presentation to the Annual Convention of Transportation Maintenance Engineers. In early June, he spoke at the Daytona Beach Hurricane Conference attended by over 200 people. He also developed customized hurricane scenarios for use in drills by county officials and water management districts. Other preparedness activities included presentations or meetings with numerous schools, aviation groups, a marine association, the American Red Cross, and many media outlets.

WSO West Palm Beach

On the Thursday before Hurricane Andrew reached Florida, the WSO West Palm Beach Meteorologist in Charge (MIC) gave a detailed hurricane preparedness presentation to amateur radio operators and emergency managers from Palm Beach, St. Lucie, and Martin Counties. A category 5 hurricane scenario was discussed. On August 10, a similar presentation was given to emergency managers, the American Red Cross, and the Florida Power and Light officials at Ft. Pierce. WSO West Palm Beach also worked with the Palm Beach Emergency Operations Center at a preparedness meeting in May 1992, covering such topics as storm surge, hurricane strike probabilities, and evacuation lead time related to storm category. Earlier in the year, WSO West Palm Beach participated in hurricane drills coordinated by WSFO Miami. Finally, WSO West Palm Beach provided preparedness talks at schools, local municipalities, agricultural and marine associations, civic groups, and supplied radio/television interviews.

WSO Tampa Bay

WSO Tampa Bay maintained an aggressive hurricane preparedness program during 1992 for their county warning area (CWA). That large area includes Fort Myers and the responsibility for the old WSO Fort Myers CWA. During the winter of 1991-92, the WSO Tampa Bay MIC attended three hurricane planning/preparedness sessions of the Southwest Florida Regional Planning Council. On April 14, 1992, the MIC and his staff hosted a workshop at WSO Tampa Bay for emergency management officials, representing Sarasota, Lee, and Charlotte Counties, and a representative from WBBH-TV in Fort Myers, to explain the functions and services of WSO Tampa Bay and WSO Fort Myers during hurricanes.

WSO Tampa Bay was involved in three meetings with area radio stations during the spring, the purpose of which was to strengthen the Emergency Broadcast System (EBS). Five meetings were held with amateur radio groups within WSO Tampa Bay's CWA to coordinate communications and train storm spotters.

A planning session for a newspaper hurricane supplement for the St. Petersburg Times was attended by the WSO Tampa Bay MIC. In attendance were representatives from the newspaper, the American Red Cross, the Florida Power Company, and Citrus, Hernando, Pasco, Manatee, Pinellas, and Hillsborough Counties. Other activities included preparedness talks to various business/civic groups and radio interviews.

On March 19, 1992, the MIC briefed the Manatee County Division of Public Safety on hurricane preparedness. On April 7, 1992, the MIC and Lee County emergency management officials gave a hurricane preparedness seminar to the Sanibel Island Condominium Association. On April 20, 1992, the MIC briefed the USCG Search and Rescue Office on NWR and provided them with a Bearcat Weather Radio. On May 21-22, 1992, the NOAA WP-3 aircraft was used for a static display at Clearwater/St. Petersburg and Sarasota/Bradenton airports. Over 700 people attended. On May 28, three hurricane preparedness seminars were given in Charlotte County to over 1,600 new residents. On June 4-5, 1992, the Florida Governor's Hurricane Conference was held in Tampa. The Area Manager and MICs from WSO Tallahassee, WSO Melbourne, and WSO Tampa Bay gave presentations and answered questions on the WSO/WSFO role both now and in the future in regards to hurricanes.

WSO Key West

The WSO Key West MIC performed several hurricane preparedness presentations in the spring and summer of 1992. One such presentation was made to a local Catholic elementary school and another was to the local public high school. Still another presentation was given to 380 local Coast Guard personnel and their dependents.

Regular contacts were made between the WSO Key West MIC and the Monroe County emergency management director during the summer updating of the county's absolutely vital hurricane evacuation plan.

WSFO Miami

WSFO Miami complements the NHC preparedness program (see below) with additional outreach activities and oversees the preparedness programs of the Florida WSOs. **Finding I.B.1: The NHC is charged with a national focus on hurricane readiness, but it dominates the NWS hurricane preparedness program in south Florida.** Dr. Sheets and the WSFO have agreed that only one voice representing the NWS be utilized in preparedness programs over south Florida. This assures that no mixed message is presented. Very little media attention is given to the WSFO in a preparedness context; both print and electronic media focus their attention on the NHC. Still, during 1992, WSFO staff conducted eight hurricane and severe weather preparedness programs across their county warning area, three of which were done with storm spotters. These were accomplished by the MIC, the Deputy MIC, and the Storm Data focal point. There is no dedicated Warning Preparedness Meteorologist (WPM) at WSFO Miami. In addition, Area Manager Paul Hebert accompanied Dr. Sheets on the annual hurricane preparedness (WP-3 Reconnaissance Aircraft) tour in late May. **Recommendation I.B.1: The NWS should staff WSFO Miami with a Warning Coordination Meteorologist (WCM) as soon as possible to enhance the WSFO's preparedness/hazard awareness program.**

National Hurricane Center

The NHC Director and his staff are traditionally involved in a heavy schedule of pre-hurricane season preparedness activities. These are aimed at sensitizing decision makers, special interest groups, and the general public to the dangers of a hurricane. In recent years, the NHC has sponsored the popular and highly effective tour by the NOAA WP-3 Reconnaissance Aircraft at many coastal sites along the Atlantic and Gulf of Mexico. These tours are usually combined with meetings emphasizing public awareness of hurricane dangers and the NOAA operations to counteract these hazards. The 1992 tour visited sites along the gulf coast. The meetings used a "Town Hall" format, involving the general public and vendors of hurricane preparedness supplies. Often featured were displays set up by the American Red Cross, emergency medical services, the military, law enforcement groups, emergency management, and the media.

The NHC director, deputy director, and other staff members participate in a Speakers' Bureau comprised of many NOAA professionals. Members of the Bureau are engaged in a variety of outreach activities focusing on hurricane preparedness. These include presentations to schools, career programs, numerous media interviews, workshops for public officials, and talks to special interests, such as hospitals and insurance groups. In 1992, similar interviews were conducted with local Miami media, and several programs were given by NHC staff at various civic meetings.

Annually, the NHC, in association with FEMA and state emergency management agencies, conducts hurricane awareness training at the NHC. The training is for emergency managers and their staff and includes information on how to use and interpret SLOSH data, the basics of how the NHC tracks and forecasts hurricanes, and elements of the public hurricane watch and warning program. Emergency managers from each of the affected Florida counties have received this training during the past few years.

Increased Preparedness Through Improved and Integrated Facilities

The NHC and WSFO Miami were extremely fortunate that they were able to continue many critical services during the hurricane, despite some power outages and communications failures. **Finding I.B.2: This was the first time that the NHC (and the collocated WSFO Miami) facility had been directly affected by a major hurricane. The impact of Andrew proved the vulnerability of NHC to the effects of extreme wind. Recommendation I.B.2: Better protected, self-contained facilities should be provided to the NHC and all NWS coastal offices. This is even more critical to National Centers, such as NHC, for which full backup procedures are extremely difficult to implement.** Such a facility should have an independent air-conditioning system and other stand-alone utilities. In addition to offering a safer working environment for the staff during a major storm, this would increase the chances for proper cooling of computers and uninterrupted communications. Of course, backup procedures should be in place to allow other NWS units to take over if necessary. Feedback from the public, the media, and many other interests indicates that there is a psychological boost in knowing that the NHC is still functioning during such a major storm.

Local Emergency Management

During the last two major hurricanes in the United States, the storm surge threat has been adequately addressed by the hazards community and understood by the public. This is due largely to the great emphasis on the dangers of the storm surge and the success of the SLOSH computer models to predict the surge. To address that threat, evacuation studies have been accomplished throughout the Florida coast, jointly by the U.S. Army Corps of Engineers (USACE) and FEMA, in coordination with state and local emergency management.

Annually, state and local emergency management, in coordination with the NWS, conduct a statewide preparedness drill. This drill is done during the NWS Hazardous Weather Awareness Week in the spring.

Finding I.B.3: Hurricane Andrew was characterized by devastating effects of strong inland winds in addition to powerful storm surges. The devastation that eventually occurred over south Florida heightened the awareness in other vulnerable areas to the significant inland wind damage which can accompany a hurricane. Recommendation I.B.3: The NWS should provide technical assistance for a much more concerted preparedness and awareness effort by state and local emergency management and such other cognizant organizations as state coastal zone management agencies in areas of high vulnerability.

Refuge of Last Resort

In an attempt to prepare better for these hazards in future storms, the NHC and emergency managers want to consider a concept called the "refuge of last resort."

Finding I.B.4: Since the lead time for evacuation may be no more than 24 hours, it may not be practical or even possible to evacuate all inland residents in the path of a hurricane eyewall. Recommendation I.B.4: The NWS should work with FEMA,

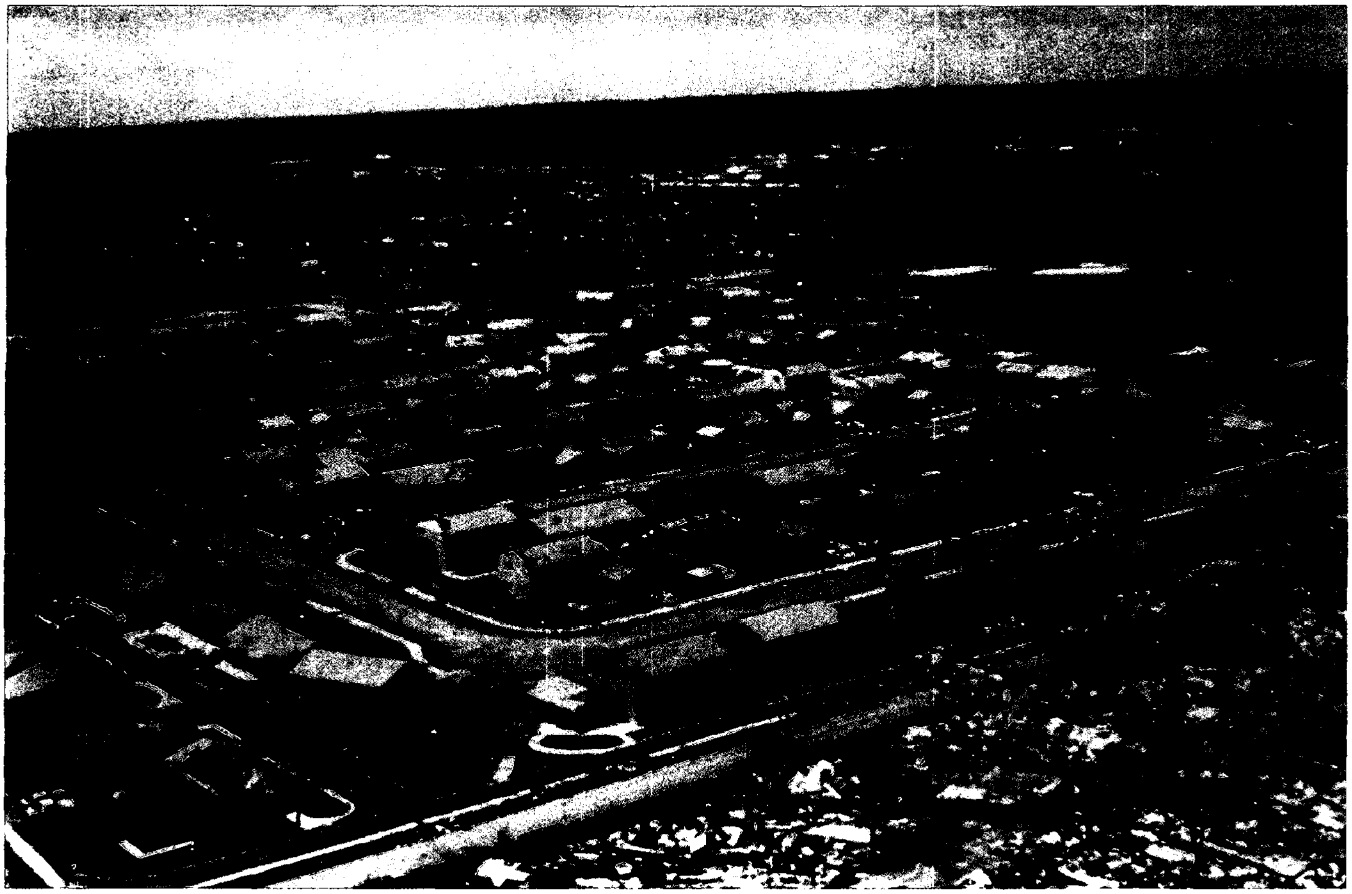
state, and local emergency planners in exploring the potential of developing a "refuge of last resort" methodology, as appropriate, for occasions when critical saturation points are reached in the flow of evacuation traffic. Local emergency planners could invoke this last refuge concept once a critical saturation point is reached in the flow of evacuation traffic. Otherwise, the evacuation traffic pattern could lead to the infamous "gridlock" where evacuees are trapped on the road while attempting to flee a hurricane.

It is better to get out of an area subject to hurricane winds or at least be protected by a substantially built structure; but if this isn't possible, a local refuge center should be available. Furthermore, consider the scenario where warning lead time is drastically cut due to an unforeseen change in the forward speed, direction, or intensity of a storm. In such cases, many residents may be prematurely cut off from evacuation routes, and a designated "refuge of last resort" would be essential.

Preparedness by the Media

Television's role in preseason specials and spot announcements helped to educate the citizenry in the appropriate responses to the hurricane threat. Local newspapers in the Keys, Miami, Fort Lauderdale, and West Palm Beach featured preseason special editions and covered the storm's advance in the Sunday editions. Also, they provided safety advice and shelter openings that enhanced the public's evacuation. Newspaper coverage at the NHC also was provided by the Associated Press (AP), United Press International (UPI), USA Today, the Los Angeles Times, and several regional news outlets. Both English and Spanish language newspapers and electronic media provided accurate and timely information to the large non-English speaking south Florida community.

Through the past few years, the NHC has entered into a partnership with the broadcasters to enable all members of the television media to provide threatened residents of the Atlantic and gulf coasts with live, up-to-the-minute reports directly from the NHC. The non-competitive pool coverage is divided into local, regional, and network pools when a tropical storm or hurricane threatens a particular area.



Aerial view of Cutler Ridge, Florida, on the right and adjacent subdivision with obviously superior construction.

CHAPTER I.C

NWS CONTINGENCY PLANNING AND BACKUP ARRANGEMENTS

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

WSO Melbourne

WSO Melbourne took specific actions to respond operationally for the hurricane. On Friday, August 21, the WSR-88D was taken down for maintenance to a potential diode stack and voltage problem. WSO Melbourne coordinated with NWS Southern Region Headquarters (SRH) and the Operational Support Facility (OSF) in Norman, Oklahoma, to secure extra parts and to deploy a Westinghouse technician to help with the problem. This turned out to be a critically important decision since it enabled the WSR-88D to operate smoothly and provide radar coverage of the hurricane after the Miami radar failed.

WSO Key West

WSO Key West coordinated with NWS Southern Region Meteorological Services Division and WSFO Miami regarding staffing. It was determined that the WSO was adequately staffed, and no supplemental staffing was provided for the event.

WSO West Palm Beach

In support of the potential threat from Andrew, the WSO West Palm Beach staff was augmented by meteorological technicians from WSOs Corpus Christi and Lake Charles. In addition, procedures and instructions from NWS SRH dictated that WSO West Palm Beach was to assume network radar responsibility and county warning responsibility for Dade and Broward Counties prior to Andrew's landfall.

WSO Tampa Bay

WSO Tampa Bay, in cooperation with NWS SRH and the Lee County Emergency Management Agency, temporarily reassigned operational staff to open WSO Fort Myers. The Fort Myers WSO is routinely operated at the Lee County EOC during periods of hurricane threat.

WSFO Miami

Backup Procedures. The WSFO, in accordance with procedures established by NWS SRH, invoked emergency backup procedures as Hurricane Andrew bore down on south Florida. In anticipation of the potential for complete failure of the WSFO, WSFOs Atlanta and Sterling were assigned public/aviation and marine forecast responsibilities for Miami's forecast area, respectively. Exact times when the hand-offs were accomplished is not certain, but WSFO Atlanta was on standby or actually doing Miami's public and aviation forecasts from 5 AM, August 24, through 6 PM, August 25 (all times EDT). WSFO Sterling performed the same function with Miami's marine forecasts during the same period. Just prior to landfall, warning responsibility for WSFO Miami's five-county warning area was assigned (mistakenly) to WSO Tampa Bay. At mid-morning of August 24, Dade and Broward Counties were reassigned to WSO West Palm Beach. WSFO Miami resumed county warning responsibility at noon August 31. Prior to that time, the area manager did not feel the forecast office had sufficient personnel and data collecting capability to handle warning responsibility.

Southern Region Headquarters, Fort Worth, Texas

Well in advance of the hurricane season and any hurricane, SRH on April 23, 1992, reviewed the Region's Hurricane Readiness Plan. Staffing and equipment status for all coastal offices was reviewed. Contingency plans were made for detailing staff in the event of a hurricane threat.

During the week of August 16, the progress of the tropical depression (which would become Andrew) was monitored. On Friday, August 21, a meeting was held at SRH to assess the situation (Andrew was tropical storm strength at the time). The support staff were identified and alerted for possible dispatch during the weekend.

The Southern Region Hurricane Watch Office opened at 4 PM Central Daylight Time (CDT) on August 22, and then maintained 24-hour-a-day operations until the hurricane was well inland on August 26. On Sunday, August 23, when it became evident that the main threat was the Miami area, contingency plans for south Florida were initiated.

National Hurricane Center

NHC Backup Procedures

Since the NHC is located in Miami, Florida, it is occasionally in harm's way when hurricanes approach the Florida coastline. The NHC has emergency backup procedures that are implemented when a storm threatens the NHC. These procedures were implemented when Hurricane Andrew approached Miami. Five backup personnel from NHC were sent to the NMC on August 23. Their immediate task was to take over dissemination of several NHC aviation and marine forecast products, allowing NHC to focus on the primary forecast mission. The other main task of the backup team was to take over as the primary hurricane forecast center should NHC become unable to maintain operations due to the effects of the storm.

Hurricane Andrew provided a severe test of the backup system. As a category 4 storm, it severely affected NHC, and then it moved quickly into the Gulf of Mexico threatening other portions of the United States coastline. Throughout the event, NHC remained operational due largely to the valiant efforts of NHC personnel who stayed at their posts and managed to keep their computer and communications systems functional despite wind damage and loss of crucial air-conditioning systems. **Finding I.C.1: The detailing of two hurricane specialists to the National Meteorological Center (NMC) is not sufficient to provide adequate continuous backup to NHC operations. Recommendation I.C.1: The NWS should adopt a plan that would increase the number of forecasters capable of acting as hurricane specialists during an emergency brought on by a hurricane threatening NHC. There must be adequate staffing at both NHC and the backup site. One plan would be to provide hurricane forecast training to a select group of forecasters, possibly from NMC, who could fly to NHC as replacements for hurricane specialists dispatched to staff the backup center.** The backup functions at NMC were executed without significant mishaps although several procedural changes are being implemented to update the backup plan.

Two of the personnel sent from NHC to NMC were hurricane specialists (Jerry Jarrell and Miles Lawrence). This left NHC understaffed, particularly since the storm remained a major forecast problem days after its landfall in south Florida. **Finding I.C.2: When NHC staff is drawn down to implement the backup at NMC, insufficient staff remains at NHC to handle advisories of multiple tropical cyclones properly. Recommendation I.C.2: See Recommendation I.C.1.** This normally will be the case for hurricanes striking Miami so the backup plan should be amended if possible to keep NHC at full strength. The problem would have been much worse had there been other hurricanes active at the same time. (As many as six were active simultaneously during September 1992. According to NHC administrative staff, they could not have handled the extreme workload of six tropical cyclones with two forecasters detailed to NMC.) Further, two hurricane specialists are not enough to staff the backup center in the event that it should have to take over the primary forecast mission. One specialist would be busy essentially full time dealing with the media, leaving only one person to handle the actual forecasting. During Andrew, a third experienced hurricane forecaster was brought in to NMC, and another former NHC forecaster was on standby.

Finding I.C.3: Facilities for interacting with the media are very limited at NMC. Recommendation I.C.3: The NMC should formulate a plan for handling the extensive interactions with the media that are required when a hurricane is threatening the United States coastline. Since NMC is the logical site for the backup forecast center, plans should be made to accommodate the large number of media personnel who will descend upon the backup center, especially if it is required to take over the primary forecast mission.

CHAPTER I.D

SUMMARY OF NWS WATCHES, WARNINGS, AND ADVISORIES

National Hurricane Center

Products

NHC disseminates information about specific tropical weather systems through three basic products: the Tropical Cyclone Public Advisory (TCP), the Tropical Cyclone Marine Advisory (TCM), and the Tropical Cyclone Discussion (TCD). These products supply data about storm location, intensity, trends, and forecasts. Hurricane and tropical storm warnings and watches are issued through these products. The TCP is the least technical, being a public advisory, but it is the most lengthy. Probability forecasts for landfall appear at the end of the TCP and TCM. TCMs are designed to supply a mixture of technical and non-technical information to users who are primarily in the marine and emergency management communities. The TCM features initial and forecast positions, wind radii for the storm out to 72 hours, and a very brief mention of current trends. The TCD is a technical discussion the audience of which includes the sophisticated users, such as the NWS, the private consultants, the emergency management community, and other technical concerns. The TCD describes storm characteristics and controlling factors.

TCPs, TCMs, and TCDs are disseminated concurrently at 6-hour intervals. Additional intermediate TCPs are issued at either 2- or 3-hour intervals when land is threatened. Those TCPs are not accompanied by TCMs or TCDs. Special information about a tropical system may be described by a tropical cyclone update (TCU). The TCU is useful for passing along information about changes to the storm system, such as the formation of an eye, a location change, or a change in intensity. Special advisories and other products also may be issued by the NHC.

The tropical disturbance that eventually became Andrew was first treated by an advisory at 11 PM EDT, August 16. Forty-seven advisories, along with intermediate advisories beginning on August 22, were used to describe the system.

Watches and Warnings

A hurricane watch is issued when NHC determines that a coastal area is at risk of hurricane conditions within 36 hours. A hurricane watch was issued in Advisory Number 24 for coastal Florida at 5 PM EDT, August 22. The watch extended from Titusville on the Atlantic coast southward through the Florida Keys to include the Dry Tortugas. A hurricane warning is issued when the NHC determines that hurricane conditions are likely along a coastal area within 24 hours. The hurricane warning for Florida was issued at 8 AM EDT, Sunday, August 23, and extended from Vero Beach south through the Florida Keys. At the same time, a hurricane watch was issued for the Florida west coast, from just north of Bayport to north of Flamingo. This included the Tampa Bay area. At the time the hurricane warning was issued, a tropical storm warning/hurricane watch was issued that bounded the hurricane warning area (the tropical storm warning included only the Florida east coast from Titusville south to Vero Beach). A comprehensive listing of all watches and warnings is provided in appendix A as table A.6.

Watch and Warning Lead Times

A critical aspect of the value of hurricane/tropical storm watches and warnings is the amount of time people have to respond to the oncoming threat. Lead time is defined as the time between watch or warning issuance and the onset of hurricane conditions. Sufficient lead time is very important for a timely and orderly evacuation. NHC's goal for lead time for hurricane watches is 36 hours (slightly less from watch to onset of hurricane winds). In south Florida, the time between watch and the time that hurricane-force winds arrived was 36 hours. The average lead time for a hurricane warning is 19.5 hours, and southeast Florida received the warning 21 hours before hurricane-force winds (see figure 5).

Finding I.D.1: NHC watch and warning lead times during Hurricane Andrew were longer than average for landfalling hurricanes. That extra margin of safety was at least partially responsible for allowing hundreds of thousands of people to evacuate safely from south Florida. Recommendation I.D.1: NOAA and the NWS should work toward increasing watch/warning lead times by supporting efforts to enhance our understanding of tropical systems, improving numerical models, providing greater data availability to feed the models, and enhancing operational forecast methodologies. A significant step in this direction would be the collocation of the Environmental Research Laboratory's Hurricane Research Division (HRD) with NHC to allow for the synergism of research and operations.

Utility of Advisories

Content of the advisories is as important to their value as timing and frequency of issuance. The manner in which they are written and the emphasis on certain forecast parameters reflect on NHC's impression of the hazard. It is very important to the way the users perceive the threat.

NHC advisories were well worded from Andrew's development through its trek across south Florida. When the storm was being sheared by strong southwesterly upper winds and its future intensification and track was uncertain, those uncertainties were reflected in the advisories. As the storm became very strong, comments highlighted that threat and warned of specific phenomena within the storm's domain. For example, in the hours preceding the south Florida impact, Andrew was referred to as "extremely dangerous," and specific references about storm surges of 10 to 14 feet were provided. Additionally, forecast rainfall totals of between 5 and 8 inches were cited. Although no tornadoes were observed in south Florida, that threat also was noted.

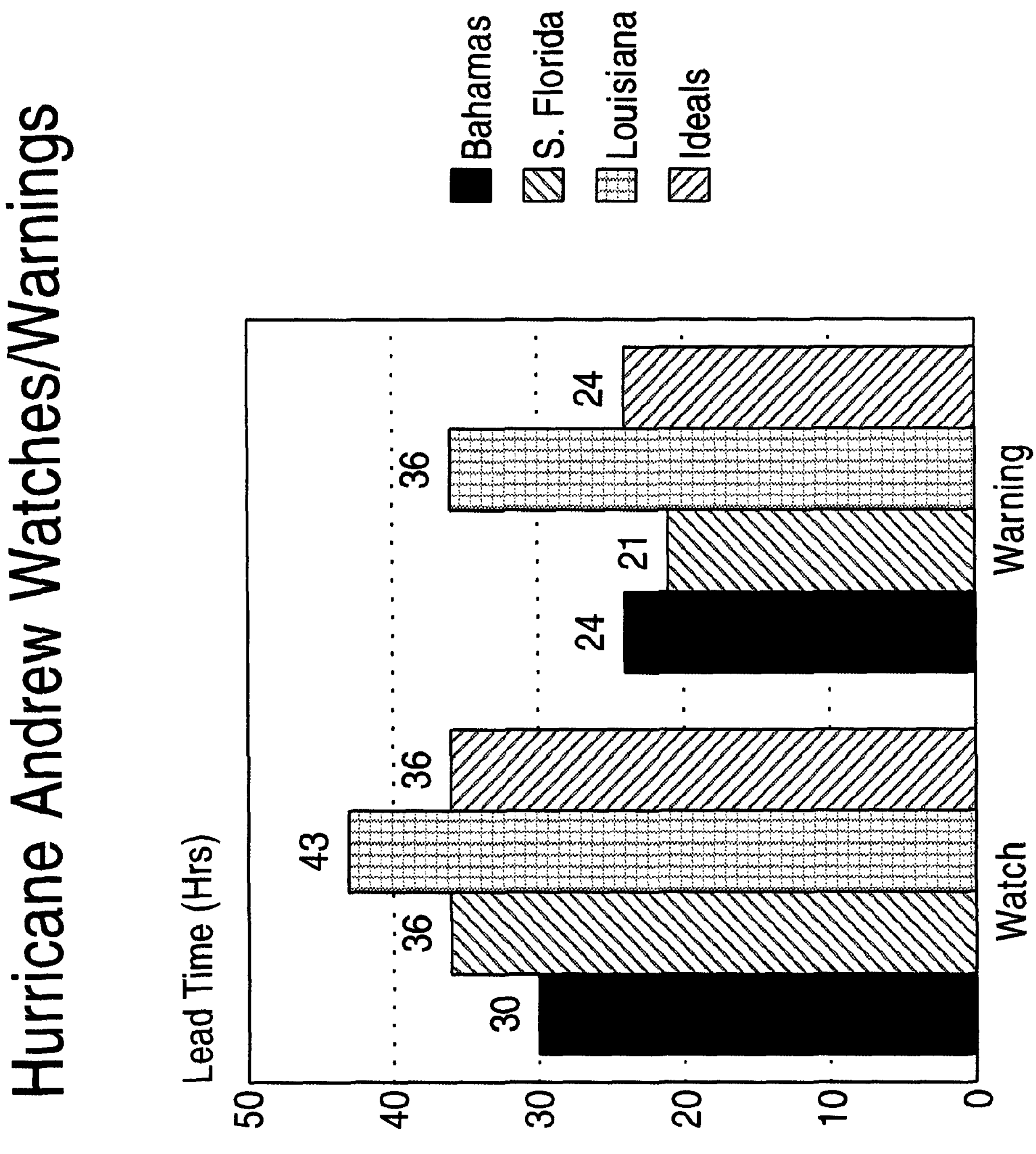


Figure 5 — Hurricane Andrew watch/warning lead times.

National Meteorological Center

NMC is responsible for generating and interpreting forecast models on the synoptic and sub-synoptic scales. They coordinate routinely with NHC via the hurricane hotline during periods of tropical cyclone threat. A number of other entities also contribute to that coordination effort, including the United States Navy in Norfolk, NWS Southern Region and Eastern Region Headquarters, selected NWS forecast offices, various state agencies, and Weather Service Headquarters. During the coordination calls which take place approximately 1 hour prior to the issuance of NHC advisories, NHC reviews its forecast reasoning and announces its forecast positions. NMC also generates forecast positions and shares their thinking at this time. The final authority on the forecast belongs to NHC.

Once Andrew moved away from inhibiting factors, it was well behaved and tracked consistently. Except for the period of storm shearing when Andrew nearly died, there was little difference in forecast tracks between NHC and NMC.

National Severe Storms Forecast Center (NSSFC)

Guidance Products

NSSFC has the primary responsibility to issue guidance and watches for severe local storms in the continental United States. Tropical cyclones often generate conditions which favor severe local storms (especially tornadoes) in addition to their tropical characteristics of high wind, heavy rainfall, and storm surge. When a tropical cyclone threatens NSSFC's area of responsibility, its effects are integrated into their forecast reasoning.

Severe weather forecast guidance products from NSSFC are generated by the Severe Local Storms (SELS) Branch. SELS provides 24-hour (SWODY1) and 48-hour (SWODY2) severe weather outlooks. Both products are provided in narrative and graphic format. The day-one outlooks detail the risk of severe weather as:

APCHG — approaching severe storm criteria
SLGHT — slight risk of severe storms
MDT — moderate risk of severe storms
HIGH — high risk of severe storms.

The SWODY2 outlook provides only the area of severe weather threat. Beginning August 22, SELS began mentioning south Florida as an area of severe weather threat. The SWODY2 outlook narrative issued at 2 PM EDT, August 22, introduced a chance for severe weather across south Florida in the latter half of the valid period which would have been between 8 PM EDT, August 23, and 8 AM EDT, August 24. The threat was based on approaching outer spiral bands in the right front quadrant of the hurricane. As the storm continued to approach south Florida, its potential effects were addressed by the SWODY1 guidance. The SWODY1 issued at 1 AM EDT, August 23, included a slight risk over south Florida. The outlook was based on a destabilizing airmass and surface convergence ahead of Andrew. Updates issued at 11 AM EDT and 2 PM EDT on August 23 reiterated the slight risk, citing increasing low level wind shear in the climatologically favored northeast quadrant of the storm. The 11 AM EDT, August 23, outlook stated that the primary threat would be for a few tornadoes, and that the biggest threat would be after 11 PM EDT on August 23. Subsequent outlooks noted that Andrew was moving across south Florida and mentioned some tornado threat lingering until the rain bands moved offshore midday on August 25. SELS then began focusing on the northern Gulf of Mexico coast.

SELS also generates discussion products on an as-needed basis. The products, called SWOMCD (mesoscale convective discussions), give insight about convective trends during the past 2 hours and for the forthcoming 2- to 4-hour period. As Hurricane Andrew approached south Florida, SELS provided a detailed evaluation of convective trends and severe thunderstorm potential. At 8:59 PM EDT, a SWOMCD indicated that one spiral band was moving onshore in east-central Florida and that another was 40-50 miles offshore and would cross the coast around 11 PM EDT. SELS, in coordination with NHC, noted that a severe weather watch would be issued with the 11 PM EDT, August 23, hurricane advisory. Another mesoscale discussion was issued at 6:31 PM EDT on August 24 as Andrew moved into the Gulf of Mexico. The 6:31 PM EDT issuance targeted the Florida Panhandle as prime for damaging thunderstorm winds due to a line of thunderstorms with forward motion around 50 knots.

Severe Weather Watches

Watches that advise of the potential for severe thunderstorms or tornadoes also are the responsibility of SELS. When conditions favor severe thunderstorms possessing hail at least 3/4-inch in diameter or wind gusts at least 50 knots (58 mph), SELS will issue a severe thunderstorm watch for the favored area. Should the potential also include tornadoes, a tornado watch will be issued instead. As Andrew approached south Florida, Tornado Watch No. 763 was issued at 9:56 PM EDT, August 23. The watch was for that part of the state along and 70 statute miles either side of a line from 15 miles west of Avon Park to 50 miles south-southeast of Miami. The watch was valid from 11 PM EDT, August 23, through 11 AM EDT, August 24. It is unusual for a severe storm watch to be valid for more than 6 hours. In this situation, however, the lengthy watch made physical sense due to the protracted hurricane conditions. Those conditions included the outer rain band approach, the passage of the storm core, and the trailing rain band passage. As the first watch expired, Tornado Watch No. 764 issued at 10:11 AM EDT, August 24, took its place. It shifted the area slightly further west, i.e., 80 statute miles either side of a line from 30 miles north-northwest of Avon Park to 70 miles southwest of Miami. It was valid until 8 PM EDT on August 24.

Status Reports

While severe weather watches are in effect, SELS provides status reports (product WWAMKC) to inform about trends. A number of status reports were provided while the tornado watches were in effect over south Florida. The principal concern was of mesocyclones in the spiral bands. As a band of convection approached the coast at 12:46 AM EDT on August 24, SELS used a WWAMKC to describe the details about timing and location. Specific mention of recent observations in the WWAMKC of 1:12 AM EDT, August 24, i.e., "PBI ERYR HAD HVY TSTM Q49..." (contraction for "West Palm Beach Airport earlier had heavy thunderstorm with squall to 49 knots"), supply excellent detail to emergency management and media about severe weather potential.

Hurricane Andrew produced no known tornadoes as it moved across south Florida. There have been unsubstantiated reports about tornado-like vortices within the eyewall based on post-event aerial surveys of damage.

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

Hurricane Local Statements (HLS)

HLSs are designed to provide information about a hurricane's anticipated effects on the CWA of the issuing WSO/WSFO. They are intended to consolidate information from the NHC, from local authorities, and from WSO/WSFO resources. That information should include in order of appearance:

- a brief statement about the current location of the storm;
- a forecast of expected weather conditions during the next hour or two;
- a brief review of watches/warnings that include the CWA;
- an assessment of storm surge and tides for local area;
- a review of how conditions will impact commerce and society, i.e., road closures, power failures, recommendations from emergency management; and
- a very brief call to action.

An HLS should **not** be a rewrite of the latest NHC advisory. Rather, it should stand on its own. It is very important to keep the HLS fresh and brief. Most HLS products issued during Andrew were issued in response to the issuance of NHC advisories. When a watch is in effect for the local area, HLS frequency should be at least once every 3 hours. When a warning is in effect, the frequency of product issuance should be increased.

All affected WSOs and WSFO Miami (with the exception of WSO Fort Myers, a part-time office) issued HLSs throughout the Andrew event in south Florida. Although NWS offices in south Florida have good working relationships with their respective county emergency management agencies, interaction between the NWS and emergency managers was markedly different from county to county during Andrew. WSO Key West reported evacuation procedures and instructions in great detail in HLSs, and WSO Tampa Bay contacted county emergency management offices regularly for updated information to be used in HLSs. HLSs issued by WSO West Palm Beach had less emergency response information than others but provided all possible details that were made available to them. Both the Palm Beach County Emergency Management (EM) and the WSO indicate that their communication was excellent during the event. Early Sunday morning, August 24, Collier County faxed statements to WSFO Miami regarding evacuation operations, but they were not included in Miami's HLSs. Since the facsimile machine is located in an administrative office at the WSFO (which is closed up over weekends), the information never was received by those forecasters on duty. Collier County EM did not telephone the WSFO to advise them of the facsimile transmittals.

Finding I.D.2: HLSs from WSO/WSFOs tend to be too lengthy, too infrequent, tend to reiterate NHC advisories too much, and tend not to include enough specific information about local conditions. Recommendation I.D.2: The NWS should

explore options to make HLSs more effective. This should include use of the "Short Term Forecast" concept and its relationship to HLSs and hurricane advisories. Furthermore, coastal offices should re-evaluate the manner in which data are collected and used to create HLS products. Emphasis should be made on use of on-station software, emergency management information, and remote sensing data to create a highly specific, current product. Most HLSs reiterated NHC information, such as the entire watch/warning layout, listings of all counties in the CWA, details on "current" position (which was sometimes 3 or 4 hours old), recommendations directed toward emergency management, and broad storm surge, rainfall, and tide information.

By focusing on the local environment and deleting information that does not concern the CWA, much of the unneeded data could have been deleted. Detailed, local meteorological information is available from remote sensing equipment, such as radar and satellite, and from surface observations as well as data extracted from on-station PC software, such as ***GDS4.0*** (Graphic Decision System for Hurricanes), ***Tides***, and SLOSH. This would have enhanced specific information about local effects of storm surge, astronomical tides, and periods of extreme wind or squalls. This, coupled with information on road closures from local officials, would have made a more useable product.

This is the Dadeland Mobile Home Park following Hurricane Andrew.

CHAPTER I.E

SUMMARY OF INFORMATION AND WARNING SERVICES AND RESPONSE ACTIONS BY EMERGENCY MANAGEMENT AND MEDIA

Non-NWS Products Available to Emergency Management (EM)

Software

All coastal county emergency managers in the affected region and the Florida Division of Emergency Management (DEM) received marine advisories from NHC as well as public advisories, HLSs, and tropical cyclone discussions. Use of these products varied greatly from county to county. All of the coastal counties and the state also have PC-based software into which marine advisory forecasts are entered. The software calculates how close the center and tropical storm-force winds are forecast to come to the user's location and when those events are forecast to occur. The times are then compared to lead times necessary to begin evacuation to help officials determine when a decision point has been reached.

All of the coastal counties have a commercially available program entitled ***Enhanced Graphic Decision System (GDS)***, which the counties purchased individually. Palm Beach, Broward, Dade, and Monroe Counties also have a program named ***HURREVAC***, primarily funded by FEMA. In addition to the basic forecast implications referred to above, ***GDS*** has the added feature of helping users account for forecast uncertainties. It not only displays NHC probabilities but also draws probability ellipses around forecast positions and calculates the closest point of approach (CPA) and timing implications of the forecast being wrong by NHC average error margins. ***HURREVAC***, in addition to performing the basic calculations described in the preceding paragraph, also features an atlas of map screens displaying the areas which could be flooded in various storm scenarios and lists data about shelters. Most counties used their computer software, but the extent of that use is unclear. The impression is that in some instances the software was used more as a tracking device.

Vendors

Some of the counties receive NWS radar and other specialized products from vendors. At least one county (Lee) contracts with a private meteorological firm for forecast information and counsel. This information was consistent with that contained in NHC/NWS products.

Interaction Between NWS and Emergency Management

Virtually all south Florida counties appeared to have good working relationships with their respective NWS offices and reported varying degrees of interaction with NWS offices during Andrew. WSO Key West, followed by WSO Tampa Bay, had the most contact with emergency management in Andrew. WSO Key West reported evacuation procedures and instructions in great detail in HLSs. WSO Tampa Bay contacted county emergency management offices regularly. HLSs issued by WSO West Palm Beach had less emergency response information than others although the WSO and EM both state that the communication was nevertheless excellent. (In fact, WSO West Palm Beach was in continuous direct contact with emergency management from Palm Beach, Martin, and St. Lucie Counties.) WSO Tampa Bay dispatched two of its staff to WSO Fort Myers where they were stationed in the Lee County EOC. Lee County officials indicated that their presence was helpful. County hurricane evacuation plans in southwest Florida (Collier County northward to the Tampa Bay area) are interdependent. Emergency management officials regularly held joint meetings and communicated with one another as Andrew approached. Collier County reported that it faxed statements to WSFO Miami regarding evacuation operations (but they were not included in Miami's HLSs as discussed in chapter I.D). Monroe County officials said they requested that WSFO Miami include evacuation information regarding the upper Keys in its NWR broadcasts, but apparently this was not done.

Monroe and Dade County emergency management are in a unique situation during hurricane threats. Due to the proximity of NHC, they interact directly with NHC staff more than with WSFO Miami. Monroe County EM Director, Billy Wagner, was present at NHC on Friday and was joined there by the Dade County EM Director, Kate Hale, on Saturday. The State of Florida pays for a telephone line to NHC so that information can be relayed directly to the state EOC. This is in addition to the NAWAS line and the hurricane hotline.

The Monroe County EM director felt that he learned of information on Saturday afternoon regarding a previously unforeseen increase in forward speed and intensity which led to his taking actions before the 5 PM forecast package was released and the watch was posted. Florida DEM officials indicated that they were not made aware of the upcoming forecast changes by NHC, but an emergency management representative present at NHC notified them of the likelihood of such an event. According to Florida DEM, the agency phoned NHC to inquire about upcoming changes in the forecast, but an NHC forecaster could not confirm anything which had not been included in the 11 AM EDT advisory. NHC Director, Dr. Robert Sheets, indicated that he and the NHC forecasters always are willing to discuss whatever information is at their disposal and believes there must have been a misunderstanding about what was being requested.

Impact of Watches, Warnings, and Probabilities

Finding I.E.1: Concern was expressed by two emergency managers over the tone set by NHC on Friday afternoon when a "Have a good weekend...tune back in on Sunday or Monday" message was given to emergency management. Some officials felt that message could have promoted a less-than-serious attitude and that it could have caused them not to pay close attention to storm information during the weekend. Recommendation I.E.1: Although NHC is extremely concerned about

how information is presented, care must continue to be exercised not to send unintended messages. At least two emergency management officials expressed concern over Dr. Sheets' comments. Because the emergency managers got such a message, city and county employees that were needed to implement an evacuation were released for the weekend and became less accessible. When that broadcast was made, Tropical Storm Andrew was slowing down as the models suggested, and the probability for landfall in Miami by 2 PM EDT Monday was only 7 percent. According to Dr. Sheets:

> "What I basically said to the emergency managers was that there was a low probability of threat over the weekend to the Florida east coast but to tune in Sunday and Monday because we were forecasting the storm to strengthen to hurricane strength and threaten the Florida coast early in the week. I made similar comments to the public, saying 'enjoy your weekend,' but I added the usual caveat that it was hurricane season and any time you have a storm east of us, you pay attention. I also added that this 'enjoy your weekend' comment assumed that you had done all the things you should have done at the beginning of the hurricane season and were prepared to act promptly if the need arose."

This situation reinforces the fact that our ability to predict the timing and intensity changes of tropical cyclones needs further improvement. This suggests that every effort must be made to maintain a heightened level of awareness when a potential threat exists.

During NOAA DST interviews with emergency management officials, not one emergency management person mentioned the use of probabilities or ***GDS's*** forecast error computations as they described their preparedness actions. Interviewers did not press the issue, and it is likely that most officials weighed the probabilities in some manner even if they didn't refer to them explicitly. Nevertheless, despite having been trained by NHC in the use of marine advisories and other products, most emergency management officials still appear to depend mainly upon watch and warning designations to trigger their evacuations. Only Monroe County initiated any evacuation activities before a warning was issued. Dade County managerial officials (above the emergency management level) apparently believe they take some sort of greater financial risk in ordering evacuations before a warning is issued. Thus, Dade County, as well as the Florida DEM, was critical of NHC for waiting until 8 AM EDT Sunday to issue a warning, rather than including it in the 5 AM advisory. However, Dade County Emergency Management Director, Kate Hale, stated that her actions would have been no different had the warning been issued at 5 AM or, for that matter, at 2 AM.

The northern extent of the warning area on the east coast was Vero Beach, which meant that only the southern third of Indian River County was under a warning. Officials there said that having part of the county in and part outside of the warning area created difficulties. Their desire was to evacuate all or none of their coastal surge vulnerable areas since the time required for evacuation and the shelter capacities needed are based upon the assumption that all of the county is evacuating. Also, they felt that the public would become confused as to why part of the county needed to evacuate and part did not. Other emergency managers disagreed and saw nothing wrong with evacuating part of a county. NHC bases warnings on meteorological and geographical information, tempered by the desire to keep overwarning to a minimum. **Finding I.E.2: Many coastal emergency managers do not understand the scientific reasoning involved in designating hurricane watch and warning areas. They want to evacuate either all or none of their coastal surge vulnerable**

area rather than parts of counties. Recommendation I.E.2: There needs to be better dialogue between NHC and emergency management involving the designation of hurricane watch and warning areas. Conference calls following or preceding a watch or warning issuance always should contain a thorough explanation for the choice of the end points of the areas. NHC also should explore the feasibility of including this information in the tropical cyclone discussions. Courses offered at NHC for emergency managers should include a segment on the subject of designating watch and warning areas.

Impact of Forecasts and Forecast Errors

As noted above, all of the county and state emergency management offices received marine advisories which included position and intensity forecasts. Officials also had tools available to help them assess the response implications of the forecasts. The track forecasts in Andrew were exceptionally good, but two other forecast components complicated response actions.

The forward speed of the storm is important information for emergency management because it indicates when response actions need to begin. There were three forecast periods when the forecast speed was notably off, the most important one being Saturday morning. The 11 AM EDT forecast Saturday morning indicated that tropical storm-force winds would arrive in West Palm Beach in 53 hours; the 5 PM forecast said tropical storm-force winds would arrive in Fort Lauderdale in 35 hours. In 6 hours, emergency management lost 18 hours of response time (12 more than anticipated). From Miami's perspective, tropical storm-force winds had been forecast at 11 AM to reach their closest point of approach in 58 hours, which changed to 36 hours at 5 PM—a 22-hour difference. Thirty-six hours still provide ample time to respond to a category 2 or 3 storm and should be enough to respond to a category 4 as well. It did, however, put officials on a decision "bubble," so to speak.

People evacuating out of the region in a category 2 or 3 storm require 25 hours, and with nightfall approaching at 5 PM EDT Saturday, either the evacuation would need to begin at night or end at night. Most emergency managers try to avoid nighttime evacuations. Only Monroe County elected to have part of its population begin moving on Saturday night. Monroe officials were able to begin preparations before the 5 PM advisory because of information gained by being present at NHC earlier Saturday afternoon. Between 5 PM and 11 PM EDT, another 9 hours of response time were lost (3 more than anticipated). NHC was forecasting a category 3 at landfall, but because of forecast uncertainty, they cautioned officials by phone to plan for a category 4. That turned out to be good advice.

Figure 6 depicts the predicted versus actual sustained winds for eight 24-hour forecast periods, beginning Friday. Throughout most of the period, NHC forecasts were too low by a category. **Finding I.E.3: One critical aspect of hurricane forecasting—the intensification of storms—lags far behind the balance of the science. SHIFOR, the computer model used to forecast hurricane intensification, is old and ineffective. It does a poor job of handling rapid intensification. Recommendation I.E.3: NHC, NMC, and HRD should redouble their efforts to develop models and operational techniques to forecast tropical cyclone intensity changes more effectively. In turn, NOAA should support research efforts at understanding and predicting cyclone intensity changes.** The 5 AM EDT Sunday forecast was the best, off by only 5 kts. This, however, did not reflect the temporary but unanticipated intensification up to 130 kts. (NHC now believes surface winds at 5 AM EDT Monday were actually 125 kts, but the 120 kt figure from the advisory was used in the graphic for consistency.) Some observers have pointed out that the forecast was good during the critical period 24 hours preceding landfall; however, the critical period for a category 4 is 36 hours, not 24.

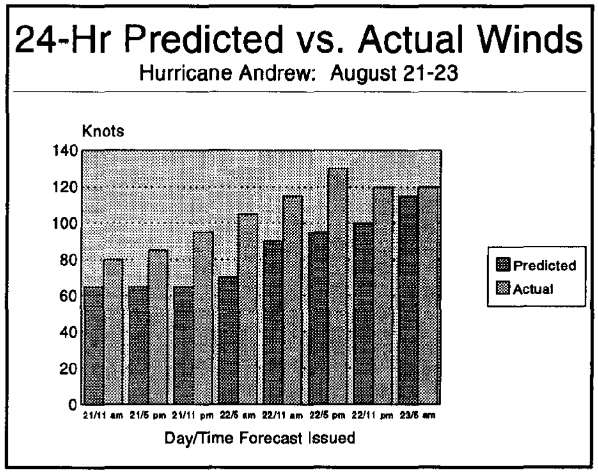


Figure 6 — 24-hour predicted vs. actual winds.

In impending hurricane situations, emergency managers are warned by NHC about the uncertainty in intensity forecasts and told to plan for events stronger than forecast—the rule of thumb being to add a category. The ***GDS*** software in possession of all the counties in south Florida indicates the likelihood of intensities exceeding various values based upon past forecast error distributions. Just as making the warning area too large or too small has economic and safety implications, so does evacuating too large or too small an area within a community. Finding I.E.4: **Some emergency managers could have made greater use of hurricane strike probabilities and personal computer (PC) software in their decision-making process. Recommendation I.E.4: Emergency management needs to use all the tools available to them to provide information for their decision-making processes, including PC-based software specifically designed for that purpose. The NWS should work with FEMA to support more workshops for coastal emergency managers. This should include instructions on how to use these tools effectively.**

Evacuation Conditions

The warning on the Florida east coast extended from Vero Beach southward through the Florida Keys and included part of Indian River County and all of Dade, St. Lucie, Martin, Palm Beach, Broward, and Monroe Counties. The watch on the east coast extended northward to Titusville and encompassed almost all of Brevard County. On the west coast of Florida, the warning went from Flamingo in the south to Venice in the north and included Monroe, Collier, Lee, Charlotte, and part of Sarasota Counties. The warnings also applied to the counties bordering Lake Okeechobee, primarily Glades and small parts of Hendry and Okeechobee Counties on the west and the north shores of Palm Beach and Martin on the east. The watch on the gulf coast went as far north as Bayport in Hernando County and also affected Pasco, Pinellas, Hillsborough, and Manatee Counties.

Although numerous Florida counties were threatened and had to make response decisions in Andrew, the counties of greatest concern were Palm Beach, Broward, Dade, and Monroe. Andrew posed the greatest threat to these counties, and they have the largest populations at risk and/or require the longest times to evacuate (table 1).

Table 1

Evacuation Data for Southeast Florida Counties

County	Storm Category	Evacuating Population	Clearance Time W/I Region	Clearance Time Out of Region
Palm Beach	1 - 2	133,000	7 hrs	15.5 hrs
	3	207,000	11 hrs	25 hrs
	4 - 5	227,000	13 hrs	37 hrs
Broward	1 - 2	187,000	12.5 hrs	15.5 hrs
	3	300,570	17.5 hrs	25 hrs
	4 - 5	426,680	23 hrs	37 hrs
Dade	1	227,210	12 hrs	15.5 hrs
	2 - 3	408,740	12 hrs	25 hrs
	4 - 5	589,000	12 hrs	37 hrs
Monroe	1 - 2	62,665	18 hrs	
	3 - 5	73,290	27 hrs	

Palm Beach, Broward, and Dade Counties all have dense populations on barrier beaches that would be affected by surge even in category 1 storms. In Palm Beach and Dade Counties, the beaches are on barrier islands; whereas in Broward, they are separated only by a narrow, dredged intracoastal waterway. Much of the Broward and southern Palm Beach County "mainland," bordering the intracoastal waterway, consists of highly vulnerable dredge-and-fill finger canal developments. The mainland topography in the region is such that flooding in category 2 and 3 storms extends only a few blocks inland in most areas of all three counties. Category 4 and 5 storms cause flooding only within a mile or less of the intracoastal waterway in most parts of the counties. The most notable exception is southern Dade County, where category 2 and 3 storms can inundate areas as much as 10 miles inland, and flooding from category 4 and 5 storms can extend inland even further. The most densely populated parts of Dade County are well north of this area, however. If the three counties evacuate for a category 4 rather than a category 3 storm, more than 300,000 additional people are affected.

Most evacuees are anticipated in evacuation plans to go to destinations within their own county or to one of the adjacent counties. The times required to evacuate those people are given in table 1 under Clearance Time Within Region. Broward requires more time than Palm Beach and Dade, especially for a category 4 or 5 storm.

Evacuation plans are designed in the anticipation that a third or fewer of the evacuees will leave the region, going to points north of Palm Beach County and/or inland. Doing so requires that most evacuees use either the Florida Turnpike or I-95, both multilane limited access highways. Transportation models indicate that congestion will be extreme on both roads **north** of Palm Beach County. The times required to evacuate safely are listed in table 1 under Clearance Time Out of Region. The times are the same for all three counties because the congestion is occurring north of Palm Beach County so all three counties are affected equally. For these evacuees, a category 3 storm requires 25 hours to evacuate and a category 4 or 5 storm requires 37 hours.

Monroe County consists mainly of the Florida Keys, a chain of islands extending from just south of the Dade County coast southwestward more than 100 miles, terminating at Key West. Most of the islands are flooded in category 1 or 2 hurricanes, and a category 3, 4, or 5 storm floods virtually all of the Keys. The two-lane roads link the Keys to the mainland. Plans anticipate that most evacuees will go to destinations in Dade County. Although a category 3 or greater storm affects only 9,000 more people than a category 1 or 2 storm, most are in Key West, and the clearance time increases from 18 to 27 hours. Evacuating **only** the middle and upper Keys (excluding Key West) requires 12 to 23 hours.

Emergency management officials attempt to complete their evacuation before the arrival of tropical storm-force winds. Therefore, the initiation of evacuation must reflect not only the clearance time but also the number of hours which tropical storm-force winds precede the arrival of the hurricane's eye.

Evacuation Actions by Local Emergency Management

Table 2 summarizes evacuation actions taken by coastal counties in Andrew. In Florida, both state and county governments have the authority to order (i.e., compel) evacuation. Failure to comply is a misdemeanor offense. Most counties exercised their authority to order evacuation, but a few, mostly on the west coast, only recommended evacuation. St. Lucie County recommended evacuation at 8 AM Sunday and then issued an evacuation order at noon. Although Lee County was one which used a recommendation rather than an order, the notice was worded so as to enhance compliance. Lee County was concerned about liability issues if police were unable to secure and protect property in areas from which residents were forced to leave.

Most counties issued press releases and held press briefings to announce the evacuations. Some faxed messages to NWS offices to be included in HLSs, and some had call-down systems to automatically notify specific groups, such as hospitals, municipal governments, and so forth. In most municipalities, the evacuation notices were disseminated by police driving through neighborhoods and using loudspeakers. All counties had plans to help evacuate people with special needs. State law requires that nursing homes have evacuation plans (including transportation and sheltering). The special needs evacuations worked to

Table 2

Evacuation Actions by Coastal Counties

County	Action	Time
St. Lucie	Evacuated for Cat. 3	4:00 PM Sunday
Martin	Evacuated for Cat. 3	3:00 PM Sunday
Palm Beach	Evacuated for Cat. 3	3:00 PM Sunday
Broward	Evacuated for Cat. 4/5	8:15 AM Sunday
Dade	Evacuated for Cat. 3	8:15 AM Sunday
	Evacuated for Cat. 4/5	9:15 AM Sunday
Monroe	Evacuated non-residents for Cat. 3/4/5	3:00 PM Saturday
	Evacuated Ocean Reef for Cat. 3/4/5	10:00 PM Saturday
	Evacuated Middle and Upper Keys for Cat. 3/4/5	6:00 AM Sunday
	Evacuated Lower Keys	11:00 AM Sunday
Collier	Evacuated for Cat. 1	8:15 AM Sunday
Lee	Evacuated for Cat. 1	2:30 PM Sunday
Charlotte	Evacuated for Cat. 1	3:00 PM Sunday

varying degrees; there were numerous examples of nursing homes "dumping" patients at public shelters. A number of hospitals elected to stay in place rather than attempt evacuation.

The most interesting and innovative response actions were in Monroe County. Officials implemented a phased evacuation, then forcibly terminated the evacuation out of the Keys, and finally opened refuges of last resort. Since the storm occurred on a weekend, there were numerous visitors from south Florida in the Keys. Officials decided to have as many visitors as possible leave early so that if it became necessary to evacuate residents, the visitor population would not add to the time needed to evacuate. Between 2 and 3 Saturday afternoon, before a watch was issued but as Andrew began to increase in forward speed, Monroe County emergency management officials requested that state parks and recreation areas be closed and urged non-residents to leave. At 6 PM EDT (after the watch was issued), visitors were ordered out. At 10 PM EDT, Ocean Reef, a resort development of approximately 3,000 people near the northern end of the Keys, was ordered to evacuate. Early Sunday morning, around 5 AM EDT, when the storm was first forecast to reach category 4 strength, the middle and upper Keys were ordered to evacuate. This included all of the Keys east of the Seven-Mile Bridge and excluded Key West, plus a few islands immediately east of Key West. When it appeared to officials that traffic was moving well throughout Sunday morning, the lower Keys were ordered to evacuate at 11 AM EDT.

One critical "choke point" for evacuation of the Keys is the two-lane segment of Route 1. Although some traffic from the upper Keys is shunted over the toll bridge, Route 997, most travel over Route 1. Both routes merge into Route 1 at Florida City. Shortly beyond the merge point, the Florida Turnpike bears off from Route 1. Most of the Keys' traffic heads north on the Florida Turnpike. All people evacuating from the Keys must eventually travel into Dade County; there is no alternative. Designated evacuation shelters for Keys' residents are located on the campus of Florida International University. Many evacuees bypassed the evacuation shelters and traveled further north along the turnpike. Since many Dade County residents also were evacuating along this route, massive traffic jams occurred.

A current concern in southern Florida is that **most** residents will attempt to evacuate, whether they live in a surge zone or not. FEMA funded a post-Andrew assessment of the increased number of evacuees on evacuation times. Their study shows that **<u>Finding I.E.5</u>: As a result of increased anxiety caused by Hurricane Andrew, many south Florida residents indicated they would evacuate for future major hurricanes. Indeed, if this was the case, evacuation times for a category 4 or 5 hurricane striking the Florida Keys would increase from the pre-Andrew level of 37 hours to 70-80 hours, depending on the percentage of residents evacuating. <u>Recommendation I.E.5</u>: NWS and FEMA should work in concert to develop response options as outlined in Recommendations I.B.4 and I.F.2.** Evacuees would be better off in their homes rather than risking being caught on the highway in their cars.

Response by the Media

The electronic and print media in south Florida played a crucial role in enabling the public to respond to the approaching hurricane. The print media maintained a steady stream of hurricane-related information, including the latest reports and forecasts as well as emergency response information. The electronic media, including radio and television, augmented the print media with the latest updates enhanced by color graphics and satellite photo-imagery. The response of the media to this impending disaster provided response information to an audience that otherwise the NWS would not have been able to reach.

The NWS recognizes the integral role that the news media and, in particular, the broadcast media plays in disseminating weather warnings and vital information to the general public. The link between the NWS, emergency management, and the broadcast media is critical to any community warning system. Never before, however, has the NWS-media alliance been more effective than during the hours preceding Hurricane Andrew's landfall in Dade County. The NHC, collocated with WSFO Miami, historically has utilized the electronic media as an indispensable element of the warning system.

Finding I.E.6: **The link between the NWS, emergency management, and the broadcast media is critical to any community warning system. A partnership developed to coordinate NHC information through a broadcast "pool" enabled a large number of media outlets to receive broadcast footage from NHC without crowding the facility and compromising the operational setting.** **Recommendation I.E.6**: **NWS should support development of similar broadcast pools at local offices along the hurricane-prone coasts, as well as at NMC, should backup for NHC be required.**

In the case of Andrew and in accordance with the pool agreement, the television stations covering Dade and Broward Counties were notified that a local pool would be established at NHC and the Dade County EOC beginning at 5 PM EDT, Saturday, August 22. Kate Hale, Dade County EM, and Billy Wagner, Monroe County EM, were present at NHC at that time and began systematic notifications and early planning of necessary evacuations.

All six local television stations, including two serving the Spanish-speaking community, responded by sending producers and technicians to NHC. In addition, NBC, CBS, ABC, and CNN all were notified and dispatched personnel. Beginning at 5 PM on Saturday, live broadcasts featuring NHC staff (mainly Director Robert Sheets) were conducted at 5-minute intervals for the duration of the event. In all, more than 600 interviews were broadcast.

Meanwhile, television meteorologists and the staffs of the major television stations provided round-the-clock coverage of the hurricane's progress and provided listeners with hurricane safety advice. They were instrumental in encouraging evacuation from the threatened areas. **Finding I.E.7**: **Television meteorologists were instrumental in encouraging evacuation from the threatened areas. Many of the television broadcasts were simulcast on AM and FM radio. This was particularly useful since many residents received lifesaving advice through their battery-operated radios when television transmitters were knocked off the air.** **Recommendation I.E.7**: **NWS offices along hurricane-threatened areas should continue to encourage proactive, weather-conscious media who will provide that essential link with the public to convey life-saving information.** Many of the television stations were simulcast on AM and FM radio. This was particularly useful since many residents received lifesaving advice through their battery-operated radios when television transmitters were knocked off the air.

Finding I.E.8: **Efforts of the NWS, in conjunction with state and local emergency management and the news media, resulted in clear and motivating messages to the general public. Those messages resulted in a superb public response, except for some residents of Miami Beach, and may have saved countless lives.** Recommendation I.E.8: **NHC and WSFO Miami should work with the local media to target those populations in Miami Beach where the response was deficient.**

CHAPTER I.F

PUBLIC RESPONSE

Andrew's approach and the flow of information from the NWS through the media and emergency management agencies strongly elevated public awareness. In fact, the convective rain bands over the Melbourne area caused much concern until it became apparent that the main thrust of the hurricane would pass further south. The devastation which eventually occurred over south Florida heightened the awareness in other vulnerable areas to the significant inland wind damage which can accompany a hurricane.

The general impression of most observers is that the evacuation of the general public went very well, with some notable exceptions along the beaches (see **Evacuation Rates** below). Times required to clear the evacuating population appeared close to the times projected in evacuation studies (see table 1). Traffic congestion that caused evacuees leaving south Dade County at noon Sunday, August 23, to arrive in Orlando at 4 AM EDT Monday, August 24, was anticipated by officials. There were unnecessary queuing delays on the Florida Turnpike as toll booths continued operating, but the problem was eventually corrected. A draw bridge in the Keys became stuck in the "up" position early Sunday morning but was fixed in less than an hour. Subsequently, all bridges in the region were locked down for the duration of the evacuation. Success in evacuating special facilities varied.

In January and February of 1993, Florida State University, with funding from the National Science Foundation, conducted a survey with 1,100 residents of Broward, Dade, and Monroe Counties to document public response to the threat.

Evacuation Rates

The percentage of residents who evacuated (i.e., left their homes to go someplace they believed would be safer) in Andrew varied by proximity to the shoreline. In Broward County, 69 percent left from the Category 1-2 surge zone; and in Dade County, 71 percent left from the Category 1 area. In the Broward Category 3 and Dade Category 2-3 zones, 63 percent evacuated; and in Category 4-5 zones, 46 percent left from Broward County and 33 percent left from Dade County. In both counties, 13 percent evacuated from inland areas beyond the Category 4-5 surge limits. Had Andrew's track been slightly farther north, a significant number of homes would have been flooded with their occupants in them.

Evacuation from the Florida Keys (Monroe County) decreased from north to south and was lower than that from the Broward and Dade County high-risk areas. In the upper Keys, 62 percent left, compared to 45 percent in the middle Keys, 40 percent in the lower Keys north of Key West, and 25 percent in Key West. If Andrew's track had been farther south, many homes in the Keys also would have been flooded with their occupants still in them.

Although only 70 percent evacuated from the high-risk areas of Broward and Dade Counties in Andrew, many residents (44 percent in Broward and 28 percent in Dade) said they *didn't hear from officials that they were supposed to leave*. Of those who said they did hear officials say that they were to evacuate, only slightly more than half believed the notice was mandatory. Overall, only 32 percent in Broward Category 1-2 and 42 percent in Dade Category 1 evacuation zones believe they were *ordered* to evacuate.

Of those who indicated that officials told them to evacuate, 80 percent did compared to only 52 percent of those who said they weren't told to leave. Of those who understood that they were *ordered* to leave, 87 percent did so, and of the respondents who said that officials actually came into their neighborhood making announcements that they *must* evacuate, 89 percent left.

Evacuation Timing

Ten percent of the evacuees from the Dade and Broward County high-risk areas said they had already left when the watch was issued. Few others left during Saturday evening and night, so that when a warning was issued the following morning, less than 15 percent of the eventual evacuees had left. At that time, officials in both Broward and Dade Counties issued evacuation orders. The evacuation rate clearly began to increase around 8 AM Sunday, and by 2 PM that afternoon, slightly more than half the evacuees had left. By 6 PM, over 90 percent of the evacuees had left. Response curves for lower risk areas of Broward and Dade Counties were comparable but lagged slightly behind the curve for the highest risk zones.

As indicated in greater detail previously, the evacuation was phased in the Florida Keys. Although most residents weren't told to leave until early Sunday morning, many were aware of the other evacuation activities going on earlier and some were probably influenced. Twenty percent of the evacuees said they had already left when the hurricane watch was issued, and another 10 percent left by Sunday morning when the general evacuation order was issued for the upper Keys. The response curve began to increase sharply at that time, and by 9 AM, 50 percent of the evacuees had left. By 5 PM, 90 percent of the evacuees had left, and officials halted evacuation out of the Keys from the upper Keys at 6 PM. Response curves for the middle and lower Keys were similar but somewhat later.

The lower Keys and Key West, in particular, are perceived by Monroe County officials as presenting a special response problem. Studies project that up to 40 percent of the residents there would refuse to leave if so ordered. At least part of the reluctance to leave is attributed to a concern that evacuation is impossible and that those attempting to leave could be trapped on roads and bridges as the storm arrived. **Finding I.F.1: NHC and NWS representatives, when making a case for refuges of last resort, may have contributed unintentionally to the problem of public resistance to evacuation by stressing the danger of being caught trying to evacuate. Recommendation I.F.1: NWS and NHC representatives need to stress to the public the importance of referring to appropriate state and local emergency management directives about evacuation orders.**

In the region overall, and perhaps beyond, most residents appear very willing to leave in the future. In fact, many who would not be included in evacuation notices say they intend to leave rather than stay behind and experience the sort of wind-borne destruction caused by Andrew in southern Dade County. If all those who said they will leave in the future attempted to do so and if they attempted to leave the region (as most say they would), the evacuation would need to begin more (perhaps **much** more) than 48 hours before the arrival of the storm. Such intentions are notoriously poor predictors of actual behavior, however, and officials would take actions designed to curtail the shadow evacuation effect. Nevertheless, this will be an added complication to evacuations in the region in the near future.

An interesting phenomena occurred in the Naranja Lakes area where damage was extreme. As an area subject to potential storm surge, evacuation was recommended due to that threat. Most residents did so, but several who did not lost their lives. However, those fatalities were the result of wind-borne missiles, not storm surge. **Finding I.F.2: If residents of the hard hit Naranja Lakes area had not evacuated because of the storm surge threat, more deaths likely would have resulted from the effects of wind. Recommendation I.F.2: Since in many cases evacuation is not a viable option, the NWS and the Federal Emergency Management Agency (FEMA) should work together to encourage the concept of engineered in-residence shelters to protect from severe wind without invoking evacuation procedures.** Had those who evacuated not done so, many more lives would have been lost.

Finding I.F.3: Many residents whose houses began to disintegrate during the storm followed "tornado safety rules" and went to the interior part of their house away from windows and outside walls. Whether this was an obvious sort of adaptive response, whether there was a background level of awareness about what to do as learned from tornado awareness efforts, or whether people were being instructed over radio and television to do so, the response was good. In response to the success of this action, Lee County has already begun to develop instructions, complete with sketches, to be included in telephone books. **Recommendation I.F.3: NWS and emergency management agencies should make "tornado safety rules" a standard component of hurricane awareness efforts, especially for strong storms. The public also should be better educated about the kinds of construction and building designs which are most vulnerable in strong hurricanes.**

Intense winds associated with Andrew caused the shearwall to fail on the lee side of this multifamily structure.

This stack storage facility at Black Point Marina, Dade County, collapsed under Andrew's intense winds. One-third of the 45,000 registered boats in Dade County were damaged.

CHAPTER I.G

PROCESSING, INTERPRETATION, AND DISSEMINATION OF NWS INFORMATION

Utilization of Hurricane Forecasting Models by NHC and NMC

The overall performance of the track prediction models used by NHC was very good during Hurricane Andrew. In particular, the Aviation (AVN) model delivered an extremely good performance. NHC's forecast operations had access to seven (7) numerical models for track prediction. These models included both statistical and dynamical types with some incorporating both concepts in their design. Although NHC depends heavily on the use of these model outputs, it is always the forecaster's judgment and experience that ultimately determines NHC's official track forecast.

Statistical models provide forecasters with calculated storm movements within minutes after initialization, while the dynamical models may take up to 6 hours to run. Therefore, the statistical models always are available to the forecaster while the dynamical models, such as the Aviation (AVN) and the Quasi-Lagrangian Model (QLM), are run every 12 hours.

The vital data ingredients for these models include the storm's direction and speed of movement (translation), storm intensity, storm geographical location, and date. These data can be most accurately assessed by aircraft reconnaissance and, as the Melbourne WSO's WSR-88D proved in Andrew, by modern radar. Satellite imagery, although vital for tracking cyclones over more remote ocean areas, does not consistently provide the degree of data accuracy needed when storms threaten coastlines.

There is only one operational model that is specifically used to predict the rate of strengthening, the SHIFOR (Statistical Hurricane Intensity Forecast) model. Although the model underestimated the rate of strengthening of Andrew particularly during its rapidly deepening period, the hurricane warning lead time was not impeded.

The NHC issued 37 official track forecasts during the time Hurricane Andrew existed as a tropical cyclone; one forecast every 6 hours. Using the best available data on the storm, an official "actual best track" is determined for comparison and verification purposes of all official forecasts.

Table A.5 in appendix A lists the official average track errors in nautical miles for various model guidance during Hurricane Andrew. The track errors for Andrew are considerably less than the 10-year average but not as small as the forecast errors for Hurricane Hugo. The CLIPER (CLImatology-PERsistence) errors are useful as a measure of forecast difficulty: the larger the CLIPER errors, the more difficult is the forecast. The Andrew CLIPER errors were much larger than the Hugo CLIPER errors, indicating that the Andrew track was a more difficult one to forecast. All of the models are verified on the same set of forecast cases.

The Aviation model, with its new synthetic data system, had the smallest errors at 36, 48 and 72 hours, while the QLM had the smallest errors at 24 hours, and CLIPER and NHC90 (NHC 1990 Hurricane Computer Forecasting Program) were tied for the smallest errors at the short range of 12 hours. **<u>Finding I.G.1</u>: Small errors in the track forecast produced by the Aviation Model were impressive for this small sample of forecasts. <u>Recommendation I.G.1</u>: NOAA should continue to support development of such models. In order to use these models most effectively, methods need to be explored to gather better data in and around tropical cyclones. The Omega dropwinsonde experiment should be conducted to evaluate the potential of this capability.**

SLOSH Model Performance

For more than 12 years, the NWS has been modelling hurricane storm surges with the SLOSH model. This numerical computer model calculates hurricane storm surges in a given area (or basin) based on hurricane track, size, and intensity. It does not incorporate the effects of wave action. The model has been applied to all of the eastern and gulf coasts of the United States. SLOSH was designed originally to compute storm surges in real-time as a hurricane threatened the coast. More recently, the model has been run in a "simulation study" mode, where hundreds of hypothetical storms are simulated with the flooding data from each stored. These data form the "hazard" basis of comprehensive hurricane evacuation planning.

Hurricane Andrew significantly affected four United States SLOSH basins as well as the Bahamas SLOSH basin. The four United States basins were Biscayne Bay (Miami), Florida; Florida Bay, Florida (Keys); Charlotte Harbor (Ft. Myers), Florida; and Vermilion Bay, Louisiana. Simulation studies were completed in both Biscayne Bay and Charlotte Harbor; only the Vermilion Bay area had no completed study.

<u>The Bahamas</u>

Early in 1990, Mr. Arthur Rolle of the Bahamas Meteorological Service (BMS) worked with the NWS's Techniques Development Laboratory (TDL) adapting the SLOSH model to parts of the Bahamas. Their efforts focused on extracting bathymetry and topographic features needed by the model as well as learning about the model itself. The Bahamas basin coverage is shown in figure 7. After completing the model, Mr. Rolle worked with NHC conducting a SLOSH simulation study. In such a study, hurricanes of various landfall directions with differing landfall points, categories, and forward speeds are chosen as storms possible in an area's climatology. In total, 1,225 hurricanes were used as input to the SLOSH model. A total of 67 composites called Maximum Envelopes of Water (or MEOWs) were formed from this massive amount of surge data by choosing the maximum surge at each model grid square from a "family" of similar storms. These MEOWs are extremely useful for emergency managers in making evacuation decisions and form the "hazards" portion of hurricane evacuation planning.

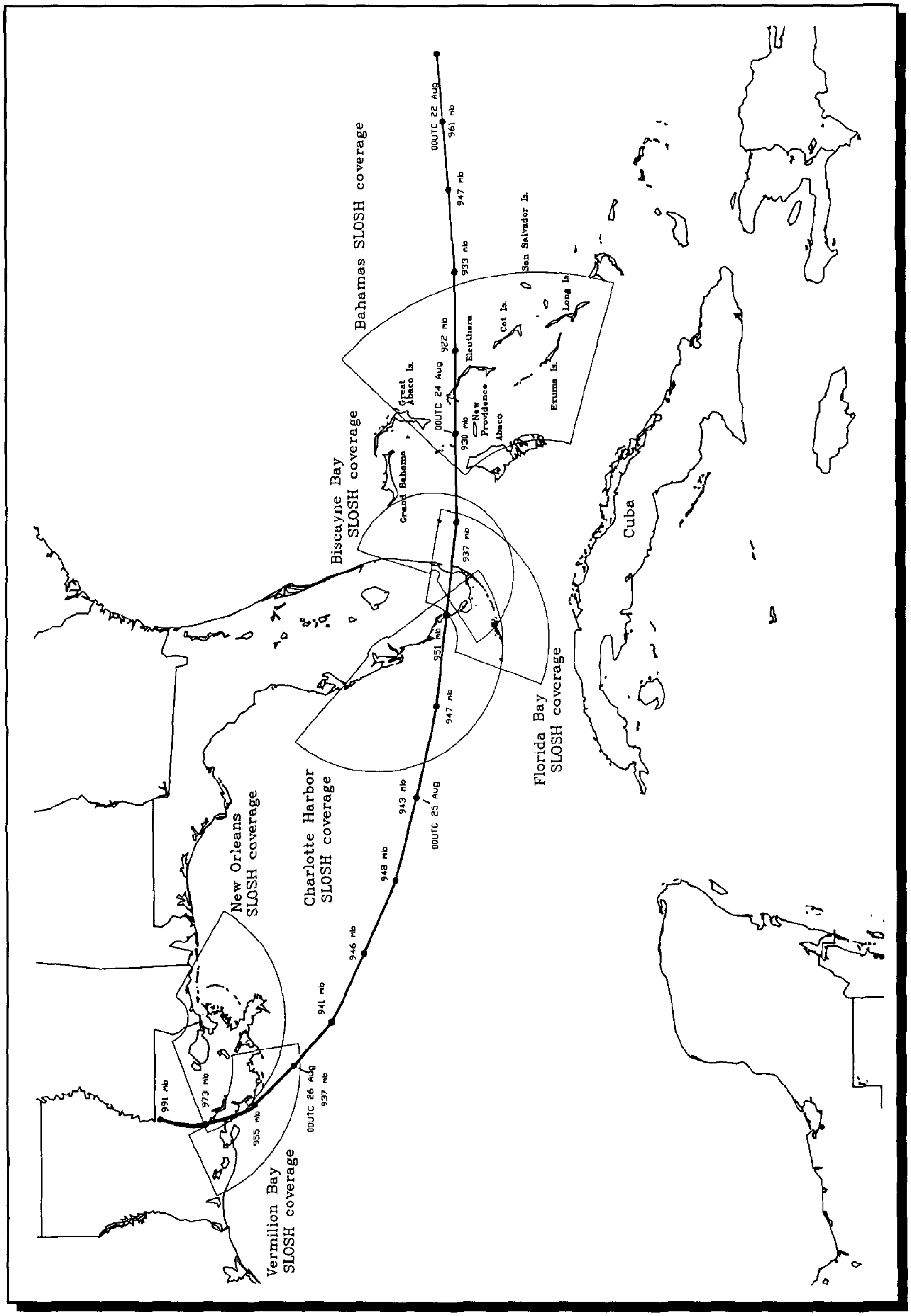


Figure 7 — SLOSH basins affected by Hurricane Andrew.

This simulation study was completed well in advance of Hurricane Andrew although a full, comprehensive hurricane evacuation plan has not been done. In addition to having the SLOSH data in its raw form, the SLOSH graphics display program developed by TDL also was available to the BMS. This program allows the rapid recall of MEOWs and presents the data on a map background. When Andrew began to threaten the Bahamas, Mr. Rolle was in contact with the storm surge experts at NHC regarding the possible impact of the hurricane. At 11 AM EDT on August 22, the Bahamas' government issued a hurricane watch for the northwestern Bahamas. At 5 PM EDT that afternoon, the watch was upgraded to a warning for the northwestern Bahamas, including the islands of Andros, Eleuthera, Grand Bahamas, and Great Abaco. Storm surges of 8-10 feet above normal and dangerous wave action were expected, according to the forecast.

Andrew continued to intensify. Forecast surge levels were raised to 10 to 12 feet at 11 PM EDT, August 22, then further increased to 10 to 14 feet in the 5 AM EDT, August 23, advisory. Andrew continued to intensify and was referred to as a "dangerous category 4" storm in the 11 AM EDT, August 23, NHC advisory. That advisory pointed out that up to 18 feet of surge was possible for the northwest portion of Eleuthera.

Andrew passed over northern Eleuthera about 5 PM EDT on August 23 and was located approximately 25 miles north of Nassau at 8 PM EDT on August 23. High water marks measured on Eleuthera ranged to 25 feet above local mean sea level in the town of The Current. One storm surge drowning occurred in Lower Bogue where a water level of 18 feet was observed. (With these values for water level, storm surge is not separated from wave run-up.)

South Florida

The first mention of surge levels along Florida's coastline was in the 8 AM EDT, August 23, advisory—8 to 12 feet of surge near where the center makes landfall. In the 11 AM EDT, August 23, advisory, the forecast was made more specific: 7 to 10 feet along the Florida east coast, with 9 to 13 feet possible in Biscayne Bay.

In 1988, NHC completed a simulation study for hurricane storm surges in the Biscayne Bay SLOSH basin. A similar study had been completed for the Florida Keys the year before. Information concerning storm surge flooding was passed along to the U.S. Army Corps of Engineers and FEMA as well as to state and local officials involved with hurricane evacuation planning. A comprehensive evacuation plan for metropolitan Dade County was distributed in May 1991, which incorporated the surge hazard as depicted by SLOSH.

Throughout past hurricane evacuation planning, the policy has been to evacuate all people living within the area of potential surge flooding. For Dade County, a threat from a category 4 hurricane would mean that all areas east of Cutler Ridge, the entire Homestead area, and Miami Beach would need to be evacuated. Cutler Ridge is an ancient coral ridge that extends southward from Miami through the town of Cutler Ridge. In Miami, the ridge has an elevation of about 22 feet. Elevations decrease to about 14 feet at the town of Cutler Ridge and to roughly 8 feet around Homestead. Miami Beach, with its large population of elderly people, presents special problems for the emergency managers since many of these elderly people would need to rely on public transportation. All of these areas were told to evacuate preceding Hurricane Andrew.

Initial reports of storm surge flooding indicated only a few feet and were based on gauges in and around the Miami area. However, these gauges were too far north to capture the peak levels of surge flooding, especially considering Andrew's compact size. Almost immediately following the storm, the USACE and U.S. Geological Survey (USGS) entered the disaster area and flagged high water marks. The observer described each mark's location and its immediate surroundings. These marks were later surveyed, tying the elevations back to known benchmarks. At the request of the NWS, observations were made inland to determine the extent and distribution of flooding.

The highest storm tide mark was found at the Burger King World Headquarters building—16.9 feet NGVD (the reference datum used on USGS quadrangle maps). Several other high water marks nearby confirm that this level was reasonable. At the Deering Estate, a level of 16.5 feet was measured. This mark was inside the building, inside a closet, under a stairwell. In such a location, a good "stilling well" effect, damping out wave action, is expected.

Peak storm tide values over 16 feet occurred in a very localized area. Flooding dropped off quickly on either side of the maximum. Figure 8 shows the distribution of storm tides as measured by the USGS and USACE.

The NOS's Office of Ocean and Earth Sciences operates one Next Generation Water Level Measurement System (NGWLMS) gauge in the Miami area, located at Haulover Pier. Although the gauge recorded water levels of only about 4.5 feet North American Vertical Datum, corresponding to storm tide levels of only about 2.6 feet, the station structure suffered major damage from Andrew.

NWS's SLOSH model was run for hurricanes similar to Andrew during the simulation studies. One storm surge product available to NWS forecasters is a MEOW which closely matches Hurricane Andrew: category 4 hurricanes moving west, figure 9. The maximum surge possible is about 14 feet. This particular MEOW was run with a forward speed of 12 mph; Andrew was moving at about 20 mph. Since faster forward speeds generally produce larger storm surges, a slightly larger surge could be expected. In addition, the initial water level of the simulation study was 1 foot. Observed water levels were running about 1 foot above the predicted astronomical tide for the day prior to Andrew. Adding to this water level, Andrew arrived at roughly the time of high astronomical tide.

Andrew's storm surge impact along the west coast of Florida was (relatively) minimal. Andrew's eye passed to the south of Marco Island, exiting over the Everglades. Several high water marks were measured in the populated areas near Marco Island. However, USGS and USACE survey crews could not locate any reliable high water marks to the south in the Everglades.

Finding I.G.2: The storm surge impacted a relatively small area of coastline, but the SLOSH model accurately depicted the surge in south Florida. Recommendation I.G.2: Refinements to the SLOSH model should continue. Also, training of NWS offices and emergency managers in its use should be emphasized. The SLOSH model should be validated in cooperation with the NOS/Office of Ocean and Earth Sciences (OES) and others to further continued improvements in the model. A greater effort should be made to document its physics and the validation efforts that justify its use. NOS should assist with such a documentation.

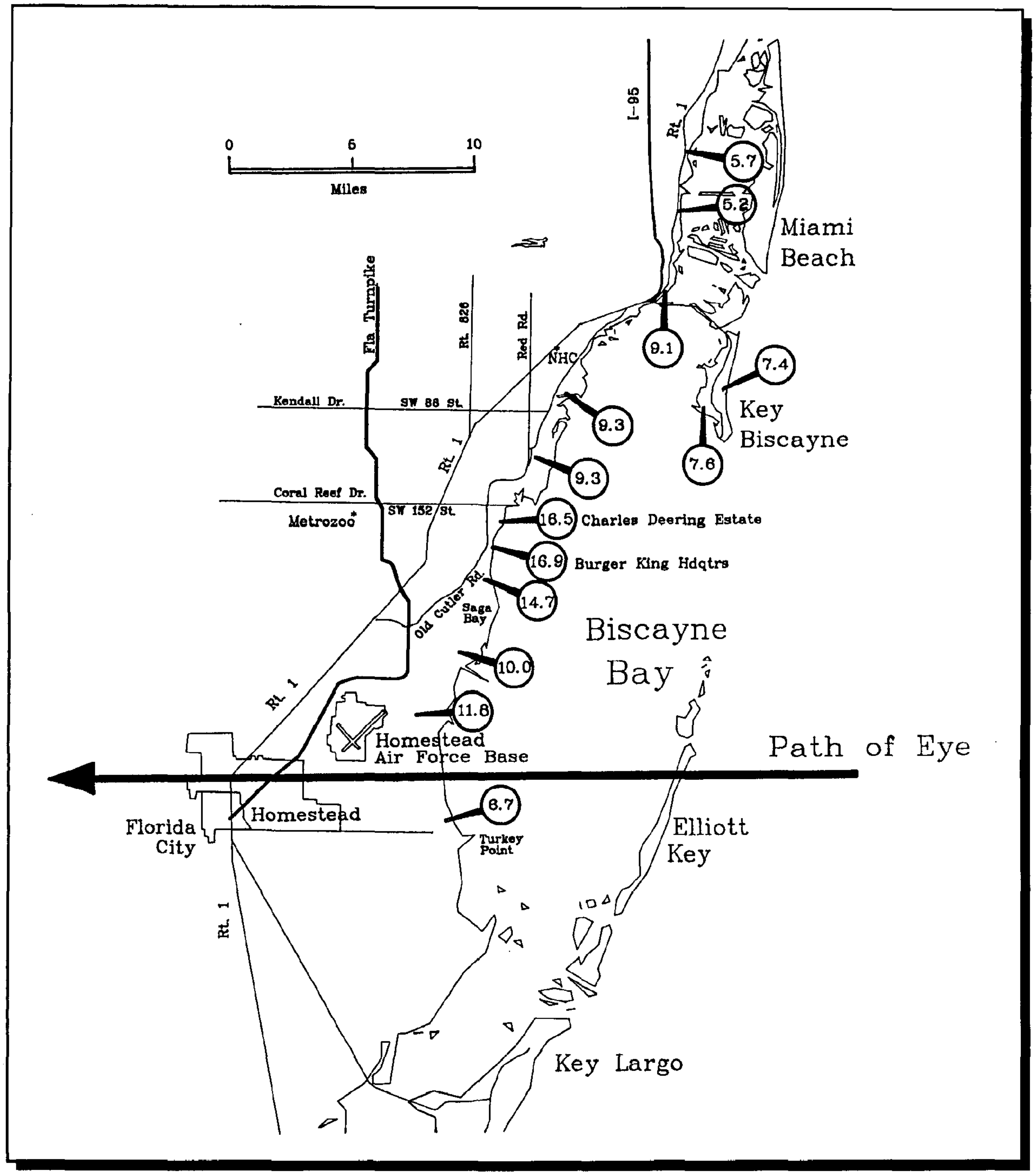


Figure 8 — High water marks in Dade County, south Florida, during Hurricane Andrew.

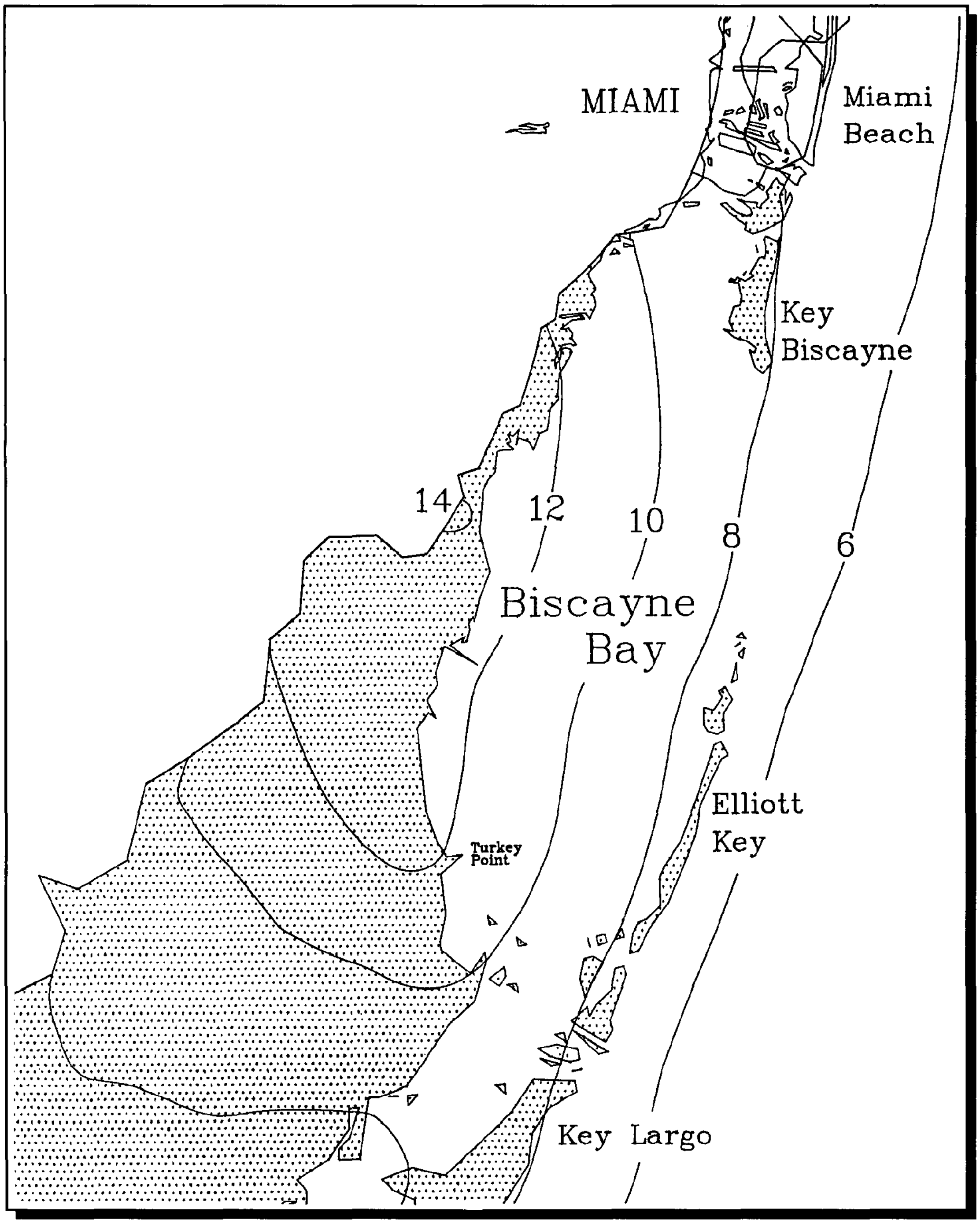


Figure 9 — SLOSH run for westward-moving category 4 hurricanes, making landfall where Andrew did in Biscayne Bay.

Hurricane Andrew was simulated in the Charlotte Harbor basin with the SLOSH model using the best available information to identify the storm. Highest surges computed in this simulation is shown in figure 10 with high water mark information superimposed. Winds were offshore to the north of the storm's track until after the eye's passage. At the time of eye passage off the coast, the winds turned, generating the observed highest surges. South of the track, winds were consistently onshore during the storm and generated storm surges of up to 7 feet. Again, no observations could be made in this area to verify the computed storm surges.

Utility of Other PC Software

Products Available to the NWS

Three major PC-based software packages are available to NWS offices along Florida coastlines: SLOSH, ***GDS4.0***, and ***Tides***. NWS personnel from the WSOs and WSFO Miami were questioned regarding their use of this software during the days and hours preceding the landfall of Hurricane Andrew. Unfortunately, due to lack of available hardware, most offices did not make active use of this software.

In most WSOs and even some WSFOs, PC use generally is limited to (1) an SRWarn Computer and (2) a Micro-Arts PC for compiling and disseminating surface observations. **Finding I.G.3: On-station computers at WSOs and WSFOs are inadequate to run storm surge and applications programs.** Limitations to these PC-type computers mean that resident programs are terminated while applications programs are run. This is cumbersome and ineffective. In some WSFOs, additional computers are on station for use by management and support staff. These PCs, however, are not routinely available to operational staff. In order to utilize the above software, the operational staff would have had to terminate resident programs, such as the surface observation program and SRWarn. This was determined to be inordinately cumbersome. AFOS does not have the capacity to serve as an alternative. **Recommendation I.G.3: Coastal NWS offices should be provided sufficient PC hardware and software to display SLOSH MEOW (Maximum Envelop of Water) data as well as to run surge applications and hurricane decision-making programs. The Advanced Weather Interactive Processing System (AWIPS), under development for future NWS Weather Forecast Offices, should be able to support these programs.**

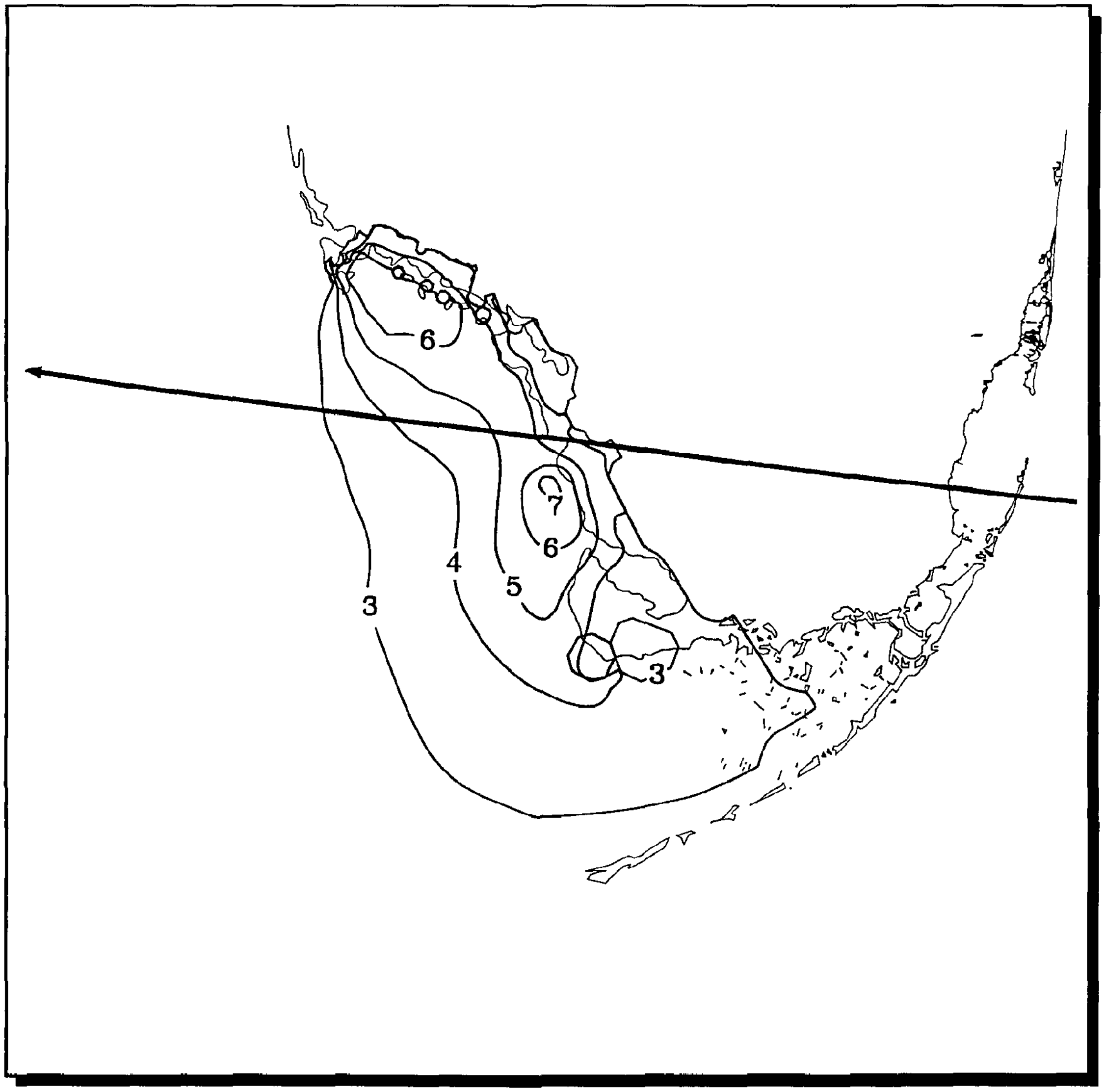


Figure 10 — South Florida west coast storm surge.

CHAPTER I.H

COMMUNICATIONS

Automation of Field Operations and Services (AFOS)

The NHC and WSFO Miami share and use many of the same communications systems. However, they are separate AFOS node sites with each AFOS mainframe containing identical data bases for reciprocal backup purposes. Both the NHC and WSFO Miami AFOS systems functioned throughout Andrew. It was not necessary to invoke any backup for these systems. Due to eventual failure of the air-conditioning system, the ambient temperature around AFOS reached approximately 100 degrees Fahrenheit. Excessive heating was avoided by turning off some unused components. WSFO Miami also called on WSFO's Sterling and Atlanta for backup of products in anticipation of the heat problems with AFOS.

AFOS also worked well at WSO Melbourne as did the Remote Terminal to AFOS (RTA) at WSO Palm Beach. On Sunday, August 23, a Melbourne electronics technician arranged an AFOS link to WSO Fort Myers, where a temporary NWS detail had been set up at the local EOC for taking calls and briefing the EOC. Melbourne also performed an AFOS dial test with WSO West Palm Beach on Sunday evening to ensure that West Palm Beach could link with AFOS through their RTA system in the event that the Miami AFOS became disabled. The AFOS communications link between NHC/WSFO Miami and WSO Key West failed at 5:15 AM on August 24 as Andrew was making landfall in south Dade County. The AFOS at WSO Key West worked well during Andrew, but the office was out of contact with the state and national AFOS network for the duration of the communications outage which lasted for just over 49 hours.

NOAA Weather Wire Service (NWWS)

NHC and WSFO Miami have separate satellite-driven NWWSs with distinct uplink and downlink antennae, all of which failed just prior to hurricane landfall. This was probably due to misalignment of the antennae caused by strong winds and/or corrosion and bending of the receiver horns. However, their respective uplink backups worked well (WSO Tampa Bay and the National Forecast Division [NFD]), and all NWWS products were successfully transmitted.

The NWWS uplink antenna at WSO Tampa Bay was damaged by lightning prior to the hurricane threat. NWS Southern Region Headquarters had difficulty in getting the maintenance contractor, GTE-CONTEL, to repair the system to ensure dependable NWWS backup. Weather Service Headquarters intervened, and the problem was corrected in time for the Tampa Bay NWWS to function properly. This turned out to be critical since the Tampa Bay backup was needed by WSFO Miami.

The NWWS receivers for both NHC and WSFO Miami were restored Monday afternoon, August 24, about 12 hours after failure. Both transmitting antennae were restored the next day after new parts were installed. In contrast to some states, Florida has a large number of NWWS subscribers as a result of an aggressive promotional campaign several years ago. These subscribers include many emergency managers, the media, utility companies, agricultural and aviation interests, and large corporations, such as Walt Disney World/Vista United. In view of such a diverse group of subscribers, it appears that the NWWS is an important method of NWS dissemination in Florida.

Neither WSO Melbourne nor WSO West Palm Beach drive an NWWS. Instead, their products are normally uplinked through the WSFO Miami system. In both cases, all hurricane-related products were successfully uplinked through WSFO Miami or the WSO Tampa Bay backup antenna once Miami's antenna failed.

NOAA Weather Radio (NWR)

WSFO Miami operates one NWR console which drives a single transmitter. This NWR failed about the time of landfall on August 24 due to wind damage to the UHF antenna at the WSFO that links the console signal to the main transmitter. The main transmitter remained intact since it was located on a multi-use commercial facility, the Gannett Tower, well north of peak hurricane winds near the Dade-Broward County line. An emergency generator supports the transmitter at the Gannett Tower. Until early August, the transmitter had been located on a commercial television transmission tower in Homestead which was destroyed by the hurricane. The damaged UHF antenna was repaired, and the NWR broadcast resumed during the early evening of August 25 after about a 36-hour outage.

There was, of course, an abundance of pictorial and detailed updates on Andrew provided by the commercial media. Nevertheless, there was widespread acceptance and use of NWR in the greater Miami area by marine and agricultural interests and the general public. They were served well by the WSFO Miami NWR which aired a complete suite of warnings, statements, and forecasts related to the hurricane until the UHF antenna failure near time of landfall. **Finding I.H.1: Despite the extensive commercial media coverage of Andrew, both the NWWS and NWR were well received and were utilized as official and timely sources of NWS information regarding the event. Recommendation I.H.1: The NWS should continue strong encouragement of the widespread use of NWWS and NWR as official sources of NWS information. High priority should be placed on planned NWR upgrades and more wind-resistant transmitters, featuring voice synthesis, to improve the quality and efficiency of NWR dissemination during major weather events. The NWS should develop partnerships with FEMA and other organizations to increase NWR coverage as well as the broadcasting of critical pre- and post-event information.**

NWR consoles and transmitters worked well at both WSO Melbourne and WSO West Palm Beach, and all pertinent hurricane products were broadcast.

National Warning System (NAWAS)

NAWAS remained functional except in the Keys where it, along with all other land-line communications, failed at 5:15 AM on August 24. Many local and state agencies have drops on NAWAS in Florida, with only two Florida counties not on the system. The Florida NAWAS also serves all emergency managers, most law enforcement offices, and the NWS offices. During Andrew, as in other recent hurricanes, the Director of NHC used the state NAWAS circuit to good advantage in briefing emergency managers and the WSOs on the latest NHC thinking and in receiving questions and comments. This helped to ensure that local decision makers were in the direct loop of critical information. **Finding I.H.2: NHC made effective use of the Florida National Warning System (NAWAS) circuit to communicate with Florida emergency managers and Florida WSOs on important hurricane information. Recommendation I.H.2: FEMA, NWS, and state emergency management offices should develop procedures to use the national NAWAS circuit for multistate conference calls so that NHC can brief all appropriate emergency management officials on the network during a hurricane threat.**

Hurricane Hotline Internal Coordination System

The hurricane hotline worked well during Andrew although in other hurricanes this dedicated telephone land line sometimes failed. The hurricane hotline is an internal system used primarily by coastal WSFOs, military weather offices, and national and regional NWS offices. The WSOs do not have a drop on the hotline. Any advance or internal coordination given to the WSOs was initiated by the WSOs over regular telephone lines. The WSOs were not included in the roll calls over NAWAS. NAWAS is not a secure circuit for discussing "internal" NWS information, as The Weather Channel has access and did a pre-release watch and warning information to the public.

IBM Mainframe Computer

The most serious communications problem at NHC was the failure of the IBM 4381 mainframe computer. This computer drives the McIDAS VDUC, which ingests and displays real-time interactive satellite, gridded, and lightning data. Due to excessive heat build-up, the IBM underwent an orderly power down. When restoration was attempted, a mechanical failure occurred. In addition, there was serious damage to the antenna which receives the GOES and Meteosat-3 (Meteorological Operations Satellite) data for display on the McIDAS. **Finding I.H.3: Excessive heat build-up contributed to the failure of the IBM mainframe computer at the NHC during the hurricane. This was the most serious communications failure at NHC because of the IBM's role in driving the McIDAS VDUC, a principal source of interactive satellite data for the NHC staff. In addition, other important circuits failed which depended on the IBM. Recommendation I.H.3: The NWS should install a stand-alone air-conditioning system for the NHC independent of leased commercial facilities. This would greatly minimize the heating problem of critical communications and computer equipment.** Although the IBM 4301 mainframe and NHC-based satellite antennas failed, a backup system through work stations linked with the VDUC system at NMC continued to operate.

This system provided a basic set of satellite imagery on NHC systems. Also, satellite data continued to be received through SWIS (Satellite Weather Information System), micro-SWIS, and the Unifax, all of which remained functional during the storm.

Telephone Systems

NHC has an Eagle electronic telephone system for use with external agencies and the public. The UPS (Uninterruptable Power Supply) battery backup system for these telephones failed. However, the phones were still useable after being connected into some dedicated Federal Telephone System (FTS) lines originally designed for data collection. In addition, other dedicated lines, such as the FAA hotlines, were used in lieu of the failed conventional telephones. Telephone lines from the Florida WSOs worked well, but telephone service into the NHC was cut off just prior to landfall. Communication between the WSOs and NHC was maintained through NAWAS.

Land Lines Versus Satellite

Many communications problems at NHC were due to failed satellite antennae on top of the NHC building. South Florida has a dependable, well constructed, land-line system which, in general, fared better than many of the modern satellite links, the antennae of which were badly damaged by the hurricane-force winds. Thus, most land-line circuits at NHC remained operational, including the radio fax circuit to marine radio station WLO in Mobile, the Tropical Regional Analysis Facsimile Circuit (TROPAN) circuit to Cape Canaveral and others, and two circuits to Jamaica and Haiti, the only source of NWS hurricane information to these countries. By contrast, the Digital Facsimile (DIFAX) failed. DIFAX is a receive-only satellite link between NMC and WSFO Miami for relay of aviation weather data. Similarly, the Chief Aerial Reconnaissance Coordination for All Hurricanes (CARCAH) reconnaissance military circuit failed due to wind damage to the receiving antenna. Thus, aircraft reconnaissance data had to be routed via the backup system through Keesler Air Force Base, Mississippi, to NWS Central Flow Computer Facility in Washington, D.C., and finally to the S-140 computer at NHC.

Amateur Radio

The Dade County Amateur Radio Public Service maintains close ties with NHC and had VHF (Very High Frequency) voice, VHF packet, and HF (High Frequency) sideband antennae at the NHC office. This equipment was checked out by amateur radio operators on Saturday, August 22. Their usual role is to communicate with the Florida Keys and other offshore areas damaged by tropical cyclones. Since Andrew did relatively little damage in the Keys, the radio operators who normally coordinate with NHC to aid the Keys decided that their services would not be needed. By late Sunday, when it was determined that they might well be useful at NHC for emergency communications, the operators were already committed for other emergency tasks and/or concerned about their own safety. Thus, no amateur radio personnel were present at NHC during the storm, but their assistance would have been limited because, like so many others, their antennae were also destroyed atop the NHC building.

The Emergency Broadcast System (EBS)

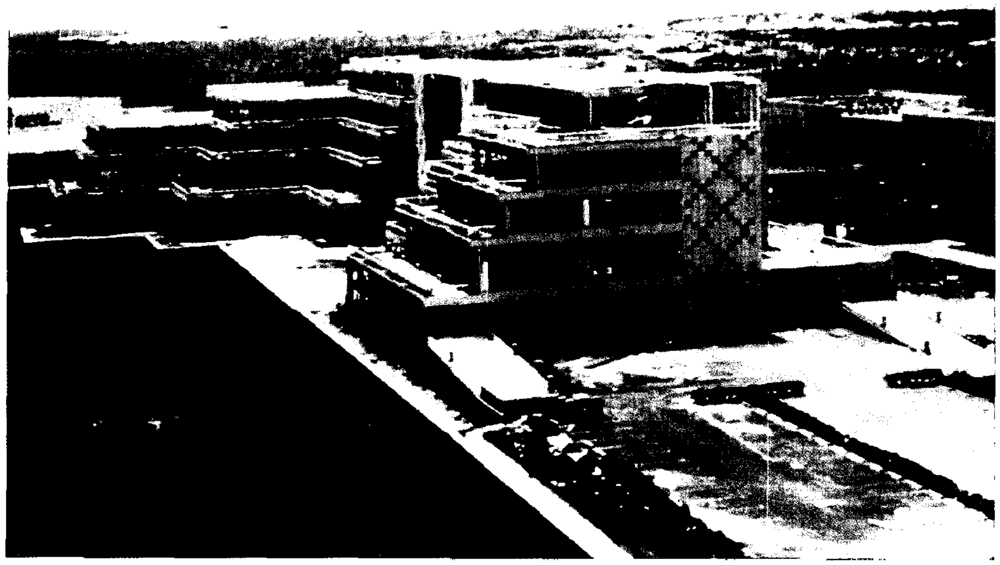
The primary Common Program Control Station (CPCS)-1 EBS station for the Miami area is WINZ/AM, transmitting at 50,000 watts. On Saturday evening, August 22, the chief engineer of WINZ called a meeting of his radio staff to alert them to the potential urgency of the situation. At that time, he assigned an additional operator to master control. According to their procedures, WINZ initially received the 8 AM EDT August 23 hurricane warning for south Florida via the WSFO Miami NWR which is carried through a dedicated phone line to a voice box at the radio station. They activated EBS after verifying the warning through hard copy receipt from AP. The chief engineer estimated that from 3 to 5 minutes elapsed between initial NWR receipt of the warning and EBS tone activation by WINZ. The range of WINZ is from Lake Okeechobee to the Florida Keys. They voluntarily sounded the EBS tone and broadcast the warning again at noon. This station is also linked to many state and county emergency managers through a VHF radio net that allowed them to receive and broadcast Governor Lawton Chiles' state of emergency and evacuation order at 3 PM EDT on Sunday, August 23.

WINZ stayed on the air throughout the storm. For about 2 weeks after the hurricane, WINZ requested and was granted a Federal Communications Commission waiver to continue 24-hour a day service at 50,000 watts. During this time, they rebroadcast "radio recovery" information from the military regarding locations of food, supplies, etc., for the hurricane-stricken area.

WQBA, the primary EBS station for Latin American residents in Miami, did not activate EBS. The chief engineer at WQBA explained that EBS is normally activated for short-fuse emergency conditions for which the public has little or no warning. The station decided not to activate because the hurricane threat to the area was already well known, and all relevant information was being widely disseminated. Except for a couple of minutes near time of landfall, WQBA stayed on the air, suspended regular programming, and broadcast emergency information as a public service. They were able to continue broadcasting because they anticipated the power failure at the studio and made arrangements to broadcast temporarily directly from their transmitter site.

Other Communications at the Florida WSOs

A packet radio link was set up by amateur radio personnel between WSO Melbourne and NHC. This would have allowed NHC to download a text file (e.g., an advisory) via radio to Melbourne who, in turn, could enter the product into AFOS. As it turned out, the link was never needed. WSO West Palm Beach had amateur radio links to EOCs in their area, and a ham operator was present at the WSO to manage this network. External users of the WSR-88D at Melbourne were served with no problem through either dedicated or dial-up lines. WSFO Sterling also dialed into the Melbourne Doppler to get data needed for their marine forecast backup of WSFO Miami.



An aerial view of the World Headquarters for Burger King, site of a 16.9-foot storm surge. Note the windows blown out by Andrew's intense winds.

This photo depicts wind damage to the top floor of the Burger King World Headquarters building.

CHAPTER I.I

DATA COLLECTION

Data used in assessing and forecasting Atlantic basin tropical cyclones is acquired using both remote sensing equipment and direct observation. The remote sensing methodology includes satellite imagery and radar, while the direct observation methodology includes aircraft reconnaissance, surface observations (both human and automatic), and unofficial public reports. All of these potential sources were used prior to and during Hurricane Andrew. What follows is an assessment of the performance of those information sources.

Satellite Imagery

The most reliable manner of examining the physical characteristics of a tropical cyclone, e.g., its wind and pressure fields, banding, and overall structure, is by direct measurement. When a storm is too far from land to be reached by reconnaissance aircraft, direct measurement is not possible. **Finding I.I.1: Satellite imagery is the only source of information over data-sparse oceans, except for ships which generally avoid rough weather. Recommendation I.I.1: NOAA must make every effort to ensure that the GOES-Next (Geostationary Operational Environmental Satellite-Next Generation Satellite) program remains on schedule. Meanwhile, No-GOES plans need to be tested routinely.**

During Hurricane Andrew, the NHC used two primary satellite data feeds to view the tropical system that became Andrew: the European owned Meteosat-3 which was moved into position on loan backup to the GOES-7. The Meteosat was used as the storm began its trek across the Atlantic, and the GOES data became valuable as the storm reached the central Atlantic. Additionally, high resolution 1-km polar orbiter data were obtained as the storm approached the Bahamas and south Florida. The Defense Military Satellite Program (DMSP) high resolution data was not utilized by the NHC. Complex down-loading procedures from Air Force Global Weather Headquarters at Offutt AFB through the NMC and then to NHC make it unavailable for NHC in real-time. The imagery, from which valuable wind and rainfall data can be obtained, is received from Offutt at NMC and is obtained via Ethernet at NHC. This results in about a 2-hour delay.

The first evidence of a developing tropical disturbance was obtained using satellite imagery from Meteosat-3. On August 14, a tropical wave was detected as it moved off the western coast of North Africa. That system was monitored continuously as it migrated west at about 15 knots (18 mph), passing south of the Cape Verde Islands on August 15. At that time, meteorologists from the NHC Tropical Satellite Analysis and Forecast (TSAF) unit and the National Environmental Satellite, Data, and Information Service (NESDIS) Synoptic Analysis Branch (SAB) found the wave sufficiently developed to begin detailed, quantitative evaluation.

In addition to examining the local environment of the tropical disturbance, satellite images were used to assess large-scale patterns. For example, soon after Tropical Storm Andrew was born on August 17, the approach of an upper level trough in the westerlies began to shear the system. The approach of the trough and its interaction with Andrew was observed using visual, infrared, and water vapor satellite imagery.

Once Andrew survived its nearly fatal interaction with the upper level trough, it grew rapidly into hurricane status. Satellite imagery, in consonance with aircraft reconnaissance, was critical to determining the character of Andrew. The intensity and rate of intensification, the convective strength and fluctuation, and spiral banding are basic features examined by satellite, especially at night when aircraft reconnaissance is not done.

Aircraft Reconnaissance

An essential data gathering tool in tropical cyclone evaluation for NHC is aircraft reconnaissance. The Air Force Reserve aircraft reconnaissance was extremely valuable. The NHC uses satellite imagery, but upon approach of a tropical cyclone to land, its prime data gathering mechanism is in situ monitoring by aircraft. Without aircraft derived data, it is doubtful that NHC would have realized the gravity of the developing situation during Andrew's approach to south Florida. **Finding I.I.2: Aircraft reconnaissance is a necessary and vital tool for measuring storm intensity, for defining wind fields, and for calibrating satellite estimates of storm intensity. However, the current airframes are aging and provide limited range and performance characteristics. Recommendation I.I.2: Aircraft reconnaissance of tropical cyclones must continue. In order to provide high quality data on the storm and its environment, NOAA should explore cost-effective options on future sensors and airframes. This must be done now if we are to make effective use of next generation models for tropical cyclone intensity and track forecasting.** The aircraft data showed reintensification after the Bahamas in the pressure measurements, a phenomena that was not detected in real-time by any other means. The reconnaissance continued until landfall and resumed promptly upon Andrew's entry into the Gulf of Mexico.

The use of NOAA's Step Frequency Microwave Radiometer and Doppler radar capabilities to measure wind fields could have been a powerful tool to confirm the magnitude of the pending disaster as well as to reduce the subsequent debate about Andrew's wind speeds. Unfortunately, the Aircraft Operations Center (AOC) was forced for safety reasons not to utilize their aircraft around the time of landfall due to increasing turbulence and vertical mixing caused by the storm's interaction with land. One of the aircraft was available to take the NHC emergency backup team to NMC. In fact, AOC does not fly reconnaissance at night with named storms near land due to the level of risk.

Radar Imagery

As Hurricane Andrew moved to within 200 nm of the south Florida coast, it came into range of the NWS Weather Surveillance Radars (WSR) at Miami, West Palm Beach, and Melbourne. Prior to that time, the Doppler radar aboard the NOAA WP-3 Hurricane Hunter aircraft were critical to evaluating the flight level (10,000 feet) wind fields surrounding the storm.

WSR-57 at Miami

The WSR-57 radar at Coral Gables was a network radar operated by WSFO Miami. Its data was readily available to the NHC staff. The WSR-57 operated flawlessly prior to the arrival of Andrew and provided coverage until 4:54 AM EDT, August 24. Shortly thereafter, the region just outside of the northern edge of the eyewall brought winds gusting to 142 knots (164 mph), and those winds sent the radar dish and support structure tumbling from its mount onto the roof. The WSR-57 will not be rebuilt.

WSR-74S at West Palm Beach

The local warning radar at WSO West Palm Beach remained operational throughout the hurricane. The 74S was very useful to the NHC, particularly after the Miami WSR-57 was lost. The NHC maintained a continuous plot of their eye center fixes as opposed to accessing the radar and making fixes locally.

WSR-74S at Key West

The network radar located at Key West also was valuable after the WSR-57 was lost at Miami. Center fixes were tabulated from its observations, similar to that which was done from the West Palm Beach radar. After Andrew's landfall, a communications outage prevented remote viewing of the imagery.

WSR-88D at Melbourne

The new Doppler radar at WSO Melbourne was an important tool for WSFO and NHC operations during Andrew. Finding I.I.3: **The precision, range, and refinement offered by the WSR-88D allowed for precise location not only of the eye but also, long before landfall, of stronger elements in the spiral bands. The ability of the WSO at Melbourne to observe and report on these small but significant features enabled them to allay public fears about a potentially approaching hurricane.**

As the hurricane eyewall moved ashore, however, the WSR-88D data was used even more. Once the WSR-57 failed, WSFO and NHC used the Principal User Processor (PUP) drop to the WSR-88D (located in NHC) to monitor the storm's progress. The WSR-88D also provided valuable information otherwise unavailable to NHC on powerful eyewall characteristics. It tracked the eye continuously from 9:56 PM EDT, August 23, through 4:27 PM EDT, August 24 (figures 11 through 14).

Recommendation I.I.3: Efforts by the NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DOD) to deploy the WSR-88D nationwide must continue. In addition, NOAA needs to assure staffing of its NWS Doppler radar equipped offices with properly trained personnel in order to take best advantage of this powerful data source.

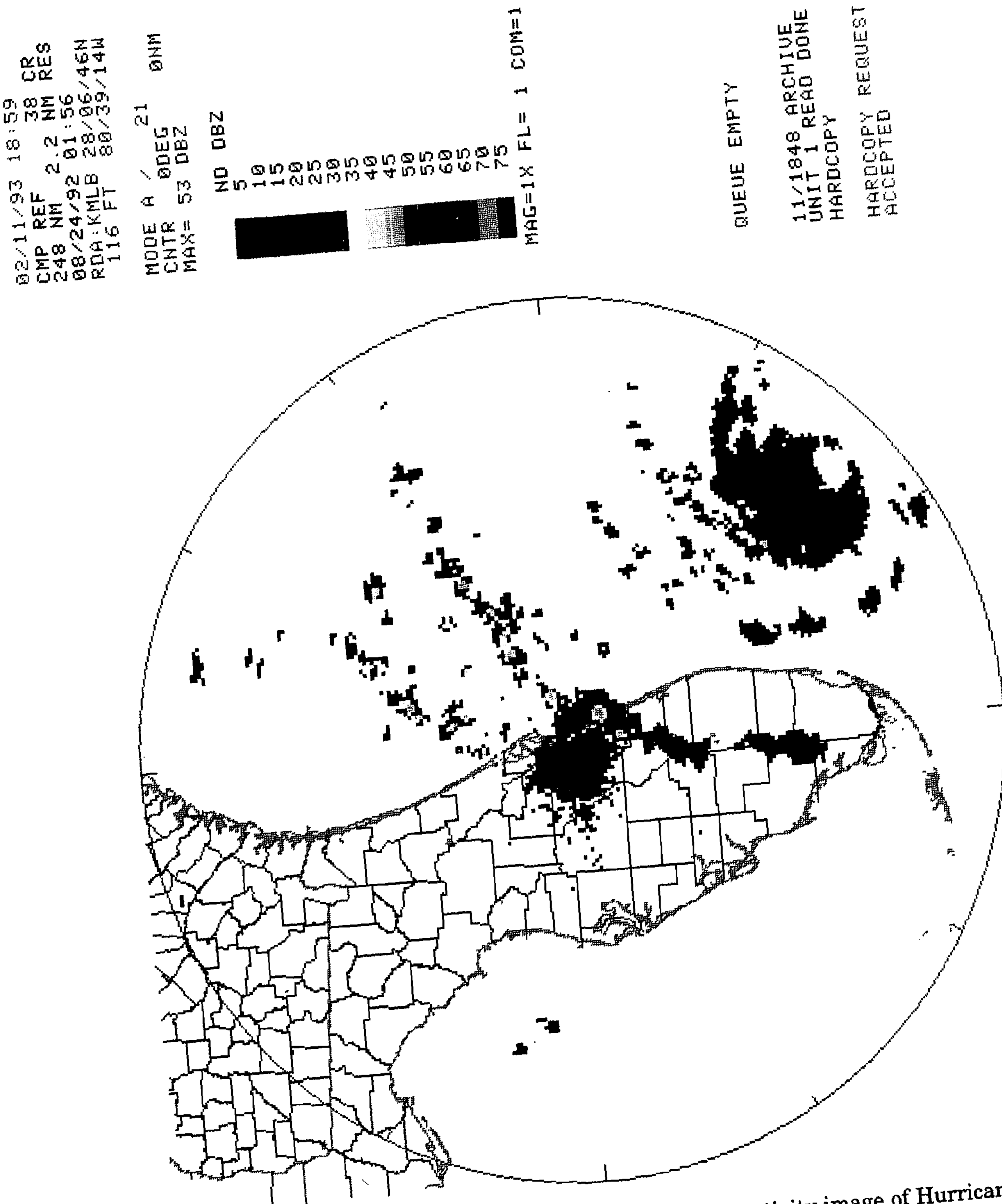


Figure 11 — WSO Melbourne, Florida, WSR-88D composite reflectivity image of Hurricane Andrew taken at 0156 UTC, August 24, 1992 (9:56 PM EDT, August 23).

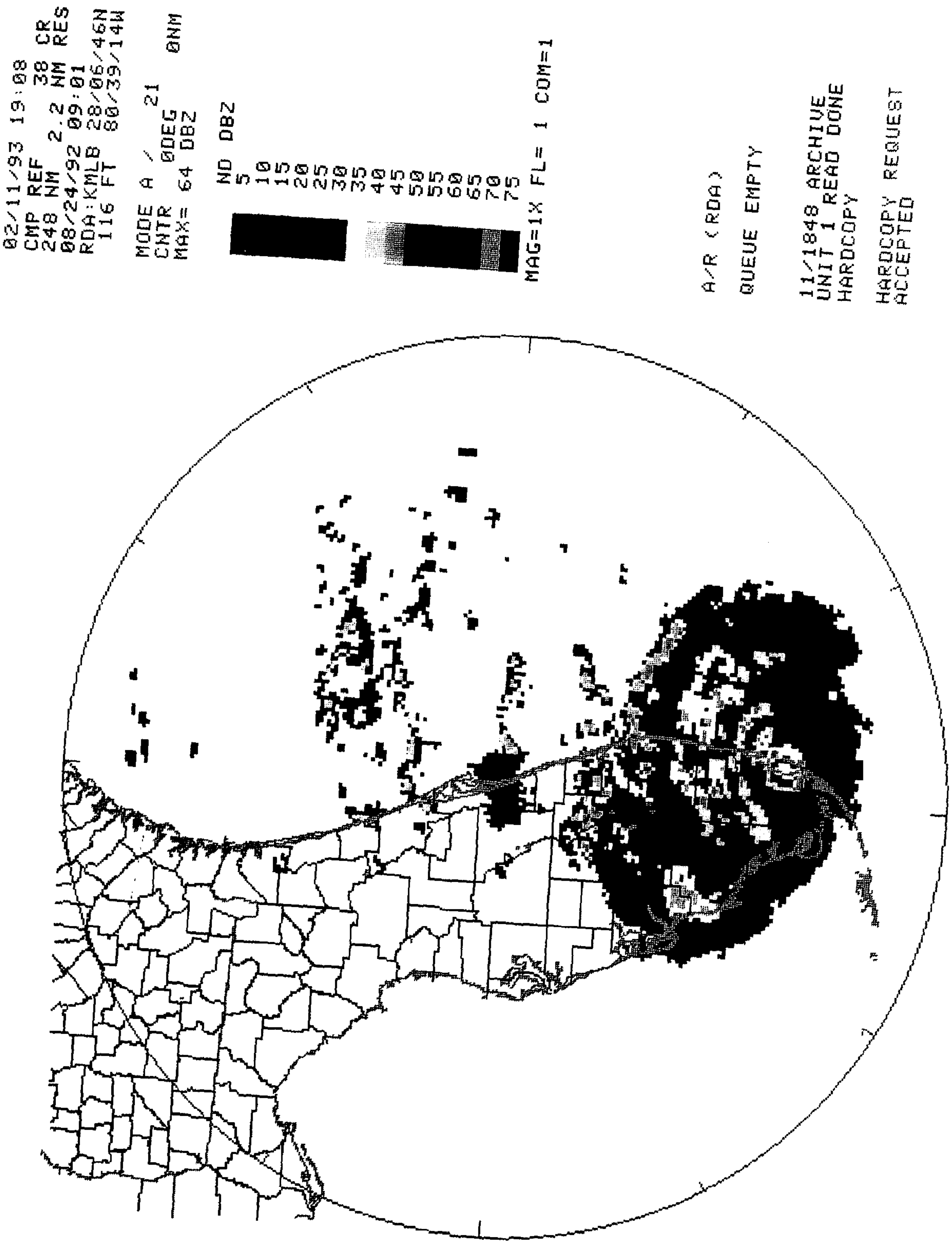


Figure 12 — WSO Melbourne, Florida, WSR-88D composite reflectivity image of Hurricane Andrew taken at 0901 UTC (5:01 AM EDT), August 24, 1992.

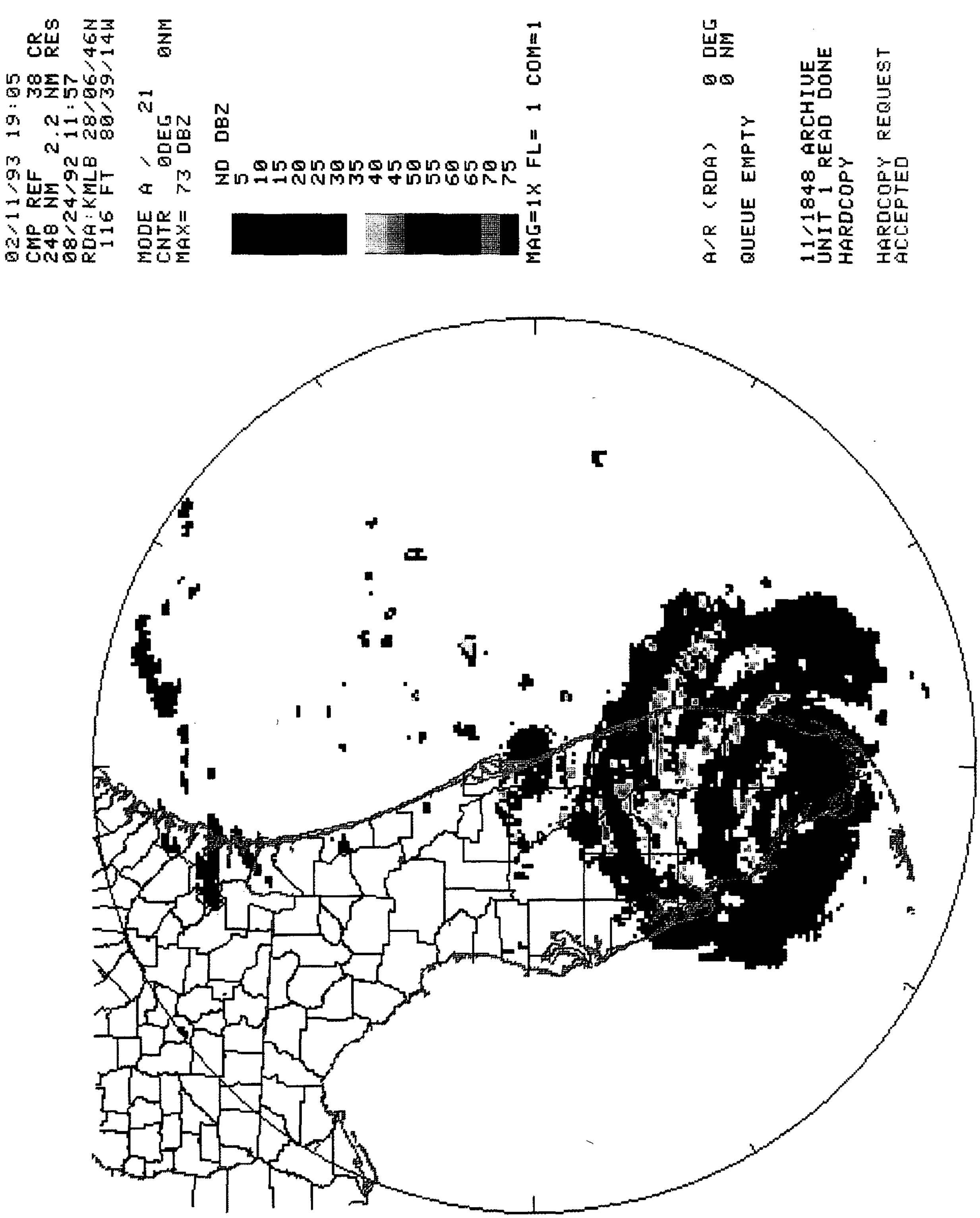


Figure 13 — WSO Melbourne, Florida, WSR-88D composite reflectivity image of Hurricane Andrew taken at 1157 UTC (7:57 AM EDT), August 24, 1992.

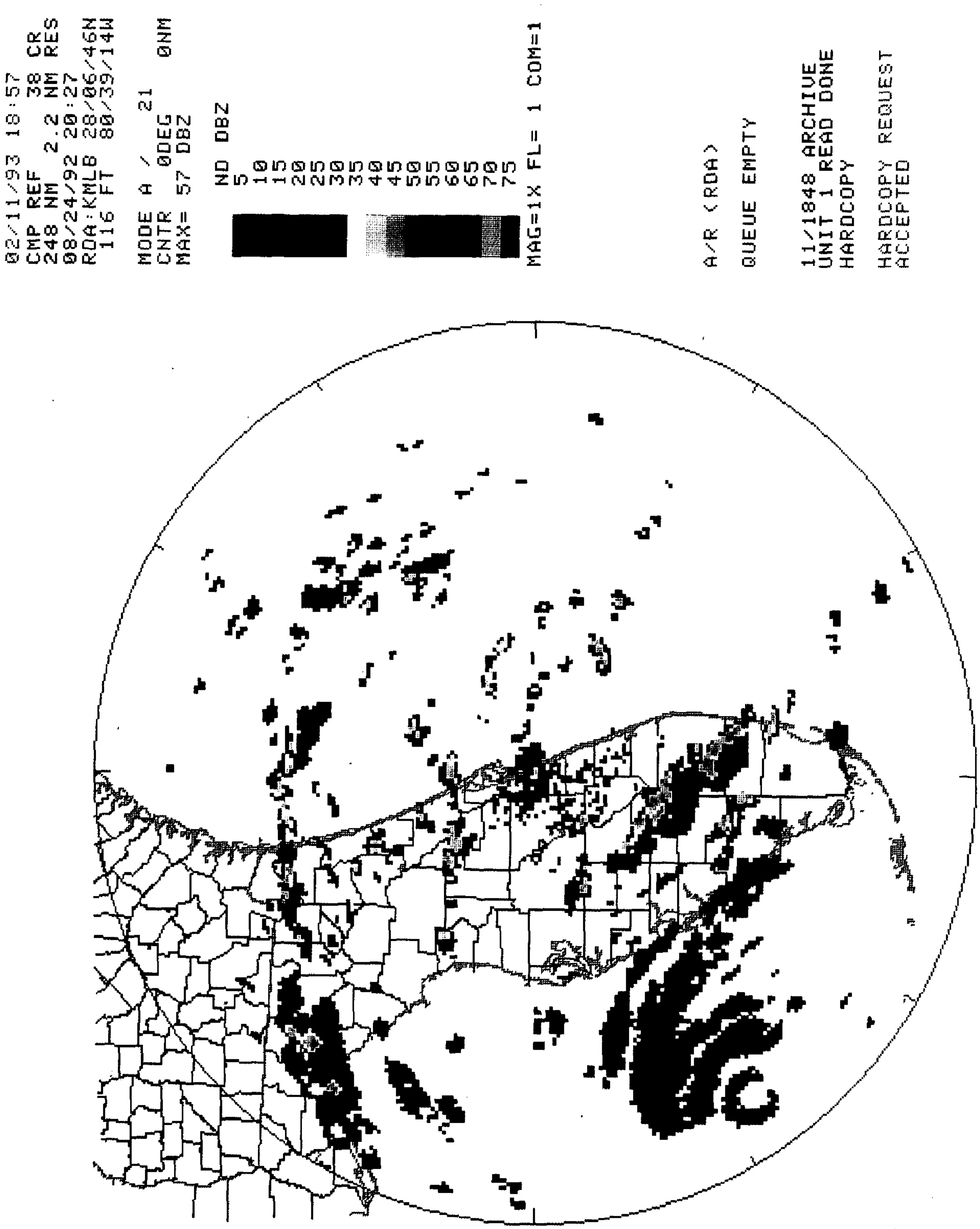


Figure 14 — WSO Melbourne, Florida, WSR-88D composite reflectivity image of Hurricane Andrew taken at 2027 UTC (4:27 PM EDT), August 24, 1992.

Rawinsonde Observations

Three special rawinsonde observations were requested by NHC during Hurricane Andrew at WSOs West Palm Beach, Key West, and Tampa Bay. The soundings were released at 1800 UTC (Coordinated Universal Time) (2 PM EDT) on August 23, 0600 UTC (2 AM EDT) August 24, and 1800 UTC (2 PM EDT) August 24.

Surface Observations

Surface observations are taken at a wide variety of heights above the surface and are reported in a variety of formats. Observation heights vary from as little as 2 meters above the surface to as high as 40 meters above the surface. Also, they may be instantaneous readings, they may be averaged over a minute, or they may be up to 10-minute averages. Normalizing these data is requisite to any interpretation. **Finding I.I.4: Wind observations are taken at varying heights and with different sampling strategies, making the determination of winds during a severe storm difficult to assess. Recommendation I.I.4: The Office of the Federal Coordinator for Meteorology should continue to work with the various Federal agencies to ensure that wind observation adjustments are standardized for height and sampling interval variations to ensure consistency of data.**

Observations of wind, pressure, rainfall, and tides were collected from a wide variety of sources prior to and during Andrew. The National Data Buoy Center (NDBC) operates an array of C-MAN platforms and data buoys in the coastal waters east and west of Florida. Numerous tide gauges are located along Florida's east and west coast. Manual surface observations are taken both from official NWS sites in Florida and from unofficial locations, such as emergency management facilities, airport sites, and other municipal installations. The official observations were available in real-time but acquiring many of the unofficial observations required a call for data. The HRD of the Atlantic Oceanographic and Meteorological Laboratory (AOML) made such a request, through the auspices of the NHC, and collected a variety of data (see appendix A, tables A.1 and A.2). When analyzing the data, they used standard methods to correct for sampling variation. It is important to note that these data, although acquired in real-time, are not available to NWS offices in real-time.

Surface Observations from NWS Offices

The NWS routinely collects official surface observations in south Florida at WSOs in Key West, West Palm Beach, and Tampa Bay. Official observations for the Miami area are taken at Miami International Airport. Except for Miami, surface observations were recorded without interruption throughout Andrew. However, many instruments in the Miami area failed. Miami International Airport observations were not reliable due to instrument failure. Wind speeds were estimated. In fact, two NWS/FAA maintained anemometers failed during Hurricane Andrew: at NHC and at Tamiami Airport. Out of 23 known anemometers from the local and Federal government (5 NWS/FAA), industry, and university sectors, complete records were obtained from 2, partial records were available from 17, and no records from 4. Four sites were disabled in advance of the storm, nine lacked recording capability or experienced recording failures, three had cross-arm problems as described below, three had guy wire/mast failures, and two lost power.

Finding I.I.5: **Many wind observation sites failed not because of a failure of the instrument but because of the manner in which the support hardware was constructed and assembled.** At the NHC and Tamiami Airport sites, the cross arm conduit pipe had no locking coupling to prevent it from unthreading from the main tower coupling during high winds. This is especially disturbing because of the large installed data base of similar F420 style anemometers throughout the NWS and FAA. It is believed that a low cost retrofit solution may exist by using commonly available conduit hardware. Recommendation I.I.5: **The NWS and FAA need to inventory their F420 anemometer installations in hurricane-threatened areas. The NWS and FAA should consider retrofitting suspect F420 sites with a locking cross arm prior to the 1994 hurricane season. Furthermore, the NWS Automatic Surface Observing System (ASOS) program office should investigate the potential for failures in the ASOS wind mast and sensors during high wind episodes.**

At NHC in Coral Gables, an anemometer is located on the roof. That instrument, which recorded wind gusts to 142 knots (164 mph) just before 5 AM EDT, August 24, was damaged at 5:17 AM and failed completely at 5:45 AM. Since the instrument is not at a standard height, its measurements may not be considered reliable before being statistically reduced to standard height. A complete listing of all observed meteorological extremes from Andrew is supplied as appendix A, tables A.1 and A.2.

Other Surface Observations

Wind and Pressure

Observations of wind and pressure were collected from two sites in the Bahamas: Harbour Island and Nassau. The Harbor Island site was very near the landfall of Andrew as it migrated across the northwest Bahamas. The lowest **observed** pressure was 935 mb. At that time, a wind of 120 knots was observed for an unknown duration. Both wind and pressure were likely more extreme since the wind instrumentation failed shortly thereafter and observation of the barometer was not constant. When the storm made landfall in south Florida, no fewer than a dozen observations were available, half on the east coast and half on the west coast. Several other observations were made available post-event. The extremes from each of those sites are documented in appendix A, table A.2.

C-MAN and Buoy Observations

C-MAN and buoy data were collected routinely until many of the sensors failed under extreme conditions. The most prominent of these observations came from the Fowey Rocks C-MAN—latitude 25.6°N, longitude 80.1°W. Its last observation at 4 AM EDT, August 24, included an 8-minute average wind of 123 knots (141 mph) with a gust of 147 knots (169 mph). Shortly thereafter, the equipment became inoperable. It was discovered with its mast bent over at a 90° angle. Since the lowest observed pressure was 967.5 mb when failure occurred, even though the eye of Andrew passed about 10 miles south of Fowey Rocks, there remained another 10 to 15 mb of pressure fall during which wind was not recorded. The wind measurements were made on a mast 43 meters (141 feet above the water). When converted to a WMO-standard (World Meteorological Organization), 10-meter height for the 2-minute standard, the NDBC used a figure of 108 knots (124 mph) for this site.

Unofficial Reports

Unofficial weather reports are provided in appendix A, table A.2. The process of screening these data for accuracy, especially the wind and pressure data, is still in progress. Wind instrumentation from Perrine was wind tunnel tested at Clemson University for accuracy. After accounting for a 16.5 percent error, a peak wind gust of 154 knots (177 mph) was found. Instruments recording the lowest south Florida pressure readings were pressure chamber tested. Analysis of that data indicates that 922 mb was the lowest verified south Florida landfall pressure from Andrew.

Some sites that could have provided valuable wind and pressure observations failed to do so. These sites are situated at the location of the eye landfall. One such observation site, Homestead AFB, performed a total power-down prior to evacuating the base. Similarly, AOML removed the wind equipment prior to the storm's landfall because of its adjacency to an atrium skylight. Had the skylight failed, the interior of the facility would have been at great risk. **Finding I.I.6: Valuable wind and pressure observations were lost when the data-gathering systems were powered down or removed before Andrew's landfall. Recommendation I.I.6: Agencies with meteorological data-gathering equipment in the path of a hurricane should be encouraged to continue the data collection process throughout the event.**

Storm Tide and Storm Surge Observations

Two terms, "storm tide" and "storm surge," often are used in measuring the increase in water level. *Storm surge* is water height above normal tide level. *Storm tide* is the water height relative to NGVD, the mean sea level of 1929. In the Bahamas, a maximum storm tide of about 25 feet was measured at Current Island, with probable wave effects superimposed. Along the coast of south Florida, there were several reliable data collection sites each measuring storm tide. In fact, literally hundreds of high water marks were measured by USACE and FEMA. Figure 8 combines many of those for representative values. The highest storm tide measured in south Florida was 16.9 feet at the Burger King World Headquarters in East Perrine.

Rainfall Observations

Despite powerful winds, many rain gauges in south Florida survived and provided reliable, representative data. Although Andrew was fast moving and, therefore, a fairly "dry" storm precipitation-wise, it generated rainfall totals of more than 7 inches in some locales across south Florida. The highest totals in south Florida included 7.79 inches (site-124 in Broward County) and 7.41 inches (site-21A in Dade County). Most other totals were between 2 and 5 inches. Flooding was not a major problem with Andrew in south Florida.

PART II:

LOUISIANA

CHAPTER II.A

BACKGROUND

Description of the Disaster Area

The State of Louisiana is bordered on the east by the Mississippi and Pearl Rivers and on the west by the Sabine River and Texas. The southern part of the state is situated entirely within the Gulf Coastal Plain. Louisiana covers an area of about 49,000 square miles, approximately 16 percent or 7,400 square miles of which is covered by water in the form of lakes, sloughs, bayous, and wetlands.

South-central Louisiana, where Andrew made landfall, was most affected by the storm. Fortunately, the hurricane began to weaken just prior to landfall southwest of Morgan City. The damage was far less dramatic in Louisiana than what was seen in Florida, but the damage was severe nevertheless.

Population

The affected parishes cover almost the entire southern half of Louisiana. The population of this area is more than 1,600,000 of which nearly 500,000 reside in Orleans Parish.

The economy of the affected area is typical of the state as a whole, being highly diversified with emphasis on petro-chemical production, a mix of light and heavy manufacturing, commercial fishing, timber and forestry-related products, and agriculture.

Climate

The entire State of Louisiana is subject to severe, frequent flooding. Heavy rains may occur at any time of the year but are more likely in April and May or October and November as a result of warm, moist air from the Gulf of Mexico overriding cooler, drier air.

From June through September, slowly moving tropical storms and hurricanes can move inland and deposit excessive rain over large areas. Louisiana is crisscrossed with numerous large and small streams, bayous, and other watercourses emptying into its major river systems. The runoff from these systems eventually discharges into the Gulf of Mexico. The relatively flat terrain is not conducive to rapid runoff so any inundation may be protracted and severe.

Average annual rainfall varies from about 44 inches in the northern sections to more than 64 inches along the coast. Most precipitation is from thunderstorms, although of short-duration, high intensity non-thunderstorm rains occur when tropical cyclones form in or move into and across the Gulf of Mexico to affect Louisiana.

Topography

Louisiana is most renowned for its bayous and waterways which account for much of the state's southern topography. Numerous barrier islands punctuate the coastline but are utilized primarily as game refuges.

The terrain of Louisiana is flat to gently rolling, ranging in elevation from sea level in the south to more than 500 feet above sea level in the north. Much of southeast Louisiana, notably the Greater New Orleans area, is at or below sea level. This densely populated region of the state is protected by a network of levees. If ever breached, the entire area would be temporarily reclaimed by the gulf.

Hurricane Vulnerability

Statistics compiled by NHC show that Louisiana ranks third behind Florida and Texas with respect to hurricane vulnerability. Louisiana is most susceptible to major hurricanes during the months of August and September. Louisiana has been struck by hurricanes 25 times since 1899; 12 of these were classified as major. About one-third of the most deadly hurricanes to strike the United States have directly or indirectly struck the state.

The following are some of the more prominent statistics about Louisiana hurricane climatology.

- The last major hurricane (category 3 or greater) this century was Carmen in 1974.
- The deadliest hurricane this century to strike Louisiana was Audrey in 1957, killing 390 persons in Louisiana and Texas. The deadliest storm to strike Louisiana was the Cheniere Caminada storm of 1893 (near Grand Isle) which killed between 1,500 and 2,000 people.
- Betsy (1965) and Bob (1979) were the last deadly hurricanes to strike Louisiana. Betsy also proved to be one of the most costly in the Nation, ranking third behind Andrew and Hugo. Curiously, Andrew followed a track with some similarities to Betsy.

CHAPTER II.B

SUMMARY OF PREPAREDNESS ACTIONS

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

WSFO Slidell

WSFO Slidell is respected by local parish officials and the media throughout their parish warning area of responsibility. They conduct a comprehensive warning and preparedness program. Under the direction of Area Manager Bill Crouch, the WSFO conducts numerous preparedness classes, training exercises, and annual coordination meetings with local officials, the media, and volunteer groups. During the 6 months preceding Hurricane Andrew, the WPM focal point provided state DEM and parish Offices of Emergency Management (OEM) with emergency planning assistance. In addition to conducting awareness seminars, the WPM focal point provided technical assistance. The WPM focal point installed SLOSH software at several parishes OEMs and trained key OEM staff on its proper use.

The first of these events occurred during Severe Weather Awareness Week, February 10-14, 1992. During that week, various aspects of the severe weather warning program were reviewed and tested by the NWS, the local emergency management officials, and the media.

Prior to the 1992 hurricane season, the WSFO coordinated the joint visit of Dr. Robert Sheets, Director NHC, and Harry Hassel, Director Southern Region, NWS. This visit was part of Dr. Sheet's annual hurricane preparedness tour. Dr. Sheets presented a press briefing to the New Orleans news media. In addition, Dr. Sheets and Director Hassel, and Meteorologist in Charge, Bill Crouch, appeared with Brian Giddings, Orleans Parish OEM Director, on cable television discussing hurricane preparedness.

A second campaign promoted hurricane awareness. Historically, hurricanes have been the most devastating natural hazard to affect the state. The WSFO staff, led by WPM Focal Point Michael Koziara, worked closely with Louisiana's DEM to coordinate Hurricane Preparedness Week, May 18-24.

An integral part of these campaigns is the ability to make an adequate number of awareness and preparedness brochures available to local emergency officials and the public. Currently, NWS offices do not have access to adequate numbers of brochures. **Finding II.B.1: There is an insufficient supply of safety and preparedness materials in support of NWS field offices, local emergency preparedness officials, and the public.** Both local NWS officials and local emergency managers feel that the limited number of available brochures restricts their overall effectiveness within their respective preparedness programs. In an effort to help offset these limited brochure resources, NWS offices have sought out other ways of acquiring additional supplies of publications. One approach used by NWS offices was to provide negatives of brochures that could be reprinted by either public or private sector groups. Unfortunately, these efforts have met with only limited success. **Recommendation II.B.1: NOAA and the Department of Commerce should increase their support for developing, printing, and distributing high quality preparedness and awareness materials. Present cooperative efforts with other agencies and the private sector to develop and distribute awareness and preparedness materials should be increased.**

During the 6 months preceding Hurricane Andrew, the WSFO provided the state DEM and parish OEMs with emergency planning assistance. In addition to conducting awareness seminars, WSFO staff provided technical assistance. WSFO staff installed SLOSH software at several parish OEMs and successfully trained key OEM staff in its proper use.

The major event of Louisiana's 1992 Hurricane Awareness Program was a hurricane exercise called "Malinda." The WSFO staff provided technical assistance in developing weather and hurricane forecast and track data for the exercise. The Hurricane "Malinda" exercise provided Louisiana's OEM a means for testing and evaluating southeast Louisiana's hurricane preparedness and response capabilities. A deficiency that was evident in both awareness campaigns was the lack of participation by the print media during these events.

This hurricane exercise proved very beneficial both to the NWS and the Louisiana OEM. It showed that a new level of commitment had been achieved. New coordination capabilities were fully tested and evaluated, and a realistic evaluation of southeast Louisiana's evacuation needs and capabilities was performed.

The Hurricane "Malinda" exercise identified weaknesses in the communications and dissemination capabilities of Louisiana's OEM. During periods of high density data traffic, the OEM had difficulty redistributing information in a timely manner. Although identified as a problem, not enough funding or time was available for any correction action prior to Hurricane Andrew.

The evacuation simulation also confirmed that portions of southeast Louisiana are not capable of efficiently evacuating. One obvious problem is the need for lead times in excess of 50 hours for some southeast Louisiana parishes. The current state of the science in hurricane forecasting does not allow for such warning lead times with a high degree of confidence. Other problem areas included transportation choke points and the inability of northern parishes to accommodate evacuees from southern parishes.

The WSFO also meets with groups that are highly vulnerable to hurricanes, such as the petrochemical industry. WSFO staff addressed several awareness and preparation meetings for offshore oil companies prior to Hurricane Andrew. These meetings supplied general hurricane information dealing with preparedness and evacuation. Other groups which the WSFO routinely supports are the U.S. Coast Guard and the American Society of Military Engineers. The WSFO staff gives periodic hurricane awareness presentations. These presentations are part of coordination meetings which provide a forum to review preparedness plans and exchange information and ideas.

As Andrew approached the east Florida coast, WSFO Slidell's warning and preparedness staff were made available to the media for interviews and presentations. These interviews gave the public a steady stream of information about Hurricane Andrew and its potential effect on Louisiana.

WSO Baton Rouge

WSOs performed their warning and preparedness responsibilities in an exemplary manner. At many offices, the local MIC or Official in Charge (OIC) is the focal point for preparedness activities within the WSO county or parish warning area (CWA). John Moseley, MIC, WSO Baton Rouge, conducts all preparedness efforts. Mr. Moseley did make himself available for coordination visits to parishes within his CWA prior to the hurricane season. The Disaster Survey Team felt that more preparedness work could have been accomplished outside of Baton Rouge Parish. Interviews with parish officials indicated that it was not totally clear as to the availability of the NWS during major weather events. The perception that the WSO would be too busy during major weather events caused some parishes to feel that it would have been an imposition on their part to call the WSO. One parish chose to post their own warning for this very reason and never contacted the WSO. This decision prompted the activation of the local siren warning system. The local parish officials stated that many residents responded by making use of available sheltering in response to the tornado threat.

Having only a limited number of available staff hours, WSOs must make the best use of their available time. Any scheduled meetings must be extremely well coordinated. It is imperative that all groups and agencies that participate in any local warning or preparedness programs be present. Participants at these coordination meetings typically include the various media outlets, sheriff's officials, local city or parish police officials, spotter and amateur radio network representatives, and parish emergency preparedness officials.

The frequency of these coordination meetings is dependent upon the number of parishes within the office's warning area of responsibility. Typically, these coordination meetings are held annually, but in some instances, groups may meet several times during the year. At these meetings, NWS officials provide a review of local hurricane climatological information and an outlook for the upcoming hurricane season. They also pass on information pertaining to NWS program changes which might affect local warning and preparedness programs. Ultimately, this group reviews and evaluates communication and dissemination capabilities, the readiness of parish spotter networks, the need for NWS training support, and issues concerning community preparedness and evacuation.

During the days prior to Andrew's making landfall in Louisiana, Mr. Moseley made himself available to the various local media outlets. These contacts continued through the events of Andrew and proved to be extremely beneficial in preparing the local populace for the impact of Andrew.

WSO Lake Charles

The Lake Charles WSO has a very active warning and preparedness program. The WSO also does not have a dedicated warning preparedness specialist. All preparedness efforts are accomplished, as time permits, by the MIC or his representative. In addition to routine presentations and annual coordination meetings, MIC David McIntosh is very proactive in southwest Louisiana natural hazards efforts.

In the months following Louisiana's Severe Weather Awareness Week, a table top exercise was developed which involved the WSO. The exercise took place May 11, 1992, and was a first for the WSO. This table top exercise focused on the hazards of tornadoes, ultimately evaluating NWS and local community plans and capabilities during such events.

The WSO also coordinated the visit of Dr. Robert Sheets, NHC Director, to the Southwest Louisiana Hurricane Preparedness Conference. More local officials and media representatives attended this year's event than ever before. The collective efforts of Dr. Sheets, David McIntosh, and Harry Hassel (Director, NWS Southern Region) were rewarded by the presentation of keys to the city of Lake Charles.

Parishes of southwest Louisiana, with assistance from the state DEM, have established the Southwest Louisiana Hurricane Task Force. This Task Force was developed to provide the citizens of southwest Louisiana with a comprehensive and coordinated effort in hurricane mitigation and response. Mr. McIntosh was asked to chair the Evacuation Committee of this Task Force. This affirms the confidence that local officials have in the Weather Service and its local officials. In addition, Mr. McIntosh has been active in the Sabine Basin Task Force, which addresses issues concerning flooding.

Each of these NWS offices have come very near to achieving their goal of being the official technical resource for their communities in matters dealing with natural hazards. Part of the NWS's modernization and restructuring effort includes the new Warning Coordination Meteorologist position. This position will provide a full time warning coordination and hazard awareness liaison for the NWS to the community.

Preparedness by the Media

Print Media

The print media were extremely active during Andrew, providing their readership with not only general information on Andrew but also preparedness information. The print media across south Louisiana worked closely with NWS and EM officials in providing the public with detailed and updated information.

As it became more evident that Andrew would be a major event for the Louisiana coast, proclamations and declarations were headlined in local newspapers. An excellent example of how the print media responded to the hurricane threat can be seen in the approach taken by the *Daily Iberian*. The paper responded to the ordered evacuation by headlining the parish council's decision, "*Iberia Parish Evacuation Urged.*" In the article that followed, the Iberian's readership was provided with the latest information on Hurricane Andrew, details of what the effect of Andrew could be, various preparedness and safety tips, and evacuation information.

Finding II.B.2: The local print media is more reactive in community preparedness than proactive. Historically, in south Louisiana, the print media has not actively

participated in preseason hurricane preparedness efforts, such as awareness campaigns. On the other hand, during the 72 hours prior to Andrew, they were extremely effective in providing their readership with detailed preparedness information. Recommendation II.B.2: NWS offices in south Louisiana need to develop stronger cooperative relationships with the print media to enhance their involvement in the hazards awareness and mitigation program.

Electronic Media

The electronic media played an enormous role in preparedness efforts. The DST felt that the graphic images of south Florida hurricane damage provided gulf residents with a clearer picture of Andrew's destructive potential. It was felt that had Andrew not made landfall in south Florida, the public response in the gulf might not have been as great. Specials prior to the hurricane season and spot announcements helped educate the local populace in hazard mitigation, preparedness, and response. Each NWS office has developed their own special partnership with local media outlets, providing the ample coverage and personal interviews as Andrew moved through the gulf toward Louisiana. The NWS should continue to nurture the cooperative relationships which were in place during Andrew.

WSOs Baton Rouge and Lake Charles provided numerous television interviews prior to and during hurricane Andrew's approach. These interviews were conducted at the local studios or, as in the case of WSO Baton Rouge, some broadcasts were done from the parish EOC.

On August 24 after Andrew had ravaged Florida, local offices were asked to participate in expanded segments of local news and weather broadcasts throughout the evening. These presentations provided details of Andrew's effect on Florida and its potential for Louisiana. As Andrew approached the Louisiana coast, the MICs or their representatives made themselves available for interviews on both radio and television.

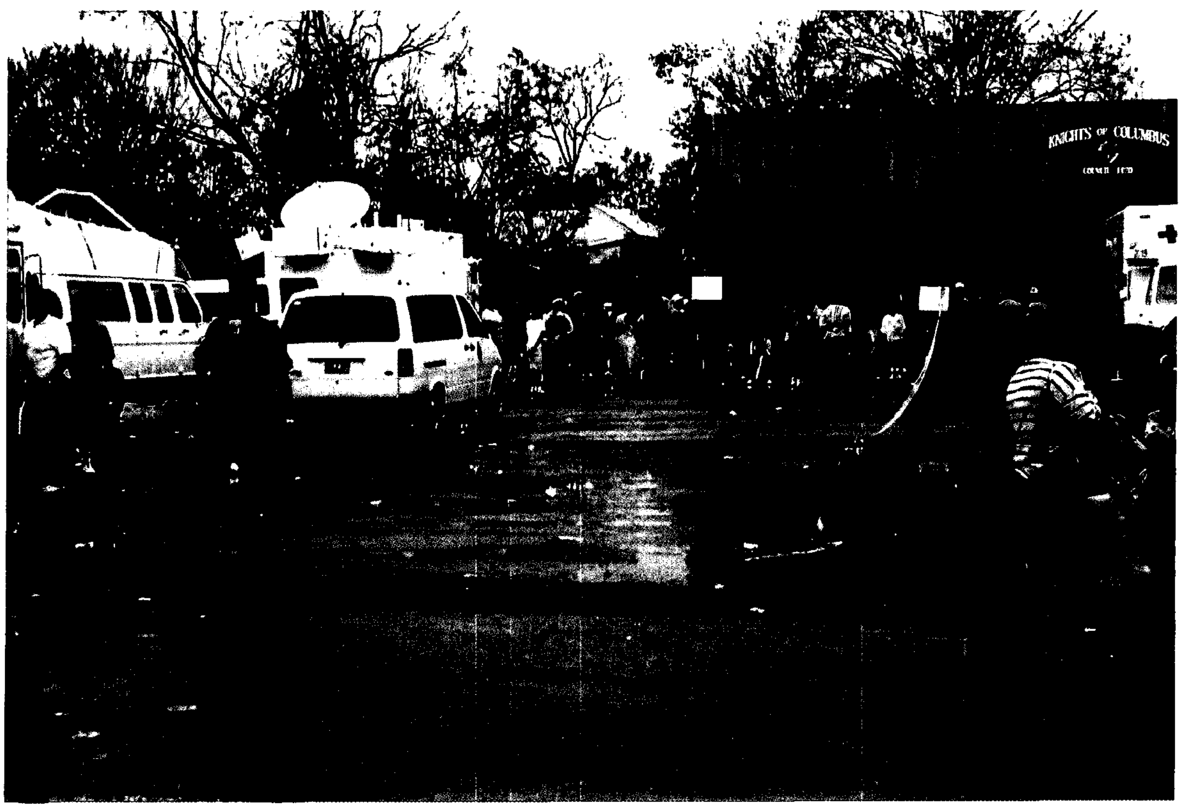
The smaller media markets, such as Baton Rouge, took advantage of the NWS presence within their local area. As the threat of Andrew became more of a reality, these media outlets began to focus on preparedness and response. They began conducting interviews from the parish EOC. During these sessions, both the NWS and local EMs provided viewers information on Andrew and how to prepare for Andrew's landfall. Proper evacuation procedures were reviewed and evacuation recommendations broadcast. Similar interviews and broadcasts were disseminated via radio and cable.

In larger media markets, such as Greater New Orleans, local affiliates made vast use of their station's meteorological support staff. Although most were done with their local staff, some interviews were conducted with the Slidell office.

Local Emergency Management

Local emergency management officials throughout south Louisiana actively prepare for each upcoming hurricane season, always assuming that the next hurricane could be the "Big One." This heightened level of awareness to the hurricane threat has prompted the development of hurricane task forces that practice and prepare for a major hurricane.

__Finding II.B.3__: **Local emergency managers in south Louisiana were very proactive, taking the early initiative in dealing with Hurricane Andrew.** Some south Louisiana parishes have special lead time requirements for safe evacuation. Since today's hurricane forecasting capability does not allow for such long lead times with a high degree of confidence for the evacuation of these parishes, emergency managers must understand that they need to initiate evacuation well before watches and warnings are issued by the National Hurricane Center. Comprehensive hurricane evacuation plans are currently in place for southeast Louisiana which aid local EMs in making well thought out decisions. Tools, such as the SLOSH computer display and various hurricane tracking programs, were actively used by managers prior to Andrew. These products gave managers the information necessary to make decisions to open shelters, to call on various hurricane response resources, or to evacuate. **__Recommendation II.B.3__: The NWS must continue working closely with local emergency managers to ensure that together they promote a unified awareness program which elicits the desired public response.**



Garden City, Louisiana, community relief efforts.

CHAPTER II.C

NWS CONTINGENCY PLANNING AND BACKUP ARRANGEMENTS

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

WSO Lake Charles

As Hurricane Andrew made its way into the Gulf of Mexico early on the morning of August 24, WSO Lake Charles' weather support activities were stepped up. Duty schedules were modified from 8-hour shifts to 12-hour shifts, and staffing for each shift was increased.

Generators used as a backup to the office's commercial power supply were tested and readied for use. These generators would ensure that the limited weather instrumentation and office's full complement of communications equipment would remain operational. The electronics technicians (ET) also checked and calibrated all weather instruments during the hours prior to Andrew's landfall. In fact, the electronics staff worked 12-hour shifts and provided 24-hour support as Andrew tracked across the gulf and into Louisiana.

Once Andrew moved into the gulf, NHC requested that gulf region field offices participating in the NWS rawinsonde program begin launching intermediate balloon releases. Beginning August 24 at 1 PM CDT, Lake Charles began launching rawinsondes every 6 hours. This schedule remained in place through 7 PM CDT, August 27.

Approximately 18 hours prior to Andrew's landfall in Louisiana, the WSO activated their local spotter and amateur radio networks. The primary purpose for activating the amateur radio network was to ensure that a means of communication remained available to the WSO throughout the event.

WSO Baton Rouge

The WSO Baton Rouge response was similar to that of Lake Charles. Once the Louisiana coast was placed under a watch, the office stepped up their level of support. WSO Baton Rouge modified their operational shift rotation from three 8-hour shifts to three 12-hour shifts. These new 12-hour shifts were staggered to allow for overlapping. This approach helped preserve operational continuity during shift changes.

The WSO Baton Rouge electronics staff conducted preventative maintenance routines on all meteorological equipment. This ensured that all equipment was properly calibrated and operationally ready well before Andrew's landfall.

Although unsuccessful, WSO Baton Rouge made every effort to secure additional generators to back up meteorological equipment not connected to their office backup system. It is evident through these actions that these WSOs were prepared for almost any situation. Every effort was made to secure necessary resources and to have the appropriate procedures in place prior to Andrew's landfall.

WSFO Slidell

Backup Procedures. As in Miami, WSFO Slidell, in accordance with procedures established by NWS Southern Region Headquarters, invoked emergency backup procedures as Hurricane Andrew bore down on the Louisiana coastline. In anticipation of a possible complete failure of the WSFO, appropriate offices designated as their backup were alerted to prepare for such a possibility.

As Andrew entered the gulf on August 24, WSFO Slidell initiated shift changes that included increasing tours of duty from 8 hours to 12 hours. In addition, two meteorologists were added to each of the two shifts to support a dedicated hurricane forecast desk. All questions and interviews dealing with the issues concerning Hurricane Andrew were handled by these meteorologists. In addition, extra staff was brought in to provide operational support to the marine and public service programs.

In support of the office's data-gathering responsibilities, the office began releasing rawinsondes every 6 hours to supplement the ongoing reconnaissance of aircraft, satellite, and radar. Meteorological technicians also worked 12-hour shift rotation for a number of days prior to Andrew. During Andrew, the need for increased radar surveillance was realized, and each shift had an extra radar operator assigned. The WSFO placed a meteorologist at the Greater New Orleans EOC during Hurricane Andrew. The NWS is not now, nor is it projected to be, staffed for such an arrangement. This meteorologist provided the New Orleans EOC with technical assistance. This support was well received by city and parish officials operating from the EOC and should be maintained in some form. The WSFO should work with the city to create an arrangement similar to the one used by Dade County and NHC/WSFO Miami. This should, if available, include space in the WSFO for media and local officials to be routinely briefed. Additionally, a coordination hotline should be installed so that EOC officials can interact with NWS staff and officials.

The electronics staff at the WSFO was activated to 24-hour status, and at least one ET was on site at all times. During Andrew, ETs worked 12-hour shifts. Prior to Andrew's landfall, all equipment and backup equipment was checked and calibrated.

As Andrew moved toward south Florida, the WSFO began an active informational campaign notifying local and state emergency management officials of the potential threat this storm might have on Louisiana. The WSFO began these messages during the day on Saturday, August 22. Soon after Andrew had made landfall on the Florida coast, Bill Crouch, MIC, WSFO Slidell, coordinated with General Stroud, Director, Louisiana's DEM, to organize a meeting of south Louisiana parish officials well in advance of Andrew's Louisiana landfall. This meeting provided parish officials with the latest information on Andrew and served as the first of several coordination meetings to formulate a coordinated preparedness and recovery effort in response to the storm. Follow-up coordination calls between the WSFO hurricane coordinator and state and local officials continued throughout the events of Hurricane Andrew.

Southern Region Headquarters (SRH) and the River Forecast Center (RFC)

Southern Region Headquarters, Fort Worth, Texas

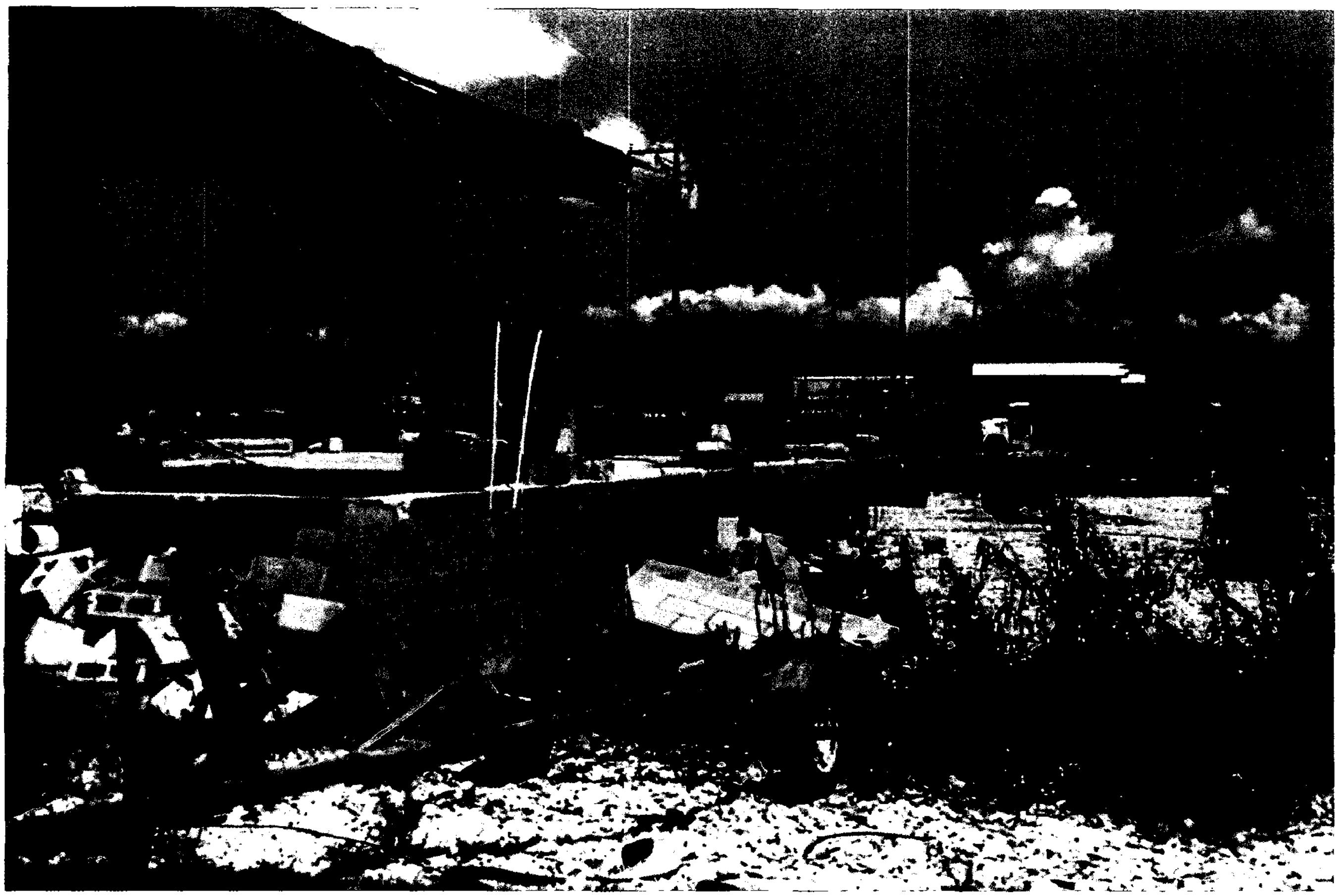
Early on Monday, August 24, as the hurricane was moving across the southern tip of Florida, actions were taken to begin adding staff to the middle gulf coast offices where the next threat was anticipated. Gulf coast offices were provided additional temporary staff support as follows:

Victoria, TX	— 2 meteorological technicians
Galveston, TX	— 1 meteorologist and 1 meteorological technician
Beaumont, TX	— 2 meteorological technicians
Mobile, AL	— 1 meteorological technician
Houston, TX	— 1 electronics technician
Fort Worth RFC, TX	— 1 hydrologist

River Forecast Center Slidell

The RFC overlapped their staff so that they could access data as it became available and provide the necessary support to the various weather offices within their region for hydrologic responsibility. Twenty-four-hour support by the RFC was not immediately implemented. It was not until the evening before Andrew's landfall that expanded hydrologic support was initiated. On the evening of August 25, RFC staff began and maintained a 24-hour hydrologic watch over the region for which they have responsibility. This expanded support continued through August 27. During this period, at least two hydrologists were on station at all hours of the day.

Contingency Planning. A question which was revisited was "Are NWS field sensors and field offices built to the specifications needed to ensure their survivability in a major hurricane?" During Hurricane Hugo, the roof of the Charlotte Weather Service Office was nearly lost. A similar question may be asked in Miami. Could the minimally hardened facility of the WSFO and NHC have survived a direct hit from Andrew? Indeed, how survivable are most gulf coast NOAA/NWS facilities? NOAA/NWS structures and remote sensing equipment are currently not designed to survive the pounding from a major hurricane. Many are cinder block structures and are susceptible to wind damage from aerial projectiles. As the NOAA/NWS moves forward with its modernization and restructuring efforts and builds new facilities and installs its next generation of remote sensors, they must not compromise facility survivability or employee safety to cost considerations.



This damage at the Petroleum Transfer Depot, Cocodrie, Louisiana (located south of Dulac), was caused by the combination of wind and surge.

CHAPTER II.D

SUMMARY OF NWS WATCHES, WARNINGS, AND ADVISORIES

National Hurricane Center

Watches and Warnings

As soon as Andrew crossed south Florida, NHC began to focus on the next possible landfall. The first advisory to mention a possible landfall on the northern gulf coast was issued at 8 AM CDT, Monday, August 24. The advisory stated that a hurricane watch was posted from Mobile, Alabama, to Sabine Pass, Texas. By this issuance, residents had 43 hours of lead time prior to Andrew making landfall (figure 5). Hurricane Andrew Advisory Number 35, issued at 5 PM EDT, August 24, upgraded that area from Pascagoula, Mississippi, to Vermilion Bay, Louisiana, to a warning. Table A.6 of appendix A lists all watches and warnings posted for the northern gulf coast.

In several situations, the strike probability tables provided sufficient guidance and confidence to initiate a fast response. The ability to launch an early response allowed emergency managers time to conduct preparedness and, if necessary, evacuation activities. Landfall strike probabilities were used by nearly all state and local agencies and were considered one of the most important elements of their decision-making process.

Watch and Warning Lead Times

The 43 hours of watch lead time exceeded the NHC desired minimum lead time target of 36 hours by about 14 percent. This ultimately gave decision makers additional time to evaluate the threats posed by Hurricane Andrew. The hurricane warning for the northern gulf coast was issued with Hurricane Advisory Number 35, giving local officials 36 hours of lead time.

The most significant changes in Andrew's track were well anticipated, and the forecast tracks lie close to the best track shown in figure 1. Overall, the NHC forecast errors for Andrew were 30 percent smaller than the current 10-year average. In part, improvement in both watch and warning lead times reflect the smaller than average forecast errors.

Utility of Advisories

As Andrew moved through the gulf toward Louisiana, advisories remained focused on the storm track and the projected changes in direction and forward speed. The hurricane warning was posted at 5 PM CDT, Monday, August 24, for a portion of the northern gulf coast. This first advisory made no mention of storm surge, tornado potential, or flood potential for the area under the warning. Information of this type did not appear in an advisory until the following morning in Intermediate Advisory Number 37A. Although mentioned in the body of the text, the mention of these threats lacked sufficient detail and failed to express any true sense of urgency. However, as the events of Andrew unfolded, the utility of advisory information increased markedly.

Finding II.D.1: Users of NWS products would like more specific, technical information to assist them in their decision-making process. During user interviews, many comments were made reflecting the need for more detailed information similar to that which is given in mesoscale discussions provided by NSSFC supporting the severe weather program. Users felt that such an approach would provide greater utility and would enhance their level of confidence in NHC advisories. **Recommendation II.D.1: The NHC should work with users to define what additional information is required and to develop a means of communicating that information to them.**

National Severe Storms Forecast Center (NSSFC)

Severe Weather Watches and Status Reports

As Hurricane Andrew moved into the Gulf of Mexico, NSSFC began issuing discussions and outlooks for the potential of severe weather along the northern gulf coast. NSSFC began focusing especially on the tornado threat to the northern gulf coast early on the morning of August 25.

The first mention of the potential for severe weather affecting the northern gulf coast was in the second day Severe Weather Outlook issued at 2 AM CDT, August 24, meaning that it was expected on August 25. NSSFC provided the field offices and the National Centers with a constant flow of discreet information. The mesoscale discussion issued at 4:30 AM CDT, August 24, detailed the features being monitored for possible severe weather potential. Subsequent discussions and outlooks suggested that Andrew's interaction with the coastline created a more volatile situation.

Over the next 48 hours, NSSFC issued and updated various tornado watch areas in response to Andrew's track. As tornado activity increased, NSSFC introduced stronger language into the text of its posted watches: **"THIS IS A PARTICULARLY DANGEROUS SITUATION WITH THE POSSIBILITY OF VERY DAMAGING TORNADOES. ALSO DANGEROUS LIGHTNING AND DAMAGING THUNDERSTORM WINDS CAN BE EXPECTED."** Statements such as this heightened the awareness of both the emergency management community and the public to the urgency of the situation.

Throughout Andrew, NSSFC guidance was extremely proactive. Noteworthy mesoscale discussions and timely watches were issued during Andrew. These products were well written and provided the reader with a heightened sense of urgency. The overall feeling of the Disaster Survey Team was that NSSFC did an exceptional job in providing severe weather guidance support to NHC, NMC, and NWS field offices along the gulf coast and inland.

Weather Service Forecast Offices/Weather Service Offices (WSFO/WSO)

Severe Weather Warnings and Statements

There is no doubt that reports of tornadoes early Tuesday evening and throughout the night caused concern and confusion just as Andrew was making landfall. The additional threat of tornadoes added to an already frightening situation for the residents of south Louisiana.

NWS offices in south Louisiana dealt well with the overall effects of Andrew, but their initial response to the tornado threat was considered to be slow and reactive in nature by some local parish officials. Such a perception is understandable since the primary focus of the NWS was on the overall event of the hurricane. NWS offices in south Louisiana were placing the greatest emphasis and attention to those elements deemed most likely to occur with a tropical cyclone. This placed the emphasis on the elements of storm surge, copious rainfall, and hurricane-force winds. The strong focus on these elements may have contributed to the perception that NWS offices were too slow in responding to the subsequent severe weather events.

One parish official felt that, for whatever reason, the NWS was unable to post a timely warning for the parish during the tornadic outbreak preceding Andrew's landfall. Based on information being passed between local parish law enforcement agencies, this official called for the activation of the parish siren system. This alerted residents to the imminent danger of nearby tornadoes. Parish officials stated that because of their actions many residents were alerted to take shelter immediately. This event occurred shortly after the La Place tornado.

NWS offices rely heavily on spotter reports to support the warning decision-making process. This is especially true during the early stages of tropical severe weather outbreaks. Spotter networks are crucial to the NWS warning process, especially in data-sparse areas such as Louisiana.

Tornadoes proved to be a major factor of Andrew's impact on southern Louisiana and neighboring Mississippi. During Andrew, Louisiana experienced 14 confirmed tornadoes and numerous funnel cloud and unconfirmed tornado reports. In neighboring Mississippi, the severe weather impact was even greater with 25 confirmed tornadoes and a comparable number of funnel cloud reports and unconfirmed tornado reports.

A post-event review of tornadoes associated with Hurricane Andrew (Kuhn, WSO Lake Charles, March 1993) was consistent with previous studies (Novlan and Gray, 1974) in showing that a majority of tornadoes occurred after the eye of Andrew moved 50 miles inland. It was during this period that the affected NWS offices issued the majority of their warnings. The La Place tornado was the lone exception, occurring prior to the landfall of Andrew.

Observed parameters critical to the predicting of severe weather includes rapid storm filling as occurs with landfalling tropical cyclones. Recent studies cite this as important to tornado development. The entire gulf region is considered data sparse which seriously impacts the ability to monitor the changes involved with a filling storm. This can significantly impede a field office's initial response capability. Available data networks are further limited by frequency of sampling. In addition, operational limitations of existing conventional radars also contributed to the perception of a slow response. The new WSR-88D radar network with its Doppler capabilities will overcome some of the limitations inherent to conventional radars operating in tropical environments. Strong vertical wind shear in the first kilometer or two is characteristic of tornadoes associated with hurricanes. Post-storm review has shown that this characteristic was associated with the tornadoes spawned by Hurricane Andrew. Had the remote sensing capabilities of wind profilers and the WSR-88D been in place, forecasters may have been able to provide more timely information.

The threat of severe weather, such as tornadoes, was mentioned early Tuesday, August 25. The mention of this threat first appeared in early morning HLSs and carried forward in subsequent statements. On Tuesday evening as the outer fringes of Andrew approached landfall, spiral rain bands began to advance into south Louisiana, increasing the likelihood of tornadoes. Although a legitimate concern, no mention of this increased threat to south Louisiana residents was made in any local statement or NHC advisory, despite having this information available to field offices through the NSSFC mesoscale discussion issued at 4:25 AM CDT, Tuesday morning.

At approximately 9:10 PM CDT, Tuesday, August 25, a tornado struck the adjacent areas of La Place and Reserve, Louisiana, in St. John the Baptist Parish. Two people were killed, 32 injured, and 60 families left homeless. Prior to this time at 7:11 PM CDT, a possible tornado had been reported to WSO Baton Rouge near the Sunshine Bridge in Ascension Parish, just west of St. John the Baptist Parish. Throughout Tuesday night and into Wednesday morning, August 26, various tornado reports were received by the Baton Rouge office. The HLSs issued by WSFO Slidell and WSO Baton Rouge did not appear to adequately heighten the threat posed by tornadoes. This was true even after the offices received additional tornado reports.

Although the WSFO highlighted the occurrence of the La Place tornado in its 10:30 PM CDT HLS issuance, no warnings or severe weather follow-up statements were issued. The HLS, issued at 12:30 AM CDT, Wednesday, August 26, for the first time mentioned the increased chance for further tornado development across southeast Louisiana as Andrew interacted with the land and slowly weakened. However, it was not until the 7 AM CDT HLS that Slidell went a step further and noted that tornadoes would be likely across southeast and south-central Louisiana, some distance from the storm. It was also stated that these tornadoes would be short lived and difficult to detect by conventional radar. During the 18 hours following the La Place tornado, a total of eight severe weather warnings were posted by the Baton Rouge and Slidell offices. Other than through the issuance of HLSs, as follow-up to posted warnings, there was little additional documentation of these events. Furthermore, the HLSs that followed these events did not adequately perform their intended function as follow-up statements to posted warnings. **Finding II.D.2: Hurricane local statements were too closely tied to the issuance of hurricane advisories. As a result, the dissemination of critical information concerning tornadic events was delayed. Recommendation II.D.2: The issuance of hurricane local statements should be event driven, rather than tied exclusively to routine NHC issuances.**

During the 18 hours following the La Place tornado, the Baton Rouge office of the NWS issued three tornado warnings, and the Slidell office issued one severe thunderstorm and four tornado warnings. The text of these warnings indicated that most of these warnings were issued on the basis of public and trained spotter sightings. Many of the warnings issued lacked one or more of the elements deemed necessary for a complete warning. Some warnings lacked reference to the speed of movement, while others lacked the important element of "pathcast." A "pathcast" alerts the user to the projected path being taken by the storm and identifies which cities or locations are in harm's way. The NWS offices could have provided users with more frequent follow-up statements to the warnings.

Hurricane Local Statements (HLS)

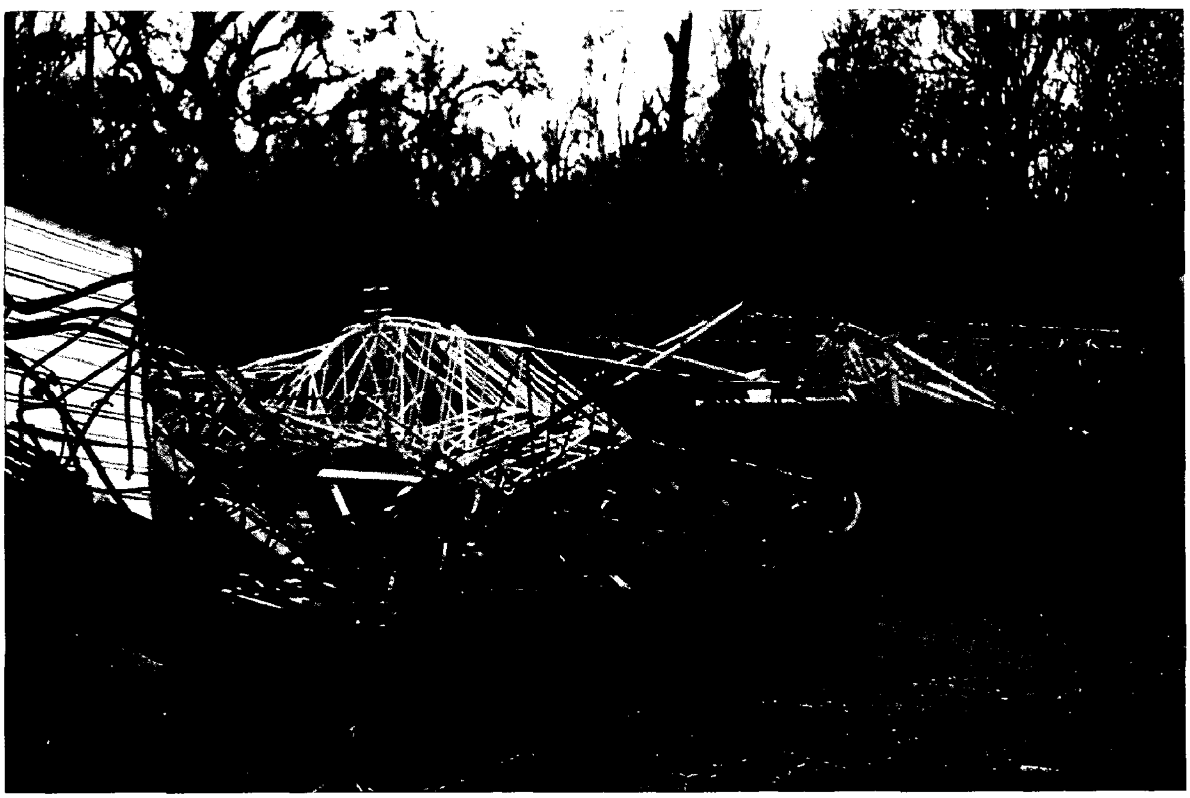
The hurricane is one of nature's largest and most complex weather events. It possesses a number of threats both to life and property which makes it one of the most difficult events to describe. The HLS is the NWS product which is used to accomplish this task. Its purpose is to complement NHC advisories and to provide detailed, tailored information on local conditions. Review of HLSs issued during Hurricane Andrew revealed a lack of detail and tailoring which led to a large degree of redundancy. Many of the HLSs issued failed to achieve their full purpose.

The HLS format used by WSFO Slidell provided a means of summarizing critical information near the beginning of the text. However, as the Andrew event became more complex, this became less effective. Gradually, data became buried within the HLS text, making it more difficult to access critical information quickly. Most HLSs issued by the gulf coast NWS offices during Andrew became too lengthy with time. The HLSs released early in the event were more effective. These early releases provided better local resolution of the problems posed by Andrew. They were short, precise, and made relevant local information available to the users. As the event progressed, HLSs became less effective due to excessive reiteration of NHC, NSSFC, and RFC information. The most notable change to the effectiveness of the HLS was the loss of specificity with respect to the impacts that Andrew would have on the local county/parish warning area. Offices did follow the prescribed format and content as described in Weather Service Operations Manual Chapter C-41, Hurricane Warnings, but the HLS as described in C-41 does not fulfill the desired intent of the product and should be reviewed for needed changes.

Despite these difficulties, the HLSs issued by WSFO Slidell and WSO Lake Charles early on were effective and gave brief summaries of critical information at the beginning of the messages. Although not consistent with the HLS format as described in C-41, the HLSs issued by these offices, especially early on during the storm, provided a much more efficient means of communicating significant information to their local users. Coastal NWS offices should re-evaluate the manner in which data and information are collected and used in the writing of HLS products. Emphasis should be placed on the use of on-station software, emergency management information, and remote sensing data to create a highly specific public product.

More details could have been incorporated into the body of the HLSs which were apparently used as follow-up statements during the peak period of severe weather activity. Such enhancements would have provided the details necessary for the HLS to adequately substitute as a follow-up statement for severe weather statements following severe weather warnings.

Corrections to HLSs during Andrew were rarely needed. However, on one occasion, an HLS was corrected. **Finding II.D.3: During the peak period of tornado activity, several reports of tornadoes were highlighted in the HLSs. One of these reports proved to be erroneous. Rather than issue a corrected HLS, the WSFO issued a special weather statement to acknowledge the error. This could have caused confusion and loss of precious time for users during a period of rapidly changing events.** In this case, the use of a special weather statement did not follow NWS correction procedures. Also, it did not provide adequate assurance that users would take note of the error. The most effective way to issue a correction is to identify the error and correct it using the proper product. **Recommendation II.D.3: NWS field offices should follow established NWS formats for issuing corrections.**



Tangled remnants of what was once a radio tower along U.S. 90, south of Centreville, Louisiana.

CHAPTER II.E

SUMMARY OF INFORMATION AND WARNING SERVICES AND RESPONSE ACTIONS BY EMERGENCY MANAGEMENT AND MEDIA

Non-NWS Products Available to Emergency Management

All coastal county emergency managers in the affected region and the Louisiana DEM received marine advisories from NHC as well as public advisories, HLSs, and tropical cyclone discussions. Use and timeliness of these products varied greatly from parish to parish. Nearly all southeast coastal parishes and the state DEM have PC-based software into which marine advisory forecasts are entered. The southwest coastal parishes have yet to be upgraded. About half the coastal parishes have ***GDS4.0***, which parishes purchased individually. Prior to Hurricane Andrew, parishes did not have access to a program named ***HURREVAC***. Since Andrew, nearly all southeast Louisiana parishes have been provided with and been trained in the use of ***HURREVAC***.

The use of these software packages is taught to emergency managers in two ways. One technique is to have the local NWS WPM or WCM provide assistance and technical training to emergency management officials. The most desired approach for local officials and their staffs is to participate in the FEMA/NWS-sponsored Hurricane Response and Decision-making Workshops. Annually, a number of week-long courses are conducted at NHC. These workshops provide emergency management officials with the background information needed to use the PC software more effectively. **Finding II.E.1: FEMA/NWS-sponsored Hurricane Response and Decision-making Workshops are conducted only a few times each year. These workshops are incapable of reaching sufficient numbers of emergency officials. This limits the effectiveness of the hurricane preparedness program.** Due to the limited number of workshops presented annually, it has become incumbent on the local NWS offices to provide the necessary training. Despite these efforts, local officials do not fully utilize the tools and information made available through local offices, such as WSFO Slidell. **Recommendation II.E.1: FEMA and the NWS should increase the number of annual hurricane workshops to train coastal emergency management officials.**

Interaction between NWS and Emergency Management

Virtually all south Louisiana parishes appeared to have excellent working relationships with their respective NWS offices and reported varying degrees of interaction with the NWS during Andrew. The problem of receiving and answering the flood of calls from various governmental agencies, the media, and the public made it extremely difficult for NWS offices to maintain an effective interaction with emergency managers. WSOs have limited staff and a limited number of available telephone lines. In addition to coordinating with various state and local law enforcement agencies, the WSFO provides direct warning support to 16 parishes and a resident population exceeding one million. WSOs Baton Rouge and Lake Charles support 13 parishes and a host of local users with less staff and phone lines. Coordination with the various parish officials, state officials, law enforcement agencies, and the media can quickly saturate local NWS telephone systems. During events such as Andrew, this could severely hamper the NWS's ability to interact effectively with state and local officials when short-fused events occur within a major event. In fact, this was part of the problem which prompted the response of the parish official described in chapter II.D, paragraph two, of the "Severe Weather Warnings and Statements" section.

Nevertheless, during Andrew, parishes did an excellent job of coordinating with their local NWS office. Evidence of this exchange of information and coordination appear within the text of the HLSs issued during Hurricane Andrew. These statements include reports of severe weather, flooding, and evacuation information—much of which was provided by the emergency management community. Local NWS and EM telephone logs also documented the interaction which took place between the various governmental agencies, the NWS, and the media.

The city of New Orleans, Orleans Parish, is in a unique situation which benefits local parish officials during hurricane events threatening New Orleans. **Finding II.E.2: Due to the close proximity of the WSFO, an agreement with the city allows for a dedicated meteorologist to be dispatched from the WSFO to the local Emergency Operations Center (EOC) during hurricane events which may threaten the city.** This interaction is very similar to the interaction between Dade County, Florida, and NHC. The primary difference between these arrangements is that in Florida, the county officials perform out of NHC; whereas in Louisiana, the WSFO assigns a meteorologist to the EOC. In Louisiana, this form of interaction, although limited in scope, is lauded by emergency managers for providing a stabilizing influence on the EOC. The ability of the assigned meteorologist to interpret weather information and control rumors was of utmost importance to state and city officials during Andrew. **Recommendation II.E.2: Appropriate NWS staff should be dedicated to work with emergency management officials during major hazardous weather events.**

Impact of Watches, Warnings, and Probabilities

During Disaster Survey Team interviews with emergency managers, nearly all coastal emergency managers mentioned the use of probabilities or ***GDS's*** forecast error computations as they described their preparedness actions. Parish and emergency management officials periodically received training either by NHC staff or local NWS staff in interpreting and using marine advisories and other hurricane-related products. However, the emergency managers still do not make the best use of local NWS meteorologists and the various computer aids mentioned.

Emergency management officials depend heavily on NHC marine advisories and the probabilities of landfall strike. Watch and warning issuances typically act as the triggering mechanism for initiating some evacuation response. Due to the longer evacuation clearance times in some Louisiana parishes, there exists a keen interest in public safety and evacuation. Many parishes initiated some form of evacuation request or activity well before any warning was issued.

Impact of Forecasts and Forecast Errors

As noted above, all parish and state emergency management offices received marine advisories which included position and intensity forecasts. Officials had the tools available to help them assess the response implications of the forecasts. The track forecasts turned out to have been the most valuable.

Andrew's forward speed was of concern because models implied that Andrew would begin an unusually rapid slowing of its forward speed—from 18 mph to 8 mph. The magnitude of the slowing varied greatly between models and was a major concern for NHC and NMC in their decision-making process. This was difficult to resolve and may have contributed to some of the timing error of Andrew's landfall in forecast periods beyond 24 hours. Early forecasts were too slow in bringing Andrew onshore. Even so, local emergency managers had adequate response time.

As in Florida, the hurricane intensity forecasts contained the greatest error. NHC intensity forecasts alerted local officials to the possibility of a category 4 hurricane rather than a rapidly diminishing category 3. Andrew's landfall in Louisiana was weaker than expected. All indications from satellite and final aircraft reconnaissance flights prior to landfall were that Andrew remained a category 4 hurricane. Andrew's interaction with an approaching upper trough and the Louisiana coastline likely had a much greater impact on its intensity than expected. Andrew eventually made landfall over south Louisiana as a category 3 hurricane and continued to weaken rapidly as it proceeded inland. Despite these intensity errors, the information provided was well received and afforded emergency managers the information necessary to conduct their decision making. Had the hurricane's intensity forecast been underforecast, the results might have been more devastating for Louisiana. The NWS's ability to accurately forecast intensity changes of hurricanes continues to be a weakness. The NWS needs to focus more research and development on producing a more reliable hurricane intensity forecast model.

Evacuation Conditions

The warning posted for the northern gulf coast extended from Pascagoula, Mississippi, west to Vermilion Bay, Louisiana. The watch area extended east from Pascagoula to Mobile, Alabama, and west from Vermilion Bay to Sabine, Texas. Table 3 lists the counties and parishes for which watches and warnings were posted.

As in Florida, numerous counties and parishes were threatened. Local and state emergency management had to make response decisions as Andrew took aim on the Louisiana coastline. Initially, the parishes and counties of greatest concern were located immediately along the southeast Louisiana coastline, including parishes adjacent to Lake Pontchartrain and the three coastal counties of Mississippi. The parishes of southeast Louisiana have some of the

Table 3

Watch and Warning Status During Hurricane Andrew*

Parish/County	Watch	Warning
Cameron, LA	X	
Vermilion, LA		X
St. Mary, LA		X
Terrebonne, LA		X
Lafourche, LA		X
Jefferson, LA		X
Plaquemines, LA		X
St. Bernard, LA		X
St. Charles, LA		X
St. John the Baptist, LA		X
Hancock, MS	X	
Harrison, MS	X	
Jackson, MS	X	

* This table depicts only coastal watch/warning areas.

largest populations at risk and require some of the longest evacuation clearance times (table 4). **Finding II.E.3: Formal evacuation clearance studies for southwest Louisiana have yet to be completed. Recommendation II.E.3: FEMA and the USACE, with NWS support, should accelerate their efforts to complete evacuation studies for all hurricane-prone coastal areas.**

Finding II.E.4: In general, coastal residents know that they have a potential storm surge problem. However, in some highly populated areas, such as Greater New Orleans, there are preliminary evacuation studies but no proven orderly plan for the safe and timely evacuation of the entire metropolitan area. Furthermore, the scope of these studies does not address regional complications which can compromise orderly evacuation. Despite having a regional plan for the evacuation of New Orleans, the effectiveness of the plan remains in question. Several problems, such as an adequate number of efficient evacuation routes, continue to resurface following each exercise. These issues must be resolved before local officials can be confident of their ability to safely evacuate the population of Greater New Orleans.

Table 4

Southeast Louisiana Regional Clearance Times

County	Storm Category	Evacuating Population	Clearance Time: Off Peak	Clearance Time: Peak Period*
Orleans	1 - 2	19,300	5 hrs	12 hrs
	4 - 5	441,400	44 hrs	50 hrs
Jefferson	1 - 2	33,635	5 hrs	12 hrs
	4 - 5	371,435	44 hrs	50 hrs
Plaquemines	1 - 2	16,410	5 hrs	12 hrs
	4 - 5	24,135	44 hrs	50 hrs
St. Bernard	1 - 2	10,275	5 hrs	12 hrs
	3 - 5	60,355	44 hrs	50 hrs
St. Charles	1 - 2	6,415	6 hrs	9 hrs
	3 - 5	37,410	13 hrs	14 hrs
St. John the Baptist	1 - 2	4,910	5 hrs	10 hrs
	3 - 5	31,325	35 hrs	38 hrs
St. James	1 - 2	3,560	5 hrs	10 hrs
	3 - 5	17,920	35 hrs	38 hrs
Lafourche	1 - 2	28,640	6 hrs	9 hrs
	3 - 5	72,395	13 hrs	14 hrs
St. Tammany	1 - 2	32,465	5 hrs	12 hrs
	3 - 5	98,320	44 hrs	50 hrs

* Background traffic conditions with a peak period condition include a normal work to home movement in addition to the movement of evacuating vehicles.

The Greater New Orleans area, which includes Orleans, St. Tammany, St. Bernard, Jefferson, St. Charles, St. John the Baptist, and north Plaquemines Parishes, has the highest population density along the gulf coast and is one of the most vulnerable. The Greater New Orleans area physically sits 5 to 10 feet below sea level and is protected by a network of levees. It is estimated that the existing levee system would protect the Greater New Orleans area from category 1 and 2 hurricanes. The levee system is rated to survive most category 3 storms and some select category 4 storms but no category 5 storms. Areas outside of the levee system are easily flooded. The degree of inundation is dependent on storm strength and landfall approach. Most evacuees are anticipated in evacuation plans to go to destinations within their own parish, to a northern adjacent parish, or, time permitting, to a parish well north of the endangered area.

Evacuation plans anticipate that a third or fewer of the evacuees will leave the region, going to points north or inland. Doing so requires that most evacuees use either US 61, I-10, or I-55, all multilane, limited access highways. Transportation models indicate that congestion will be extreme on both US 61 and I-55, exiting north from the Greater New Orleans area. Areas west would use I-49, US 171, or US 165, also multilane highways. Clearance times required to evacuate residents and seasonal visitors safely are listed in Table 4, Southeast Louisiana Regional Clearance Times. These longer evacuation clearance times reflect the limited number of evacuation routes from the Greater New Orleans area and the need for many coastal residents to evacuate through New Orleans. Despite the fact that New Orleans was within the warning area, its evacuation response was poor considering the potential threat for loss of life.

Ideally, emergency management officials attempt to have all evacuation requirements completed prior to the arrival of gale-force winds and the flooding of roadways. Therefore, the initiation of evacuation must reflect not only the clearance time but also the number of hours which tropical storm-force winds precede the arrival of the hurricane's eye. The average additional time required is about 6 hours. **Recommendation II.E.4: FEMA, in concert with the NWS, should ensure the completion of local evacuation studies and integrate them into a comprehensive regional evacuation plan.** It is hoped that the results of such a regional study would provide local officials with new response options that would reduce overall evacuation clearance times.

Evacuation Actions by Local Emergency Management

The state, parish, and city governments have the authority to order evacuation in response to any imminent threat. Failure to comply, however, carries no penalty.

Over the past 20 years, the State of Louisiana has worked slowly toward the development of an effective hurricane preparedness program. Their progress was very evident in Andrew. The Adjutant General for the State of Louisiana oversees the state's DEM. The Adjutant General's staff has been overseeing the DEM for slightly more than a year prior to Andrew. Despite this short tenure, the General's staff was aware of the pending situation, in part due to the excellent on-going working relationship between NWS and DEM officials. As part of a coordinated effort between the DEM and the NWS, Adjutant General Stroud called a meeting of NWS, parish, and state officials well before Andrew's entry into the gulf—a full

5 days before landfall in Louisiana. Similar planning and coordination sessions would continue through Andrew.

Local parish officials were aggressive in securing access to the various media outlets. Voluntary evacuation of area residents in nearly all coastal parishes started 2 days prior to landfall. The second tier parishes, those adjacent to coastal parishes, were not far behind in calling for voluntary evacuations since they wanted residents to take the threat seriously and take every precaution, including possible evacuation. Most parishes of south Louisiana initiated actions similar to those conducted by Iberia Parish.

The first phase initiated by local parish officials was to call together elected officials to review the situation. The decision was made to call for a ***Voluntary Evacuation*** of:

— low-lying areas.
— areas prone to flooding from heavy rains or storm surge.
— all mobile homes.
— anyone with easy access to safe shelter.

As it became more apparent that the parish was to be affected, a second meeting was called, and phase two was initiated and a call for a ***Recommended Evacuation*** of:

— all mobile homes.
— the area of Iberia Parish south of US 90 and southeast of Louisiana Highway 14.
— the town of Delcambre.

Approximately 24 hours prior to landfall, elected officials again met, and the decision was made to call for a ***Mandatory Evacuation*** of:

— the area of Iberia Parish south of US 90 and southeast of Louisiana Highway 14.
— the town of Delcambre.

To some degree, this sequence of events was played out in many of the first and second tier coastal parishes of south Louisiana as noted in table 5.

Since Hurricane Andrew, it has been estimated that anywhere between 20 and 40 percent of the local population evacuated following the issuance of warnings and ordered evacuations. The DST interviewed local emergency management officials from the affected parishes over the months following Hurricane Andrew. **Finding II.E.5: The emergency management community of southeast Louisiana felt strongly that the fear of looting was partially responsible for a smaller than expected number of evacuees.** It was noted that, through their contacts with parish residents, they sensed a sincere fear of having their homes looted should they evacuate. Parish officials felt that the issue of looting should be addressed within the scope of hurricane preparedness. Local parish officials have conducted

Table 5

Parish Evacuations for Andrew

Parish	Recommended	Ordered	Estimate of Evacuees
St. Bernard	Yes	No	3,000
Orleans	Yes—East Bank	Yes—West Bank	Unknown
Jefferson	Yes—West Bank	No	Unknown
St. Tammany	Yes	No	Unknown
Plaquemines	Yes—North Half	Yes—South Half	18,000
Lafourche	Yes—North Half	Yes—South Half	Unknown
Terrebonne	Yes—North Half	Yes—South Half	33,000
St. Charles	Yes	No	Unknown
St. John the Baptist	No	No	Unknown
St. James	Yes	No	5,000
Assumption	Yes	No	Unknown
St. Mary	No	Yes	42,000
St. Martin	No	Yes—Lower Half	650
Iberia	No	Yes	35,000
Cameron	No	Yes	10,000
Vermilion	Yes	No	37,000
Calcasieu	Yes	No	20,000
Acadia	No	No	Unknown
Lafayette	Yes	No	17,000
Jefferson Davis	No	No	Unknown

* Evacuation estimates provided by Parish Emergency Management Officials

surveys which indicate that the threat from looting during evacuation is no higher than, and usually lower than, local burglary crime rates. **Recommendation II.E.5: Local governments, with NWS and FEMA assistance, need to educate residents to alleviate these inaccurate perceptions.**

The premise behind coastal evacuations continues to be—move people out of flood-prone and surge-prone areas prior to a hurricane making landfall. Andrew did not fit this prototype. Its damaging winds were the primary cause of life and property loss. The NWS and various preparedness agencies need to examine the need for and feasibility for the development of an evacuation plan in response to the adverse effects of hurricane-force winds.

Response by the Media

The electronic and print media in the gulf region played a crucial role in enabling the public to respond to the approaching hurricane. The print media maintained a steady stream of hurricane-related information, including the latest reports and forecasts as well as emergency response information. The electronic media, including radio and television, augmented the print media with later and more frequent updates enhanced by color graphics and satellite photo-imagery. The media performed a tremendous service to the residents of the gulf coast. The ability to provide real-time, graphic pictures of the devastation wrought upon south Florida added to achieving the desired local government and public response. Undoubtedly, had the NWS relied solely on its own capabilities without the efforts of the media, awareness and response information would not have reached an audience of the size that it did.

The NWS recognizes the integral role that the news media and, in particular, the broadcast media played in disseminating weather warnings and vital information to the general public. The link between the NWS, the emergency management, and the broadcast media is critical to any community warning system. As in south Florida, the performance of the NWS-media alliance has never been more effective than during the hours preceding Hurricane Andrew's landfall in south Louisiana. The electronic media were in place and awaiting Andrew, providing on-site reporting which proved to be an indispensable element of the warning system. The NWS must continue to nurture these strong partnerships and working relationships with the media. Local media, the NWS, and local governments need to re-evaluate their roles in this partnership routinely, ensuring that its goal of public warning and preparedness is achieved most effectively.

To take fullest advantage of the media's capacity to disseminate information to a wide audience, a partnership was developed to coordinate NHC information through a broadcast "pool" as described in chapter I.E.

<u>Finding II.E.6</u>: **There were a few instances where one local television station presented forecast track scenarios that conflicted with official NHC forecasts. That caused some problems for local parish and NWS officials.** In these instances, the media interviewed some of the more flamboyant hurricane "experts" in the area. On occasion during these interviews, these supposed experts would differ markedly from the forecasts issued by the NHC. Following these interviews, questions and concerns over the official NHC forecast would briefly inundate NWS and EOC offices. These episodes were few in number and did little harm but placed additional workload on already overworked NWS and EOC staffs. **<u>Recommendation II.E.6</u>: The local NWS offices in Louisiana should make a renewed effort to impress upon the local media that providing consistent information to the public is critical during emergency situations.**

Significant tree damage north of Avery Island, Louisiana, home of the world famous McHilheny Tabasco Sauce.

CHAPTER II.F

PUBLIC RESPONSE

Background

The State of Louisiana does not have a mandatory evacuation policy. Although the governor possesses authority to call for an evacuation, these decisions are usually deferred to city and parish officials in coordination with their local emergency management staff. Public response to requests for evacuation are voluntary in nearly all situations despite the reference to an "ordered" or "mandatory" evacuation. Failure to comply carries no penalty.

Local Response

There are nine Louisiana parishes situated along the coastline. An additional eleven parishes lie adjacent to the north. Much of the area covered by these parishes is near sea level and, therefore, highly vulnerable to storm surge. The degree of vulnerability is dependent upon both storm track and storm intensity. In response to Andrew, a northwest-moving category 4 hurricane, all of the 20 vulnerable parishes recommended some level of evacuation. The parishes are listed in table 5 along with best estimates of the number of evacuees.

During Andrew's advance toward the Louisiana coast, emergency managers initiated a phased approach to evacuating coastal and second tier parishes. A concern of some parish officials was that there would be some resistance to evacuation due to a fear of looting, largely a myth. This was a major concern to the public in south Florida but not as much of a concern in Louisiana. Statistics on burglaries during and shortly after natural disasters as compared to normal other times show no significant increase in crime rates. The myth of the looting threat, largely media-perpetuated, needlessly endangers lives during hurricanes.

The first phase of evacuation called for voluntary evacuation. These were initiated at least 48 hours prior to landfall. This approach worked especially well in areas where the evacuation clearance times are long due to inadequate transportation networks. This approach also works well in areas with higher degrees of vulnerability. Areas, such as barrier islands, usually have over 80 percent of the residents evacuate voluntarily. Offshore oil rigs experience 100 percent evacuation. In less vulnerable areas, these numbers fall off to 20 percent or less. Many residents who evacuate less vulnerable areas are the infirm, the elderly, and those who require greater time to evacuate. During Hurricane Andrew, the most vulnerable areas, the barrier islands and oil platforms, did evacuate as expected, but the actual evacuation response in less vulnerable areas has not been ascertained. Perceptions are that the response was significantly less than expected.

Depending on the time needed, the next phase—recommended evacuation—is initiated. By the time this stage is reached, most of the highly vulnerable coastal areas have been evacuated, and the last few depart. In addition, another 20 percent of those who ultimately leave do so from second tier parishes.

Usually coincident with the issuance of a hurricane warning, Louisiana parishes will order evacuation. This typically occurs about 24 hours prior to landfall. In most instances, highly vulnerable areas have achieved nearly 100 percent evacuation. Barrier islands and offshore oil stations are such areas. A final 30 to 40 percent of those who evacuate second tier parishes do so only when the local parish government declares an ordered evacuation. These ordered evacuations are executed through the issuance of parish proclamations or emergency declarations. Such documents better define the urgency of the situation for those people who wait until the last possible moment to leave.

Nearly all coastal and second tier parishes recommended voluntary evacuation as Andrew approached. Table 5 lists these parishes and whether or not they recommended or ordered evacuation. The table also provides a rough estimate of the number of evacuees based on shelter information provided by the parishes.

Less than 30 percent of the entire population of south Louisiana actually evacuates under these circumstances. This low number concerns the NWS and the local officials. An additional concern surfaced during interviews with residents of some coastal communities. **Finding II.F.1: Many southeast Louisiana residents did not understand the full extent of danger from storm surge.** In interviews with residents of Cocodrie, it was discovered that many evacuated north to Houma. Houma is about 25 miles north of Cocodrie. The change in highest elevations in Cocodrie, about 5 feet NGVD, increases to near 10 feet NGVD in Houma. This would not have provided safe refuge from forecast storm surges of 10 to 15 feet. One could speculate that had a 10- to 15-foot storm surge occurred, a number of lives might have been lost. **Recommendation II.F.1: The NWS needs to work more closely with FEMA, as well as state and local officials, to develop more effective preparedness information about storm surge. Presentations tailored to local areas could provide information about situations to which residents could better relate.**

Finding II.F.2: Some south Louisiana residents interviewed commented that they had evacuated highly vulnerable areas only to find themselves threatened by other hurricane dangers. Some residents of New Orleans, highly vulnerable to storm surge and flooding, evacuated to Baton Rouge. They had no idea that Baton Rouge would be in the direct path of Andrew. Although these individuals felt secure in the fact that they had safely avoided the storm surge threat, they did not fully realize that they were not clear of the wind effects of Andrew. The public needs to be made more aware of the multiple threats a landfalling hurricane presents and how to monitor the storm's progress better.

In Iberia Parish, two schools housing evacuees lost part of their roof due to wind gusts of 70 mph. Had Andrew not weakened as rapidly, the damage sustained to these structures would have been significantly greater, possibly injuring or killing scores of people. The selection of these wide-span structures almost proved to be disastrous for those sheltered. Evacuees were gathered in the school gymnasiums, an area of high risk, rather than their interior hallways—areas usually much safer. Wide-span structures, such as a school gymnasium, tend to fail more often during high wind situations and should not have been utilized as shelters. **Recommendation II.F.2: The NWS, in concert with local emergency management officials, should ensure that evacuation studies are up to date and accurate. Given widespread distribution, the results of these studies can direct the public to appropriate shelter.**

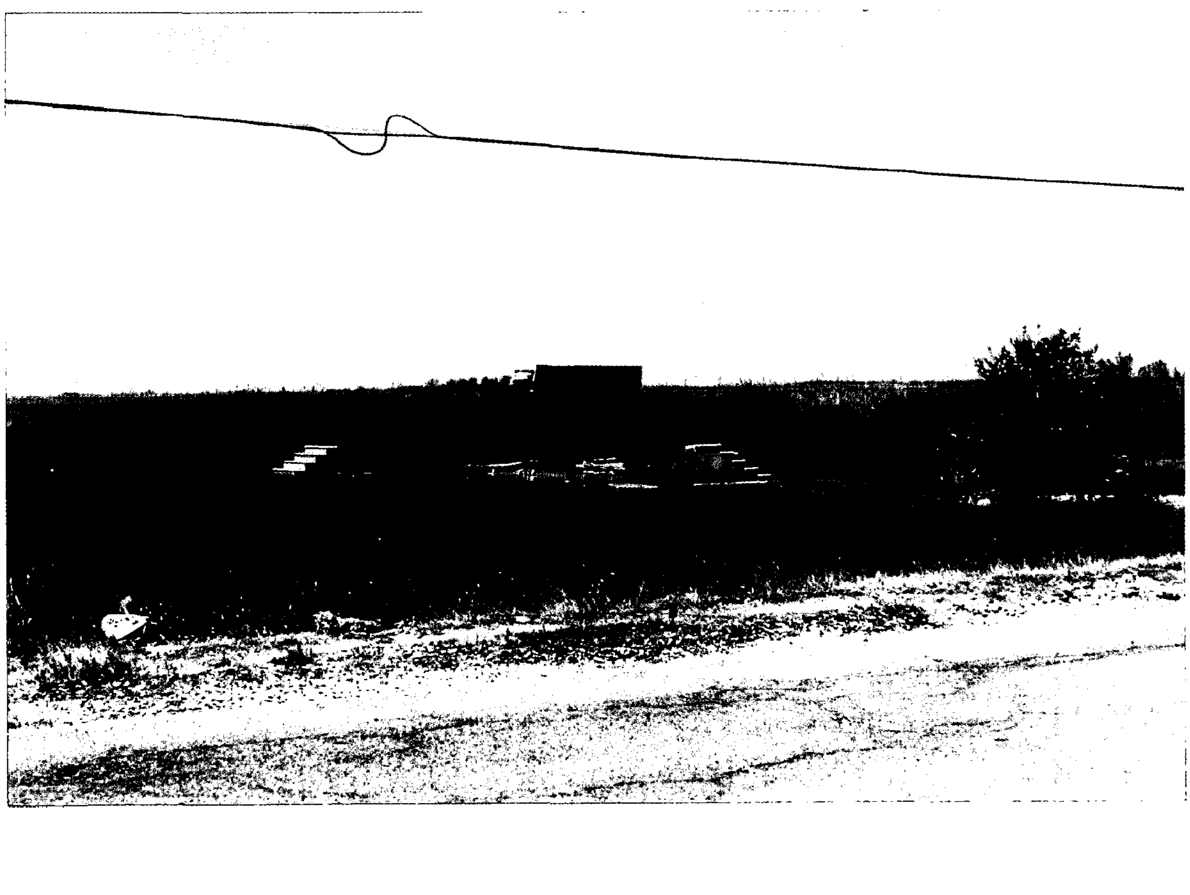
In general, most parishes reported no significant problems with the evacuation process. However, it continues to be speculated that this was in part due to the small numbers evacuating. Initial estimates of 1.3 million people evacuating south Louisiana are believed to be greatly overestimated. Social scientists continue gathering data in hopes of formulating a best estimate of the number of evacuees. There were a few minor cases of gridlock reported on northbound routes exiting coastal areas for the central sections of Louisiana. Many of these were easily resolved once the problem was identified. One choke point was identified on Interstate 10, west of New Orleans. Road construction choked off exiting traffic, causing gridlock throughout the area. The state should monitor all construction projects and anticipate their potential impact should a hurricane threaten the area. If a construction project is significant enough to be deemed as a problem for evacuation, alternatives should be defined and made ready rather than risking lives through avoidable gridlock.

Finding II.F.3: Despite the efforts of the NWS and state and local emergency managers, not all residents heeded the various evacuation requests even though their lives may have been in jeopardy had the storm made landfall further east along the Louisiana coast. During post-Andrew interviews with local emergency managers, it was noted that in many cases they were unsure of the actual numbers of residents who evacuated. This left parish officials, especially second tier parishes, with the feeling that the number that actually evacuated was rather small. Evacuation surveys were not conducted on the parish level after Andrew; therefore, no reliable estimate as to the number of evacuees currently exists. The USACE and FEMA have contracted for a survey, as part of their Louisiana version of a Hurricane Andrew assessment, to better define the actual number of evacuees during Andrew. Preliminary results indicate that of the three areas evacuated—Chalmette, New Orleans, and Norco—all experienced evacuation rates of less than 35 percent. The lowest was New Orleans—12 percent. When asked why they did not evacuate, the two most common responses were that they felt that there was little chance of the storm hitting southeast Louisiana. The other most common response was the storm wasn't severe enough to necessitate their evacuation. **Recommendation II.F.3: The NWS and FEMA need to increase their efforts to educate and train the public. Each agency needs to consider expanding their training capabilities to overcome the public's denial of the threat from hurricanes.**

Parish officials suggested two possibilities regarding the low evacuation rates. Either the evacuation went so well that there were few problems, or so few residents had actually evacuated that there were too few evacuees to create problems. One case supporting the latter was in the city of Lafitte where only about half of the residents evacuated. Most of them sought refuge within the levee system. About half of the town lies outside of the protective levee system. Had Andrew made landfall further east and moved north, that portion of the town outside of the levee system would have been inundated, and the levy system may have been overtopped by storm surge. Local officials feel that persons who reside within and outside the levee system have over the years developed a false sense of security about the levees. Much of this can be attributed to the fact that the majority of residents have never experienced a major hurricane. In fact, very few residents have ever experienced the maximum storm surge from a major hurricane.

Although yet to be confirmed, many emergency managers felt that not all residents heeded the various evacuation recommendations and orders for evacuation, especially in the parishes that make up Greater New Orleans.

<u>Finding II.F.4</u>: **Some residents of Greater New Orleans who evacuated and later returned to their homes felt that local officials overreacted in their evacuation recommendations, especially since Andrew made landfall further west than projected.** Local emergency managers fielded numerous complaints concerning overreaction, but felt that under the circumstances there was no alternative. Given the same circumstances today, they stated that they would have reacted in a similar manner. <u>Recommendation II.F.4</u>: **The NWS needs to work closely with the emergency management community in convincing this most skeptical segment of the population that the advantages of evacuating far outweigh the disadvantages of remaining in place.**



North of Cocodrie, Louisiana, home in the background was removed from its foundation by a combination of storm surge and wind.

CHAPTER II.G

PROCESSING, INTERPRETATION, AND DISSEMINATION OF NWS INFORMATION

Utilization of Hurricane Forecasting Models by NHC and NMC

A comprehensive description of the hurricane forecasting models run by NMC and NHC is provided in chapter I.G. The general performance of the models remained consistent with the trend established through the Atlantic and across Florida. The greatest confidence was placed in the AVN (Aviation) model which remained the most consistent throughout the entire event. The various BAM (Beta Advection) models were less reliable and given less credibility during the event. The storm track through the gulf was generally well forecast.

The greatest weakness in tropical cyclone forecasting remains in the inability of existing computer models to project and anticipate storm intensity changes accurately. This was evident in both Louisiana and south Florida. The SHIFOR model does not resolve short-term rapid intensity changes. Fortunately for Louisiana, the storm did weaken rapidly, resulting in less significant damage to the region which experienced landfall. The overforecasting of intensity at landfall resulted in an overestimation of the storm winds at landfall. The forecasting of tropical cyclone intensity changes continues to be the most difficult element of a hurricane to accurately predict. Additional research is greatly needed in the area of tropical cyclone intensity forecasting. NOAA should continue to support development of new models and methods to better gather data in and around tropical cyclones to more effectively evaluate and accurately project intensity changes within tropical cyclones.

SLOSH Model Performance

Forecast surge height values for the Louisiana coast were predicted to reach values of 10 to 15 feet. Actual surge height values measured from 5 and 8 feet. Compared to other forecast cases, this could be considered a significant error.

Past experience with the SLOSH model indicates that coastal Louisiana would have experienced the 10- to 15-foot storm surge if the storm made landfall as a category 4 hurricane. However, the storm decreased in intensity rapidly just prior to landfall. The storm's central pressure was 937 mb at 7 PM CDT on August 25. The storm filled to 955 mb 6 hours later and to 973 mb by 7 AM CDT on August 26. At the same time that the storm was weakening, there is evidence that the diameter of the storm's eye also had decreased. The radius of maximum winds (Rmax) decreased from approximately 25 miles to 14 miles during this period.

Such changes in a hurricane's characteristics are beyond current forecasting capabilities. NHC has little skill in forecasting hurricane intensity changes, other than to forecast decreasing intensity as a storm moves inland. In general, NHC assumes constant Rmax and storm intensity until landfall, then increases the Rmax and weakens the storm intensity following landfall. This is consistent with past observational data studies and is applied when forecasting storm surges or in the preparation of storm surge studies.

To understand why storm surges were about half of their predicted height, the SLOSH model was run with an interpolation of the **"best fit"** track developed by NHC for Andrew's landfall in Louisiana. Table 6 lists the "best fit" values for the Louisiana portion of Andrew's storm track, including central pressures and the radius of maximum winds along that segment of its track. For this particular run, a Rmax of 14 miles was used. Highest observed surge heights are presented in figure 15. They were obtained from data gathered by the New Orleans office of the USACE. Within the figure, squares are used to depict the highest gauge levels; circles are used to identify observed high water marks. Generally, gauge levels are much more reliable and have less error than high water marks.

Table 6

Hurricane Andrew (Louisiana)
Best Track Data Interpolated For Use in SLOSH

Date	Time	Lat	Lon	P-Drop (mb)	Rmax (mi)
AUG 24	0400	25.4	79.3	65	14
		25.6	81.2	65	14
	1600	25.8	83.1	65	14
		26.2	85.0	65	14
AUG 25	0400	26.6	86.7	65	14
		27.5	89.0	65	14
	1600	27.8	90.05	65	14
		28.84	90.92	60	14
AUG 26	0400	29.63	91.58	54	14
		30.5	91.7	35	14
	1600	31.2	91.4	20	14
		31.5	91.1	15	14
AUG 27	0400	32.1	90.5	13	14

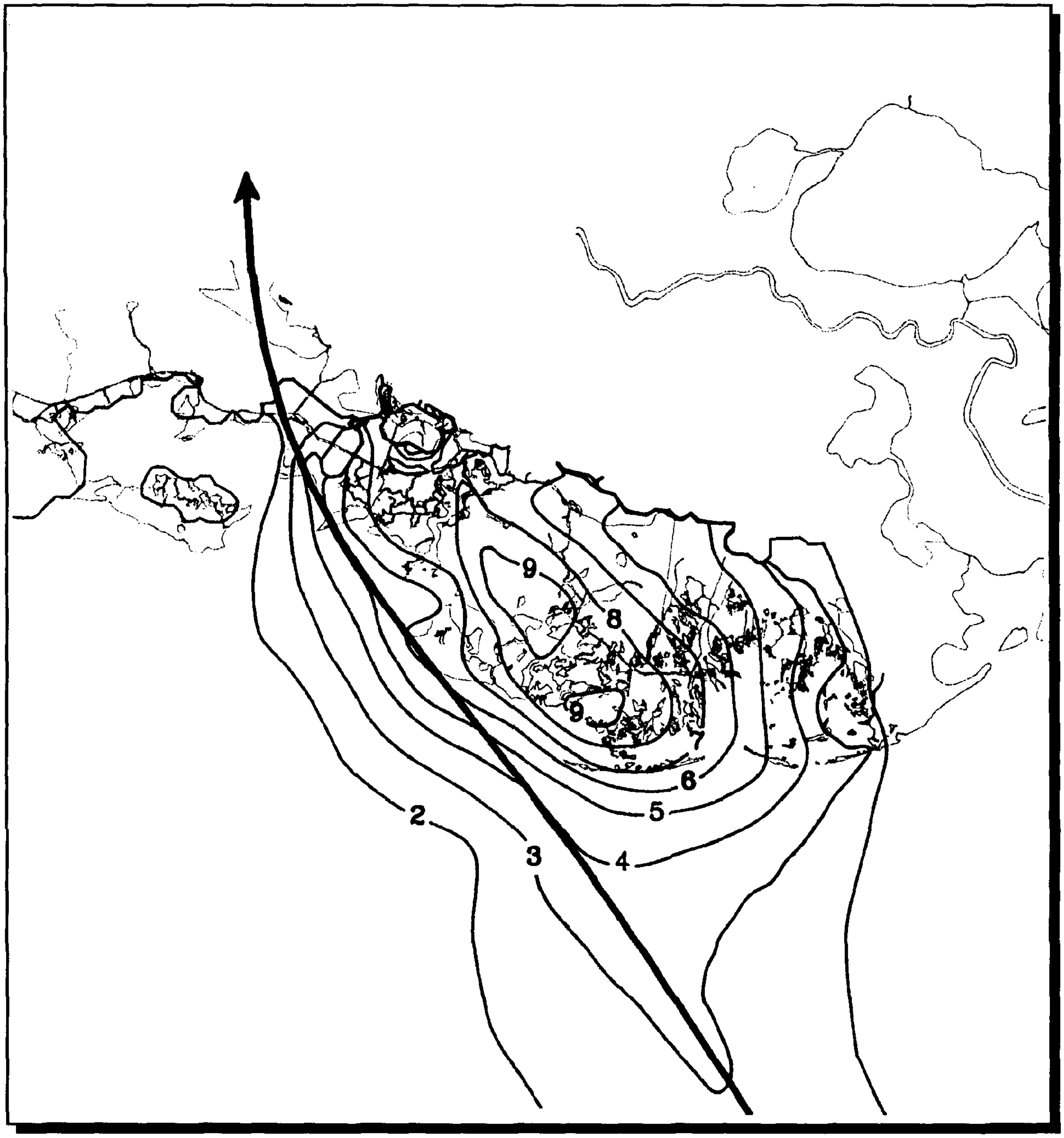


Figure 15 — Louisiana coastal storm surge.

These data were taken from the NHC best track, interpolated to intermediate times. The model uses "landfall" at 4 AM CDT on August 26. Within the SLOSH model, the size of the hurricane is parameterized by the Rmax and the intensity by the pressure drop (ambient pressure outside storm minus the storm's central pressure). Rmax was held constant at 14 miles for this model run.

Agreement between observed and computed surges generally was good although values far to the east of the track appeared higher than the values indicated in the model run. It is likely that the storm's Rmax wind was larger than 14 miles prior to landfall, then diminished as Andrew made landfall. Tests of these hypotheses will be done by the NWS's Techniques Development Laboratory in the near future.

Utility of Other PC Software

As in Florida, three major PC-based software packages were available to the various NWS offices along the gulf coast: SLOSH display, ***GDS4.0***, and ***Tides***. Similar to Florida WSOs, WSOs Lake Charles and Baton Rouge had little available time or hardware to make use of this software.

Finding II.G.1: WSFO Slidell, being collocated with the Lower Mississippi River Forecast Center (LMRFC), had access to RFC PCs and was able to run SLOSH MEOW and other hurricane decision-making applications. The ability to use these software packages allowed WSFO Slidell to keep state and local officials better informed. The ability to run the full SLOSH model on NOAA's mainframe computers was available to the WSFO through the RFC. This capability was lost early on in Andrew due to software problems. The capability of running SLOSH was very beneficial to WSFO Slidell. The staff felt that the loss of this capability was a major blow to their ability to support local emergency management officials on issues of storm surge.

PC availability is limited at most NWS offices to one or two—a computer dedicated to SRWarn and network backup use, and a Micro-Arts PC used for compiling and disseminating surface and rawinsonde observations. In order to operate SLOSH display, ***GDS4.0***, and ***Tides***, other resident programs had to be terminated. **Recommendation II.G.1: See Recommendation I.G.3.**

CHAPTER II.H

COMMUNICATIONS

Automation of Field Operations and Services (AFOS)

WSFO Slidell operates as the AFOS node for the State of Louisiana. They host the primary data base in support of the collocated LMRFC and WSOs Baton Rouge, Lake Charles, and Shreveport. AFOS performed efficiently during the event. Early interviews with the media and emergency management agencies revealed that some product transmissions were missing. Not all missing products were the result of an AFOS problem. Most were traced to improper or missing Universal Generic Coding, necessary for proper and timely relay of data to users.

NOAA Weather Wire Service (NWWS)

The satellite driven uplink for the NWWS is located at WSFO Slidell. It did not have any problems during Hurricane Andrew.

Two local jurisdictions, Jefferson and Orleans Parishes, experienced periodic difficulties with their NWWS during Andrew. In addition, two vendors of weather information discovered that some NWS products were periodically missing. **Finding II.H.1: The Universal Generic Codes (UGC) were incorrectly entered in several of the products disseminated by south Louisiana offices.** The AFOS relay system relies on these codes for automatic product distribution and purging of products at predetermined expiration times. During Andrew, it was noted that for an 8- to 12-hour period, a few offices were incorrectly entering the UGC or providing an incorrect expiration time. Most of these error relay problems were caught and corrected at the data relay point in Washington, D.C. **Recommendation II.H.1: NWS offices should perform more on-the-spot quality control of products prior to their public release. The use of software, such as version 6.0 of SRWarn, would help eliminate many of these errors.**

The State of Louisiana currently has 40 NWWS drops. Table 7 lists the various subscribers. The two state agencies that have drops on the NWWS are the state police and the state DEM. Both the state DEM and law enforcement agencies relay critical forecast products to local and state officials. The news media rely primarily on other wire services, e.g., AP, UPI, and commercial data vendors, such as Weather Services Incorporated and Kavouras Incorporated, for receipt of NWS products.

Table 7

Louisiana NOAA Weather Wire Subscribers

Media		Government	
Cable TV	2	Federal	1
Television	8	State	2
AM Radio	4	Local	7
FM Radio	2		
AM/FM Stations	-	Utilities	8
Newspaper	2		
Wire Services	1	Other	3
Total	19	Total	21

Family of Services

NWS forecast products and data are distributed to the electronic media via private sector vendors through the Family of Services. This indirect method probably was the most important factor in evacuating southern Louisiana effectively and rapidly prior to Andrew.

NOAA Weather Radio (NWR)

This radio broadcast system uses nine transmitters to cover the entire coastal area of Louisiana. All local officials interviewed by the survey team monitored NWR during the approach and impact of Andrew. Many officials noted that they acquired more specific information from direct contacts with NWS officials or from copies of NOAA Weather Wire products, however.

Much of the NWR system in Louisiana remained on air throughout Andrew. The only exceptions were Morgan City and Lafayette, where hurricane-force winds toppled transmission towers several hours prior to landfall. In addition to the loss of the tower at Morgan City, the facility which houses the electronics suffered structural damage. Wind-driven rain damaged much of the equipment within the facility. Both systems were either partially or fully operational within weeks following Andrew.

National Warning System (NAWAS)

NAWAS remained functional throughout the storm. As in Florida, the Louisiana link to NAWAS serves as an emergency communications link among the NWS, a limited number of emergency management offices, and law enforcement offices. NAWAS provides the NWS an additional means of contacting nine state police offices, the Louisiana DEM, and several of the larger local emergency management offices. NAWAS provides its users a means of exchanging emergency information critical to the decision-making process. This system, however, remains relatively unused by the groups who have access.

Hurricane Hotline Internal Coordination System

The hurricane hotline remained functional and worked well during Andrew. The only problem encountered was with voice quality at several sites along the Texas and Louisiana coasts. This created a minor inconvenience for NHC and other offices who relied on this system for information. These offices had to repeat elements of their transmissions several times before a message was completely understood. **Finding II.H.2: Currently, not all coastal WSOs have access to the hurricane hotline. Recommendation II.H.2: NOAA needs to expand the hurricane hotline to all coastal WSOs in hurricane vulnerable areas.**

The Emergency Broadcast System (EBS)

Through interviews with emergency management officials, it was discovered that because of the national and local news media coverage of Hurricane Andrew, there was no perceived benefit to activating the EBS. As Andrew approached the Florida coast, it was **the** news story. The attention of the residents of Louisiana was firmly fixed upon Andrew as it devastated south Florida.

Telephone Systems

Routine telephone service between the WSFO and the WSOs remained operational. Understandably, access to coastal parishes was limited following the landfall of Andrew. In those instances where communication was not possible via land line telephone systems, other methods of communication were utilized.

Amateur Radio

Amateur radio operators were instrumental in providing valuable information both to the NWS and local officials. They pass on warnings and exchange information between the NWS and EM officials. Several severe weather spotter networks and base stations were activated during Andrew. There were no documented instances of any difficulties.

Army Military Affiliate Radio System (MARS)

The Army Military Affiliate Radio System (MARS) provided communications support to the State of Louisiana during Hurricane Andrew. Army MARS affiliates maintain an extensive HF/VHF communications network throughout the continental United States with long-range HF relay capabilities (voice/digital) to military and civilian MARS units assigned to stateside and overseas commands. The primary mission of MARS is to provide DOD-sponsored emergency communications support on a local, national, and international basis to military, civil, and disaster officials during periods of emergency. **Finding II.H.3: The use of Army MARS (Military Affiliate Radio System) within the Louisiana emergency communications system was very successful.** Since Andrew, the State of Louisiana has formulated a memorandum of understanding/agreement (MOU/A) with Army MARS that integrates Army MARS operationally into the State of Louisiana emergency communications system. **Recommendation II.H.3: The NWS and FEMA need to coordinate with Army MARS to ensure that these capabilities can be extended to other locations.**

Telephone Facsimile Transmissions

The Louisiana OEM pays for a drop on NWWS. They retransmit severe weather warnings and selected forecast products to all affected state and local emergency management agencies. This system works but is very time consuming, taking up to 15 minutes to transmit a product to only a few users during small-scale weather events. During major events, such as Andrew, the system becomes extremely congested as the event unfolds. In some instances, it was taking 30 minutes to an hour to receive critical information. The overall effectiveness of this form of dissemination was questioned by all parish officials interviewed. An alternative system to warning and forecast dissemination should be pursued.

Telephone facsimile transmissions from the NWS offices to state and local government offices are available. Although this service gives additional technical support and may save lives, it can drain personnel resources. This technique was used early during Andrew to keep local emergency managers as informed as possible.

Louisiana Law Enforcement Telecommunications System (LALETS)

The Louisiana State Police operates LALETS as the statewide telecommunications system. It also is linked to the National Law Enforcement Telecommunications System (NLETS). The NWS provides a drop on NWWS to the Louisiana State Police. The system is programmed to disseminate all warnings and selected weather forecast products automatically to affected state police troopers and local law enforcement agencies. During Andrew, this system was one of the most reliable and efficient means of disseminating information to state and local law enforcement agencies. **Finding II.H.4: The State of Louisiana, Division of Emergency Management, currently does not have a fully automated information redistribution system.** The Louisiana DEM should look into taking advantage of this existing communications system to facilitate the widespread communication of severe weather and flood warnings, watches, and statements to local officials. **Recommendation II.H.4: The NWS and FEMA should encourage the State of Louisiana to explore options for**

providing a fully automated communications system to law enforcement agencies and local emergency operating centers. Once in place, the NWS should arrange to link with that system, allowing two-way communication of critical warning information between the NWS and the emergency management community.

Personal Briefings

The MICs from WSO Baton Rouge, Lake Charles, and WSFO Slidell provided detailed briefings to state and local officials at meetings called to coordinate emergency preparedness for Hurricane Andrew. These meetings proved very beneficial. In addition, a meteorologist from the WSFO was detailed to the New Orleans EOC to coordinate information and provide technical assistance to local officials. This was done in accordance with an existing agreement between the city of New Orleans and the NWS as part of the move to Slidell.

Communication With Users

There are numerous direct and indirect ways the NWS disseminates its forecast products to users. In spite of these point-to-multi-point dissemination systems, many officials still do not receive timely or complete information and, in many cases, have extreme difficulty in contacting their local NWS office directly. Most local emergency managers stated that a more efficient and technically advanced method of communication is long overdue.

Many users find that visual imagery provides greater confirmation of an impending threat, making the forecast more credible. The NWS needs to consider providing products and information in a visual format rather than purely written or verbal. The New Orleans Coast Guard Office is one agency that is interested in receiving plots of track forecasts in graphical form. The only current means of conveying this information is by facsimile.

CHAPTER II.I

DATA COLLECTION

National Data Buoy System

The path of Hurricane Andrew through the Gulf of Mexico and across south-central Louisiana brought the storm within approximately 100 nm of seven weather stations operated by the NDBC (see figures 16 and 17).

The only failure in the gulf, as a result of the storm, was a sea temperature thermistor at a station on the Louisiana coast. These units provide extremely valuable data, but unfortunately there are not enough of them available. Figures 16 and 17 depict the C-MAN network density. The network is rather sparse along the Louisiana coast and the gulf coast, in general. South Florida has a more dense network but that is still not totally adequate.

Aircraft reconnaissance information is combined with nearby C-MAN observations to estimate wind data in and near a hurricane. Andrew's track took it between three C-MAN sites: C-MAN S-2 (Sabine, Texas) on the westernmost portion of the Louisiana coast, and C-MAN S-6 (Grand Isle, Louisiana) and C-MAN S-3 (Southwest Pass, Louisiana) on the east end of the Louisiana coast. Hurricane Andrew was many miles from any C-MAN station. Wind estimates made from data derived through aircraft reconnaissance and compared to distant C-MAN sites are not deemed helpful for estimating maximum landfall winds.

Some significant changes are occurring in the moored buoy and C-MAN networks. **Finding II.I.1: The U.S. Coast Guard (USCG) has decided to remove all large navigational buoys and replace them with other, smaller types of buoys. The replacement buoys are too small to be fitted with meteorological instruments. Loss of the current buoys, in the near future, will mean the loss of hourly data from stations along the Atlantic and Gulf of Mexico coasts.** In many coastal regions, there is a lack of important wind, rain, tide, and other hydrometeorological instrumentation. The lack of fully instrumented buoys significantly affected the computer models due to the paucity of data. **Recommendation II.I.1: The NWS, through its National Data Buoy Center, should ensure that sufficient capabilities are present to maintain hourly observations along the Atlantic and Gulf of Mexico coastal waters.** An enhanced program would greatly benefit the NWS in its assessment of storms.

As seen in figures 16 and 17, many coastal regions lack important wind, rain, tide, and other hydrometeorological measuring devices. This contributed to a lack of data describing current conditions as Andrew was making landfall. This further highlights the importance of a comprehensive data buoy network.

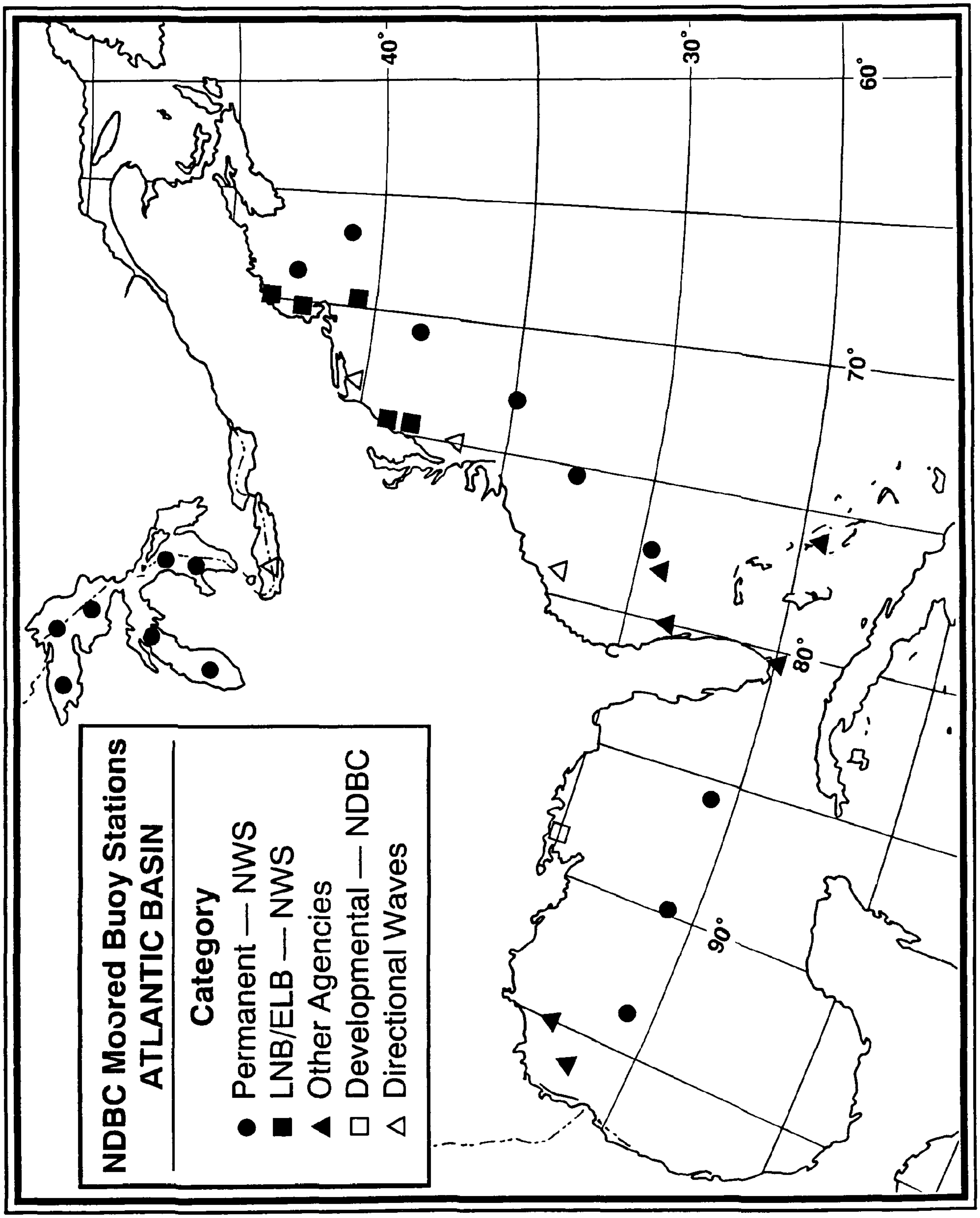


Figure 16 — NDBC Moored Buoy Stations—Atlantic Basin.

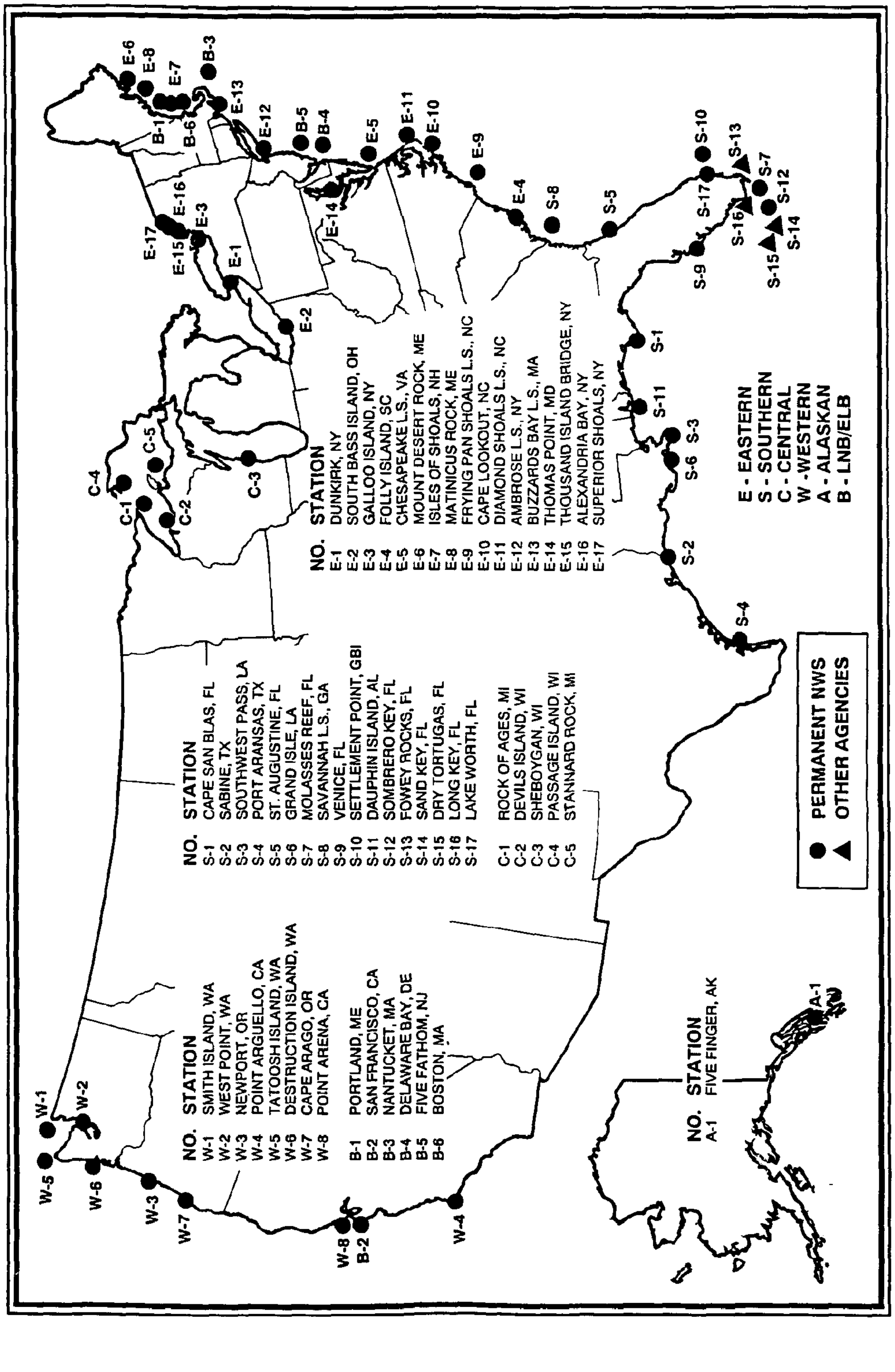


Figure 17 — Coastal C-MAN sites.

A supplemental data source that complements the Data Buoy Network is a fixed remote meteorological network mounted on selected oil platforms. For years, this network has provided the NWS with supplemental hydrometeorological information by filling many of the data gaps between data buoys along the gulf coast. Due to the high cost of maintenance, NOAA has been forced to assess a servicing fee for oil companies. The oil companies have been either unable to or unwilling to pay the service fee, ultimately opting to have all meteorological equipment removed from their oil platforms. <u>Finding II.I.2</u>: **The implementation of service maintenance fees has resulted in the removal of meteorological equipment from gulf oil platforms, and a significant loss of data has occurred.**

The events of Hurricane Andrew continually point to the need for not only more data but more accurate data. <u>Recommendation II.I.2</u>: **NOAA must review its position on charging oil platforms a service fee to maintain meteorological equipment.**

NWS Radars—WSR-57, WSR-74C, and WSR-88D

This complement of radars was used to track the progress of Andrew over portions of the gulf and on to its eventual landfall in Louisiana. The data provided by these systems complemented aircraft reconnaissance and satellite data by giving NWS offices an accurate indication of Andrew's position and movement.

These vintage radar systems performed admirably during Andrew with no recorded equipment failures. These coastal radars provided hourly fixes of Andrew, verifying Andrew's position and track.

The WSR-88D Doppler radars have recently been installed and placed in operation at only a few sites along the gulf coast. None have been installed in Louisiana, but the system in Houston was operational during Andrew. <u>Finding II.I.3</u>: **Although Andrew did not move into WSO Houston's effective Doppler range, the WSR-88D radar did provide extremely detailed reflectivity data on the storm.** The consensus following Andrew was that the performance of Houston's WSR-88D provided the NWS with a glimpse of its operational capabilities. <u>Recommendation II.I.3</u>: **See Recommendation I.I.3.** Examples of the Houston WSR-88D conventional display capabilities are provided as figures 18 and 19.

Aircraft Reconnaissance

Reconnaissance off the Louisiana coast was conducted by U.S. Air Force Reserve (USAFR) aircraft. At their peak, reconnaissance flights were conducted every 2 hours, providing NHC with data critical to NHC and NMC forecast models.

The reconnaissance missions flown during Andrew were conducted through DOD aircraft, dispatched by the USAFR. Department of Commerce aircraft were not employed during Andrew. Utilization of these aircraft was coordinated through NHC and CARCAH. Hurricane track and intensity forecast errors are highly dependent on the accuracy of initial conditions and on the ability of the forecast model to predict the future state of the

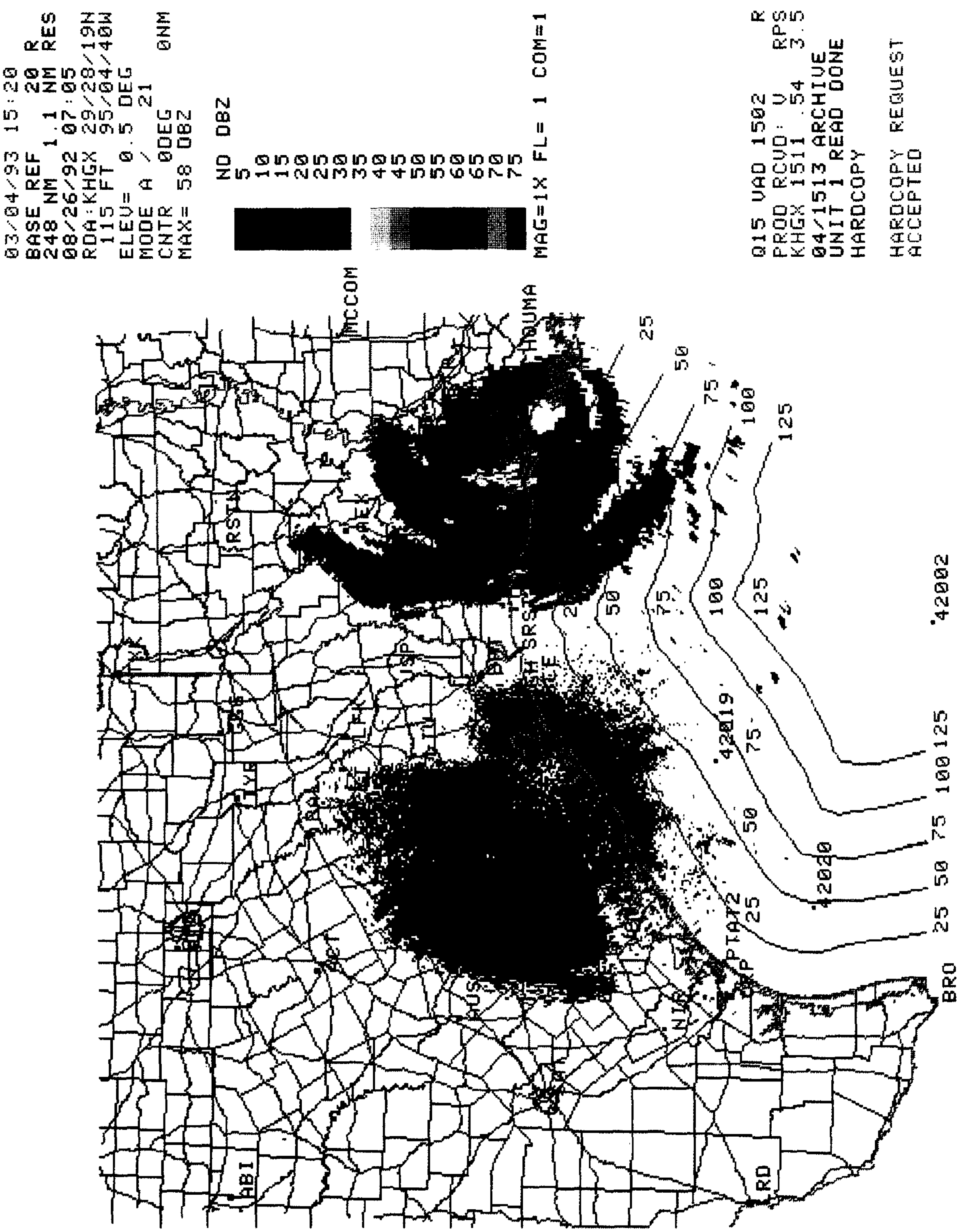


Figure 18 — WSO Houston, Texas, WSR-88D composite reflectivity image of Hurricane Andrew taken at 7:05 UTC, August 26, 1992 (2:05 AM CDT, August 26).

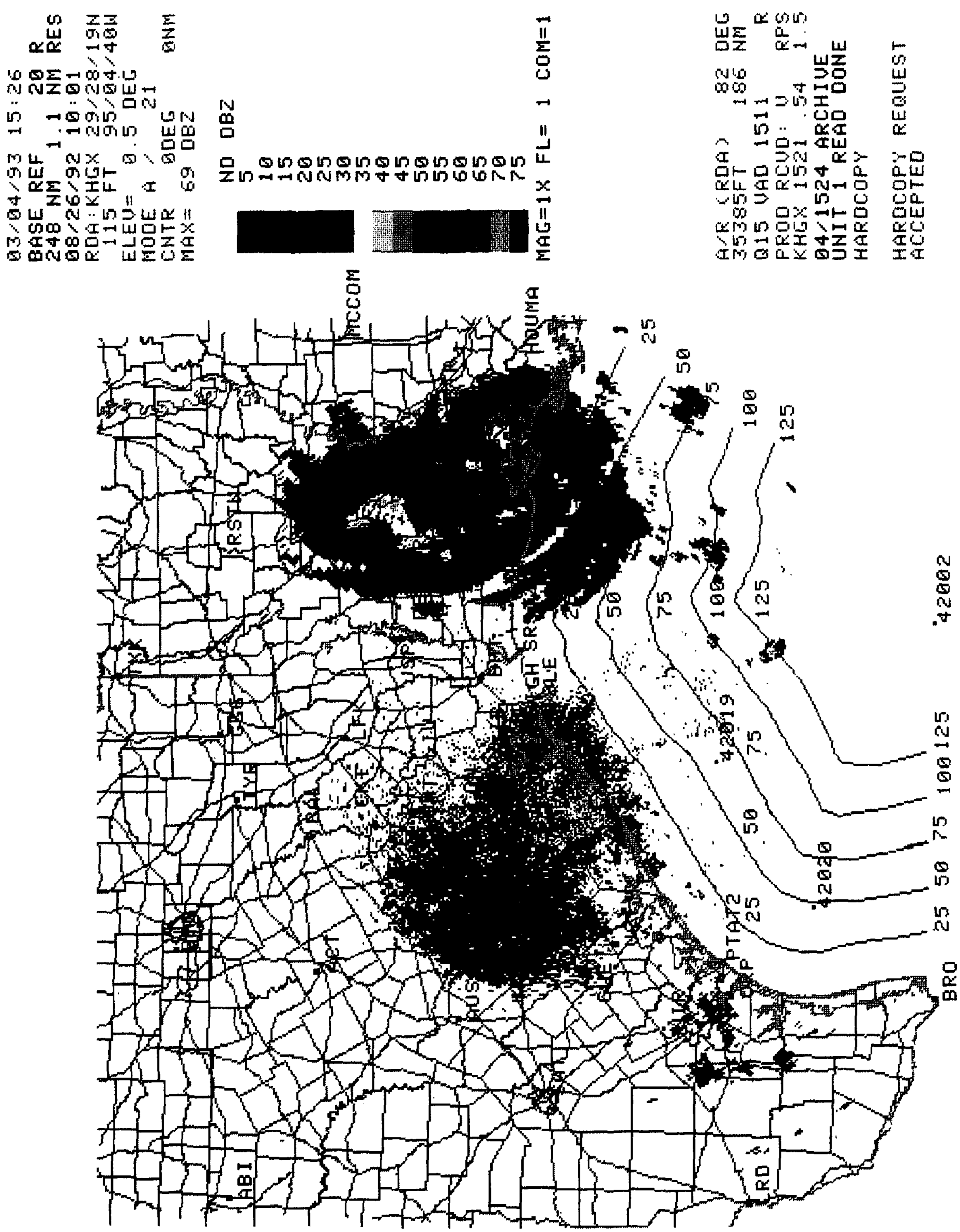


Figure 19 — WSO Houston, Texas, WSR-88D composite reflectivity image of Hurricane Andrew taken at 10:01 UTC, August 26, 1992 (5:01 AM CDT, August 26).

atmosphere. Over oceans, where hurricanes originate, inadequate observations make a major contribution to analysis errors and are, therefore, a formidable obstacle to improved forecasts.

Recent research has proven that supplemental observations around hurricanes can result in large improvements in hurricane track forecasting. This was evidenced in the resulting track forecasts during Hurricane Andrew and supported by the results of a study conducted by the Hurricane Research Division of AOML. Ultimately, aircraft reconnaissance of tropical cyclones must continue in order to make effective use of next generation models for tropical cyclone track and intensity forecasting.

The Hurricane Research Division collected reconnaissance aircraft data off the Louisiana coast and combined them with data from land stations, automated coastal platforms, moored buoys, and ships and assimilated into a composite representation of the storm. Some of these data were collected and processed in real-time, but most of the final composites were compiled during post-storm analysis efforts but show promise for real-time application. The data composites are in a storm-relative coordinate system over a period of several hours in order to provide a field of sufficient data density for analysis. Due to the limited remote sensing data available along the Louisiana coast, the resulting wind composites for Louisiana were less accurate than over Florida. All wind data are converted to produce estimates of sustained winds at the standard 10-meter (33-foot) height over a standard terrain exposure. This approach provides a snapshot of the hurricane's wind field.

Satellite Observations

GOES satellite platform information provided NWS offices with details on storm track, forecast model initialization, and variations within the storm's structure. Satellite information was frequently referenced in NSSFC mesoscale discussions and local office forecast discussion. The use of satellites remains an integral element of the NWS's remote sensing program but must be complemented by other remote sensing equipment. This last satellite of the GOES 7 era has for the past year been experiencing a decaying of its orbit. Had this last remaining satellite failed, the "No-GOES" backup plan would have been implemented. This raises the question of whether under the No-GOES plan the NWS could adequately address the problems of hurricane tracking and forecasting. Periodic testing of the No-GOES plan should ensure its implementation readiness and effectiveness.

Storm Tide and Storm Surge

Increases in water level are measured by two methods, *storm tide* and *storm surge.* Both are described in chapter I.I. Along the Louisiana coast, there were scores of measurements taken by the USACE and USGS. Figure 20 depicts many of these measurements. Note that most of these observations were taken from tide gauges rather than high water marks. Gauges are much more reliable than high water mark observations.

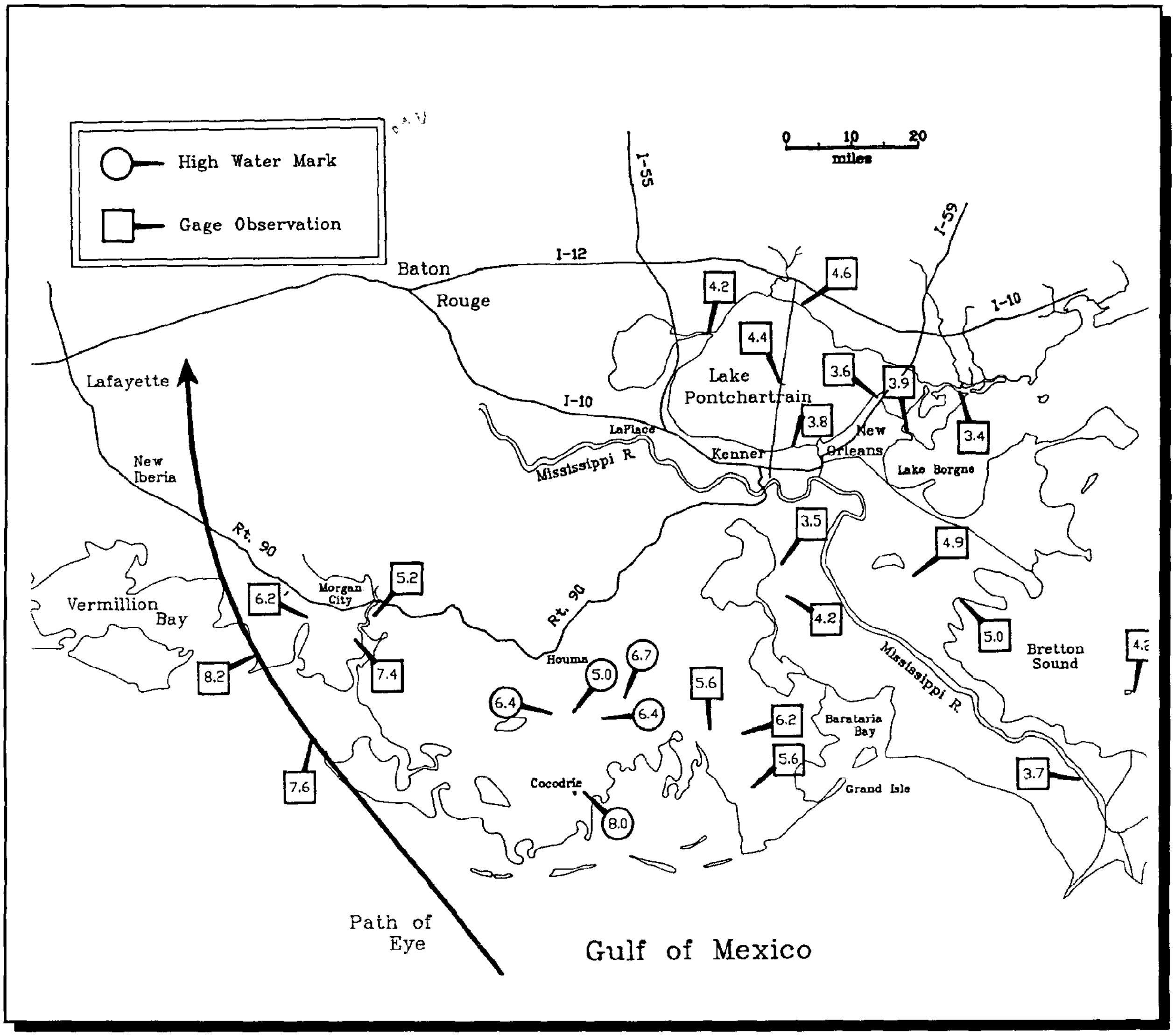


Figure 20 — High water marks along the Louisiana coast during Hurricane Andrew.

CONCLUSION

Its inconspicuous beginning as a weak tropical disturbance in the central Atlantic gave no indication of Andrew's ultimate destiny as "The Hurricane" to change the fabric of south Dade County society. Nevertheless, the damage left in Andrew's wake has become a monument to the potentially profound impact that a powerful hurricane can have on a modern coastal community. Collectively, we among the hazards community should regard Andrew as an ominous wake-up call—a call to mitigate as it were.

As terrible a disaster as Hurricane Andrew was, the economic impact of the storm, had it moved on a path just 20 miles further north, would have been much, much worse. Evidence (figures 21 and 22) suggests that a direct hit on Miami would have cost not $25 billion but $60 billion. Continuing the more northerly track across south Florida to Fort Myers, then across the Gulf of Mexico to New Orleans, compounds the incredible devastation that very easily could have occurred. The difference between the actual track and the one we have just conjectured, from a forecast model standpoint, is in the noise level of resolution.

The substantial change in population distribution along our hurricane vulnerable coastlines dictates that we confront the reality that is the hurricane threat. Major hurricanes possess arsenals that include flash flood producing-rainfall, killer storm surges, and devastating winds. The latter element was the prime cause of damage during Andrew, and those winds swept well inland far from areas evacuated because of the storm surge threat.

If Andrew taught us nothing else, it conveyed the reality that hurricane winds constitute a major threat not only along the immediate coastline but for many miles inland. Preparing for the possibility of extreme inland winds, in addition to the threat of tornadoes, flash floods, riverine flooding, and storm surge, is necessary for private citizenry and emergency planners alike. That another "Andrew" will occur is not conjecture, it is a certainty. Our ability to respond to that reality hinges on how we answer the call to mitigate.

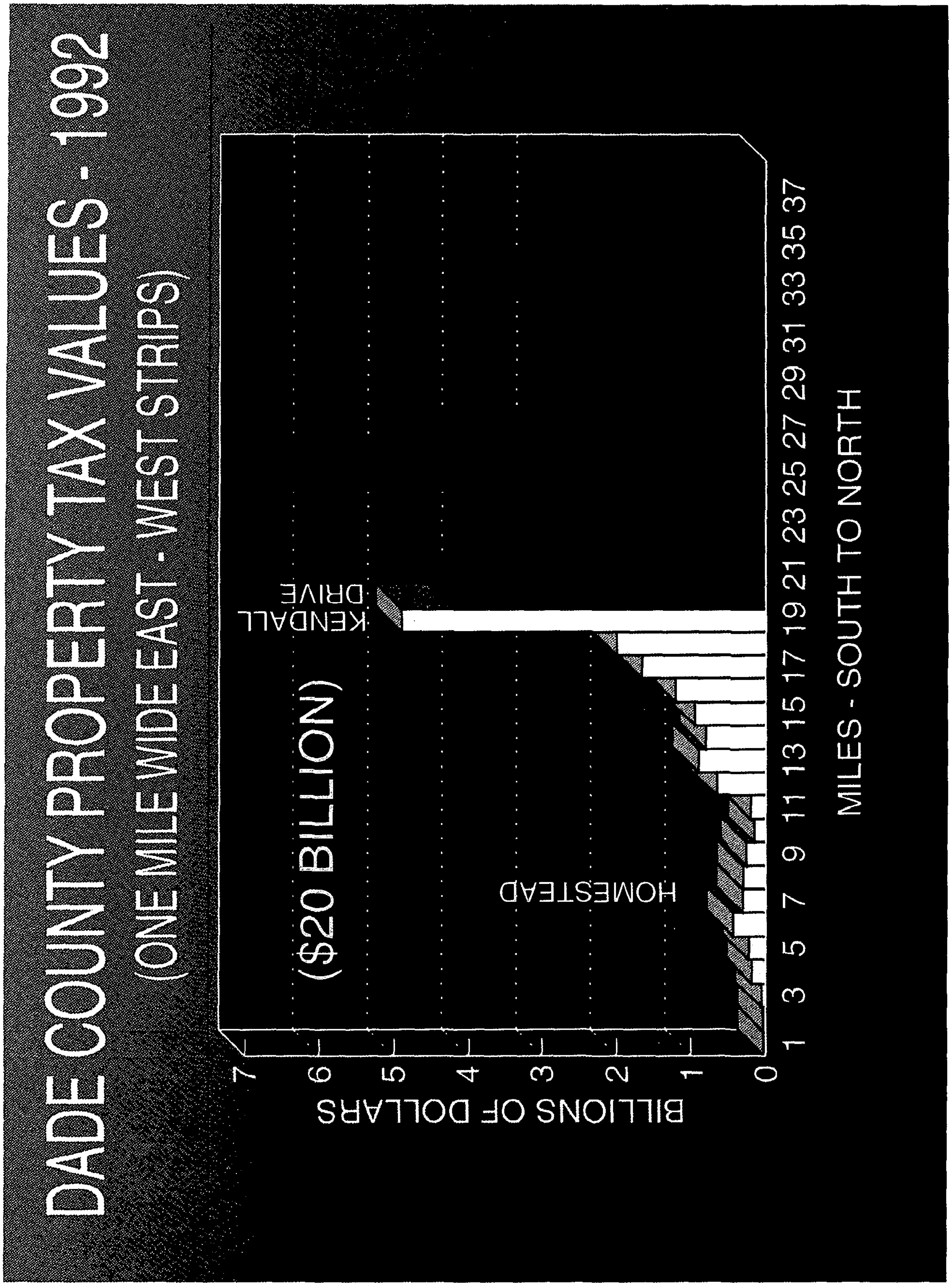


Figure 21 — Dade County Property Tax Values—1992.

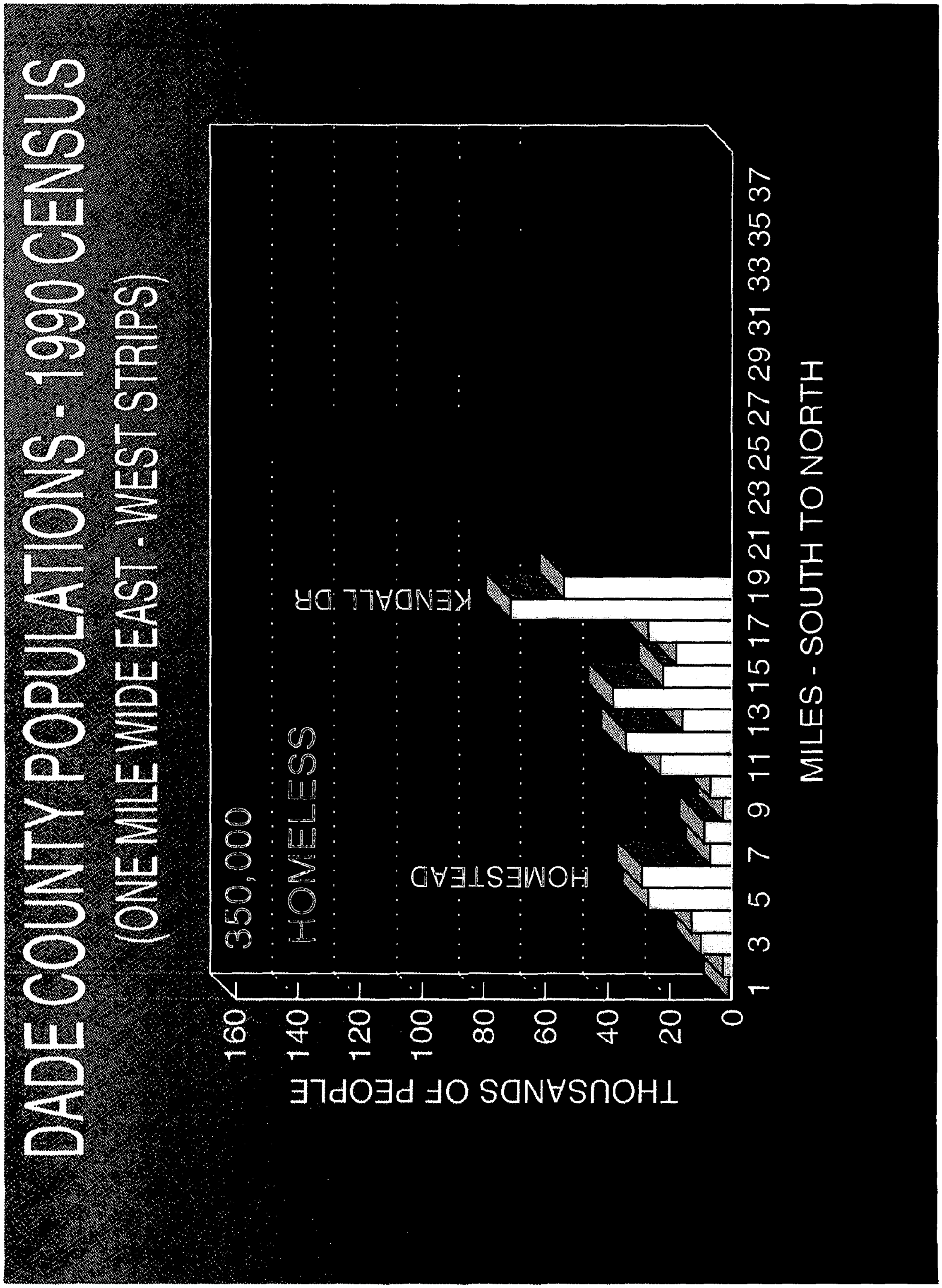


Figure 22 — Dade County Populations—1990 Census.

APPENDICES

APPENDIX A

SUMMARY TABLES

Appendix A, Table A.1

Hurricane Andrew Selected Surface Observations
August 1992

Location	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)			Storm Surge[b] (ft)	Storm Tide[b] (ft)	Rain (Storm Total) (in)
	Pressure (mb)	Date/Time (UTC)	1-Minute Average	Peak Gust	Date/Time (UTC)[a]			
Bahamas								
Harbour Island	935.0[c]	23/2100		120[c,d]	23/shortly after 2100			
Nassau	999.0[c]	24/0000	80	100	24/0025			
Current Island						23		
Lower Bogue (1 n mi inland)						16		
Florida East Coast and Keys								
Tamiami (TMB)	988.0[c,d]		110[c,d,i]		24/0848F			
Miami WSFO/NHC	982.0[c,d]	24/0900	100[c,d,e]	142[c,d,e]	24/0850			
NOAA/AOML	984.0			87[c,d]				
Miami I. Arpt. (MIA)	992.6	24/0900	75[e]	100	24/0950			2.04
Miami Beach DARDC			65[c]	92[c]	24/0816			
Haulover NOS NGWLMS	1004.0		58[c]	115	24/0900			
Fort Lauderdale (FLL)				53[c]				
Palm Beach (PBI)	1010.8	24/0259,0420	43	51	24/1033			
Palm Beach ASOS			42		24/1036			
Key West WSO (EYW)	1010.1	24/1400	25	37	24/1614			0.33
Patrick AFB (COF)	1016.2	24/0955	22	31	24/0735			
Melbourne (MLB)	1016.3	24/0950	15	21	24/1151			
Orlando (MCO)	1016.9	24/0950		30	24/1850			
NASA Shuttle (X68)	1016.9	24/0855	11	23	24/1149			
Titusville (TIX)	1017.9	24/1053	8	14	24/1149			0.80[c]
East Perrine							16.9	
Florida West Coast								
Collier County EOC				87[e]	24/			
Captiva Fire Station				63				
Fort Myers (RSW) `	1010.2	24/1347,1446	30	45	24/1446,1547			0.56
Cape Coral								
Glades County EOC				44	24/btwn 1100 and 1200			
Clrwtr./St. P. Arpt.			30	40	24/1625			
Goodland							6.0[g]	
Everglades City							6.0[g]	

Appendix A, Table A.1

Hurricane Andrew Selected Surface Observations
August 1992

Location	Minimum Sea-level Pressure: Pressure (mb)	Minimum Sea-level Pressure: Date/Time (UTC)	Maximum Surface Wind Speed (kt): 1-Minute Average	Maximum Surface Wind Speed (kt): Peak Gust	Maximum Surface Wind Speed (kt): Date/Time (UTC)[a]	Storm Surge[b] (ft)	Storm Tide[b] (ft)	Rain (Storm Total) (in)
Florida West Coast (cont.)								
Fort Myers Beach							2.0	
Venice							1.8	
Anna Marie Island							1.5	
Homosassa							1.5	
Gulf Harbors							1.5	
Indian Rocks Beach							1.0	
Louisiana								
Morgan City (P42)			80[e]	94[e]				
Baton Rouge (BTR)	996.5	26/1427	42	61	26/1452			5.70
New Orleans (MSY)	1006.6	26/0805	39	57	26/0950			5.70
Bayou Bienvenue								6.28
Salt Point AMOS (P92)			40	72	26/0728			
Lafayette (LFT)	990.5	26/1250	46	62	26/1057			5.51
Lake Charles (LCH)	1008.8		21	34	26/2152			0.05
Berwick Fire Stn.			83[e]	104[e]				
Jeanerette	975.0		71	78[c]				
Jeanerette			67	75	26/0845			
Near Brusly	990.2	26/1337	69	90[c]	26/1310			5.05
Lafayette Courthouse				90[e]				
Mooring 17 (29.2°N 92.0°W)	994.9	26/0930						
Cocodrie							8.0	
Burns Point (St. Mary Parish)							6.8[h]	
Bayou Dupre							6.5	
Bayou Bienvenue							6.3	
NWS HANDAR east N. Orleans							5.6	
Port Fourchon							5.0[h]	
N end of causeway							4.9	
Industrial canal							4.4	
Marina							4.3	
Rigolets							4.2	
Grand Isle							3.5[h]	

Appendix A, Table A.1

Hurricane Andrew Selected Surface Observations August 1992

Location	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)			Storm Surge[b] (ft)	Storm Tide[b] (ft)	Rain (Storm Total) (in)
	Pressure (mb)	Date/Time (UTC)	1-Minute Average	Peak Gust	Date/Time (UTC)[a]			
Alabama								
Huntsville (HSV)	1000.3	27/2250	22	36	27/1742			0.92
Birmingham (BHM)	1001.7	27/2215	19	35	27/1640			1.77
Montgomery (MGM)	1008.8	27/2045	23	31	27/2307			1.55
Mobile (MOB)	1010.1	27/2051	26	35	25/1844			0.64
Mobile State Docks						2.6	3.5	
Dauphin Island							6.0	
Georgia								
Atlanta (ATL)	1005.4	28/0400		39	27/2039			
Mississippi								
Jackson (JAN)	998.6	26/0750	28	49	27/0219			4.79
Tupelo (TUP)			24	36	27/2000			1.86
Meridian (MEI)	1004.4		25	48	27/0945			5.29
State Port (Gulfport)				39	27/1951			
Bay St. Louis							4.5[f]	
Texas								
Port Arthur (BPT)	1011.5	26/1000	22	30	26/1953			
Sabine Pass							1.1	1.3
Ship reports								
OYGK2 (29.5°N 80.6°W)			60		25/1200			
ELLE2 (19.4°N 56.6°W)	1013.5	19/1500	35		19/1500			
C6KD (28.1°N 79.2°W)	1015.5	24/0600	35		24/0600			

Appendix A, Table A.1

Hurricane Andrew Selected Surface Observations
August 1992

Location	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)			Storm Surge[b] (ft)	Storm Tide[b] (ft)	Rain (Storm Total) (in)
	Pressure (mb)	Date/Time (UTC)	1-Minute Average	Peak Gust	Date/Time (UTC)[a]			
Gulf of Mexico platforms[(c,e)]								
SS 198G (28.2°N 92.0°W)			78	100	26/0330			
EC 83H (28.2°N 92.0°W)			46	49	26/0330			
EC 42B (29.5°N 92.8°W)			38	88	26/0430			
SM 136B (28.2°N 92.0°W)			38	44	25/2230			

a Time of 1-minute wind speed unless only gust is given.
b Storm surge is water height above normal tide level. Storm tide is water height relative to National Geodetic Vertical Datum (NGVD) which is defined as mean sea level in 1929.
c A more extreme value may have occurred.
d Equipment became inoperable after this measurement.
e Non-standard elevation.
f Estimated.
g Above Mean Low Water.
h Above Mean Water Level.
i Subsequent laboratory tests at the NHC indicate that the needles on the two windspeed dials at Tamiami Airport "peg" at about 104.6 and 108.1 knots, respectively.

Appendix A, Table A.2

Selected Rainfall Totals Associated with Hurricane Andrew August 1992

Location	Total Rain (in)
Florida	
S-124 (Broward County)	7.79
S-21A (Dade County)	7.41
S-20G (Dade County)	5.19
S-37A (Broward County)	5.14
S-39 (Broward/Palm Beach Counties)	5.12
S-80 (Martin-St. Lucie)	4.94
Everglades Park (Collier County)	*4.50
S-18C (Dade County)	4.48
Marco Island	*3.50
S-20F (Dade County)	4.12
S-308 (Lake Okeechobee area)	3.47
Cudjoe Key	2.02
Louisiana	
Hammond	11.92
Robert	11.02
Amite	10.36
Morgan City	9.31
Manchac	8.75
Jeanerette	7.96
Butte La Rose	7.90
Ponchatoula	7.54
Mt. Herman	7.50
Franklin	7.03
WSFO Slidell	5.06
Jena 4WSW	4.42
Alabama	
Aliceville	4.40
Tuscaloosa	3.60
MRGA1 Morgan	3.46
MRZA1 Mount Roszell	3.21
CDCA1 Red Bay Creek	2.90
WRTA1 Wright	2.89
CBTA1 Colbert	2.75
AKDA1 Lexington	2.66
OAKA1 Oakland	2.62
Georgia	
Hurst	5.24
Mountain City	4.60
Burton	4.31
Clayton	4.30
Nacoochee Pwr	3.83
Helen	3.40
SCHG1 Suches G. Creek	3.32
TUSG1 Titus	3.13
Tallulah	3.05
Jasper	2.67
BRDG1 Blue Ridge Dam	2.65
EPWG1 Epworth H. Store	2.64

* Indicates estimate.

Appendix A, Table A.2

Selected Rainfall Totals Associated with Hurricane Andrew August 1992

Location	Total Rain (in)
Kentucky	
BLWK2	2.56
Mississippi	
Sumrall	9.30
Pelahatchie (gauge)	8.20
Yazoo City	7.63
Crystal Springs	7.24
Pelahatchie (co-op)	7.07
Collins	7.04
Union Church	7.04
Brookhaven	7.02
Mize	6.71
Rockport	6.36
Monticello	6.36
Booneville	6.30
Good Hope	6.14
Vicksburg	5.95
McComb	5.93
Ofahoma	5.82
Bay St. Louis	5.72
White Oak	5.65
Forest	5.59
Liberty	5.59
Goshen Springs	5.52
Port Gibson	5.51
Meadville	5.45
Tylertown	5.38
Columbia	5.32
Philadelphia	5.06
North Carolina	
HDSN7 Highlands	4.68
WLGN7 F-Wallace Gap	2.73
RMNN7 Rosman	2.62
Tennessee	
ELKT1 Elkton	3.80
WNBT1 Waynesboro	3.64
GEOT1 Georgetown	3.43
IRCT1 Iron City-S.C.	3.33
BGLT1 Big Lick	3.25
CBOT1 Crab Orchard	3.07
CLLT1 Collinwood	3.07
PSKT1 Pulaski	3.03
LNVT1 Lynnville	2.97
PICT1 Pickwick Dam	2.95
CLET1 Cleveland	2.91
CLBT1 Columbia	2.80
DYNT1 Dime	2.74
LEWT1 Lewisburg	2.58
CSV Crossville Arpt.	2.57
PKVT1 Pikeville	2.50

Appendix A, Table A.3

Hurricane Andrew Selected NDBC Observations
August 1992

Platform/ Location	Minimum Sea-Level Pressure: Pressure (mb)	Minimum Sea-Level Pressure: Date/Time (UTC)	Maximum Wind Speed (kt): Average[a]	Maximum Wind Speed (kt): Peak Gust	Maximum Wind Speed (kt): Date/Time (UTC)
Fowey Rocks C-MAN FWYF1/ 25.6°N 80.1°W	967.5[b,c]	24/0800	123[b,c]	147[b,c]	24/0800
Bullwinkle Platform BUSL1/ 27.9°N 90.9°W	998.5	25/2300	52	63[b]	25/2225
Molasses Reef C-MAN MLRF1/ 25.0°N 80.4°W	998.5	24/0900	48	59	24/1000
Eastern Gulf Buoy 42003/ 25.9°N 85.9°W	997.4	25/0400	45	63	25/0250
Grand Isle C-MAN GDIL1/ 29.2°N 90.0°W	1005.2	25/2300	48	73	25/2200
Southwest Pass C-MAN BURL1/ 28.9°N 89.4°W	1006.1	25/2200	56	80	25/2100
Sombrero Key C-MAN SMKF1/ 24.6°N 81.2°W	1007.7	24/1100	34	42	24/1130
Lena Platform C-MAN LNEL1/ 28.2°N 89.1°W	1007.7	25/1600			
Eleuthera Buoy 41016/ 24.6°N 76.5°W	1007.9	23/2040	29	35[b]	24/0040
Sand Key C-MAN SANF1/ 24.5°N 81.9°W	1010.2	24/1100,1400	30	43	24/1600
Settlement Point C-MAN SPGF1/ 26.7°N 79.0°W	1012.7	24/0600	38	47	24/0500
Buoy 42007/ 30.1°N 88.8°W	1013.5	25/2250	30	46	25/1850
Dauphin Island C-MAN DPIA1/ 30.2°N 88.1°W	1016.1	26/0000	32	46	25/2100

[a] NOAA buoys report an 8-minute average wind. C-MAN station reports are 2-min. average winds at the top of the hour and 10-min. averages at other times. Contact NDBC for additional details.

[b] A more extreme value may have occurred.

[c] Equipment became inoperable shortly after observation.

Appendix A, Table A.4

Initial Estimates of Casualties and Damages Incurred in Association With Hurricane Andrew.

	Deaths Direct	Deaths Indirect	Damage ($Billion)
Bahamas	**3**	**1**	**0.25**
Florida	**15**[a]	**29**	**20-25**
Dade County	15	25	20-25
Broward County	0	3	0.1
Monroe County	0	1	0.131
Collier County	0	0	0.03
Louisiana	**8**[a]	**9**	**1**
St. J. the B. Parish	2		
Offshore	6		
Lafayette Parish		2	0.017
Vermilion Parish			0.001
Iberville Parish		1	
Terrebonne Parish		3	
Orleans Parish		1	
Plaquemines Parish		1	
Iberia Parish		1	
Georgia			0.001
Total	**26**	**39**	**20-25**

[a] Total includes missing individuals presumed dead.

Appendix A, Table A.5

Hurricane Andrew Average Track Forecast Errors (Nautical Miles), Non-homogeneous Sample

Model	Forecast Period (Hours) 12	24	36	48	72
Official	33	65	106	141	243
(no. of cases)	(37)	(35)	(33)	(31)	(27)
CLIPER	35	81	148	233	437
	(37)	(35)	(33)	(31)	(27)
AVNO	60	75	89	97	132
	(15)	(15)	(14)	(13)	(11)
BAMD	45	93	141	182	268
	(37)	(35)	(33)	(31)	(27)
BAMM	40	81	121	151	229
	(37)	(35)	(33)	(31)	(27)
BAMS	39	77	114	135	197
	(37)	(35)	(33)	(31)	(27)
QLM	39	64	93	130	192
	(19)	(18)	(17)	(16)	(14)
NHC90	35	77	135	197	330
	(37)	(35)	(33)	(31)	(27)
VBAR	32	60	93	138	287
	(23)	(23)	(23)	(23)	(23)
GFDL	36	71	93	117	209
	(9)	(9)	(9)	(9)	(7)

Appendix A, Table A.6

Watch and Warning Summary
Hurricane Andrew

Date/Time(UTC)/Action	
22/1500 Hurricane Watch	Northwest Bahamas from Andros and Eleuthera Islands northward through Grand Bahama and Great Abaco
22/2100 Hurricane Warning	Northwest Bahamas from Andros and Eleuthera Islands northward through Grand Bahama and Great Abaco
22/2100 Hurricane Watch	Florida east coast from Titusville southward through the Florida Keys including the Dry Tortugas
23/0600 Hurricane Warning	Central Bahamas including Cat Island, Great Exuma, San Salvador, and Long Island
23/1200 Hurricane Warning	Florida east coast from Vero Beach southward through the Florida Keys to the Dry Tortugas including Florida Bay
23/1200 Tropical Storm Warning	Florida east coast north of Vero Beach to Titusville
23/1200 Hurricane Watch	Florida west coast south of Bayport including the greater Tampa area to north of Flamingo
23/1800 Hurricane Warning	Florida west coast south of Venice and Lake Okeechobee
23/1800 Tropical Storm Warning	Florida west coast north of Venice to Bayport
24/0900 Hurricane Warning discontinued	Bahamas except for Bimini and Grand Bahama
24/1300 Hurricane Warning discontinued	Remainder of the Bahamas
24/1300 Hurricane Warning discontinued	Florida except for Lake Okeechobee and the west coast south of Venice to Flamingo
24/1300 Tropical Storm Warning and Hurricane Watch discontinued	Florida east coast from Vero Beach to Titusville and Florida west coast from Venice to Bayport
24/1300 Hurricane Watch	Northern gulf coast from Mobile, Alabama, to Sabine Pass, Texas
24/1800 Hurricane Warning discontinued	Remainder of Florida
24/2100 Hurricane Warning	Northern gulf coast from Pascagoula, Mississippi, to Vermilion Bay, Louisiana
25/0900 Hurricane Warning	Vermilion Bay, Louisiana, to Port Arthur, Texas
25/0900 Hurricane Watch	West of Port Arthur through High Island, Texas
25/1500 Hurricane Warning	West of Port Arthur through the Bolivar Peninsula, Texas
25/1500 Hurricane Watch	West of the Bolivar Peninsula to Freeport, Texas
26/0700 Hurricane Warning discontinued	East of Grand Isle, Louisiana
26/0700 Hurricane Watch discontinued	West of the Bolivar Peninsula
26/1100 Hurricane Warning discontinued	West of Port Arthur, Texas
26/1300 Hurricane Warning discontinued	West of Cameron, Louisiana
26/1700 Hurricane Warning discontinued	Remainder of gulf coast

Appendix A, Table A.7

Watch and Warning Lead Times for Landfall Sites during Hurricane Andrew. Lead Time Refers to Time Lapsed From Advisory to Landfall.

Location	Type	Lead Time (hours)
Northwest Bahamas	Hurricane Watch	30
	Hurricane Warning	24
Southeast Florida	Hurricane Watch	36
	Hurricane Warning	21
South-central Louisiana	Hurricane Watch	43
	Hurricane Warning	24

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	16/11PM	17/5AM	17/11AM	17/5PM	17/11PM
Probability End Time:	19/8PM	20/2AM	20/8AM	20/2PM	20/8PM
SVMG 110N 640W	4	5	7	6	X
TTPP 106N 614W	7	8	9	6	X
TTPT 112N 608W	8	10	11	8	X
TGPY 120N 618W	8	10	11	9	X
TBPB 131N 595W	11	14	15	14	4
TVSV 131N 612W	9	11	14	12	3
TLPL 138N 610W	10	12	15	14	5
TFFF 146N 610W	10	12	15	15	8
TDPR 153N 614W	10	12	15	15	10
TFFR 163N 615W	10	12	16	16	13
TAPA 171N 618W	9	11	15	16	15
TKPK 173N 627W	8	10	14	15	14
TNCM 181N 631W	8	9	14	14	14
TISX 177N 648W	6	7	12	12	9
TIST 183N 650W	6	7	11	12	10
TJPS 180N 666W	4	5	9	10	6
TJSJ 184N 661W	4	5	10	11	8
MDSD 185N 697W	X	X	5	5	X
MDCB 176N 714W	X	X	2	3	X
MTPP 186N 724W	X	X	2	2	X
TNCC 122N 690W	X	X	3	2	X
MDPP 198N 707W	X	X	3	4	X
MBJT 215N 712W	X	X	2	3	X
MYMM 224N 730W	X	X	X	2	X
ST CROIX VI	6	7	12	12	9
ST THOMAS VI	6	7	11	12	10
SAN JUAN PR	4	5	10	11	8
PONCE PR	4	5	9	10	6

Advisory Issue Time:	18/5AM	18/11AM	18/5PM	18/11PM	19/5AM
Probability End Time:	21/2AM	21/8AM	21/2PM	21/8PM	22/2AM
TBPB 131N 595W	4	3	X	X	X
TVSV 131N 612W	3	3	X	X	X
TLPL 138N 610W	6	6	2	X	X
TFFF 146N 610W	9	9	4	2	2
TDPR 153N 614W	11	13	7	4	3
TFFR 163N 615W	15	18	13	8	6
TAPA 171N 618W	18	21	17	14	10
TKPK 173N 627W	16	20	17	14	10
TNCM 181N 631W	17	21	19	19	17
TISX 177N 648W	12	16	14	14	12
TIST 183N 650W	13	17	16	16	15
TJPS 180N 666W	8	13	12	12	11
TJSJ 184N 661W	10	15	14	14	14
MDSD 185N 697W	3	6	7	8	8
MDCB 176N 714W	X	2	3	3	3
MTPP 186N 724W	X	2	3	3	3
MDPP 198N 707W	3	6	8	8	9

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	18/5AM	18/11AM	18/5PM	18/11PM	19/5AM
Probability End Time:	21/2AM	21/8AM	21/2PM	21/8PM	22/2AM
MBJT 215N 712W	3	7	8	9	11
MYMM 224N 730W	X	4	5	6	8
MYSM 241N 745W	X	2	3	4	6
MYEG 235N 758W	X	X	2	2	3
MYNN 251N 775W	X	X	X	X	2
ST CROIX VI	12	16	14	14	12
ST THOMAS VI	13	17	16	16	15
SAN JUAN PR	10	15	14	14	14
PONCE PR	8	13	12	12	11

Advisory Issue Time:	19/11AM	19/5PM	19/11PM	20/5AM	20/11AM
Probability End Time:	22/8AM	22/2PM	22/8PM	23/2AM	23/8AM
TAPA 171N 618W	2	X	X	X	X
TKPK 173N 627W	4	X	X	X	X
TNCM 181N 631W	7	3	X	X	X
TISX 177N 648W	6	3	2	2	2
TIST 183N 650W	9	5	3	3	3
TJPS 180N 666W	7	5	4	4	4
TJSJ 184N 661W	9	6	4	4	4
MDSD 185N 697W	6	7	6	6	6
MDCB 176N 714W	3	4	3	3	4
MTPP 186N 724W	3	6	4	4	5
MDPP 198N 707W	8	11	9	9	9
MBJT 215N 712W	11	16	13	13	12
MYMM 224N 730W	8	14	11	12	11
MYSM 241N 745W	6	14	9	10	10
MYEG 235N 758W	3	10	6	6	7
MYNN 251N 775W	X	8	3	4	5
MUGM 200N 751W	X	6	3	3	4
MUCM 214N 779W	X	3	X	X	2
MYAK 241N 776W	X	7	3	3	5
MTCA 183N 738W	X	4	3	3	3
MYGF 266N 787W	X	6	2	2	4
ST CROIX VI	6	3	2	2	2
ST THOMAS VI	9	5	3	3	3
SAN JUAN PR	9	6	4	4	4
PONCE PR	7	5	4	4	4
MARATHON FL	X	2	X	X	X
MIAMI FL	X	3	X	X	2
W PALM BEACH FL	X	4	X	X	2
FT PIERCE FL	X	3	X	X	2
COCOA BEACH FL	X	3	X	X	X
DAYTONA BEACH FL	X	2	X	X	X
MARCO ISLAND FL	X	2	X	X	X
BERMUDA	X	X	3	X	3

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time: Probability End Time:	20/5PM 23/2PM	20/11PM 23/8PM	21/5AM 24/2AM	21/11AM 24/8AM	21/5PM 24/2PM
MDSD 185N 697W	4	X	X	X	X
MDCB 176N 714W	2	X	X	X	X
MTPP 186N 724W	4	X	2	2	2
MDPP 198N 707W	7	3	3	3	6
MBJT 215N 712W	12	6	8	6	6
MYMM 224N 730W	13	7	9	8	8
MYSM 241N 745W	13	8	12	11	12
MYEG 235N 758W	10	5	8	9	10
MYNN 251N 775W	8	3	7	9	10
MUGM 200N 751W	5	X	3	4	3
MUCM 214N 779W	4	X	2	5	5
MYAK 241N 776W	7	2	6	8	9
MTCA 183N 738W	3	X	2	2	X
MYGF 266N 787W	6	2	6	9	9
MUHA 230N 824W	X	X	X	3	3
MKJS 185N 779W	X	X	X	2	2
MWCG 193N 814W	X	X	X	2	X
MUCF 221N 805W	X	X	X	4	4
MUSN 216N 826W	X	X	X	2	2
MARATHON FL	2	X	X	5	6
MIAMI FL	3	X	2	7	7
W PALM BEACH FL	4	X	3	7	8
FT PIERCE FL	3	X	3	7	8
COCOA BEACH FL	3	X	3	6	7
DAYTONA BEACH FL	2	X	2	6	6
MARCO ISLAND FL	2	X	X	5	6
BERMUDA	2	6	3	2	2
MYRTLE BEACH SC	2	X	3	4	4
WILMINGTON NC	2	2	4	3	4
MOREHEAD CITY NC	3	3	5	3	3
CAPE HATTERAS NC	2	3	5	3	3
CHARLESTON SC	2	X	3	4	4
NORFOLK VA	X	X	3	2	2
OCEAN CITY MD	X	X	2	X	X
SAVANNAH GA	X	X	2	4	4
KEY WEST FL	X	X	X	5	5
JACKSONVILLE FL	X	X	X	5	6
FT MYERS FL	X	X	X	5	6
VENICE FL	X	X	X	5	5
TAMPA FL	X	X	X	5	5
CEDAR KEY FL	X	X	X	4	4
ST MARKS FL	X	X	X	3	3
APALACHICOLA FL	X	X	X	X	3
PANAMA CITY FL	X	X	X	X	2
GULF 29N 85W	X	X	X	X	2
GULF 29N 87W	X	X	X	X	2

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	21/11PM	22/5AM	22/11AM	22/5PM	22/11PM
Probability End Time:	24/8PM	25/2AM	25/8AM	25/2PM	25/8PM
MBJT 215N 712W	3	2	X	X	X
MYMM 224N 730W	6	6	5	X	X
MYSM 241N 745W	11	13	17	27	35
MYEG 235N 758W	9	10	12	15	11
MYNN 251N 775W	11	13	17	27	35
MUGM 200N 751W	3	X	X	X	X
MUCM 214N 779W	4	5	6	7	2
MYAK 241N 776W	9	11	14	22	27
MYGF 266N 787W	11	13	17	24	24
MUHA 230N 824W	4	5	8	14	16
MWCG 193N 814W	X	X	X	4	X
MUCF 221N 805W	X	X	X	4	X
MUSN 216N 826W	2	3	6	10	9
MUAN 219N 850W	2	3	5	9	11
MMCZ 205N 869W	X	X	3	5	5
MARATHON FL	6	8	12	19	23
MIAMI FL	8	10	14	21	23
W PALM BEACH FL	9	11	15	20	20
FT PIERCE FL	9	11	15	18	16
COCOA BEACH FL	9	11	14	16	13
DAYTONA BEACH FL	8	10	12	13	10
MARCO ISLAND FL	7	9	13	19	21
BERMUDA	2	X	X	X	X
MYRTLE BEACH SC	6	6	5	X	X
WILMIMGTON NC	5	5	4	X	X
MOREHEAD CITY NC	5	5	3	X	X
CAPE HATTERAS NC	4	4	2	X	X
CHARLESTON SC	6	7	6	3	2
NORFOLK VA	2	2	X	X	X
SAVANNAH GA	6	7	7	5	4
KEY WEST FL	5	7	11	18	21
JACKSONVILLE FL	7	8	9	9	7
FT MYERS FL	7	9	13	18	19
VENICE FL	6	8	12	17	17
TAMPA FL	7	9	11	15	14
CEDAR KEY FL	6	8	10	13	11
ST MARKS FL	4	6	8	10	9
APALACHICOLA FL	4	5	7	11	10
PANAMA CITY FL	3	5	6	10	9
GULF 29N 85W	4	6	8	12	11
GULF 29N 87W	2	4	6	11	11
PENSACOLA FL	2	3	5	9	8
MOBILE AL	2	X	4	8	7
MMD 210N 897W	X	X	2	3	5
GULFPORT MS	X	X	3	8	7
BURAS LA	X	X	3	8	9
NEW ORLEANS LA	X	X	3	7	7
NEW IBERIA LA	X	X	2	5	6
GULF 28N 89W	X	X	4	10	11

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	21/11PM	22/5AM	22/11AM	22/5PM	22/11PM
Probability End Time:	24/8PM	25/2AM	25/8AM	25/2PM	25/8PM
GULF 28N 91W	X	X	2	7	9
FREEPORT TX	X	X	X	2	4
PORT O CONNOR TX	X	X	X	2	3
PORT AUTHUR TX	X	X	X	3	4
GALVESTON TX	X	X	X	3	4
GULF 28N 93W	X	X	X	5	7
GULF 28N 95W	X	X	X	3	5
GULF 27N 96W	X	X	X	2	4
BROWNSVILLE TX	X	X	X	X	3
CORPUS CHRISTI TX	X	X	X	X	3
GULF 25N 96W	X	X	X	X	4

Advisory Issue Time:	23/5AM	23/11AM	23/5PM
Probability End Time:	26/2AM	26/8AM	26/2PM
MYSM 241N 745W	26	13	X
MYEG 235N 758W	12	2	X
MYNN 251N 775W	51	68	99
MYAK 241N 776W	34	34	17
MYGF 266N 787W	36	43	61
MUHA 230N 824W	18	15	10
MUCF 221N 805W	10	5	X
MUSN 216N 826W	9	5	X
MUAN 219N 850W	11	9	6
MMCZ 205N 869W	5	4	X
MARATHON FL	30	32	37
MIAMI FL	34	40	56
W PALM BEACH FL	30	33	47
FT PIERCE FL	23	23	28
COCOA BEACH FL	11	10	9
DAYTONA BEACH FL	11	10	9
MARCO ISLAND FL	28	31	42
CHARLESTON SC	X	X	X
SAVANNAH GA	3	2	X
KEY WEST FL	27	28	31
JACKSONVILLE FL	7	6	X
FT MYERS FL	25	27	37
VENICE FL	21	22	29
TAMPA FL	17	17	20
CEDAR KEY FL	13	12	13
ST MARKS FL	10	10	9
APALACHICOLA FL	12	12	12
PANAMA CITY FL	12	11	11
GULF 29N 85W	14	14	15
GULF 29N 87W	14	14	15
PENSACOLA FL	11	11	11
MOBILE AL	10	11	11
MMMD 210N 897W	5	5	X
GULFPORT MS	10	11	12

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	23/5AM	23/11AM	23/5PM
Probability End Time:	26/2AM	26/8AM	26/2PM
BURAS LA	12	13	14
NEW ORLEANS LA	11	12	13
NEW IBERIA LA	9	11	13
GULF 28N 89W	14	16	17
GULF 28N 91W	12	14	16
FREEPORT TX	7	9	12
PORT O CONNOR TX	6	8	11
PORT AUTHOR TX	7	10	12
GALVESTON TX	7	10	12
MMSO 238N 982W	2	3	X
MMTM 22N 979W	X	2	X
GULF 28N 93W	10	12	14
GULF 28N 95W	7	10	12
GULF 27N 96W	6	9	11
BROWNSVILLE TX	4	6	8
CORPUS CHRISTI TX	4	7	9
GULF 25N 96W	4	7	8

Advisory Issue Time:	23/11PM	24/5AM	24/11AM	24/5PM
Probability End Time:	26/8PM	27/2AM	27/8AM	27/2PM
MYGF 266N 787W	60	30	X	X
MUHA 230 N 824W	4	2	X	X
MUAN 219N 850W	3	3	X	X
MMCZ 205N 869W	X	2	X	X
MARATHON FL	53	62	X	X
MIAMI FL	71	99	X	X
W PALM BEACH FL	42	73	X	X
FT PIERCE FL	14	8	X	X
COCOA BEACH FL	7	4	X	X
DAYTONA BEACH FL	5	3	X	X
MARCO ISLAND FL	50	83	99	X
CHARLESTON SC	X	X	X	X
SAVANNAH GA	2	X	X	X
KEY WEST FL	41	37	X	X
JACKSONVILLE FL	4	3	X	X
FT MYERS FL	37	67	94	X
VENICE FL	26	46	62	X
TAMPA FL	16	19	6	X
CEDAR KEY FL	10	10	4	X
ST MARKS FL	8	8	6	6
APALACHICOLA FL	11	12	9	8
PANAMA CITY FL	10	11	11	10
GULF 29N 85W	13	15	13	9
GULF 29N 87W	14	16	25	23
PENSACOLA FL	10	12	15	16
MOBILE AL	10	12	17	18
MMMD 210N 897W	3	3	X	X
GULFPORT MS	11	13	19	21
BURAS LA	13	16	24	26

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	23/11PM	24/5AM	24/11AM	24/5PM
Probability End Time:	26/8PM	27/2AM	27/8AM	27/2PM
NEW ORLEANS LA	12	14	21	23
NEW IBERIA LA	12	14	20	21
GULF 28N 89W	16	19	33	36
GULF 28N 91W	15	17	26	28
FREEPORT TX	10	11	13	13
PORT O CONNOR TX	10	10	11	10
PORT ARTHUR TX	10	12	16	17
GALVESTON TX	11	12	15	15
MMSO 238N 982W	5	3	X	X
GULF 28N 93W	13	15	19	19
GULF 28N 95W	11	12	13	13
GULF 27N 96W	10	10	9	8
BROWNSVILLE TX	8	6	4	3
CORPUS CHRISTI TX	9	8	7	6
GULF 25N 96W	9	7	4	4
MMTM 222N 979W	3	X	X	X
MMTX 210N 974W	2	X	X	X

Advisory Issue Time:	24/11PM	25/5AM	25/11AM	25/5PM	25/11PM
Probability End Time:	27/8PM	28/2AM	28/8AM	28/2PM	28/8PM
FT PIERCE FL	2	X	X	X	X
COCOA BEACH FL	2	X	X	X	X
DAYTONA BEACH FL	3	X	X	X	X
MARCO ISLAND FL	2	X	X	X	X
CHARLESTON SC	2	X	X	X	X
SAVANNAH GA	3	X	X	X	X
JACKSONVILLE FL	4	X	X	X	X
FT MYERS FL	2	X	X	X	X
VENICE FL	3	X	X	X	X
TAMPA FL	4	X	X	X	X
CEDAR KEY FL	6	X	X	X	X
ST MARKS FL	9	5	X	X	6
APALACHICOLA FL	11	7	6	4	6
PANAMA CITY FL	13	8	7	6	7
GULF 29N 85W	11	6	5	4	5
GULF 29N 87W	21	15	9	6	6
PENSACOLA FL	16	13	11	9	11
MOBILE AL	18	16	14	13	11
GULFPORT MS	20	20	18	16	15
BURAS LA	23	32	50	44	64
NEW ORLEANS LA	21	25	36	37	66
NEW IBERIA LA	19	23	38	50	76
GULF 28N 89W	37	68	99	99	6
GULF 28N 91W	24	40	63	99	99
FREEPORT TX	11	16	17	15	5
PORT O CONNOR TX	9	13	13	10	2
PORT ARTHUR TX	14	18	24	28	30
GALVESTON TX	13	17	20	19	11

Appendix A, Table A.8

Chances of the Center of Hurricane Andrew Passing within 65 Miles of Listed Locations by Date and Time (EDT) Indicated, Probabilities in Percent With X for Less than 2 Percent

Advisory Issue Time:	24/11PM	25/5AM	25/11AM	25/5PM	25/11PM
Probability End Time:	27/8PM	28/2AM	28/8AM	28/2PM	28/8PM
MMSO 238N 982W	X	3	X	X	X
GULF 28N 93W	17	21	21	22	8
GULF 28N 95W	12	16	14	11	3
GULF 27N 96W	8	12	9	6	X
BROWNSVILLE TX	4	7	5	2	X
CORPUSCHRISTI TX	6	10	9	6	X
GULF 25N 96W	4	7	4	X	X

APPENDIX B

FLORIDA DEATHS DIRECTLY ATTRIBUTABLE TO HURRICANE ANDREW AUGUST 1992

AGE	RACE	SEX	CAUSE OF DEATH	CIRCUMSTANCE
47	BLACK	MALE	ASPHYXIA DUE TO CHEST COMPRESSION	TREE FELL ON CAMPER
12	WHITE	FEMALE	BLUNT HEAD TRAUMA	STRUCK BY BEAM FROM ROOF WHILE IN HER HOME
25	WHITE	MALE	MASSIVE HEAD TRAUMA	ROOF OF HOME CAVED IN
74	WHITE	MALE	MULTIPLE INJURIES	TRUCK TRAILER WITHOUT WHEELS (BEING USED AS A SHELTER)
49	WHITE	MALE	CRANIOCEREBRAL TRAUMA	ROLLED OVER AND COLLAPSED (ELEVEN OTHERS SURVIVED)
32	WHITE	MALE	DROWNING	ABOARD ANCHORED BOAT AT TIME OF STORM; LATER FOUND FLOATING IN CANAL
62	WHITE	MALE	MECHANICAL ASPHYXIA	TRAILER COLLAPSED AND ROLLED OVER
67	WHITE	MALE	POSITIONAL ASPHYXIA	TRAPPED UNDER DEBRIS FROM CEILING THAT COLLAPSED
80	WHITE	FEMALE	MECHANICAL ASPHYXIA	REFUSED EVACUATION; BURIED UNDER DEBRIS WHEN TRAILER COLLAPSED
46	WHITE	MALE	MULTIPLE BLUNT TRAUMA	FOUND IN RESIDENCE DESTROYED BY STORM
49	WHITE	MALE	MULTIPLE BLUNT TRAUMA	LEFT HOME WHEN IT BEGAN TO COLLAPSE; KILLED BY FLYING DEBRIS OUTSIDE HOME
67	WHITE	FEMALE	MULTIPLE PENETRATING INJURIES	TOWNHOUSE COLLAPSED
54	WHITE	MALE	MULTIPLE BLUNT TRAUMA	ROOF COLLAPSED
37	WHITE	MALE	BLUNT CRANIOCEREBRAL TRAUMA	STRUCK BY FLYING OBJECT ABOARD BOAT, AND FELL OVERBOARD DURING STORM; LATER WASHED ASHORE ON ISLAND
56	WHITE	MALE	DROWNING	WASHED OVERBOARD (BODY NEVER RECOVERED)

APPENDIX C

HURRICANE ANDREW "BEST TRACK" SUMMARY: AUGUST 16-28, 1992

Appendix C
Hurricane Andrew "Best Track" Summary: August 16-28, 1992

Date/Time (UTC)	Location (lat/long)		Wind (kts)	Pres (mb)	Stage	Movement (spd/dir) (kts)	Remarks
16/1800	10.8	35.5	25	1010	Depression	280/18	
17/0000	11.2	37.4	30	1009		280/18	
17/0600	11.7	39.6	30	1008		280/20	
17/1200	12.3	42.0	35	1006		285/22	
17/1800	13.1	44.2	35	1003	Tropical Stm.	285/20	Dvorak 2.5
18/0000	13.6	46.2	40	1002		290/18	
18/0600	14.1	48.1	45	1001		285/18	
18/1200	14.6	49.9	45	1000		285/20	
18/1800	15.4	51.8	45	1000		285/20	Pulsating deep convection
19/0000	16.3	53.5	45	1001		290/17	
19/0600	17.2	55.3	45	1002		295/16	
19/1200	18.0	56.9	45	1005		295/18	Upper low shearing system
19/1800	18.8	58.3	45	1007		295/18	Wind 63 kts at flight lvl
20/0000	19.8	59.8	40	1011		295/18	
20/0600	20.7	60.0	40	1013		305/14	Ill-defined center
20/1200	21.7	60.7	40	1015		305/14	
20/1800	22.5	61.5	40	1014		310/09	Sustained 54-kt wnd @ 5,000
21/0000	23.2	62.4	45	1014		310/10	Recon unable to find center
21/0600	23.9	63.3	45	1010		315/12	Pk wind 64 kt 65 nm E of ctr
21/1200	24.4	64.2	50	1007		310/10	Better organization
21/1800	24.8	64.9	50	1004		300/09	Shear decreasing
22/0000	25.3	65.9	55	1000		300/09	Strong ridge N of storm
22/0600	25.6	67.0	60	994	Hurricane	290/09	Sust. 83-kt wnd FL/Eye forms
22/1200	25.8	68.3	70	981		275/12	Max. 99-kt wnd FL/stg eyewall
22/1800	25.7	69.7	80	969		270/13	Hcn. watch NW Bahamas/S. Fl.
23/0000	25.6	71.1	90	961		265/12	
23/0600	25.5	72.5	105	947		270/14	Recon Pk wnd 121 kts.
23/1200	25.4	74.2	120	933		270/14	Hcn. warning S. Florida
23/1800	25.4	75.8	135	922		270/14	Eye 8 nm./LF Eleuthera 23/21z
24/0000	25.4	77.5	125	930		270/14	Concentric eye/LF SBay 24/01z
24/0600	25.4	79.3	120	937		270/16	Landfall S.Fl. 24/09z--922mb
24/1200	25.6	81.2	110	951		275/14	Hcn. watch NW gulf coast
24/1800	25.8	83.1	115	947		275/16	Clear eye MLB WSR-88D
25/0000	26.2	85.0	115	943		280/16	
25/0600	26.6	86.7	115	948		280/15	
25/1200	27.2	88.2	115	946		290/15	Hcn. watch expanded west
25/1800	27.8	89.6	120	941		300/15	Concentric eye
26/0000	28.5	90.5	120	937		300/14	2nd min pres 25/21z--932 mb
26/0600	29.2	91.3	115	955		310/11	La Place tornado 26/0010z
26/1200	30.1	91.7	80	973		320/10	LA Landfall 26/0830z-956 mb
26/1800	30.9	91.6	50	991		010/07	{At least 10 tornadoes LA
27/0000	31.5	91.1	35	995	Tropical Stm.	010/07	& 27 MS, 26/1930z-27/0030z}
27/0600	32.1	90.5	30	997	Depression	030/07	
27/1200	32.8	89.6	30	998		050/08	
27/1800	33.6	88.4	25	999		050/08	
28/0000	34.4	86.7	20	1000		050/08	
28/0600	35.4	84.0	20	1000		050/08	Dissipated

APPENDIX D

ANDREW'S TOLL ON LOUISIANA

Death and Injury Toll

Hurricane Andrew's track was well forecast and public health officials had adequate time to prepare. The Epidemiology Section of Louisiana's Office of Public Health established an injury reporting procedure. Hospital emergency rooms and coroners' offices in 19 parishes were asked to report hurricane-related health problems. The period of surveillance (August 24 through September 21) included all injuries or illnesses related to the hurricane, including pre-storm preparation and post-storm recovery and cleanup efforts.

The efforts of the state's health department's epidemiological section incorporated the services of 21 hospitals, 1 public utility, and 5 coroner's offices. In total, they reported 462 hurricane-related events, including 17 deaths. Of the 17 documented deaths, 8 were *directly* attributed to Hurricane Andrew (see appendix D, table D.1). Table D.2 of appendix D lists and describes the 9 deaths *indirectly* attributed to Andrew.

Of the non-fatal events, 383 of 445 (86 percent) were injuries and 62 of 445 (14 percent) were illnesses. Only 17 percent of these cases occurred during Hurricane Andrew; the large majority (79 percent) occurred during the aftermath. High percentages such as this have been documented in numerous other hurricanes.

Most events happened in or around the home. The most common non-fatal injury was a cut/laceration/puncture wound, followed by a sprain/strain (appendix D, table D.3).

St. Mary, St. John, and Iberia Parishes incurred the highest injury rates (appendix D, figure D.1). Figure D.1 depicts the rates of injury and illness by parish. Note the relationship of the hardest hit parishes to their relative position to Andrew's landfall point and the eye-wall region.

Future planning for hurricanes should take into account the high rate of lacerations, particularly during the cleanup phase of the recovery. Based upon projected landfall, areas should prepare well in advance of landfall for the potential of significantly higher rates of incidence.

Property and Resource Losses

Preliminary data for the 36-parish disaster area indicated that 3,301 single, multifamily, and mobile homes were destroyed, and 18,247 units received major or minor damages. Data compiled by a consortium of state agencies and groups with specific responsibilities in agriculture indicated that estimated agricultural losses would exceed $288 million.

Sugarcane yield losses were estimated at $128.4 million, cotton losses at $68.2 million, and forestry-related losses at $38.6 million. The consortium also estimated losses of $13.2 million for the soybean crop, $12.7 million for corn, and $9.1 million for rice.

Commercial and Recreational Boating

Andrew affected an unknown number of commercial ships, recreational vessels, and barges throughout the Mississippi basin and the northern gulf coast.

Documentation, as provided by U.S. Coast Guard, District Eight, revealed that a number of ships were lost and rescue efforts had to be conducted. Despite efforts by the NWS, local emergency management, and state officials, many persons were slow to respond or failed to heed warnings.

Louisiana fared much better than south Florida since Andrew missed the major boating areas north and east of New Orleans. Many boat owners also had enough advance warning and moved their vessels out of the path of the storm up into one of Louisiana's many bayous where they had more protection. To date, no formal estimate of monetary loss has been computed for commercial and recreational marine interests as the result of Hurricane Andrew.

F-3 tornado damage to the communities of La Place/Reserve located 30 miles west of New Orleans, Louisiana.

Appendix D, Table D.1

Deaths Directly Attributable to Hurricane Andrew (Louisiana) August 1992

(Source: Centers for Disease Control)

AGE	RACE	SEX	CAUSE OF DEATH	CIRCUMSTANCE
32	ASIAN	MALE	DROWNING	COMMERCIAL FISHING LOST DURING ANDREW IN INTERNATIONAL WATERS (GULF OF MEXICO) WITH FIVE OTHERS
33	ASIAN	MALE	DROWNING	(SAME AS ABOVE)
26	ASIAN	MALE	DROWNING	(SAME AS ABOVE)
30	ASIAN	MALE	DROWNING	(SAME AS ABOVE)
44	ASIAN	MALE	DROWNING	(SAME AS ABOVE)
??	ASIAN	MALE	DROWNING	(SAME AS ABOVE)
2	WHITE	FEMALE	HEMORRHAGE SECONDARY TO FRACTURES OF HEAD, NECK, AND TORSO	INJURED WHEN HURRICANE-RELATED TORNADO STRUCK HOME
63	WHITE	MALE	CRUSHING INJURIES TO HEAD AND NECK	(SAME AS ABOVE)

Appendix D, Table D.2

Deaths Indirectly Attributable to Hurricane Andrew (Louisiana) August 1992

(Source: Centers for Disease Control)

AGE	RACE	SEX	CAUSE OF DEATH	CIRCUMSTANCE
??	WHITE	MALE	MULTIPLE TRAUMATIC INJURIES	MOTOR VEHICLE ACCIDENT DURING EVACUATION
50	WHITE	FEMALE	MULTIPLE BLUNT FORCE TRAUMA	MOTOR VEHICLE ACCIDENT; BECAME DISORIENTED WHILE DRIVING DURING THE STORM
34	WHITE	MALE	ELECTROCUTION	CLEARING YARD DEBRIS WHEN CAME IN CONTACT WITH LIVE ELECTRICAL POLE
42	WHITE	MALE	CRUSH INJURIES TO TORSO	FALL FROM TREE WHILE CUTTING TREE FROM HOME
33	WHITE	MALE	POSSIBLE ELECTROCUTION AND CARDIOPULMONARY ARREST	WORKING ON ELECTRICAL POLE
79	WHITE	MALE	CARDIAC ARREST	COMPLAINED OF SHORTNESS OF BREATH
86	BLACK	MALE	ASPHYXIATION	(NO INFORMATION)
44	BLACK	MALE	CARDIAC ARREST	(NO INFORMATION)
65	WHITE	MALE	CARDIAC ARREST	COMPLAINED OF CHEST PAIN

Appendix D, Table D.3

Nature of Hurricane Andrew-related Injury and Illness in Louisiana August 24-September 21, 1992

(Source: Centers for Disease Control)

Nature	Deaths Frequency (%)	Injury/Illness Frequency (%)
Cut/laceration/puncture	0	184 (41)
Sprain/strain	0	49 (11)
Contusion/impact	3 (19)	46 (10)
Insect bite/sting	0	23 (5)
Rash	0	23 (5)
Fall	1 (6)	23 (5)
Crush	1 (6)	15 (4)
Burn	0	10 (2)
Anxiety	0	8 (2)
Drowning	6 (37)	0
Dog bite	0	1 (.2)
Asphyxiation	1 (6)	0
Electrocution	2 (12)	1 (.2)
Other	3 (19)	62 (14)
TOTAL	17 (100)	445 (100)

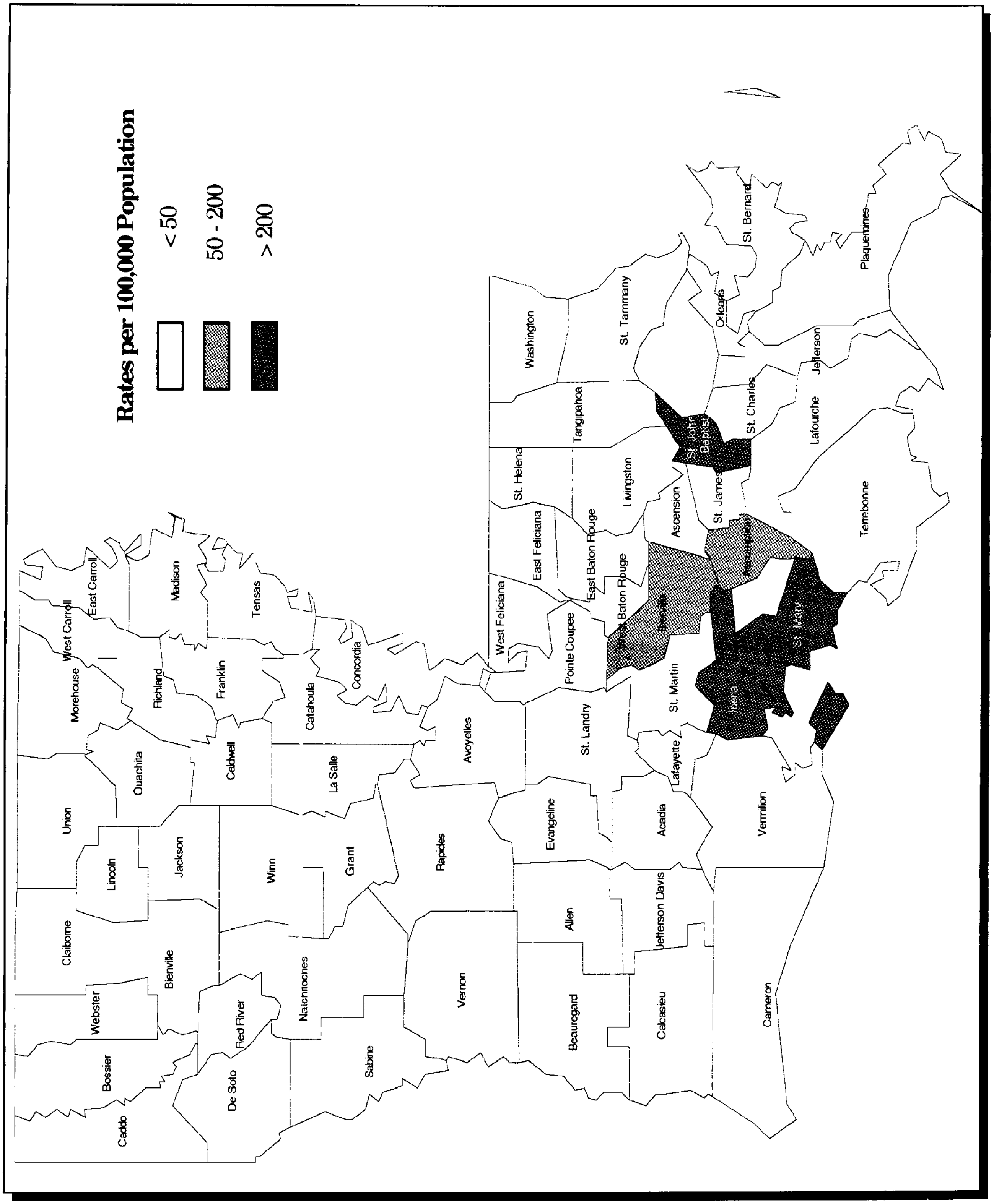


Figure D.1 — Rates of injury and illness by parish.
(Source: Centers for Disease Control)

APPENDIX E

LOUISIANA DAMAGE DESCRIPTION

Wind and Tornadoes

Most storm-related damage was caused by wind, wind-blown rain, and tornadoes. Post storm summaries compiled by WSFO Slidell confirmed 14 tornadoes. There were numerous additional reports of small tornadoes and funnel clouds. In Mississippi, 27 tornadoes were confirmed with numerous tornado and funnel cloud reports received.

In south Louisiana, tornadoes ranged from F-0 to F-3 on the Fujita Tornado Intensity Scale, Figure 4. A tornado of F-3 intensity touched down near the subdivision of Belle Pointe near Reserve in St. John the Baptist Parish. The tornado skipped along a 9- to 10-mile path between La Place and Reserve on the evening of August 25. The best estimate of tornado inflicted damage is excess of $20 million. Table E.1 of appendix E presents a breakdown of the tornado damage inflicted upon St. John the Baptist Parish.

St. Mary and Iberia Parishes received widespread wind and wind-blown rain damage. In all areas, mobile homes were the most susceptible to damage or destruction. Many mobile homes fell victim to extreme wind loads and airborne debris caused by Andrew. Even in the coastal areas where mobile homes were "cradled" and elevated, the cradled foundations remained intact, but the mobile homes mounted to these foundations were often heavily damaged or destroyed. Other minor to moderate wind damage occurred throughout much of the declared disaster area (Disaster Declaration Map, Appendix E, Figure E.1), including damaged building roofs and windows.

Flooding

Although Andrew's rainfall pattern (see figure E.2, appendix E) in Louisiana was similar to other hurricanes making landfall in the central gulf coast region both in terms of magnitude and distribution, very little in the way of significant flooding developed in Louisiana. This was primarily due to the fact that hydrologic conditions prior to Hurricane Andrew's arrival in Louisiana were quite dry. Minor to moderate river flooding did develop along portions of several rivers in Louisiana, but damages caused by the flooding were limited. Instead, the flooding caused mainly nuisance-type problems, such as road closures, minor urban flooding, and agricultural flooding.

Storm Surge

The majority of flood damage caused by Hurricane Andrew was storm surge related and occurred in Lower Terrebonne Parish. Damage, in general, was minimal as surge values were half their expected levels in the vicinity of Cocodrie (7-9 ft), Dulac and Chauvin (4-5 ft), and Montegut (2-4 ft). Even so, a high percentage of older homes and businesses in Cocodrie suffered extensive damage.

The highest recorded storm surge mark was recorded at Luke's Landing along East Cote Blanche Bay, where 8.2 feet was observed at a USACE water level gauge. Several other gauges recorded surge heights over 6 feet during Andrew. Lake Pontchartrain was raised to a level of approximately 4.5 feet NGVD. Fortunately, these surge heights occurred shortly before the occurrence of normal (astronomical) high tide. In the area impacted by Andrew, this would have added about 1 foot to the observed readings. Tidal traces indicate that prior to Andrew's landfall, water was being forced away from the coastline by offshore winds, resulting in depressed water levels (below MSL). As the eye passed and the winds became onshore, water levels rose rapidly and reached their observed peaks.

Impact on Fisheries and Wildlife

Louisiana's legendary fisheries received a severe blow when Andrew slid along the Louisiana coast before making landfall. Fresh water fish kill estimates have been estimated at nearly $160 million. Louisiana Department of Wildlife and Fisheries biologists estimate that, of this total, nearly 5 million were large mouth bass valued at $21 million. In the Atchafalaya Basin, it has been estimated that nearly 182 million fresh water fish have died. Saltwater fish biologists have compiled fish kill counts at beaches and bays in south Terrebonne Parish, where Andrew was most brutal. They calculated that 9.4 million fish suffocated as of August 31. The loss of fish native to this area is estimated at $8 million.

While the numbers of marine fishes killed is not expected to impact greatly the coastal recreational fishing, biologists estimate conservatively that the coastal sports industry will suffer a loss of $12 million during September and October of 1992. Louisiana's marine recreational fishing industry depends on the accessibility to coastal waters and the availability of marine facilities. These have both suffered greatly due to the effects of Andrew.

The commercial fishing industry also is expected to be heavily impacted for months. Louisiana harvests 3.5 million pounds of seafood during September and October at an estimated retail value of $210 million. It was estimated that the industry would experience an immediate loss of $54 million. This figure does not reflect direct physical damage to shoreside support facilities or the loss of markets. Similar losses were inflicted on wildlife resources, furbearers, and alligators.

The total monetary loss to the state based on these studies, including losses to natural resources, impacts on industry, and impacts on the department, is nearly $266 million. The total is expected to rise even higher. The above figures were provided by the Information and Education Division of the Louisiana Department of Wildlife and Fisheries.

Appendix E, Table E.1

St. John the Baptist Parish
Damage Assessment
(Source: St. John the Baptist Parish)

PRIVATE SECTOR		
Housing (Homes/Mobile Homes)	$ 6,726,250	
Business/Commercial	$ 3,428,500	$10,154,750
PUBLIC BUILDINGS		$ 1,957,500
AGRICULTURE		
Sugar Cane	$ 1,000,000	
Soy Bean	$ 100,000	$ 1,100,000
ELECTRICAL UTILITY		$ 1,500,000
TOTAL FOR THE PARISH		$14,712,250

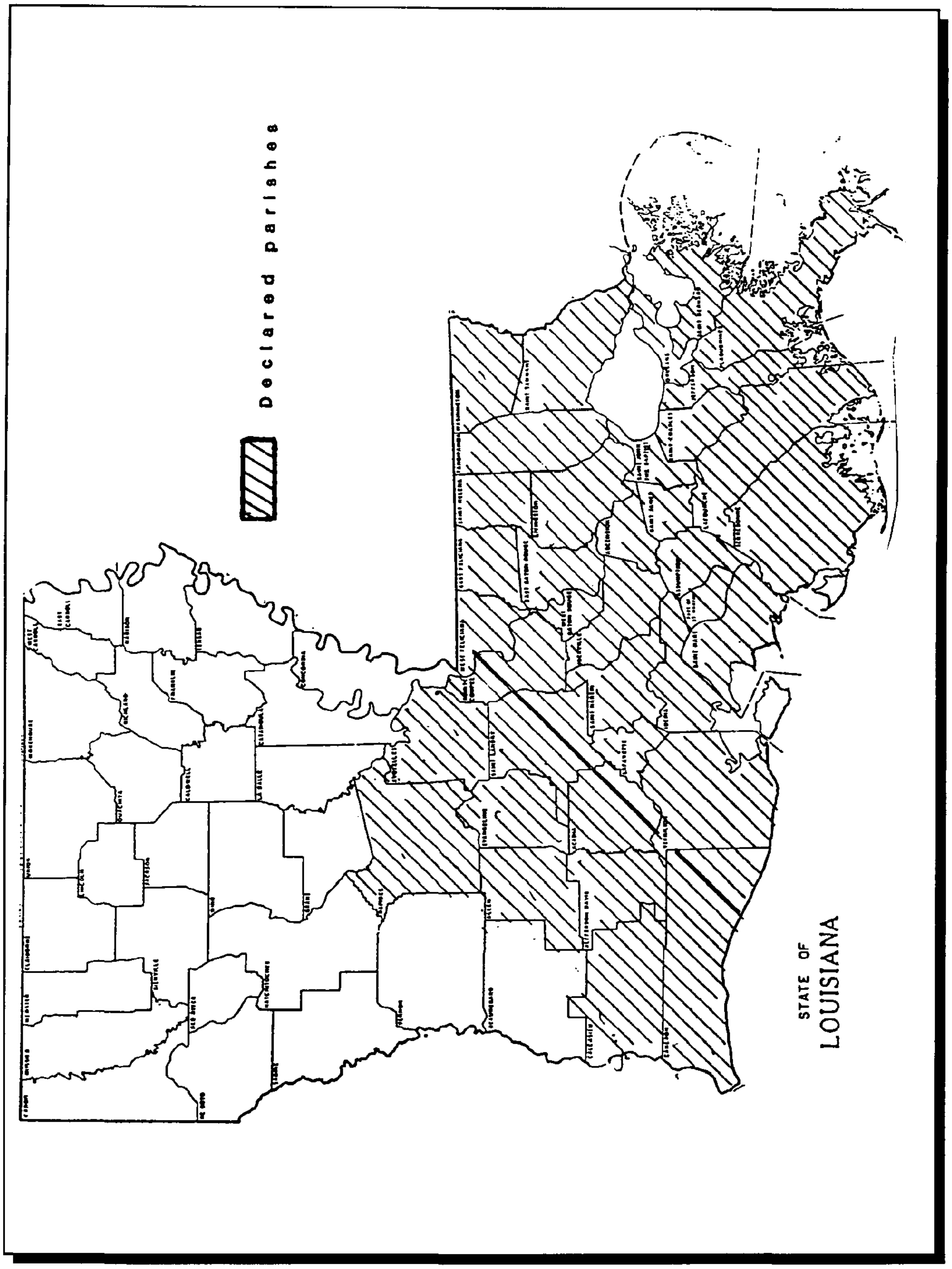


Figure E.1 — Disaster Declaration Map.
(Source: FEMA)

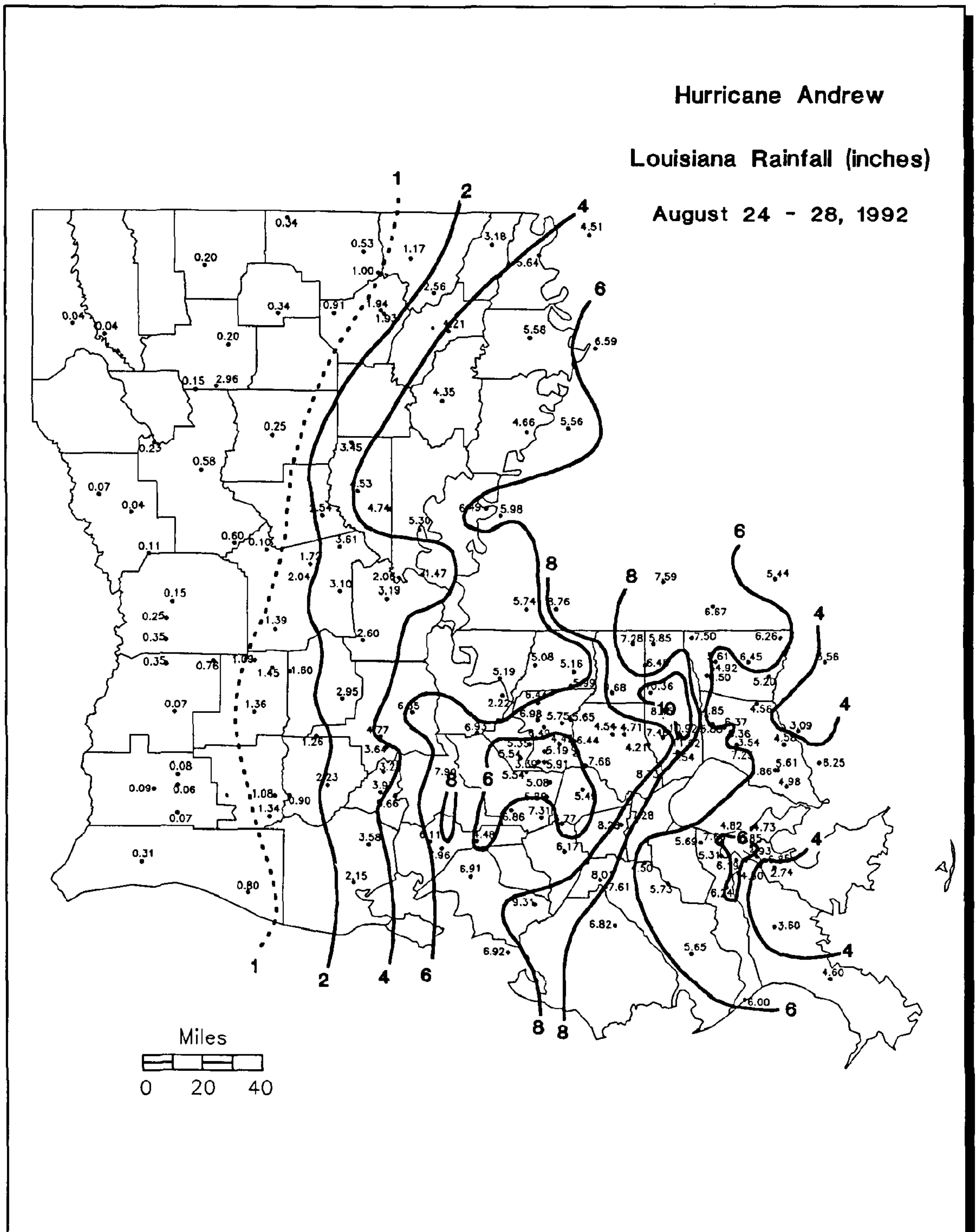


Figure E.2 — Louisiana Rainfall Totals and Analysis for Hurricane Andrew.

Impact on the Petroleum Industry

The petroleum industry plays a large role in the economy of Louisiana. The gulf coast from Texas to Mississippi is dotted by numerous submerged wells and oil well structures (platforms), including appurtenances, such as satellite wells and oil pipes. The largest concentration of oil platforms, satellites, and drilling rigs are located off the Louisiana coast. The total number of oil platforms and satellites is approximately 3,800, with about 150 oil drilling rigs. These facilities are extremely vulnerable to hurricanes. Their destruction poses a major threat to the ecology of the gulf. Appendix E, table E.2, is a summary of hurricane damage as a result of Andrew.

Appendix E, Table E.2

Summary of Damage

(Source: NWS Lower Mississippi River Forecast Center)

Platforms Toppled	14
Platforms Leaning	4
Satellites Toppled	31
Satellites Leaning	82
Structural Damage	112
Pollution Incidents	7
Fires	2
Drift	5

In addition to platforms damaged, 309 pipelines were damaged. Damage also was inflicted on oil storage tanks both onshore and offshore. The Ship Shoal and South Timbalier areas suffered the most damage to their pipeline network (appendix E, figure E.3). The damage inflicted upon the various petroleum networks is congruent to the region along Andrew's track where the greatest damage would be expected. The various petroleum companies operating in the gulf have as yet not provided damage estimates from Andrew. The petroleum industry estimates a one-half billion dollars in losses due to the damaged equipment and the interruption of operations caused by the storm.

The U.S. Coast Guard, District Eight, reported working as many as 79 reports of pollution or lost oil as a result of Andrew. Spill emanated from a variety of sources, with approximately two-thirds offshore in Federal and state waters. Most spills were considered minor, but one ruptured pipeline released between 300 and 500 barrels of oil.

Considering the number of wells and pipelines, the petroleum industry fared very well. This can be attributed to the safety efforts employed by the industry and the efforts that they put into their awareness and preparedness programs.

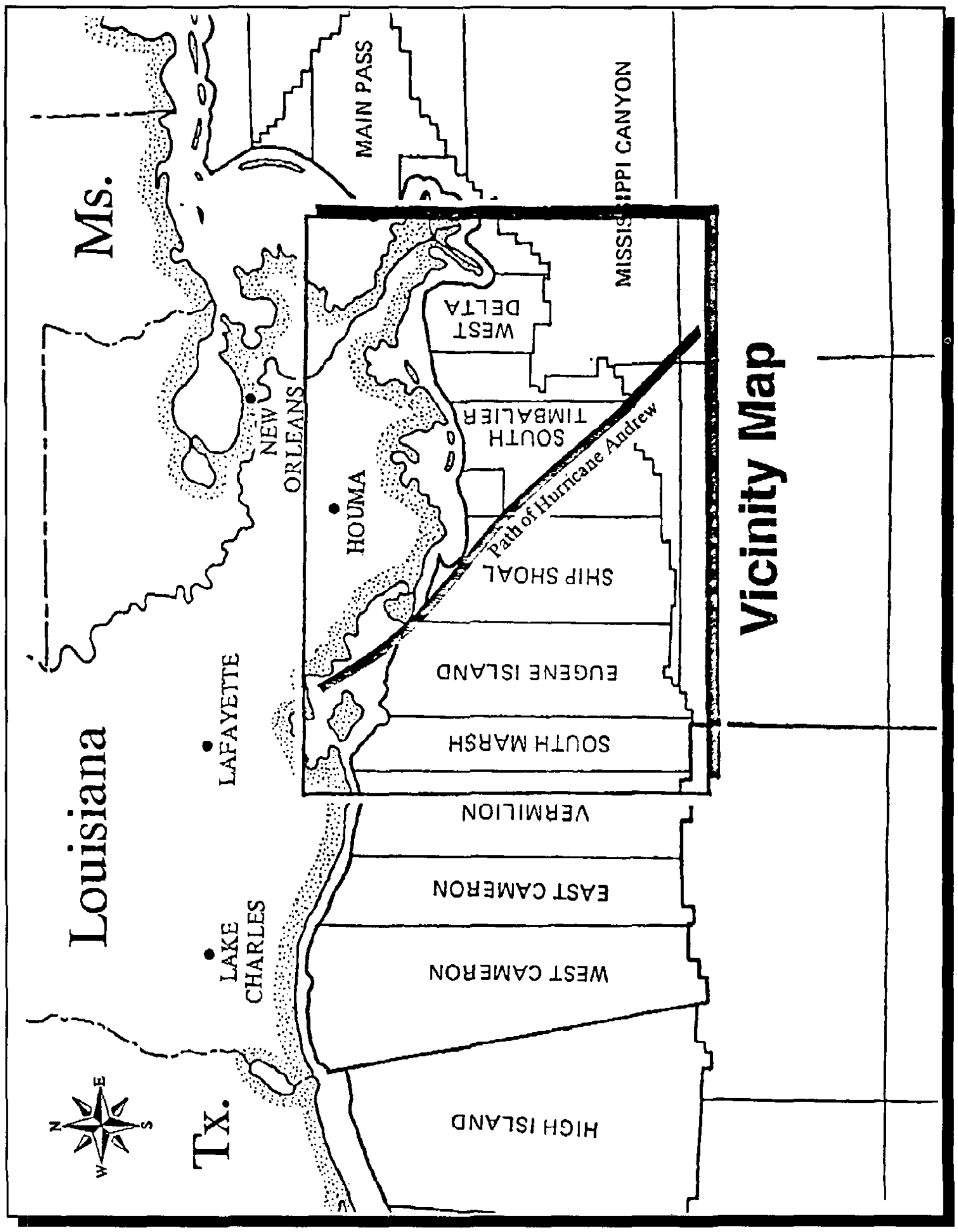


Figure E.3 — Coastal Petroleum Pipeline Network.
(Source: U.S. Department of the Interior)

APPENDIX F

INTERAGENCY COORDINATING COMMITTEE ON HURRICANES (ICCOH)

Background

The ICCOH consists of a group of agencies brought together to broaden the areas of cooperation between the agencies in matters dealing with hurricane-related activities. The primary agencies involved are NOAA, FEMA, USACE, and the American Red Cross.

Following Hurricane Hugo, great interest was placed on the National Hurricane Program. Unfortunately, the Loma Prieta earthquake redirected this interest to the National Earthquake Hazards Reduction Program. Subsequently, great strides were realized in the Earthquake Preparedness Program. Following Andrew, the most devastating natural disaster in American history, the ICCOH toured the devastated area and came to the conclusion that a formal national hurricane preparedness program was needed that emphasized evacuation but had funding to actively pursue mitigation activities.

Finding

When a tropical cyclone strikes, the combination of wind, rain, and storm surge can cause enormous sociological, economical, and ecological damage. It threatens the lives and livelihood of all who lie in its path. Although a tropical cyclone can move across an area in only a few hours, billions of dollars in property can be lost and many deaths and injuries can occur. The sociopolitical infrastructure, including highways, communications systems, power grids, and pipelines can be decimated. The amount of time necessary to recover fully from such a catastrophe may require years.

The United States coast from Brownsville, Texas, to East Port, Maine, is subject to the ravages of hurricanes as are the Hawaiian Islands and the United States protectorates in the Pacific Ocean and Caribbean Sea. Today, there is a growing awareness in the United States that hurricanes are a national threat, both economically and sociologically. Moreover, the direct, localized effects of a major hurricane does not fully define the full scope of its effects.

Balancing the risks of the Nation's hurricane threat are technology and understanding which can mitigate much of the damaging effects of hurricanes. Modern hurricane forecasting and hurricane evacuation planning have dramatically reduced the loss of life in recent hurricane events. Methods have been developed which, when fully implemented, will reduce further the effects of storms both to life and property. Presently, several Federal agencies are engaged in hurricane impact mitigation activities. Still, a cooperative, interagency program to develop such activities is not in place.

The principle cooperative, multiagency hurricane activity is the Federal Hurricane Preparedness Program (HPP). The HPP, through its Hurricane Evacuation Study program, has been extremely effective in reducing loss of life caused by storm surge drowning. However, to date it has done relatively little to address the need to mitigate structural damage caused by hurricane-induced wind. The enormous damage caused by Hurricane Andrew is compelling evidence that the present Federal hurricane program is inadequate. It presents strong argument to create a comprehensive hurricane program which recognizes the need to reduce future loss of life and property from all effects of hurricanes, including wind.

Recommendation

In recognition of the need for such a comprehensive Federal hurricane hazard mitigation program, the ICCOH proposes establishing a National Tropical Cyclone Hazard Reduction Program, comparable to the earthquake mitigation program which gained greater prominence and support after the 1989 Loma Prieta earthquake.

APPENDIX G

SAFFIR-SIMPSON HURRICANE SCALE

Category	Definition—Effects
ONE	**Winds 74-95 mph:** No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal road flooding and minor pier damage.
TWO	**Winds 96-110 mph:** Some roofing material, door, and window damage to buildings. Considerable damage to vegetation, mobile homes, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of center. Small craft in unprotected anchorages break moorings.
THREE	**Winds 111-130 mph:** Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain continuously lower than 5 feet ASL may be flooded inland 8 miles or more.
FOUR	**Winds 131-155 mph:** More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Major damage to lower floors of structures near the shore. Terrain continuously lower than 10 feet ASL may be flooded requiring massive evacuation of residential areas inland as far as 6 miles.
FIVE	**Winds greater than 155 mph:** Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Major damage to lower floors of all structures located less than 15 feet ASL and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5 to 10 miles of the shoreline may be required.

AFTERWORD

OUTSIDE CONSULTANT'S SUPPLEMENT TO THE DISASTER SURVEY REPORT ON HURRICANE ANDREW SUBMITTED TO THE NOAA ADMINISTRATOR

NOTE: The views and opinions expressed in the following commentary do not necessarily reflect the views and opinions of NOAA, the National Weather Service, or any of the other outside consultants involved in the Hurricane Andrew Disaster Survey Report.

Natural Disaster Surveys performed after catastrophic weather events call for the participation of a consultant outside the government. While serving in that role in Louisiana during the aftermath of Hurricane Andrew (and later in Hawaii, following Hurricane Iniki), I was struck by the uniformly high regard for the National Weather Service expressed by the public, the emergency management community, and local governmental officials. Though there was an occasional crack that the Weather Service is unable to get the daily forecasts right, there was uniform trust in NWS pronouncements on the hurricane threat.
Very few agencies of the Federal Government are viewed so positively by the public and state officials as the National Weather Service.

NWS Staffing Issues

Local emergency managers' trust of NWS personnel is largely the result of regular contact over a long period of time preceding the hurricane threat, often several years. During the preparation for Hurricane Andrew, emergency managers did not question the competence of the NWS. In interviews, they explicitly attributed this to the long-standing relationship between the NWS offices and their local community. Emergency managers and municipal leaders in Louisiana also noted that they trusted the local NWS offices to evaluate information coming from the National Hurricane Center to be sure that it was appropriate for their locale before passing it on.
Plans should be made to maintain the high level of individual contact between the NWS staff and local emergency managers, despite the reduction in number of offices scheduled under the modernization plan. Furthermore, multiple simultaneous changes in senior personnel at local NWS facilities should be avoided unless that office has lost the trust of its community.

The emergency managers also based their trust of NWS on the expertise of their regular NWS contacts. In particular, several emergency managers spoke of increased confidence from the fact that they received information directly from NWS personnel involved in making forecasts, rather than from individuals whose responsibilities had been limited to preparedness issues and communications.

The individuals responsible for liaison with emergency managers, regardless of their titles, should have regular forecasting duties. With the scheduled reduction in the number of offices, this may require that more than one individual per office have outreach responsibilities to the emergency management community, especially if the amount of contact is not to be reduced.

The public's trust in the NWS was significantly greater than that placed in media meteorologists, even when media personnel were actually meteorologists and not just weather readers. Concern was expressed to us that private providers of weather information have a vested interest in magnifying threats and leaving issues unsettled for the purpose of keeping the public coming back to them for more information. The NWS was viewed as having no goal except that of ensuring public safety. Continually larger amounts of weather information are wholesaled by the government and then further disseminated by commercial sources.
The government needs to be careful that privatization of services does not result in decreased trust in the information provided, particularly when public safety is involved.

Disaster Survey Management

The procedures for Natural Disaster Surveys following catastrophic events specify a disaster survey team of at least six individuals, with at least two of them from NOAA but outside NWS (including the team leader) and one of them from outside the government. However, there appears to be confusion within NWS headquarters over whether disaster survey reports should be largely NWS staff-authored exercises, with some outside advice, or an objective review combining opinions of the NWS staff, other NOAA staff, and outsiders. To encourage objectivity in disaster surveys of NWS activities,
NOAA should affirm that disaster surveys are a team process organized by NOAA and not subject to control by NWS headquarters.

The NOAA members of the Disaster Survey Team were fairly unforgiving in their evaluation of their fellow NOAA employees and honest in their evaluation of the efforts of the NWS and NOAA. Also, the NWS employees we interviewed were quite candid in describing and evaluating their own performance. This is to be commended. The large number of NOAA employees on the Team, chosen for their broad range of expertise, were able to examine NWS and NOAA activities much more efficiently than a team largely composed of outsiders could. However, in making recommendations within this report, NOAA staff on the Team were not fully able to disentangle themselves from their positions. This sometimes led to recommendations that were limited by concern for the internal response to those recommendations, to possibly more conservative recommendations than outsiders would have made, and to recommendations that occasionally seemed designed mostly to promote ongoing or proposed NOAA programs.

Although the total Disaster Survey Team for Hurricane Andrew had four members who were not NOAA staff, the team largely functioned as two disconnected parts (one for Florida and one for Louisiana), each with only two outsiders. Furthermore, one of those assigned to each state had very strong ties to NOAA. This left only two true outsiders, who then had no opportunity to interact since they were dispatched to different states. A stronger group of outside consultants might be more able to provide useful recommendations to NOAA on its preparedness and response to severe weather events. However, obtaining outside consultants on the extremely short notice available for assembling disaster survey teams is admittedly difficult.

For at least one Disaster Survey Team each year, strong efforts should be made to have at least three members without strong ties to NOAA.

While contributing to this report, as well as to the one on Hurricane Iniki, this outside consultant has been frustrated by some of his interactions with the team member assigned from NWS Headquarters. The problems appear to be related to how disaster survey reports are viewed by NWS management, rather than to the personalities of the individuals. The transmittal memorandum for the procedures on Natural Disaster Surveys notes that "Reports are normally written through a cooperative effort of team members." However, the technical leader at NWS Headquarters, through dual roles as team member and report coordinator, has far too great control over the final product. The model for report preparation used by the National Research Council, where the responsible staff member is knowledgeable in the field but not an author of the report, prevents staff from overly controlling the results without losing the value of their expertise.

In setting up Disaster Survey Teams, NOAA should continue to make at least one member of NWS Headquarters available. However, this individual should serve only as staff for the Team, not as a member.

There is great interest in the response of NOAA, as well as the responses of more local agencies discussed in disaster survey reports, to hurricane threats. Disasters provide perhaps NOAA's best chance to evaluate the success and resilience of NWS operations. Still, it has taken a long time to prepare this report, largely because it was not part of anyone's regular responsibilities, much less their primary focus.

Preparation of disaster surveys should be given higher priority. NWS or NOAA Headquarters should budget more time for staff to assist in producing disaster surveys. In particular, some of the responsibilities for the staff member in charge of coordinating production must be shifted if a report of high quality is to be produced in a timely manner.

Respectfully submitted,

Mark David Handel, Sc.D.