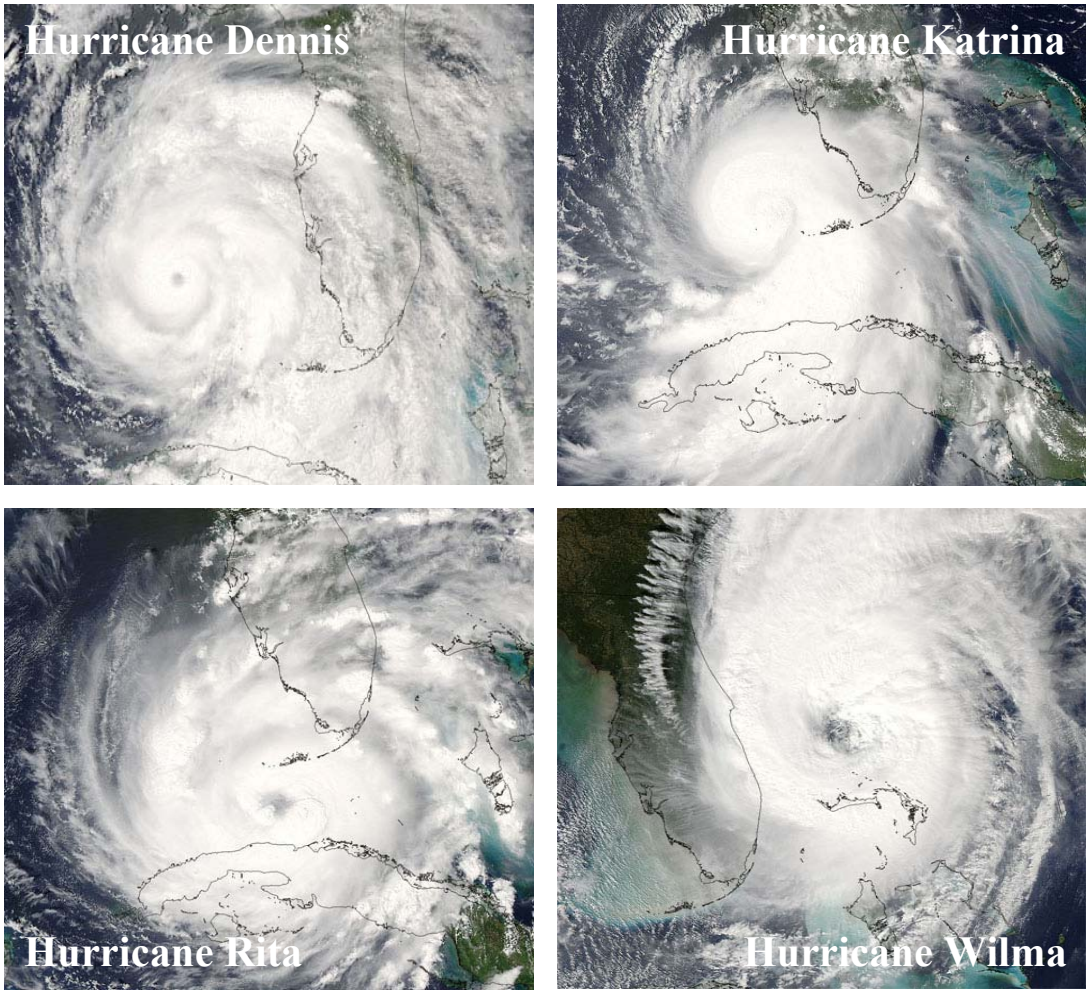
# *2005 Hurricane Season Impacts: Dade & Monroe Counties, Florida*

## POST-STORM BEACH CONDITIONS AND COASTAL IMPACT REPORT




**Florida Department of Environmental Protection**
**Division of Water Resource Management**
**Bureau of Beaches and Coastal Systems**
**December 2005**

# Foreword

The Bureau of Beaches and Coastal Systems of the Florida Department of Environmental Protection is responsible for protection and management of Florida's sandy beaches fronting the Gulf of Mexico, the Atlantic Ocean and the Straits of Florida, and the regulation of coastal development adjacent to those coastal beaches. The monitoring and assessment of hurricane impacts to Florida's beaches and coastal construction and the preparation of post-storm recovery responses and management strategies are important elements of the Bureau's responsibilities.

This report provides documentation of the impacts of Hurricanes Dennis, Katrina, Rita, and Wilma on the south coast of Florida along Dade and Monroe County beaches. The report also provides preliminary recommendations for post-storm response activities. This report was prepared by the Coastal Engineering Section for the Bureau of Beaches and Coastal Systems. The report was written by Ralph R. Clark, P.E., P.L.S., with major contributions and preparation of graphics by James LaGrone, Coastal Engineer, and additional contributions by Jennifer Koch, Coastal Geologist. Field data of beach and dune erosion and structural damage were obtained by Ralph Clark, James LaGrone, Jennifer Koch, and Guy Weeks. Aerial videography and oblique aerial photography were supplied by Stacey B. Roberts of PBS&J and Camera Copters, Inc.

STATE OF FLORIDA, DEPARTMENT
OF ENVIRONMENTAL PROTECTION

Michael R. Barnett, P.E., Chief
Bureau of Beaches and Coastal Systems

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# Hurricane Dennis

July 4 – 11, 2005

Hurricane Dennis, the first hurricane of the 2005 hurricane season for the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, spawned as a tropical depression over the southeastern Caribbean Sea on Monday, July 4. In its initial advisory, the National Weather Service, Tropical Prediction Center (National Hurricane Center, Miami, Florida) located this depression near latitude 12.5 degrees north, longitude 63.1 degrees west, or about 100 miles west-northwest of Grenada. Movement was west-northwest near 17 miles per hour (mph). Figure 1 illustrates the track history of Hurricane Dennis combined with satellite imagery done by the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin - Madison.

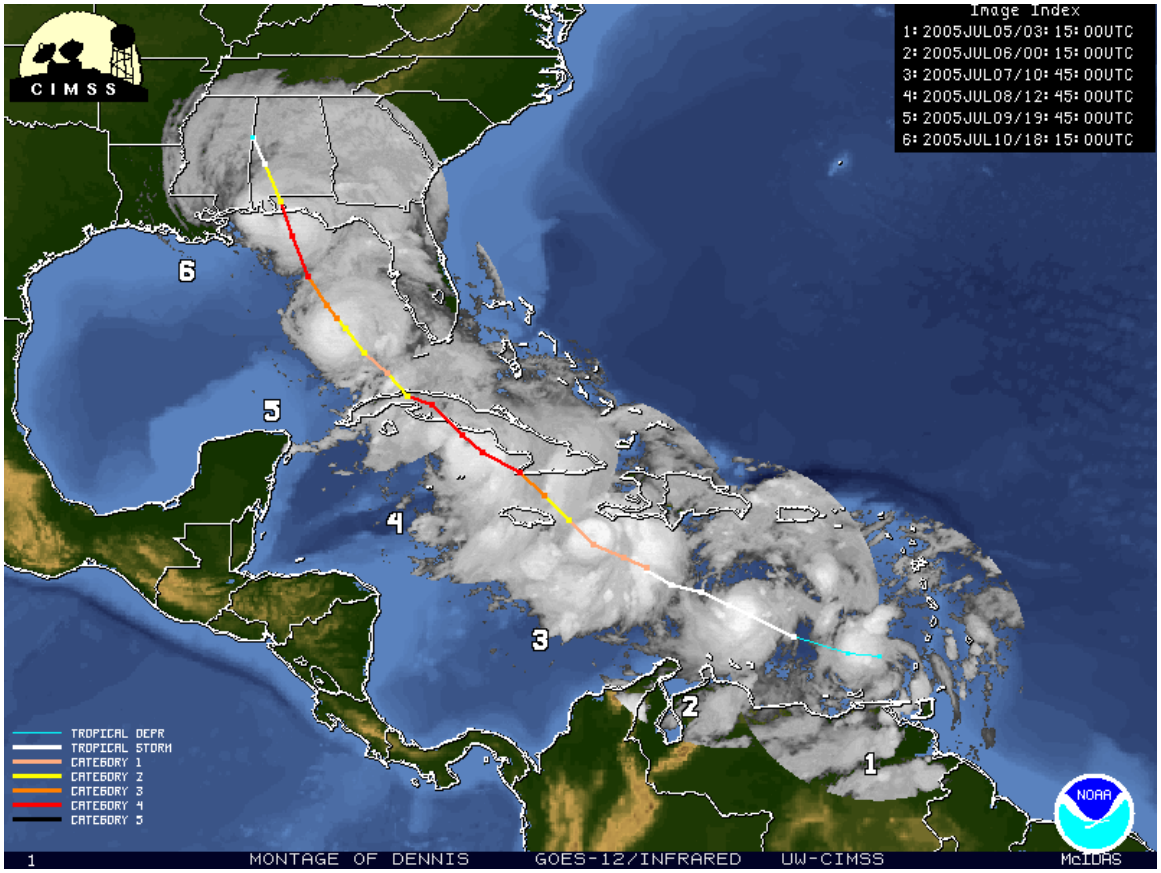


Figure 1. Hurricane Dennis storm track with landfall on western Florida Panhandle coast (Source: CIMSS/Univ. of Wisconsin-Madison via NOAA / NCEP / TPC).

At 11:00 a.m. on Tuesday, July 5, the National Hurricane Center's (NHC) third advisory upgraded the depression to a tropical storm naming it Dennis and locating it near latitude

13.3 degrees north, longitude 66.6 west, or about 355 miles south of San Juan, Puerto Rico. Movement was west-northwest near 18 mph. This became the earliest date on record for a fourth named tropical storm to have formed in the Atlantic basin.

At 6:00 p.m. on Wednesday, July 6, the NHC's ninth advisory upgraded Dennis to a hurricane locating it about 335 miles south-southeast of Guantanamo, Cuba. Dennis was moving west-northwest near 14 mph with winds near 80 mph.

Hurricane Dennis strengthened to a major hurricane and at 5 p.m., Thursday, July 7, the NHC's 13th advisory upgraded Dennis to a category three hurricane on the Saffir-Simpson hurricane intensity scale. At this time Dennis was located near latitude 19.0 north, longitude 76.6 west, or about 90 miles southeast of Cabo Cruz in southeastern Cuba. Dennis was moving northwest near 15 mph with maximum sustained winds of 115 mph. At 11 p.m., the NHC upgraded Dennis further to a category four hurricane with maximum sustained winds of 135 mph. Dennis was near Cabo Cruz, Cuba.

Thursday night and Friday morning, July 8, Hurricane Dennis crossed the Cuban barrier islands known as the Archipelago de la Reina. At 2 p.m., the NHC announced that Dennis had made landfall on the south-central coast of Cuba near the city of Cienfuegos. Dennis was a strong category four hurricane with maximum sustained winds of 150 mph and was moving northwest near 17 mph across central Cuba.

After midnight, Saturday, July 9, Dennis moved into the Straits of Florida after crossing Havana, Cuba. Dennis weakened to a category two hurricane after crossing Cuba. Throughout Saturday morning Dennis continued on a northwest track, passing the Florida Keys about 125 miles west of Key West. Waves propagating from the winds of Dennis caused minor to moderate beach erosion impact along the lower keys. By 7 p.m., Saturday, the 22nd advisory of the NHC reported that Dennis had re-strengthened to a major category three hurricane with winds of 115 mph. Movement across the Gulf of Mexico remained northwest at about 14 mph. Hurricane warnings were posted across the northeastern gulf coast from Louisiana through the Florida Panhandle.

Throughout Saturday evening, Dennis continued to strengthen over warm gulf waters. The 24th advisory of the NHC, at 4 a.m. Sunday, July 10, reported Dennis was a strong category four hurricane with winds of 145 mph. The center of Hurricane Dennis was located about 170 miles south of Panama City, Florida, and movement was north-northwest near 15 mph. At 2:25 p.m. CDT, Hurricane Dennis made landfall on Santa Rosa Island, Florida, between the beach communities of Pensacola Beach and Navarre Beach. Some weakening of the storm occurred before landfall and Dennis was a category three hurricane with winds of 115 to 120 mph.

Hurricane Dennis moved northward into Alabama and eventually dissipated after bringing flooding rains throughout north Florida, Alabama, and Georgia. Rain from the remnant tropical system continued for several days into the western Tennessee valley.

## Hurricane Katrina

August 23 – 29, 2005

Hurricane Katrina, the fourth hurricane of the 2005 hurricane season for the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, spawned as a tropical depression over the Bahamas on Tuesday, August 23. In its initial advisory, the National Weather Service, Tropical Prediction Center located this twelfth tropical depression of the season near latitude 23.2 degrees north, longitude 75.5 degrees west, or about 175 miles southeast of Nassau. Movement was northwest near eight miles per hour (mph). Figure 2 illustrates the track history of Hurricane Katrina combined with satellite imagery done by the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin - Madison.

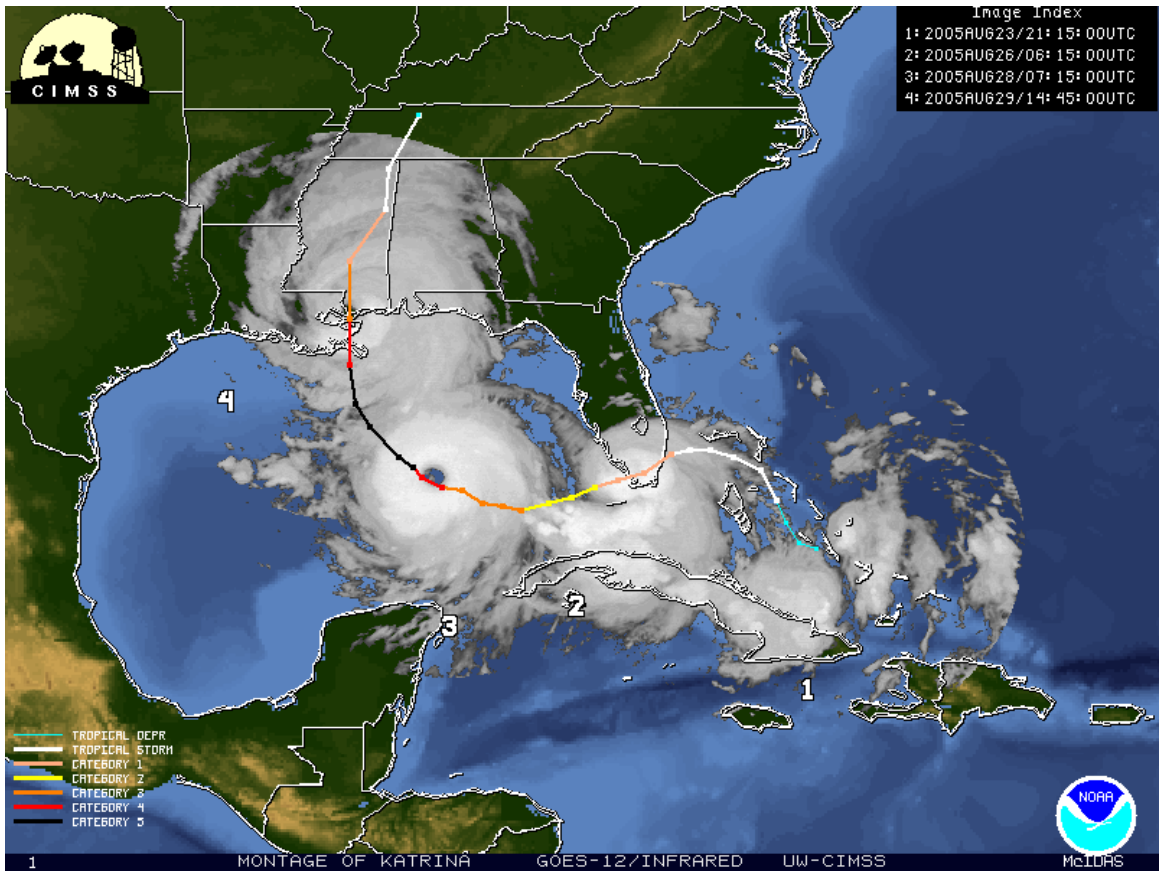


Figure 2. Hurricane Katrina storm track with landfall on eastern Louisiana coast (Source: CIMSS/Univ. of Wisconsin-Madison via NOAA / NCEP / TPC).

At 8:05 a.m. on Wednesday, August 24, a special update by the National Hurricane Center (NHC) advised that Air Force Reserve Unit reconnaissance aircraft measured winds exceeding 40 mph indicating that tropical depression 12 had strengthened into

Tropical Storm Katrina. At 11:00 a.m., the NHC's fourth advisory located Tropical Storm Katrina near latitude 24.7 degrees north, longitude 76.7 degrees west, or about 50 miles east-southeast of Nassau and about 230 miles from the southeast coast of Florida. A tropical storm warning and a hurricane watch was issued for southeast Florida from the northern Florida Keys to Vero Beach.

At 11:00 p.m., August 24, the NHC's sixth advisory indicated that the storm was strengthening and had turned toward the west with a forward speed of eight mph and maximum sustained winds of 50 mph. At 2:00 a.m., Thursday, August 25, hurricane warnings were posted for southeast Florida.

At 5:00 a.m., August 25, the NHC's seventh advisory indicated Katrina was passing south of Grand Bahama Island. The center of Tropical Storm Katrina was located at latitude 26.2 degrees north, longitude 78.7 degrees west, or about 20 miles south-southeast of Freeport, Grand Bahama Island, and about 90 miles east of Fort Lauderdale, Florida.

At 3:35 p.m., August 25, a special update from the NHC advised that reconnaissance aircraft reports and NOAA (National Oceanic and Atmospheric Administration) Doppler radar data from Miami indicated maximum sustained surface winds had increased to 75 mph upgrading Katrina to a category one hurricane on the Saffir-Simpson hurricane intensity scale. At 5:00 p.m., the center of Hurricane Katrina was located at latitude 26.1 degrees north, 79.9 degrees west, or about 15 miles east-northeast of Ft. Lauderdale with movement to the west at six mph. A wind gust of 64 mph was reported from Boca Raton, 25 miles north-northwest of the hurricane's eye. Hurricane warnings were in effect from Jupiter Inlet (Palm Beach County) south to Florida City (Dade County).

At about 6:30 p.m., August 25, the center of Katrina's eye made landfall on the southeast coast of Florida in Bal Harbour, north of Miami Beach, with 80 mph winds. The geographic center of Katrina's eye was located about midway between the Department of Environmental Protection reference monuments R29 and R30, just south of Bakers Haulover Inlet in Dade County. Katrina was moving southwest and intensifying at landfall bringing storm tides of two to four feet above normal along the coast of Dade and Broward Counties. A maximum wind gust of 92 mph was reported in Port Everglades. The NOAA weather station at Fowey Rocks off south Dade County reported maximum sustained winds from the southwest at 56 mph with a peak gust to 61 mph. The NOAA office on Virginia Key measured a peak gust of 95 mph. By 11:00 p.m., Katrina was located 35 miles southwest of Miami with continued southwesterly movement at eight mph. The Miami National Weather Service forecast office reported a gust to 87 mph and the Tamiami Airport reported a gust of 81 mph. Heavy rainfall was sustained over Dade County.

In the early morning hours of Friday, August 26, Katrina moved off the mainland of Monroe County and into the open waters of the Gulf of Mexico. Katrina spent only

about seven hours over land, most of which was the wet Florida Everglades, and therefore only slight weakening occurred. Heavy rain squalls occurred across the Florida Keys and northwestern Cuba. By late morning, the NHC advised that a NOAA vessel in port at Key West had reported sustained winds of 59 mph and a peak gust to 86 mph. The NHC's 13th advisory at 11:30 a.m., reported that Katrina was moving away from southwest Florida and the Florida Keys and was strengthening to a category two hurricane with 100 mph winds.

At 5:00 a.m., Saturday, August 27, the NHC's 16th advisory located Katrina at latitude 24.4 degrees north, longitude 84.4 degrees west, or about 165 miles west of Key West and 435 miles southeast of the mouth of the Mississippi River. Movement was west near seven mph and maximum sustained winds had increased to 115 mph making Katrina a major category three hurricane. Through Saturday night and Sunday morning, Katrina passed over the warmer waters of the Loop Current in the Gulf of Mexico causing continued and rapid intensification. At 1:00 a.m., Sunday, August 28th, the NHC's 20th advisory upgraded Katrina to a powerful category four hurricane with 145 mph winds. At 7:00 a.m., the NHC's 22nd advisory upgraded Katrina to a potentially catastrophic category five hurricane with maximum sustained winds of 160 mph. Movement was west-northwest near 12 mph and Katrina was located about 250 miles south-southeast of the mouth of the Mississippi River. By 10:00 a.m., Katrina's winds had increased to 175 mph and the northern gulf states from Louisiana to the Florida Panhandle were evacuating this extremely dangerous storm.

At 4:00 p.m., Sunday, August 28th, the NHC's 24th advisory reported that a NOAA hurricane hunter aircraft had measured a minimum central pressure of 902 millibars or 26.64 inches of mercury, making Hurricane Katrina the fourth most powerful hurricane ever recorded in the Atlantic basin. At 4:00 a.m., Monday, August 29th, the NHC's 26th advisory reported Katrina was located about 90 miles south-southeast of New Orleans, Louisiana. Katrina weakened to a still powerful category four hurricane with maximum sustained winds of 150 mph. Movement was north near 15 mph. At 6:10 a.m., Katrina made landfall between Grand Isle and the mouth of the Mississippi River with the eye passing over Buras, Louisiana. Maximum sustained winds were about 145 mph.

Powerful category four Hurricane Katrina passed over the Mississippi River delta and northward across Breton Sound and Lake Borgne to the east of New Orleans during the next few hours. New Orleans was within the western eye wall of the large storm. At 8:00 a.m., the Pascagoula Civil Defense reported a wind gust to 118 mph. The Gulfport, Mississippi Emergency Operations Center reported sustained winds of 94 mph and a gust to 100 mph. The New Orleans Lakefront Airport reported a gust to 86. The NHC issued storm surge flooding advisories of 10 to 15 feet, or near the tops of the levees.

At 10:00 a.m., Monday, August 29th, the NHC's 27th advisory reported the center of Hurricane Katrina again moved ashore near the Louisiana-Mississippi state line with maximum sustained winds of 125 mph. Katrina was now a category three hurricane with

hurricane force winds extending up to 125 miles from its center and tropical storm force winds extending up to 230 miles from its center. NWS stations reported maximum wind gusts reaching 102 mph on Dauphin Island, Alabama, 83 mph in Mobile, Alabama, and 69 mph in Pensacola, Florida. Pensacola reported sustained winds of 52 mph.

Katrina moved north through Mississippi throughout the day at between 17 and 18 mph. At 4:00 p.m., the NHC's 28th advisory reported the center of a weakening Hurricane Katrina about 30 miles northwest of Laurel, Mississippi, which is located over 90 miles north of Gulfport. The Jones County Emergency Management Office, in Laurel, reported a peak gust to 110 mph at 2:00 p.m., before their anemometer failed. The south and central Mississippi cities of Hattiesburg, Laurel, and Meridian, and surrounding communities and rural areas, sustained major wind damage along Katrina's path of destruction.

By 10:00 p.m., the NHC had downgraded Katrina to a tropical storm with 60-mph winds and located near Columbus, Mississippi, about 220 miles inland of the coast. Throughout Monday evening strong winds and heavy rainfall spread through Mississippi, Alabama, northwest Florida, Georgia, and Tennessee. Katrina spawned at least 25 tornados, including one in north Florida and a maximum of 10 in Georgia. Through the morning, Tuesday, August 30th, Katrina continued to weaken to a tropical depression over Tennessee, and rapidly moved northward through the day becoming extratropical.

## Hurricane Rita

September 17-25, 2005

Hurricane Rita, the ninth hurricane of the 2005 hurricane season for the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, spawned as a tropical depression east of the Turks and Caicos Islands south of the Bahamas on Saturday, September 17. In its initial advisory, the National Weather Service, Tropical Prediction Center located this 18th tropical depression of the season near latitude 22 degrees north, longitude 69.7 degrees west, or about 95 miles east-northeast of Grand Turk Island. Movement was west-northwest near 10 miles per hour (mph). Figure 3 illustrates the track history of Hurricane Rita combined with satellite imagery done by the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin - Madison.

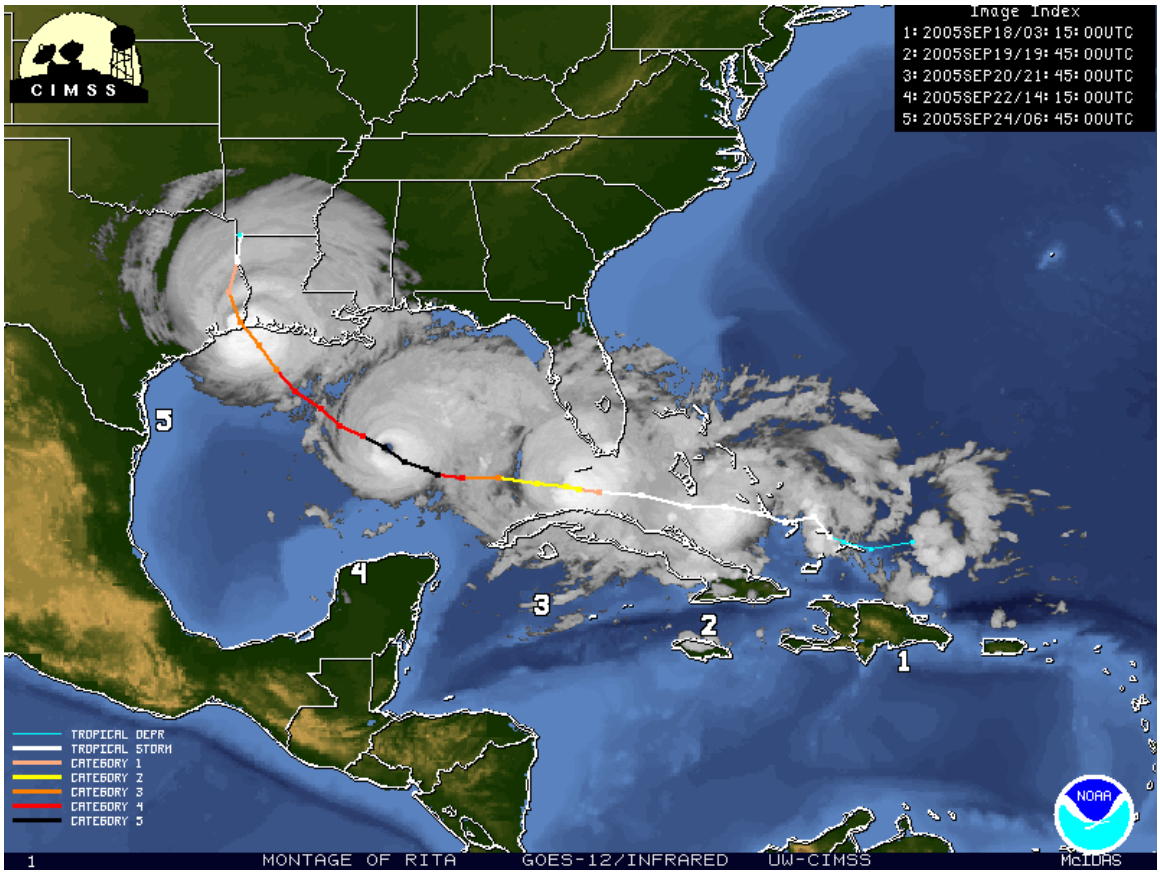


Figure 3. Hurricane Rita storm track with landfall on western Louisiana coast (Source: CIMSS/Univ. of Wisconsin-Madison via NOAA / NCEP / TPC).

At 5:00 p.m. on Sunday, September 18, the National Hurricane Center's (NHC) fourth advisory upgraded the depression to a tropical storm naming it Rita and locating it near latitude 22.2 degrees north, longitude 72.7 degrees west, or about 355 miles east-

southeast of Nassau, Bahamas. Movement was west near 10 mph. Rita became the 17th tropical storm of the season and a hurricane warning was issued for the Florida Keys.

Throughout Monday, September 19, Tropical Storm Rita strengthened and moved west-northwest through the southern Bahamas passing south of Andros Island. At 11:00 a.m., Tuesday, September 20, the NHC's 11th advisory upgraded Rita to a hurricane locating it about latitude 23.8 degrees north, longitude 81 degrees west, or about 75 miles southeast of Key West, Florida, and about 100 miles east-northeast of Havana, Cuba. Rita was moving west near 15 mph with maximum sustained winds near 85 mph. The NOAA weather station on Sombrero Key reported sustained winds of 59 mph and gusts to 72 mph.

Rita strengthened rapidly and passed 50 miles south of Key West. Citing winds near 100 mph, the NHC's 12th advisory upgraded Rita to a category two hurricane on the Saffir-Simpson hurricane intensity scale. The NOAA weather station on Sand Key near Key West reported sustained winds of 60 mph and a maximum gust of 92 mph. Throughout Tuesday evening, Rita tracked westward through the Straits of Florida passing about 45 miles south of the Dry Tortugas. The Dry Tortugas reported sustained winds of 51 mph and a peak gust to 64 mph.

Hurricane Rita strengthened and entered the Gulf of Mexico as a major hurricane, and at 5:00 a.m., Wednesday, September 21, the NHC's 15th advisory upgraded Rita to a category three hurricane. At this time Rita was located near latitude 24.3 degrees north, longitude 84.6 degrees west, or about 175 miles west of Key West. Movement was west near 14 mph and maximum sustained winds were near 120 mph. Rita continued to intensify during the morning, reaching category four intensity with maximum sustained winds near 140 mph. With further intensification during the afternoon, Rita reached category five hurricane intensity with maximum sustained winds near 165 mph. The Texas gulf coast was placed under a hurricane watch.

At 10:00 p.m., Wednesday, September 21, the NHC's 18th advisory located Rita near latitude 24.6 degrees north, longitude 87.2 degrees west, or about 570 miles east-southeast of Galveston, Texas. Maximum sustained winds were near 175 mph. An air force reserve unit reconnaissance aircraft measured a minimum central pressure of 897 millibars or 26.49 inches of mercury, making Hurricane Rita the third most powerful hurricane ever recorded in the Atlantic basin.

On Thursday morning, September 22, with Rita tracking northwestward across the gulf, hurricane warnings and evacuation orders were posted for the upper Texas coast and southwest Louisiana. Through the day Thursday, Rita weakened from a powerful category five hurricane to a dangerous category four hurricane with maximum sustained winds near 145 mph. On Friday, September 23, Rita continued to track northwestward and weaken to a category three hurricane with winds down to 120 mph. A wind gust of 78 mph was measured on Marsh Island, Louisiana, where storm tides reached eight feet

above normal and breached two levees in New Orleans causing repeat flooding to areas previously devastated by Hurricane Katrina.

At 2:30 a.m., Saturday, September 24, Rita made landfall in southwestern Louisiana between Sabine Pass and Johnson's Bayou. Rita made landfall as a category three hurricane with winds estimated at near 120 mph. The Florida Coastal Monitoring Program measured sustained winds of 91 mph and a gust to 116 mph in Port Arthur, Texas. A NOAA station at Sea Rim State Park in Texas measured a gust to 101 mph, and a NOAA station at Calcasieu Pass, Louisiana, measured a gust to 112 mph. A storm surge of 15 feet was reported along coastal Louisiana and flooding extended roughly 20 miles inland. The media reported an estimated 80 percent of the homes and buildings in Cameron, Louisiana, and 50 percent of those in Creole, Louisiana, were destroyed. In Terrebonne Parrish, officials counted nearly 10,000 homes as destroyed or severely damaged. Lake Charles, Louisiana, sustained major wind damage throughout the city and surrounding region.

## Hurricane Wilma

October 15-25, 2005

Hurricane Wilma, the twelfth hurricane of the 2005 hurricane season for the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, spawned as a tropical depression over the western Caribbean Sea on Saturday, October 15. In its initial advisory, the National Weather Service, Tropical Prediction Center located this depression near latitude 17.6 degrees north, longitude 78.8 degrees west, or about 85 miles southwest of Montego Bay, Jamaica. Movement was west near 3 miles per hour (mph). Figure 4 illustrates the track history of Hurricane Wilma combined with satellite imagery done by the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin - Madison.

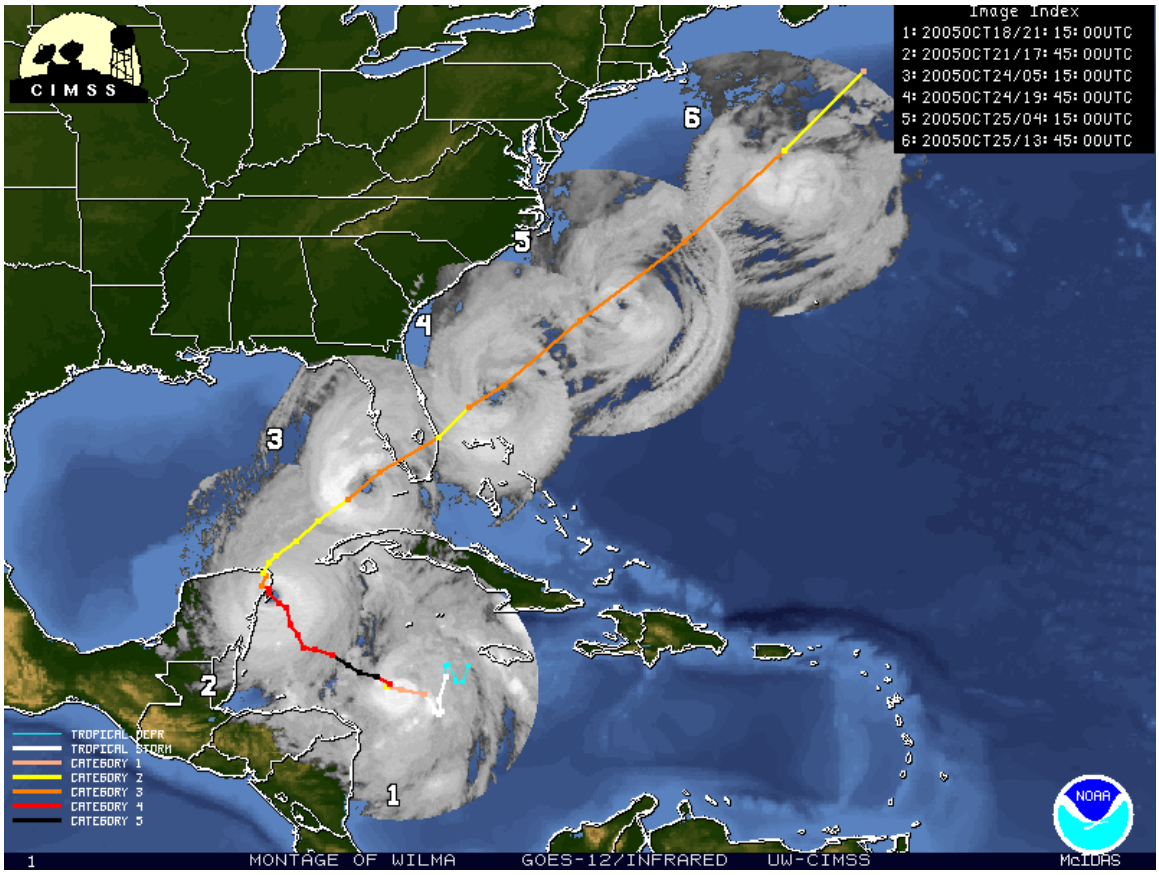


Figure 4. Hurricane Wilma storm track with landfall on southwest Florida coast (Source: CIMSS/Univ. of Wisconsin-Madison via NOAA / NCEP / TPC).

At 5:00 a.m. on Monday, October 17, the National Hurricane Center's (NHC) seventh advisory upgraded the depression to a tropical storm naming it Wilma and locating it near latitude 17.2 degrees north, longitude 79.7 degrees west, or about 175 miles southeast of

Grand Cayman. Movement was southwest near 3 mph. Wilma became the 21st tropical storm of the season and tied the record set in 1933 for the number of tropical storms forming in one season.

Throughout Monday, October 17, Tropical Storm Wilma slowly strengthened and moved southwest in the western Caribbean Sea. At 11:00 a.m., Tuesday, October 18, the NHC's 12th advisory upgraded Wilma to a hurricane locating it about latitude 16.5 degrees north, longitude 80.6 degrees west, or about 195 miles south-southeast of Grand Cayman, and about 200 miles east-northeast of Cabo Gracias a Dios on the Nicaragua/Honduras border of Central America. Wilma was moving northwest near 7 mph with maximum sustained winds near 75 mph.

Hurricane Wilma continued to strengthen and at 11:00 p.m., Tuesday, October 18, the NHC's 14th advisory upgraded Wilma to a category two hurricane. At this time Wilma was located near latitude 16.8 degrees north, longitude 82.1 degrees west, or about 185 miles south-southwest of Grand Cayman, and about 405 miles southeast of Isla de Cozumel, Mexico. Movement was west-northwest near 8 mph and maximum sustained winds were near 110 mph. A NOAA weather buoy in the western Caribbean Sea reported a sustained wind of 50 mph and a peak gust of 58 mph.

Wilma continued to intensify throughout the night, reaching category four intensity with maximum sustained winds near 150 mph near midnight. With further intensification during the early morning, Wilma reached category five hurricane intensity with maximum sustained winds near 175 mph. A U.S. Air Force reconnaissance airplane reported a minimum central barometric pressure of 882 millibars, which is the lowest minimum pressure ever measured in the Atlantic basin. At 11:00 a.m., Wednesday, October 19th, the NHC's 17th advisory located Wilma near latitude 17.4 degrees north, longitude 83.2 degrees west, or about 325 miles southeast of Cozumel. Movement was west-northwest near 7 mph and maximum sustained winds were near 175 mph. The government of Mexico issued a hurricane warning for the states of Quintana Roo and Yucatan on the Yucatan Peninsula.

Wilma slightly weakened Wednesday evening and Thursday morning. At 4:00 p.m., Thursday, October 20, the NHC's 22nd advisory located Wilma near latitude 18.9 degrees north, longitude 85.7 degrees west, or about 135 miles southeast of Cozumel. Movement was northwest near 6 mph and maximum sustained winds were near 150 mph. Wilma was still an extremely dangerous category four hurricane and warnings were extended eastward along Quintana Roo from Tulum to Chetumal.

Throughout the evening Wilma moved closer to the state of Quintana Roo, Mexico. A NOAA weather buoy located about 75 miles east of the eye of Wilma measured maximum sustained winds of 71.6 mph and a peak gust of 91.7 mph. A maximum significant wave height was measured at 36.1 feet. At 10:00 a.m., Friday, October 21st, the NHC's 25th advisory located Wilma near latitude 20.2 degrees north, longitude 86.5

degrees west, or about 35 miles southeast of Cozumel. Movement was northwest near 5 mph and maximum sustained winds were near 145 mph. The northwestern eye wall had already moved over Cozumel.

Near 4:00 p.m., the eye of Wilma crossed near the north end of the island of Cozumel and an automated weather station measured a minimum pressure of 927.4 millibars or 27.39 inches of mercury. Another automated weather station in Cancun measured a wind gust of 133 mph before contact with the station was lost. Throughout Friday evening the winds and waves of Wilma battered the Quintana Roo coast of Mexico along the beaches of the Maya Riviera. At 4:00 a.m., Saturday, October 22nd, the NHC's 28th advisory located Wilma near latitude 20.9 degrees north, longitude 87.2 degrees west, or about 25 miles southwest of Cancun. The large eye of Wilma passed over Playa del Carmen and the hurricane became stationary with its unrelenting energy affecting the northern coast of Quintana Roo. Maximum sustained winds decreased to about 125 mph.

Throughout Saturday, October 22nd, Wilma slowly drifted north just inland of the coast of northern Quintana Roo. At 11:00 p.m., a hurricane warning was issued for south Florida and the Florida Keys as Wilma drifted north off the coast of Quintana Roo at Cabo Catoche and into the Yucatan Strait with maximum sustained winds of 100 mph. Throughout Sunday, October 23rd, Wilma crossed the Yucatan Strait and extreme southeastern Gulf of Mexico with an accelerating northeast forward speed and a steady increase in strength. At 11:00 p.m., the NHC's 35th advisory located Wilma near latitude 24.4 degrees north, longitude 83.7 degrees west, or about 120 miles west of Key West, Florida, and 170 miles southwest of Naples, Florida. Wilma was moving northeast near 18 mph with maximum sustained winds near 115 mph, making Wilma a major category three hurricane.

Throughout Monday morning, October 24th, Wilma tracked northeast into southwest Florida, impacting the north coast of Cuba and the Florida Keys with an eight to ten-foot storm surge. Wilma made landfall near Cape Romano in Collier County, Florida, bringing its approximately 10-foot storm surge into the Ten Thousand Islands region of Collier County and the Florida Everglades National Park segment of coast in Monroe County. At 7:00 a.m., the NHC's advisory number 36A located Wilma near latitude 26.1 degrees north, longitude 81.4 degrees west, or about 10 miles north of Everglades City, Florida. Wilma was moving northeast near 23 mph with maximum sustained winds near 120 mph, making Wilma a category three (major) hurricane crossing south Florida. A wind gust of 95 mph was measured at Everglades City, where the lowest barometric pressure recorded over land was 28.12 inches of mercury. From other recording stations some peak wind gusts include: 127 mph at Fowey Rocks, 123 mph at Cudjoe Key, 121 mph at Naples, 111 mph at Miami, 100 mph at Ft. Myers Beach, and 101 mph at Sombrero Key. Maximum sustained winds reached 101 mph at Fowey Rocks, 87 mph at Sombrero Key, and 79 mph at the Naples Pier.

Near noon Monday, October 24th, the large eye of Wilma (60 nautical miles in diameter) moved off the coast of southeast Florida north of West Palm Beach with maximum sustained winds down to 105 mph. Wilma quickly re-intensified back over the warm waters of the Gulf Stream. At 2:30 p.m., the NHC's 38th advisory located Wilma near latitude 28.1 degrees north, longitude 78.8 degrees west, or about 125 miles northeast of West Palm Beach. Movement was northeast near 29 mph and maximum sustained winds were near 115 mph, making Wilma a category three hurricane once again. A maximum sustained wind of 96 mph and a peak gust of 119 mph were recorded at Settlement Point, Grand Bahama Island. Maximum significant wave heights were obtained from the NOAA buoy 20 nautical miles east of Cape Canaveral at 19.7 feet, and from the NOAA buoy 120 nautical miles east of Cape Canaveral at 33.5 feet. At the NOAA buoy located 40 nautical miles east of St. Augustine, Florida, maximum significant wave heights reached 14.4 feet.

Throughout Monday evening and Tuesday, October 25th, Wilma raced northeastward across the North Atlantic Ocean, traveling at speeds reaching 53 mph as it merged with a strong cold front and became a large extratropical storm that moved across the ocean and away from North America.

## Post-storm Beach Conditions and Coastal Impact Summary and Overview

The south Florida counties of Dade and Monroe sustained significant beach erosion conditions from the 2005 hurricane season. Four hurricanes – Dennis (July 10), Katrina (August 25), Rita (September 20), and Wilma (October 24) – caused erosion and flooding along the coastal barrier beaches of Dade County and the Florida Keys and mainland beaches of Monroe County.

Figure 5 presents the combined tracks of Hurricanes Dennis, Katrina, Rita, and Wilma, and their proximity to the coasts of Monroe and Dade Counties. Hurricanes Dennis, Katrina, and Rita affected south Florida as a category one or two hurricane before crossing the Gulf of Mexico and becoming major hurricanes before making landfall on the northern gulf coast. Hurricane Wilma crossed the southeast Gulf of Mexico from the west and made landfall to the north of Monroe and Dade Counties as a category three hurricane before exiting southeast Florida into the Atlantic Ocean.

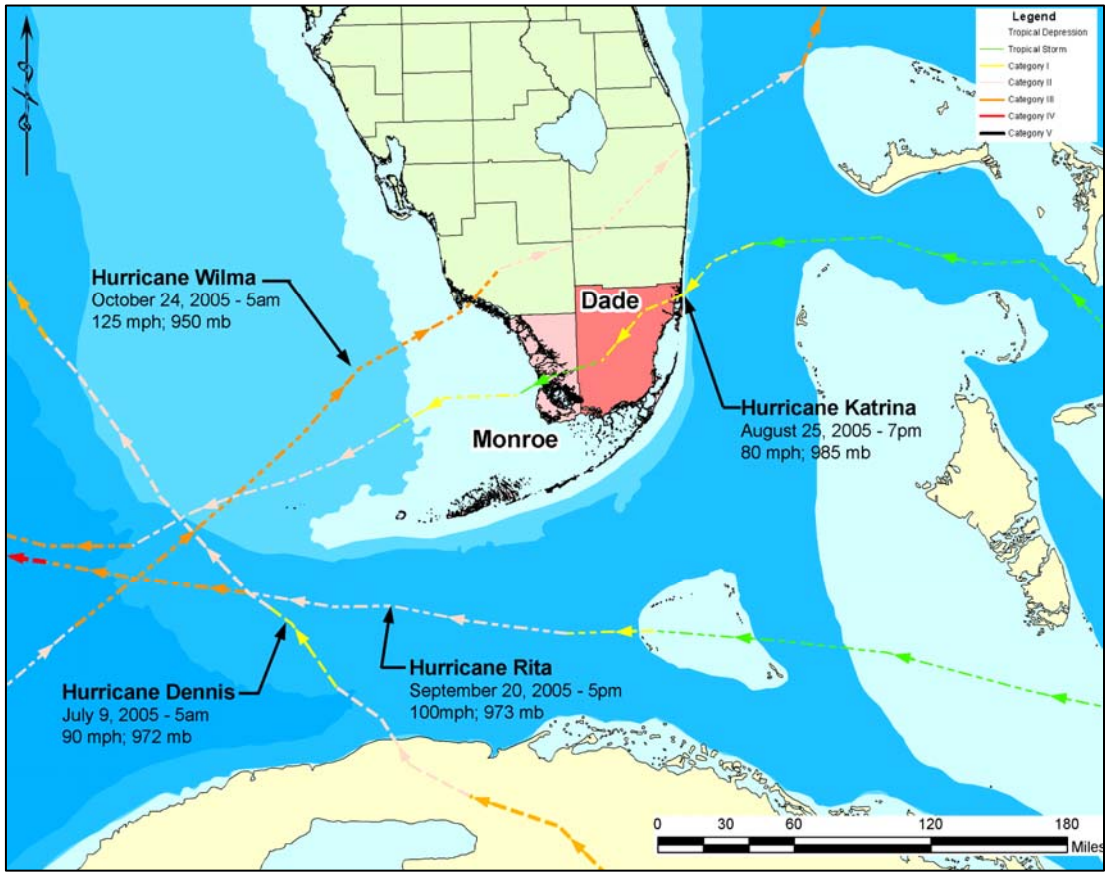


Figure 5. Combined tracks of Hurricanes Dennis, Katrina , Rita, and Wilma.

The winds of each hurricane are graphically presented in the wind swath maps shown in Figures 6 - 9. The data was prepared and provided by the Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanographic and Atmospheric Administration, on Virginia Key. Storm tide data are available at the Key West NOAA tide station during Hurricane Dennis (Figure 10) and Hurricane Wilma (Figure 13), at the Virginia Key NOAA tide station during Hurricane Katrina (Figure 11), and at the Vaca Key (Marathon) NOAA tide station during Hurricane Rita (Figure 12).

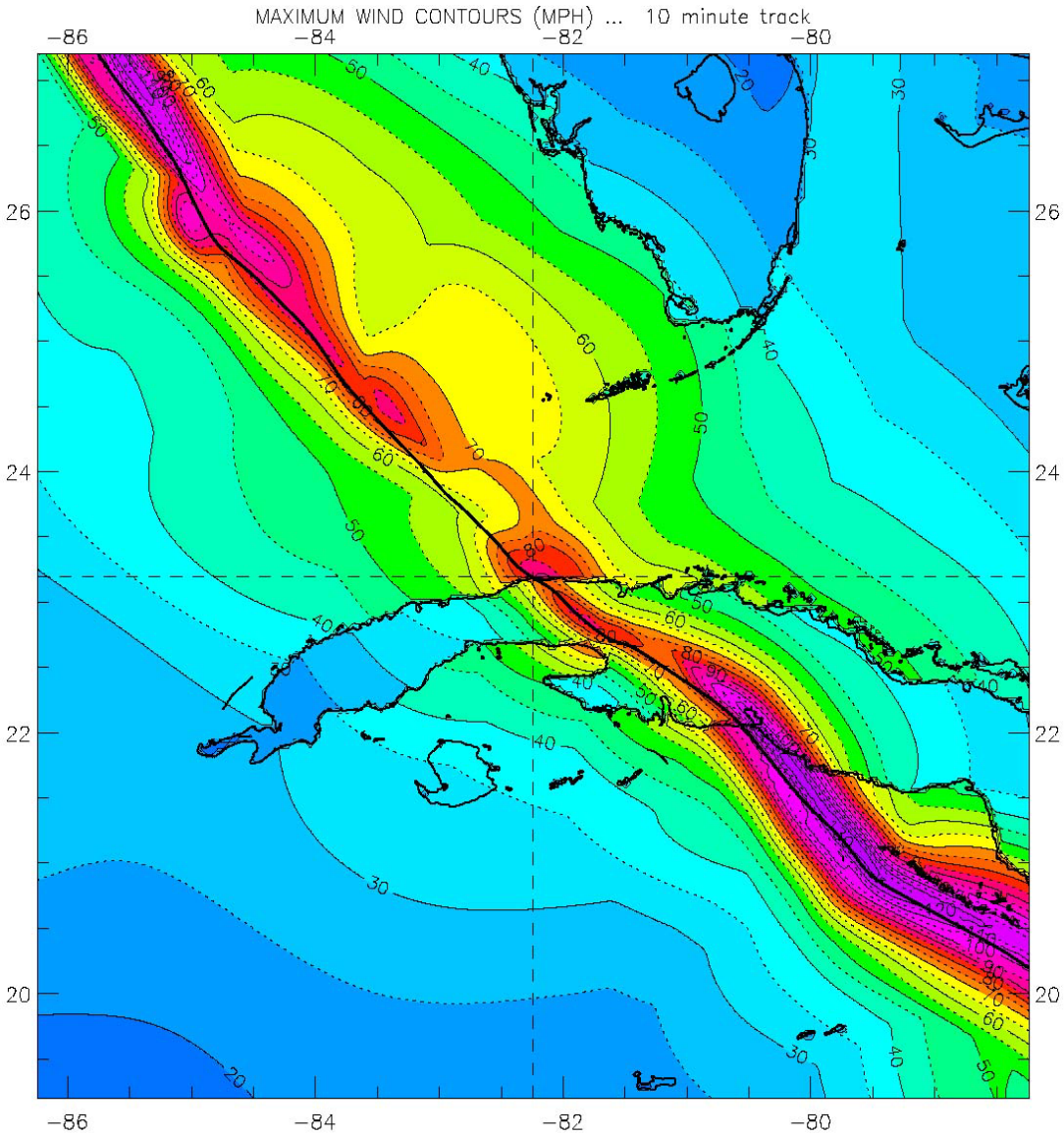


Figure 6. Surface wind fields associated with Hurricane Dennis (NOAA, AOML).

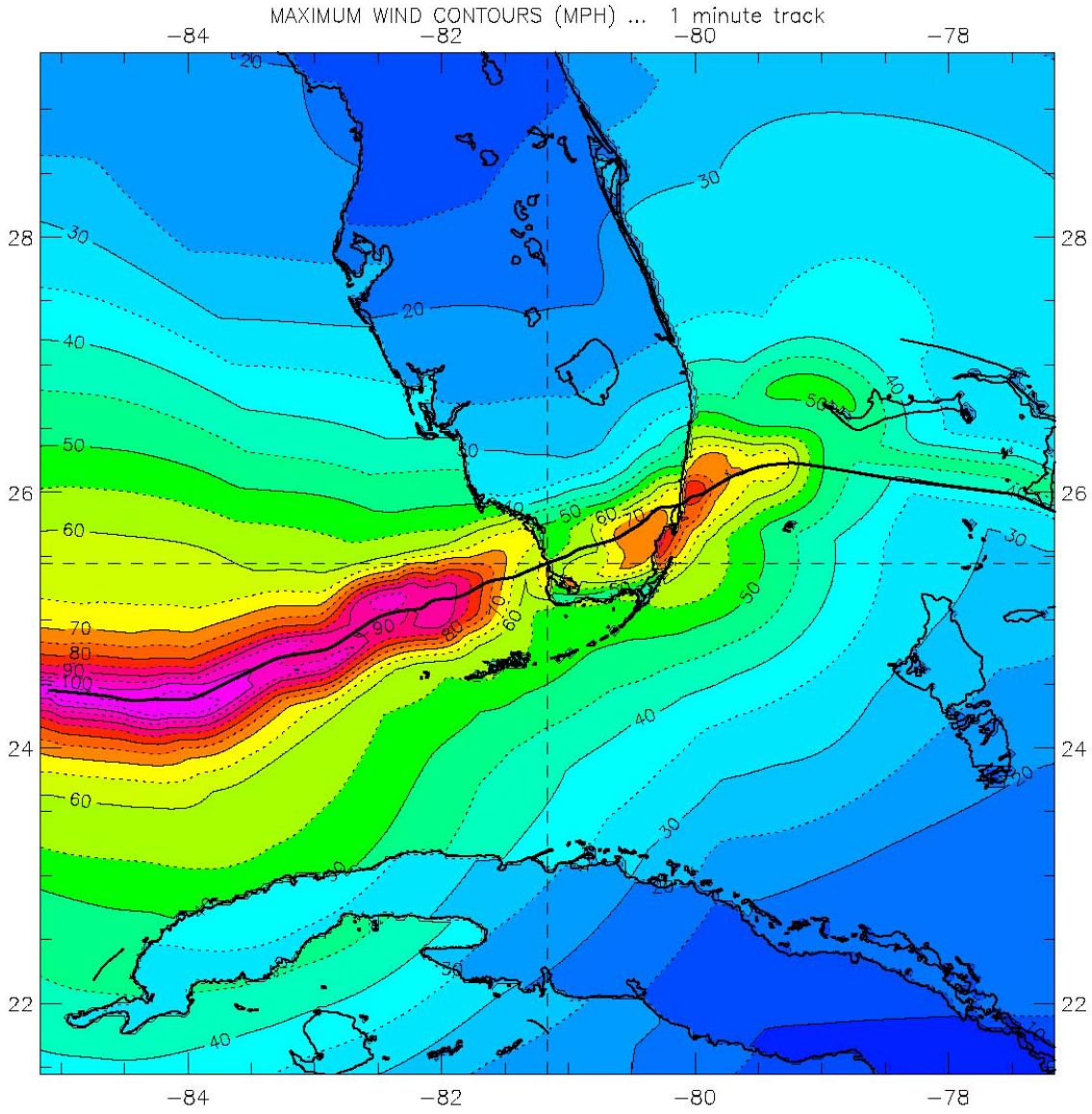


Figure 7. Surface wind fields associated with Hurricane Katrina (NOAA, AOML).

Pending Graphics

**Figure 8.** Surface wind fields associated with Hurricane

**Figure 9.** Surface wind fields associated with Hurricane Wilma (NOAA, AOML).

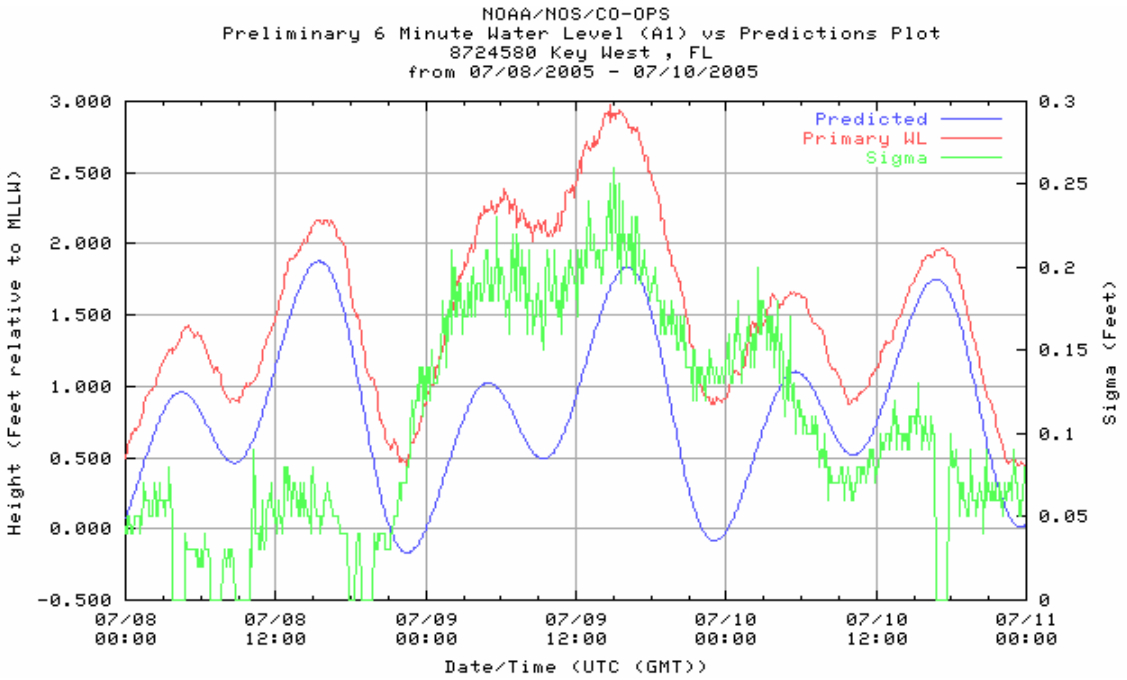


Figure 10. MLLW data from Key West NOAA Tide Station during Hurricane Dennis.

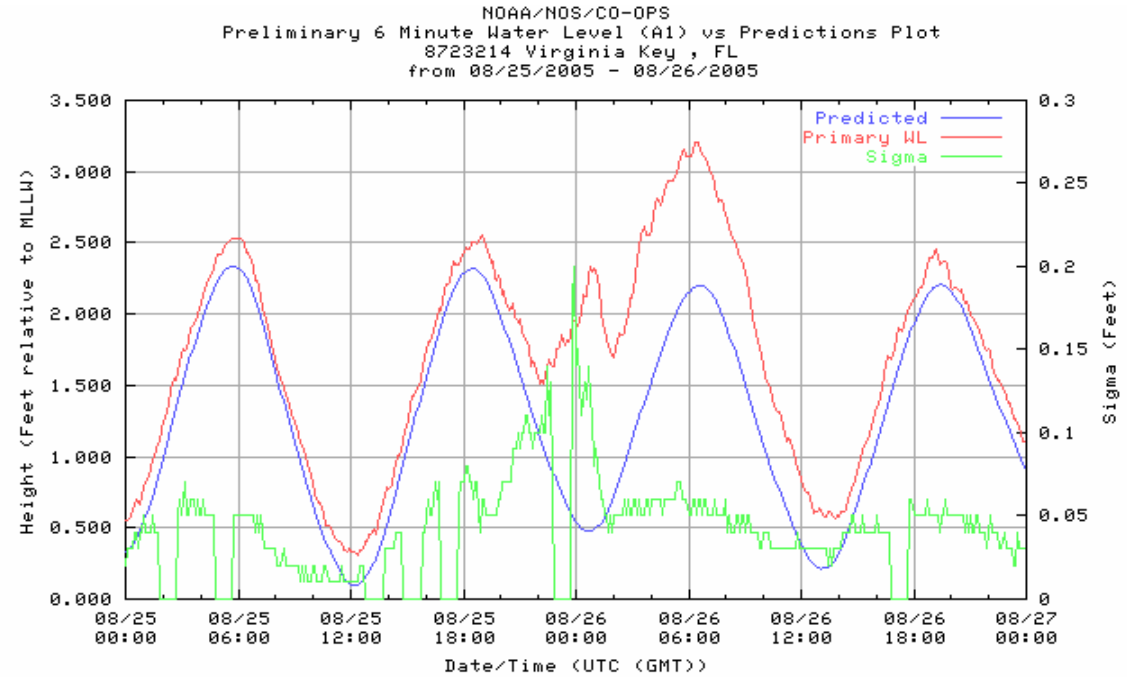


Figure 11. MLLW data from Virginia Key NOAA Tide Station during Hurricane Katrina.

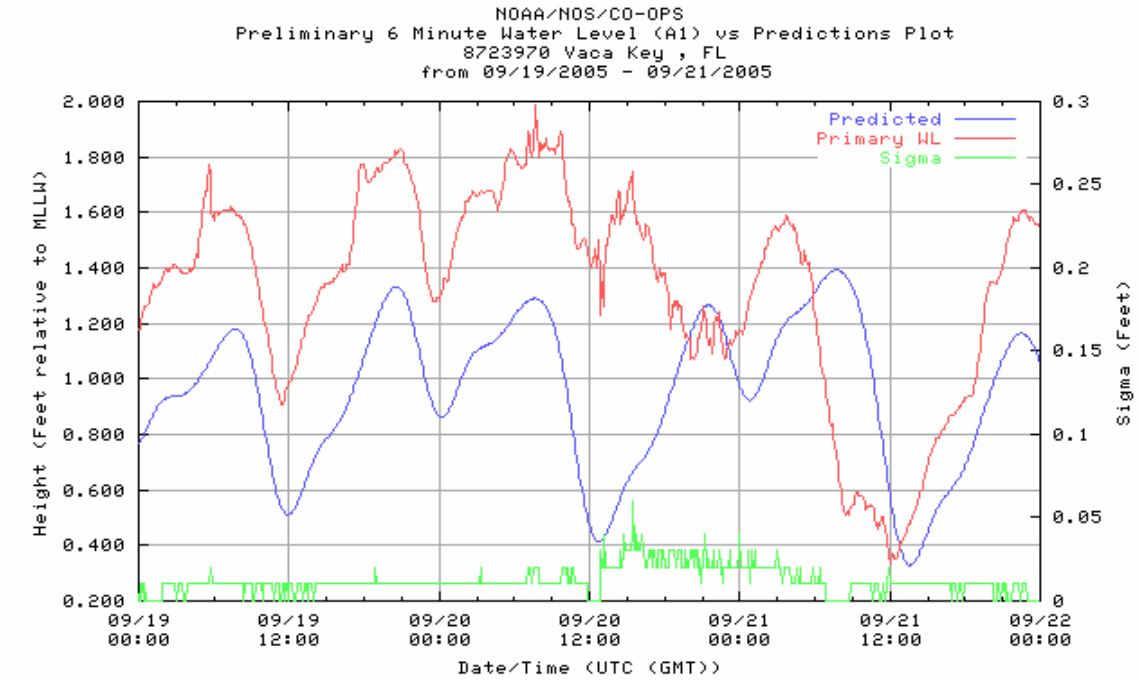


Figure 12. MLLW data from Vaca Key NOAA Tide Station during Hurricane Rita.

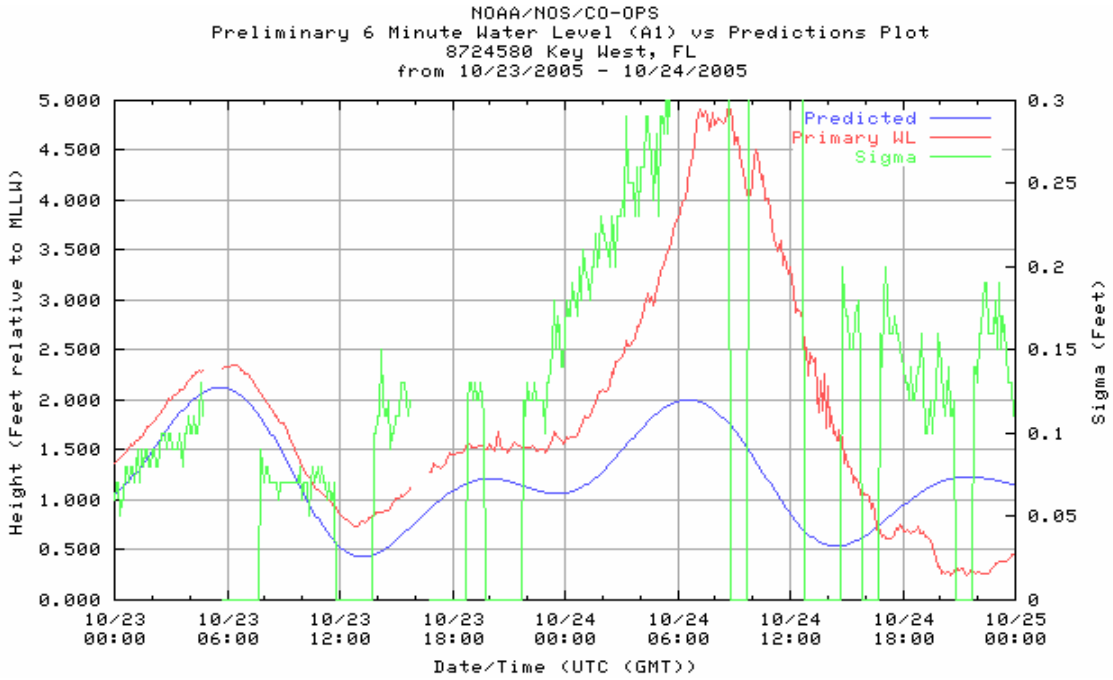


Figure 13. MLLW data from Key West NOAA Tide Station during Hurricane Wilma.

The cumulative impact of Hurricanes Dennis, Katrina, and Rita caused beach erosion conditions, summarized in Table 1, using the qualitative scale shown in Figure 14.

*Table 1. Beach and Dune Erosion Summary – Post-Rita*

| **Dade County** | **Erosion Condition** |
|---|---|
| North Dade County, R1-R74 | I (Minor) |
| Virginia Key, R79-R87 | I (Minor) |
| Key Biscayne, R90-R102 | I (Minor) |
| Key Biscayne, R102.8-R103.5 | III (Moderate) |
| Key Biscayne, R105-R107 | II (Minor) |
| Cape Florida State Park, R108-R113 | I (Minor) |
| Cape Florida State Park, R113.7-R113+1000 | II (Minor) |

| **Monroe County** | **Erosion Condition** |
|---|---|
| Islamorada, Lower Matecumbe Key | III (Moderate) |
| Long Key State Park | III (Moderate) |
| Grassy Key | I (Minor) |
| Curry Hammocks State Park | I-II (Minor) |
| Coco Plum Beach | I-II (Minor) |
| Key Colony – private beaches | I (Minor) |
| Key Colony, Sunset Beach | II (Minor) |
| Vaca Key, Sombrero Beach | II (Minor) |
| Little Duck Key, Missouri Key, Ohio Key | I (Minor) |
| Bahia Honda State Park | II-III (Moderate) |
| Big Pine Key | I (Minor) |
| Boca Chica Key | II (Minor) |
| Key West, Smathers Beach | I (Minor) |
| Key West, Rest Beach | II (Minor) |
| Key West, Higgs Beach | I (Minor) |
| Key West, South Beach | I (Minor) |
| Fort Zachary Taylor State Park | II-III (Moderate) |
| Garden Key, Ft. Jefferson | I (Minor) |
| Loggerhead Key, Dry Tortugas | II-III (Moderate) |

The impact of Hurricane Wilma caused beach erosion conditions, summarized in Table 2, using the qualitative scale shown in Figure 14.

*Table 2. Beach and Dune Erosion Summary – Post-Wilma*

| **Dade County** | **Erosion Condition** |
|---|---|
| North Dade County, R1-R74 | I (Minor) |
| Virginia Key, R79-R87 | I (Minor) |
| Key Biscayne, R90-R111.5 | I (Minor) |
| Cape Florida State Park, R111.5-R114 | II (Minor) |

| **Monroe County** | **Erosion Condition** |
|---|---|
| Islamorada, Lower Matecumbe Key | III (Moderate) |
| Long Key State Park | III-IV (Major) |
| Grassy Key | III-IV (Major) |
| Curry Hammocks State Park | III-IV (Major) |
| Coco Plum Beach | II-IV (Major) |
| Key Colony – private beaches | II-III (Moderate) |
| Key Colony, Sunset Beach | III-IV (Major) |
| Vaca Key, Sombrero Beach | II-III (Moderate) |
| Little Duck Key, Missouri Key, Ohio Key | III (Moderate) |
| Bahia Honda State Park | II-IV (Major) |
| West Summerland Key | III-IV (Major) |
| Long Beach, Big Pine Key | III-IV (Major) |
| Newfound Harbor Keys | III-IV (Major) |
| Sugarloaf Beach, Sugarloaf Key | III-IV (Major) |
| Boca Chica Key | III-IV (Major) |
| Key West, Smathers Beach | II (Minor) |
| Key West, Berg & Kitsos Beach | III-IV (Major) |
| Key West, Rest Beach | IV (Major) |
| Key West, Higgs Beach | I (Minor) |
| Key West, South Beach | I (Minor) |
| U.S. Navy, Truman Annex | I (Minor) |
| Fort Zachary Taylor State Park | II-IV (Major) |
| Woman Key | no report |
| Boca Grande Key | no report |
| Marquesas Keys | no report |
| Garden Key, Ft. Jefferson | report pending |
| Loggerhead Key, Dry Tortugas | report pending |
| Cape Sable | IV (Major) |
| Key McLaughlin | IV (Major) |
| Everglades Sloughs Debouchure | IV (Major) |

Pages 24 through 81 provide discussions of each storm's effects, erosion conditions, and damage.

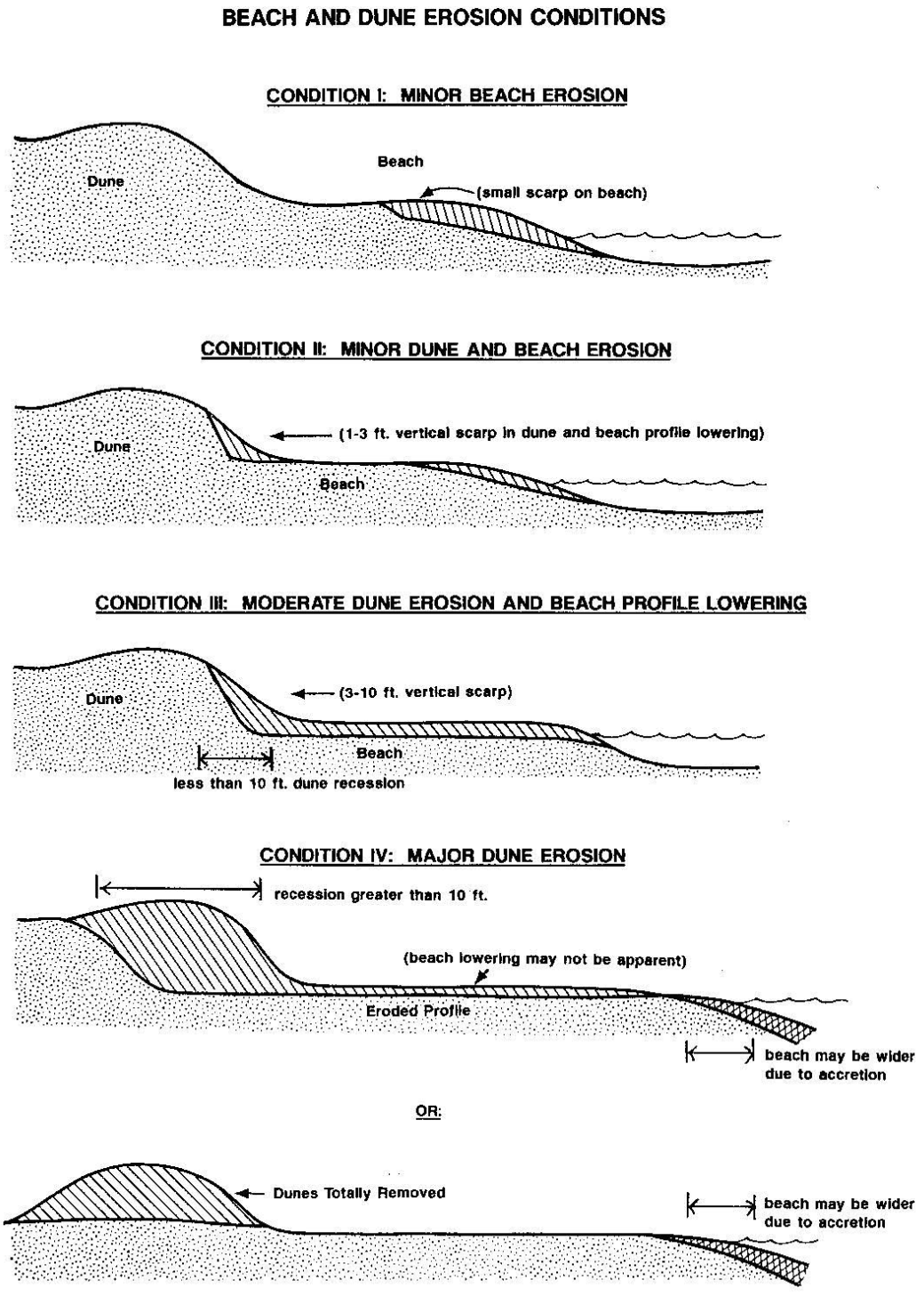


Figure 14. Beach and dune erosion conditions (Clark, 1980).

## Dade County

The Dade County coast includes 20.8 miles of barrier beaches extending southward from Broward County to Cape Florida at the south tip of Key Biscayne (Figure 15). South of Key Biscayne, the central Dade County coast is a generally open water stretch fronting Biscayne Bay for eight miles between Cape Florida and the Ragged Keys. One small island, Soldier Key, is located in this open water stretch of coast, located roughly five miles south of Cape Florida. The southern 15 miles of the Dade County coast are the northern Florida Keys islands of the Ragged Keys (1.7 miles of five small islands), Sands Key (1.7 miles), Elliot Key (8 miles), Old Rhodes Key (2.6 miles), and Swan Key (0.7 mile). There are four coastal barrier inlets in northern Dade County, including from north to south, Bakers Haulover Inlet, Government Cut, Norris Cut, and Bear Cut. The four major tidal passes in south Dade County are Sands Cut, Caesar Creek, Old Rhodes Channel, and Broad Creek. Dade County includes the following barrier beach communities and major parks: Golden Beach, Sunny Isles, Haulover Beach Park, Bal Harbour, Surfside, Miami Beach, Fisher Island, Virginia Key Beach Park, Crandon Park, Village of Key Biscayne, Bill Baggs Cape Florida State Park, and Biscayne National Monument.


Figure 15. Northern Dade County location map.

Prior to the 2005 hurricane season, most of Dade County's barrier island coast north of Cape Florida was designated critically eroded. There are designated three critically eroded areas (17 miles), two noncritically eroded areas (1.4 miles), and one noncritically eroded inlet shoreline area (0.3 mile). The northern 5.1 miles of Dade County (R1-R26.7) has critical erosion threatening development along Golden Beach and Sunny Isles and recreational interests at Haulover Beach Park. This segment of coast has a federal and state cost-shared beach restoration project along Sunny Isles and Haulover Beach Park.

Between Bakers Haulover Inlet and Government Cut (R27-R74.4) are 9.4 miles of critical erosion, which threatened development and recreational interests along Bal Harbour, Surfside, and Miami Beach. This reach is also a federal and state cost-shared beach restoration project.

The northern end of Virginia Key along the south shoreline of Norris Cut (0.3 mile) has noncritical inlet shoreline erosion. The southern 0.8-mile of beach on Virginia Key (R84-R88) is also noncritically eroded. The northern end of Key Biscayne (R89-R92) has 0.6 mile of noncritical erosion, and the southern half of Key Biscayne (R101-R113) has 2.5 miles of critical erosion. The critically eroded area threatens development in the Village of Key Biscayne and recreational interests at Bill Baggs Cape Florida State Park. This shoreline segment is another federal and state cost-shared beach restoration project.

### Hurricane Katrina Storm Effects and Erosion Conditions

The center of the eye of Hurricane Katrina made landfall between the Department of Environmental Protection's reference monuments R29 and R30, just south of Bakers Haulover Inlet. The NOAA office on Virginia Key measured a peak wind gust of 95 mph. The NOAA weather station at Fowey Rocks off south Dade County reported maximum sustained winds from the southwest at 56 mph with a peak gust to 61 mph.

Katrina was intensifying at landfall, resulting in storm tides of two to four feet above normal along the coast of Dade County. However, the northern Dade County beaches sustained generally only minor beach erosion (condition I). Some overtopping of the beach berm was experienced throughout the county; however, no significant erosion problems were incurred. Katrina also caused severe rainfall and associated flooding throughout Dade County.

### Hurricane Rita Storm Effects and Erosion Conditions

The eye of Hurricane Rita passed over 100 miles south of Dade County as it tracked westward through the Straits of Florida. Wind velocities in Dade County remained in the tropical storm intensity range. Rita brought storm tides of three to four feet along the northern county beaches. Generally only minor beach erosion (condition I) was sustained north of Government Cut from Broward County to Miami Beach. Virginia Key,

likewise, only sustained minor beach erosion (condition I), although overtopping (resulting in a washover deposit of sand) was observed across the narrow beach to the mangrove wetlands near R79.6 (Photo 1).


Photo 1. Washover deposit at the north end of Virginia Key.

Along most of Key Biscayne minor beach erosion (condition I) prevailed; however, two specific areas also sustained dune erosion. Adjacent to and north of the Sonesta Beach Resort, a stretch of coast between R102.8 and R103.5 sustained moderate beach and dune erosion (condition III) with the ends immediately tapering to condition I erosion (Photo 2). A short distance further south, minor beach and dune erosion (condition II) prevailed between R105 and R107. Along Cape Florida State Park (R108-R113) conditions ranged from minor beach erosion (condition I) along the north beach to slightly accretional towards the terminal groin at the Cape. South of the terminal groin, minor dune erosion (condition II) was sustained immediately landward of the concrete seawall south of the lighthouse. The storm tide at Cape Florida was observed to be about four feet.

Photo 2. Moderate beach and dune erosion at Sonesta Beach Resort, Key Biscayne.

## Hurricane Wilma Storm Effects and Erosion Conditions

The center of the eye of Hurricane Wilma passed approximately 70 miles north of Dade County on a west to east track. This track placed Dade County within the maximum wind field where the majority of the county experienced hurricane force winds. The direction of Wilma's sustained wind in Dade County was primarily from the southwest to west. Due to the predominantly offshore wind, the storm tide along the county's beaches fronting on the Straits of Florida was minimal. Some wave set-up along the west shorelines of the barrier islands did occur. The storm tide at Cape Florida was observed to be about five to six feet. Generally, only minor beach erosion (condition I) was sustained from the Broward-Dade County line south to Government Cut, as well as, along Virginia Key. To the south, along most of Key Biscayne, minor beach erosion (condition I) prevailed; however, at Bill Baggs Cape Florida State Park (R108-R113) erosion conditions transitioned from minor beach erosion (condition I) between R108 and R111.5 to minor beach and dune erosion (condition II) between R111.5 and the terminal groin at the cape near R114. Along this segment, a debris line comprised of old trash and marine invertebrates was deposited (Photo 3).

Photo 3. Minor beach erosion at Bill Baggs Cape Florida State Park (R112)

**Hurricane Katrina Storm Damage**

No structural damages were sustained along the Dade County coast seaward of the coastal construction control line or within the coastal building zone; however, a number of single-family dwellings were flooded on Key Biscayne forcing their evacuation. Katrina did cause significant tree damage at Cape Florida State Park.

Inland of the coast, a reported 40 mobile homes at three mobile home parks in the Broward County community of Davie sustained considerable wind damage including four destroyed when their roofs were blown off. Major wind damages were also sustained to a hotel in Pompano Beach, a commercial building in Ft. Lauderdale, and a two-story apartment building in Davie. In the south Dade County community of Homestead, about 50 single-family dwellings were flooded from a measured 12.25 inches of rain, but no major structural damage was reported. Adjacent Homestead to the south, storm water flooding was also sustained in Florida City. In addition, an overpass under construction in Miami collapsed onto the Dolphin Expressway between 87$^{th}$ and 97$^{th}$ Avenues.

## Hurricane Rita Storm Damage

No structural damages were sustained along the Dade County coast seaward of the Coastal Construction Control Line (CCCL) or within the Coastal Building Zone (CBZ) during the passage of Hurricane Rita.

## Hurricane Wilma Storm Damage

The majority of the structural damage that occurred in Dade County was caused by hurricane force winds out of the west and southwest. Widespread light to moderate wind damage was sustained throughout the county. In downtown Miami, numerous high-rise office buildings were severely impacted by hurricane force winds. The Miami Metromover was closed due to falling debris from a neighboring high rise building. Power outages occurred county-wide for three weeks due to damaged power lines and utility poles. Power losses to service station fuel pumps caused a major but temporary impact on recovery operations. Wind damage to trees and shrubs (native and ornamental) was extensive throughout the county. Ficus trees and Australian Pines sustained the majority of the tree damage, while palms appeared to fare well.

Throughout the Biscayne Bay area there was significant marine damage. Many boats were blown up into bulkheads, docks, and overpasses. Some vessels were freed from their moorings and deposited hundreds of feet from where they were originally docked. The Port of Miami sustained damage to roughly 2,000 feet of bulkheads and a cruise terminal lost a section of its roof. The Sunny Isles Marina dry storage facility collapsed, damaging close to 300 vessels. Numerous docks and pilings throughout the county were severely damaged by the battering of vessels that were moored to them.

On the barrier islands, there was sporadic minor to moderate wind damage to ocean front high-rise condominiums, low-rise motels, commercial buildings, and single-family dwellings (Photo 4). The typical wind damages were broken windows, damaged hurricane shutters, and minor roofing losses. No major structural damage was observed seaward of the coastal construction control line or within the coastal building zone. The majority of the damage near the coast occurred north of Bakers Haulover Inlet.

At Cape Florida, a concrete seawall and rock revetment sustained level three damage (See Table 3 for damage levels). A 72-foot section of the wall was leaning towards the ocean and a 12-foot section of the wall lost its concrete cap (Photo 5).

Photo 4. Broken windows, Golden Nugget Motel, Sunny Isles Beach.

Photo 5. Concrete cap damage, Cape Florida.

*Table 3. Levels of Damage for Coastal Protection Structures (Tabor, J. et al, 2005).*

**Damage Level I: Minimal Impact**

*Sustained little to no damage*

- Increased exposure
- Structure uncovered
- Negligible displacement of armor stone
- Negligible displacement of geotextile bags

**Damage Level II: Minor Damage**

*Sustained minor damages*

- Damage to seawall cap
- Damage to some tiebacks
- Damage to a few wall panels
- Displacement of a few armor stones/geotextile bags; rips and tears observed in a few sand bags

**Damage Level III: Major Damage**

*Significant destruction requiring reconstruction*

- Anchor system compromised
- Significant loss of backfill
- Wall panels damaged
- Displacement of armor stones/geotextile bags

**Damage Level IV: Total Destruction**

*Structure completely destroyed*

- Complete failure of anchoring system
- Entire structure compromised
- Majority of wall panels missing and/or destroyed
- Majority of armor stones/geotextile bags displaced and/or destroyed

## Monroe County

The Monroe County coast includes the Florida Keys south of Dade County fronting on the Straits of Florida and Gulf of Mexico, and the peninsula mainland fronting on the Gulf of Mexico between Cape Sable and Collier County to the north (Figure 16). The Florida Keys is an elongate, arcuate archipelago over 220 miles in length from Soldier Key at its northeast end of the chain near Miami, southwest to the Dry Tortugas. The Florida Keys are separated from the mainland by Florida Bay, a broad shallow marine system which is compartmentalized by numerous carbonate mud banks. Sand beaches exist throughout the Florida Keys; however, beach and dune formation is not common in comparison to the barrier island coasts of peninsula Florida (Clark, 1990). There are 26.4 miles of Monroe County beaches fronting on the Straits of Florida and 26.1 miles of beaches fronting on the Gulf of Mexico, including 16.2 miles of mainland peninsula beaches of Cape Sable and Key McLaughlin.

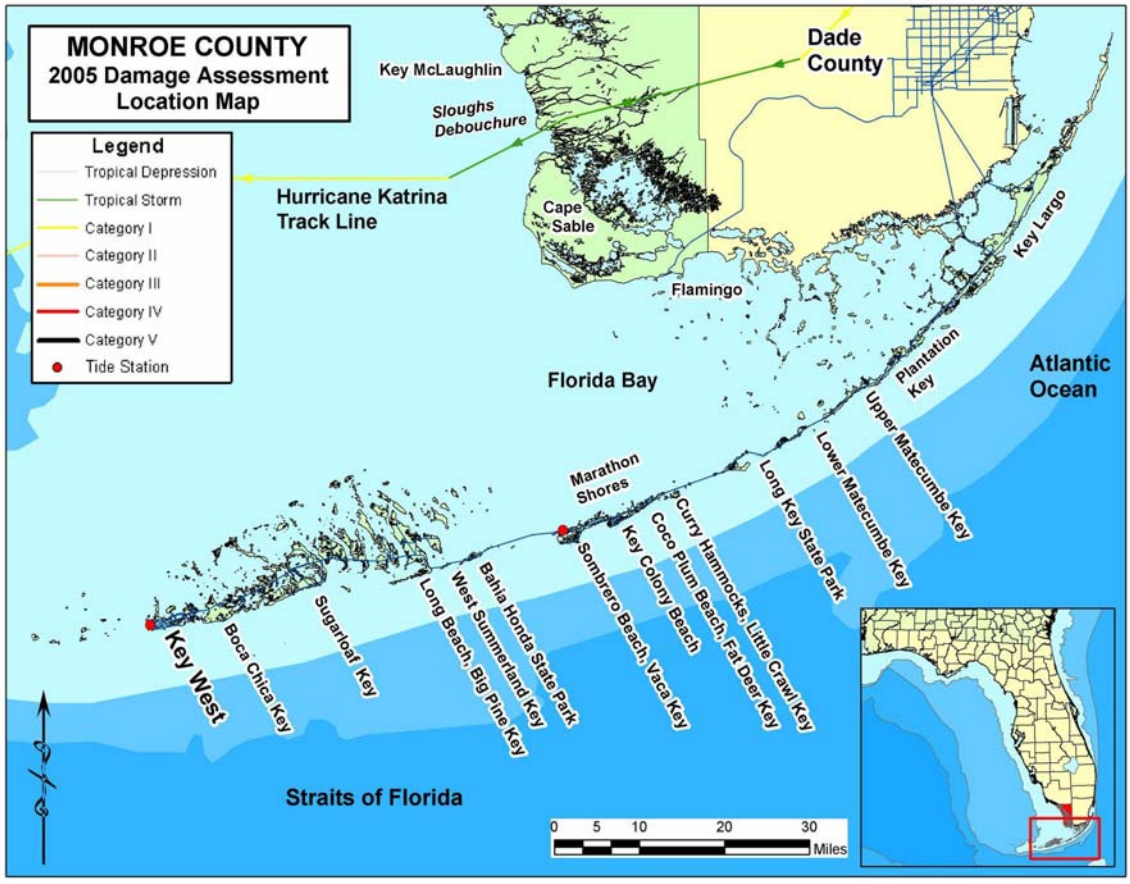


Figure 16. Monroe County location map.

Prior to the 2005 hurricane season, there were eight designated critically eroded beach areas (7.7 miles) and three noncritically eroded beach areas (2.9 miles) along the Florida Keys fronting on the Straits of Florida between Key Largo and Key West. There are no identified erosion problem areas in the upper keys but there are four in the middle keys. A one-mile stretch of Long Key is critically eroded, threatening recreational interests at the Long Key State Park. Another 0.1-mile segment at Curry Hammocks State Park on Little Crawl Key is also critically eroded threatening recreation interests. Near Key Colony, the eastern 0.6-mile of Coco Plum Beach is noncritically eroded. This area is a Marathon city park. The western 0.3-mile of Coco Plum Beach and the entire 0.9-mile stretch of Key Colony Beach is critically eroded threatening private development. At Sombrero Beach on Vaca Key is a small stretch (0.3-mile) of critical erosion threatening recreational interests at another Marathon city park.

The lower keys have significantly more erosion than the upper or middle keys, as calcium carbonate sand beaches become more frequent although still limited. The sandy island of Bahia Honda Key has three erosion areas. Within Bahia Honda State Park, Calusa Beach (between the bridges), Loggerhead Beach (a western segment) fronting on the Straits of Florida, and a stretch of Sandspur Beach at the east end of Bahia Honda Key have two miles of critically eroded shoreline, threatening recreational interests as well as the park road. Further west are two separate designated noncritically eroded beach areas including one mile of Long Beach on Big Pine Key and 1.3 miles on Boca Chica Key.

Nearly the entire south coast of the island of Key West is critically eroded extending for 2.8 miles. Erosion along the eastern portion of Key West completely eliminated the recreational beach. A beach restoration project has been constructed at Smathers Beach and minor nourishment projects have been constructed at other public and private beaches to the west including Rest Beach and Higgs Beach. At the west end of Key West, the 0.3-mile beach along Fort Zachary Taylor Historic State Park is critically eroded threatening recreational interests. A terminal groin and breakwater project has been constructed and minor nourishment has been conducted at this site.

### Hurricane Dennis Storm Effects and Erosion Conditions

Hurricane Dennis crossed Cuba into the Straits of Florida as a category two hurricane on Saturday, July 9th. Throughout Saturday morning Dennis continued on a northwest track passing the Florida Keys about 125 miles west of Key West. Waves propagating from the winds of Dennis caused minor to moderate beach erosion impact (condition I-III) along the middle and lower keys. Coco Plum Beach and Sombrero Beach in Marathon sustained significant, but generally only minor beach erosion (condition I). Boca Chica Key's beaches and Key West's beaches experienced overtopping and erosion. Generally, minor beach erosion (condition I) was sustained along the Key West beaches – Smathers Beach, Rest Beach, and Higgs Beach.

Erosion was sustained along the distal islands west of Key West; however, no data is currently available. The National Park Service reported erosion and wind damage at Fort Jefferson National Monument, including Garden Key and Loggerhead Key within the Tortugas Keys. Located 70 miles west of Key West, the Dry Tortugas was the closet land to the eye of Hurricane Dennis as it tracked northward into the Gulf of Mexico.

**Hurricane Katrina Storm Effects and Erosion Conditions**

In the early morning hours of Friday, August 26th, Hurricane Katrina crossed the south Florida peninsula moving off the mainland gulf coast of Monroe County and into the open waters of the Gulf of Mexico. Heavy rain and wind squalls occurred across the Florida Keys. By late morning, the National Hurricane Center advised that a NOAA vessel in port at Key West had reported sustained winds of 59 mph and a peak gust to 86 mph. By mid-day, Katrina moved away from southwest Florida and the Florida Keys, and strengthened to a category two hurricane with 100 mph winds.

Generally, only minor beach erosion (condition I) was sustained along the middle and lower keys beaches.

**Hurricane Rita Storm Effects and Erosion Conditions**

The eye of Hurricane Rita passed roughly 50 miles south of the Florida Keys in Monroe County as it tracked westward through the Straits of Florida. Wind velocities in Monroe County generally remained in the tropical storm range; however a peak gust of 92 mph was measured in Key West. Rita brought storm tides of three to four feet along the keys shorelines fronting the Florida Straits. Post-storm beach conditions generally varied from minor beach erosion (condition I) to moderate beach and dune erosion (condition III). Specific beach conditions at various major beach sites are discussed as follows.

Islamorada, Lower Matecumbe Key

Lower Matecumbe Key sustained minor flooding along its shoreline fronting on the Straits of Florida. Sea Oats Beach seaward of U.S. Highway 1 sustained moderate beach and dune erosion (condition III). Sand and debris overwashed the highway from the erosion of 0.7 mile of beach. Minor flooding with no erosion was observed along Calusa Cove or Anne's Beach.

Long Key State Park

Hurricane Rita inflicted substantial overwash from its storm tide of 4-6 feet (Photo 6). Moderate beach and dune erosion (condition III) was sustained throughout the park (Photo 7). However, unlike condition III erosion along the more dynamic barrier island beaches, erosion of this level along Long Key is locally significant. Condition III erosion along the barrier island beaches may substantially recover by natural processes. Erosion of this severity will not naturally recover to its pre-storm beach position along Long Key. Put into perspective, Hurricane Rita has inflicted the worst storm erosion to the park in

six years since Hurricane Irene (1999), but the erosion was not quite as severe as during either Irene or Hurricane Georges (1998) (Clark, 1998; Clark, 2000).


Photo 6. Overwash at Long Key State Park.

Photo 7. Beach erosion at Long Key State Park.

Grassy Key

Minor flooding and beach erosion (condition I) was sustained along 1.3 miles of Grassy Key; however, true to its name, substantial quantities of drifting sea grass were piled a few feet deep covering the beach and upland.

Curry Hammocks State Park, Little Crawl Key

Generally, the park sustained condition I erosion (minor beach erosion) throughout, with the exception of a short segment of condition II erosion toward the west end (Photo 8). Sand transport during the storm was to the west, and there was very little overtopping due to the four-foot storm tide.

Photo 8. Minor beach and dune erosion at Curry Hammocks State Park.

Coco Plum Beach

A four-foot storm tide caused substantial flooding along the entire coast of Coco Plum Beach and deposited a large wrack of sea grass up to two feet deep along the shoreline. Along the eastern two-thirds of shoreline within the Marathon city park, the beach erosion varied between conditions I to II. Significant overwash was also observed depositing sand into the mangrove wetland landward of the beach. Along the critically eroded western 0.3 mile of Coco Plum Beach, condition II erosion prevailed.

City of Key Colony Beach

Minor flooding and beach erosion (condition I) was sustained throughout the city's critically eroded groin field. The city's newly developed public beach, Sunset Beach, sustained condition II erosion.

Sombrero Beach, Vaca Key

Minor beach and dune erosion (condition II) was sustained along the City of Marathon park at Sombrero Beach. Erosion conditions were additive to that erosion sustained during Hurricane Dennis in July.

Little Duck Key, Missouri Key, and Ohio Key

Minor beach erosion (condition I) was sustained.

Bahia Honda State Park

Calusa Beach – As has been the trend at this small beach, the north end experienced accretion and the south end sustained condition II erosion (Photo 9).

Photo 9. Minor beach and dune erosion at Calusa Beach.

Loggerhead Beach – The west end near the old Bahia Honda Bridge experienced accretion; however, condition III erosion (moderate beach and dune erosion) was

Photo 10. Moderate beach and dune erosion at Loggerhead Beach.

sustained along the section of service road west of the marina (Photo 10). Condition II erosion was sustained along most of the remainder of Loggerhead Beach. Some natural beach recovery is taking place through the onshore transport of eroded material deposited in the nearshore.

Sandspur Beach – Minor beach and dune erosion (condition II) was sustained along this beach. The erosion and impact was the worst since Hurricane Irene (1999), but not as severe as Irene or Hurricane Georges (1998).

Long Beach, Big Pine Key

Minor beach erosion (condition I) was sustained.

Boca Chica Key

Minor beach and dune erosion (condition II) was sustained along this eroding shoreline of over 1.3 miles. Erosion conditions were additive to that erosion sustained during Hurricane Dennis in July, and Hurricanes Georges (1998) and Irene (1999). This beach is not expected to naturally recover to its pre-storm beach position, as most of its sand loss has been due to overwash deposits.

Key West Beaches

South Roosevelt Boulevard – The eastern three-quarters of a mile of seawalled shoreline fronting U.S. Highway A1A was overtopped by the storm tide and waves associated with Hurricane Rita.

George Smathers Beach – The city's 3,000-foot man-made public beach fronting the Straits of Florida sustained minor beach erosion (condition I). Minor overwash deposits of sand were carried across South Roosevelt Boulevard. The erosion was additive to the losses sustained during Hurricanes Dennis and Katrina.

Rest Beach – Condition II erosion was sustained at this 0.1-mile city park beach. Significant flooding and overwash occurred across Atlantic Boulevard. The beach was also covered by a large wrack of sea grass (Photo 11).

Photo 11. Minor beach and dune erosion at Rest Beach, Key West.

Clarence Higgs Beach – Condition I erosion was sustained along this one-quarter mile long county park beach. The seawall protecting the historic West Martello Tower was overtopped and minor ponding of water was observed behind the wall.

Private beaches extend between Reynolds Street and Simonton Street, which sustained condition I erosion and minor flooding. Street ends at Alberta Street, Vernon Street, and Simonton Street received significant deposits of sea grass wracks.

South Beach – Minor beach erosion (condition I) was sustained at this city park and the street end of Duval Street sustained flooding and received a deposit of sea grass wrack.

Simonton Beach – No erosion was observed at this small city park on the gulf shoreline of Key West.

Ft. Zachary Taylor Historic State Park

Minor beach and dune erosion (condition II) was generally sustained along this man-made beach except for the western segment between the terminal groin and the west breakwater, where moderate beach and dune erosion (condition III) was observed (Photo 12). The erosion from Rita has been additive to the erosion from Hurricanes Dennis and Katrina.

Photo 12. Western end of beach, Fort Zachary Taylor Historic State Park.

Distal Sand Keys

No report is available on the beach erosion conditions of Woman Key, Boca Grade Key, or the Marquesas Keys; however, significant erosion impacts were likely sustained along the shorelines facing the Florida Straits.

Dry Tortugas

A report is pending from the National Park Service on the erosion impact to Loggerhead Key and Garden Key.

## Hurricane Wilma Storm Effects and Erosion Conditions

The center of the eye of Hurricane Wilma passed approximately 70 miles north of Key West as the storm tracked from west to east, and made landfall on the coast of Collier County just north of the Ten Thousand Islands and close to the north Monroe County line. Wilma's maximum sustained winds of 125 mph crossed northern Monroe County near Cape Sable. The peak winds of Wilma measured throughout the Florida Keys include (from west to east):

- Dry Tortugas – 134 mph
- Key West – 85 mph
- Cudjoe Key – 123 mph
- Sombrero Key – 101 mph
- Long Key – 81 mph

Wilma brought storm tides estimated to reach approximately 10 feet along the northern gulf coast of Monroe County affecting the Florida Everglades National Park. Storm tides of eight to ten feet inundated the lower and middle keys, with the highest storm surge affecting the keys from the Gulf of Mexico and Florida Bay sides of the islands. Roughly 35 percent of the island of Key West was flooded, including the airport, which had five feet of water at its entrance and three feet of water on the runway. Photos 13-15 depict the storm surge flooding in Key West.

In contrast to the prior three hurricanes of the 2005 hurricane season, Wilma caused moderate to major beach and dune erosion throughout the keys. Specific beach conditions at various major beach sites are discussed as follows.

Photo 13. North Roosevelt Boulevard, Key West (Credit: City of Key West).

Photo 14. Key West flooding (credit: City of Key West)

Photo 15. Key West flooding (credit: City of Key West).

Upper Keys

On Key Largo, the man-made beaches at Ocean Reef Club and John Pennekamp State Park sustained no apparent erosion. The man-made beaches of Tavernier, and the private beaches of Plantation Key and Windley Key sustained no apparent erosion.

Islamorada, Upper and Lower Matecumbe Key

Upper and Lower Matecumbe Keys sustained significant flooding from Florida Bay. Sea Oats Beach along Lower Matecumbe Key sustained additional moderate beach and dune erosion (condition III) (Photo 16). As occurred during Hurricane Rita, Wilma's surge and waves from the Straits of Florida overwashed U.S. Highway 1, pushing debris and sand across the road.

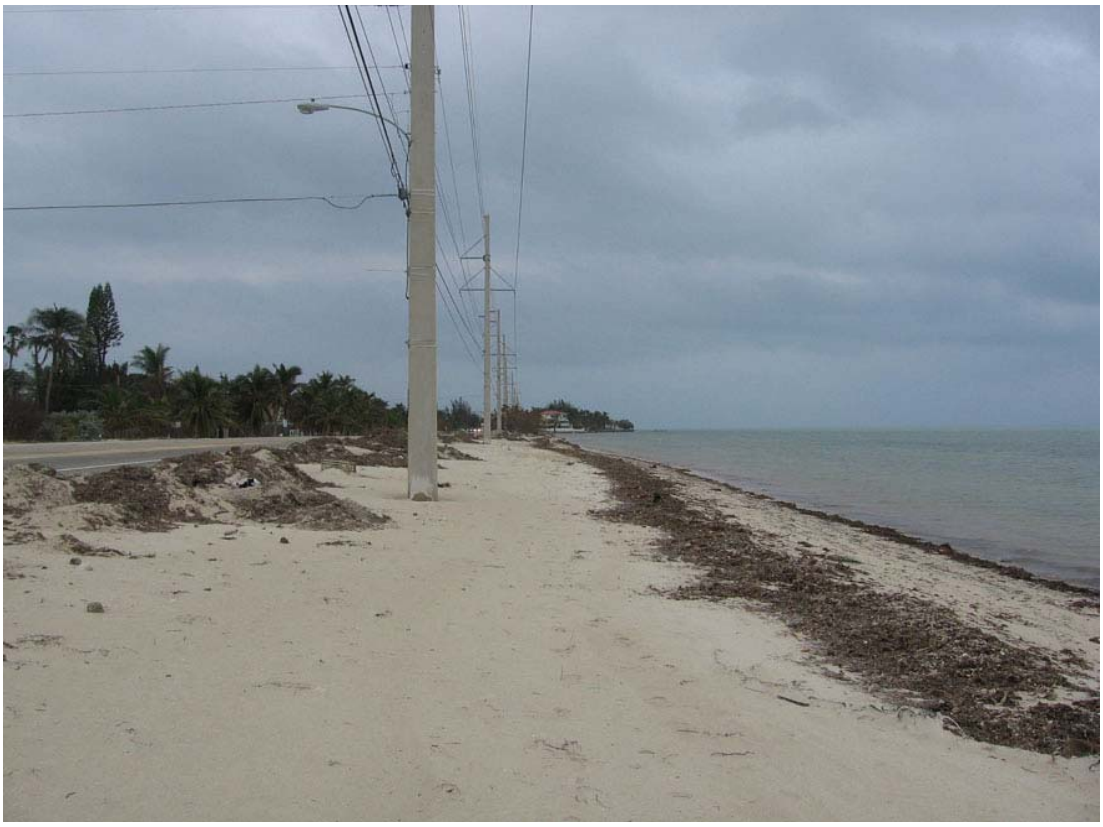

Photo 16. Sea Oats Beach, Lower Matecumbe Key (Islamorada).

Long Key State Park

As previously discussed, Rita severely impacted the beach along Long Key State Park and destroyed all 60 camp sites. Wilma significantly worsened the beach conditions and camp sites. In the early stages of the storm's impact, the surge and waves from the straits were inflicting additional erosion of the shoreline and upland. As the eye of Wilma passed to the north, the large storm surge from within Florida Bay overtopped the island from the north, and flood waters were conveyed southward across U.S. Highway 1 and the state park. This "back door" flooding caused large scour channels throughout the park's camp grounds and transported beach and overwash sediments seaward into the nearshore waters off the park's beach (Photo 17).

Photo 17. Storm surge scour channels, Long Key State Park.

Grassy Key and Toms Harbor Keys

Grassy Key, like other islands in the middle keys, sustained significant flooding from the storm surge out of Florida Bay following significant erosion from waves out of the straits. Moderate to major beach and dune erosion (condition III-IV) was sustained. Ironically, the wrack of sea grass left by Rita and piled a few feet deep along the shoreline, was lifted and transported away toward the straits during the storm surge flooding of Wilma.

Curry Hammocks State Park, Little Crawl Key

The beach conditions at Curry Hammocks State Park substantially worsened. After Rita, there was only a small segment of condition II erosion; however, after Wilma most of the park's shoreline had sustained moderate to major erosion (condition III-IV). Most surprising was the significant erosion into what were essentially marl uplands of a former dredge and fill project (Photo 18). A beach restoration project in the planning stages will now have to factor into account additional quantities of beach fill.

Photo 18. Significant erosion, Curry Hammocks State Park.

Coco Plum Beach

The flooding of Coco Plum Beach was not as severe as many other keys in the vicinity due to its lesser exposure to the surge off Florida Bay. Still, Coco Plum has very low elevations and flooding was significant. Along the developed segment of Coco Plum Beach, which is designated as critically eroded, the erosion conditions varied from minor beach and dune erosion (condition II) at the Coco Plum Beach Villas and Royal Plum Condominium to moderate beach and dune erosion (condition III) along the west end of Coco Plum Beach. The City of Marathon park that traverses the eastern two thirds of Coco Plum Beach, sustained additional erosion and overwash of beach sediments into the mangrove wetlands landward of the beach. The extreme east end of the park sustained severe major beach erosion (condition IV) (Photo 19).

Photo 19. Severe beach erosion, Coco Plum beach.

City of Key Colony Beach

The City of Key Colony Beach sustained less flooding than did Marathon Shores, which was flooded from Florida Bay; however, the flooding was still significant off Hawk Channel. The west shoreline of Key Colony Beach northwest of Sandy Point sustained moderate to major beach and dune erosion (condition III-IV). Sunset Beach, the city's public beach, sustained major erosion conditions into the uplands (Photo 20).

Along the private beaches east of Sandy Point, minor to moderate beach and dune erosion (condition II-III) was sustained. These beaches are within a groin field and the cumulative erosion conditions since Hurricanes George (1998) and Irene (1999) have severely reduced their recreational and storm protective values. The segment of beach at the Key Colony Point Condominiums has been totally lost seaward of the seawall that fronts the development (Photo 21).

Photo 20. Sunset Beach, City of Key Colony Beach.

Photo 21. Complete loss of beach at Key Colony Point, Key Colony Beach.

City of Marathon, Vaca Key and Tingler Island

Storm surge flooding was sustained throughout Marathon as the flooding crossed U.S. Highway 1 from Florida Bay. Flood waters two to four feet deep flowed across parts of the island and the runway of the Marathon Florida Keys Airport, partially submerging planes, cars, homes, and businesses.

Sombrero Beach, Vaca Key

Significant overwash from four hurricanes has caused minor to moderate beach and dune erosion (condition II-III) along the City of Marathon park at Sombrero Beach (Photo 22). Additional sediment losses have occurred as the southwest waves have driven beach material into the Tingler Island canals as well as the nearshore.

Photo 22. Sombrero Beach erosion, Marathon.

Little Duck Key, Missouri Key, and Ohio Key

Moderate beach and dune erosion (condition III) was sustained along Little Duck Key, Missouri Key and Ohio Key. At Veterans Memorial Park on Little Duck Key the erosion and flooding was the most severe in recent history. The park's recreation beach has now been critically eroded.

Bahia Honda State Park

Calusa Beach – Due to the exposure of Calusa Beach to the storm surge and waves of Wilma off the bay of Bahia Honda, the erosion conditions were much worse than occurred during Rita. The north half of the beach sustained significant overwash which transported sand into the public parking area and northern four picnic shelters. The south half of the beach sustained moderate to major beach and dune erosion (condition III-IV) leaving some park facilities destroyed and others threatened (see Wilma damage discussion for Bahia Honda State Park).

Loggerhead Beach – Exposed to the south waves of Wilma, Loggerhead Beach sustained moderate to major beach and dune erosion (condition III-IV). The erosion conditions were the greatest to the west of the bathhouse, where 300 feet of service road was lost to the erosion (Photos 23 & 24).


Photo 23. Severe erosion at Loggerhead Beach, Bahia Honda State Park.

Photo 24. Eroded bluff at Loggerhead Beach.

Sandspur Beach – As occurred during Rita, minor dune erosion (condition II) was sustained along Sandspur Beach; however, there was substantial accretion of the beach during Wilma. Historically and prior to the 2005 hurricane season, the beach width at Sandspur Beach was roughly 50 feet (Clark, 1990). After Wilma, the beach width exceeds 100 feet (Photo 25). In contrast, on the east end of the island, condition IV erosion was sustained due to scour by the storm surge being conveyed through the Ohio Bahia Honda Channel.

Photo 25. Substantial beach accretion at Sandspur Beach, Bahia Honda State Park.

West Summerland Key

Moderate to major beach and dune erosion (condition II-IV) was sustained along West Summerland Key. Along the eastern segment of beach at the Camp Wesumkee Girl Scout Camp, moderate dune erosion and overwash has leveled the coastal ridge, which now provides a wider recreational sandy beach. Along the western segment of beach at Camp Sawyer Boy Scout Camp, moderate to major beach and dune erosion was sustained (condition III-IV). A segment of the coastal ridge was leveled and deposited as overwash across the campgrounds.

Long Beach, Big Pine Key and Newfound Harbor Keys

Moderate to major beach and dune erosion (condition III-IV) was sustained along the private residential area of Long Beach. Significant overwash contributed to the beach losses. Storm surge discharge channels were incurred along the beach similar to Long Key (Photo 26). Moderate to major beach and dune erosion (condition III-IV) was also sustained along the Newfound Harbor Keys.

Photo 26. Storm surge discharge channels, Long Beach, Big Pine Key.

Sugarloaf Beach, Sugarloaf Key

Sugarloaf Beach sustained moderate to major beach and dune erosion (condition III-IV). Storm surge discharge scour channels caused extensive beach damage similar to that observed along Long Key and Big Pine Key. The beach gullies along Sugarloaf Key were particularly severe and caused the destruction of a single-family dwelling, and left two other dwellings imminently threatened.

Boca Chica Key

The beach conditions at the Monroe County park along Boca Chica Key substantially worsened. After Rita, there was generally condition II erosion; however, after Wilma most of the park's shoreline had sustained moderate to major erosion (condition III-IV). Rita caused overwash deposits onto Boca Chica Road, while Wilma substantially damaged a considerable stretch of the road (see Wilma damage discussion). This

critically eroded beach is not expected to naturally recover to its pre-2005 beach position as most of its sand loss has been due to overwash deposits.

Key West Beaches

South Roosevelt Boulevard – The eastern three-quarters of a mile of seawalled shoreline fronting U.S. Highway A1A was overtopped by the storm tide and waves of Wilma. Significant scour was sustained landward of the seawall (Photo 27).

Photo 27. Scour behind seawall along South Roosevelt Boulevard (credit: City of Key West)

George Smathers Beach – The city's 3,000-foot man-made public beach fronting the Straits of Florida sustained minor beach and dune erosion (condition II). Major overwash deposits of sand were carried across South Roosevelt Boulevard (Photos 28 and 29). The erosion was additive to the losses sustained during Hurricanes Dennis, Katrina, and Rita. No storm effects performance data will be available for the project; however, following recovery of all overwash sediments back to the beach system, surveys will be obtained to determine the net deficit of beach sand needed for future maintenance.


Photo 28. Overwash from Smathers Beach onto South Roosevelt Boulevard (credit: City of Key West).


Photo 29. Overwash from Smathers Beach onto South Roosevelt Boulevard (credit: City of Key West).

Berg and Kitsos Beach – To the west of Smathers Beach is a segment of straits fronting beach at the 1800 Atlantic Condominium and the City of Key West public beach known as Berg and Kitsos Beach. Moderate to major beach and dune erosion (condition III-IV) was sustained along this segment of shoreline. When the storm surge that inundated Key West withdrew, scour channels were carved across Berg and Kitsos Beach (Photo 30). The city will have to fill these storm surge discharge scour holes and channels. Additional beach sediments have been lost through overwash into the mangrove wetlands landward of the beach.

Photo 30. Scour channel, Berg and Kitsos Beach.

Rest Beach - The beach conditions at the City of Key West park known as Rest Beach substantially worsened. After Rita, there was generally condition II erosion; however, after Wilma most of the park's shoreline had sustained major beach and dune erosion (condition IV) (Photo 31). Rita caused flooding and some overwash deposits onto Atlantic Boulevard, but Wilma inflicted severe erosion, flooding, and overwash, and substantially destroyed the entire park's recreational infrastructure (see Wilma damage discussion). This critically eroded beach is not expected to naturally recover to its pre-2005 beach condition, as most of its sand loss has been due to overwash deposits.

Photo 31. Beach erosion, overwash, and infrastructure damage, Rest Beach.

Clarence Higgs Beach – Condition I erosion was sustained along this one-quarter mile long Monroe County park beach.

Casa Marina Beach – Private beaches exist to the west of the city and county park beaches. At the Casa Marina Hotel, a restored perched beach constructed in 1979, sustained minor beach and dune erosion (condition II). To the west, adjacent the Reach Hotel, minor beach erosion (condition I) was sustained.

South Beach and Dog Beach – Dog Beach, the tiny beach at the end of Vernon Street, and South Beach, the city's public beach adjacent the end of Duval Street, sustained minor beach erosion (condition I) due primarily to overwash losses.

Truman Annex, U.S. Navy – The federal beaches both east and west of the reveted headland (Whitehead Spit) sustained minor beach erosion (condition I) due primarily to overwash losses. The east beach was somewhat sheltered from the west and southwest waves of Wilma, and the west beach received some accretion from the adjacent state park beach to minimize the erosion conditions.

Fort Zachary Taylor Historic State Park – As occurred during Rita, continued minor beach and dune erosion (condition II) was sustained along the eastern half of the park's shoreline during Wilma. From the middle of the park's shoreline to the west end at the terminal groin, erosion conditions worsened from moderate to major beach and dune erosion (condition III to IV). Wilma's southwest storm waves propagating on the storm surge across the Key West Ship Channel inflicted substantial dune recession near the terminal groin (Photo 32). In addition, the west shoreline of the park, exposed to waves from both the straits and the gulf, sustained moderate upland bank erosion (condition III) behind the rock revetment.

Simonton Beach – The City of Key West's public beach fronting on the Gulf of Mexico at the end of Simonton Street sustained minor beach and dune erosion (condition II). This beach was exposed to the significant storm surge flooding and storm waves of Wilma. Beach conditions at this small public recreation beach are not expected to naturally recover to its pre-2005 condition. The city's recreation beach is now critically eroded.

Photo 32. Severe dune erosion, Fort Zachary Taylor Historic State Park.

Sunset Key (formerly Tank Island)

Conditions varied around the island ranging from minor to major beach and dune erosion (condition II-IV).

Christmas Tree Island

Moderate to major beach and dune erosion (condition III-IV) was sustained around this sandy island northwest of Key West. Over 30 boats (sailboats and other pleasure craft) were deposited on and landward of the beach by the storm surge.

Distal Sand Keys

No report is available on the beach erosion conditions of Woman Key, Boca Grade Key, or the Marquesas Keys; however, given the proximity to these sandy islands to the eye of Wilma, severe erosion impacts were probably sustained along the shorelines facing not only the Florida Straits, but also the Gulf of Mexico.

Dry Tortugas, including Loggerhead Key and Garden Key (Fort Jefferson)

A report from the National Park Service is pending.

Cape Sable

The maximum wind field and highest storm surge of Hurricane Wilma devastated the 12.2 miles of carbonate sand and shell beaches of Cape Sable. Severe beach and dune erosion (condition IV) was sustained throughout this undeveloped region on the mainland gulf coast of Monroe County (Photo 33). Along segments where important sea turtle nesting habitat has been lost, the beaches have become critically eroded.

Everglades Sloughs Debouchure (Shark River to Pavilion Key)

The maximum wind field and highest storm surge of Hurricane Wilma devastated the discontinuous carbonate sand and shell beaches of this region. Severe beach and dune erosion (condition IV) was sustained throughout this undeveloped region on the mainland gulf coast of Monroe County (Photo 34). Along segments where important sea turtle nesting habitat has been lost, the beaches have become critically eroded.

Photo 33. Severe beach erosion north of the Northwest Cape (Cape Sable).

Photo 34. Storm surge scour channels between Shark River and Pavilion Key.

**Hurricane Dennis Damage**

Hurricane Dennis caused an estimated 300 feet of revetment damage to the 1,500-foot long rock revetment at the U.S. Naval Station, Truman Annex, fronting on the Florida Straits in Key West. The damage included rock displacement, overtopping, and scour behind the structure (Photo 35).


Photo 35. Revetment damage at U.S. Naval Station, Truman Annex (photo by Danielle Rogers, D.E.P.).

Roughly six miles off Key Largo, the 510-foot long, 6880-ton U.S. Navy ship, the Spiegel Grove, was up-righted in its sunken position as an artificial reef. The Spiegel Grove was sunk prematurely on May 17, 2002, and landed on its side in 130 feet of water where it has remained for the past three years. The waves and currents generated by Hurricane Dennis moved the ship from laying on its side to an upright position, which was originally intended for the artificial reef.

Fort Jefferson National Park in the Dry Tortugas was closed after initial assessments of the park's fort, housing units, docks, and communications tower revealed extensive structural damage.

## Hurricane Katrina Damage

There were few major damages reported in the Florida Keys from Katrina. In Tavernier in the upper keys, a commercial building (a lumber company building) sustained major wind damage. A tornado spawned from Katrina was reported by the Monroe County Sheriff's Office, and caused major damage to two single-family dwellings and an aircraft hanger at the airport in Marathon.

## Hurricane Rita Damage

Islamorada

Flood damages were sustained throughout Upper Matecumbe Key, Lower Matecumbe Key, Windley Key and Plantation Key. Marinas throughout Islamorada were damaged, including the Holiday Isle Resort, Bud and Mary's Marina, and Whale Harbor. The Seabreeze Trailer Park on Plantation Key and the San Pedro Trailer Park sustained flood damage to some mobile homes.

Long Key State Park

Rita inflicted substantial overwash from its storm tide of four to six feet within the park (Photo 36). Virtually all the gulf-front camp sites were destroyed or substantially damaged as well as the stretch of park road that parallels the beach. In addition, the 650-foot rock revetment was both damaged and overtopped causing a significant loss of material from behind the structure (Photo 37). Along with the restoration of the park's campsites and road, there is a critical need for beach and dune restoration.

Photo 36. One of the sixty campsites destroyed by Rita at Long Key State Park.

Photo 37. Revetment damaged by Rita at Long Key State Park.

Curry Hammocks State Park

Generally, the park sustained little overtopping due to the four-foot storm tide. There may have been some minor movement of the rocks along the eastern stretch of shoreline; however, no major damage was observed to any of the park facilities. Beach restoration is needed.

Coco Plum Beach

At the extreme east end of Coco Plum Beach, 275 feet of an unauthorized rock wall were substantially destroyed. At the east end of the designated critically eroded area, a 175-foot rock revetment was damaged at Coco Plum Beach Villas. Within the designated critically eroded area, two single-family dwellings were undermined by wave induced scour.

City of Key Colony Beach

The rock revetment fronting Sunset Beach was destroyed. Throughout Key Colony, beach front structures incurred minor flooding.

Bahia Honda State Park

Calusa Beach and Loggerhead Beach – There was no damage observed to picnic shelters or any other park facilities. Beach nourishment is needed at these beaches and dune restoration is needed at Loggerhead Beach.

Road to Sandspur Beach – The rock revetment along the park road sustained minor to moderate damage (Photo 38). Some small revetment stones and debris were scattered across the road. The bridge was generally undamaged; however, the north abutment sustained minor erosion damage. The campgrounds sustained minor wind damage.

Sandspur Beach – The west beach access boardwalk was destroyed (Photo 39). Beach and dune restoration is needed.

Boca Chica Beach

The erosion and major overwash impacted 1480 feet (0.28 mile) of ocean-front road (Photo 40).

Photo 38. Revetment overtopped and damaged by Rita at Bahia Honda State Park.

Photo 39. Dune walkover destroyed at Sandspur Beach, Bahia Honda State Park.

Photo 40. Roadway overwash by Rita at Boca Chica Beach.

Key West

Along South Roosevelt Boulevard, the U.S. A1A road shoulder sustained scour damage from the waves overtopping the seawall. The street-end at Bertha Street sustained pavement damage to its southeast corner (Photo 41). To the west, 90 feet of concrete block wall was destroyed. No major wind damage was observed in Key West.


Photo 41. Pavement damage by Rita at Bertha Street, Key West.

Fort Zachary Taylor Historic State Park

No major damage was observed to any of the park facilities. Some minor revetment damage was observed along the west shoreline fronting the Key West Ship Channel.

## Hurricane Wilma Damage

Throughout the Florida Keys were moderate to major flooding damages and minor to moderate wind damages to residential, commercial, and public buildings and infrastructure. The Monroe County Growth Management Department assessed residential damages in unincorporated areas of the county where approximately 4,100 single-family dwellings, 2,500 mobile homes, and 90 apartment/condominium units sustained at least minor damage. Of these, six single-family dwellings and 15 mobile homes were destroyed, and 20 single-family dwellings and 257 mobile homes sustained major damage.

Upper Keys

Sections of U.S. Highway 1 linking Florida City (Dade County) with Key Largo were flooded by the storm surge from Florida Bay. Much of the highway was impassable after the storm due to flooding and debris on the road. On Key Largo, generally light wind damages were observed; however, one commercial building (the Key Largo Shopper) lost

its roof and many single-family dwellings on the bayside were flooded. Along Tavernier a 100-foot concrete seawall was destroyed.

Islamorada

Severe flood damages were sustained throughout Plantation Key, Windley Key, Upper Matecumbe Key, and Lower Matecumbe Key. Light to moderate wind damages were sustained on Plantation Key, and 36 piers and docks were substantially damaged or destroyed on the Straits of Florida. Some docks and marina damage was sustained on Windley Key. Marinas, commercial businesses, and residential development throughout Islamorada were damaged by the storm surge flooding that was the worst since Hurricane Betsy in 1965. The Islamorada town hall building was made uninhabitable by the flooding and the town has removed all personnel, furniture and records from the premises. Flood damage figures are currently being developed by the town and will be included in any future up-date to this report. On Upper Matecumbe Key there were minor damages sustained by a number of rock revetments and major damage to approximately 300 feet of concrete seawalls. Light to moderate wind damage was sustained and 16 piers and docks were substantially damaged or destroyed on the straits. On Lower Matecumbe Key, an additional eight piers and docks were destroyed or substantially damaged.

Long Key

The community of Layton on the north side of Long Key sustained severe flood damage from the storm surge of Wilma. An oceanographic research center sustained severe damage to all its buildings and facilities. Single-family dwellings along the west end of Long Key sustained flooding and understructure damages. In addition, three piers were destroyed. Minor revetment damage was also sustained along the Conch Keys west of Long Key.

Long Key State Park

As previously discussed, Wilma significantly worsened the beach conditions and the 60 camp sites that were destroyed. West of the campgrounds, 50 feet of the end of the park road was destroyed by a storm surge discharge channel that has created a deep gully across the dune and beach (Photos 42 and 43). In addition, the 650-foot rock revetment east of the campsites that was both damaged and overtopped during Rita, sustained additional level three damage.

Photo 42. Storm surge discharge gully, Long Key State Park (Hurricane Wilma).

Photo 43. Storm surge discharge gully, Long Key State Park (Hurricane Wilma).

Grassy Key and Crawl Key

Single-family dwellings, motels, and commercial buildings on both the Florida Straits shoreline and Florida Bay shoreline sustained significant flood damage from the storm surge of Wilma. Four mobile homes were destroyed by the surge and waves off the straits and a number of others were severely flooded. A pool house and two piers were also destroyed. Eight concrete seawalls (450 feet) sustained major damage (level three to four). Another concrete seawall (100 feet) was destroyed on Crawl Key. Light to moderate wind damage was also sustained throughout Grassy Key and Crawl Key.

Curry Hammocks State Park

There may have been some additional minor damage to the shoreline rock structure along the eastern segment of the park shoreline; however, no major damage was observed to any of the park facilities other than a barricade-type fence that was destroyed adjacent the beach.

Coco Plum Beach

Wilma inflicted little additional damage to coastal or shore protection structures, including those revetments damaged by Rita. Flooding damage was sustained to development within the designated critically eroded area. Minor flood damage was sustained at the Royal Plum Condominium and the Coco Plum Beach Villas. A single-family dwelling sustained first floor side wall damage and a pier was also destroyed near the west end.

City of Key Colony Beach

The rock revetment fronting Sunset Beach was substantially destroyed by Rita; however, Wilma inflicted even greater damage given the park's exposure to the storm's southwest waves. Throughout Key Colony Beach, beach front structures incurred minor to moderate flooding. The pool deck at the Key Colony Beach Motel was destroyed and piers were destroyed or substantially damaged at the Tortuga Club, the Casa Clara Condominium, the Key Colony Beach Motel, and the Castillo del Sol Condominiums. Light to moderate wind damage was sustained throughout the city, including damages to roofing, siding, signs, fences, trees and shrubs.

City of Marathon

Throughout the City of Marathon on Fat Deer Key, Stirrup Key, Vaca Key, Boot Key, and Tingler Island, light to moderate wind damage was sustained, including damages to roofing, siding, signs, fences, trees and shrubs. Flooding was incurred to residential development and commercial development on both the straits and bay sides of the city. Flood damage figures are currently being developed by the city and will be included in any future up-date to this report.

On Vaca Key, two seawalls (125 feet) and four rock revetments (150 feet) were destroyed or substantially damaged. In addition, six piers were destroyed fronting on the straits. On Tingler Island, two seawalls were damaged. One 90-foot concrete seawall on the exposed west shoreline was totally destroyed (level four damage) (Photo 44) and another 100-foot concrete seawall was damaged (level two damage). At the city's public beach, Sombrero Beach, much of the park's infrastructure was damaged, including beach access walkways, picnic shelters, fences, trees and shrubs. In addition, 35 feet of the end of the asphalt paved road at Sombrero Beach was destroyed. Offshore, all the trees on the small island of West Sister Rock were completely removed by the storm surge, wind and waves.

Photo 44. Seawall destroyed by Wilma, Tingler Island.

Little Duck Key

Veteran's Memorial Park, a Monroe County beach, was severely impacted by the storm surge and waves of Wilma. Five concrete picnic shelters were substantially damaged and rendered unrepairable (Photo 45).

Photo 45. Damaged picnic shelter, Little Duck Key (Hurricane Wilma).

Photo 46. Destroyed picnic shelters, Calusa Beach (Hurricane Wilma).

Bahia Honda State Park

Calusa Beach – The park's public beach facilities on Calusa Beach were substantially damaged by the storm surge and waves of Wilma from the Gulf of Mexico that propagated across the bay of Bahia Honda. The north half of the beach sustained significant overwash which transported sand into the public parking area and the northern four picnic shelters. The middle two concrete picnic shelters were undermined, but are being salvaged by the emergency placement of sand obtained from overwash deposits. The southern three concrete picnic shelters were destroyed by the storm surge and waves (Photo 46). In addition, the park's interpretive center building is presently threatened by the condition IV erosion.

Loggerhead Beach – The park's west end beach fronting the Straits of Florida was severely impacted by the surge and waves of Wilma (see Photos 23 and 24). A 300-foot long service road west of the public bathhouse was destroyed by the erosion, and a beach access walkway was also destroyed. A section of the paved parking lot was also damaged.

Road to Sandspur Beach – Along the road east of the park entrance, about 600 feet of rock revetment was substantially damaged (level four damage) and 75 feet of road had pavement damage (Photo 47; compare with Photo 38).

Photo 47. Road and revetment damage, Bahia Honda State Park (compare with Photo 38).

Sandspur Beach – In addition to the beach access walkway destroyed by Rita (see Photo 39), five beach access walkways were destroyed by Wilma. Also, a pavilion had its concrete slab destroyed by scour and undermining.

West Summerland Key

Minor wind and flooding damage was sustained to the Girl Scout and Boy Scout facilities of Camp Wesumkee and Camp Sawyer. In addition, a swimming area dock was destroyed at Camp Sawyer and 25 feet of the bridge abutment wall was damaged.

Lower Keys, including Big Pine Key, No Name Key, Big and Little Torch Keys, Ramrod Key, Summerland Key, Knockemdown Keys, Cudjoe Key, Sugarloaf Key, Saddlebunch Keys, Big Coppit Key, Geiger Key, Rockland Key, Raccoon Key, and Stock Island

Moderate to major flooding damages were sustained to residential and commercial development throughout the lower keys. Flood damage figures are currently being developed by Monroe County, and will be included in any future update to this report. Light to moderate wind damage was also sustained throughout the lower keys, including damages to roofing, siding, signs, fences, trees and shrubs. Docks, bulkheads, and other marina facilities, as well as small craft (recreational and commercial vessels) were particularly hard hit by the storm surge (Photos 48 and 49).

Additional damages were realized along the Straits of Florida shoreline. On Big Pine Key, a 100-foot rock revetment was destroyed. On the Newfound Harbor Keys, a single-family dwelling was destroyed and others sustained major flood damage. On Munson Key, a pier was substantially damaged, and on Cudjoe Key nine piers were destroyed or substantially damaged. Along the Cudjoe Bay shoreline, numerous docks, boats, and gazebos were damaged, along with 150 feet of rock revetment and two concrete seawalls (200 feet). On Sugarloaf Key, three piers, 200 feet of concrete seawalls, and 100 feet of rock revetments were destroyed. One single-family dwelling was destroyed by the storm surge and two other dwellings are imminently threatened by the erosion conditions (Photo 50). On Geiger Key, another single-family dwelling was destroyed by the storm surge, and 50 feet of rock revetment was damaged.


Photo 48. Trailered boat damaged by Wilma's storm surge on Stock Island.

Photo 49. Damaged house boat, Garrison Bight (Hurricane Wilma).

Photo 50. Imminently threatened dwelling, Sugarloaf Key (Hurricane Wilma).

Boca Chica Key

Along with the erosion and overwash of 1480 feet of Boca Chica Beach Road at the Monroe County park, 620 feet of the road was destroyed or substantially damaged (Photos 51 and 52). West of the county park, two additional 1000-foot segments of the paved road at the Naval Air Station were destroyed.

Photo 51. Boca Chica Beach Road damaged.

Photo 52. Boca Chica Beach Road damaged.

Key West

Throughout the City of Key West , moderate to major flooding damages were sustained to residential and commercial development. An estimated 35 percent of the city was flooded impacting infrastructure and utilities as well as city parks (Photo 53). A large number of vehicles were also destroyed by the flood waters. Widespread light to moderate wind damage was sustained throughout the city (Photo 54).

Photo 53. Key West interior city park flooded.

Photo 54. Key West wind damage.

South Atlantic Boulevard and Bertha Street – Roughly 50 feet of the street end at Bertha Street and another 25 feet of South Atlantic Boulevard was damaged (Photos 55 and 56).


Photo 55. Bertha Street during Wilma's falling storm surge (credit: City of Key West).

Photo 56. Bertha Street damaged (credit: City of Key West).

West of Smathers Beach, the 1800 Atlantic Condominium sustained understructure damage. At Berg and Kitsos Beach, two beach access walkways were destroyed.

Rest Beach – Wilma inflicted severe erosion, flooding, and overwash, and substantially destroyed the entire park's recreational infrastructure (Photo 57). Two beach access walkways were destroyed along with a picnic shelter. Approximately 175 feet of concrete sidewalks were also destroyed. East of Rest Beach, 35 feet of concrete block wall was destroyed.

Photo 57. Damage to Rest Beach infrastructure by Hurricane Wilma.

Clarence Higgs Monroe County Beach – The White Street Pier sustained minor damage, losing some of its rails to the storm surge and waves. A county pavilion known as the Yoga by the Sea Platform was separated by the storm surge, which floated it northeastward and set it down on the northwest corner of Rest Beach (Photo 58). At the west end of Higgs Beach, a concrete public fishing pier was substantially damaged and lost all its wood deck.


Photo 58. Wilma's storm surge carried the Yoga by the Sea Platform from Higgs Beach east to Rest Beach.

Along the southeastern shoreline of the city, various damages were incurred by the storm surge and waves. Between Rest Beach and Truman Annex, six piers were substantially damaged or destroyed. East of Dog Beach and Vernon Street, a commercial nonhabitable major structure was destroyed. A historic single-family dwelling was also flooded and damaged. West of South Beach, another historic dwelling sustained flood damage and a recreation building sustained ground floor major structural damage landward of 30 feet of concrete seawall that was destroyed. East of Southmost Point, another concrete seawall was damaged, and to the north, 150 feet of ornamental concrete block wall was destroyed. Truman Annex sustained additional revetment damage. A pier near Mallory Square adjacent to the Key West Ship Channel was also destroyed.

Fort Zachary Taylor Historic State Park

The park's coastal and shore protection structures withstood their most significant storm surge and wave effects since they were constructed. Of the four detached breakwaters, the second breakwater from the west sustained major damage (level three); however, the structure appears to still provide substantial wave energy dissipation. Along the west shoreline, the first 150 feet of revetment landward of the terminal groin sustained level two damage that can be repaired by adding additional rocks to raise the crest up to the

design elevation. Elsewhere along the revetment was approximately 50 feet of level one damage where any rocks displaced by the waves can likely be replaced by a front-end loader.

Sunset Key (formerly Tank Island)

Approximately 2,000 feet of rock revetment was substantially damaged (level three to four) along the southern and southwestern portion of the island. Docks were also damaged.

## Beach Recovery Recommendations and Management Strategies

### Area-wide Strategies and Recommendations

- Assist local governments in seeking Federal Emergency Management Agency (FEMA) assistance to repair nonfederal beach and dune restoration projects.

- Conduct assisted-recovery activities consisting of dune restoration and revegetation, with supplemental beach fill as needed, in areas above mean high water where valuable natural resources are vulnerable to damage from the impact of a moderate storm.

- Support further sand search studies to locate sufficient upland and offshore sand resources to replenish storm-eroded beaches and dunes.

### Site-specific Recommendations

- **Northern Dade County beaches**
  Continue beach monitoring.

- **Virginia Key**
  Continue beach monitoring.

- **Key Biscayne**
  Continue beach monitoring.

- **Islamorada**
  Designate the sandy shoreline of Lower Matecumbee Key, including Sea Oats Beach, as critically eroded (0.7 mile).
  Initiate a feasibility study to evaluate erosion control solutions.

- **Long Key State Park**
  Expedite planning, design, and construction of beach and dune restoration.
  Conduct post-storm survey to evaluate beach conditions.

- **Curry Hammocks State Park**
  Expedite planning, design, and construction of beach and dune restoration.
  Conduct post-storm survey to evaluate beach conditions.

- **Coco Plum Beach**
  Assist recovery through beach nourishment of the public beach areas above mean high water using trucked-in sand.

- **Key Colony Beach**
  Designate the west shoreline of Key Colony Beach, including Sunset Beach, as critically eroded (0.2 mile).
  Assist recovery through beach and dune nourishment of the public beach areas above mean high water using trucked-in sand.

- **Sombrero Beach**
  Assist recovery through beach nourishment of the public beach above mean high water using trucked-in sand.

- **Little Duck Key**
  Designate the sandy shoreline of Little Duck Key as critically eroded (0.2 mile).
  Assist recovery through beach nourishment of the public beach above mean high water using trucked-in sand.

- **Bahia Honda Key State Park**
  Expedite planning, design, and construction of beach and dune restoration.
  Conduct post-storm survey to evaluate beach conditions.

- **Boca Chica Beach**
  Designate the public shoreline segment of Boca Chica Beach as critically eroded (1.3 miles).
  Assist recovery through beach and dune nourishment of the public beach areas above mean high water using trucked-in sand.

- **Key West beaches**
  Conduct post-storm survey to evaluate beach conditions.
  Assist recovery through beach and dune nourishment of the public beach areas above mean high water using trucked-in sand.
  Designate Simonton Beach on the gulf as critically eroded (0.1 mile).

- **Fort Zachary Taylor Historic State Park**
  Expedite planning, design, and construction of beach and dune restoration.
  Conduct post-storm survey to evaluate beach conditions.
  Repair the west shore revetment to prevent breaching of the terminal groin.

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