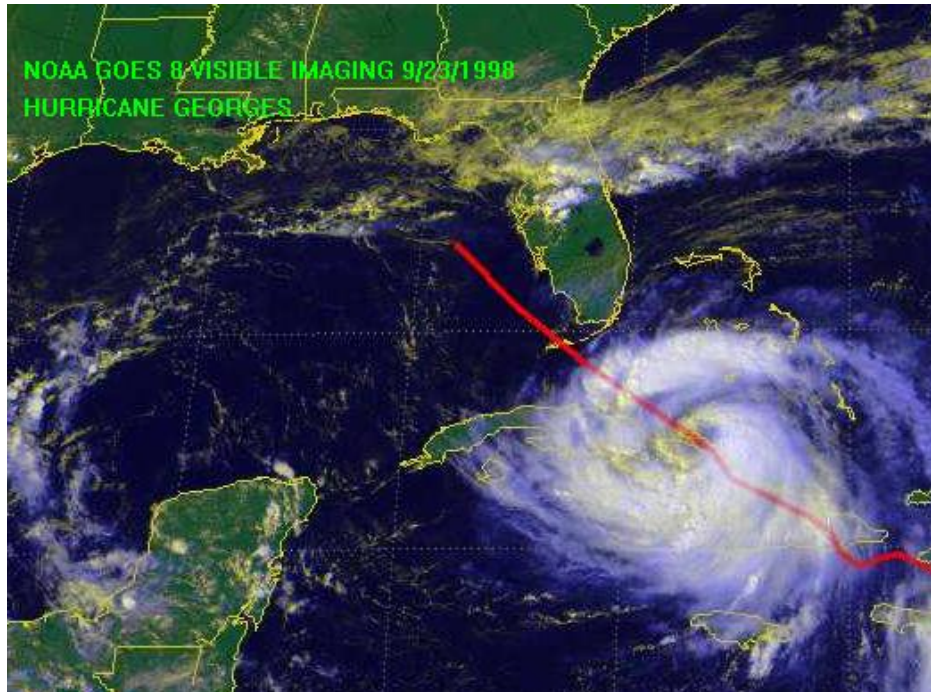


THE IMPACT OF HURRICANE GEORGES ON THE CARBONATE BEACHES OF THE FLORIDA KEYS

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November 1998



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INTRODUCTION

Given the track of Hurricane Georges in 1998, the windward coast fronting on the Straits of Florida of the middle and lower keys received the predominate impact from the storm surge and storm wave conditions. Shorelines of the distal islands west of Key West also received a lesser but significant impact. The following summarizes the most significant areas affected, starting with Upper Matecumbe and continuing westward. The first landfall of Hurricane Georges in the continental U.S. occurred on September 25, 1998 in south Florida, with the eye of the storm crossing Key West as a Category 2 hurricane. Maximum sustained winds at that time were recorded at 105 m.p.h. with gusts estimated at 115 m.p.h. Storm surge elevations were estimated at 4-5 feet National Geodetic Vertical Datum (NGVD). The windward coast fronting on the Straits of Florida of the middle and lower keys received the predominate impact from the storm surge and storm wave conditions. Shorelines of the sandy islands west of Key West also received a lesser but significant impact. See **Figures 1** and **2** for images of Hurricane Georges' path.

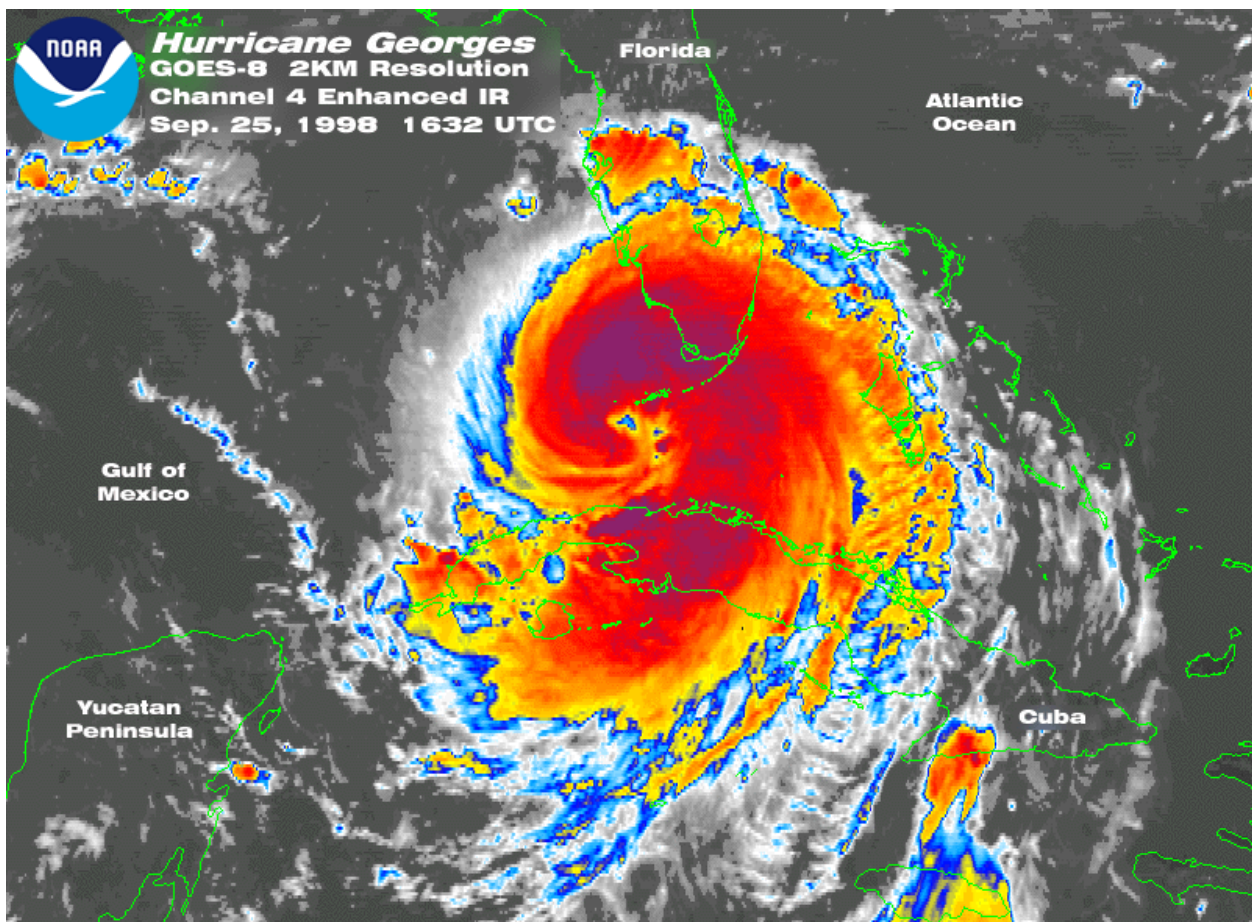


Figure 1: NOAA satellite image of Hurricane Georges over Key West, Fl. on Sept. 25, 1998.

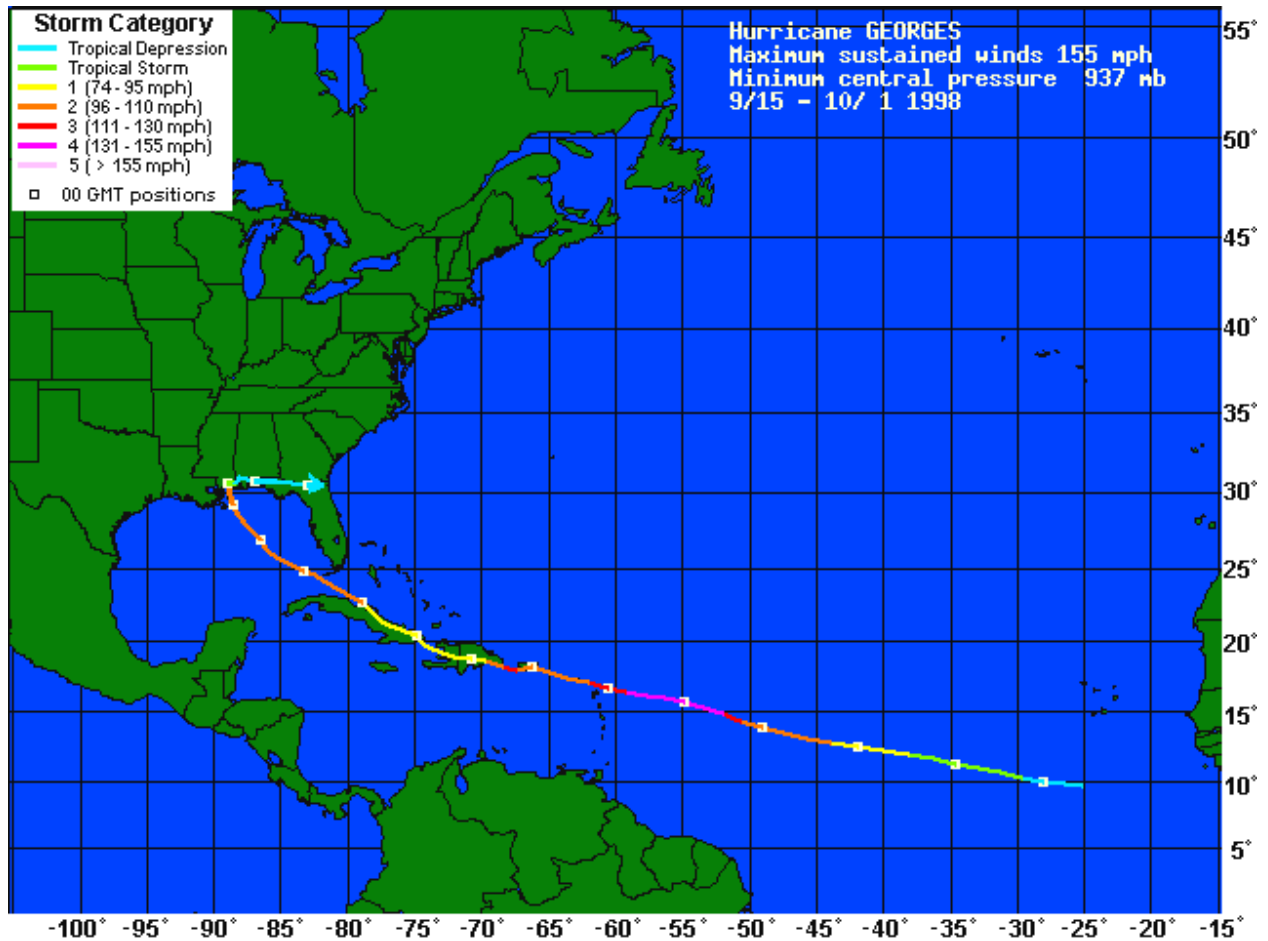


Figure 2: NOAA image of Hurricane Georges positions from Sept. 15 through Oct. 1, 1998

UPPER MATECUMBE KEY

EROSION CONDITION: I

The four-mile long Upper Matecumbe Key with the community of Islamorada has 9,800 feet of coarse-grained sand beaches. These privately owned pocket beaches average approximately fifteen feet in width. Along with these beaches, the Straits shoreline also includes a mix of riprap, bulkheads, groins, breakwaters, and natural rock of the Key Largo formation. Unlike the famous hurricane of September 2, 1935, which devastated the Matecumbes, Georges had only a fringe impact. Along with storm tide flooding conditions, minor beach erosion was experienced along the island with sand being transported generally landward on properties. Numerous walls and piers were also damaged or destroyed.

LOWER MATECUMBE KEY

EROSION CONDITION: I to III

The 4.5-mile long Lower Matecumbe Key has 14,900 feet of privately owned coarse grained sand pocket beaches which average fifteen feet in width. Also existing along the Strait's shoreline is a mix of riprap, bulkheads, and natural rock shoreline along with six groins, two shore parallel breakwaters and two shore normal breakwaters. The southeast end of Lower Matecumbe Key or Calusa Cove has 2,200 feet of fine grained sandy beach (Anne's Beach) averaging 25 feet in width. Lower Matecumbe Key received a fringe but substantial impact to its

shoreline. Minor to moderate erosion was sustained along the beaches and numerous walls and piers were damaged or destroyed. Along 4,200 feet of sandy and rocky shoreline fronting on U.S. Highway 1 at the western end of the island, the beach (in places 50 feet wide) was eroded and sand was transported across the road. A substantial seaweed rack has been deposited along the shore. Anne's Beach sustained minor beach erosion.



Damage at Lower Matecumbe Key.

LONG KEY

EROSION CONDITION: I

The 4.2-mile long island of Long Key has a predominately coarse-grained sand beach with a couple of short segments of mangrove shoreline fronting on the Straits of Florida. Roughly one half of the island is within the Long Key State Recreation Area. With the longest sandy shoreline in the Keys, the State Recreation Area has approximately 15,800 feet of beach averaging 25 feet in width. A 2,950-foot segment of shoreline along the Park's camping and swimming areas is a designated critical erosion area where shoreline recession between 1970 and 1990 was estimated to be about -3 feet per year. Notwithstanding extensive damage within the park and to most all facilities, the beach sustained relatively minor erosion losses. The dune or upland areas actually gained sand as the 4 to 5-foot storm tide transported a substantial quantity of sand inland from the offshore areas. An average of 6 inches of sand blanketed the park. However, given the degree of threat to recreational interests which exists within the park, the stretch of shoreline designated as critical erosion should be doubled.



Damage at Long Key.

GRASSY KEY

EROSION CONDITION: I

On the 3-mile long island of Grassy Key, a mangrove shoreline exists at the east end due to the sheltering effect of the islands to the southeast, but 6,800 feet of coarse grained sand beach exists along numerous private pocket beaches which average 15 feet in width. Along this moderately developed shoreline exist six groins and three shore normal breakwaters. Actual erosion appeared to be relatively minor from the hurricane; however, storm tides and waves damaged and destroyed numerous piers and walls and flooded many buildings. The most objectionable effect on the Grassy Key shoreline was the addition of more dead seagrass, which in addition to that which already existed, has created a very large seagrass wrack accumulation.



Damage at Grassy Key.

CRAWL KEY & LITTLE CRAWL KEY

EROSION CONDITION: I

The east half of Crawl Key is a mangrove shoreline. The small residential peninsula known as Valhalla Beach has riprap and a bulkhead at its west end and 600 feet of coarse-grained sand beach at its east point. The low Little Crawl Key has 1,200 feet of beach averaging 15 feet wide. The west half of Little Crawl Key is a mangrove shoreline sheltered by the small mangrove island of Deer Key. The hurricane caused wall damage, minor erosion and extensive flooding damage in these areas.

COCO PLUM BEACH

EROSION CONDITION: I to III

South of Fat Deer Key, Coco Plum Beach has 7,500 feet of fine grained sand beach averaging 25 feet wide. The eastern 0.6 mile of beach is currently designated as noncritical erosion. At the east end of the beach is a terminal rock groin and at the west end are two rock groins. The net sediment transport direction is to the southwest as seen by the severe erosion west of the eastern groin and the accretion at the west groins. The east end of the beach sustained moderate erosion from the hurricane along with additional damage to the road. Extensive tree damage was sustained along the beach. The west end of the beach sustained only minor erosion as seen by the 50-foot wide beach at the Royal Plum Club. However, flooding damages were sustained throughout the area and a large wrack of seagrass has been deposited on the Coco Plum Beach. The designated noncritical erosion area should be lengthened by 0.3 mile.

KEY COLONY BEACH

EROSION CONDITION: I to III

West of Coco Plum Beach is Key Colony Beach, which is substantially developed and is incorporated as the City of Key Colony Beach. This 4,550-foot long private beach averages 50 feet wide and is stabilized by 15 limerock groins, which were constructed in 1958. The longshore transport direction is to the southwest. The hurricane inflicted substantial flooding and structural damage along these beaches along with minor to moderate beach erosion. A number of piers were destroyed or severely damaged. Buildings and walls also sustained major damage. For example: the seawall and pool at the Key Colony Beach Motel was destroyed, buildings were damaged at the Ocean Beach Club, the Beach House Restaurant was destroyed or sustained major damage, the seaward two units of the Ocean Front Condominium were undermined, damaged, and condemned, and a 30-foot wall section was destroyed at the Sunset Beach Club. Overall, erosion conditions have now become critical for this community.



Damage at Key Colony Beach.

VACA KEY – MARATHON

The east half of the 5.5-mile long Vaca Key shoreline is protected by bulkheads and riprap, and a shoreline segment fronting the Vaca Key Bight is predominately a mangrove shoreline. Flooding damages, but little erosion was sustained in this area.

SOMBRERO BEACH

EROSION CONDITION: III

The small Tingle Island at the southern tip of Vaca Key is armored with bulkheads and riprap. To the west, and sheltered from east and southeast wave activity, is the Monroe County Park at Sombrero Beach. This fine-grained sandy beach is 1,600 feet long. The eastward transport of beach sediment off Sombrero Beach and into the adjoining canal to the east has resulted in critical erosion. The entire park and facilities sustained major damage from the storm tide flooding and landward sediment transport during Georges. Sand was transported inland across the park burying nearly all existing ground vegetation. Longshore stabilization remains critically needed now, as it did when recommended in 1990.



Damage at Sombrero Beach.

LITTLE DUCK KEY, MISSOURI KEY, OHIO KEY EROSION CONDITION: II

West of the Seven Mile Bridge, Little Duck Key has a 25-foot wide, 825-foot long public beach maintained by Monroe County. Missouri Key has a couple of narrow pocket beaches of 500 feet at its west end. The larger Ohio Key has 1,600 feet of narrow beach along the eastern half of its shoreline and mangrove along the western half. These islands sustained only minor beach and dune erosion but extensive flooding damage. Many mobile homes were damaged on Ohio Key from the flooding and the hurricane winds.



Conditions at Little Duck Key.

BAHIA HONDA KEY

EROSION CONDITION: III to IV

The most significant carbonate beaches and dunes of the lower Keys are on Bahia Honda Key and are part of the Bahia Honda State Recreation Area. The island has 11,900 feet of beach south of U.S. Highway 1 fronting on the Straits and another 800 feet of beach north of the highway fronting on the Gulf of Mexico. The estimated annual longshore transport of sediment is to the southwest in excess of 2000 cubic yards.

The 600-foot long public recreation beach (Caloosa Beach) between the Flagler Bridge and the U.S. Highway 1 Bridge is a designated critical erosion area. Caloosa Beach sustained moderate beach and dune erosion from the hurricane despite the stabilization of a 100-foot terminal groin that was constructed in 1989. Renourishment is critically needed on this beach.

The western 3,500 feet of beach fronting directly on the Straits is also a designated critical erosion area. Between 1971 and 1986 the west beach eroded about -5 feet per year. Past erosion control efforts have included the placement of 24-inch by 36-inch concrete bridge piles near the west end of the island, riprap placed along 400 to 500 feet of erosion threatened roadway in the early 1970's, the 1988/89 construction of a 1,200-foot long limerock revetment, and substantial sea oats plantings during the 1980's and 1990's. The hurricane caused major beach and dune erosion and severe damage along this entire stretch of critical erosion. The roadway and bridge were also damaged. A major coastal engineering and planning investigation is now needed for

this segment to evaluate sediment transport conditions, erosion rates, and storm damage protection measures.

The eastern 7,400 feet of beach of Bahia Honda Key is known as Sandspur Beach, which, with prominent vegetated barrier dunes and a beach width averaging 60 feet, had previously appeared stable for most of its length. Only a 650-foot eastern segment was designated as noncritical erosion. Historically the park staff has planted sea oats and constructed beach access structures on this well managed beach, previously designated as the number one best beach in America in a nationwide study conducted by the University of Maryland. Hurricane Georges has had a devastating impact throughout Sandspur Beach. Camping sites have been destroyed, the parking area, restrooms and bathhouse have been destroyed, and all beach access walkways have been destroyed. Condition IV erosion (major beach and dune erosion) was sustained and 1.4 miles of shoreline should now be added to the existing designated critical erosion area.



Conditions and damage at Sandspur Beach.



Conditions and damage at Bahia Honda State Park.

SPANISH HARBOR KEYS

EROSION CONDITION: IV

West of Bahia Honda Key and east of Big Pine Key lie the relatively small Spanish Harbor Keys. Several bulkheads exist along the predominately natural rock shoreline fronting the Straits and two small pocket beaches of 1,000 feet in length exist on the south and west shores. This island sustained severe damage with many single-family dwellings and mobile homes destroyed by the storm tides and winds. Condition IV erosion was also sustained.

BIG PINE KEY

EROSION CONDITION: II to III

The easternmost lower Keys Island with the exposed Miami oolite limestone is Big Pine Key. Much of the Strait's shoreline of Big Pine Key is a coarse-grained sand, perched beach. Although mollusks and coral fragments provide an available source for natural renourishment and although a prominent barrier dune backed much of the shoreline, erosion had substantially reduced the width and quality of the beach and a 1.0 mile length known as Long Beach has been designated a noncritical erosion area. Continued development pressures have substantially impacted the barrier dune. Hurricane Georges inflicted minor to moderate erosion along Long Beach and caused substantial damage to single-family dwellings, especially to first floors and understructures.



Conditions at Big Pine Key.

SUGARLOAF KEY

EROSION CONDITION: UNKNOWN

In the geographic center of the lower Keys lies the large island of Sugarloaf Key. The privately owned Strait’s shoreline of Sugarloaf Key is predominately a mangrove shoreline; however, Sugarloaf Beach comprises 3,000 feet of sandy beach. Like Long Beach of Big Pine Key, Sugarloaf Beach is a narrow, severely eroded, perched beach fronting a prominent barrier dune and is a designated noncritical erosion area. Hurricane Georges caused extensive tree damage throughout Sugarloaf Key and may have substantially eroded all that remained of the barrier dune. Actual erosion conditions were not determined as access across private properties was denied.

GEIGER KEY, BIG COPPITT KEY, SHARK KEY

Along US Highway 1 at Shark Key over 300 feet of seawall was destroyed. Numerous other walls were damaged or destroyed on Big Coppitt Key and Geiger Key. On Geiger Key a 60-foot section of street-end seawall was destroyed and an adjacent single-family dwelling damaged. Other single-family homes were damaged by the flooding and many mobile homes were damaged or destroyed.



Damage at Geiger Key.

BOCA CHICA KEY

EROSION CONDITION: IV

West of Geiger Key, the large island of Boca Chica Key is mostly within federal ownership within the U.S. Naval Air Station. Half of Boca Chica Key's shoreline is a natural mangrove shoreline and half is a narrow severely eroded coarse-grained sandy shoreline. The beach area was significantly wider prior to the 1944 and 1948 hurricanes, which inflicted severe erosion throughout the area. Lacking a threat to specific interests, this 1.3 mile long erosion area has been designated a noncritical erosion area. Hurricane Georges has continued past history by inflicting major beach and dune erosion along Boca Chica Key and also caused road damage.

KEY WEST

EROSION CONDITION: III to IV

There are two designated critical erosion areas on Key West – 2.8 miles of shoreline along the City of Key West and 0.3 mile at Fort Zachary Taylor State Historic Site. Key West has the best studied sandy shoreline in Monroe County. Between 1851 and 1934 the mean high water shoreline receded an average of –1.5 feet per year along the stretch of shoreline identified by the U.S. Army Corps of Engineers to be a problem area. In the same area between 1934 and 1957 the rate ranged as high as –3 feet per year. The net annual longshore sediment transport direction along the Key West shoreline fronting on the Straits of Florida is to the west. There is little littoral material entering the area from the east and because the erosion has resulted in the loss of all beach at the east end of the island's shoreline, the seawall fronting South Roosevelt Boulevard now defines the shoreline.

The South Roosevelt Boulevard seawall was constructed in 1926 and was repaired in 1951 after the hurricane of October, 1944 destroyed 4,000 feet of the wall and road. Hurricane Georges destroyed one-tenth of that previously destroyed or about 400 feet in five separate sections of damage.

To the west is the 3,300-foot segment of shoreline named George Smathers Beach which was originally constructed in 1960 and consisted of the construction of four limestone rock groins (200 to 300 feet long) and of beach restoration with 30,000 cubic yards of sand. Smathers Beach was subject to erosion from several storms and was renourished once in 1989. Hurricane Georges inflicted moderate beach and dune erosion throughout Smathers Beach as the storm tides transported sand across Roosevelt Boulevard as well as offshore. The City of Key West has removed sand from the street and spread it back on the beach. A pending beach restoration project will compensate for any beach losses from Georges and past storms.

West of Smathers Beach at the end of Bertha Street about 50 feet of wall and revetment and an adjacent slab sidewalk were damaged. West of Bertha Street the 480-foot shoreline fronting the 1800 Atlantic Condominium sustained moderate erosion. Erosion will soon encroach on the buildings. Private property to the west also sustained moderate erosion.

A 660-foot stretch of shoreline to the west of private properties is owned by the City of Key West and is known as Rest Beach. A wide beach prior to the hurricane of 1944, Rest Beach was adversely affected by the White Street Pier construction in the mid-1960's. After opening a breach in the pier to allow circulation, Rest Beach was recently renovated by the City. However, Georges inflicted a substantial impact damaging all the beach access walkways and causing moderate erosion. Major restoration efforts are now needed at Rest Beach.

West of White Street is a 1,250-foot shoreline segment of Monroe County owned park known as the Clarence S. Higgs Memorial Beach. In 1951, the county initially improved the beach by constructing a sheet pile wall and by placing about 10,000 cubic yards of limerock screenings over exposed rock. Georges only caused minor erosion along Higgs Beach, although no beach now exists seaward of the wall section at the east end.

West of Higgs Beach is a 50-foot wide and 950-foot long beach at the Casa Marina Hotel. Nourished in 1978-79, the Casa Marina Hotel's beach is a perched artificial beach, which sustained only minor erosion from Georges. West of the Casa Marina Hotel, the Reach Hotel's pocket beach (300 feet long by 35 feet wide) sustained moderate erosion and pier damage. Restoration of the Reach Hotel's beach is underway. Between the Casa Marina Hotel and the Reach Hotel, a pocket beach at the end of Vernon Street had moderate erosion and a deck destroyed.

At the end of Duval Street is another pocket beach owned by the City of Key West known as South Beach. South Beach is 300 feet long by 50 feet wide and was in need of nourishment prior to the storm. Georges totally destroyed South Beach, completely eliminating its function as a recreation beach. Along with the lost beach, all the recreation facilities and the beach restaurant sustained major damage. South Beach is now in critical need of restoration.



Photos both above and below showing damage and repair work being done at Smathers Beach.





Damage along South Roosevelt Boulevard, Key West.



Damage along South Roosevelt Boulevard, Key West.



Damage along South Roosevelt Boulevard, Key West.



Key West east of Smathers Beach along South Roosevelt Boulevard.

FORT ZACHARY TAYLOR STATE HISTORICAL SITE EROSION CONDITION: IV

On the southwest tip of Key West is an area which was built by dredge spoil from the ship channel dredging project. The fill site includes the nearly 150-year old fort and a 1,500-foot artificial recreational beach. Erosion has been ongoing at this beach since the initial filling. Between 1971 and 1985 the shoreline receded as much as 160 feet. The state constructed a 100-foot detached offshore breakwater and a 110-foot long terminal groin and placed additional sand fill in 1989. Another breakwater was constructed in the mid-1990's. Hurricane Georges inflicted major beach and dune erosion along this beach leaving an 8 to 9 foot vertical escarpment along the dune line between the west breakwater and the terminal groin. Many trees were toppled and park facilities damaged. Extending north from the terminal groin along the ship channel shoreline the rock revetment experienced major settlement and the perimeter access road was destroyed.



Conditions at Ft. Zachary Taylor State Historic Site.

BALLAST KEY, WOMAN KEY AND BOCA GRANDE KEY

EROSION CONDITION: I to III

Across the Key West ship channel on a privately owned and developed spoil island known as Tank Island, only minor erosion was sustained given its relatively sheltered location from the maximum storm wave conditions. Cumulatively the outer islands nearest Key West have over 2.6 miles of calcareous sand beaches. The longest continuous beaches are on Boca Grande Key and Woman Key which both have nearly 5,000 feet of beach. The outer islands were positioned to the lee of the eye of Hurricane Georges and consequently were spared the greater impact of the maximum wind field. Boca Grande Key, the furthest west of these sand islands, sustained minor beach and dune erosion (erosion condition II) along its west beach fronting the Boca Grande Channel and the eastern two-thirds of its south beach fronting the Straits. Only minor beach erosion (erosion condition I) was sustained along the western one-third of the south shore with accretion occurring at its southwest point. Wave damage was also sustained to mangrove on the island's east shore which was more exposed to Georges' wind field.

Woman Key to the east also sustained minor beach and dune erosion (erosion condition II) along nearly its entire length except at the accretional east end which was sheltered by Ballast Key to the immediate east. The major loss on Woman Key was to the woody dune vegetation including palms at the west end of the beach. Large clumps of sea lavender grace the beach ridge along Woman Key in an abundance probably not seen elsewhere on the coast of Florida. Unfortunately most of these majestic sea lavender plants were destroyed and their recovery is of concern.

Adjacent to and east of Woman Key is the privately owned and developed island of Ballast Key. The south shore of Ballast Key sustained minor beach and dune erosion (condition II) while the east shore sustained minor to moderate beach and dune erosion (condition II to III) given its greater exposure to the winds of Georges.

MARQUESAS KEYS

EROSION CONDITION: I to II

Located eighteen miles west of Key West and part of the Florida Keys National Marine Sanctuary managed by the Department of Environmental Protection, the calcareous sand beaches of the island group known as the Marquesas Keys have a cumulative length of nearly 4.5 miles. A 1,200-foot beach exists on Southeast Key and 8,250 feet of beach exists on the three islands which make up the Southwest Keys. Condition I erosion was sustained throughout these areas except for the middle island of the Southwest Keys where condition II erosion was sustained.

The northern most Marquesas Keys Island, Long Beach Key, with over 2.5 miles of continuous beaches fronting on the Gulf of Mexico is the longest and largest of all the islands west of Key West. The beach and dune system of Long Beach Key characterizes the high energy conditions, which may be expected associated with winter frontal systems crossing the Gulf. The wide dune ridge along Long Beach Key is well stabilized by one of the densest communities of sea oats found along Florida's beaches. During Hurricane Georges the western shore of Long Beach Key sustained only condition I erosion tapering into condition II erosion along the northern shoreline.

TORTUGAS KEYS

EROSION CONDITION: UNAVAILABLE

The most remote beaches of Florida are those of the Dry Tortugas or Tortugas Keys, which are located 65 to 70 miles west of Key West. All six islands of this group have beaches which cumulatively measure 4.5 miles. Beach processes of the Dry Tortugas are generally unresearched and in need of further study to determine erosion/accretion patterns and longshore transport processes. These islands were probably spared any significant impact given their location in the lee of the eye's track over Key West.

BEACH AND DUNE RECOVERY RECOMMENDATIONS FOR THE FLORIDA KEYS

- (1) Long Key State Recreation Area – plant dune vegetation.
- (2) Key Colony Beach – beach nourishment and plant vegetation.
- (3) Sombrero Beach – plant vegetation and possible nourishment; terminal groin recommended.
- (4) Bahia Honda State Recreation Area, Caloosa Beach – beach nourishment.
- (5) Bahia Honda State Recreation Area, Loggerhead Beach – beach nourishment, plant vegetation, and possible armoring to protect the road.
- (6) Bahia Honda State Recreation Area, Sandspur Beach – dune restoration with planted vegetation.
- (7) Key West, Smathers Beach - a major beach restoration project has already been approved, permitted and funded.
- (8) Key West, Rest Beach - the City needs a major dune restoration project now.
- (9) Key West, South Beach - this is a small, 300-ft. long beach which needs beach nourishment.
- (10) Key West, Zachary Taylor State Historical Site – beach nourishment to cover small rocks and dune restoration is needed; repair to the west of the shore armoring may be needed.