

Hurricane Rita Impacts on the Texas Shoreline A Summary Report

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Prepared for the Texas General Land Office under GLO Interagency Contract Number 02-267C

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March 2008

Introduction

Hurricane Rita made landfall at Sabine Pass on the Texas/Louisiana border at 7:40 UTC on September 24, 2005. Rita was a large category 3 hurricane with maximum sustained winds of about 100 kts (Knabb et al. 2006). According to NOAA forecast maps, at the time of landfall Hurricane force winds were expected to extend from Bolivar Peninsula, Texas to Southwest Pass in Louisiana, a total distance of about 140 miles (Fig. 1). Storm surge in southwest Louisiana was more than 10 ft and possibly as high as 15 ft (Knabb et al. 2006). On September 27, 28, and 29, the Coastal Studies Group of the Bureau of Economic Geology (BEG), The University of Texas at Austin, made field observations of beaches from Quintana Beach/Freeport to High Island, Texas (Fig. 2). This work included photos and observations, several beach profile measurements, and preparation for a lidar survey that we conducted on October 5, 6, and 7. We coordinated with the U.S. Geological Survey who acquired oblique photos and a shoreline lidar survey on September 28. This document describes our findings and analyses.



Figure 1. Cumulative wind distribution taken from NOAA Website.

Water Level, Waves, and Wind

The Texas coast was on the left side (“weak” side) of the storm at landfall, which made a large difference in how the Texas Gulf shoreline was affected compared to the Louisiana shoreline. Analysis of water levels recorded by the open-ocean tide gauge at the Pleasure Pier on Galveston Island and wind and wave data recorded by NOAA’s National Data Buoy Center

(NDBC) buoy #42035 30 km offshore of Bolivar Peninsula (Fig. 2) reveals that the erosion and overwash on the Texas Gulf beaches from Surfside to High Island probably occurred before the storm made land fall. Furthermore, the data show that combined wave and surge conditions did not reach the level of Tropical Storm Frances in 1998. Frances is a benchmark storm for the upper Texas coast because it caused the line of vegetation to retreat landward of more than 100 beach-side houses. This placed the houses on the public's beach easement and in violation of the Texas Open Beaches Act.

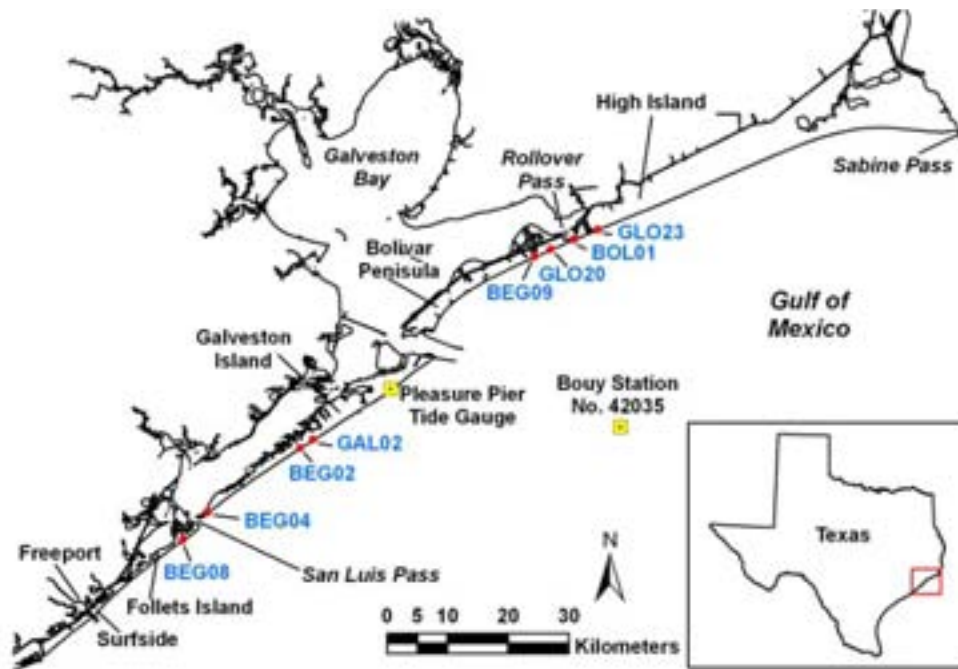


Figure 2. Location map showing beach profile network, offshore buoy, and Pleasure Pier tide gauge. Profiles surveyed following Hurricane Rita were BEG08, GLO23, BOL01, BEG09, GLO20, GAL02, BEG02, and BEG04.

Water level at the Pleasure Pier tide gauge is computed by smoothing 181, 1-second readings. The standard deviation (σ) of these 181 readings is higher during high waves which cause high-amplitude water-level variations. Therefore, σ measured by the tide gauge correlates with the wave energy arriving at the shoreline. Figure 3A is a plot of water level, σ , and the product of σ and water level. The greatest amount of erosion and overwash will occur when high waves and high water levels occur at the same time, which is indicated by the $\sigma \times$ water level curve.

Water level peaked at 0.93 m above mean sea level (msl) early on September 23rd, about 28 hours before landfall. This peak corresponded with an astronomical high tide of 0.43 m and, hence, a storm surge of 0.5 m. Water level remained elevated for 36 hours until mid day on the 24th and through an astronomical low tide. By the time of the low tide on the 23th, the storm surge had increased to 0.95 m, but because of the astronomical low tide the water level did not exceed 0.93 m above msl. σ (Fig. 3A) shows that wave energy arriving at the Galveston Island gauge peaked early during the storm surge and rapidly decreased even as the water level remained elevated. This means elevated water levels and high waves did not occur together for

long. The surge on the 23rd occurred before local wind speed increased and during a time when large swells (note the long wave periods in Fig. 3C) were arriving on Galveston Island from the east (Fig. 3B, C).

On the 23rd before data were lost, TABS buoy 'B', which is 30 km offshore San Luis Pass in 19 m water depth, recorded strong alongshore currents flowing toward the southwest consistent with the wind and wave directions. Wind speed and wave height peaked in the Galveston area early on the 24th at about the time of Rita's landfall at the border of Texas and Louisiana. During these peaks, however, the winds and waves were directed offshore in the Galveston and Bolivar areas. The offshore winds decreased wave energy arriving at the shoreline while increasing wave heights at the offshore buoy (#42035). A set down in water level at the coast rapidly developed (Fig. 3A). As Rita moved inland, wind speed decreased rapidly and shifted to a high-angle onshore direction from the southwest (Fig. 3B). Apparently, the relaxing of the offshore winds allowed water to flow back to the coast causing a second surge of 0.62 m that coincided with an astronomical high tide resulting in a water level of 1.06 m above msl on the 25th. High waves did not coincide with this second surge and hence probably had little effect on beach erosion.

The rapid rate and amount of fall of the Gulf of Mexico water level mid day on the 24th was caused by a falling astronomical tide and strong offshore winds. This created a situation where ebb flow through San Luis Pass was probably at an unusually high velocity as indicated by the Texas Water Development Board's TxBLEND hydrodynamic model. This ebb flow event, along with strong southwestward littoral currents, had the potential to make significant changes to the channel and shoal configurations on the San Luis Pass ebb-tidal delta. Past shifts in the ebb-tidal delta have resulted in subsequent changes in shoreline change patterns in the area, and there is the potential for this to happen in the months following Rita.

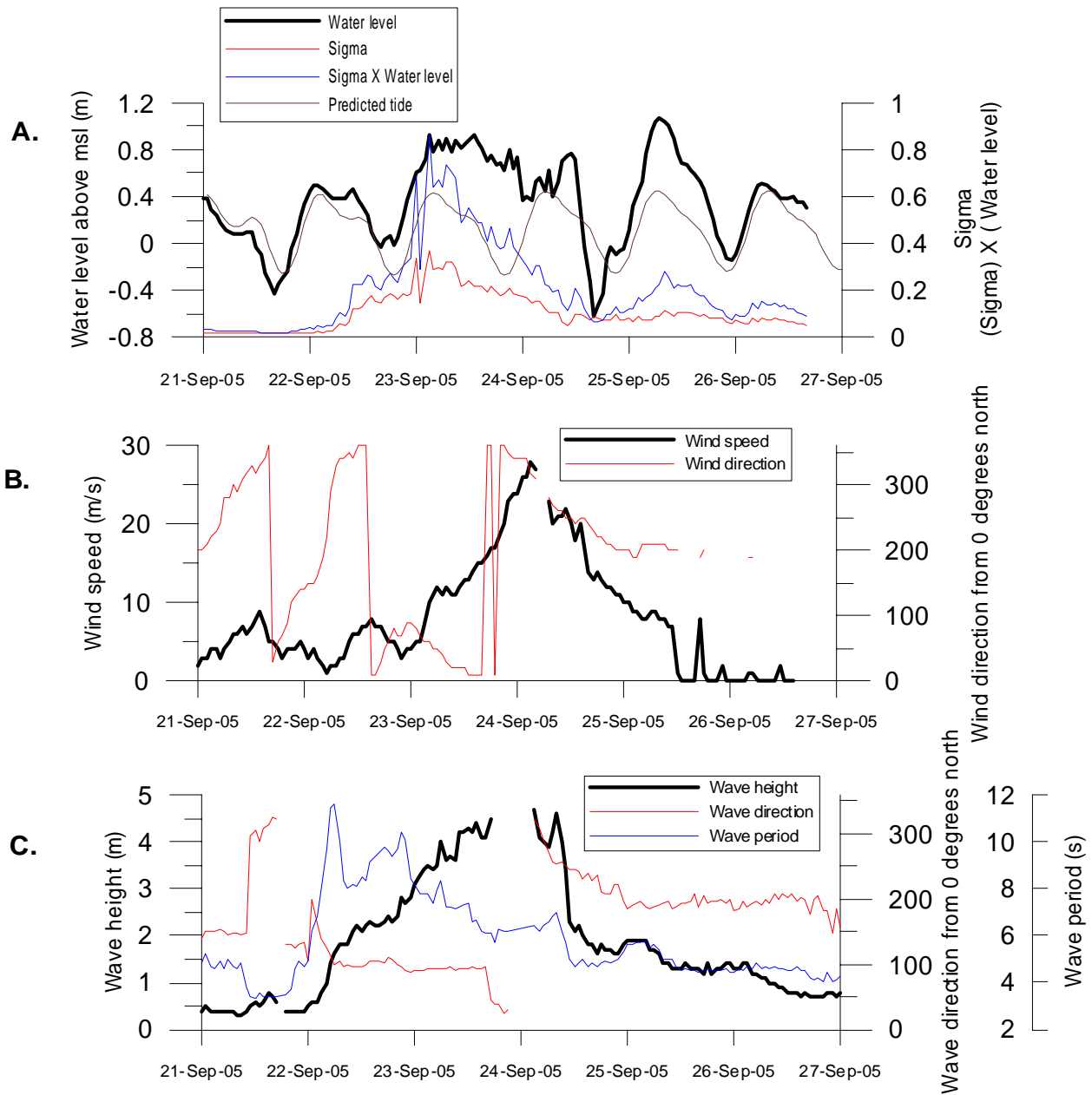


Figure 3. Water level, wind and wave data. Time is in UTC. (A.) water level, standard deviation of water level (Sigma), and predicted water levels recorded by the open-ocean, Pleasure Pier tide gauge on Galveston Island, (B.) wind speed and direction recorded by NDBC buoy #42035, and (C.) wave height, direction, and period recorded by NDBC buoy #42035. See Figure 2 for locations of tide gauge and buoy.

Figure 4 compares the sigma X water level curves for Hurricane Rita and Tropical Storm Frances in 1998. Using data from the Pleasure Pier tide gauge, the mean and standard deviation of the sigma X water level hourly time series from June 1992 to October 2002 were computed, and values greater than 3 times the standard deviation above the mean are considered extreme conditions. The Frances curve in Figure 4 shows extreme values (>0.409) lasted for 119 hours and peaked at 1.138. In contrast, during Rita sigma X water level peaked at 0.86 and extreme

values lasted for only 17 hours. Integrating these curves above the extreme value of 0.409 yields a value called the extreme area (EA). The EA parameter is a measure of surge, wave energy, and duration of extreme conditions. The EA was calculated for several storms since 1995 and a value of 12 or greater is thought to cause episodic beach erosion and vegetation line retreat great enough to create significant coastal management issues along the upper Texas coast (Tropical Storm Josephine in 1996 is considered to be a “threshold” storm for creating significant problems) (Gibeaut et al. 2002). The EA for Frances is 36, and for Rita it is only 3.3. Table 1 list the EA computed for recent storms.

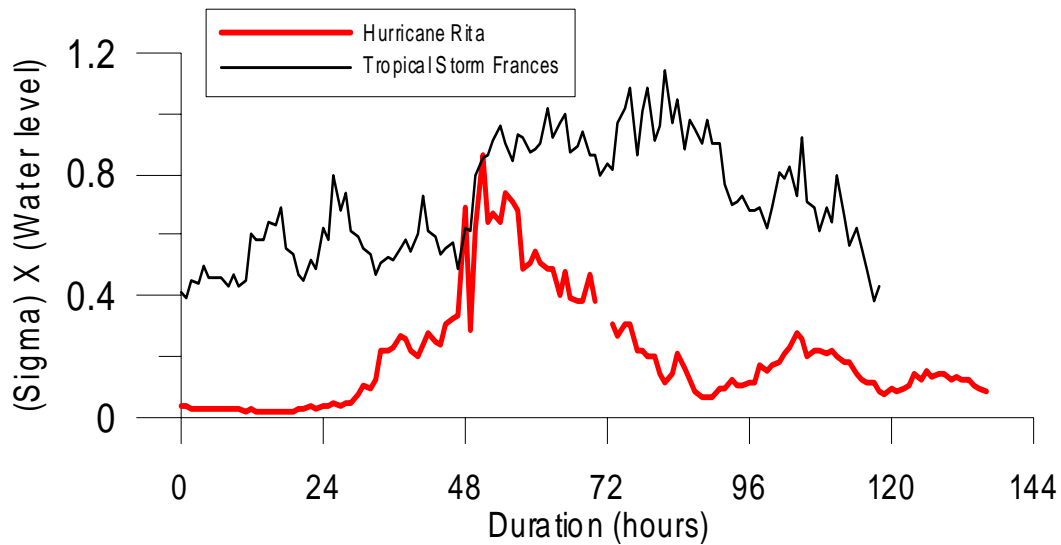


Figure 4. Sigma X water level curves computed from the Pleasure Pier tide gauge for Hurricane Rita in 2005 and Tropical Storm Frances in 1998.

Table 1.

Storm	Water Level X Sigma		
	Peak (m2)	Hours > .409 (m2)	EA (Integrated above .409) (hr m2)
TS Dean July 1995	0.546	17	0.9
HU Opal October 1995	0.678	66	6.1
TS Josephine October 1996	0.825	79	12.7
HU Danny July 1997	0.035	0	0.0
TS Charley August 1998	0.668	30	3.8
TS Frances September 1998	1.138	119	36.0
TS Allison June 2001	0.484	5	0.2
TS Fay September 2002	0.926	81	13.6
HU Isadore September 2002	0.757	72	11.2
HU Lili October 2002	0.783	11	2.3
HU Rita September 2005	0.86	17	3.3

Beach Erosion: Freeport to High Island

Overall, Rita did not cause episodic beach and dune erosion from Freeport to High Island, which is an area 100 to 60 km southwest of landfall, as Josephine and Frances did in 1996 and

1998, respectively. This is consistent with an EA of only 3.3 for Rita. Figure 5 is a plot of pre- and post-storm beach profiles measured at the Galveston Island State Park. Ball High School science students measured the pre-storm profile as part of the Texas High School Coastal Monitoring Program (Hepner and Gibeaut 2004). Rita flattened the profile and caused a small amount of overwash deposition, but the position of the vegetation line and shoreline was not greatly affected (Fig. 6). The state park is a relatively naturally managed beach/dune system and the wide beach, foredune, and structures setback from the shoreline served to limit problems at this location due to beach erosion and washover. However, Rita worsened conditions at locations where structures encroached on the beach before Rita.

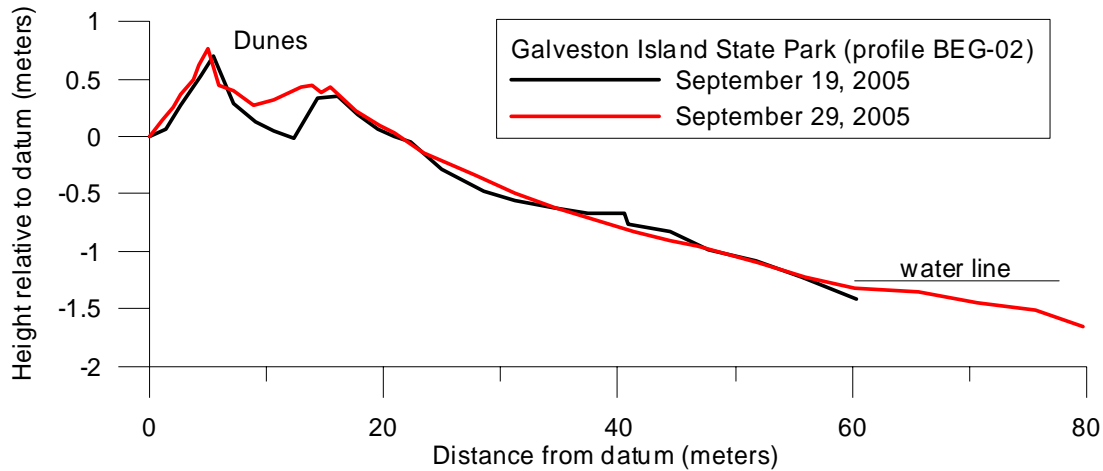


Figure 5. Beach profile comparison at profile BEG-02. See Figure 2 for location.



Figure 6. Washover deposition at the Galveston Island State Park, BEG-02 profile location.

The Surfside area within 1.5 km north of the Freeport jetties was washed over and the beach surface seaward of the shore-parallel beach road was lowered 0.5 to 1.0 m (Figs. 7 and 8). Two old metal and piling bulkheads had been protecting houses since at least the 1990's and the beach in front of them was very narrow or nonexistent before Hurricane Rita. Rita severely damaged the southwestern bulkhead, and destroyed the northeastern bulkhead (Figs. 7, 9, and 10). In an area within about 450 m of the jetty, concrete rip rap appeared to have remained in place, but erosion and washover deposition occurred behind it (Fig. 11). First-row houses to the northeast, which were on the public beach before the storm, were further undermined. Power, water, and sewage connections to these houses were damaged (Figs. 12 and 13). Washover deposition covered the shore-parallel beach road (Beach Drive) and extended to behind the second row of houses, a distance from the shoreline of about 60 m. This washover deposition is evident in the lidar comparison (Fig. 7). On September 29, there was much activity scraping washover sand from the roads and putting it on the beach (Figs. 14 and 15).

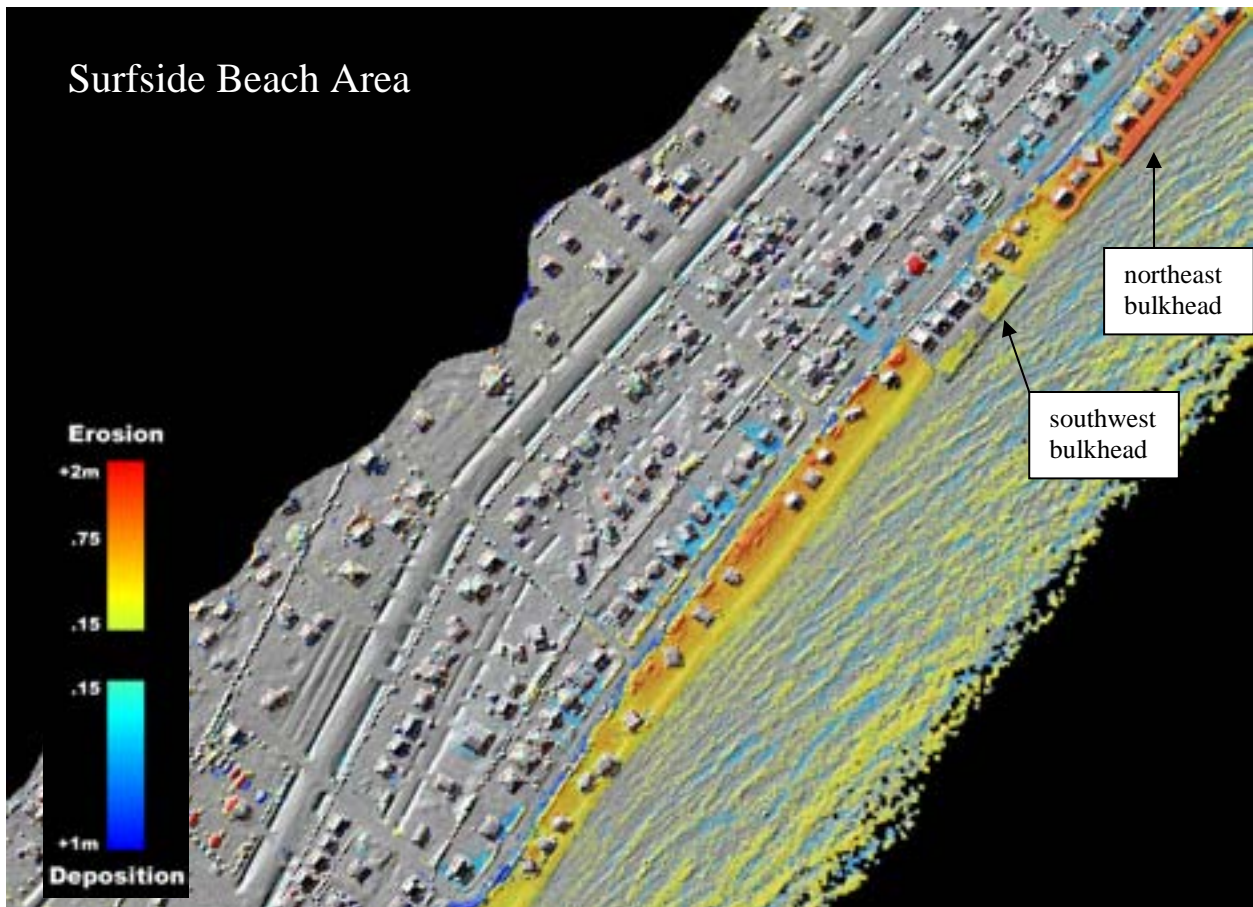


Figure 7. Comparison of pre- and post-storm lidar digital elevation models showing erosion and deposition of 0.15 m or more caused by Hurricane Rita.



Figure 8. Erosion exposing stair supports indicating a lowering of the beach in Surfside Beach.



Figure 9. Damaged southwest bulkhead in Surfside Beach.



Figure 10. Destroyed northeast bulkhead in Surfside Beach.



Figure 11. Surfside Beach. Beach eroded and washed over landward of concrete rip rap.



Figure 12. Looking southwest along Beach Drive in Surfside Beach.



Figure 13. Surfside Beach houses in the surf zone. Layer of Holocene sandy mud exposed in foreground which attests to the erosional state of the beach.



Figure 14. Washover deposition including debris and asphalt pieces transported landward of Beach Drive. Beach Drive has been plowed.



Figure 15. Washover sand deposited beyond row of houses landward of Beach Drive in Surfside Beach.

Lidar data show that beaches along Follets Island northeast of Surfside Beach (Fig. 2) suffered little. However, there was washover through the beach access roads, and sand was deposited on the main road where the road is close to the beach (Fig. 16). A Pre- and post-storm beach profile comparison at the BEG-08 location (Fig. 2) showed only moderate change similar to that discussed for the Galveston Island State Park profile (BEG-02).



Figure 16. Follets Island. The road is only about 50 m from the shoreline here and had no pre-storm foredune. Sand was transported onto the road by Rita's waves and surge and then bulldozed.

The Treasure Island subdivision on the north end of Follets Island adjacent to San Luis Pass is another location with significant erosion problems made worse by Hurricane Rita. Figure 17 is a pre- and post-storm lidar comparison. Considerable erosion and shoreline retreat occurred along this shoreline. Rip rap along the beach road prevented shoreline retreat, but despite this the road was damaged and made impassable by cobbles deposited on it (Figs. 17, 18, and 19). Some of the large rip rap was dislodged and this and the transport of cobbles attest to the power of the waves striking this shoreline. The area between the fishing pier and the rip rap experienced lowering of 1 m or more and shoreline retreat that placed several houses in the surf zone (Figs. 17, 20, and 21). A geotextile tube was installed along this shoreline, but it had been seriously compromised by ongoing erosion before Rita struck (Gibeaut et al. 2003). Washover sand and debris was deposited and one particularly large wash over deposit is shown in figure 22. Also in figure 22 is a large pile of sand. Piles of sand like the one in figure 22 were placed by workers around the subdivision.

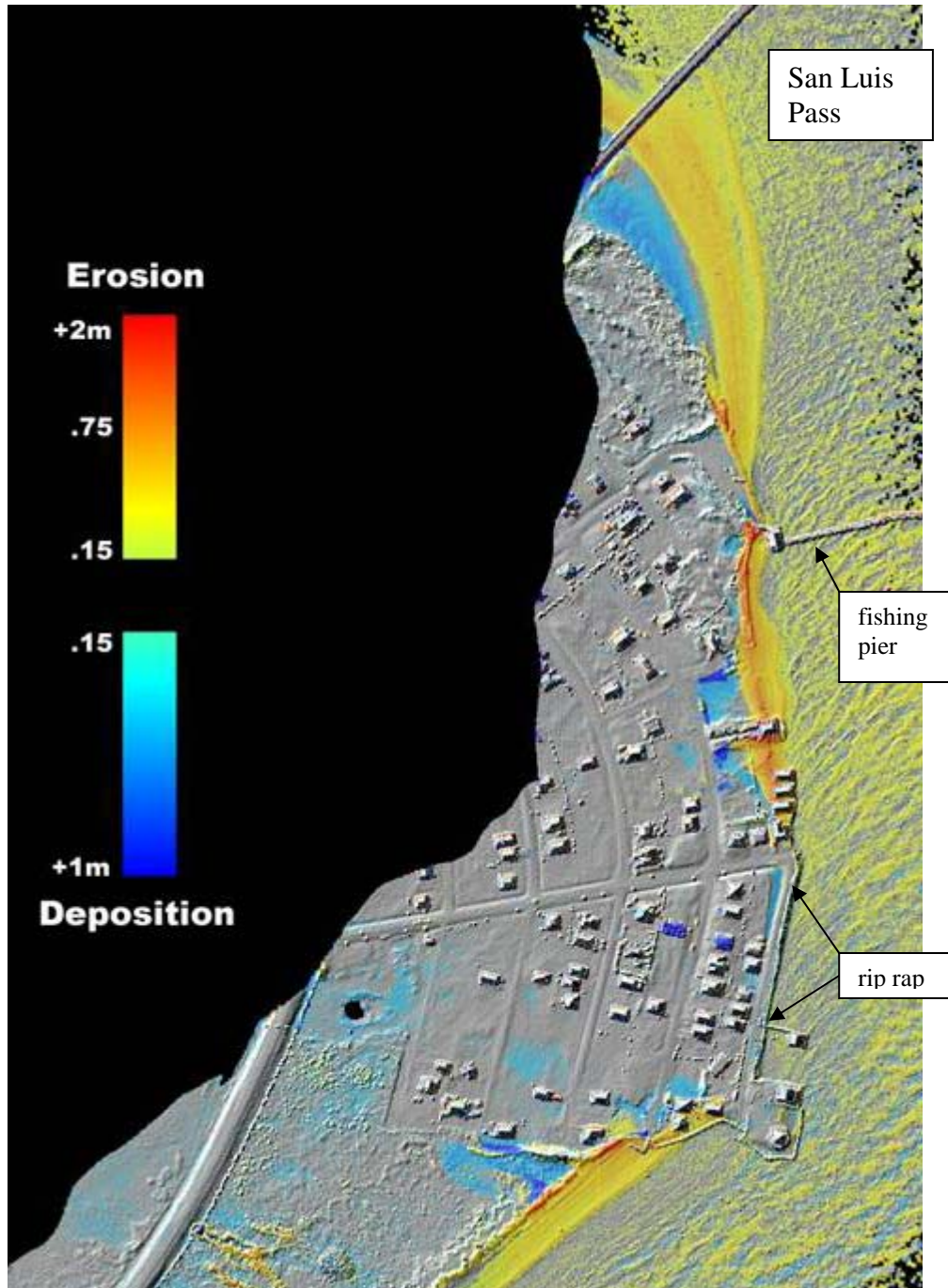


Figure 17. Pre- and post-Rita lidar comparison showing areas of erosion and deposition of at least 0.15 m. Change shown in water is simply a result of different tide levels during the lidar surveys.



Figure 18. Treasure Island subdivision. Asphalt road is damaged and rip rap dislodged.



Figure 19. Treasure Island subdivision. Cobbles from shore-protection efforts deposited by Rita's waves on the road.



Figure 20. Looking toward the fishing pier in the Treasure Island subdivision.



Figure 21. Houses in surf zone in Treasure Island subdivision. Remnants of geotextile tube in water on left. Tube was largely destroyed before Rita.



Figure 22. Sandy washover fan deposit in the Treasure Island subdivision. Also note stock piles of sand on left of fan. Piles like these were being placed around Treasure Island.

The beach on the southwest end of Galveston Island adjacent to San Luis Pass showed evidence of strong alongshore currents directed to the southwest. Figure 23 is an aerial photo taken two days after Hurricane Rita. It shows sand waves oriented to the southwest (toward the pass). Figure 24 is a ground photograph of these features. Given the large waves out of the east, we expect that littoral currents and sand transport were strongly directed toward the southwest during the storm and that sand was transported into San Luis Pass from Galveston beaches. This sand transport into San Luis Pass and the strong ebb flow out of the pass discussed earlier will potentially affect shoreline change on each side of the pass.



Figure 23. Vertical aerial photograph of Galveston Island at San Luis Pass taken 2 days after Hurricane Rita landfall. Note the train of sand waves on the left and other asymmetrical features on the upper beach to the right indicating littoral drift toward the southwest (right to left). Photo acquired from NOAA website.



Figure 24. Galveston Island near San Luis Pass. Looking updrift at sand waves formed by alongshore currents caused by oblique wave approach and flood tidal currents during Rita. Sand waves have been modified by wind.

Geotextile tubes along Galveston Island and Bolivar Peninsula were installed beginning in 1999 as a stop-gap measure to stem beach retreat and for protection from storm surge (Gibeaut et al. 2002). These tubes were largely exposed by Rita. The southwest end of the Pirates Beach project on Galveston Island northeast of the BEG-02 beach profile site (Fig. 2), and a portion of a project adjacent to the southwest side of Rollover Pass (Fig. 2), however, were not exposed. Sand fencing in front of the Pirates beach project was damaged (Fig. 25), but large-scale damage to the geotextile tubes was not observed. Overall, the beach was narrower at the geotextile tube projects. Erosion and damage at Bermuda Beach and Spanish Grant on Galveston Island was similar to that observed at Surfside Beach and Treasure Island. These are also areas with pre-Rita erosion problems.



Figure 25. Exposed geotextile tube, eroded beach, and damaged sand fencing (only posts remaining) along Pirates Beach at the GAL-01 location (see Fig. 2 for location).

Beach erosion was moderate and did not cause significant damage to structures along Bolivar Peninsula, including the geotextile tube projects. The area of Rollover Pass is particularly low and prone to washover (Fig. 2). Sand deposits including landward oriented sand waves indicate that Rollover Pass was washed over and that unidirectional flow of about 0.5- to 1-m depth occurred in the sand parking lot next to the channel (Fig. 26, 27). Other than at Rollover, there was a lack of sand washover deposition along Bolivar Peninsula. There were, however, grassy debris lines on the back barrier indicating levels reached by the surge and waves from the bay side (Fig. 28). Wind damage to structures and power lines was consistent with offshore directed (northerly winds). Broken power poles were leaning or lying toward the south (Fig. 29).



Figure 26. Rollover Pass. Landward oriented sand waves indicating washover flow during Rita.



Figure 27. Rollover Pass. Rita caused washover and sand transport through the unpaved parking lots and across highway 87. Geotextile tubes are exposed to the northeast (right) of the pass but not on the southwest side.



Figure 28. Bolivar Peninsula grassy debris line landward of first row of houses. Main highway and bay is on the left, Gulf of Mexico on the right.



Figure 29. Power poles lying in the offshore direction along Bolivar Peninsula.

Closer to landfall the uninhabited shoreline from High Island to Sabine Pass (Fig. 2) experience episodic retreat and washover deposition as shown by unvegetated sand creating a new storm platform (Fig. 30). This stretch of shoreline consists of cohesive muddy sediments and fringing, narrow sandy beaches backed by brackish wetland environments. In places, the sand is more plentiful and may form foredunes. Washover deposition by large storms resulting in the vertical accretion of a storm platform and subsequent dune development on that platform is an important process along this shoreline. The storm platform protects landward wetland habitats during more common events that raise water level moderate amounts and helps maintain the shoreline during long-term relative sea level rise. Figure 31 is a lidar change comparison map and profile for a portion of this shoreline. It shows well the landward translation of the profile and the alongshore variation of this shift. Figure 32 shows the difference in Rita's impact on shoreline retreat between the right (east) and left (west) sides of the landfall. On the right, shoreline retreat reached up to 80 m with some of the variation caused by shoreline structures, such as breakwaters, and varying shoreline types. On the left side (Texas), retreat rates were less than 15 m and generally less than 10 m.



Figure 30. Rita erosion and washover deposition building up the storm platform along the Texas chenier plain between High Island and Sabine Pass.

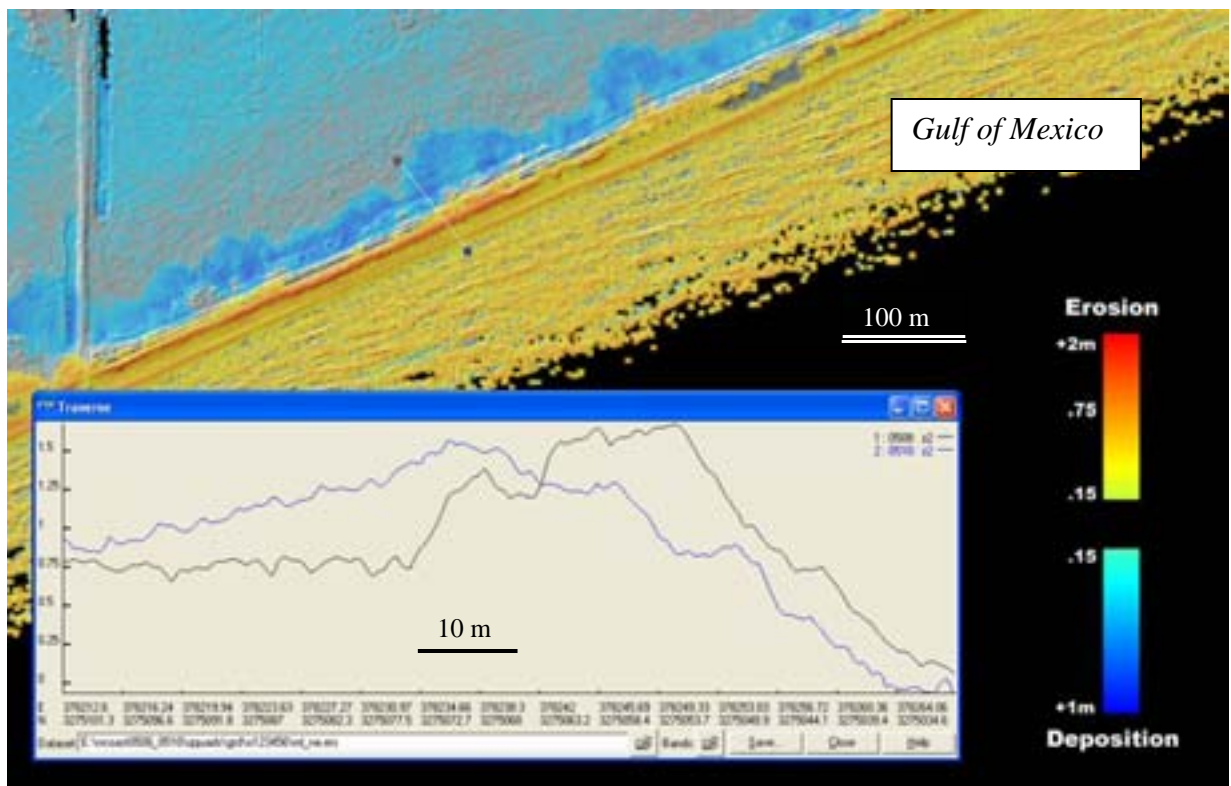


Figure 31. Lidar elevation comparison for a portion of shoreline between High Island and Sabine Pass, Texas.

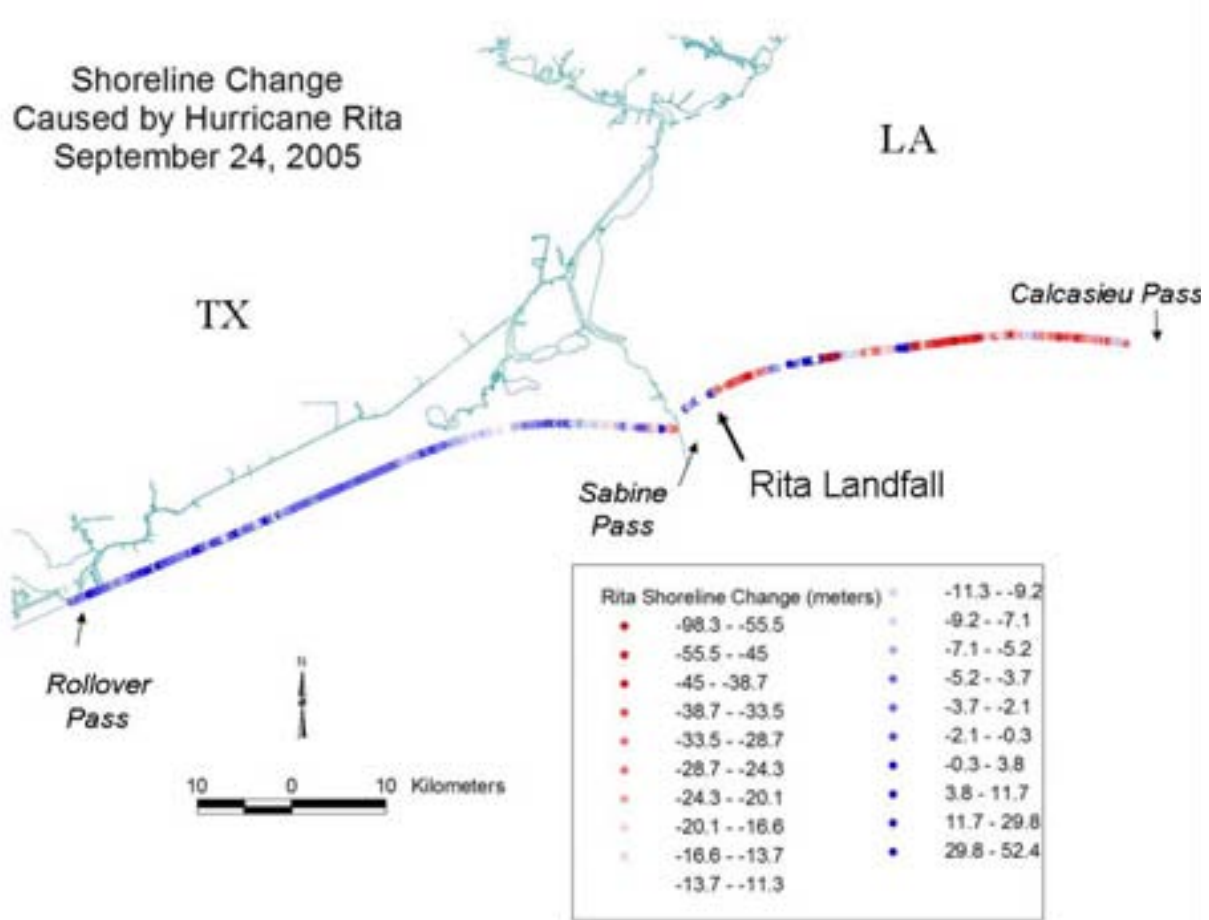


Figure 32. Shoreline change caused by Hurricane Rita.

Bayside of Galveston Island

Strong northerly winds (Fig. 3b) created a setup and relatively high waves on the bayside of the barrier islands. In the town of Jamaica Beach on Galveston Island, debris lines of mostly vegetation revealed that a storm tide about 0.6 to 1 m above mean sea level occurred here (Fig. 33). Geotextile tubes also appeared damaged in that the ultraviolet shrouds were not completely covering the tubes and that they appeared to have slumped and lost the usual rounded shape (Figs. 34 and 35). It is not clear how much of this damage Rita caused, if any.



Figure 33. Grass debris line left by Hurricane Rita at 0.6 to 1-m above mean sea level. Jamaica Beach on West Bay side of Galveston Island.



Figure 34. Damaged geotextile tube protecting marsh restoration project adjacent to Jamaica Beach (Galveston Island State Park project). The UV shroud is not present, the tube appears slumped and flattened. It is possible that the tube was damaged further during Hurricane Rita.



Figure 35. Aerial view of geotextile tubes protecting marsh restoration project in Galveston Island State Park.

Summary

Hurricane Rita made landfall near the border of Texas and Louisiana. Texas was on the left side of Hurricane Rita at landfall, which meant that Bolivar Peninsula and Galveston and Follets Islands did not experience wide-spread washover and severe beach and dune erosion as occurred in Louisiana. In fact, the surge and wave conditions along the developed Texas shoreline did not exceed levels thought to be required to produce significant erosion-related coastal management problems. Closer to landfall along the mostly undeveloped Texas chenier plain, significant change to the shoreline did occur. This wetland area is an important biological habitat and includes Sea Rim State Park and the McFaddin and Texas Point National Wildlife Refuges.

Even though the Texas developed shoreline was not subject to severe storm attack, it is notable that some areas, including Surfside Beach and Treasure Island, did experience significant impacts showing how highly susceptible these places are to even moderate storm conditions. The lack of foredunes, houses close to the shoreline, and low upland elevations create hazardous conditions. Geotextile tubes on Galveston Island and Bolivar Peninsula were generally not damaged but the damage to sand fencing and the narrowed beach in front of the projects illustrates how difficult it is to maintain these projects with vegetated sand cover.

Rita sent high, long-period waves to the Texas shoreline, but little surge. The energy of the waves was evident in the cobbles and rip rap they dislodged, but low-storm tide elevations prevented dune erosion and extensive wash over. If the storm surge peak had occurred about 12 hours earlier at the time of high tide and high-wave energy, then the storm tide would have been almost 0.5 m higher than it was. This amount would probably have been enough to erode dunes, severely damage geotextile tubes, and significantly cut back the line of vegetation along Follets and Galveston Islands, and Bolivar Peninsula. If the Texas shoreline had been on the right-hand side of the storm, as it was projected to be several days before actual landfall, then the impact on

Texas would have been much different and more like what we observed at Holly Beach in Louisiana.

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