SEDIMENT TRANSPORT ALONG THE SOUTHWESTERN LOUISIANA SHORELINE: IMPACT FROM HURRICANE RITA, 2005

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Abstract: The landfall of Hurricane Rita in 2005 significantly altered physical and morphological characteristics along the southwestern Louisiana coastline and interior marshes. An excessive storm surge event linked to Rita resulted in widespread, storm-induced overwash deposits in Cameron and Vermilion Parishes, Louisiana. These deposits superseded prior deposits and were aligned parallel to predominant flow patterns associated with the storm’s counter-clockwise circulation. These responses became more pronounced farther west and culminating at eyewall impact. Excessive salinity levels resulting from salt-water intrusion severely impacted local vegetation several kilometers inland and over the longer term may exacerbate the loss of vegetation that retards coastal erosion and attenuates waves and storm surge during high-energy events. Massive water levels introduced onshore by surge remained locally ponded several weeks after the hurricane; however, morphological patterns along the coastline had begun facilitating the return flow of water and sediment to the Gulf of Mexico.

INTRODUCTION

A significant coastal sediment transport and storm surge event occurred along the southwestern Louisiana shoreline concurrent with the landfall of Hurricane Rita on September 24, 2005. This hurricane, which made landfall as a Category Three storm near the Texas/Louisiana border, significantly altered coastal sediment transport patterns.
through (1) the effects of a strong storm surge, and (2) the post-storm return flow to the Gulf of Mexico of elevated water levels within inland bays and marshes. Additionally, coastal morphology was influenced by post-storm beach recovery as indicated by bar welding to the lower shoreface only several weeks after the passage of Hurricane Rita.

Research by the Coastal Studies Institute of Louisiana State University revealed sand overwash deposits and evidence of excessive storm surge and salt-water intrusion along the southwest Louisiana coast. These responses became more pronounced farther west and closer to eyewall impact near the Texas/Louisiana border. Excessive salinity levels resulting from salt-water intrusion severely impacted local vegetation both along the coast and several kilometers inland. These impacts may locally exacerbate existing problems linked to coastal erosion through the loss of vegetation that retards coastal erosion and attenuates waves and storm surge during high-energy events.

Storm surge associated with the passage of Hurricane Rita infiltrated tens of kilometers inland. Ponded surge water remained trapped even several weeks after Hurricane Rita struck the southwestern Louisiana coast. However, distinct return flow patterns of water and sediment were observed along the southwestern Louisiana coastline, which indicate active processes by which excessive water volume returns to the open Gulf.

**STORM HISTORY AND SEA STATE**

Hurricane Rita began as a tropical depression just east of the Turks and Caicos Islands on September 17, 2005 and intensified steadily over the next several days as it moved westward through the Florida Straits. The eye of Hurricane Rita passed approximately 50 miles (80 km) south of Key West, Florida on September 20 and thus missed the U.S. mainland as it approached southern Florida as a Category 2 hurricane on the Saffir-Simpson scale. However, upon entering the Gulf of Mexico, Rita intensified rapidly and attained Category 5 status and a peak sustained wind strength of 175 mph (78 m/second) within only 24 hours. The barometric pressure recorded during this phase of the storm reached 897 millibars, the third-lowest ever recorded for a tropical system in the Atlantic Basin at that time. This pressure reading simultaneously displaced to fifth-lowest the 902 millibar minimum pressure measurement from Hurricane Katrina recorded only one month earlier (National Hurricane Center, 2005; Knabb et al., 2006). However, both of these measurements were subsequently displaced one level lower in October 2005 by Hurricane Wilma, which yielded the lowest barometric pressure ever recorded to date in the Atlantic Basin, at 882 millibars (Pasch, et al., 2006).

Wind and wave conditions during Hurricane Rita were measured by a series of buoys maintained by the National Data Buoy Center. While still at sea in the Gulf of Mexico, the eye of Rita passed approximately 2 miles (3 km) southeast of Buoy 42001, the data buoy closest to the path of the storm (Figure 1). A barometric pressure of 926 millibars was recorded at 6:00 PM (2300 Z) on September 23, about 8.5 hours prior to landfall. The maximum significant wave height measurement was 38 feet (11.6 m), sustained winds were measured at 100 mph (45 m/second), and maximum gusts were measured at nearly 136 mph (61 m/second) approximately 7 hours prior to landfall. As Rita neared the coast, C-MAN station SRST2, located near Sabine Pass on the upper Texas coast
Hurricane Rita weakened as it approached the north-central coast of the Gulf of Mexico on September 23, eventually becoming a Category 3 hurricane as it made landfall. The hurricane moved ashore between Sabine Pass and Johnson’s Bayou, Louisiana early on September 24 with sustained winds of 120 mph (54 m/second). Concurrent with its onshore arrival and wind field, Rita initiated a substantial storm surge east of its center that reached a maximum of 18-20 feet (5-6 m). Rita then weakened rapidly as it continued northward through east Texas and western Louisiana, eventually turning northeastward and merging with an advancing cold front on September 26, 2005.

OBSERVATION METHODS

A helicopter overflight was taken to observe post-hurricane coastal conditions along practically the entire south-central and southwestern Louisiana coastlines and interior marshlands (Figure 2). The coastal flight path began near the Atchafalaya and Wax Lake Delta, extended westward toward Marsh Island and Vermilion Bay, and concluded at Sabine Pass in Cameron Parish, Louisiana. An interior marshland flight pass was then made that extended eastward from Sabine Pass and continued through Cameron, Calcasieu and Vermilion Parishes. Digital photos were taken throughout the trip as were a constant stream of video data that provided a continuous record of the entire trip. Photos were calibrated to a GPS to ensure accurate positioning of each picture so that sedimentologic and morphologic changes detected in potential follow-up trips could be accurately calibrated to those from this original flight.

RESULTS

Several unique phenomena were observed during the overflight. Massive overwash deposits were observed on the backside of many beaches along the coast. These became
more pronounced farther west and culminated near where the eye moved ashore at Johnson’s Bayou. In addition, excessive storm surge and salt-water intrusion also became more evident farther west as indicated by the loss of vegetation in inland marshes as well as the catastrophic infrastructure and property loss in locations such as Holly Beach and Cameron. Scour effects and sediment re-distribution patterns were also noted, particularly in association with several series of rock jetties located just offshore from the southwestern Louisiana coast. Despite the destructive nature of the phenomena observed, the initial phases of post-storm recovery were also detected, primarily through bar welding to the lower shoreface as sediment was being reworked from offshore by post-storm waves.

**Storm Surge and Return Flow Observations**

Overwash deposits were observed in western Vermilion Parish and continued westward through most of Cameron Parish. These overwash deposits were typically located approximately 30-50 feet (9-15 m) behind the immediate coastline and were approximately 40 feet (12 m) wide (Figure 3). In many cases, ripple beds were detected on top of overwash deposits, indicating significant wave-induced currents. In other cases, overwash deposits were seen as distinct lobes in tandem with distributary patterns that appeared to consist of relatively finer-grained, muddier material (Figure 4).

However, overwash was not detected continuously along the coast. This fact may stem from either the lack of an initial, sand-sized offshore sediment supply or from localized variations in coastline morphology. In some cases, distinct incision events were detected across a broad mud apron along the immediate shoreline and seemed to indicate evidence of return flow of water and sediment to the Gulf of Mexico (Figure 5). These dendritic-shaped patterns continued from the shoreline southward to a hinge point just offshore where they appeared to bifurcate and form subaqueous channels directed offshore. Although significant onshore sediment movement occurred during Hurricane Rita, this evidence indicates that steady, post-storm sediment and water movement had been taking place in the offshore direction.
Hurricane Rita generated a significant storm surge event that resulted in substantial salt water intrusion, much of which occurred as far as 25 miles (40 km) inland. Evidence for this intrusion was noted by several different means. First, severe vegetation loss was noted during the October 2005 overflight, primarily through marsh grass that had been
killed off through saline seawater intolerance. Second, numerous debris fields were observed, particularly near Cameron and Holly Beach, Louisiana and all were aligned in a southeast-northwest direction, indicating how surge had transported both beach and man-made material parallel with the hurricane’s predominant counter-clockwise flow. Third, ponded water, remaining from the surge event three weeks earlier and trapped from re-entering the Gulf by localized topographic relief, was also clearly evident along the coast (Figure 6). Fourth, a series of high-water observations was undertaken by staff from the LSU Hurricane Center to visually observe storm surge water level heights based on markings from debris and water levels carried inland by storm surge.

**Storm Surge Water Levels**

Field observations of high water marks along the coast and inland for several kilometers were obtained by the LSU Hurricane Center (LSUHC; Figure 7) and the Federal Emergency Management Agency (FEMA; Figure 8; URS Group, Inc., 2006). Both data sets are in generally good agreement. Maximum water levels associated with Rita were observed at 14-15 feet (4-4.5 m) at Cameron and slightly farther to the east (all elevations were measured relative to NAVD88). Inland along the margins of Calcasieu Lake, storm surge was significantly attenuated, and high water marks ranged between 3-10 feet (1-3 m). To the east as far as Vermillion Bay, storm surge water levels remained significant and high water marks of up to 12 feet (3.7 m) were measured.

High-water surge observations noted in the field were compared to publicly available numerical models (SLOSH and AdCirc; FEMA, 2005, Figure 9). The datasets generally agree on the relative intensity of storm surge along the immediate southwestern Louisiana coast although the FEMA model consistently under-predicted surge levels at
West of the eyewall impact along the upper Texas coast, storm surge levels were much lower compared to areas east of eyewall impact in southwestern Louisiana. The counter-
clockwise circulation associated with Rita resulted in a primary wind field along the upper Texas coast from the north and northeast. This flow direction suppressed any excessive surge events and therefore minimized morphologic effects west of the point of eyewall impact. Preliminary observations along the upper Texas coast have confirmed these findings (King, personal communication, 2006).
LONG TERM CONSEQUENCES
Since 1901, at least 55 tropical storms and hurricanes have made landfall within Louisiana, implying a long-term average of one storm about every-other year (Stone et al., 1997). However, storm frequency along the central and southwestern Louisiana coasts is nearly twice that of eastern Louisiana with a peak in activity usually occurring in the month of September. The relatively high frequency of storms along this section of the Gulf coast therefore exerts a cumulative effect on and can significantly alter coastal geomorphology from year-to-year. Previous sand overwash deposits have been noted along the southwestern Louisiana coastline (Williams, 2006) as driven by excessive storm surge events. However, post-storm adjustments to these effects also play a critical role. As an example, post-storm recovery has been previously documented along several Louisiana barrier islands after Hurricanes Juan (1985), Danny (1985) and Gilbert (1988; Stone et al., 1999; Guidroz et al., 2006). Although post-storm recovery depends upon the degree of damage and the availability of sediment within the coastal system, more investigation is needed to further quantify the full effects. This overflight was only the initial investigation into documenting destruction and recovery effects; follow-up observations are required to adequately address the pace and efficiency of future beach recovery.

CONCLUSION
The observations noted in the aftermath of Hurricane Rita demonstrate several distinct phenomena prevalent within the coastal environment after severe storms. Storm surge, combined with post-storm water and sediment return flow back to the open Gulf, can greatly influence sediment patterns along and adjacent to nearshore and inland coastal areas. The observations made during the study will serve as the basis for future investigations to document longer-term effects on local sediment distribution patterns as a result of Hurricane Rita. However, these effects may be interrupted, and possibly delayed, by future tropical cyclones that impact the north-central and northwestern Gulf of Mexico coasts.

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