A Wave, Water Level, and Structural Monitoring Plan for Dauphin Island, Alabama

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ABSTRACT

The results of damage assessments following recent hurricane events suggest that predictions of wave transformation across barrier islands during overtopping events are unreliable and, even worse, inaccurate. In many cases, inaccurate model predictions of wave heights in high hazard areas are translating into improper standards for "lowest structural member" elevations on residential and commercial structures. The substantive result of which is increased cost of construction, whether initial or replacement costs. The purpose of this research is to improve guidance on building elevations in high hazard flood plain areas where wave action is the primary structural damage mechanism. A number of novel, autonomous wave gauges will be temporarily mounted to fixed structures on Dauphin Island, Alabama, in advance of an overtopping event during future hurricane seasons. Measured wave heights and water levels will provide an opportunity to characterize wave transformation across the barrier island. When combined with surveyed building elevations and a detailed inventory of structural and foundation characteristics, the measured waves and water levels will provide an opportunity to identify critical building elevations that delineate survival and destruction, as well as determine the adequacy of structural connections and foundations.

INTRODUCTION

The results of damage assessments following recent hurricane events (e.g. Ivan, Katrina, Ike) suggest that predictions of wave transformation across barrier islands during overtopping events (e.g. WHAFIS, SWAN, etc.) are unreliable and, even worse, inaccurate. In many cases, inaccurate model predictions of wave heights in high hazard areas are translating into improper standards for "lowest structural member" elevations on residential and commercial structures. Regardless of whether such predictions are higher or lower than necessary, the substantive result is increased cost of construction, whether initial or replacement costs. As a result, additional *in situ* data are needed to more accurately describe the characteristics of waves and water levels across a barrier island during overtopping events. It would be beneficial, too, if detailed data about a structure's foundation and structural characteristics were also well documented so that its performance can be compared to measured waves and water levels after an overtopping event.

This paper describes the details of a specific wave, water level, and structural monitoring plan for selected residential structures on Dauphin Island, Alabama. The results of this monitoring plan will ultimately provide opportunities to characterize wave transformation across a barrier island during overtopping events, and to identify critical structural connections and member elevations that delineate destruction and survival.

Background. The U.S. Geological Survey (USGS) has an active, and expanding, program for measuring storm surge in the southeastern United States. McGee et al. (2006) obtained extensive storm surge measurements in southwestern Louisiana and southeastern Texas during Hurricane Rita (2005). However, the locations of the instruments and their sampling rates generally have not provided opportunities for evaluating wave characteristics.

For the first time, a pair of USGS storm surge gauges, deployed on the Bolivar Peninsula (TX) during Hurricane Ike (2008), have confirmed that wave transformation is taking place over flooded land areas. Data obtained during the storm helped to explain structural damage patterns after the fact (Kennedy et al., 2011). With only two storm surge gauges in place during the storm, it was impossible to measure where and how that transformation was taking place. In addition, it is logistically difficult to (a) respond rapidly in advance of an overtopping event to prepare and activate the gauges, and (b) know where to deploy the gauges to ensure that beneficial data will be obtained. Furthermore, it is unlikely that one could perform the detailed surveying and documentation of subject structures quickly enough without knowing exactly when and where a storm will make landfall. Planning a deployment of gauges for a specific location that is prone to overtopping, therefore, addresses some of the more common problems associated with such experiments.

Study Area. The wave, water level, and structural monitoring plan is focused on seven residential structures in the Town of Dauphin Island, Alabama (Figure 1). The subject structures are oriented in a line perpendicular to the island cross-section, and mostly parallel with the anticipated overtopping flow and direction of wave propagation (Figure 2). The subject structures were chosen based on their perceived susceptibility to storm surge and waves in a particularly narrow portion of the island with a relatively low elevation (Figure 3).

Dauphin Island is a 22.5-km-long microtidal barrier island situated along the north central gulf coast. Part of the Mississippi-Alabama chain of barrier islands, it is the only island with permanent settlements. The easternmost 10 km of the island is home to about 1300 permanent residents and the westernmost 12.5 km is largely undeveloped. The width of the island varies significantly from nearly 3000 m at the east end, to less than 300 m along much of the lightly-developed portion of the island. This narrow portion of the island has a typical elevation of +2 m above mean sea level (MSL) and provides a stark contrast to the east end of the island, which has 10 – 15 m dunes and a maritime forest. The low, narrow portion of Dauphin Island is so susceptible to overwashing through a combination of astronomical tides, storm tides, wave setup, and wave runup that the island has been overtopped dozens of times in the previous 15 hurricane seasons, including most tropical storm events.

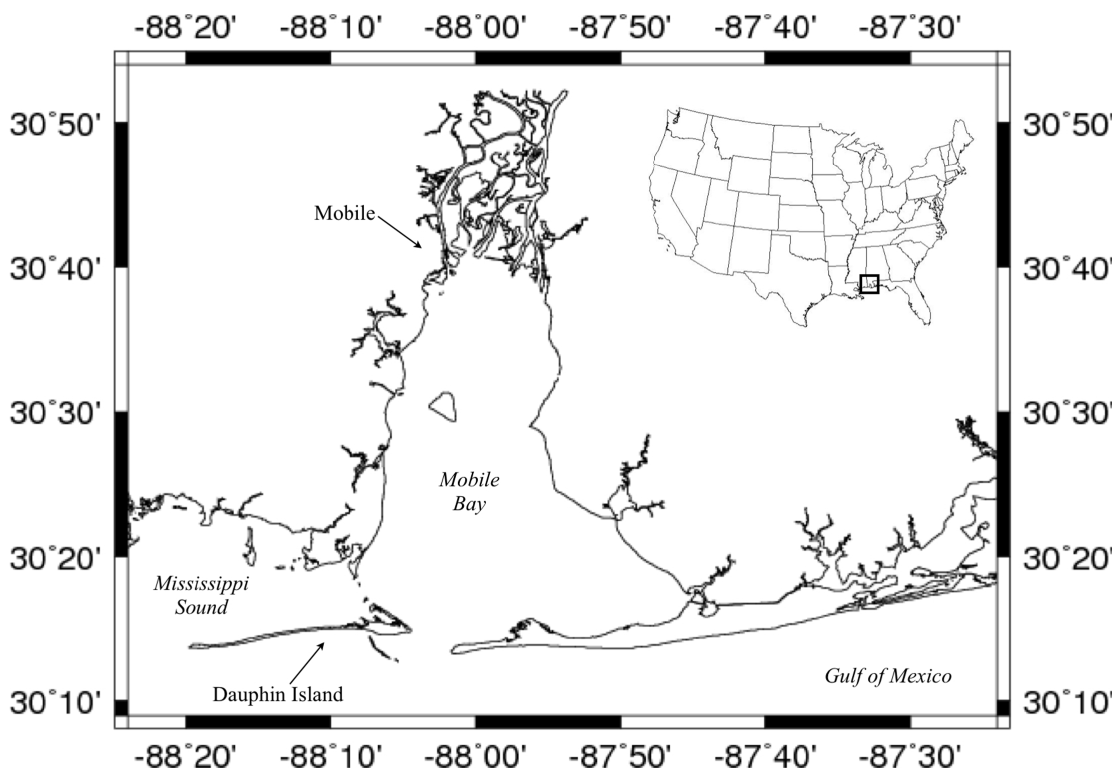

Figure 1. An overview of the study area showing Dauphin Island, Alabama.

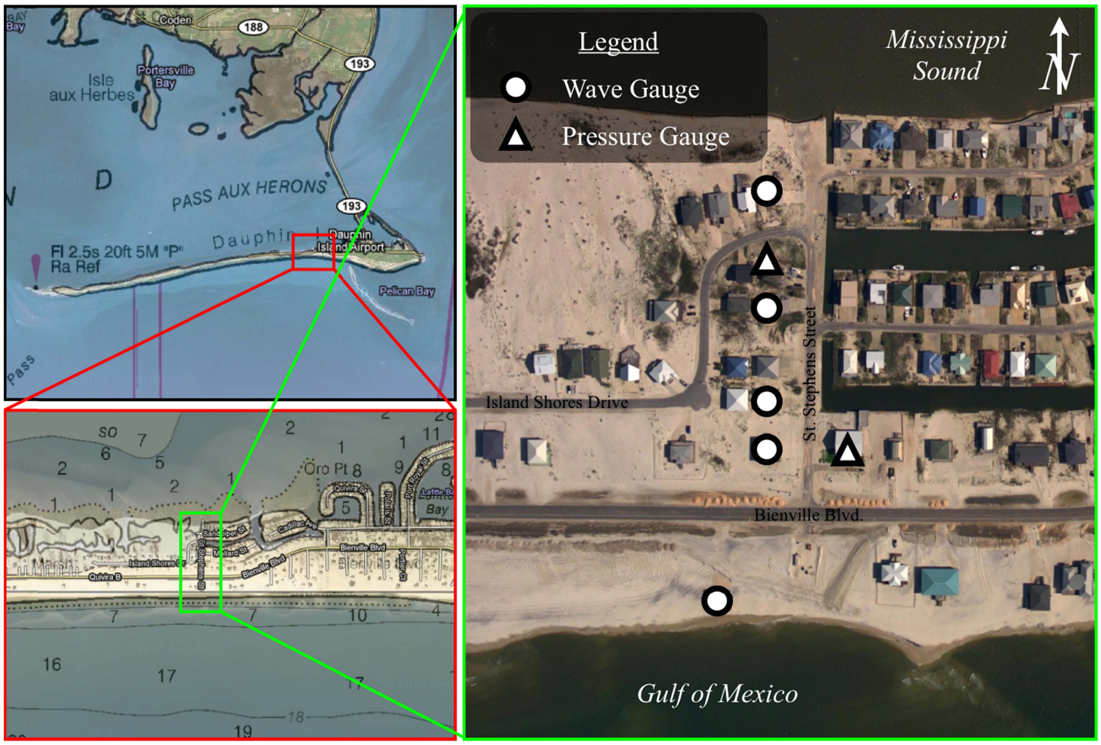

Figure 2. A more detailed overview of the study area showing the locations of wave and pressure gauge locations located across Dauphin Island, Alabama. The lower left panel shows NOAA bathymetric depths in feet relative to mean lower low water.

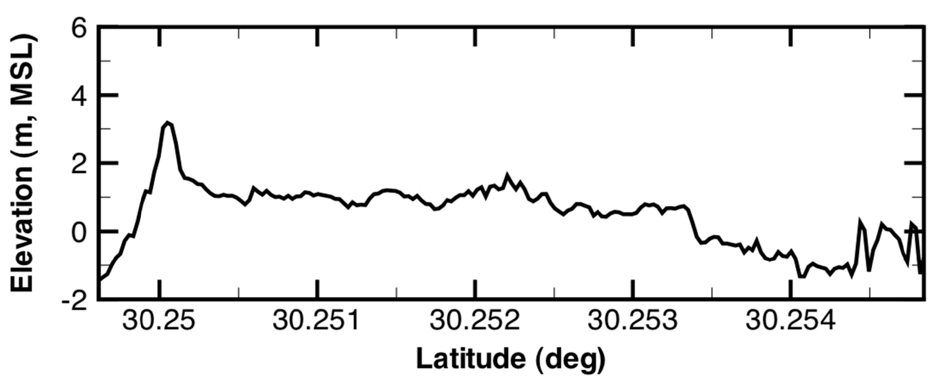

Figure 3. A cross-section of Dauphin Island obtained within the study area shows a nominal island elevation of 1.5 – 2 meters above MSL. In this graphic, the Gulf of Mexico is on the left and Mississippi Sound is on the right.

MONITORING PLAN

Waves and Water Levels. The purpose of the monitoring plan is to acquire data that can be used to improve guidance on building elevations in high hazard flood plain areas where wave action is the primary structural damage mechanism. A number of novel, autonomous wave gauges (Kennedy et al., 2010) will be temporarily mounted (Figure 4) to participating residential structures on Dauphin Island, Alabama in advance of an overtopping event during future hurricane seasons. The proposed deployment location for the five wave gauges (Figure 2) offers the best chance of locating and measuring the transformation of waves over the submerged barrier island during a storm event. Two small pressure gauges will be deployed in the study area (Figure 2) to provide collocated atmospheric pressure measurements for applying barometric corrections to the measured water levels. The mounting locations and elevations of all wave and pressure gauges are pre-determined to eliminate having to survey during an actual deployment.

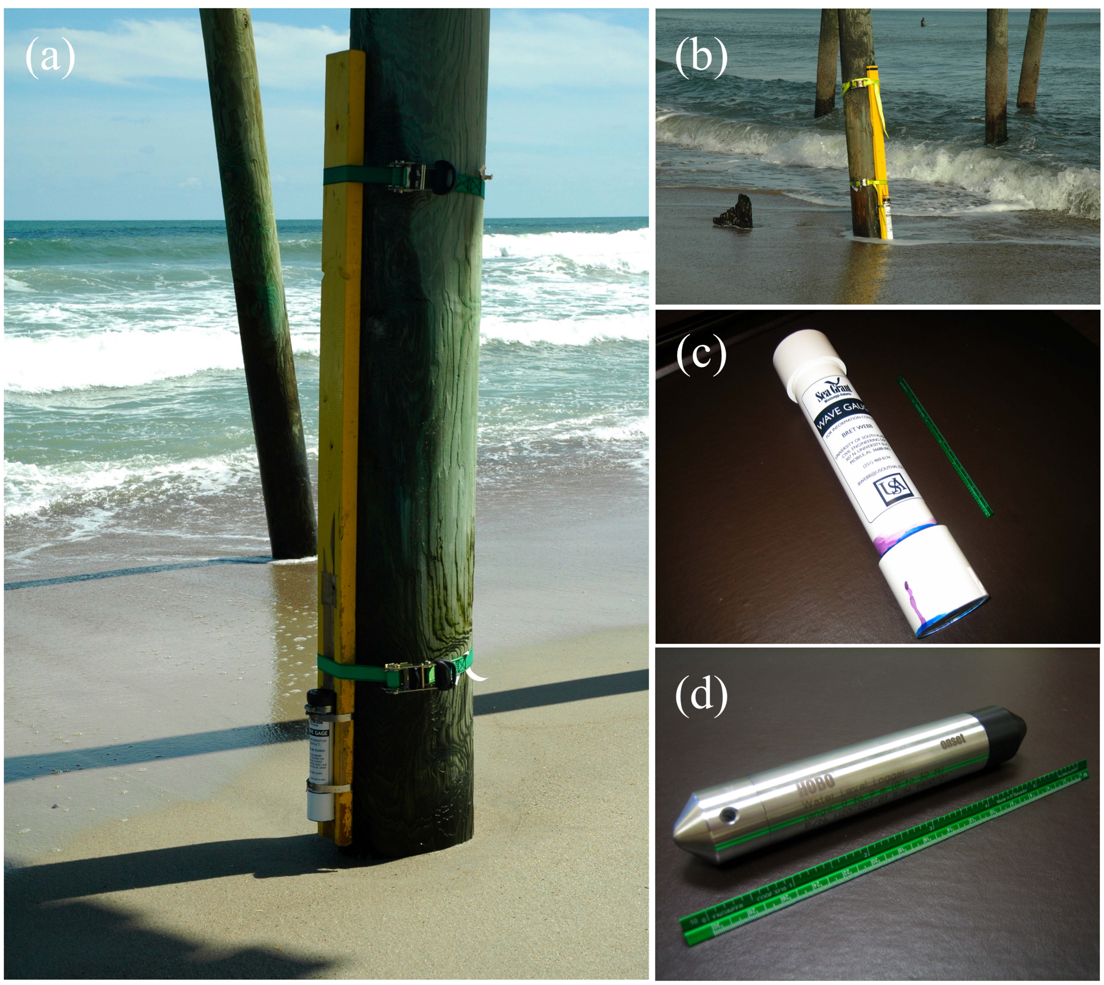

Figure 4. Typical wave gauge deployments on residential structures are shown in (a) and (b). The wave gauge (c) and pressure gauge (d) are shown next to a 15 cm (6 in) scale.

Structural Inventory. A detailed structural database for each subject structure will be used after an overtopping event to compare noted damage to the measured waves and water levels at those structures. Detailed photographs of each subject structure (Figure 5), its foundation system, its floor joist system, and its beam-column connections are included in the structural database for reference. The elevations of critical structural connections and elements are also included in the database. In particular, the elevations of connections for lateral bracing, floor joists, and roof trusses are determined for each subject structure, along with details regarding the type, material, and condition of significant structural connections. Specific information regarding structural connections includes the type of connection (e.g., bolted, nailed, screwed, plate, hanger, etc.), the connection material (e.g., stainless steel, galvanized, anodized, etc.), the integrity and condition of the connection material (e.g., original, oxidized, rusted, etc.), the specifications of the connection material (e.g., diameter, length), and the connection bolting/nailing pattern. Detailed information about each structure's foundation system will also be documented in the database for later use, including column type, size, and spacing.

Figure 5. Example of subject structure photo showing locations of critical and assessment elevations included in the structural monitoring database.

CONCLUSIONS

Measured wave heights and water levels on Dauphin Island will provide an opportunity to characterize wave transformation across the barrier island during future storm surge events. When combined with surveyed building elevations and documentation of structural connection details and foundation characteristics, such measurements will provide an opportunity for detailed post-storm damage assessments. In the event of failure, the measurements of waves and water levels, when combined with the structural database, will provide an opportunity to identify critical elevations and characteristics of structural members and connections as a function of wave exposure. In addition, characterization of the wave transformation process will lead to improved parameterizations of such processes in wave transformation models used by federal and state agencies.

The central goal of this research is to improve guidance on building elevations, structural connections, and foundation systems in high hazard flood plain areas where wave action is the primary structural damage mechanism. The proposed activities will both support and enhance guidance on construction materials, techniques, and building elevations in coastal communities. The expected outcomes of the project include: the first detailed measurements of wave transformation over a barrier island; improved predictions of wave heights during storm surge event; enhanced descriptions of storm surge components including wave setup; better guidance on construction methods and materials in high hazard flood areas; and determination of critical structural elevations

When wave transformation processes are evaluated in tandem with ground surveys of structural damage, an opportunity for improving specifications and codes for foundation-floor joist-wall connections, similar to Tung et al., (1999), and appropriate elevations of the "lowest structural member" will be realized. These results can lead to a reduction in repetitive losses, and more efficient construction.

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REFERENCES

Kennedy, A.B., U. Gravois, B. Zachry, R. Luettich, T. Whipple, R. Weaver, J. Reynolds-Fleming, Q. J. Chen, and R. Avissar (2010). Rapidly installed temporary gauging for waves and surge during Hurricane Gustav. *Continental Shelf Research* 30(16): 1743-1752.

Kennedy, A., S. Rogers, A. Sallenger, U. Gravois, B. Zachry, M. Dosa, and F. Zarama (2011). Building destruction from waves and surge on the Bolivar Peninsula during Hurricane Ike. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 137(3): 10 pp.

McGee, B.D., B.B. Goree, R.W. Tollett, B.K. Woodward, and W.H. Kress (2006). Hurricane Rita surge data, Southwestern Louisiana and Southeastern Texas, September to November 2005. United States Geological Survey, Louisiana Water Science Center. Data Series 220.

Tung, C.C., B. Kasal, S.M. Rogers, and S.C. Yeh (1999). Behavior of breakaway wall subjected to wave forces: analytical and experimental studies. Report UNC-SG-99-03, North Carolina Sea Grant, 57 pp.