CHANGES IN BEACHFACE BED ELEVATION OVER A TIDAL CYCLE ON SANTA ROSA ISLAND, FLORIDA AND MATAGORDA PENINSULA, TEXAS

A Senior Scholars Thesis

by

GEMMA BARRETT

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2009

Major: Environmental Geosciences

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Approved by:

Research Advisor: Chris Houser
Associate Dean for Undergraduate Research: Robert C. Webb

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ABSTRACT

Changes in Beachface Bed Elevation over a Tidal Cycle on Santa Rosa Island, Florida and Matagorda Peninsula, Texas. (April 2009)

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Wave-scale changes in beach elevation were measured using a cross-shore array of ultrasonic distance sensors on a dissipative beach at Matagorda Peninsula, Texas, in December 2008. The data collected in this study are compared to data collected in a companion study on an intermediate beach in Pensacola, Florida in June 2008. Both beaches are currently in a state of recovery from hurricane activity within the last 5 years, and therefore serve as good comparison sites for bed elevation change models. At both sites, the ultrasonic distance sensors were used to measure the bed elevation changes to 0.08 m which is smaller than the median grain size at both study sites (0.2 mm and 0.3 mm respectively). The dissipative Matagorda site was found to be less affected by swash over the study period and maintained a steady state bed elevation with max change of .01 m. In comparison, the intermediate, Pensacola site was more affected by the swash and varied by 0.14 m in its bed elevation over a tidal cycle. It is argued that

intermediate beaches are more affected by individual swash, while dissipative beaches are more affected overtime by the migration of bedforms rather than individual swash.

ACKNOWLEDGMENTS

I would like to thank my research advisor, Dr. Chris Houser, for all of his help. Without his guidance, I wouldn’t have known where to start with this project. I also want to thank him for his assistance in the field and the creation of this undergraduate thesis.

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CHAPTER I

INTRODUCTION

The swash zone is the area of the coastal system covered and uncovered by the propelled uprush and gravity-drawn backwash of waves on the beachface (KOMAR, 1998). In general, this area has high sediment concentrations (HUGHES et al., 1997), high levels of turbulence through multiple influences (PULEO et al., 2000; BUTT et al., 2004), and large flow velocities (ELFRINK and BALDOCK, 2002). With the exception of non-tidal beaches, this area is known as the foreshore and serves as the transition zone between subtidal and subareal environments (MASSELINK AND HUGHES, 1998; PULEO ET AL., 2000). Swash zone sediment becomes available for transport by wind depending on a combination of factors including wind direction and velocity, shear stress at the boundary, the degree and uniformity of moisture content of the sediment, the availability and grain size of sediment, beach slope, bed roughness, vegetation cover, as well as other defining features on the beachface (SHERMAN and HOTTA, 1990; BAUER et al., 2009). Many models (BAGNOLD, 1941; KAWAMURA, 1951; ZINGG, 1953; BELLY, 1964; KADIB, 1964; LETTAU and LETTAU, 1977; WHITE, 1979; SØRENSON, 1991) have been able to predict aeolian transport rates under the constant conditions provided by wind tunnels (SHERMAN and HOTTA, 1990) but none are able to obtain consistent results on natural beaches (BAUER, 2009). Variables accounted for in these models include wind

The thesis follows the style of *Journal of Coastal Research.*

characteristics including shear stress, mean wind velocity, and shear velocity along with sediment characteristics such as grain size and density (BAUER, 2009). Similar to aeolian transport associated with beach environments, the swash zone's non-stationary, non-uniform flow makes measuring net sediment transport challenging (ALSINA et al., 2009) which has caused some hesitation to work in this area compared to the surf zone where data collection has been found to be less problematic (BUTT and RUSSELL, 2005). Little is known about the overall transport of sediment throughout the swash zone or the individual influences and mechanisms that drive its movement. Further research and discovery in the area of swash zone morphodynamics would be beneficial to many of the other coastal areas that are interconnected with the swash zone through feedback processes.

Morphological change in the swash zone is driven by gradients in sediment transport (PULEO et al., 2003). These gradients result from asymmetries in fluid velocities and sediment concentrations in the uprush and backwash (PULEO et al., 2000; MASSELINK and HUGHES, 1998; BUTT and RUSSELL, 1999). Uprush and backwash are not simply the reverse of one another, as backwash is longer in duration than uprush (HUGHES et al., 1997). Uprush has a higher flow velocity at the beginning of its uprush that decelerates up the beachface, while backwash accelerates to its peak velocity in the lower swash (HUGHES et al., 1997). Despite on accelerating flow, backwash usually takes longer to move across the beachface due to its diverging flow (LARSON and SUNAMURA, 1993). Suspended load tends to be largest during accelerating uprush compared to backwash due to swash bores which create turbulence at the base of the swash zone (PULEO et al., 2000; PULEO et al., 2003; BUTT et al., 2002; MASSELINK et al., 2005). Accelerating uprush is attributed to this bore turbulence or horizontal pressure gradients which occur at the beginning of an uprush event. An increase in bed shear stress during accelerating uprush is the reason for this increase in suspended sediment mainly because water velocities are higher and sediment is more concentrated as compared to backwash (BUTT and RUSSELL, 1999; PULEO et al., 2000; MASSELINK et al., 2005). For this reason, uprush is known to be a better transporter of sediment, compared to backwash (MASSELINK et al., 2005).

While swell and local wind waves are more visible on a dissipative beach, the effect of low-frequency infragravity waves has been found to be a primary control on sediment transport and morphological change on these beaches also (GUZA and THORNTON, 1982). Infragravity waves differ from gravity waves due to their larger wave period ranging between 30 and 300 seconds and frequencies between 0.004 and 0.05 Hz (MASSELINK and HUGHES, 2003). Infragravity influences have been connected with sediment transport in the swash zone (BEACH and STERNBERG, 1991) along with afflicting much of the energy on shorelines during storms (GUZA and THORNTON, 1982; RAUBENHEIMER and GUZA, 1996). For these reasons, possible infragravity influences can't be overlooked when researching the swash zone.

The Bagnold energetic model (BAGNOLD 1963, 1966) has been the most popular method of attempting to measure sediment concentrations in the swash zone through uprush and backwash. According to Bagnold (MASSELINK and HUGHES, 1998), suspended sediment found in uprush (1) and backwash (2) can be written as

$$I_u = \frac{k_u \bar{u}_u^3 T_u}{\tan\varphi - \tan\beta} \tag{1}$$

$$I_b = \frac{k_b \bar{u}_b^3 T_b}{\tan\varphi - \tan\beta} \tag{2}$$

where the subscripts of *u* and *b* indicates uprush and backwash. *I* is the immersed weight sediment transport per unit meter beach width (N m^{-1}), k is the calibration coefficient (kg m^{-3}), ū is the mean flow velocity (m s^{-1}), T is the uprush or backwash duration (s), φ is the sediment's friction angle, and β is the beachface angle. Others have chosen to use the Shields parameter (θ) to measure suspended sediment in the swash zone:

$$\theta = \frac{\tau}{\rho(s-1)gD_{50}} \tag{3}$$

where τ is the bed shear stress calculated as:

$$\tau = \frac{1}{2}\rho f u^2 \tag{4}$$

where s is the density of the sediment (s = ρ_s/ρ, where ρ_s and ρ are sediment density and water density), g is the gravitational constant, D_{50} is the median grain size, f is the friction coefficient and u is the fluid velocity. The Shield's parameter has been used in addition to the Bagnold model because it factors in boundary shear stress which is not a factor in the surf zone (NIELSEN, 1992). When using these two models, results are biased to offshore transport due to uprush's larger duration (LARSON and SUNAMURA, 1993) which steady flow models can not accommodate for (ELFRINK and BALDOCK, 2002). Bagnold energetic equations were originally produced as a steady-flow model for suspended sediment in the surf zone. These equations do not consider any pre-suspended sediment in its formula (BUTT et al., 2005), so results do not take into account any sediment entrained in the system before approaching the swash zone. Masselink and Hughes (1998) found that twice as much sediment is transported on the uprush than the backwash according to the Bagnold model, however inconsistencies for applying this model to the swash zone were found. Calibration coefficients differ between uprush and backwash events as well as depending on your location within the swash zone (AAGAARD and HUGHES, 2006). Many have agreed that these models are inadequate at determining sediment suspension and transport and a new model needs to be developed to replace them (MASSELINK and RUSSELL, 2006; AAGAARD and HUGHES, 2006; MASSELINK and HUGHES, 1998) or at least, modifications need to be made to include processes that are present in the swash zone that aren't in the surf zone (BUTT et al., 2005). These swash zone processes include infiltration and exfiltration (BUTT et al., 2007), the effects of bore turbulence (PULEO et al., 2000; BUTT et al., 2004; BUTT et al., 2005), and the effects of rapid gravity-driven flow reversal associated with backwash (BUTT and RUSSELL, 2005). The equations have been found to be more accurate if these horizontal and vertical components are used when finding the fluid coefficient due to turbulence in the swash zone (AAGAARD and HUGHES, 2006). It is still unclear, how much of an individual effect each of these processes has on each type of beach

(Masselink and Puleo, 2006). The next step in this area will require determining how much each process affects the beachface individually. The ability to measure the beachface to a high degree of accuracy is needed.

As stated by Houser and Barrett (*in press*), few studies have examined the wave-scale changes in bed elevation in the swash zone. With the exception of Houser and Barrett (*in press*), no detailed beachface morphology measurements have been taken that can monitor bed elevation to the scale of an individual grain of sand, and capable of showing the effect of individual swash events on the bed. Turner (*et al.*, 2008) also used ultrasonic sensors in the swash zone and noted that the beachface shows dynamic fluctuations over the short time periods. The purpose of this study is to measure bed elevation change to a high degree of accuracy over a tidal cycle using ultrasonic distance sensors on two beaches. This study will characterize erosional and accretional swash and determine if changes in the swash zone are the cumulative effect of individual swash and change gradually, or the result of specific swash that are more erosive or accretional and accrete or erode in steps with specific waves.

To meet the broad objectives of the study, swash and bed elevation data are collected from Matagorda Peninsula, Texas (December, 2008) and compared to data collected by Houser and Barrett (*in press*) from Santa Rosa Island, Florida (June, 2008). With one beach being dissipative and one being intermediate, a comparison can be made about the types of sediment transport that occurs on different natural beach profiles. Both study sites were chosen because they are currently in a state of recovery from recent hurricane activity which makes them acceptable locations for monitoring tidal beachface bed elevation changes.

Study sites

Matagorda Peninsula, Texas

The first study site is a beach on Matagorda Peninsula. Data was collected on December 17, 2008. Figure 1 shows the location of the study site.

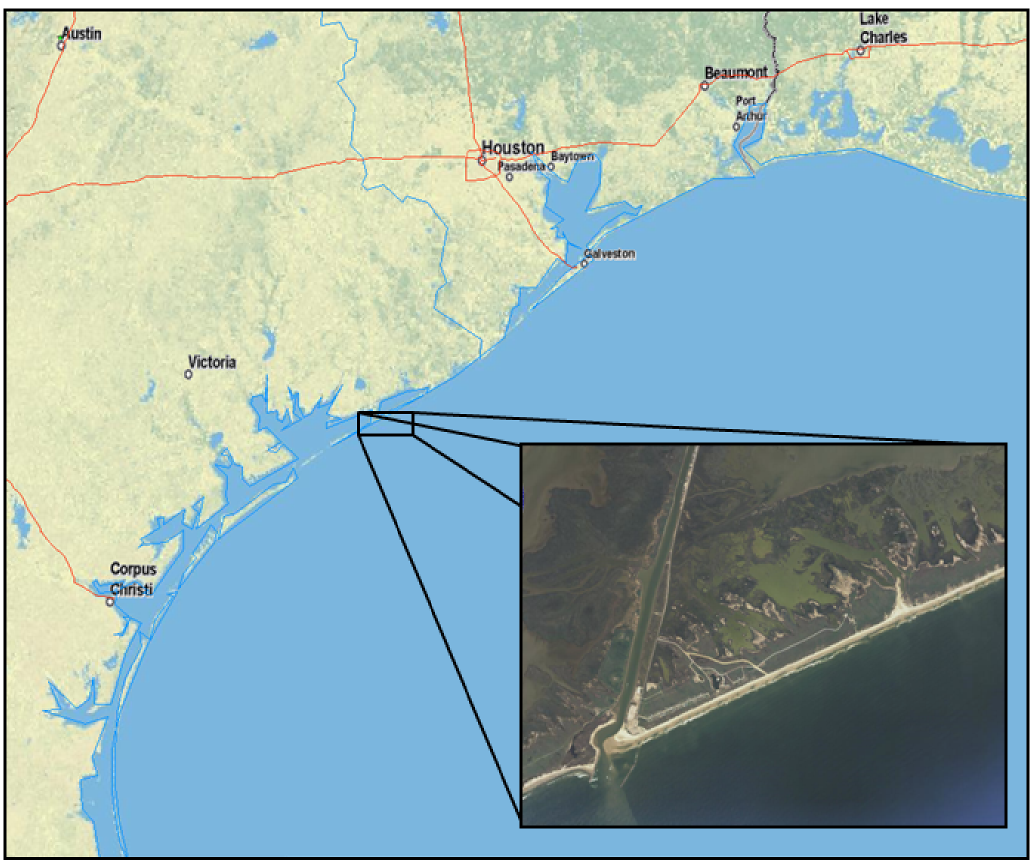

Figure 1. Satellite image of Matagorda Peninsula, Texas. Satellite imagery provided by Google Earth.

Matagorda Peninsula is a spit of land on the Texas coast and sits between the Gulf of Mexico and Matagorda Bay. The Colorado River empties directly into this bay before making its way to the Gulf of Mexico. Data was collected on a dissipative beach on Matagorda Peninsula in December 2008. This beach is open to vehicle traffic year-round with a permit. This area of the Texas coast was impacted heavily by Hurricane Ike which moved inland on September 13, 2008 as a Category 2 storm approximately 85 miles to its east. The direct long term impacts of Ike on this beach are currently unknown. Areas of overwash and flooding were evident in the areas surround the study site on the day of the field experiment three months after Hurricane Ike.

Pensacola, Florida

Swash data was also acquired from a barrier island near Pensacola, Florida. Santa Rosa Island is the barrier island farthest seaward from Pensacola. The study site was located on the western end of Santa Rosa Island and data was collected in June 2008. This is an intermediate beach with two nearshore bars located offshore. This island was directly affected by Hurricanes Ike, Dennis and Arlene between 2004 and 2005 (HOUSER *et al*., 2008) with numerous locations experiencing beach overwash and erosion. Specifically, this barrier island was hit directly by Hurricane Ivan in 2004 and washed out sections of the road running down the western end of the island. This area is currently in a state of recovery from these hurricane events. During this summer data collection, the wind direction was from the S to SE. Data from this study site was taken on June 7, 2008.

Figure 2 shows the location of the study site.

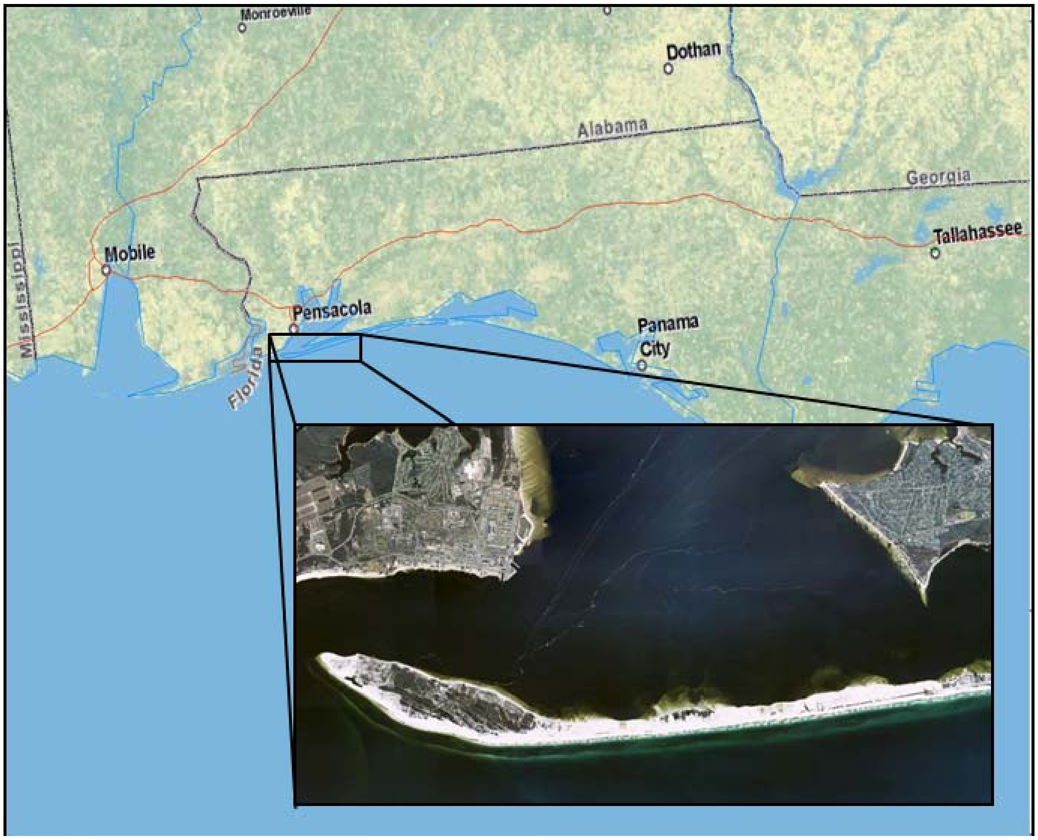

Figure 2. Satellite image of Pensacola, Florida. Satellite imagery provided by Google Earth.

CHAPTER II

METHODS

Matagorda Peninsula, Texas

A transect of ten cross-shore stations were constructed out of galvanized pipe and spaced at ~1 meter through the swash zone. Figure 3 shows the cross-shore transect stations in the swash zone with ultrasonic sensors attached perpendicular to the beachface. Figure 4 shows the cross-shore profile of the Matagorda study site.

Figure 3. Matagorda field site set-up for ultrasonic sensors on cross-shore transects.

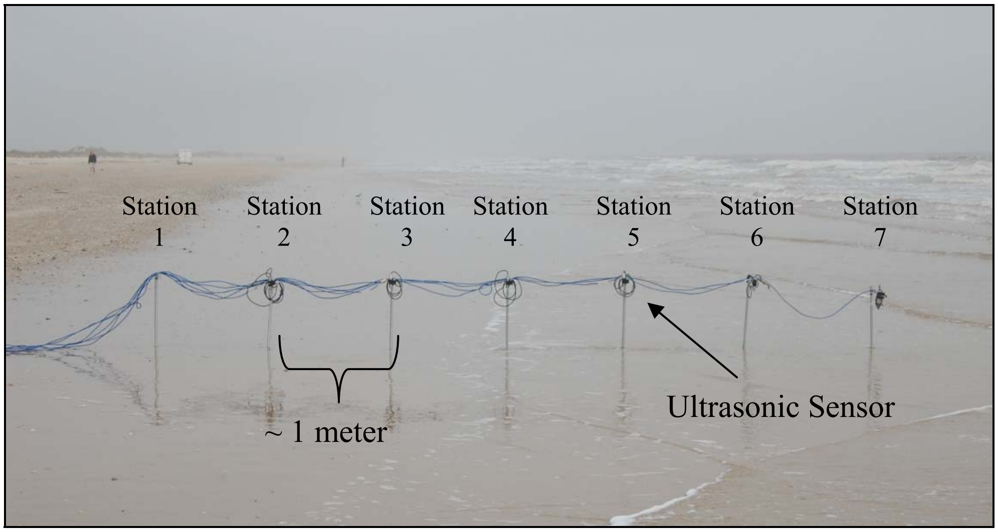

Figure 4. Matagorda cross-shore profile. Three more stations were later put landward of station 1 to accommodate for rising tide.

Senix Toughsonic ultrasonic distance sensors (TS-30S) were attached to the stations through the swash zone to measure bed elevation. Five ultrasonic sensors were used for the Matagorda study site and were transitioned between 10 stations during the study to accommodate for the larger swash zone. The ultrasonic sensors were connected to cables using RJ-45 connectors and a Daqbook data logger was connected to a field laptop for data collection.

Pensacola, Florida

Eight cross-shore transect stations were constructed out of galvanized pipe and spaced ~1 m apart through the swash zone. These stations were constructed differently, out of a need to also hold pressure transducers which were used in a different study (HOUSER and BARRETT, in press). Four ultrasonic sensors were used at this study site. Ultrasonic sensors were not transitioned between stations at this study site because the 8 stations with spacing of ~1 m covered the extent of the foreshore and recorded all data within the swash zone. Figure 5 shows the cross-shore profile for Pensacola, Florida.

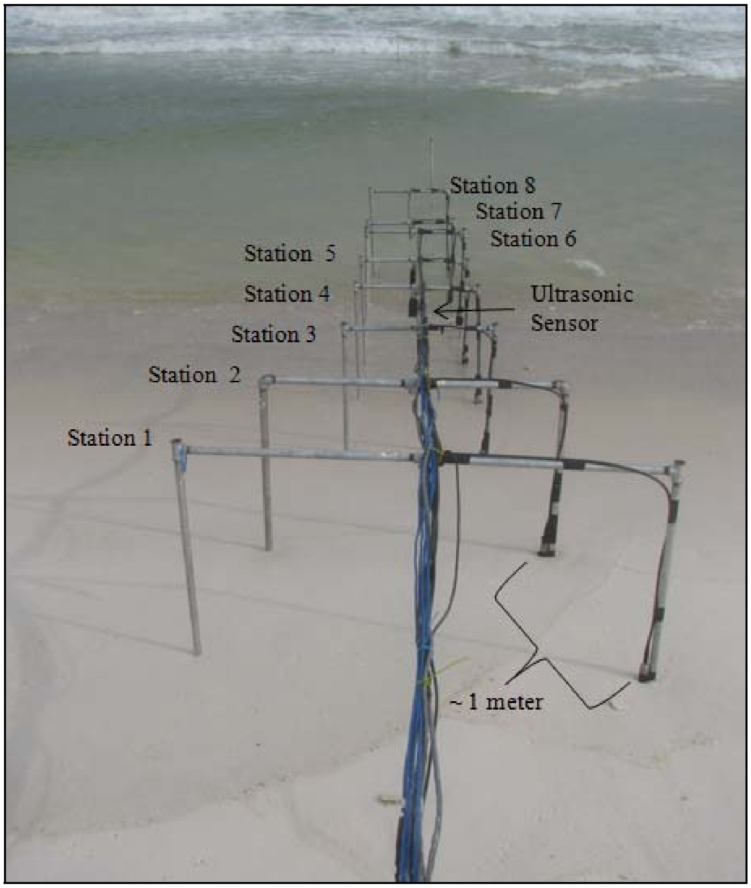

Figure 5. Pensacola cross-shore profile. Picture taken by Chris Houser.

Ultrasonic sensors

Senix Toughsonic ultrasonic distance sensors (TS-30S) were attached at each station to measure changes in bed elevation, as shown in Figure 3. Each ultrasonic sensor's beam was oriented perpendicular to the beachface. The resolution of the sensors is set to measure 0.086 mm, which is smaller than the average median sediment grain size at each of the study sites (0.2 mm for Matagorda and 0.3 mm for Pensacola). This enables the ultrasonic sensors to pick up grain-by-grain changes in the beach bed elevation. The ultrasonic sensors were "taught" to maintain a sampling frequency of 25 recordings a second (as Hz) for the duration for data collection at both sites. This allows every small variation to beachface as well as wave heights to be recorded to a high degree of accuracy. Between each data run, which is approximately 15 minutes, the following measurements were taken and recorded in a field notebook: wind speed, wind direction, barometric pressure, current weather conditions, and the distance from each ultrasonic sensor's beam to the beachface. Before and after the field experiments at each site, the ultrasonic sensors were calibrated using a bench test. Each sensor was attached to a stationary metal frame in the lab and oriented perpendicular to a lab bench. The sensors were connected to the Daqbook datalogger and the field laptop so that hertz readings could be recorded. Fifteen items of known heights were placed under the ultrasonic sensors beam and the hertz output was recorded for each known height. Each sensor was calibrated individually to accommodate for differences between sensors. This data was used to create data points which were used to create a calibration formula for each sensor which was then applied to all data recorded. Figures 6 and 7 show ultrasonic distance sensor calibrations for each instrument for each study site. Table 1 shows the calibration equations.

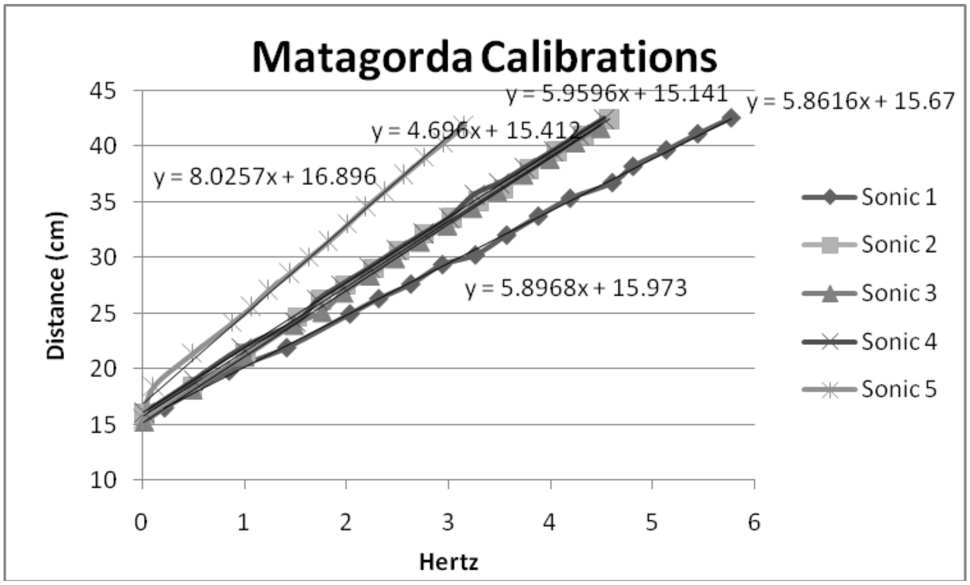

Figure 6. Matagorda ultrasonic sensor calibrations.

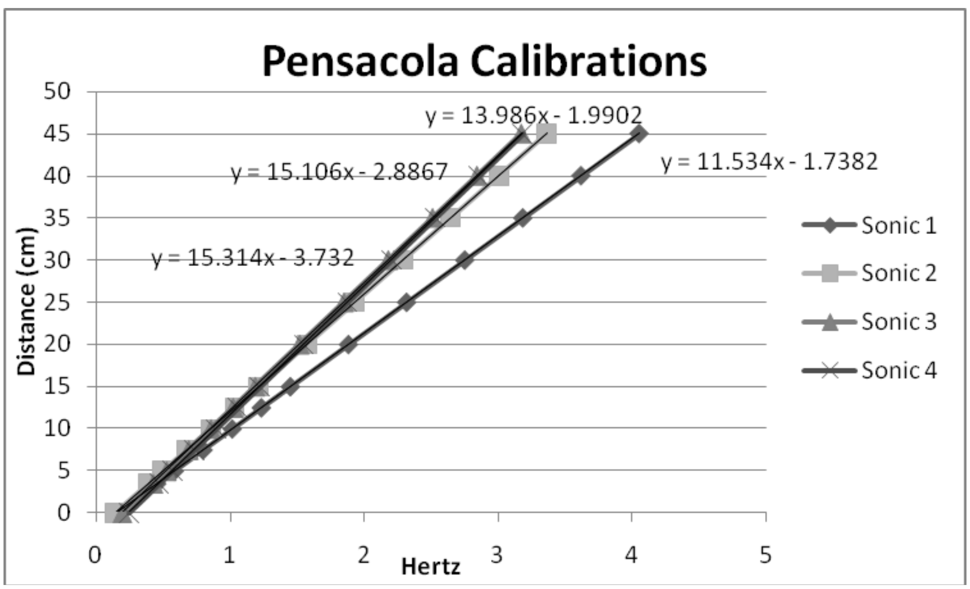

Figure 7. Pensacola ultrasonic sensor calibrations.

Table 1. Calibration Equations

Matagorda Calibrations		Pensacola Calibrations	
Ultrasonic Sensor	Calibration Equation	Ultrasonic Sensor	Calibration Equation
1	$y = 4.6960x + 15.412$	1	$y = 11.534x + 1.7382$
2	$y = 5.8616x + 15.670$	2	$y = 13.986x + 1.9902$
3	$y = 5.9596x + 15.141$	3	$y = 15.106x + 2.8867$
4	$y = 5.8968x + 15.973$	4	$y = 15.314x + 3.7320$
5	$y = 8.0257x + 16.896$		

CHAPTER III

RESULTS

Matagorda Peninsula, Texas

On the day of data collection, conditions were cloudy with a temperature of 60°F with a barometric pressure of 1019.5 mb. Winds were out of the ESE at 4.0 mph. According to tidal data acquired from the tides and currents page on the NOAA website, the tide minimum and maximum heights for the month leading up to December 17 were 0.195 m and -0.282 m which shows this area as having a tidal range of 0.477 m. The average tidal height averaged over the previous month was -0.0373 m.

Data was collected from approximately 12:30 to 3:30 pm with rising tide. Data from one ultrasonic sensor was chosen to be compiled into one graph to show the entire tidal cycle. Sonic 1 was chosen because it was located midway through the swash zone and recorded rising tide through the day. Figure 8 shows the compiled ultrasonic data from ultrasonic sensor which collected the best overall cross-section of data for the study site.

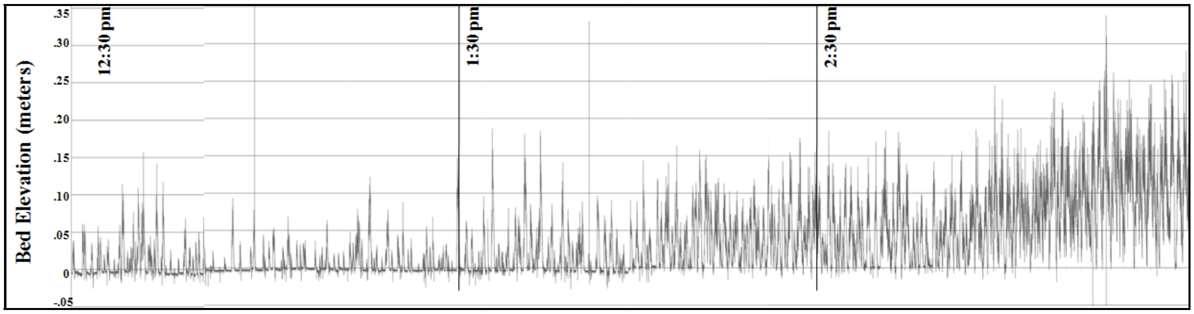

Figure 8. Compiled ultrasonic data for bed elevation change at Matagorda Peninsula, Texas. This data was taken over a three hour period on December 17, 2008 from Sonic 1. An enlarged version of this figure is included in the appendix.

Each individual spike in data is a single wave moving up the beachface and under the ultrasonic sensor recording the uprush and subsequent backwash of each wave. The lowest extent the each spike reaches indicates the elevation of the beachface. The beachface is located at 0 m at the beginning of the data collection but varies slightly over the three hours. Any variation in the bed elevation value from 0 m denotes a change in bed elevation from the bed elevation recorded at the beginning of the data collection. Wave heights range from less than 0.01 m to 0.34 m. Wave heights reach 0.34 m after 2:30. An increase in swash frequency and height denotes rising tide. After 2:30pm, swash increases significantly in energy and the underlying beachface elevation is barely uncovered because of the constant bombardment of waves running up and down the beachface. Even though the bed is exposed less often, the bed elevation is still recorded as being within +/- 0.01 m of the original beachface elevation. A closer look at the ultrasonic data will show individual waves and their influence on the beachface. Figure 9 shows the first 1000 seconds of this data collection.

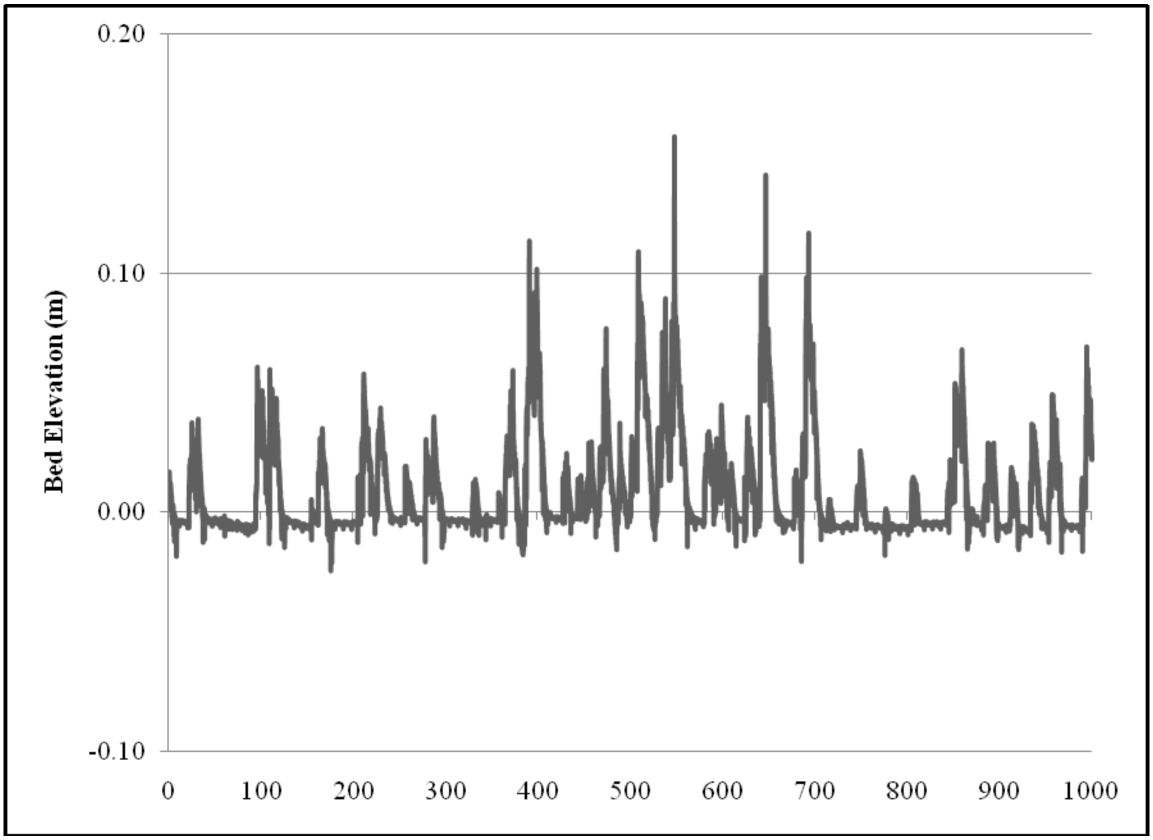

Figure 9**.** First 1000 seconds of Matagorda data. Seconds are displayed on the x-axis.

As previously mentioned, each individual swash event is shown by a spike in the data, followed by a leveling out around 0 m after the backwash has proceeded down the swash zone. In these first 1000 seconds, wave heights vary from approximately 0.01 m to 0.155 m. Here, you can see that the beachface elevation is actually ranges between about -0.005and -0.01 m. These ultrasonic sensors do make it possible for the erosive or accretional affects of each individual wave to be measured by taking the original bed elevation value before a wave and comparing it to the bed elevation value after the wave has retreated. This sensor also provides the swash height, which is a useful tool in determining wave influence. It appears that 39 individual waves moved under the sensor during this 1000 second recording. Figure 10 shows the last 1000 seconds of the study data which shows swash inundation moving into high tide.

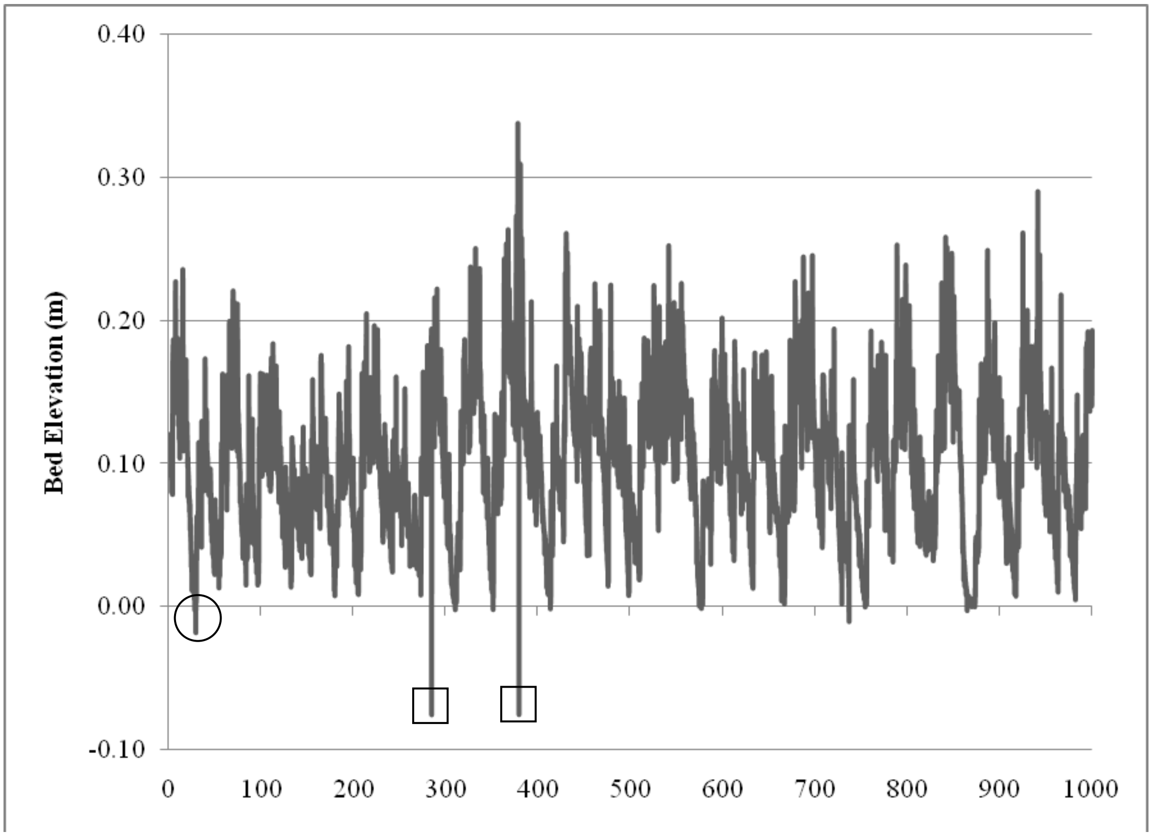

Figure 10. Last 1000 seconds of Matagorda data. Seconds are displayed on the x-axis. Squares indicate area of water on the sensor. The circle indicates the area of largest change in bed elevation.

Despite entering high tide and having high energy swash, the bed elevation on this dissipative beach still remains steady within +/- .01 m of 0 m. The largest change occurs at approximately 40 seconds (which is identified by a circle around the data in figure 10) where the bed elevation drops to -0.02 m. The two drops in bed elevation around 290 and 370 seconds (identified by squares around the data in figure 10) are due to water on the sensor which gives a false reading. These errors are easily detectable in the data because they show a drastic change in bed elevation and therefore can’t be identified as an erosive event. A visible trend in the swash can be seen as recorded by the ultrasonic sensors at tidal and wave-by-wave scales.

Pensacola, Florida

The data collection on June 7, 2008 was taken during sunny conditions with winds averaging 7.2 mph and gusting up to 8 mph from the SSE. The barometric pressure read steadily at 1020.5 mb. Using data provided by NOAA, the lowest averaged annual tide leading up to the data collection occurred in August 2007 at -0.231 m. The highest averaged annual tide occurred in October 2007 at 0.619 m. The tide minimum and maximum heights for the month leading up to June 7 were -0.326m and 0.461 m which shows this area as having a tidal range of 0.787 m. Pensacola has a larger tidal range compared to Matagorda Peninsula.

Data was collected during a 7 hour period on June 7, 2008 to record the entrance and exit of high tide. Data from one ultrasonic sensor was chosen to compile for the tidal cycle. Sonic 4 was chosen because it was located midway through the swash zone and positioned on station 4 of the 8 transect stations which showed the best data for rising, high tide, and falling tide as shown in figure 11.

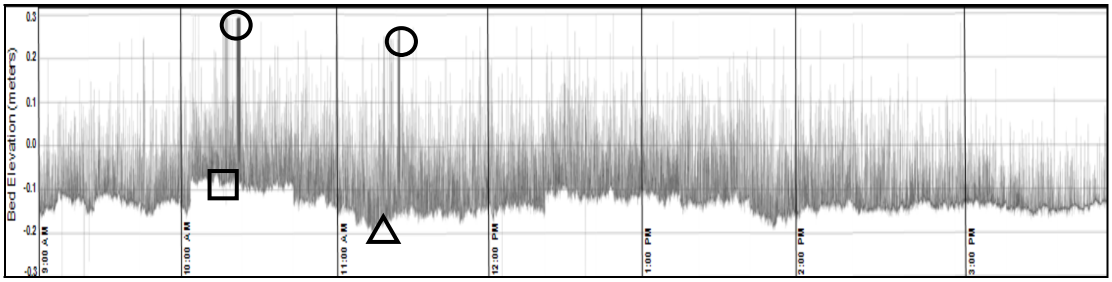

Figure 11. Compiled ultrasonic data for bed elevation change at Pensacola, Florida. This data was taken over a seven hour period showing the entrance and exit of high tide on June 7, 2008. Circles indicate area of splash that give false readings. Square indicates highest bed elevation and triangle indicates lowest bed elevation. An enlarged version of this figure is included in the appendix.

Figure 11 shows a variable beachface elevation over the seven hour period of data collection. The maximum wave heights reached in this data are 0.4 m. There are a few areas where splash on the sensor from incoming waves gave false readings and a few of these are marked by circles on figure 11. The bed elevation ranges from the lowest point at 0.05 m (indicated by a square on the data) to 0.20 m (indicated by a triangle on the data) producing a bed elevation range of 0.14 m. Comparing figure 11 to figure 8 of the compiled Matagorda data, it appears that Pensacola's bed elevation has a larger bed elevation range while the wave heights are comparable (0.34 m for Matagorda and 0.4 m for Pensacola). Overall, the trend for the seven hours isn't a gradual change but rather appears to be influenced by individual waves or as groups of waves. Some changes in elevation were quite drastic, seen as sudden drops in the bed elevation. The wave-beach face relationship appears to be episodic in nature, evident by the large fluctuations between erosional and accretional events throughout the day. However, the underlying variation in the data looks to be that of the infragravity waves with periods greater than

20 seconds. Figure 12 shows a 1000 second section of bed elevation data during rising tide.

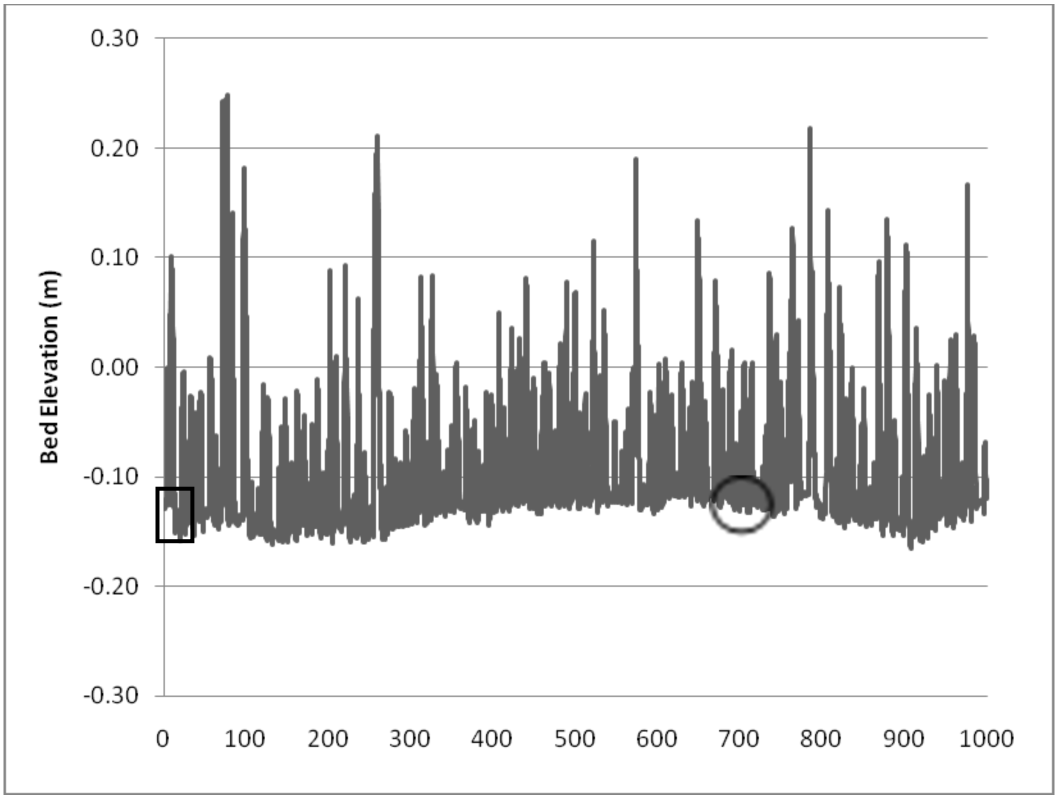

Figure 12. Close-up of 1000 seconds of Pensacola ultrasonic data. Seconds are displayed on the x-axis. The circle indicates area of direct variation by individual swash. Rectangle indicates area of data for figure 13.

Compared to figure 9 of the Matagorda Peninsula data, it appears Pensacola has a shorter wave period and wavelength. Wave heights range from 0.4m down to less than .07m. The number of individual waves recorded during this 1000 second data record was counted to be 84. This is more than double the 39 waves recorded during Matagorda's 1000 second data recording during their equivalent rising tide. The bed elevation varies has a range of 0.05 m as it fluctuates between -0.125 and -0.175 m. Individual waves also seem to have more of an influence on the beachface measurements. There are more slight variations in the bed elevation rather than a steady trend as in the Matagorda data. An example area of this is shown by the circle on the figure. These could be areas where single waves have individually eroded or accreted to the beachface and each wave, depending if it is erosive or accretional, changes the beachface slightly. An example of what appears to be an erosive wave can be found in figure 13. This wave was taken from the first 30 seconds of data from figure 12 as indicated by the rectangle.

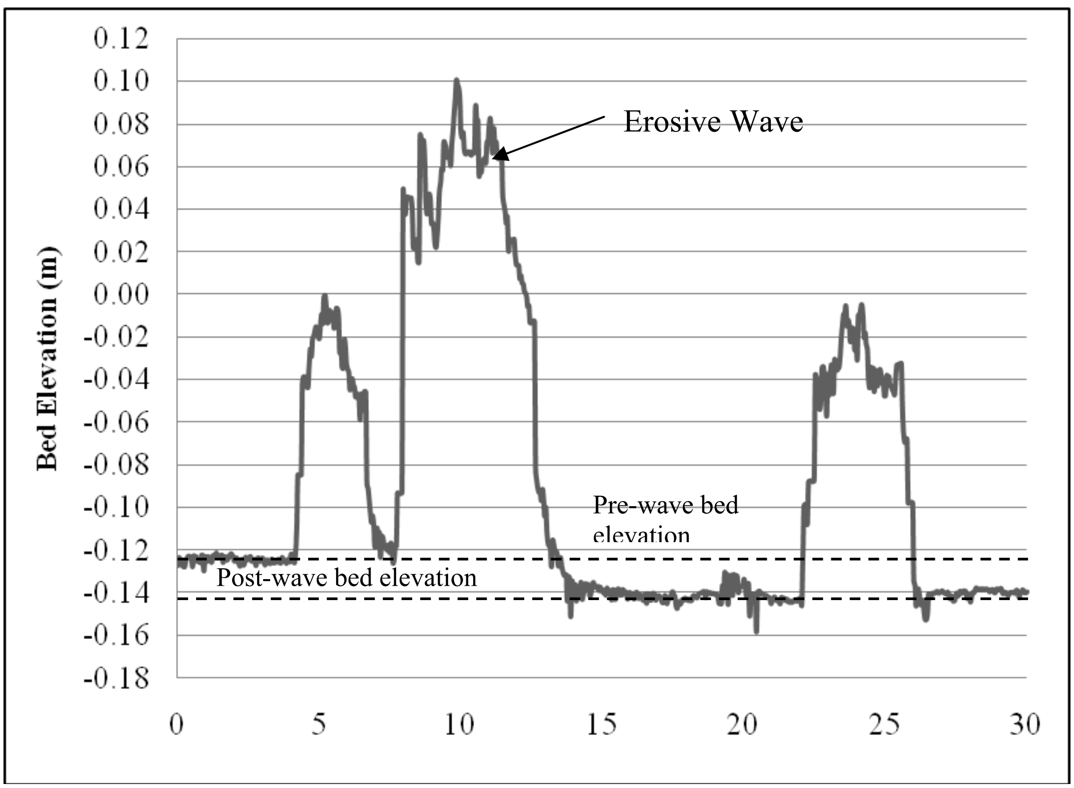

Figure 13**.** Erosive swash in Pensacola data. Seconds are displayed on the x-axis. Dashed lines show the pre-wave bed elevation and the post-wave bed elevation.

Figure 13 presents the bed elevation before the wave, the wave height, followed by the resulting erosion of the beachface by approximately 0.018 m. The bed elevation pre-wave is -0.124 m, followed by a wave with a height of .224 m, followed by the post-wave elevation of -0.142 m. This is significant erosion for a single wave. The wave immediately before this erosive wave has close to no affect on the bed elevation. This may be attributed to the fact that it has a smaller wave height and shorter wave duration. The wave immediately following the erosive wave contains the same qualities and again, has no noticeable erosive or accretional effect on the bed elevation. Conversely, an example of an accretional wave is found in figure 14.

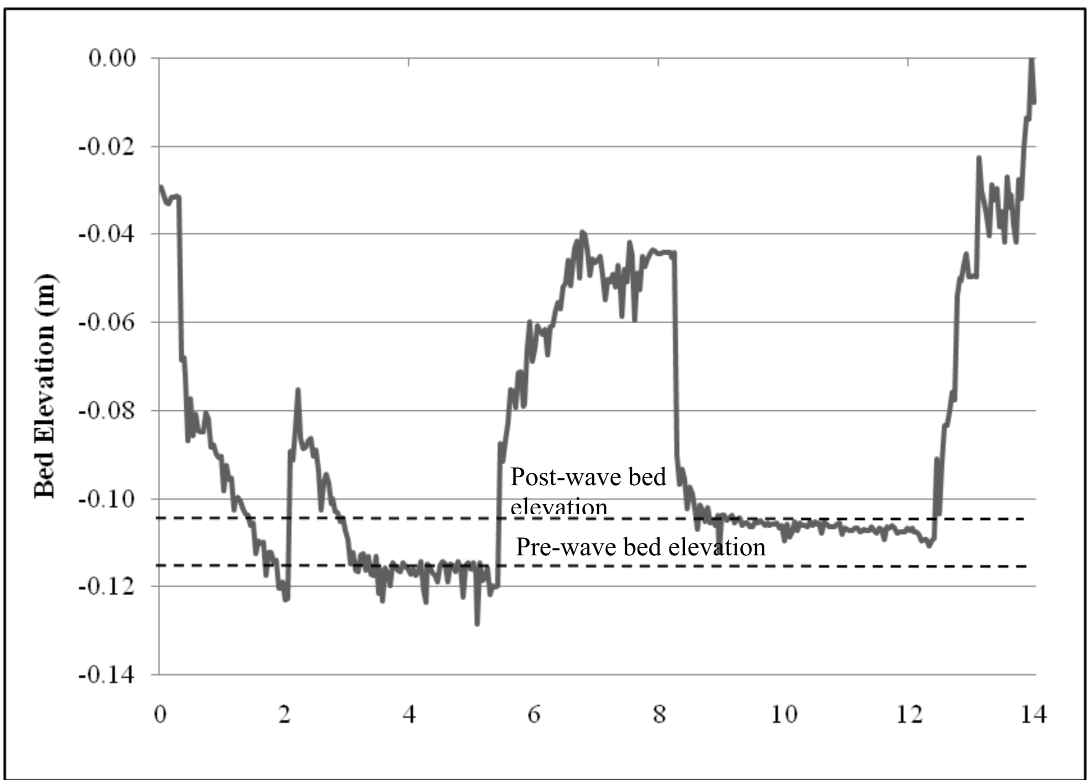

Figure 14. Accretional swash in Pensacola data. Seconds are displayed on the x-axis. Dashed lines show the pre-wave bed elevation and the post-wave bed elevation.

Figure 14 shows an accretional wave in the Pensacola data as the data moves into falling tide. The accretional wave itself is shown from seconds 5 to 9. The beachface elevation is at approximately -0.114 m before the wave event. The uprush and backwash of the .074 m wave is recorded and the resulting bed elevation is shown before the next wave moves up the swash zone. By comparing the bed elevation before and after this wave we can see that accretion of approximately .01 m occurs due to this single wave. Accretion from -0.114 m to approximately -0.104 m at 9 seconds or -0.106 m at 12 seconds is shown. Between 9 and 12 seconds, the bed elevation reading visibly trends downward for .002 m. This change in the bed elevation appears to be water infiltration picked up by the ultrasonic sensors. Infiltration measurements and recordings have been difficult to acquire in the past due to the high-frequency, small-scale measurements required. It appears possible that these ultrasonic sensors can pick up water infiltration into the beachface after each wave event and could be used in the future for this purpose. Because water infiltration is being recorded, the approximate bed elevation at 9 seconds isn't an accurate reading of bed elevation and the reading at 12 seconds of approximately -.106 m will be used as the final bed elevation. Therefore, the actual accretion by this single wave to the beachface is .008 m.

Discussion

The two study sites present two very different sets of data. The dissipative beach at Matagorda recorded small changes in bed elevation less than 0.01 m while the intermediate beach recorded bed elevation fluctuations with a 0.14 m range over the seven hours. According to the number of waves recorded in the 1000 second data runs in figures 9 and 12 which both showed rising tide, the wave frequency for Matagorda is

0.039 and Pensacola is 0.084. Pensacola then has a shorter wave period and a larger frequency making it a more energetic beach environment. NOAA tidal records also showed that Pensacola has a larger tidal range as compared to Matagorda. This helps compare the conditions at each of the study sites and is useful when analyzing and comparing data.

Ultrasonic distance sensors were able to record small-scale high-frequency changes to the beachface that were smaller than the median grain size on both beaches. Other than small errors due to water on the sensor which are easily distinguishable in the data, the sensors were capable of collecting bed elevation data at a high degree of precision. Ultrasonic sensors were able to simultaneously measure beachface elevation change along with measuring the wave heights of swash directly affecting them. These sensors are capable of measuring an individual wave's affect on the beachface on a tidal scale and a wave-by-wave scale.

It is generally accepted that beaches erode and accrete due to sediment gradients created over time due to wave influence on the beachface (TURNER *et al*., 2008). These time scales vary from minutes to months or years, if the result is long term coastline change. It is unclear whether these gradients are due to a certain wave's influence or whether they are the combined effects of each wave which add equally to the gradient. There are currently no measurements on the affect an individual wave makes to the bed elevation of a beachface. There is also unclear whether specific erosional or accretional waves exist. According to the data collected, waves with erosive and accretional characteristics are present in the swash zone. Erosive waves characteristically have a larger wave height than other waves in the wave field and accretional waves have a smaller wave height than the other waves in the wave field. A larger wave height appears to have an erosive effect while a smaller wave height has an accretional effect. For example, the accretional wave in figure 14 had a wave height of 0.074 m while the erosive wave in figure13 had a wave height of 0.224 m, more than three times as large. The degree of elevation change also varied by the type that was affecting it. The erosive wave lowered the bed elevation by 0.018 m while the accretional wave raised the bed by only half of that to 0.009 m. Considering both of these waves had approximately the same wave height (0.4 m and 0.34 m respectively), it appears that there is some other variables affecting the amount of sediment advected or eroded by these waves. These may be due to wave velocity or may be due to the 0.06 m difference in wave height between the erosive and accretional waves.

The dissipative beach at Matagorda exhibited little variation in bed elevation even with the effect of 0.34 m waves. The bed elevation remained steady within 0.01 m of its original elevation. The intermediate beach at Pensacola had comparable wave heights of 0.4 m but exhibited a variable and constantly fluctuating beachface. With a bed elevation range of 0.14 m over 7 hours, this beach was much more affected by individual swash events. Within the Pensacola data, individual erosional and accretional swash events could be identified and their effects measured. This highly variable beachface readily advects and erodes sediment with each incoming wave. According to these results, it would appear that intermediate beaches are more affected by swash events and therefore change over time due to the overall gradient that this swash takes. The movement of individual sediment would then be the morphologic cause of erosion and accretion on intermediate beaches and would be the defining feature to their formation. Dissipative beaches exhibited little affect to individual swash events and did not readily advect sediment. The field data suggests that dissipative beaches like Matagorda would then change through the migration of large bedforms such as the migration of swash bars onshore. These events would take place over time naturally or as of the result of large storms or hurricanes which cause nearshore bars to migrate onshore.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Ultrasonic sensors were accurately able to measure individual swash influence on the bed as well as larger scale changes throughout a tidal cycle. Wave-by-wave scale changes to the beachface could be observed and measured by measuring the bed elevation before and after a wave moved up and down the swash zone. Changes in the beachface up to 0.086 mm were measured which was smaller than the average grain size at both study sites. This technology allows for the relative importance of gravity and infragravity swash to be determined.

Overall, bed elevation changes were considered dynamic. Due to the precise measurement of the ultrasonic sensors, a highly fluctuating and dynamic beachface on both tidal and infragravity scales was shown at the Pensacola study site. Bed elevation fluctuations of 0.14 m were shown over the seven hour study on the intermediate beach. A less variable bed elevation was shown on the dissipative beach which fluctuated by less than .01 m over the three hour study. According to the results collected, individual waves events did not appear to have a significant affect on the Matagorda (dissipative) beach environment as much as the Pensacola (intermediate) beach environment. This strong fluctuation on the Pensacola beach was due to each single wave’s influence on the beachface. Some waves were accretional, some were erosive, and some had little impact. This shows that some waves are more erosive than others and sediment is more readily advected by swash than on a more dissipative beach, such as at Matagorda. Dissipative beaches are not as affected as a result of individual swash events. Sediment is not as readily advected and therefore appear to change as a result of the migration of large bedforms.

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APPENDIX

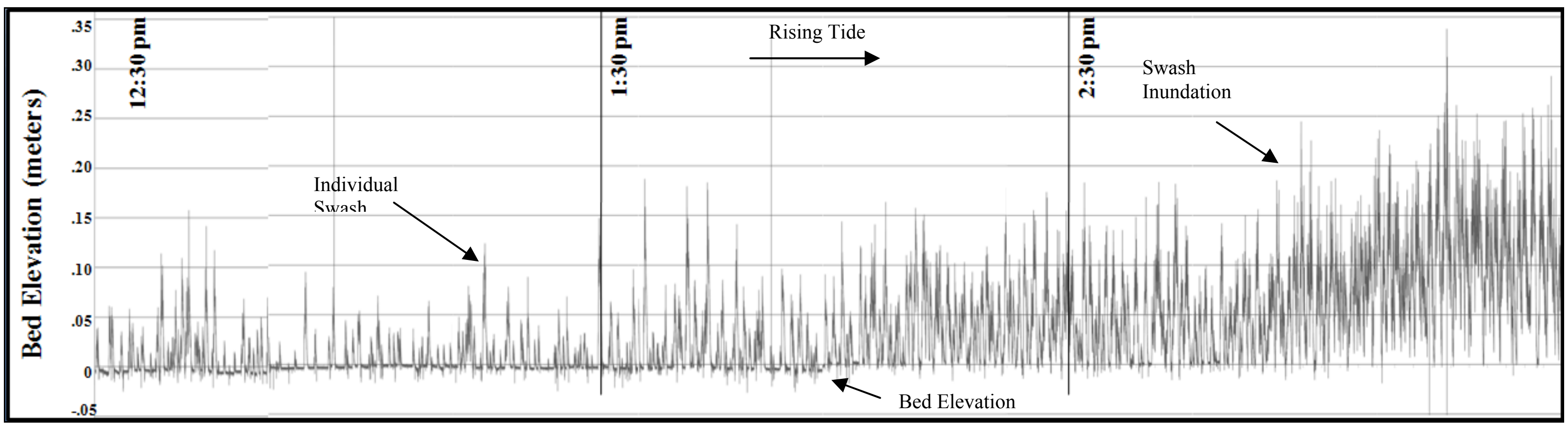

Figure A1. Detailed compiled ultrasonic distance sensor data with descriptions for Matagorda Peninsula, Texas. Data collected on December 17, 2008 from Sonic 1.

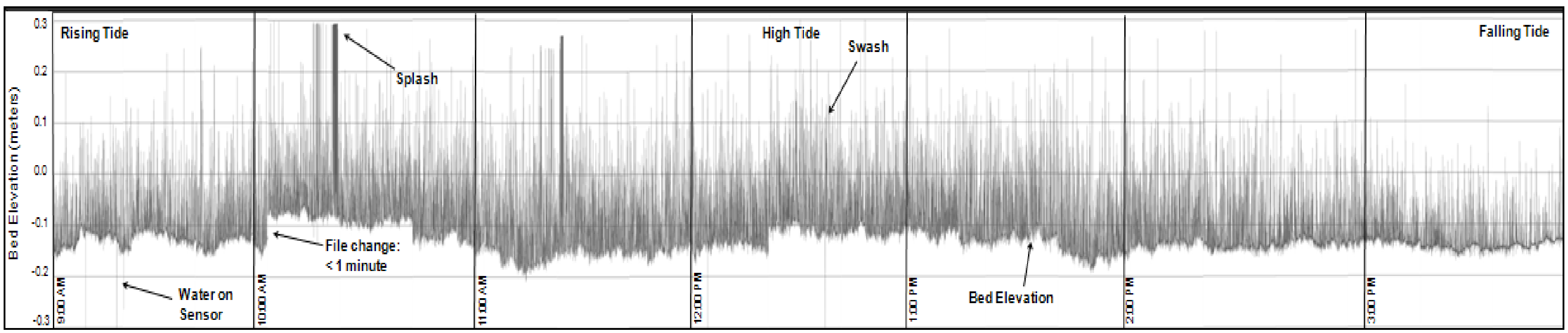

Figure A2. Detailed compiled ultrasonic distance sensor data with descriptions for Pensacola, Florida. Data collected on June 6, 2008 from Sonic 4.

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