IDENTIFICATION OF EROSIONAL HOTSPOTS AND SHORELINE POSITION UTILIZING AN ALONGSHORE SHORELINE MONITORING SYSTEM: GALVESTON ISLAND'S WEST END

A Senior Scholars Thesis

by

ANDREW J. MCINNES

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 2006

Major: Ocean and Coastal Resources

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Approved by:

Research Advisor:	Timothy M. Dellapenna
Associate Dean for Undergraduate Research:	Robert C. Webb

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ABSTRACT

Identification of Erosional Hotspots and Shoreline Position Utilizing an Alongshore Shoreline Monitoring System: Galveston Island's West End (April 2006)

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A continuous synoptic alongshore method of beach surveying was developed to identify shoreline position, erosional hotspots, and to examine the morphological variation of the Gulf beaches of Galveston Island's west end. Near-weekly (average 3 per month) surveys were conducted over 15 consecutive months for the approximately 30 km section of the west end of Galveston Island beginning April 2004 through September 2005. Erosional or accretional hotspots are operationally defined here as areas which can be statistically determined to have significantly greater migration than the mean migration for the entire beach, and are often, but not necessarily, ephemeral. The shoreline, by definition, is the wetline - the wet/dry interface on the beach, the furthest point of wave run-up - and was recorded by tracing the wetline immediately after the turn of the high tide utilizing an all Terrain Vehicle (ATV) equipped with a post-processed kinematic Global Positioning System (GPS). This system provides high-resolution topographical surveying with sub-decimeter accuracy in the both the horizontal and vertical dimensions. The data were assembled in order to determine mean wetlines – monthly, quarterly, or annually; repeated localized statistically significant landward advance of the shoreline is indicative of potential erosional hotspots while an annual net landward migration of the wetline indicates a retreating shoreline - erosion. This work demonstrates that by using this economically feasible surveying method, highly accurate shoreline positions can be used to monitor the morphological changes of the shoreline and to identify erosional hotspots. Over the study period the area exhibited a mean annual erosion rate of 4.95m $^{-1}$ with a range of 59.83m (-23.86m to 36.04m); the median offset was 4.73m; and mean elevation of the wetline was 1.15m (elevation lacks uniformity both spatially or temporally). This project shows that frequent synoptic surveys enable the identification of erosional hotspots and enables the establishing of an accurate, non-datum corrected shoreline position. Regular monitoring enables determination of erosional hotspots and shoreline migration due to storm events and annual cycles. Archiving and analysis of these short-term vacillations provides a long time-series of shoreline position and is of utility to coastal management and numerous stakeholders.

ACKNOWLEDGMENTS

This project was initiated as an independent undergraduate effort and the author is deeply indebted to Tim Dellapenna, Ph.D., for his support, guidance, and mentorship which were above and beyond anything hoped for. Appreciation also goes to the researchers at TAMUG’s Coastal Geology Laboratory, especially Eddie Majzlik and Chris Noll, for their inquisitiveness, assistance, suggestions, and concerns. Guarav Singhal contributed greatly by developing and refining the MATLAB script which was so vital to the analysis process. Also, Fred Pearl, Ph.D. generously loaned the GPS equipment and post-processing software thereby enabling this unfunded project to begin without any start-up costs. The Texas General Land Office (TGLO) and its Coastal Management Program (CMP) purchased the ATV and supplied salary support through other funded grants and the author and Coastal Geology Laboratory are deeply grateful for their continued support. Richard Krauss, Ph.D., and Patricia Edwards aided significantly in guiding my statistical analysis of the data. Fellow undergraduates Allison Skinner and Derek Shultz added much input and support toward my writing of this manuscript. This project was partially supported by a grant from the Texas Institute of Oceanography (TIO).

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Galveston Island is a heavily developed and modified transgressive barrier island. Enhanced subsidence due to ground water withdraw, reduced and interrupted sediment supply, and response to engineered hard structures including a 22 km long seawall and installation of Geotubes® along the western portion of the island has resulted in areas of chronic erosion. Galveston Island is recognized as having one of the most rapidly retreating shorelines along the Gulf coast with erosion rates reported between 3m y^{-1} (Heinz Center, 2000; Ravens and Sittangang, 2002), and 4m y^{-1} (Lee *et al*., 2003).

The shoreline, by definition, is the position of the wetline (the wet/dry interface on the beach) and is the furthest point of wave run-up. Enhanced wave run-up may result in erosion and landward migration of the wetline while reduction of wave run-up may result in beach accretion and shoreline advance. Erosional or accretional hotspots are operationally defined here as areas which can be statistically determined to have significantly greater migration than the mean migration for the entire beach, and are often, but not necessarily, ephemeral. Beach monitoring efforts typically focus on cross-shore profiling of the beach using standard surveying techniques such as a total station (electronic distance measurement) and GPS. The major assumption is that a

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

single profile is representative of the three-dimensional morphology of a beach segment (Swales, 2002) - these profiles provide a cursory view of beach change on the timescale over which the survey is conducted and require significant interpolation due to their temporal and spatial nature. However, the spacing of these 2-D profiles lines is usually too large to allow meaningful interpolation between them and, as a result, geomorphic patterns and local erosional hotspots may not be adequately described (Freeman *et al*. 2003).

Shoreline movement is both non-uniform and non-linear. Consequently, trend reversals as well as accelerations and decelerations in rates of shoreline movement need to be assessed if accurate modeling and prediction of shoreline positions are expected (Morton *et al*. 1995). Freeman *et al*. (2003), argue that a ground based technique which combines traditional shore-normal profiles with alongshore data is optimal for small scale, high frequency monitoring and takes advantage of 3-D analysis without the expense of swath-based systems and without the limitations of 2-D methods.

In an effort to investigate the morphological response of Galveston's west end beaches, a temporal and spatial monitoring method was developed whereby near-weekly (average 3 per month) synoptic surveys were conducted to record the position of the wetline immediately after the turn of the high tide. Thirty-two surveys were conducted over a 15 month period, each averaging 3269 shot points (data points recorded every second - every 9.36m).This continuous alongshore measurement was accomplished by utilizing an All Terrain Vehicle (ATV) mounted with a post-processed kinematic differential Global Positioning System (GPS) which was driven along the beach –

tracing the wetline while logging data every second. This method quantifies the relationships between temporal and spatial scales of morphologic change and establishes alongshore monitoring techniques to determine migration of the shoreline and the identification of erosional hotspots.

The purpose of this study was to develop a cost effective, accurate, and adaptable alongshore beach monitoring method for Galveston's west end which permits: (1) rapid, regular, on-going assessment of beach conditions, (2) identification of variability in beach morphology on weekly, seasonal, and annual timescales which may provide insight into sediment dynamics and budgets, (3) establishment of a long-term baseline data set for detecting shoreline change, (4) identification, quantification, and tracking of statistically verifiable hotspots as they develop, (5) extraction of highly accurate shoreline positions using the interface between wet and dry beach, and (6) enhanced public awareness and knowledge.

STUDY AREA

Coastal Setting

Galveston Island is part of the longest barrier island system in the United States and strikes northeasterly, extending approximately 52 km from its western extremity at San Luis Pass to the South Jetty at the Houston/Galveston Entrance Channel. The island is roughly 3km wide, tapering to <1 km wide at the western end, and is located on the upper Texas coast (Giardino *et al*. 1987, in Robb *et al*. 2004) (Figure 1).

The unarmored west end is approximately 30 km in length, and the remaining shoreline of Galveston Island, excluding the eastern most 6 km, is armored by a 22 km long seawall that encompasses a 6 km groin field: the seawall, along with other engineered structures, have drastically altered the shoreface of Galveston Island, causing, among other morphological changes, a landward retreat of the shoreline of greater than 30 meters at the western end of the seawall since the completion of the final phase of seawall construction in 1962 (Giardino *et al*.1987; Robb *et al*. 2004).

The study area begins at the western terminus of the 4.25m tall seawall - a reported “erosional hotspot” where average erosion rates are reported between 3m y^{-1} (Heinz Center, 2000; Ravens and Sittangang, 2002), and 4m y^{-1} (Lee *et al*. 2003).

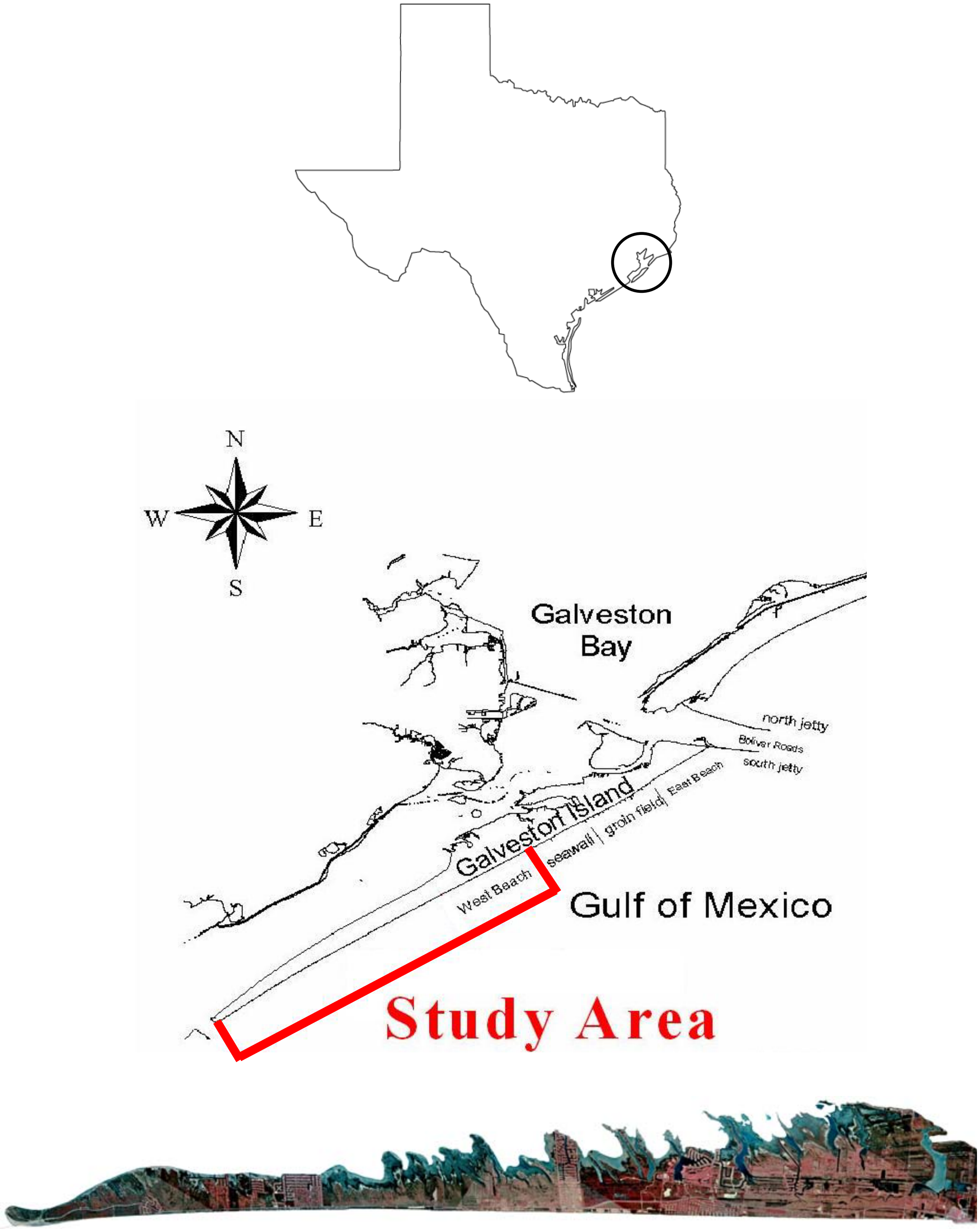

Figure 1. Study Area – Galveston Island’s west end, Galveston Island, Texas.

Physical Setting

The upper Texas coast is characterized by fair weather astronomical tides ranging from 0.3 to 0.6 meters and relatively low amplitude waves with periods ranging between 4 to 6 seconds (Morton and McGowen, 1980). Wave energy is generally low to moderate with most significant wave heights being less than 0.6 meters; shallow waves greater than 1 meter occur less than 1% of the time and storm waves are typically less than 1.8 meters high (USACE, 1983). The microtidal nature of the study area is dominated by a diurnal/mixed tidal signal with diurnal range (MHHW-MLLW) of 0.43m and mean range (MHW-MLW) of 0.31m as measured at Galveston Pleasure Pier (NOAA/NOS).

The west end of Galveston has a straight shoreline, with bathymetric contours that are parallel to the shore. The beaches are composed of fine grain sand extending 1.25 km offshore to the toe of the beach, where it transitions to a progressively muddier seabed (Robb *et al*., 2004). Estimated long-term longshore transport rates for the study area are 180,000 m^3 yr^{-1} from northeast to southwest (Ravens and Sittangang, 2003).

Hurricanes strike the Texas coast with moderate frequency; 0.67 hurricanes per year since 1900 (Hayes, 1967; in Davis, 1972, and Morton and Paine, 1985). Historical records clearly show that Galveston beachfront property will receive minor storm damage every few years and extreme storm damage about every 20 years (Morton and Paine, 1985). In addition to hurricanes, from October through April, on the average, there are 46 cold fronts a year which pass through the Northern Gulf of Mexico (Henry, 1979), causing high waves and enhancing littoral transport. Cold fronts occur at 3-10 day intervals in a given year and are characterized by a pre-frontal phase of high-energy southeasterly winds for 1-2 days, followed by a 12-24 hour period of strong northwesterly to northeasterly winds following passage of the front (Co-ops, 2005).

The upper Texas coast also experiences a rate of relative sea-level rise of 0.65 cm yr $^{-1}$ - this local rate of sea-level rise is about 3 times faster than the global rise in sea level, which recently has averaged approximately 0.18 m per century (Gornitz and Lebedeff, 1987).

Beach Morphology

Beaches serve many roles, not the least of which is the absorption and subsequent dissipation of wave energy. Factors such as beach slope, sediment supply, type, and size; tidal range, wave energy, wind energy, frequency of storms, and human impacts all factor into the formation of physiographic features of the beach.

Variability can be largely affected by the presence of structures, especially a large variety of structures placed on long coastal stretches (Perlin and Dean, 1983), and the most recent historical changes appear to be greatly influenced by anthropogenic activities. The strongest indictments against such human-induced shoreline changes are the unpredictable but rapid local responses associated with engineering modifications (Morton, 1979). Capobianco *et al*. (2002), report that if a number of artificial morphodynamic states are introduced, [as is the case on Galveston Island], they will influence the “chronology of events” on the morphodynamic evolution of the area.

Erosion is part of the natural response of a beach to changing wave and water level conditions. Typically, as stated in the Bruun Rule, the eroded sand is returned to shore and the beach is rebuilt during calmer periods (Bruun, 1962). There are, however, more severe energy episodes that cause the semi-permanent transport of sand out of the littoral system by cross-shore transport to the adjacent backshore flats (Ravens and Sittangang, 2006).

Erosional Trends

Morton (1979) reports that since 1960, a loss of equilibrium between sediment supply and sediment removal has resulted in prevalent shoreline erosion on the Texas coast, and that post 1955-1960, the total length of eroding shoreline increased from 55% to nearly 80%. On the Texas coast nearly half of the total beach sand supplied by updrift erosion, presently a major sediment source, has been trapped by jetties at harbor entrances. More recently, Ravens and Sittangang (2002) concur, stating that there is no significant supply of sand to the island due to the jetties.

Morton and Paine's (1985) delineation of aerial photographs and topographic maps of the unarmored west end, spanning 120 years (1851 to 1973), exhibited differing long-term beach sediment movement. Their analysis showed that three shoreline segments varied over this time span; they are: (1) The easternmost segment (adjacent to the seawall terminus) showed the greatest rates and distance of shoreline retreat (3.0m yr $^{-1}$), diminishing westward to Bermuda Beach (0.30m yr $^{-1}$), which is the transition to the stable shoreline segment**,** (2) The middle segment (<0.30m yr $^{-1}$)

suggesting a relatively stable shoreline, and (3) The western segment showed long-term erosion rates of 0.30 to 0.61m yr $^{-1}$ (figure 2).

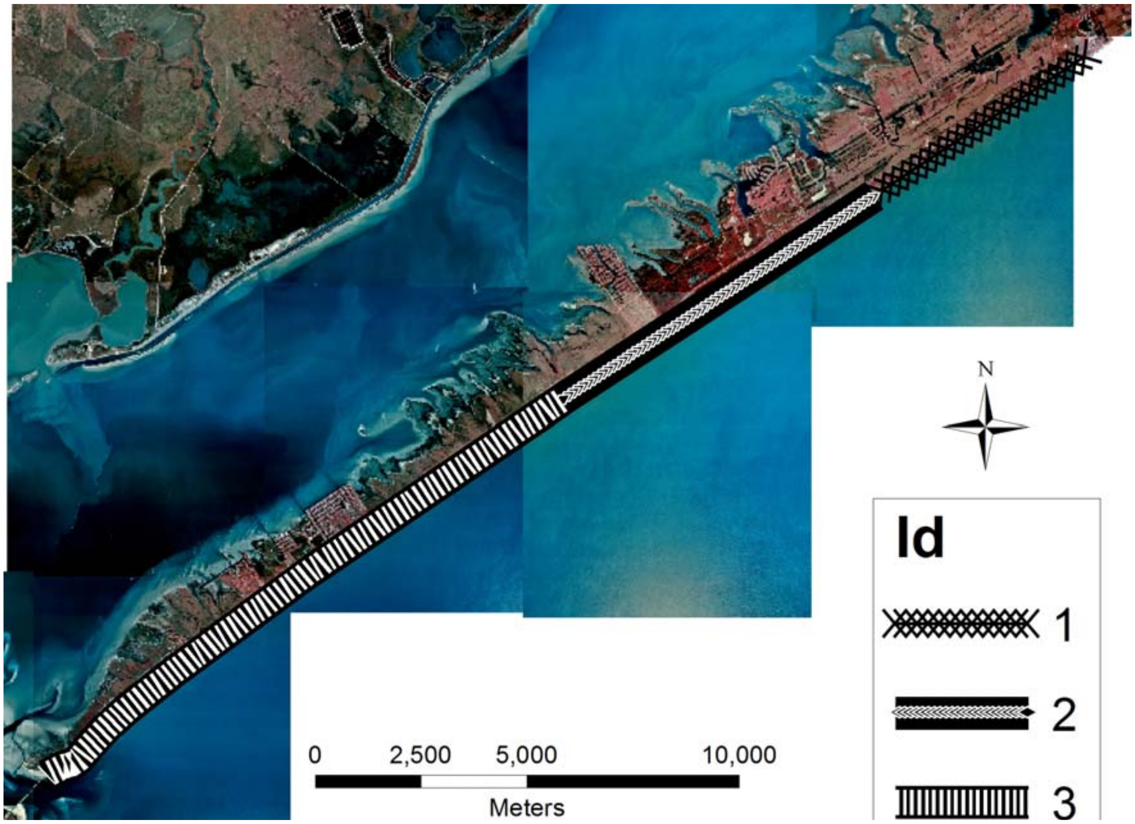

Figure 2. Tripartite division of erosion rates on Galveston Island's west end based on Morton and Paine's (1985) analysis. The easternmost segment showed the greatest rates and distance of shoreline retreat (3.0m yr $^{-1}$), diminishing westward to Bermuda Beach (0.30m yr $^{-1}$), which is the transition to the stable shoreline segment**,** (2) The middle segment (<0.30m yr $^{-1}$) suggesting a relatively stable shoreline, and (3) The western segment showed long-term erosion rates of 0.30 to 0.61m yr $^{-1}$.

METHODOLOGY

Base station establishment

A GPS base station was established at the residence of the author, located 8km from San Luis Pass on Galveston’s west end. This location fell within the range of vector length required for survey control as stated by the manufacturer and was also a secure site for the unattended base unit. This base station was established by transferring National Geological Survey (NGS) benchmark elevations and positions using Thales Navigation® processing software.

Data Collection

Each alongshore survey records a series of points of known easting, northing, and elevation, and yields a position in 3 dimensions for every data point. Coordinates for geographic position are referenced to the Universal Transverse Mercator grid (UTM) and elevations are referenced to the North American Vertical Datum (NAVD); Specifically, UTM NAD 83, Zone 15, and NAVD 88, Geoid 99 for the datum.

For each survey the shoreline position was recorded immediately after the turn of the high tide utilizing an ATV driven along the wetline of the beach. Two Promark2® differential GPS systems were utilized to collect data every second for the duration of each survey. Thirty-two surveys were conducted beginning April 2004 through September 2005, each averaging 3269 shot points (data points recorded every second -

every 9.4m).The base station unit collected data in static mode while the roving unit, mounted on the ATV (Figure 3), operated in kinematic mode . The manufacturers claim a survey accuracy of 0.005m +1ppm for horizontal, and 0.010m + 2ppm for vertical with a satellite elevation mask of 10 degrees. Huang *et al.* (2002) reported in a comparative 2-D study in Northern Ireland that the typical precision of an initialized kinematic survey is 0.01m +2ppm – fitting well with the accuracies claimed by manufacturers. Elevation errors due to changes in the vehicles weight and tire pressure are negligible.

Beginning at the seawall terminus and heading west toward San Luis Pass, the seaward tire of the ATV tracked the wet/dry interface. Survey speed was 35 km hr $^{-1}$ in order to keep up with the progression of the tide; total survey time was 50 minutes. Each survey is a synoptic cusp to cusp “best fit line” due to required survey speed.

Figure 3. ATV mounted with post-processed differential kinematic GPS receiver and antenna.

Data Processing

The data for each survey were exported from the two receivers and post-processed to correct for acquisition error, then integrated into GIS where it was filtered. The processing shows vectors between the base station and the roving unit and the respective accuracies. The GPS files also contain position precision information which allows the examination of each data point for accuracy (Huang *et al*, 2002). This information is in the form of PDOP (Positional Dilution of Precision) and the value estimates the impact on the precision of the GPS observations due to satellite geometry (Magellan Corporation®, 2001). The data processing software utilized was Ashtec Solutions® (a commercial data post-processing application from Magellan Corporation). This package identifies any records with an unacceptable quality and rejects them from further treatment.

These filtered data sets were then exported into MATLAB® and analyzed using a custom script which generated a mean of the data points for the period under examination (i.e. monthly, quarterly, or annual). The wetline is not in the same geographic location for each survey; however, each survey begins at approximately the same position alongshore and is conducted at the same speed. Because data is gathered every second, the data points are spaced equally alongshore, but with differing eastings and northings. The MATLAB script groups data points by time interval (every second) alongshore and then calculates the mean for that "time interval" and partitions the positions into discrete geographic cells which are 9.8m long (figure 4). For each geographic cell, a Mean Cell Position (MCP) is calculated. For each MCP a best-fit line is generated using ArcMap® (GIS).

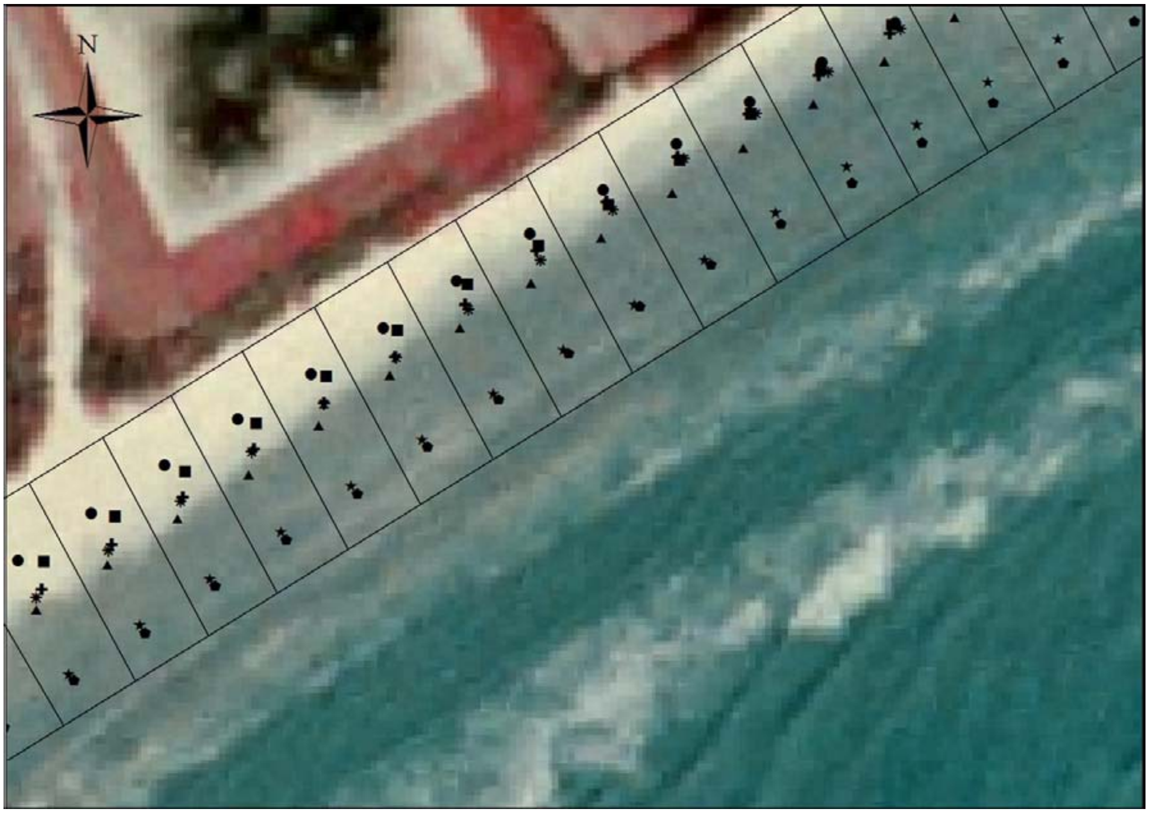

Figure 4. A GIS image showing discrete geographic cells which allow for a Mean Cell Position (MCP) to be calculated.

Because elevation and horizontal position of the wetline varies with the tidal cycle (Parker, 2003), each survey is not run on the same absolute position - all lines are offset from each other up and down the beach. Offsets were quantified from the mean of the period in question (e.g. 2nd quarter 2005) to the reference mean (e.g. 2nd quarter 2004) and were then exported to a database.

The quantification of offsets was conducted in ArcMap after the creation of polyline shapefiles using the MATLAB output of mean x and y points for the period of interest. An additional shapefile was created composed of a grid of shore- perpendicular lines spaced every 250m starting behind the back-beach dune and ending approximately 100m into the surf zone. This spacing was chosen due to time and labor considerations. These shore-perpendicular lines enable the measurement of offsets at the same position alongshore for any wetline of interest (figure 5).

After the importing of the shapefiles of the surveys under consideration, the reference line of interest is imported (for this project the baseline was the meanline of the second quarter of 2004). The measurement tool in ArcMap is used to measure the distance between the survey lines of interest and the reference line, as measured along the 250m spaced shore-perpendicular lines. The measurements are then transcribed into spreadsheets thereby enabling statistical analyses, the generation of graphs, models, and other analyses.

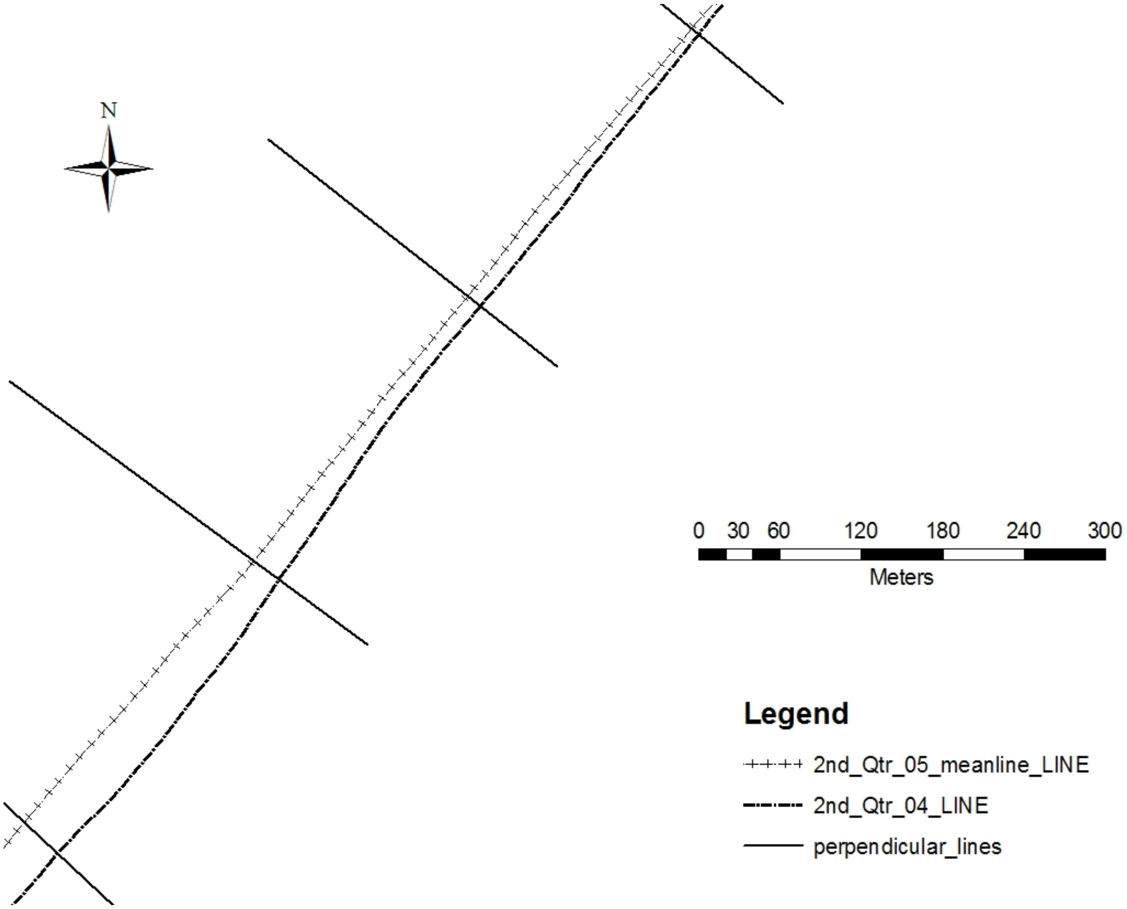

Figure 5. Illustration of shore-perpendicular lines used for the measurement of meanline (mean shoreline-line) offsets at the same alongshore position.

Statistical Analysis

A primary objective of this project was to identify erosional hotspots. Erosional hotspots are operationally defined here as areas where the wet line was consistently significantly landward of the baseline measurement (2^{nd} quarter 2004). At each of the 117 cells (see section on Data Processing), differences were calculated between the baseline and the wet line position measured in four subsequent quarters (3rd quarter ’04; 4th quarter ’04; 1st quarter ’05; and 2nd quarter ’05). To account for differences in tidal height and forcing between each quarterly survey, the overall mean was subtracted (centered the data) in each quarter; within each cell, the centered baseline value was subtracted from each of the centered values for the other quarters to calculate the movement (deviation) of the wet line. Therefore, negative values indicated that the wet line deviated seaward and positive values indicate a landward deviation.

At each of the 117 locations, the mean wet line deviation of the four quarterly surveys were tested to see if they were significantly different from zero (t-test, alpha=0.05), and hence consistently landward or seaward of the baseline (see APPENDIX A). Finally, the mean deviations of the wet line (in meters) were plotted with 95% confidence intervals in order to locate specific areas of the shoreline that were identified as hotspots.

RESULTS

Thirty-two surveys were conducted over a 15 month period. These data enabled quantification of shoreline migration rate (figure 6), and also the identification of 20 hotspot sites, 9 of which are erosional (figure 7). The mean annual erosion rate was 4.95m $^{-1}$ with a range of 59.83m (-23.86m to 36.04m); the median offset was 4.73m. The data indicate a tripartite division of shoreline migration rates: the highest rates of shoreline retreat are located at the extreme ends of the beach while the middle section is more stable and exhibits decreased rates of retreat.

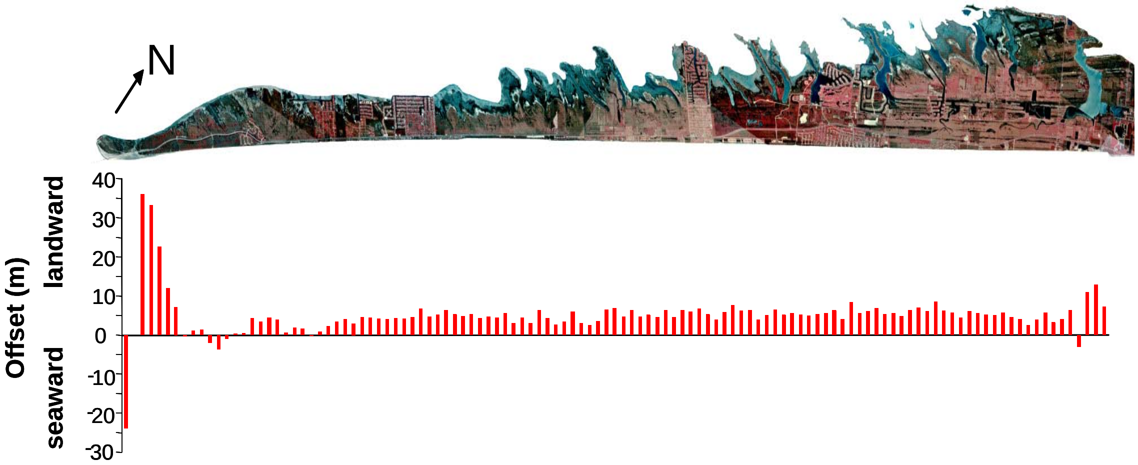

Figure 6. Graph showing quantitative offset of the 2nd Quarter 2005 meanline from the 2nd Quarter 2004 meanline. The data on the graph correspond to the alongshore position in the image shown above it.

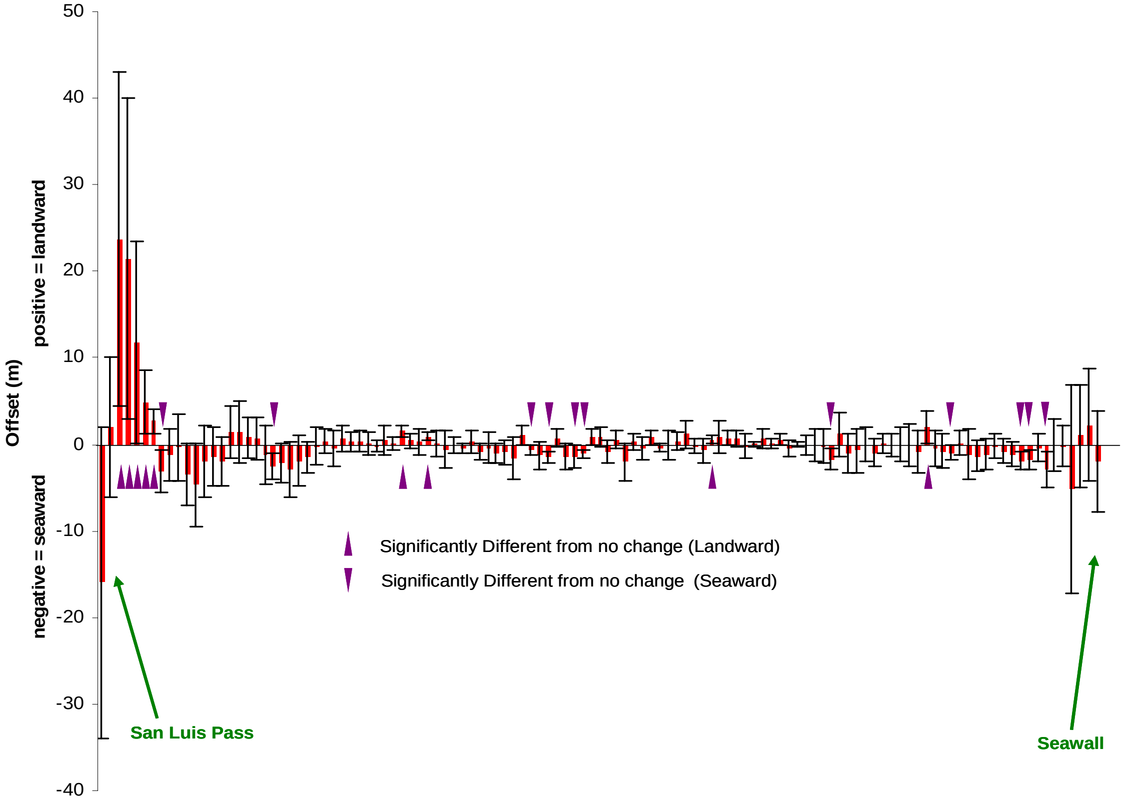

Figure 7. Graph showing the mean quarterly offsets for each alongshore position. Error bars indicate whether the offset is statistically significant (a hotspot).

The greatest variance (147.07m) occurred at very western end of the study area – an area which showed an oscillating trend of the shoreline marked by the greatest migration of the shoreline (figures 8 and 9). The easternmost zone displayed a continued erosional trend with a variance of approximating 15.00m. The mid-zone exhibited relatively small scale rates of erosion with an average variance of <1.00m.

DISCUSSION

During the period of this study there was considerable morphological alteration of the beach which was uniquely expressed through the weekly shoreline observations. Quantitative analysis of the wetline deviations from the 2nd quarter 2004 mean line to 2nd quarter 2005 mean line has enabled estimation of the rate of shoreline migration, position, and the identification of 20 hotspot sites, nine of which are erosional (table 1). The seawall terminus, though exhibiting a large relative erosion rate, is not an erosional hotspot under the operational definition in this paper.

During the duration of the study period, the study area exhibited a mean annual erosion rate of 4.95m $^{-1}$ which is considerably larger than the 3m y^{-1} commonly reported in literature (see Heinz Center, 2000), with a range of 59.83m (-23.86m to 36.04m); the median offset was 4.73m. The location of this extreme range was at the very western end of the study site, an area that is heavily influenced by tidal-pass dynamics.

Table 1. Analysis of hotspots including distance alongshore, type of hotspot, and anthropogenic features for that site.

Hotspot #	**Location** distance from seawall (m)	**Accretional** or **Erosional**	**Association**	**Statisticly significant value** ($\alpha < 0.05$)
1	1520	A	nourished	.0205
2	2020	A	-	.0149
3	2270	A	-	.0108
4	4270	A	nourished	.0316
5	5030	E	nourished	.0459
6	7870	A	nourished + geotube	.0181
7	11380	E	-	.0454
8	15240	A	-	.0063
9	15490	A	-	.0410
10	16260	A	nourished	.0077
11	16770	A	-	.0493
12	19820	E	nourished	.0116
13	20560	E	nourished	.0054
14	24250	A	nourished	.0126
15	27500	A	-	.0251
16	27750	E	-	.0090
17	28000	E	-	.0249
18	28250	E	-	.0499
19	28500	E	-	.0347
20	28750	E	-	.0297

Immediately prior to the commencement of this study there was a re-nourishment project conducted over much of the west end of Galveston. This involved the placement of 226,730 cubic yards of sand from Blackard Pit on FM3005 onto numerous beaches of the west end and was completed by October 2003 (Survey Galveston, Inc., personal communication). Due to the physical reworking of these nourished templates by wind and waves, it is likely that these nourished templates amplified the erosional signature for the study area.

The greatest variance occurred in the western zone of the study area, which showed a general oscillating trend marked by the greatest migration of the shoreline with significant erosion in particular areas. The lower elevation and beach slope, proximity to San Luis Pass (one of two natural tidal passes on the Texas coast), and the associated tidal pass dynamics likely explains these large scale changes in shoreline position. GIS ortho-rectified aerial photography from 1995 – 2003, in conjunction with the annual mean shoreline positions generated, enable visual representation and analysis of shoreline migration rates over time (Figures 8 and 9).

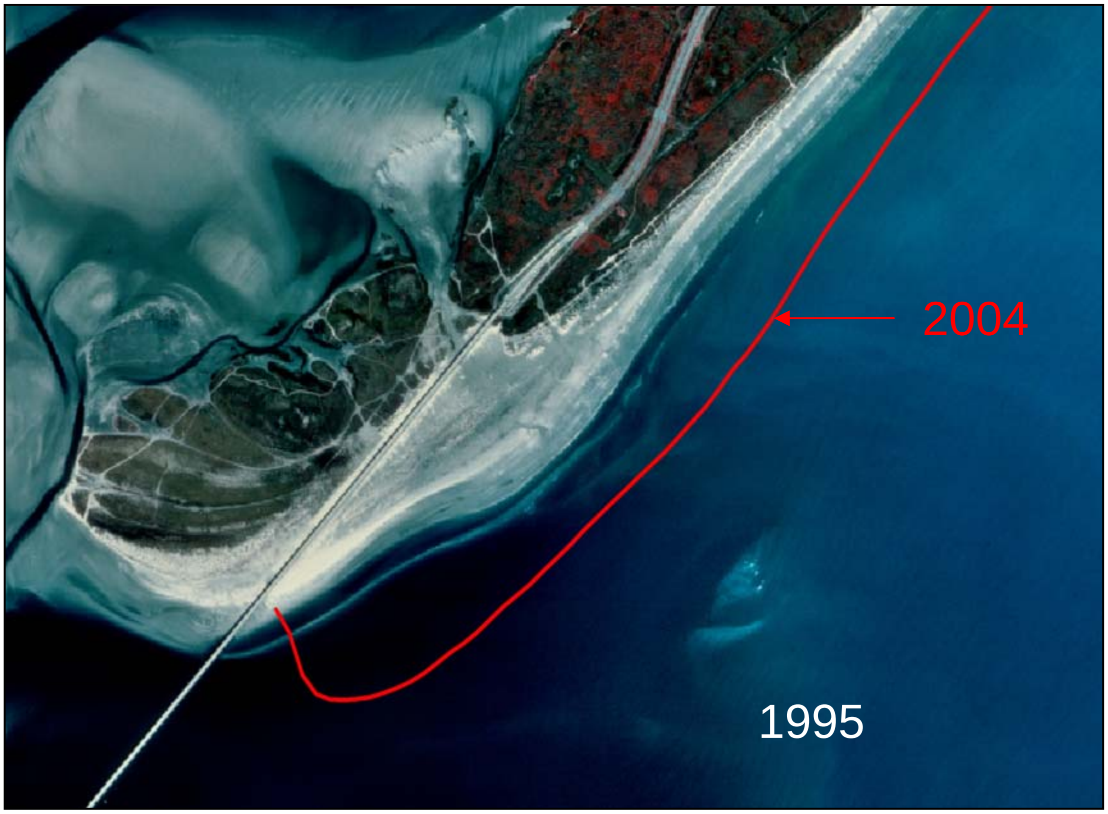

Figure 8. GIS illustration of shoreline migration from 1995-2004 at the western end of study area. 2004 meanline layered on 1995 Digital Ortho Quarter Quadrangle (DOQQ).

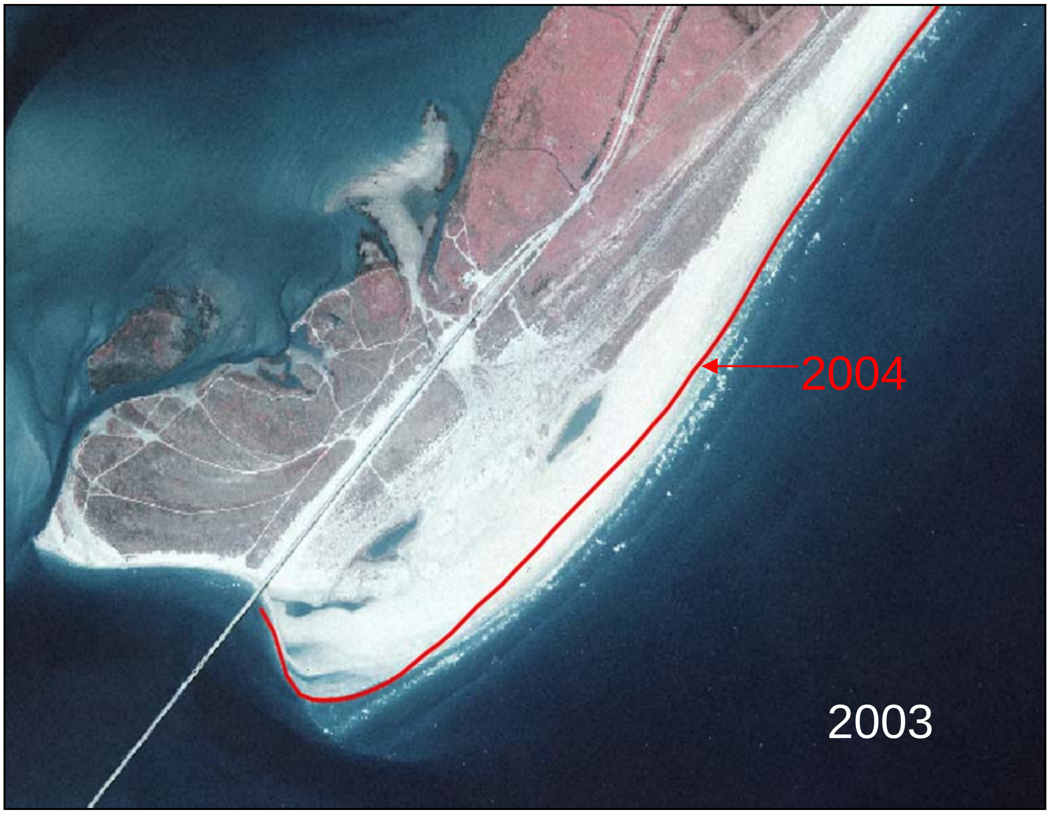

Figure 9. GIS illustration of shoreline migration from 2003-2004 at the western end of study area. 2004 meanline layered on 2003 DOQQ.

The easternmost zone displayed a continued erosional trend of generally uniform scale. The mid-zone exhibited relatively small scale rates of erosion. These results are similar to the decadal shoreline behavior observed in the late 1980’s and early 1990’s by Morton *et al*. (1995). This study’s results show significant spatial and temporal movements in the shoreline (figures 10, 11, and 12) and also the identification of statistically significant erosional hotspots; however, continued long-term data collection is needed to track and identify additional ephemeral erosional hotspots.

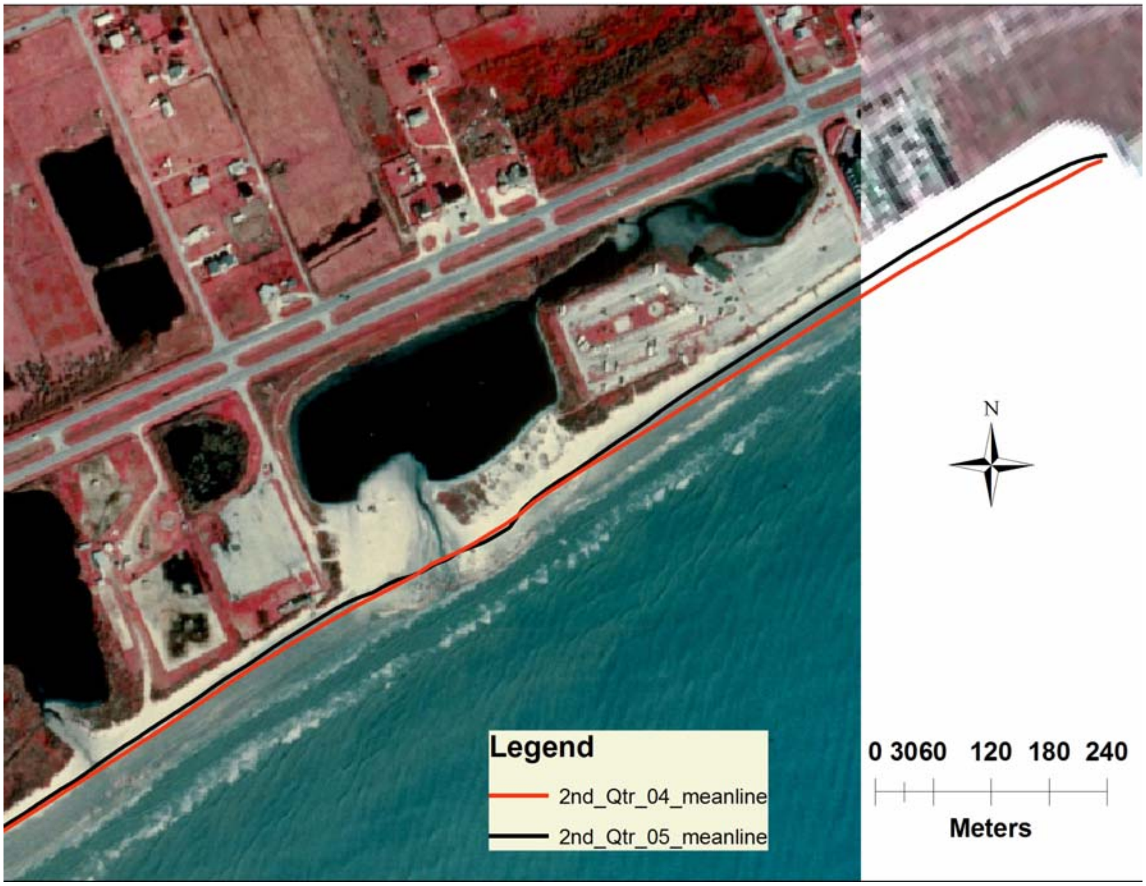

Figure 10. GIS image of shoreline migration at a representative section of the eastern zone of the study area from 2004 -2005.

Figure 11. GIS image of shoreline migration at a representative section of the middle zone of the study area from 2004 -2005.

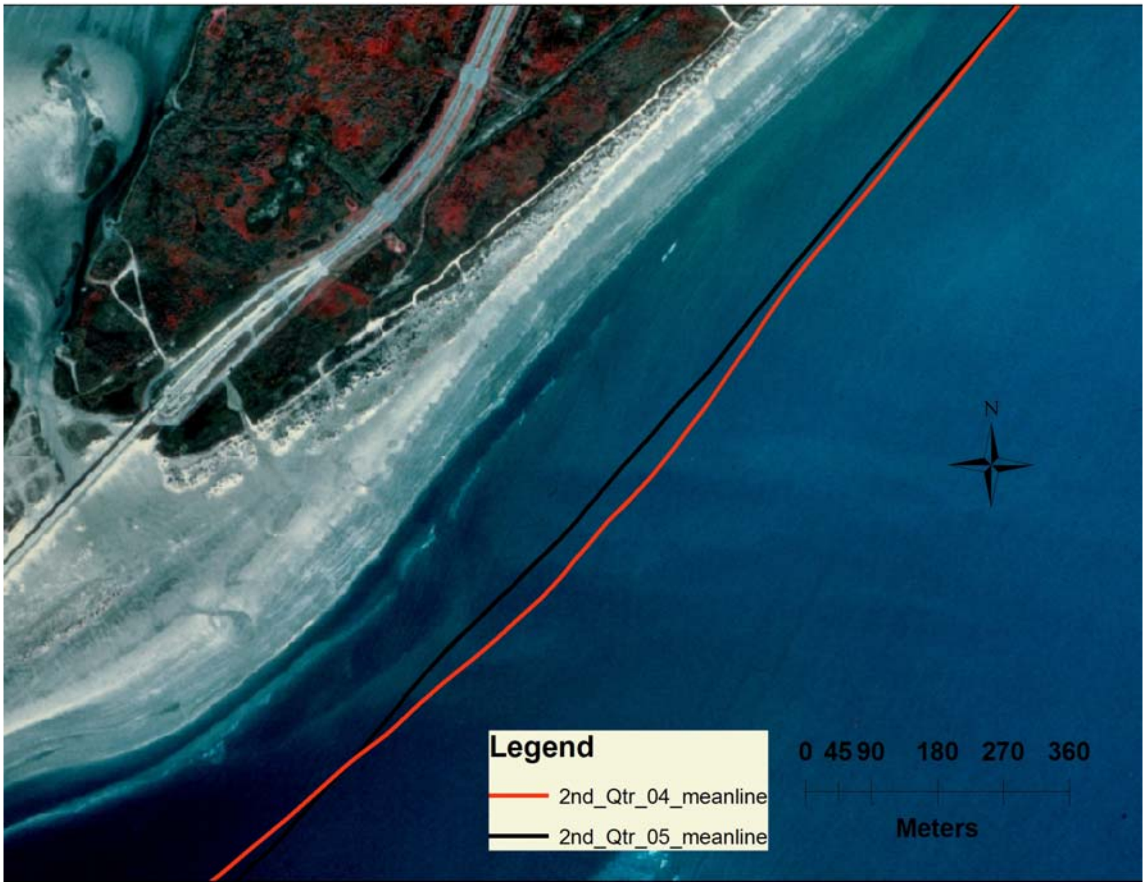

Figure 12. GIS image of shoreline migration at a representative section of the western zone of the study area from 2004 -2005.

Galveston Island's economy depends largely on the influx of tourism dollars, primarily as a result of its beaches. With the current boom in property development on the west end, the practice of beach nourishment as a "soft solution" for beach erosion mitigation, increased civic pressure to maintain beach access, and pending litigation and legislation, state, city and coastal managers are seeking relevant studies to enable sound enviro/socioeconomic decision making. The coastal management community uses scientific data in at least three ways: planning coastal communities, permitting and reviewing shoreline stabilization projects, and developing a conceptual understanding of the coastal system (Ruggiero *et al*. 2000). While this method was developed for Galveston Island's west end, it is easily adaptable to other locations.

The intent of this project was to develop a monitoring method to record and analyze coastal processes and shoreline responses to energy fluxes over temporal and spatial scales and to identify and predict erosional hotspots. This project shows that the wetline is *not* uniform in elevation, and that frequent synoptic surveys enable the averaging of short term and seasonal variations thereby establishing an accurate non-datum corrected shoreline position. Importantly, the identification of localized erosional hotspots is also achieved.

Comparison and analyses of quarterly mean lines showed that during the period of this study there has been considerable morphological alteration of the beach. These analyses also allowed for the identification of zones experiencing repeated relative advance/retreat of the shoreline and this is uniquely expressed in the weekly shoreline observations. Enhanced wave run-up may result in erosion (wetline advance landward), while reduction of wave run-up may result in accretion (wetline retreat seaward).

Since 1995, the first year of beach nourishment on Galveston Island (Ravens and Sitanggang, 2002), significant tax dollars have been spent in an effort to (1) locate and provide beach quality sand, (2) monitor the longevity and effectiveness of nourishment templates, and (3) identify and model the relocation of the nourished sand.

There are some limitations to the method, however, and these include: (1) obstructions along the wetline such as large debris, beachgoers, and vehicle barricades, (2) the inability to survey during periods of rain because there may be no discernable wetline, (3) accumulation of *Sargassum* seaweed along the wetline during the Spring and early Summer, which hides the true location of the wetline, (4) houses and sand-socks on the beach limit the landward advance of the wetline during spring tides and storm events, (5) beach nourishment projects likely impact the magnitude of the shoreline migration signal, and (6) only sub-aerial portions of the coastal zone are monitored, exempting the significantly active sub-aqueous zone.

It is an underlying assumption of this project, however, that the sub-aqueous zone alterations will be directly represented in shoreline fluctuation. Consequently, the costly acquisition of data from this zone is unnecessary. Additionally, this alongshore monitoring method provides an important advantage over traditional beach surveying methods in the greater spatial coverage that can be achieved by running continuous data collection in parallel survey lines along the beachface. The alongshore method will be minimal in both cost and survey time, adaptable and transferable to other locations on the Texas coast, and sufficiently precise (sub decimeter).

CONCLUSIONS

Beginning April 2004 through September 2005, thirty-two synoptic surveys were conducted along the wetline of Galveston Island's west-end. Quantification of the shoreline deviations during this study clearly show that the beach is undergoing considerable shoreline retreat. This paper presents successful identification of the shoreline position and erosional hotspots utilizing an alongshore post-processed kinematic GPS monitoring method. The data collection technique is accurate, rapid, repeatable, economical, and transferable to many locations. The method eliminates the problem of a "snapshot in time" analysis of shoreline position, removes the need for data to be corrected to a vertical datum, and also averages out short term variations in the signal.

Archiving and analyses of these short-term changes will provide a long time-series of shoreline position and behavior. This will be used to strengthen existing and future models of shoreline change and will also project future coastal change. Further analyses such as month-to-month or quarter-to-quarter could also be useful in analyzing the morphological behavior of Galveston's west-end. Incorporation of this monitoring method with existing data enables the opportunity of scientifically-based sound management. It also provides utility for the complex task of state and local coastal planning and decision making. The 15 months of data from this study indicates that this method of shoreline monitoring is indeed viable, enabling stakeholders to utilize the results as another tool in their deliberations.

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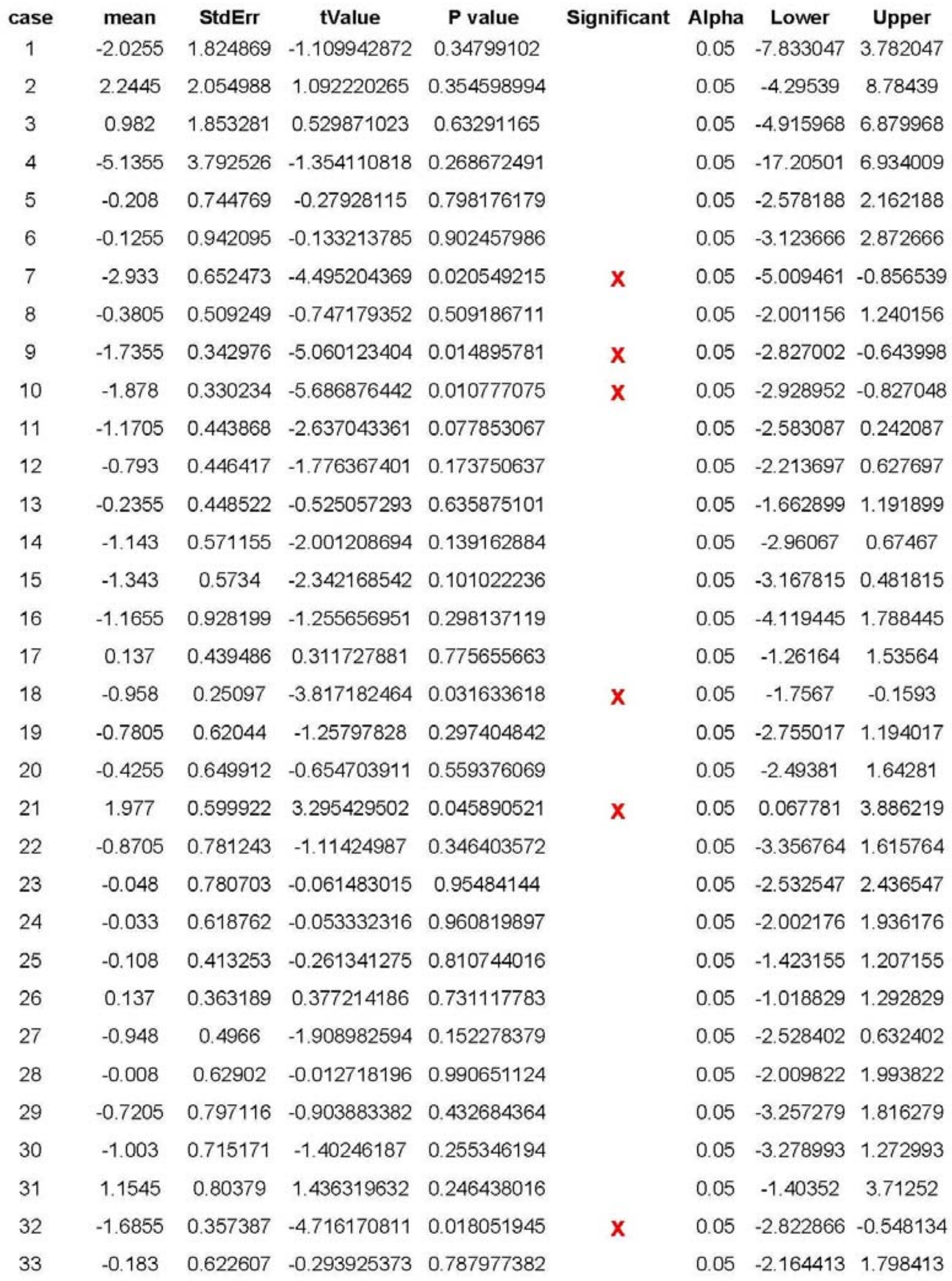
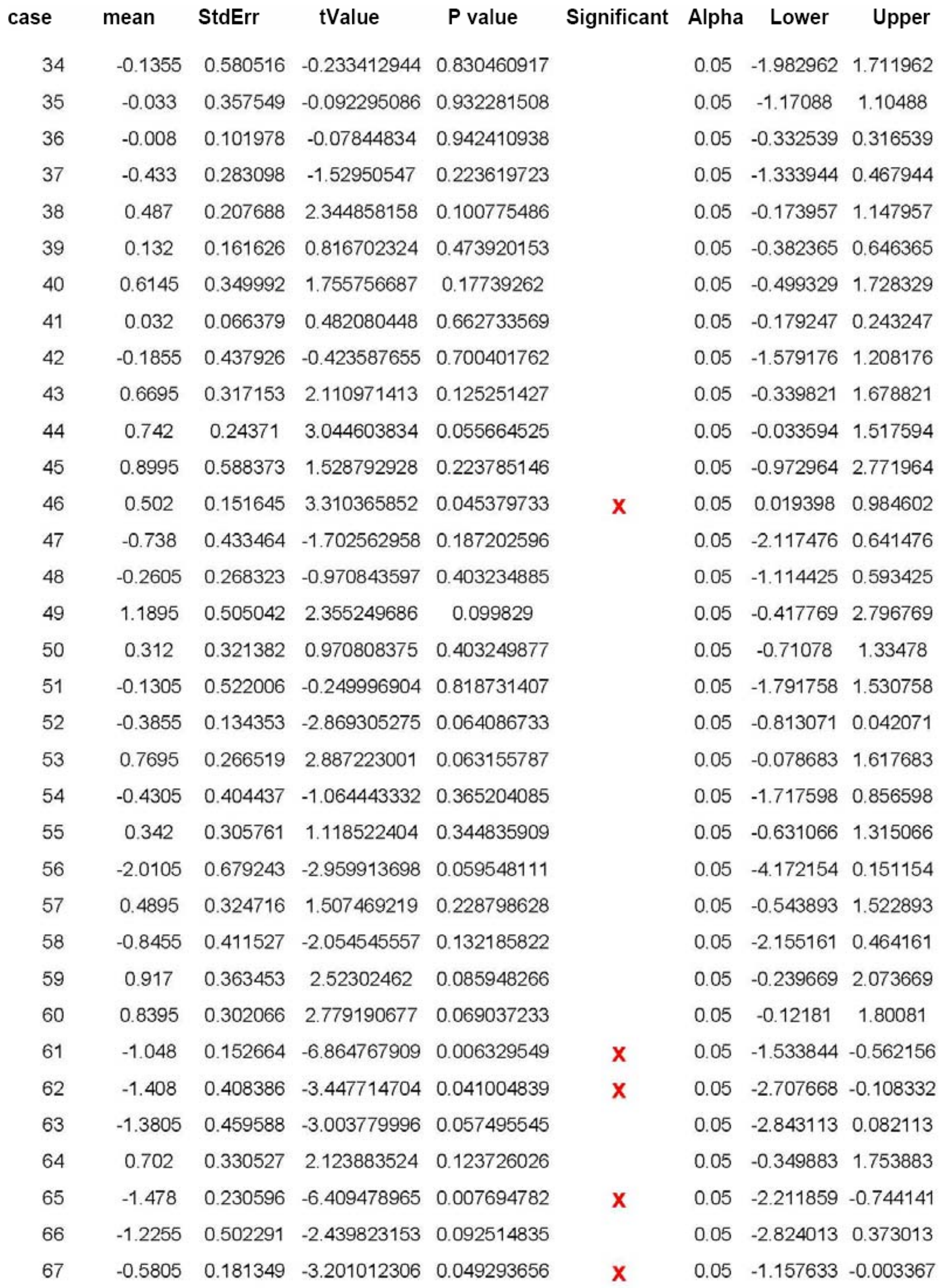
APPENDIX A

A-1.

Results of t-test and identification of hotspots.



case	mean	StdErr	tValue	P value	Significant	Alpha	Lower	Upper
1	-2.0255	1.824869	-1.109942872	0.34799102		0.05	-7.833047	3.782047
2	2.2445	2.054988	1.092220265	0.354598994		0.05	-4.29539	8.78439
3	0.982	1.853281	0.529871023	0.63291165		0.05	-4.915968	6.879968
4	-5.1355	3.792526	-1.354110818	0.268672491		0.05	-17.20501	6.934009
5	-0.208	0.744769	-0.27928115	0.798176179		0.05	-2.578188	2.162188
6	-0.1255	0.942095	-0.133213785	0.902457986		0.05	-3.123666	2.872666
7	-2.933	0.652473	-4.495204369	0.020549215	x	0.05	-5.009461	-0.856539
8	-0.3805	0.509249	-0.747179352	0.509186711		0.05	-2.001156	1.240156
9	-1.7355	0.342976	-5.060123404	0.014895781	x	0.05	-2.827002	-0.643998
10	-1.878	0.330234	-5.686876442	0.010777075	x	0.05	-2.928952	-0.827048
11	-1.1705	0.443868	-2.637043361	0.077853067		0.05	-2.583087	0.242087
12	-0.793	0.446417	-1.776367401	0.173750637		0.05	-2.213697	0.627697
13	-0.2355	0.448522	-0.525057293	0.635875101		0.05	-1.662899	1.191899
14	-1.143	0.571155	-2.001208694	0.139162884		0.05	-2.96067	0.67467
15	-1.343	0.5734	-2.342168542	0.101022236		0.05	-3.167815	0.481815
16	-1.1655	0.928199	-1.255656951	0.298137119		0.05	-4.119445	1.788445
17	0.137	0.439486	0.311727881	0.775655663		0.05	-1.26164	1.53564
18	-0.958	0.25097	-3.817182464	0.031633618	x	0.05	-1.7567	-0.1593
19	-0.7805	0.62044	-1.25797828	0.297404842		0.05	-2.755017	1.194017
20	-0.4255	0.649912	-0.654703911	0.559376069		0.05	-2.49381	1.64281
21	1.977	0.599922	3.295429502	0.045890521	x	0.05	0.067781	3.886219
22	-0.8705	0.781243	-1.11424987	0.346403572		0.05	-3.356764	1.615764
23	-0.048	0.780703	-0.061483015	0.95484144		0.05	-2.532547	2.436547
24	-0.033	0.618762	-0.053332316	0.960819897		0.05	-2.002176	1.936176
25	-0.108	0.413253	-0.261341275	0.810744016		0.05	-1.423155	1.207155
26	0.137	0.363189	0.377214186	0.731117783		0.05	-1.018829	1.292829
27	-0.948	0.4966	-1.908982594	0.152278379		0.05	-2.528402	0.632402
28	-0.008	0.62902	-0.012718196	0.990651124		0.05	-2.009822	1.993822
29	-0.7205	0.797116	-0.903883382	0.432684364		0.05	-3.257279	1.816279
30	-1.003	0.715171	-1.40246187	0.255346194		0.05	-3.278993	1.272993
31	1.1545	0.80379	1.436319632	0.246438016		0.05	-1.40352	3.71252
32	-1.6855	0.357387	-4.716170811	0.018051945	x	0.05	-2.822866	-0.548134
33	-0.183	0.622607	-0.293925373	0.787977382		0.05	-2.164413	1.798413



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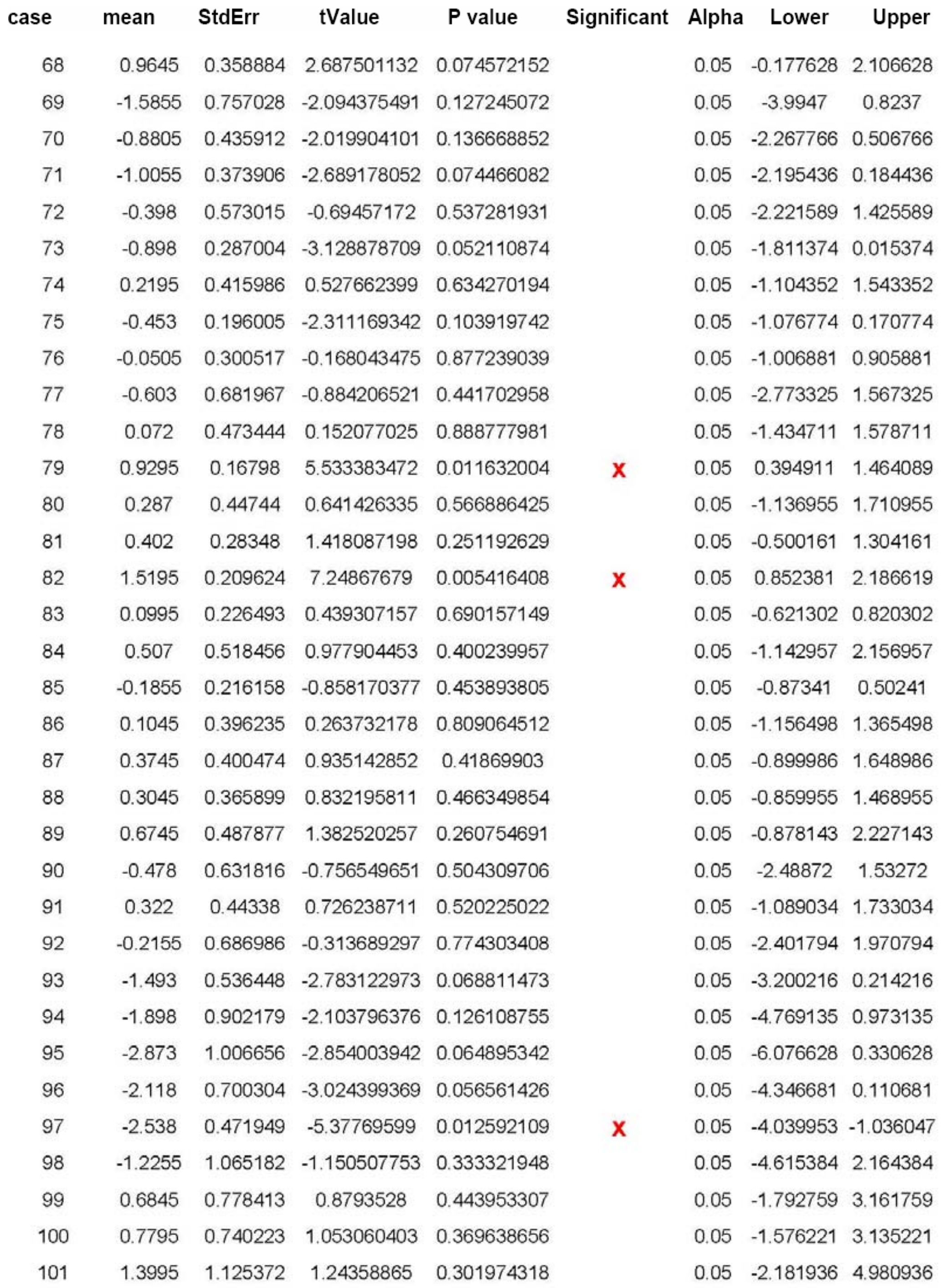
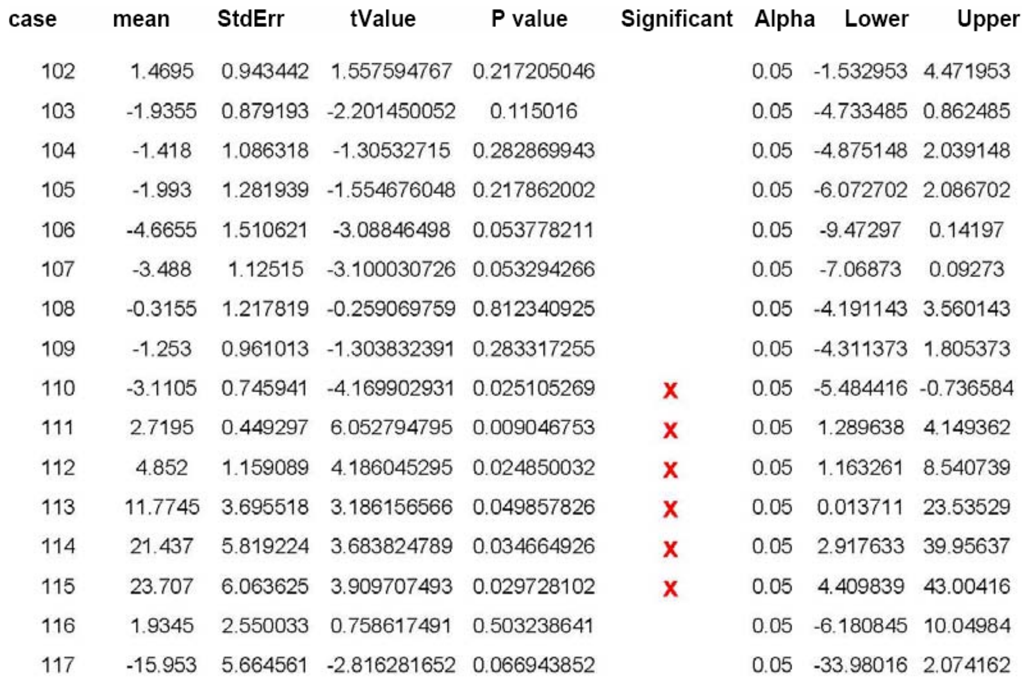
35	-0.033	0.357549	-0.092295086	0.932281508		0.05	-1.17088	1.10488
36	-0.008	0.101978	-0.07844834	0.942410938		0.05	-0.332539	0.316539
37	-0.433	0.283098	-1.52950547	0.223619723		0.05	-1.333944	0.467944
38	0.487	0.207688	2.344858158	0.100775486		0.05	-0.173957	1.147957
39	0.132	0.161626	0.816702324	0.473920153		0.05	-0.382365	0.646365
40	0.6145	0.349992	1.755756687	0.17739262		0.05	-0.499329	1.728329
41	0.032	0.066379	0.482080448	0.662733569		0.05	-0.179247	0.243247
42	-0.1855	0.437926	-0.423587655	0.700401762		0.05	-1.579176	1.208176
43	0.6695	0.317153	2.110971413	0.125251427		0.05	-0.339821	1.678821
44	0.742	0.24371	3.044603834	0.055664525		0.05	-0.033594	1.517594
45	0.8995	0.588373	1.528792928	0.223785146		0.05	-0.972964	2.771964
46	0.502	0.151645	3.310365852	0.045379733	x	0.05	0.019398	0.984602
47	-0.738	0.433464	-1.702562958	0.187202596		0.05	-2.117476	0.641476
48	-0.2605	0.268323	-0.970843597	0.403234885		0.05	-1.114425	0.593425
49	1.1895	0.505042	2.355249686	0.099829		0.05	-0.417769	2.796769
50	0.312	0.321382	0.970808375	0.403249877		0.05	-0.71078	1.33478
51	-0.1305	0.522006	-0.249996904	0.818731407		0.05	-1.791758	1.530758
52	-0.3855	0.134353	-2.869305275	0.064086733		0.05	-0.813071	0.042071
53	0.7695	0.266519	2.887223001	0.063155787		0.05	-0.078683	1.617683
54	-0.4305	0.404437	-1.064443332	0.365204085		0.05	-1.717598	0.856598
55	0.342	0.305761	1.118522404	0.344835909		0.05	-0.631066	1.315066
56	-2.0105	0.679243	-2.959913698	0.059548111		0.05	-4.172154	0.151154
57	0.4895	0.324716	1.507469219	0.228798628		0.05	-0.543893	1.522893
58	-0.8455	0.411527	-2.054545557	0.132185822		0.05	-2.155161	0.464161
59	0.917	0.363453	2.52302462	0.085948266		0.05	-0.239669	2.073669
60	0.8395	0.302066	2.779190677	0.069037233		0.05	-0.12181	1.80081
61	-1.048	0.152664	-6.864767909	0.006329549	x	0.05	-1.533844	-0.562156
62	-1.408	0.408386	-3.447714704	0.041004839	x	0.05	-2.707668	-0.108332
63	-1.3805	0.459588	-3.003779996	0.057495545		0.05	-2.843113	0.082113
64	0.702	0.330527	2.123883524	0.123726026		0.05	-0.349883	1.753883
65	-1.478	0.230596	-6.409478965	0.007694782	x	0.05	-2.211859	-0.744141
66	-1.2255	0.502291	-2.439823153	0.092514835		0.05	-2.824013	0.373013
67	-0.5805	0.181349	-3.201012306	0.049293656	x	0.05	-1.157633	-0.003367



case	mean	StdErr	tValue	P value	Significant	Alpha	Lower	Upper
68	0.9645	0.358884	2.687501132	0.074572152		0.05	-0.177628	2.106628
69	-1.5855	0.757028	-2.094375491	0.127245072		0.05	-3.9947	0.8237
70	-0.8805	0.435912	-2.019904101	0.136668852		0.05	-2.267766	0.506766
71	-1.0055	0.373906	-2.689178052	0.074466082		0.05	-2.195436	0.184436
72	-0.398	0.573015	-0.69457172	0.537281931		0.05	-2.221589	1.425589
73	-0.898	0.287004	-3.128878709	0.052110874		0.05	-1.811374	0.015374
74	0.2195	0.415986	0.527662399	0.634270194		0.05	-1.104352	1.543352
75	-0.453	0.196005	-2.311169342	0.103919742		0.05	-1.076774	0.170774
76	-0.0505	0.300517	-0.168043475	0.877239039		0.05	-1.006881	0.905881
77	-0.603	0.681967	-0.884206521	0.441702958		0.05	-2.773325	1.567325
78	0.072	0.473444	0.152077025	0.888777981		0.05	-1.434711	1.578711
79	0.9295	0.16798	5.533383472	0.011632004	x	0.05	0.394911	1.464089
80	0.287	0.44744	0.641426335	0.566886425		0.05	-1.136955	1.710955
81	0.402	0.28348	1.418087198	0.251192629		0.05	-0.500161	1.304161
82	1.5195	0.209624	7.24867679	0.005416408	x	0.05	0.852381	2.186619
83	0.0995	0.226493	0.439307157	0.690157149		0.05	-0.621302	0.820302
84	0.507	0.518456	0.977904453	0.400239957		0.05	-1.142957	2.156957
85	-0.1855	0.216158	-0.858170377	0.453893805		0.05	-0.87341	0.50241
86	0.1045	0.396235	0.263732178	0.809064512		0.05	-1.156498	1.365498
87	0.3745	0.400474	0.935142852	0.41869903		0.05	-0.899986	1.648986
88	0.3045	0.365899	0.832195811	0.466349854		0.05	-0.859955	1.468955
89	0.6745	0.487877	1.382520257	0.260754691		0.05	-0.878143	2.227143
90	-0.478	0.631816	-0.756549651	0.504309706		0.05	-2.48872	1.53272
91	0.322	0.44338	0.726238711	0.520225022		0.05	-1.089034	1.733034
92	-0.2155	0.686986	-0.313689297	0.774303408		0.05	-2.401794	1.970794
93	-1.493	0.536448	-2.783122973	0.068811473		0.05	-3.200216	0.214216
94	-1.898	0.902179	-2.103796376	0.126108755		0.05	-4.769135	0.973135
95	-2.873	1.006656	-2.854003942	0.064895342		0.05	-6.076628	0.330628
96	-2.118	0.700304	-3.024399369	0.056561426		0.05	-4.346681	0.110681
97	-2.538	0.471949	-5.37769599	0.012592109	x	0.05	-4.039953	-1.036047
98	-1.2255	1.065182	-1.150507753	0.333321948		0.05	-4.615384	2.164384
99	0.6845	0.778413	0.8793528	0.443953307		0.05	-1.792759	3.161759
100	0.7795	0.740223	1.053060403	0.369638656		0.05	-1.576221	3.135221
101	1.3995	1.125372	1.24358865	0.301974318		0.05	-2.181936	4.980936



case	mean	StdErr	tValue	P value	Significant	Alpha	Lower	Upper
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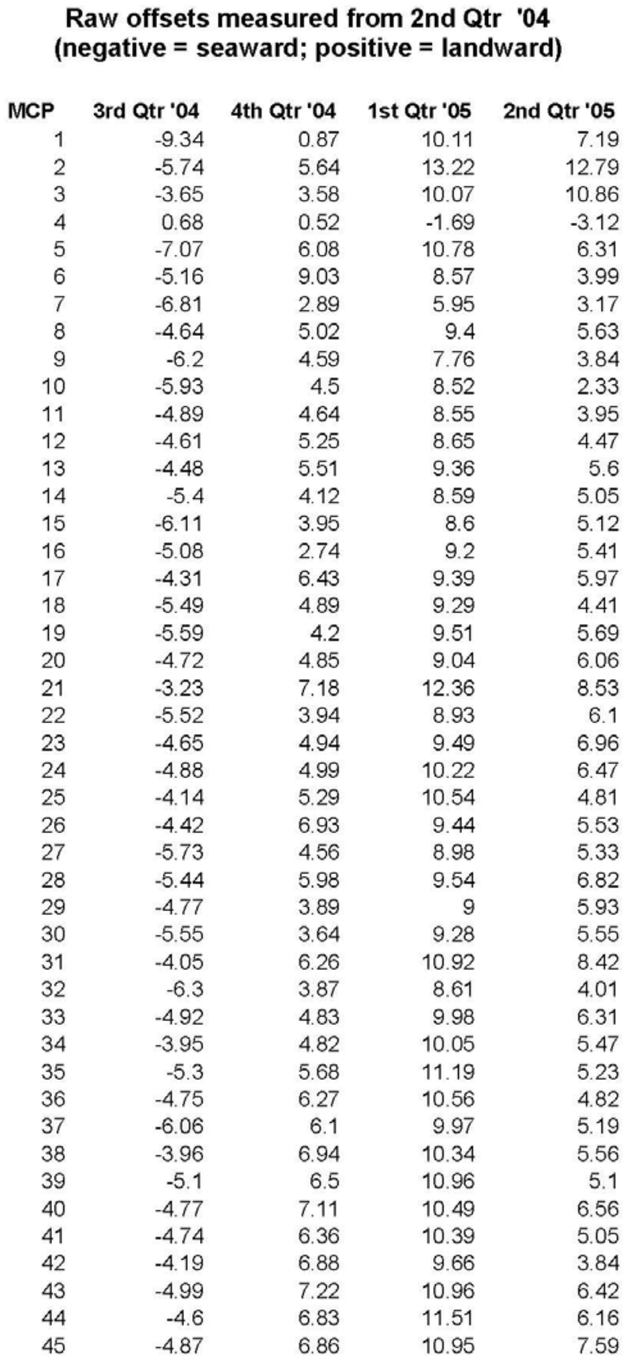
103	-1.9355	0.879193	-2.201450052	0.115016		0.05	-4.733485	0.862485
104	-1.418	1.086318	-1.30532715	0.282869943		0.05	-4.875148	2.039148
105	-1.993	1.281939	-1.554676048	0.217862002		0.05	-6.072702	2.086702
106	-4.6655	1.510621	-3.08846498	0.053778211		0.05	-9.47297	0.14197
107	-3.488	1.12515	-3.100030726	0.053294266		0.05	-7.06873	0.09273
108	-0.3155	1.217819	-0.259069759	0.812340925		0.05	-4.191143	3.560143
109	-1.253	0.961013	-1.303832391	0.283317255		0.05	-4.311373	1.805373
110	-3.1105	0.745941	-4.169902931	0.025105269	x	0.05	-5.484416	-0.736584
111	2.7195	0.449297	6.052794795	0.009046753	x	0.05	1.289638	4.149362
112	4.852	1.159089	4.186045295	0.024850032	x	0.05	1.163261	8.540739
113	11.7745	3.695518	3.186156566	0.049857826	x	0.05	0.013711	23.53529
114	21.437	5.819224	3.683824789	0.034664926	x	0.05	2.917633	39.95637
115	23.707	6.063625	3.909707493	0.029728102	x	0.05	4.409839	43.00416
116	1.9345	2.550033	0.758617491	0.503238641		0.05	-6.180845	10.04984
117	-15.953	5.664561	-2.816281652	0.066943852		0.05	-33.98016	2.074162

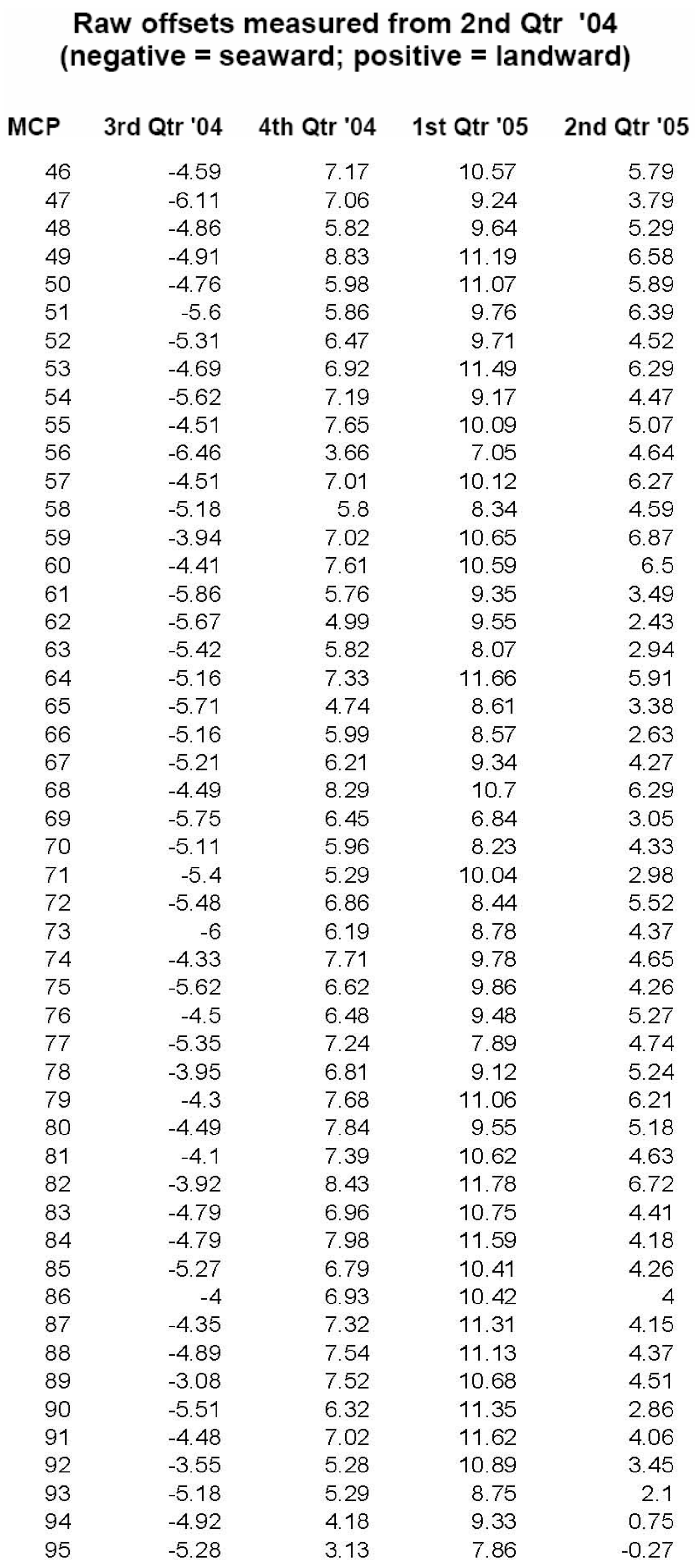
A-2.

Raw offset data for each quarter's MCP.



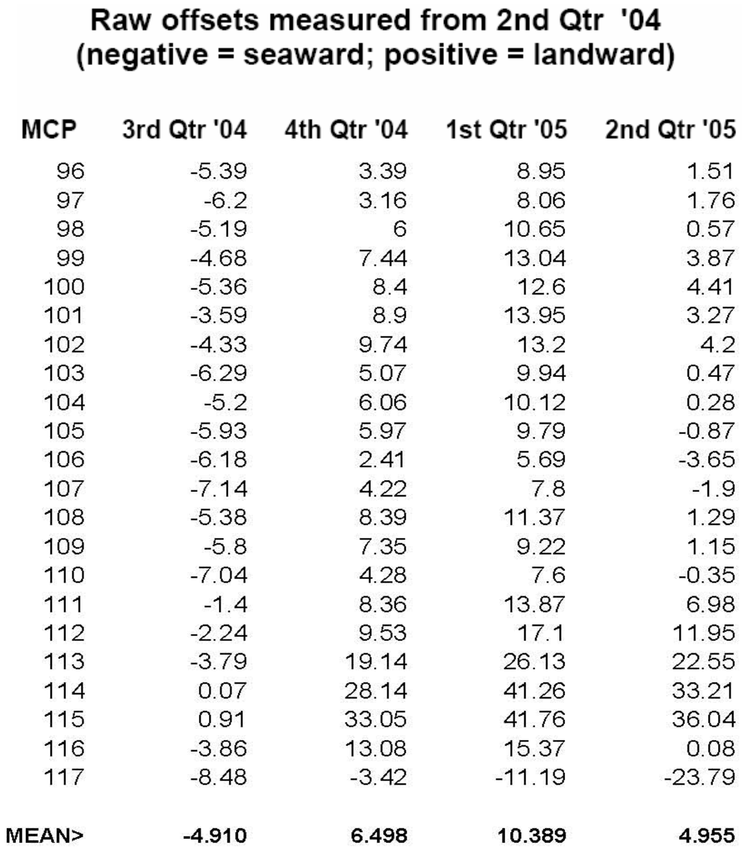
Raw offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
1	-9.34	0.87	10.11	7.19
2	-5.74	5.64	13.22	12.79
3	-3.65	3.58	10.07	10.86
4	0.68	0.52	-1.69	-3.12
5	-7.07	6.08	10.78	6.31
6	-5.16	9.03	8.57	3.99
7	-6.81	2.89	5.95	3.17
8	-4.64	5.02	9.4	5.63
9	-6.2	4.59	7.76	3.84
10	-5.93	4.5	8.52	2.33
11	-4.89	4.64	8.55	3.95
12	-4.61	5.25	8.65	4.47
13	-4.48	5.51	9.36	5.6
14	-5.4	4.12	8.59	5.05
15	-6.11	3.95	8.6	5.12
16	-5.08	2.74	9.2	5.41
17	-4.31	6.43	9.39	5.97
18	-5.49	4.89	9.29	4.41
19	-5.59	4.2	9.51	5.69
20	-4.72	4.85	9.04	6.06
21	-3.23	7.18	12.36	8.53
22	-5.52	3.94	8.93	6.1
23	-4.65	4.94	9.49	6.96
24	-4.88	4.99	10.22	6.47
25	-4.14	5.29	10.54	4.81
26	-4.42	6.93	9.44	5.53
27	-5.73	4.56	8.98	5.33
28	-5.44	5.98	9.54	6.82
29	-4.77	3.89	9	5.93
30	-5.55	3.64	9.28	5.55
31	-4.05	6.26	10.92	8.42
32	-6.3	3.87	8.61	4.01
33	-4.92	4.83	9.98	6.31
34	-3.95	4.82	10.05	5.47
35	-5.3	5.68	11.19	5.23
36	-4.75	6.27	10.56	4.82
37	-6.06	6.1	9.97	5.19
38	-3.96	6.94	10.34	5.56
39	-5.1	6.5	10.96	5.1
40	-4.77	7.11	10.49	6.56
41	-4.74	6.36	10.39	5.05
42	-4.19	6.88	9.66	3.84
43	-4.99	7.22	10.96	6.42
44	-4.6	6.83	11.51	6.16
45	-4.87	6.86	10.95	7.59



Raw offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
46	-4.59	7.17	10.57	5.79
47	-6.11	7.06	9.24	3.79
48	-4.86	5.82	9.64	5.29
49	-4.91	8.83	11.19	6.58
50	-4.76	5.98	11.07	5.89
51	-5.6	5.86	9.76	6.39
52	-5.31	6.47	9.71	4.52
53	-4.69	6.92	11.49	6.29
54	-5.62	7.19	9.17	4.47
55	-4.51	7.65	10.09	5.07
56	-6.46	3.66	7.05	4.64
57	-4.51	7.01	10.12	6.27
58	-5.18	5.8	8.34	4.59
59	-3.94	7.02	10.65	6.87
60	-4.41	7.61	10.59	6.5
61	-5.86	5.76	9.35	3.49
62	-5.67	4.99	9.55	2.43
63	-5.42	5.82	8.07	2.94
64	-5.16	7.33	11.66	5.91
65	-5.71	4.74	8.61	3.38
66	-5.16	5.99	8.57	2.63
67	-5.21	6.21	9.34	4.27
68	-4.49	8.29	10.7	6.29
69	-5.75	6.45	6.84	3.05
70	-5.11	5.96	8.23	4.33
71	-5.4	5.29	10.04	2.98
72	-5.48	6.86	8.44	5.52
73	-6	6.19	8.78	4.37
74	-4.33	7.71	9.78	4.65
75	-5.62	6.62	9.86	4.26
76	-4.5	6.48	9.48	5.27
77	-5.35	7.24	7.89	4.74
78	-3.95	6.81	9.12	5.24
79	-4.3	7.68	11.06	6.21
80	-4.49	7.84	9.55	5.18
81	-4.1	7.39	10.62	4.63
82	-3.92	8.43	11.78	6.72
83	-4.79	6.96	10.75	4.41
84	-4.79	7.98	11.59	4.18
85	-5.27	6.79	10.41	4.26
86	-4	6.93	10.42	4
87	-4.35	7.32	11.31	4.15
88	-4.89	7.54	11.13	4.37
89	-3.08	7.52	10.68	4.51
90	-5.51	6.32	11.35	2.86
91	-4.48	7.02	11.62	4.06
92	-3.55	5.28	10.89	3.45
93	-5.18	5.29	8.75	2.1
94	-4.92	4.18	9.33	0.75
95	-5.28	3.13	7.86	-0.27

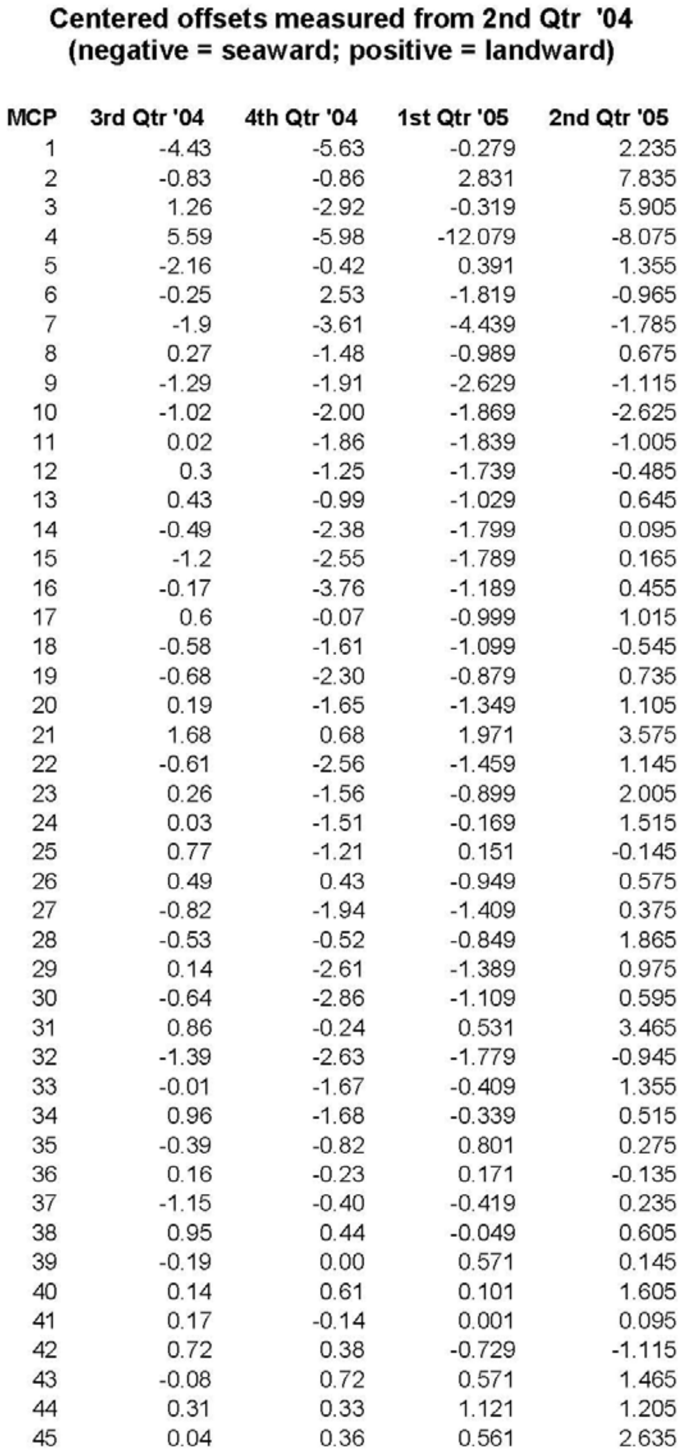


Raw offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
96	-5.39	3.39	8.95	1.51
97	-6.2	3.16	8.06	1.76
98	-5.19	6	10.65	0.57
99	-4.68	7.44	13.04	3.87
100	-5.36	8.4	12.6	4.41
101	-3.59	8.9	13.95	3.27
102	-4.33	9.74	13.2	4.2
103	-6.29	5.07	9.94	0.47
104	-5.2	6.06	10.12	0.28
105	-5.93	5.97	9.79	-0.87
106	-6.18	2.41	5.69	-3.65
107	-7.14	4.22	7.8	-1.9
108	-5.38	8.39	11.37	1.29
109	-5.8	7.35	9.22	1.15
110	-7.04	4.28	7.6	-0.35
111	-1.4	8.36	13.87	6.98
112	-2.24	9.53	17.1	11.95
113	-3.79	19.14	26.13	22.55
114	0.07	28.14	41.26	33.21
115	0.91	33.05	41.76	36.04
116	-3.86	13.08	15.37	0.08
117	-8.48	-3.42	-11.19	-23.79
MEAN>	**-4.910**	**6.498**	**10.389**	**4.955**

A-3.

Centered offset data for each quarter's MCP.

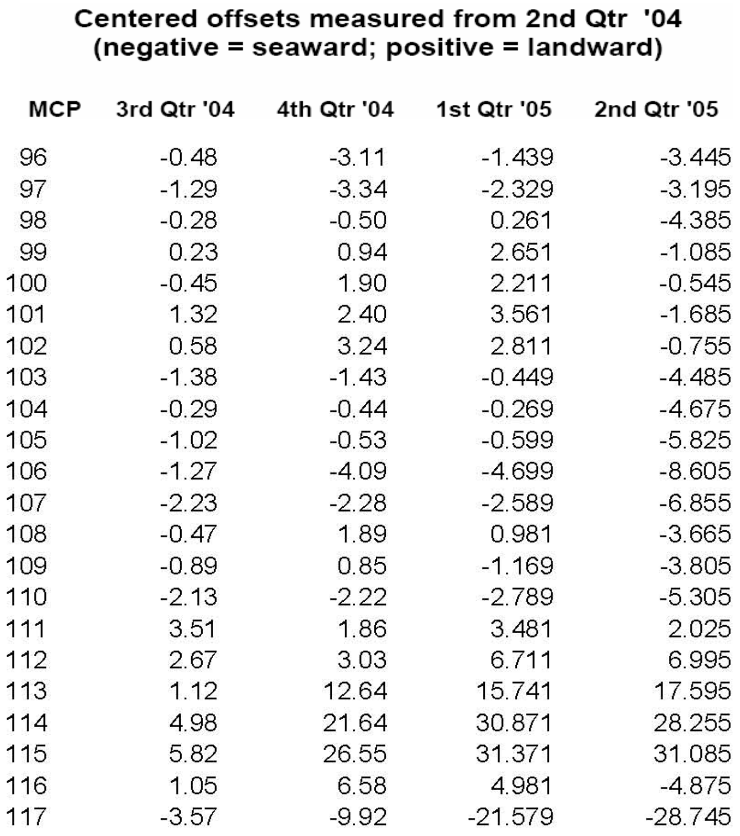


Centered offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
1	-4.43	-5.63	-0.279	2.235
2	-0.83	-0.86	2.831	7.835
3	1.26	-2.92	-0.319	5.905
4	5.59	-5.98	-12.079	-8.075
5	-2.16	-0.42	0.391	1.355
6	-0.25	2.53	-1.819	-0.965
7	-1.9	-3.61	-4.439	-1.785
8	0.27	-1.48	-0.989	0.675
9	-1.29	-1.91	-2.629	-1.115
10	-1.02	-2.00	-1.869	-2.625
11	0.02	-1.86	-1.839	-1.005
12	0.3	-1.25	-1.739	-0.485
13	0.43	-0.99	-1.029	0.645
14	-0.49	-2.38	-1.799	0.095
15	-1.2	-2.55	-1.789	0.165
16	-0.17	-3.76	-1.189	0.455
17	0.6	-0.07	-0.999	1.015
18	-0.58	-1.61	-1.099	-0.545
19	-0.68	-2.30	-0.879	0.735
20	0.19	-1.65	-1.349	1.105
21	1.68	0.68	1.971	3.575
22	-0.61	-2.56	-1.459	1.145
23	0.26	-1.56	-0.899	2.005
24	0.03	-1.51	-0.169	1.515
25	0.77	-1.21	0.151	-0.145
26	0.49	0.43	-0.949	0.575
27	-0.82	-1.94	-1.409	0.375
28	-0.53	-0.52	-0.849	1.865
29	0.14	-2.61	-1.389	0.975
30	-0.64	-2.86	-1.109	0.595
31	0.86	-0.24	0.531	3.465
32	-1.39	-2.63	-1.779	-0.945
33	-0.01	-1.67	-0.409	1.355
34	0.96	-1.68	-0.339	0.515
35	-0.39	-0.82	0.801	0.275
36	0.16	-0.23	0.171	-0.135
37	-1.15	-0.40	-0.419	0.235
38	0.95	0.44	-0.049	0.605
39	-0.19	0.00	0.571	0.145
40	0.14	0.61	0.101	1.605
41	0.17	-0.14	0.001	0.095
42	0.72	0.38	-0.729	-1.115
43	-0.08	0.72	0.571	1.465
44	0.31	0.33	1.121	1.205
45	0.04	0.36	0.561	2.635

Centered offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
46	0.32	0.67	0.181	0.835
47	-1.2	0.56	-1.149	-1.165
48	0.05	-0.68	-0.749	0.335
49	0	2.33	0.801	1.625
50	0.15	-0.52	0.681	0.935
51	-0.69	-0.64	-0.629	1.435
52	-0.4	-0.03	-0.679	-0.435
53	0.22	0.42	1.101	1.335
54	-0.71	0.69	-1.219	-0.485
55	0.4	1.15	-0.299	0.115
56	-1.55	-2.84	-3.339	-0.315
57	0.4	0.51	-0.269	1.315
58	-0.27	-0.70	-2.049	-0.365
59	0.97	0.52	0.261	1.915
60	0.5	1.11	0.201	1.545
61	-0.95	-0.74	-1.039	-1.465
62	-0.76	-1.51	-0.839	-2.525
63	-0.51	-0.68	-2.319	-2.015
64	-0.25	0.83	1.271	0.955
65	-0.8	-1.76	-1.779	-1.575
66	-0.25	-0.51	-1.819	-2.325
67	-0.3	-0.29	-1.049	-0.685
68	0.42	1.79	0.311	1.335
69	-0.84	-0.05	-3.549	-1.905
70	-0.2	-0.54	-2.159	-0.625
71	-0.49	-1.21	-0.349	-1.975
72	-0.57	0.36	-1.949	0.565
73	-1.09	-0.31	-1.609	-0.585
74	0.58	1.21	-0.609	-0.305
75	-0.71	0.12	-0.529	-0.695
76	0.41	-0.02	-0.909	0.315
77	-0.44	0.74	-2.499	-0.215
78	0.96	0.31	-1.269	0.285
79	0.61	1.18	0.671	1.255
80	0.42	1.34	-0.839	0.225
81	0.81	0.89	0.231	-0.325
82	0.99	1.93	1.391	1.765
83	0.12	0.46	0.361	-0.545
84	0.12	1.48	1.201	-0.775
85	-0.36	0.29	0.021	-0.695
86	0.91	0.43	0.031	-0.955
87	0.56	0.82	0.921	-0.805
88	0.02	1.04	0.741	-0.585
89	1.83	1.02	0.291	-0.445
90	-0.6	-0.18	0.961	-2.095
91	0.43	0.52	1.231	-0.895
92	1.36	-1.22	0.501	-1.505
93	-0.27	-1.21	-1.639	-2.855
94	-0.01	-2.32	-1.059	-4.205
95	-0.37	-3.37	-2.529	-5.225



Centered offsets measured from 2nd Qtr '04
(negative = seaward; positive = landward)

MCP	3rd Qtr '04	4th Qtr '04	1st Qtr '05	2nd Qtr '05
96	-0.48	-3.11	-1.439	-3.445
97	-1.29	-3.34	-2.329	-3.195
98	-0.28	-0.50	0.261	-4.385
99	0.23	0.94	2.651	-1.085
100	-0.45	1.90	2.211	-0.545
101	1.32	2.40	3.561	-1.685
102	0.58	3.24	2.811	-0.755
103	-1.38	-1.43	-0.449	-4.485
104	-0.29	-0.44	-0.269	-4.675
105	-1.02	-0.53	-0.599	-5.825
106	-1.27	-4.09	-4.699	-8.605
107	-2.23	-2.28	-2.589	-6.855
108	-0.47	1.89	0.981	-3.665
109	-0.89	0.85	-1.169	-3.805
110	-2.13	-2.22	-2.789	-5.305
111	3.51	1.86	3.481	2.025
112	2.67	3.03	6.711	6.995
113	1.12	12.64	15.741	17.595
114	4.98	21.64	30.871	28.255
115	5.82	26.55	31.371	31.085
116	1.05	6.58	4.981	-4.875
117	-3.57	-9.92	-21.579	-28.745

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