Changes in Gulf Shoreline Position, Mustang, and North Padre Islands, Texas

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Introduction

This report presents long-term rates of shoreline change along the Texas Gulf of Mexico Shoreline from Aransas Pass to the north boundary of the Padre Island National Seashore. This shoreline reach includes the barrier islands of Mustang and North Padre. The successive positions of historical shorelines are combined in a linear regression model that provides the average annual rate of shoreline change. Based on previous years, therefore, these rates indicate how the shoreline is expected to advance seaward or retreat landward during the next several decades, making this information useful for coastal planning. The Bureau of Economic Geology is currently updating shoreline change rates for most of the Texas coast under the Texas Shoreline Change Project. All data, including what is presented in this report, are being placed in a web-based Geographic Information System (ArcIMS) on the Bureau's Coastal Studies web site (http://www.beg.utexas.edu/coastal/coastal01.htm). The public can use this web site to create custom maps and download data.

The Nature of Shoreline Change

The natural character of sandy beaches is to change shape constantly and to move landward (retreat) or seaward (advance). The changes are caused by changes in the forces that move the sand, namely wind, waves, and currents, and by the supply of sand. Short- and long-term relative sea-level changes also control shoreline movement. The setting of the shoreline and the supply of sand determine how the shoreline changes at a particular location. Setting refers to whether a beach is sheltered from waves, adjacent to a tidal or storm channel, or next to a jetty or seawall, to state a few examples. To understand and predict the rate of change, we need to distinguish between long-term, short-term, and episodic changes and to understand their causes. Long-term change occurs over tens to thousands of years, short-term change refers to movement occurring over several seasons to 5 or 10 years, and episodic change is that which occurs in response to a single storm.

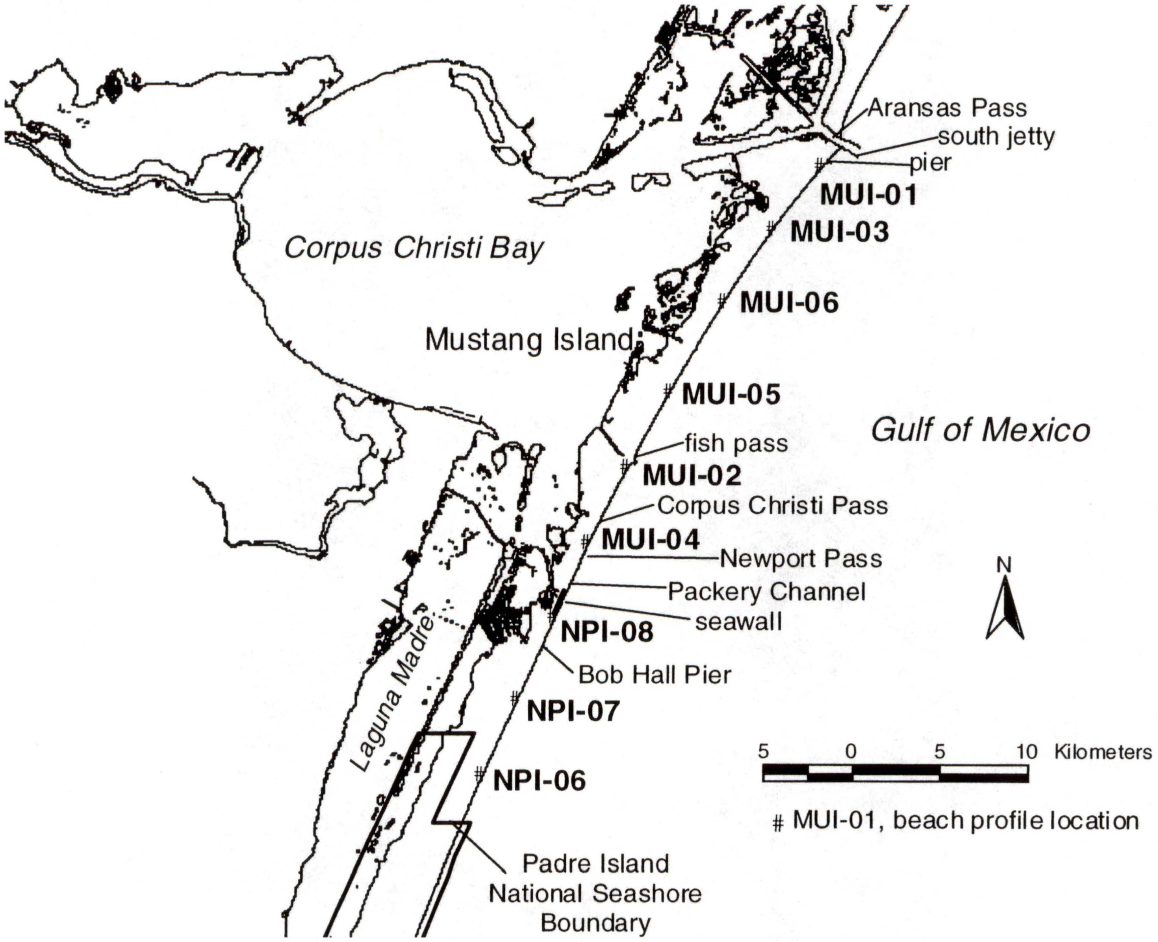

Figure 1. Mustang and North Padre Islands. Average annual shoreline change rates for the Gulf of Mexico shoreline between the Padre Island National Seashore and Aransas Pass are presented in this report. Plots of the beach profiles are in the appendix.

Long-Term Change

We basically understand that it is the changing of sea level relative to the land and the increase and decrease in sand supply to the coast that cause the shoreline to retreat or advance over a period of about 50 years or more. The long-term rise in relative sea level along the Texas coast has moved the shoreline by simply inundating it and by shifting the action of waves and currents landward. Relative sea-level rise has also limited sand supply to the coast by drowning ancient river valleys and forming the coastal bays, such as Corpus Christi Bay. Rivers that used to supply sand to the beaches now dump their sand at the heads of these bays where it is kept from reaching the open coast. The natural geologic setting has not much sand left offshore to resupply eroding beaches either. Generally the sand turns to mud 6 to 9 km offshore (White et al., 1983). Thus the natural geological setting of the Mustang/North Padre Island coast has created a shoreline that is low in sand supply and that is undergoing long-term relative sea-level rise. For these reasons, the shoreline will continue to undergo long-term retreat unless human intervention prevails.

Short-Term Change

Shoreline change that occurs over about ten years or less and that may be in the opposite direction of the long-term trend is difficult to understand and predict. These short-term shoreline changes can also be quite variable alongshore. One portion of the coast may be experiencing retreat while just a few kilometers away stable or advancing conditions may prevail. A shoreline that has retreated over the last 100 years may have experienced periods of shoreline advance, and this is the case for various periods and locations along Mustang and North Padre Islands since the 1930's (Morton and Pieper, 1977). It is important, however, for coastal residents to understand that even though a particular beach may have been advancing or stable over the last several years, if it has been retreating for the previous decades, then retreat will eventually resume. An exception to this rule would be if something fundamental, such as a "permanent" increase or decrease in the sand supply, has changed in the system.

Episodic Shoreline Retreat

Shoreline retreat is not always a continuous and steady process with a little more of the beach eroded each year. Tropical storms and hurricanes along the Texas coast can move the shoreline more than 30 m landward in a day. During Hurricane Carla in 1961, foredunes on Mustang Island were eroded back 50 to 100 m (Hayes, 1961). There is often dramatic recovery for months and years following a storm, but it is usually incomplete, and the shoreline remains significantly landward of its prestorm position. Even though shoreline change rates are given as annual rates, they must be considered "average" annual rates. A particular shoreline with a long-term retreat rate of 2 m/yr would be expected to be 120 m landward in 60 years. A single storm, however, could cause much of this movement.

Previous Work

Scientists at the Bureau of Economic Geology have been mapping historical shorelines and determining shoreline change rates since the early 1970's. Morton and Pieper (1977) determined historical rates of shoreline change by comparing shorelines from topographic surveys conducted by the U. S. Coast Survey in the mid to late 1800's and several shorelines mapped using aerial photography from the 1930's to the 1970's. This publication also discusses the shoreline mapping procedure and limitations using aerial photography. These shorelines originally mapped by Morton and Piper (1977) were digitized and used in this report. Paine and Morton (1989) compared 1974 and 1982 shorelines and vegetation lines mapped from aerial photography. Morton (1993) calculated long-term shoreline change rates using data from the 1800's up to 1982.

Methods

Airborne LIDAR Survey and Extraction of the 2000 Shoreline

Airborne LIDAR (LIght Detection and Ranging) surveys of the shoreline from Aransas Pass to the Padre Island National Seashore were conducted on September 21, 2000. Airborne LIDAR is a new technique to obtain highly accurate and detailed topographic measurements of the Earth's surface. LIDAR surveys involve combining a scanning laser, a device that records aircraft motion, and Global Positioning System (GPS) receivers. LIDAR can acquire beach surveys with vertical precision from 8 to 15 cm and data-point spacing less than 1 m. From these data, a shoreline may be extracted for use in shoreline change analyses.

The LIDAR surveys were conducted using the Bureau's Optech Airborne Laser Terrain Mapper (ALTM) 1225 instrument. The ALTM was installed in a Cessna 206 single engine airplane operated by the Texas State Aircraft Pooling Board. The GPS ground reference station was installed at the Corpus Christi Naval Air Station. The aircraft was navigated along the shoreline using a video camera with the same look direction as the LIDAR instrument. Four passes were made at an altitude of 750 m. A swath of data extending about 500-m inland was acquired. This swath covered the shoreline, foredunes, secondary dunes, and oceanfront structures.

A digital elevation model (DEM) with a 1.5 m × 1.5 m grid was constructed from the LIDAR data points. LIDAR data are collected using a GPS reference frame, which means heights are measured relative to an ellipsoid. Heights above the ellipsoid (HAE) must be converted to heights above a sea-level datum before a shoreline can be extracted from the DEM. Therefore, a grid of the GEOID99 geoid model was subtracted from the DEM to transform the HAE grid to a grid that conforms to sea level. Although the transformed grid should be parallel to sea level, it will not necessarily coincide with local sea level. The height of the water level along the beach, as displayed in the transformed grid, was compared with water levels recorded by the open-coast tide gauge at Bob Hall Pier on north Padre Island during the time of the survey. This comparison allowed the correlation of grid heights to heights relative to a local tidal datum, specifically mean sea level as measured at the Bob Hall Pier tide gauge. Comparison of ground-surveyed beach profiles and the wet/dry line as shown by LIDAR intensity data (Fig. 2), which were acquired at the same time as the LIDAR topography data, were used to pick 1 m above mean sea level as the level to represent the shoreline. The transformed DEM was contoured and the +1-m contour line extracted as the shoreline.

The +1 m contour line has much small-scale (5 m) alongshore and cross-shore variability, which is accurate, but not significant when considering long-term changes in shoreline position. Therefore, the contour line was smoothed. There were also places where the +1 m line enclosed berms separated by a landward berm runnel and shore-normal oriented rip channels to each side. In these cases the seaward edge of the berms were used as the shoreline, and the shoreline was extrapolated across the small rip channels (Fig. 2). The resulting shoreline corresponds to earlier shorelines mapped using aerial photography but is much more rigorous in its definition and an order of magnitude more accurate in its position.

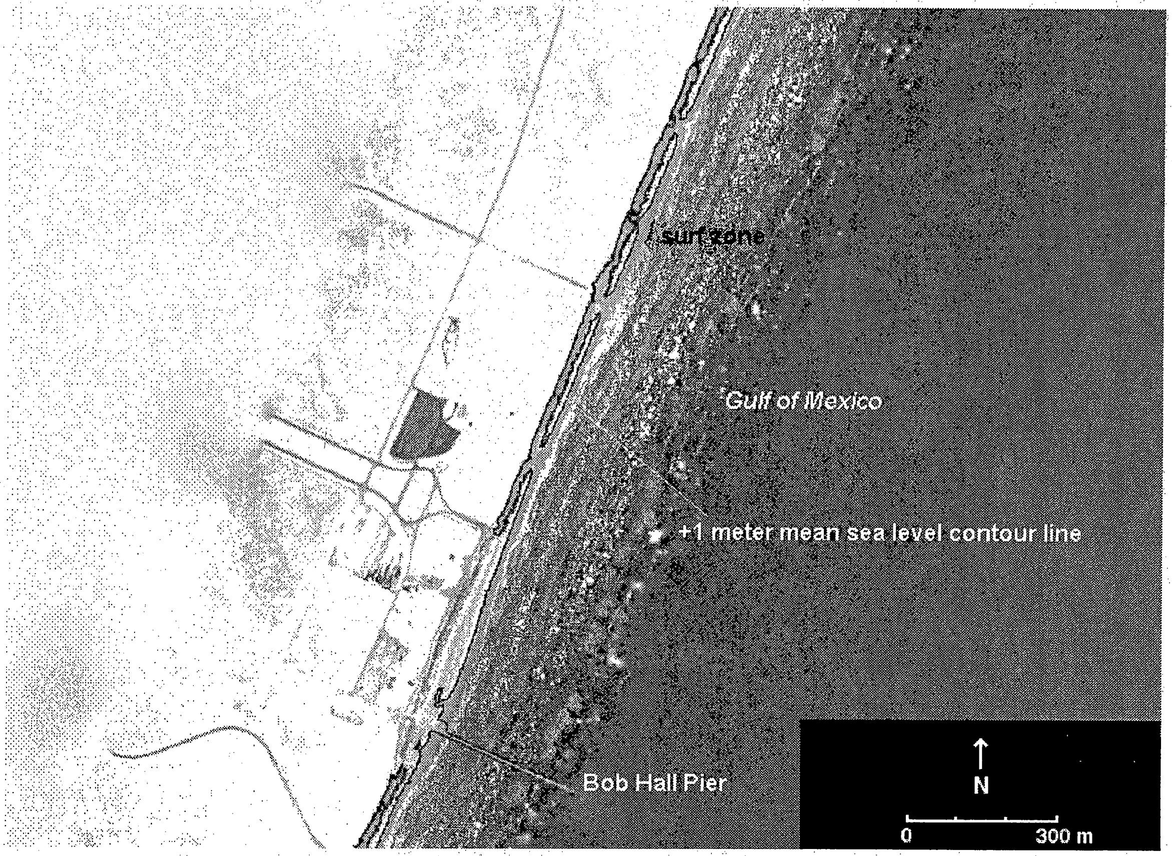

Figure 2. Grid of laser intensity from LIDAR survey with the +1 m mean sea level contour line superimposed (black line). The dry beach, upland, and surf zone are light in color while the asphalt roads, parking lots, and wet beach are dark. The +1 m contour line borders the wet/dry line on the beach and encloses berms separated from the dunes by landward runnels.

Historical Shoreline Mapping

Shorelines from 1937, 1956/58/59, 1965/69, 1974, and 1990/95 were mapped using black-and-white vertical aerial photographs at a scale of 1:24,000 or larger. Mapping shorelines from aerial photographs is a two-step process. First, the shoreline feature is identified and traced on the photograph; second, the shoreline is transferred to a common base map. The shoreline feature used in the photographs was the boundary between wet and dry sand (wet/dry line) evident by a tonal contrast. This boundary represents the upper reach of the wave swash during the preceding high tide and is less susceptible to daily changes in ocean water levels, which are not related to shoreline changes, than the water line.

Stereo viewing and optical magnification of photographs aided the identification and tracing of the wet/dry boundary on the photographs. After the shorelines were drawn directly on the photographs or on overlays, they were transferred to a common base map. The common base maps are the U.S. Geological Survey, 7.5-minute quadrangle maps that have a scale of 1:24,000. A zoom-transfer scope was used to optically register the photographs and base maps. The shorelines were drawn directly onto the base maps, with only the relatively undistorted central portions of the photographs being used. For this study, the 1990/95 shorelines were mapped. Other shorelines were mapped previously by Morton and Pieper (1977), and were checked during this study for consistency in interpreting the shoreline feature on the photographs and for accuracy in the transfer to the base map. Crowell et al. (1991) determined that error involved in locating relative positions of shorelines taken from aerial photographs is about 8 m.

Geographic Information System (GIS)

All shoreline data were compiled into ArcView GIS software. Shorelines that were transferred onto hardcopy base maps from the historical photographs were digitized. The shoreline from the LIDAR survey was also transferred to ArcView. Once in the GIS, the shorelines were compared against each other for consistency. They were also overlain on digital orthophotos produced by the Texas Orthoimagery Program to help determine proper registration. At many base map boundaries, shorelines did not match. This problem is caused by lack of control on one-half of the base map during transfer of the shorelines from the photographs. In some cases, base maps were spliced together to prevent these offsets during the photograph-to-base-map transfer. In other cases, lines were merged across base map boundaries in the GIS. The historical and projected 2060 shorelines will soon be on the Texas Shoreline Change Project Web site for viewing and downloading (http://www.beg.utexas.edu/coastal/intro.htm).

Calculation of Average Annual Rate of Shoreline Change

Shoreline data were exported from ArcView and analyzed by the Shoreline Shape and Projection Program (SSAPP) developed by the Bureau of Economic Geology. SSAPP automatically draws a segmented baseline that follows the trend of the historical shorelines. Transects that intersect the shorelines are constructed perpendicular to this baseline. Distances between the shoreline positions along each transect are determined, and in this study a linear regression model was used to calculate the average annual rate of shoreline change. A baseline segment length of 400 m was used so that shoreline curvature could be adequately defined. Transect spacing was 50 m.

Beach Profiles

From January 30, 2001, to February 1, 2001, topographic ground-survey transects were conducted at 9 locations along the shoreline between the Aransas Pass and Padre Island National Seashore (Fig. 1, Appendix). The transects are oriented perpendicular to the shoreline and extend from landward of the foredunes to about mean sea level. These transects, or "beach profiles," provide data for checking the accuracy and calibration of LIDAR data. They also provide data on the geomorphology and sediment and vegetation characteristics needed to interpret LIDAR data. The ground surveys can be repeated frequently to detect short-term shoreline changes.

Before the field survey was conducted, transect locations were selected. Nine locations were spaced roughly equally along this stretch of Gulf shoreline. The approximate coordinates of the selected transects were used with real-time differential GPS to navigate to the proposed transect sites. Once in the vicinity, the actual profile site was selected to best represent the area and to avoid eminent destruction by development. One site (MUI-01) had already been established and measured in October 1999 in conjunction with Port Aransas High School science students.

At each location, a temporary marker consisting of a steel pipe with a piece of flat stock welded on the end was buried with about 30 cm of the pipe above ground. The X, Y, Z positions of the tops of the datum pipes were determined by using precise differential GPS surveying techniques. Geodetic Trimble 4000ssi GPS receivers were used with the base station operating at the Corpus Christi Naval Air Station. Each profile location was occupied for at least 30 minutes depending on the satellite constellation. Heights above the ellipsoid calculated using phase differencing techniques on the GPS data were converted to orthometric heights using the GEOID99 model. Beach profiles were measured using a Sokkia Set 5W Electronic Total Station and a reflecting prism. Vegetation, sediment type, and geomorphic features were noted along each transect line. Navigation back to the marker locations will be possible using real-time differential GPS.

Beach profiles are plotted relative to the orthometric heights derived using GEOID99 (Appendix). Also included on the data plots is the location of approximate local mean sea level. Local mean sea level was determined by examining tide gauge data from Bob Hall Pier on north Padre Island. Approximate location of mean sea level on the transects was determined by the offset of the water level from mean sea level at the time the position of the water line was obtained for each transect. Also included on the profile plots is the designation of the datum marker, vegetation line, wet/dry line, and water line at the time of the survey.

Average Annual Rate of Shoreline Change

The purpose of calculating the average annual rate of shoreline change is to provide an indication of likely future changes. Therefore, shorelines from a time before permanent and significant engineering changes were made are not used in the calculation. From Aransas Pass to the Padre Island National Seashore, shorelines prior to the jetty and channel construction at Aransas Pass are not used. The dredged channel and jetties at Aransas Pass, which were largely in place by 1911 (U.S. Army Corps of Engineers, 1992), interrupt southerly littoral drift affecting the long-term sediment budget along Mustang Island. The enhanced tidal exchange through the pass may also affect the length of time the storm surge channels of Packery, Newport, and Corpus Christi Passes remain open after storms. Dredging and jetty maintenance at Aransas Pass has proceeded since 1911 and will continue for the foreseeable future. Therefore, shorelines used to determine the average annual rate of shoreline change are from 1937, 1956/58/59, 1965/69, 1974, 1990/95, and 2000.

Figure 3 is a plot of the long-term average annual rate of shoreline change. The shoreline is overall retreating with an area of stability or slight seaward advancement for 7 km of shoreline south of the Aransas Pass jetty, and in 2 local areas around the fish pass and Corpus Christi Pass. The fish pass was dredged and jettied in August 1972. Even though it closed naturally in 1979, the 2 rock jetties remain and extend seaward 160 m from the 2000 shoreline. The jetties have interrupted the littoral drift causing stabilization or slight advancement of the shoreline 1 km to the south and 0.5 km to the north. The local stabilization of the shoreline around Corpus Christi Pass is anomalous and reflects the closing of the pass in 1943 after having been dredged in 1938 (U. S. Army Corps of Engineers, 1992).

There are 3 areas where moderate shoreline retreat is punctuated by relatively high retreat rates. These areas are 7 to 11 km south of the Aransas Pass jetty, a 3 km area around Newport Pass and a 3-km stretch of shoreline south of Bob Hall Pier. Inspection of the beach profiles (appendix) reveals that the foredunes and secondary dunes are generally lower in elevation in the high retreat areas compared to those in the relatively stable areas. For example, NPI-07 is in an area with a retreat rate of almost 2 m/yr and the foredune and secondary dunes have an elevation of about 4 m. Five kilometers to the south at profile NPI-06 the retreat rate decreases to 0.5 m/yr and the dune complex reaches about 7 m elevation. A similar comparison can be made between the relatively high retreat rate, low-elevation profile at MUI-06 and the low retreat rate, high elevation profile at MUI-05 (Fig. 1, appendix).

Discussion and Conclusions

Overall, the Gulf of Mexico Shoreline between Aransas Pass and the north boundary of the Padre Island National Seashore is retreating. However, there are several scales of alongshore variability in the average annual rate of shoreline change. Some of this variability is caused by human alterations. Engineering modifications at Aransas Pass have changed the sediment budget by trapping sand in the littoral drift system on both sides of the pass. As a result, the shoreline position is more stable for a distance 6 km to the south of the pass than it otherwise would be. Farther to the south of the pass, the overall retreat of the shoreline is probably enhanced because of the sand trapping. The modifications at Aransas Pass have also created a more efficient channel for tidal exchange with Corpus Christi Bay. This effects shoreline dynamics along Mustang and North Padre Islands by limiting the flow through the storm channels to the south causing

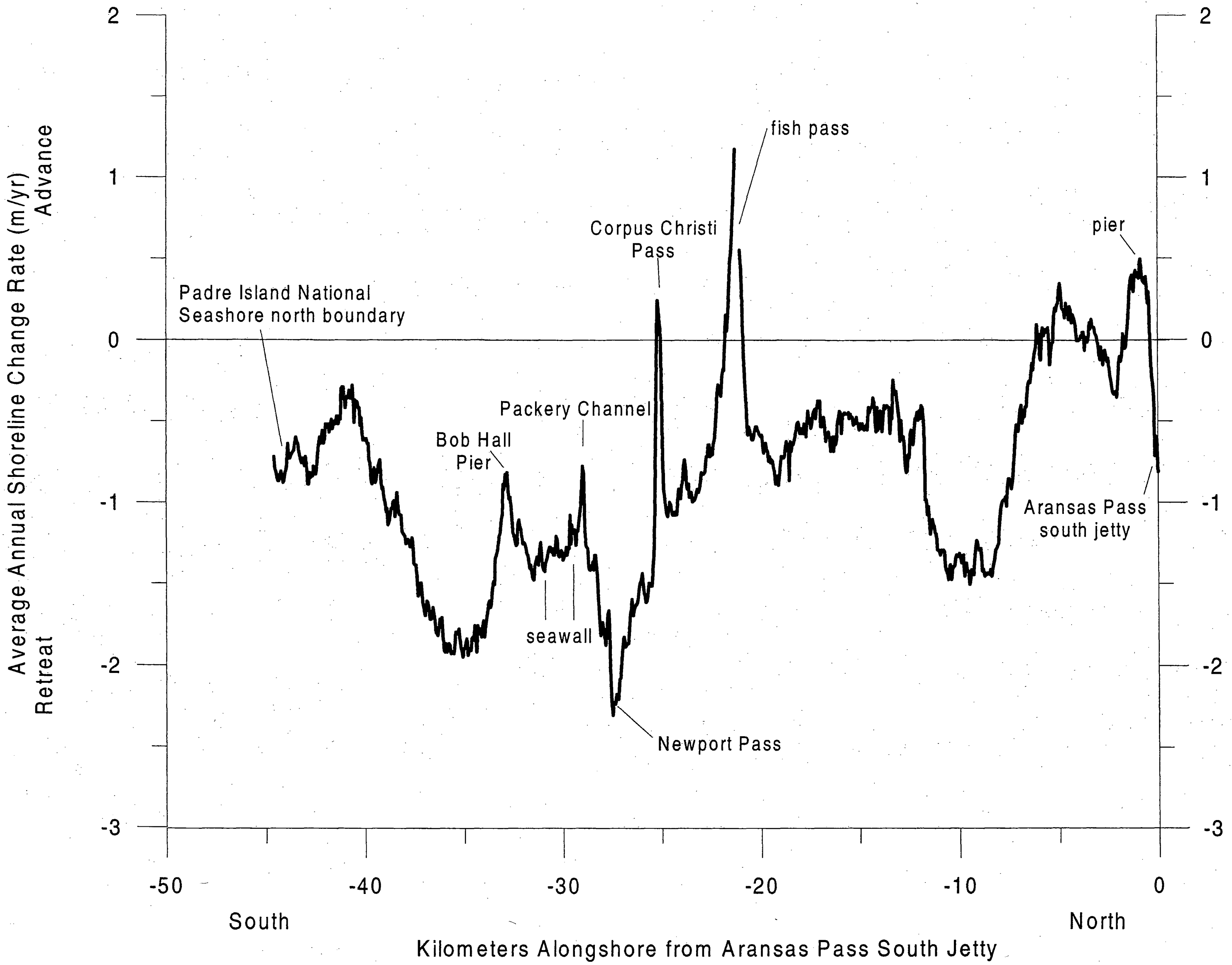

Figure 3. Long-term average annual rate of shoreline change. Six shorelines from 1937, 1956/58/59, 1965/69, 1974, 1990/95, and 2000 were used to determine rate of change based on a linear regression model.

them to close relatively quickly after storms. Modifications at Corpus Christi Pass and the Corpus Christi Water Exchange Pass (fish pass) have had large but only local effects. The piers and seawall have only caused minor alterations in the shoreline change rates (Fig. 3).

The most interesting variations in the average annual shoreline change rates are the areas of relatively high retreat south of Bob Hall Pier, around Newport Pass, and 7 to 11 km south of Aransas Pass. The cause of the higher retreat rates is not know specifically, but probably reflect variations in littoral drift rates or the amount of wave energy reaching the shoreline. The better-developed dunes in the low-retreat areas compared to the high-retreat areas suggest that the dunes are storing greater amounts of sand in the low retreat areas, which may enhance even further the high retreat rates along adjacent shorelines. The relationship between dune development and long-term retreat rates will be further investigated using the detailed topographic data from the LIDAR survey.

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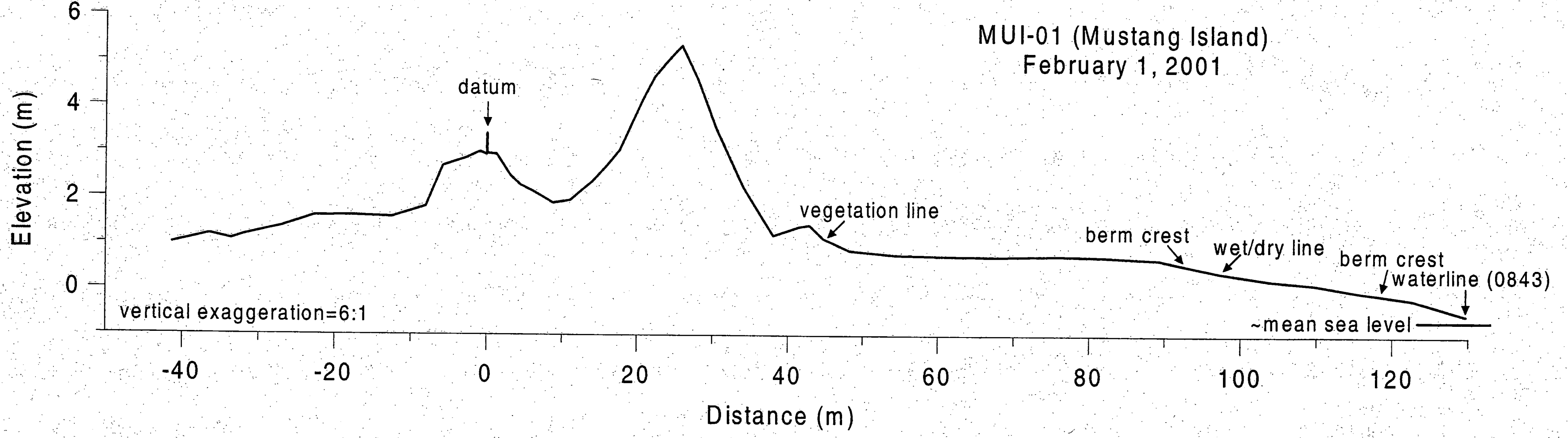
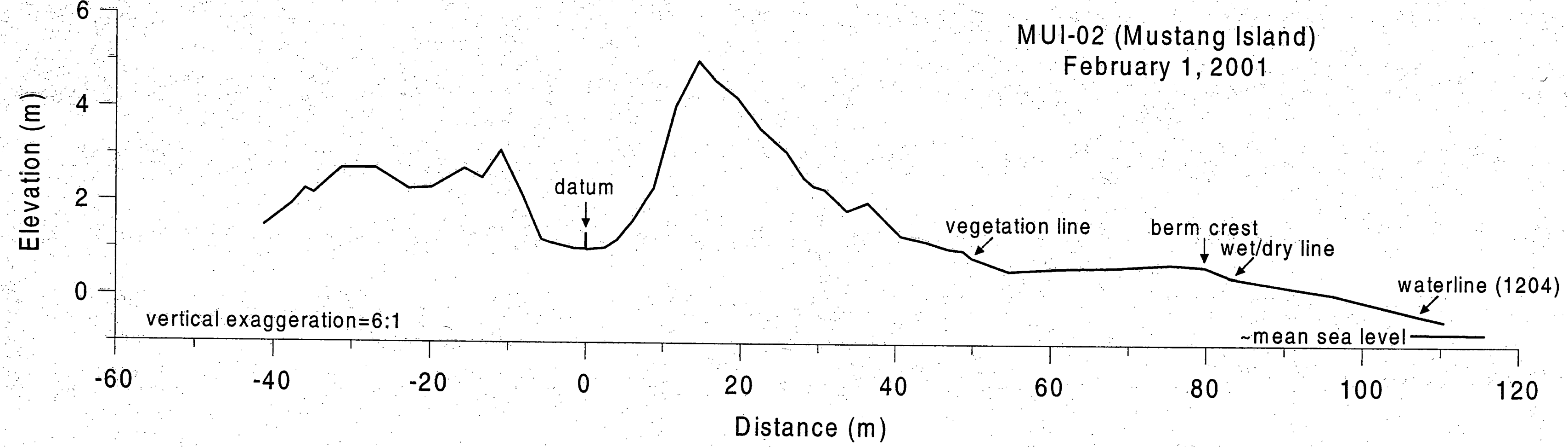
Appendix

Plots of beach profiles and data tables. Plots are relative to the geoid as determined by converting heights above the ellipsoid (HAE) to orthometric heights using the GEOID99 model.


MUI-01 (Mustang Island)
February 1, 2001
Elevation (m)
Distance (m)
datum
vegetation line
berm crest
wet/dry line
berm crest
waterline (0843)
~mean sea level
vertical exaggeration=6:1
6
4
2
0
-40
-20
0
20
40
60
80
100
120


MUI-02 (Mustang Island)
February 1, 2001
Elevation (m)
Distance (m)
datum
vegetation line
berm crest
wet/dry line
waterline (1204)
~mean sea level
vertical exaggeration=6:1
6
4
2
0
-60
-40
-20
0
20
40
60
80
100
120

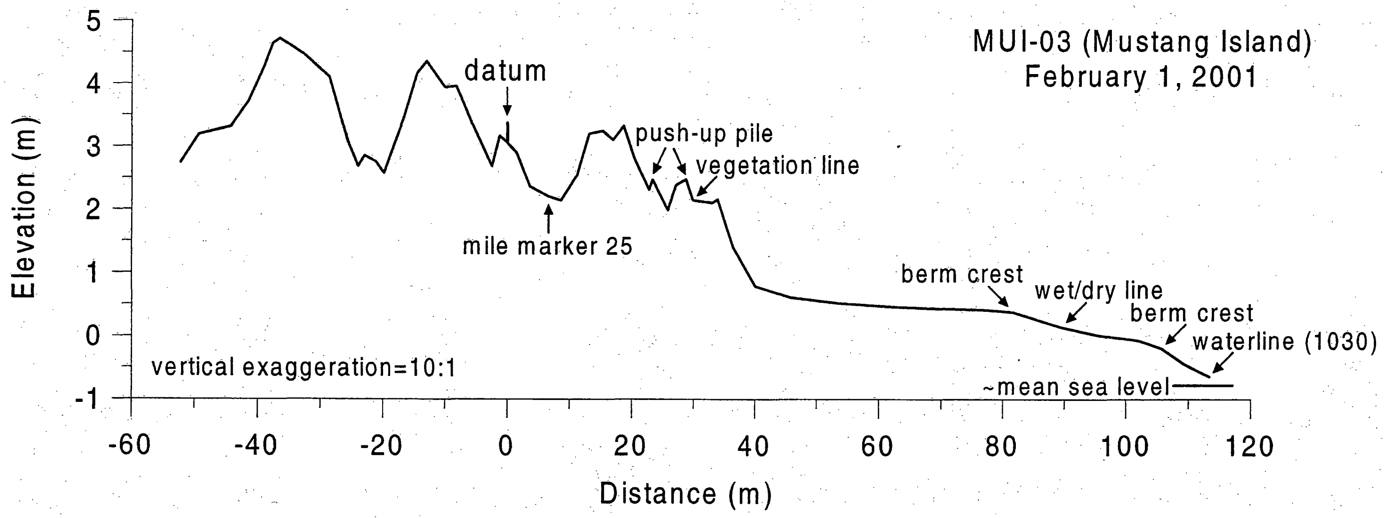
MUI01 Datum Latitude: 27° 49’ 32.33928” N
Datum Longitude: 97° 03’ 24.20630” W
Azimuth: 123° Magnetic North
HAE: -23.62 meters
Orthometric Height: 3.41 meters

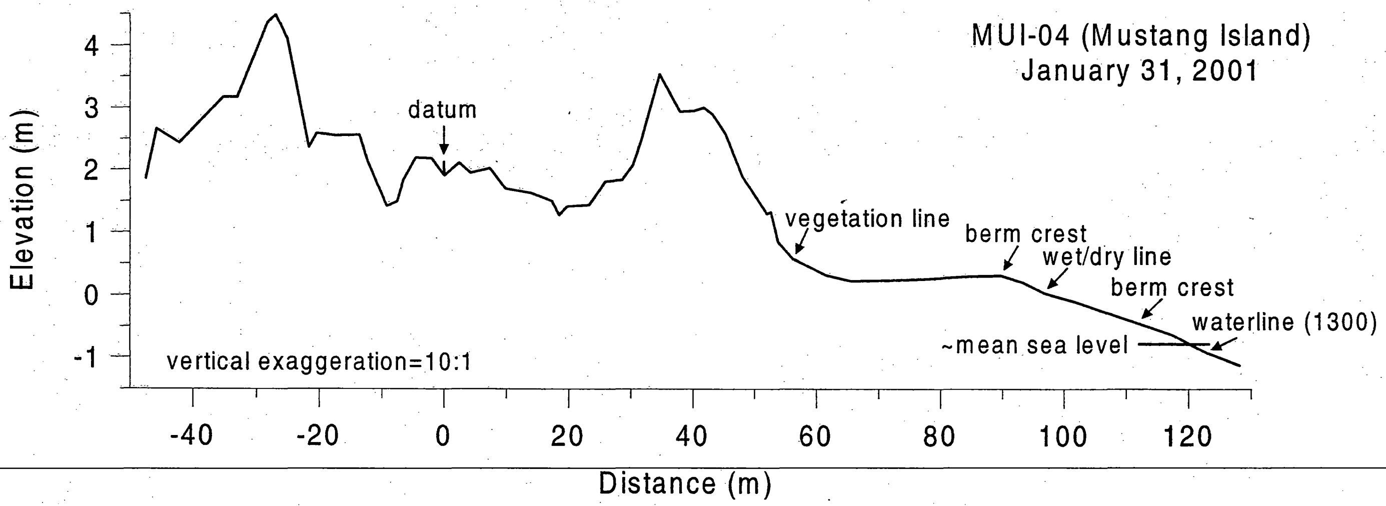
X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-41.36	0.99		24.16	5.04	
-36.52	1.18		25.87	5.35	dune crest
-33.64	1.08		28.04	4.59	
-32.08	1.16		30.34	3.58	
-27.02	1.36		34.09	2.23	
-22.66	1.60		38.04	1.19	
-17.51	1.60		41.42	1.38	
-12.54	1.57		42.84	1.42	
-8.08	1.81		44.72	1.13	vegetation line
-5.86	2.70		48.23	0.87	
-2.84	2.87		54.37	0.78	
-0.91	3.01		60.55	0.75	
-0.05	2.95		67.93	0.74	
0.00	3.41	datum	75.77	0.76	
0.03	2.97		81.85	0.74	
1.24	2.95		89.26	0.68	
3.10	2.49		92.86	0.55	berm crest
4.42	2.28		97.32	0.40	wet/dry line
6.76	2.08		103.88	0.24	
8.78	1.89		109.69	0.14	
11.06	1.94		115.73	-0.03	
14.03	2.37		118.45	-0.08	berm crest
16.03	2.73		122.66	-0.17	
17.65	3.06		129.70	-0.51	water line
20.79	4.19		130.78	-0.56	~mean sea level
22.26	4.67				

MUI02

Datum Latitude:	27° 40' 25.06082" N
Datum Longitude:	97° 10' 11.45948" W
Azimuth:	120° Magnetic North
HAE:	-25.47 meters
Orthometric Height:	1.33 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-41.25	1.48		22.48	3.59	
-37.62	1.94		25.84	3.09	
-35.96	2.27		28.08	2.54	
-34.85	2.17		29.33	2.36	
-31.31	2.71		30.75	2.29	
-26.95	2.70		33.66	1.83	
-22.76	2.27		36.38	2.01	
-19.85	2.30		40.70	1.30	
-15.65	2.70		43.99	1.18	
-13.40	2.51		46.90	1.02	
-11.00	3.09		48.76	0.99	
-8.27	2.17		49.84	0.84	vegetation line
-5.75	1.20		54.62	0.56	
-4.62	1.13		61.10	0.62	
-1.53	1.01		68.25	0.65	
-0.05	1.00		75.38	0.72	
0.00	1.33	datum	79.81	0.67	berm crest
0.05	0.98		83.18	0.45	wet/dry line
2.47	1.02		90.25	0.25	
4.03	1.19		96.35	0.09	
6.02	1.59		101.21	-0.11	
8.76	2.31		106.81	-0.33	water line
11.62	4.05		110.19	-0.46	~mean sea level
14.61	5.02	dune crest	110.36	-0.47	
16.68	4.62				


MUI-03 (Mustang Island)
February 1, 2001
datum
push-up pile
vegetation line
mile marker 25
berm crest
wet/dry line
berm crest
waterline (1030)
~mean sea level
vertical exaggeration=10:1
Elevation (m)
5
4
3
2
1
0
-1
-60
-40
-20
0
20
40
60
80
100
120
Distance (m)


MUI-04 (Mustang Island)
January 31, 2001
datum
vegetation line
berm crest
wet/dry line
berm crest
waterline (1300)
~mean sea level
vertical exaggeration=10:1
Elevation (m)
4
3
2
1
0
-1
-40
-20
0
20
40
60
80
100
120
Distance (m)

MUI03

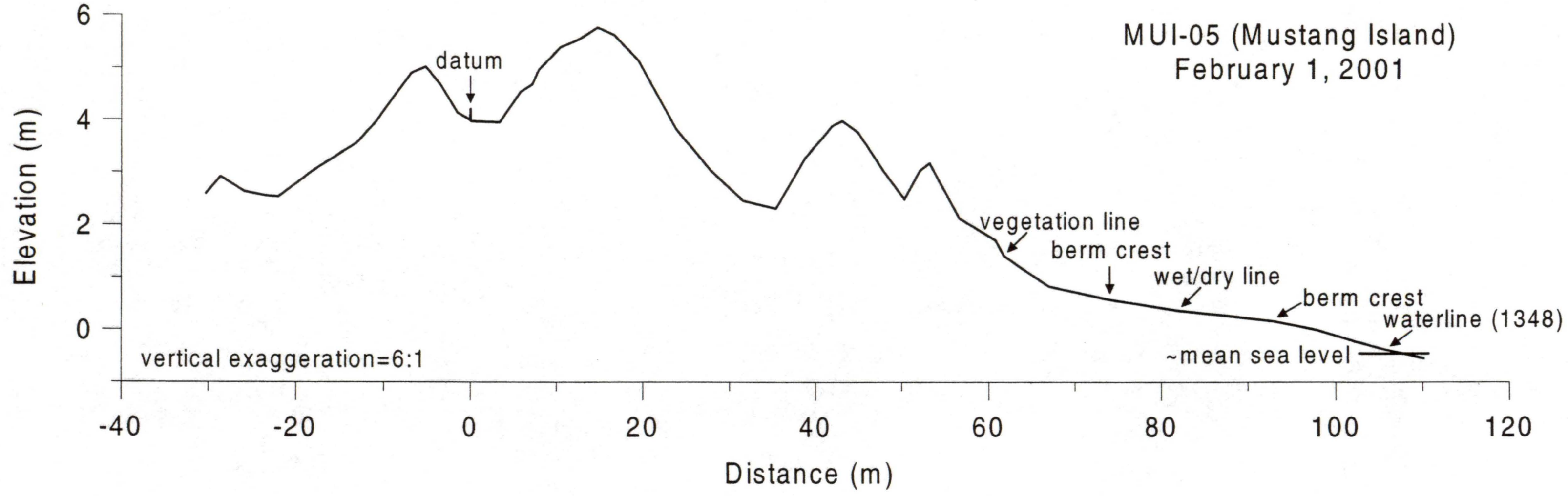
Datum Latitude: 27° 47’ 39.33388” N
Datum Longitude: 97° 05’ 04.80860” W
Azimuth: 125° Magnetic North
HAE: -23.41 meters
Orthometric Height: 3.38 meters

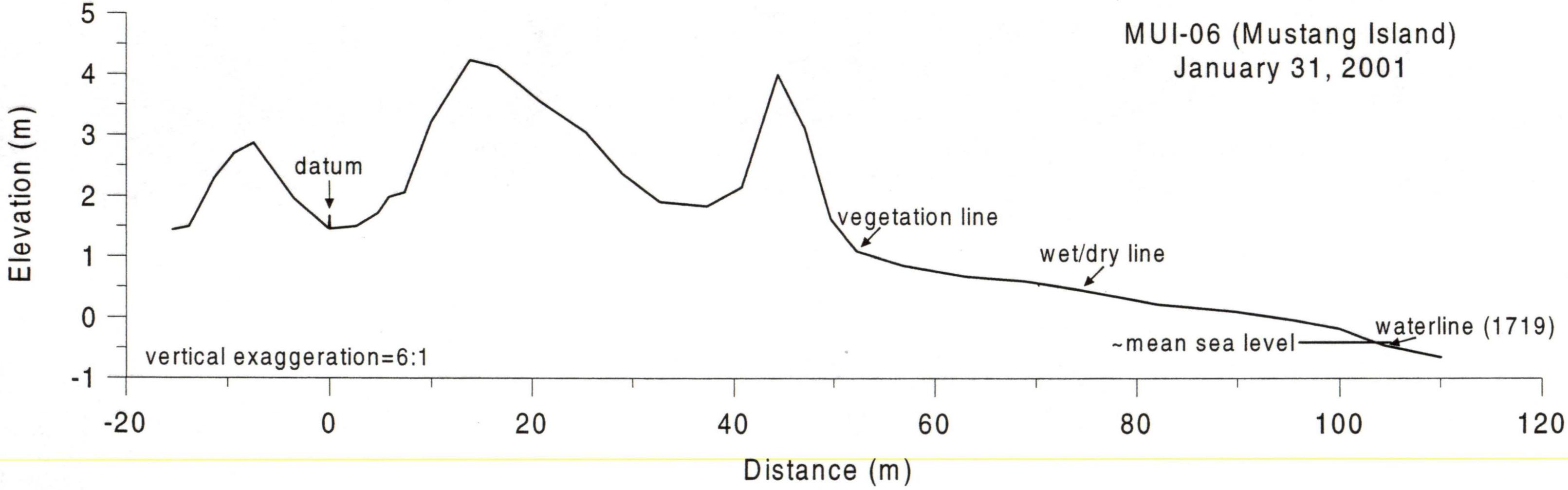
X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-52.30	2.74		11.16	2.55	
-49.34	3.20		13.14	3.21	
-44.24	3.32		15.30	3.26	
-41.56	3.72		17.01	3.12	
-38.97	4.29		18.69	3.34	dune crest
-37.62	4.65		20.44	2.82	
-36.57	4.73		22.81	2.32	
-32.69	4.47		23.41	2.48	
-28.62	4.12		25.83	2.00	
-25.63	3.06		27.15	2.39	
-24.02	2.69		28.76	2.49	
-23.02	2.86		29.91	2.16	vegetation line
-21.22	2.77		33.07	2.12	
-19.86	2.58		33.90	2.17	
-16.65	3.47		36.41	1.41	
-14.54	4.18		40.09	0.80	
-12.99	4.36		45.69	0.62	
-10.05	3.96		53.61	0.53	
-8.18	3.97		62.30	0.47	
-5.50	3.33		71.37	0.44	
-2.50	2.69		76.71	0.43	
-1.26	3.18		81.56	0.39	berm crest
-0.05	3.07		89.59	0.15	wet/dry line
0.00	3.38	datum	95.69	0.02	
0.06	3.05		101.98	-0.07	
1.44	2.91		105.75	-0.19	berm crest
3.62	2.37		109.36	-0.44	
6.65	2.21		113.37	-0.63	water line
8.62	2.15		115.72	-0.75	~mean sea level

MUI04

Datum Latitude: 27° 38' 06.26816" N
Datum Longitude: 97° 11' 34.55159" W
Azimuth: 110° Magnetic North
HAE: -24.16 meters
Orthometric Height: 2.14 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-47.47	1.86		25.92	1.82	
-45.77	2.67		28.67	1.85	
-42.16	2.44		30.37	2.09	
-35.23	3.17		31.71	2.50	
-33.04	3.18		34.67	3.55	dune crest
-28.30	4.37		37.94	2.95	
-26.90	4.50		40.17	2.96	
-25.11	4.11		41.79	3.01	
-21.68	2.37		43.22	2.91	
-20.46	2.60		45.34	2.59	
-17.32	2.57		48.07	1.90	
-13.57	2.57		52.02	1.31	
-12.24	2.14		52.68	1.33	
-9.19	1.43		53.84	0.85	
-7.57	1.50		56.18	0.58	vegetation line
-6.53	1.84		61.57	0.33	
-4.53	2.21		65.67	0.23	
-1.98	2.19		71.51	0.24	
-0.02	1.93		76.99	0.26	
0.00	2.14	datum	84.79	0.31	
0.06	1.91		89.82	0.32	berm crest
2.43	2.12		93.37	0.21	
4.32	1.96		96.87	0.04	wet/dry line
7.43	2.04		101.96	-0.10	
9.88	1.71		107.85	-0.31	
14.01	1.64		111.97	-0.45	berm crest
17.27	1.51		117.38	-0.63	
18.46	1.28		119.37	-0.78	~mean sea level
19.71	1.42		123.01	-0.92	water line
23.24	1.45		128.12	-1.11	


MUI-05 (Mustang Island)
February 1, 2001
Elevation (m)
Distance (m)
datum
vegetation line
berm crest
wet/dry line
berm crest
waterline (1348)
~mean sea level
vertical exaggeration=6:1
6
4
2
0
-40
-20
0
20
40
60
80
100
120


MUI-06 (Mustang Island)
January 31, 2001
Elevation (m)
Distance (m)
datum
vegetation line
wet/dry line
waterline (1719)
~mean sea level
vertical exaggeration=6:1
5
4
3
2
1
0
-1
-20
0
20
40
60
80
100
120

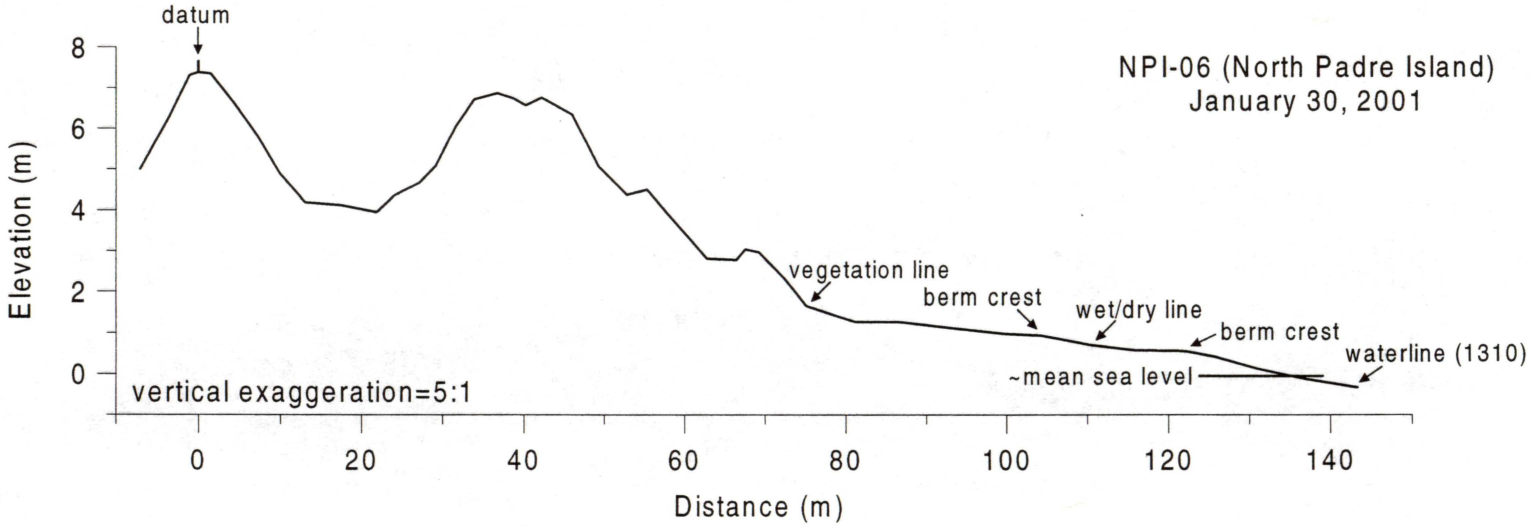
MUI05 Datum Latitude: 27° 42' 44.43636" N
Datum Longitude: 97° 08' 42.79258" W
Azimuth: 115° Magnetic North
HAE: -22.65 meters
Orthometric Height: 4.21 meters

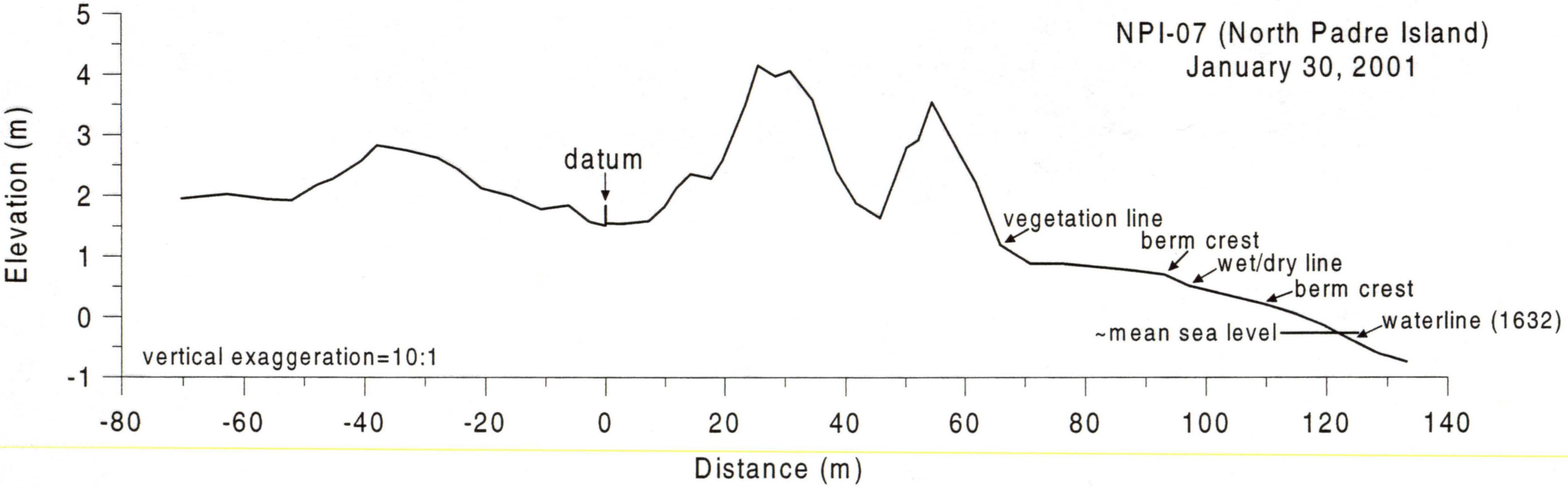
X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-30.35	2.59		23.81	3.84	
-28.64	2.92		27.73	3.05	
-25.91	2.64		31.51	2.47	
-23.43	2.55		35.38	2.31	
-22.00	2.54		38.76	3.27	
-18.23	3.01		41.97	3.89	
-13.16	3.56		43.12	3.99	dune crest
-10.98	3.96		44.96	3.77	
-8.39	4.55		47.71	3.07	
-6.80	4.91		50.29	2.50	
-5.17	5.03		52.11	3.04	
-3.43	4.68		53.20	3.18	
-1.51	4.14		56.63	2.14	
-0.06	4.00		60.83	1.71	
0.00	4.21	datum	61.77	1.41	vegetation line
0.04	3.98		66.98	0.83	
3.37	3.96		73.89	0.58	berm crest
5.87	4.55		81.99	0.37	wet/dry line
7.17	4.69		87.94	0.26	
7.95	4.96		92.86	0.17	berm crest
10.46	5.39		97.80	0.00	
12.60	5.55		102.16	-0.22	
14.76	5.77	dune crest	105.60	-0.38	water line
16.69	5.63		107.07	-0.43	~mean sea level
19.51	5.14		110.11	-0.54	

MUI06

Datum Latitude: 27° 45’ 26.48189” N
Datum Longitude: 97° 06’ 49.34206” W
Azimuth: 115° Magnetic North
HAE: -25.26 meters
Orthometric Height: 1.67 meters

X (m)	*Z (m)*	*Beach feature*
-15.45	1.44	
-13.79	1.50	
-11.30	2.29	
-9.35	2.70	
-7.43	2.87	
-3.49	1.96	
-0.07	1.46	
0.00	1.67	datum
0.04	1.46	
2.58	1.50	
4.67	1.72	
5.81	1.99	
7.33	2.06	
9.95	3.22	
13.85	4.24	dune crest
16.54	4.13	
20.75	3.56	
25.36	3.05	
29.04	2.37	
32.69	1.91	
37.37	1.84	
40.80	2.15	
44.42	4.00	
47.15	3.11	
49.72	1.63	
52.26	1.09	vegetation line
56.89	0.86	
63.09	0.67	
68.86	0.60	
74.66	0.45	wet/dry line
82.11	0.22	
89.60	0.10	
95.60	-0.05	
99.97	-0.19	
103.38	-0.42	~mean sea level
104.40	-0.46	water line
110.03	-0.65	


datum
NPI-06 (North Padre Island)
January 30, 2001
Elevation (m)
8
6
4
2
0
vegetation line
berm crest
wet/dry line
berm crest
waterline (1310)
~mean sea level
vertical exaggeration=5:1
0
20
40
60
80
100
120
140
Distance (m)

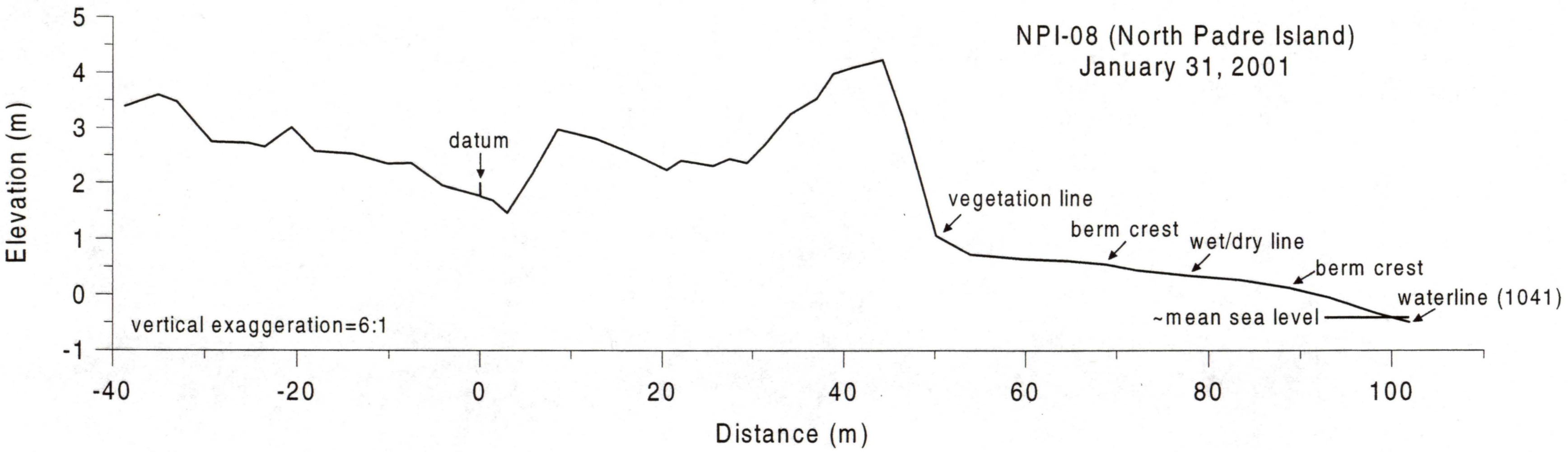

NPI-07 (North Padre Island)
January 30, 2001
Elevation (m)
5
4
3
2
1
0
-1
datum
vegetation line
berm crest
wet/dry line
berm crest
waterline (1632)
~mean sea level
vertical exaggeration=10:1
-80
-60
-40
-20
0
20
40
60
80
100
120
140
Distance (m)

NPI06 Datum Latitude: 27 31 01.13077" N
Datum Longitude: 97 15 18.86224" W
Azimuth: 110° Magnetic North
HAE: -19.10 meters
Orthometric Height: 7.39 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-7.11	5.00		52.79	4.38	
-3.63	6.28		55.34	4.50	
-1.11	7.32		58.70	3.74	
-0.10	7.39		62.79	2.82	
-0.05	7.66		66.45	2.78	
0.00	7.39	datum	67.54	3.05	
1.46	7.36	dune crest	69.21	2.97	dune crest
4.33	6.62		72.37	2.35	
7.19	5.82		75.11	1.67	
9.97	4.89		81.19	1.28	vegetation line
13.04	4.18		86.56	1.28	
17.41	4.13		93.20	1.13	
21.82	3.96		99.91	0.98	
24.06	4.36		104.29	0.95	berm crest
27.11	4.67		110.35	0.72	wet/dry line
29.10	5.07		115.95	0.58	
31.66	6.07		121.05	0.58	
33.86	6.72		122.16	0.56	berm crest
36.70	6.88		125.64	0.43	
38.68	6.75		130.62	0.15	~mean sea level
40.23	6.58		131.01	0.13	
42.20	6.77	dune crest	136.89	-0.12	water line
45.94	6.36		143.34	-0.32	
49.28	5.07				

NPI07 Datum Latitude: 27° 33’ 18.91023” N
Datum Longitude: 97° 14’ 06.69026” W
Azimuth: 110° Magnetic North
HAE: -24.73 meters
Orthometric Height: 1.84 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-70.27	1.95		25.57	4.16	
-62.82	2.02		28.48	3.98	
-55.99	1.94		30.88	4.07	dune crest
-52.16	1.92		34.62	3.58	
-47.79	2.18		38.47	2.42	
-45.27	2.28		41.77	1.88	
-40.56	2.58		45.72	1.64	
-37.99	2.83		50.22	2.80	
-33.00	2.74		52.16	2.92	
-27.87	2.63		54.49	3.55	foredune crest
-24.49	2.44		59.04	2.71	
-20.69	2.12		61.81	2.22	
-15.78	2.00		65.85	1.20	vegetation line
-10.83	1.78		70.92	0.89	
-6.23	1.85		76.26	0.89	
-2.76	1.57		82.55	0.83	
-0.07	1.51		88.26	0.78	
0.00	1.84	datum	93.13	0.71	berm crest
0.04	1.55		97.06	0.53	wet/dry line
2.96	1.54		104.52	0.34	berm crest
7.23	1.59		109.36	0.23	
9.89	1.82		114.81	0.06	
11.86	2.13		119.60	-0.13	
14.28	2.36		121.80	-0.25	~mean sea level
17.70	2.29		124.19	-0.38	water line
19.62	2.58		128.70	-0.60	
23.48	3.51		133.12	-0.73	


NPI-08 (North Padre Island)
January 31, 2001
Elevation (m)
Distance (m)
datum
vegetation line
berm crest
wet/dry line
berm crest
waterline (1041)
~mean sea level
vertical exaggeration=6:1
5
4
3
2
1
0
-1
-40
-20
0
20
40
60
80
100

NPI08
Datum Latitude: 27° 35’ 51.37036” N
Datum Longitude: 97° 12’ 47.09885” W
Azimuth: 110° Magnetic North
HAE: -24.65 meters
Orthometric Height: 2.01 meters

X (m)	*Z (m)*	*Beach feature*
-38.69	3.39	
-35.04	3.60	
-33.06	3.47	
-29.29	2.75	
-25.33	2.73	
-23.53	2.66	
-20.62	3.02	
-18.11	2.58	
-13.96	2.54	
-10.21	2.36	
-7.59	2.37	
-4.16	1.97	
-1.64	1.86	
0.01	1.78	
0.00	2.01	datum
0.04	1.77	
1.40	1.70	
2.98	1.48	
5.66	2.15	
8.55	2.98	
12.80	2.81	
17.24	2.51	
20.48	2.26	
22.09	2.42	
25.63	2.33	
27.47	2.46	
29.40	2.39	
31.27	2.69	
34.21	3.27	
37.03	3.54	
38.83	4.00	
41.04	4.12	
44.29	4.25	dune crest
46.62	3.14	
50.18	1.07	vegetation line
53.95	0.73	
59.90	0.66	
64.64	0.62	
68.82	0.56	berm crest
72.18	0.45	
77.82	0.35	wet/dry line
83.52	0.27	
88.88	0.13	berm crest
93.02	-0.04	
97.02	-0.25	~mean sea level
98.43	-0.33	water line
101.92	-0.49	