Field Identification and Classification of Coastal Dunes, Galveston County, Texas

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by

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EXECUTIVE SUMMARY

As part of the Texas Natural Resources Inventory (NRI), beach and dune profiles were surveyed at 33 transects spaced 7,000 to 10,000 ft apart along the Gulf shore of Galveston County. These surveys were conducted to establish the position of the dune protection line and the vegetation line. Geographic positions of the dune protection line and the vegetation line on each transect were obtained with geodetic quality Global Positioning System (GPS) receivers. The GPS positions were converted to state plane coordinates to facilitate entry into ARC/INFO, the NRI geographic information system.

Dune characteristics such as height, continuity, density of vegetative cover, and location with respect to the Gulf shore were recorded to determine the occurrence and distribution of different dune types. The functional relationships and response of different dune types to storm conditions were reviewed, and an ordinal ranking of dunes was prepared. On one end of the spectrum are high, continuous well-vegetated foredune ridges, and on the other end are low, isolated, barren or sparsely vegetated coppice mounds.

Field observations revealed that beach cleaning activities have extensively modified the dunes and vegetation line of Galveston County since Hurricane Alicia (1983). A ranking of human impacts was developed to provide a basis for evaluating the degree of dune modification. The impact indicies range from 0 to 5 with 0 indicating no visible evidence of human interference and 5 indicating major alterations to the natural dune system and position of the vegetation line. Most beach segments in Galveston County have an impact index of 3, indicating that the natural dunes are supplemented with large mounds of sand and debris (wood, beach trash) scraped from the beach during cleaning operations and placed in the backbeach seaward of the natural dunes.

In general, the foredunes of Galveston County are less than 11 ft high, narrow, densely vegetated, and relatively continuous. They will provide adequate protection

against washover and flooding for hurricanes up to category 2, but are vulnerable to complete destruction by more intense hurricanes (categories 3-5).

INTRODUCTION

A cooperative study was conducted by the Texas General Land Office (GLO) and the Bureau of Economic Geology (BEG) to investigate the coastal foredunes along the Gulf beaches of Galveston County. Several tasks were involved including examination of aerial photographs, field surveys of beach and dune profiles, location of the dune protection line and vegetation line, and evaluation of human modifications to the dune system. Protecting the foredunes from adverse human impacts is necessary because they serve as the primary line of defense against storm surge, high waves, and coastal flooding. Stable dunes can help minimize storm damage to roads and buildings and can protect back-island areas and the mainland from the direct impact of a storm. The dunes also contain a reservoir of sand that reduces instantaneous beach erosion during storms and assists in post-storm beach recovery.

A principal objective of the study was to provide geographic coordinates of the dune protection line at selected sites and to format those data so that they can be incorporated into the Texas Natural Resources Inventory (NRI) database. Other objectives were to review the factors that are critical to the maintenance of dunes along coastal barrier islands, to describe the various dune types observed along Gulf beaches of Galveston County from San Luis Pass to High Island (fig. 1), to consider the function of each dune type and their response to storm conditions, to describe the relative importance of each dune type in protecting both the natural coastal system and human construction within that system, and to evaluate the impact of human modifications on the natural formation of dunes.

FIELD METHODS

Air Photo Analysis and Profile Locations

Composite strips of air photos of Galveston County Gulf beaches taken in 1991 by the GLO were used to tentatively locate 33 profiles that represent dune conditions along a particular beach segment. Using the air photos, profiles were optimally spaced about every 7,000 to 10,000 ft along the Gulf shore (fig. 1). The final locations of the profiles were determined in the field considering the proximity of the profiles to houses or other obstructions that would alter the beach and dune morphology. Eight of the profiles are referenced to markers established by the BEG in 1983 when monitoring of beach recovery from Hurricane Alicia began. Six of the BEG profiles are on West Beach of Galveston Island, one is at Caplen on Bolivar Peninsula, and one is at High Island (Table 1).

All of the GLO profiles (Appendix A) are referenced to an orange metal stake that protrudes a few inches above the ground surface. Each stake is constructed of a three-foot piece of one-inch pipe welded to a two-foot piece of flat steel that forms a T. The T was inverted and buried in a trench to discourage removal by vandals. Each profile is identified by a number inscribed on a metal tag that is attached to the top of the stake.

Field notes, sketches of the profiles and profile locations, and comments regarding the dune types and modifications (Appendix B) were recorded in standard field books kept on file at the Bureau of Economic Geology and the Texas General Land Office.

Total Station Surveys

The primary field surveys involved shore-normal beach and dune profiles (transects) measured with a total station and reflecting prism. Standard profiling techniques were

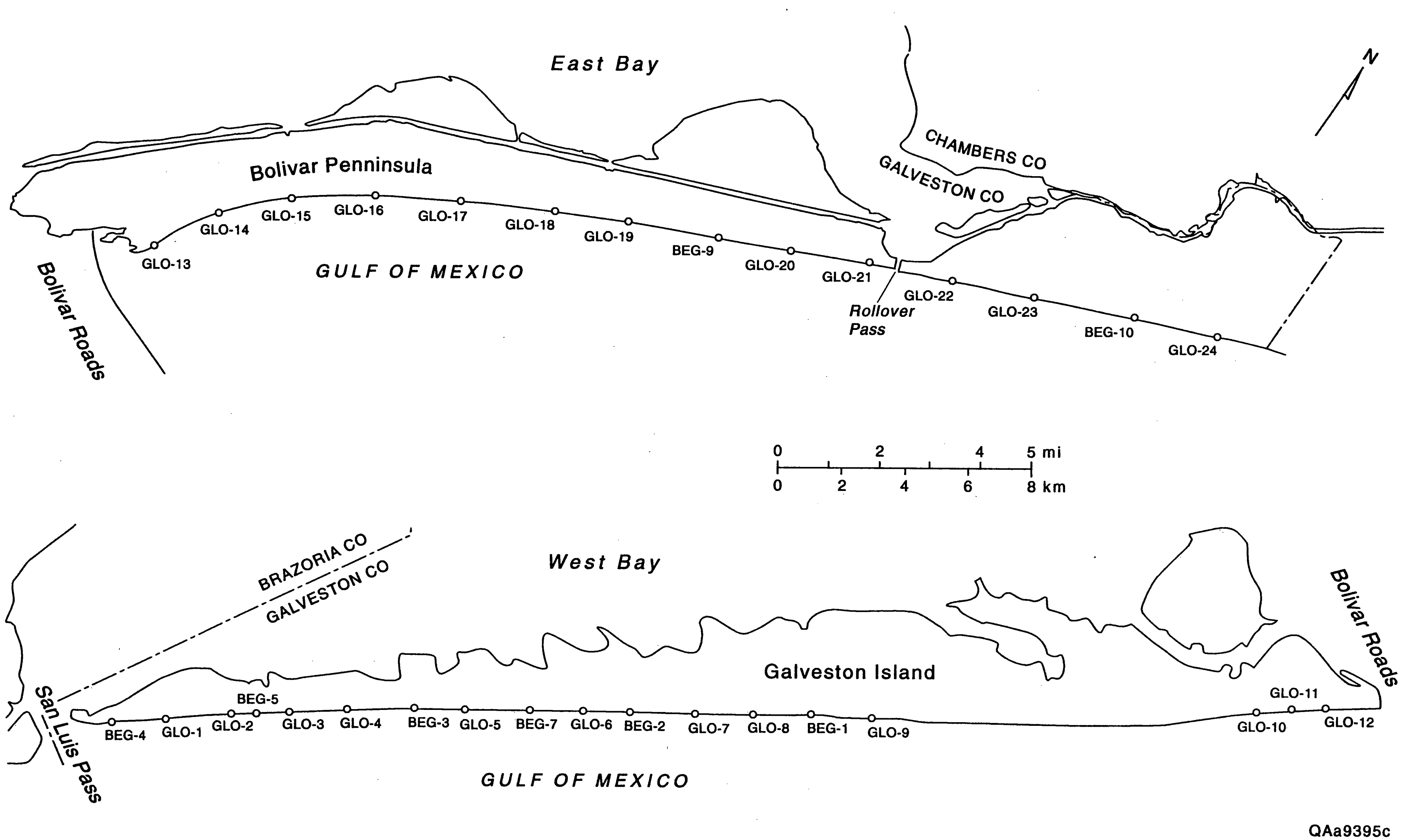

Figure 1. Locations of beach and dune transects, Galveston County, Texas. BEG=Bureau of Economic Geology transects established in 1983, GLO=General Land Office profiles established in 1994.

Table 1. Beach and dune profiles arranged in geographical order from San Luis Pass to High Island, Galveston County, Texas. The index of human impact (Indx.) is defined in Table 3.

Profile	Indx.	Profile	Indx.	Profile	Indx.
BEG-4 (San Luis Pass)	0	GLO-7	5	GLO-17	3
GLO-1	0	GLO-8	3	GLO-18	3.5
GLO-2	2	BEG-1 (Tower base)	4	GLO-19	4
BEG-5 (Terramar)	3	GLO-9	2	BEG-9 (Caplen)	0
GLO-3	2	GLO-10 (East Beach)	3	GLO-20	3
GLO-4	3.5	GLO-11 (East Beach)	3	GLO-21	3
BEG-3 (Sea Isle)	4	GLO-12 (East Beach)	3	GLO-22	3
GLO-5	3	GLO-13 (Bolivar Flats)	1	GLO-23	4
BEG-7 (Jamaica Beach)	3	GLO-14	3	BEG-10 (High Island)	3
GLO-6 (Gal. Is. St. Park)	1	GLO-15	4	GLO-24	4
BEG-2 (Gal. Is. St. Park)	1	GLO-16	3		

employed whereby changes in beach and dune morphology (elevation and slope) are used to determine survey stations, otherwise measurements are made about every 25 or 30 ft along the profile where there are no abrupt changes in slope.

In the raw data columns (Appendix B), the origin (0,0) is the instrument station. The top of the stake and the bottom of the stake are also recorded in the raw data columns. The stake locations can be identified in the raw data columns from the annotations and by looking for adjacent readings with essentially the same horizontal position. The height of the stake above the ground surface can be calculated by subtracting the top and bottom measurements. The height of the top of the stake was removed from the corrected data (X CORR, Y CORR) to prevent plotting of an erroneous topographic feature. Most of the plotted profiles (Appendix A) originate at the stake (adjx, adjy) because it is the only physical feature in the field that is stable and can be recovered using field descriptions or GPS coordinates.

Each profile was taken to the maximum wading depth, which is about -5 ft. During the surveys, profiling conditions were nearly ideal. The wind was calm, waves were very low, and water levels in the Gulf of Mexico were low. Under these conditions, measurements were made farther into the Gulf than under normal conditions of higher waves and water levels.

Absolute elevations are unavailable for any of the beach and dune profiles. Approximate elevations have been determined for the BEG profiles based on elevations from nearby benchmarks. Because the GLO profiles are referenced to the datum stake, the heights shown on the illustrations (Appendix A) are only relative elevations. Dune elevations stated in the text were estimated by observing the height of the dunes above the backbeach and assuming a backbeach elevation of about 3 ft. Surveys conducted by the Corps of Engineers and the BEG with vertical control established by bench marks show that the backbeach elevation is consistent along Galveston County beaches because sand size and wave heights are uniform.

Global Positioning System Surveys

State-of-the-art, geodetic-quality multichannel Global Positioning System (GPS) receivers were used to obtain precise positions of the dune protection line and vegetation line along each beach and dune transect of Galveston County. The GPS rover antenna collected data for at least 20 minutes at flags placed along each transect to mark the dune protection line and vegetation line. The GPS receivers recorded phase and range data every five seconds. The positions for the dune protection line and vegetation line were estimated from all data recorded during the 20 minute occupations. The GPS positions were converted to state plane coordinates (Appendix C) to facilitate entry into ARC/INFO, the NRI geographic information system.

A combination of static and rapid-static GPS surveys were conducted to provide geodetic control for all beach profiles. The reference station during surveys of Galveston Island and Bolivar Peninsula was the Texas Department of Transportation Regional Reference Point (RRP) at Houston, Texas. The coordinates of the Houston RRP were held fixed and the positions of five base stations (three on Galveston Island and two on

Bolivar Peninsula, Table 2) were estimated with respect to the RRP for each day of the survey. Selected points on each beach profile were occupied by a mobile GPS receiver and the position of these beach profile points were, in turn, estimated with respect to the base station. The GPS field work was conducted using two Trimble 4000SSE GPS receivers.

Table 2. List of survey dates, base station locations, and beach profiles surveyed in Galveston County.

Date	Base station	Beach Profiles Surveyed
09 Sept. '94	Galveston State Park *M460, 1951*	no profiles surveyed
10 Sept. '94	Galveston State Park	BEG-03 BEG-07 GLO-05 GLO-06
11 Sept. '94	*M460, 1951*	BEG-04 GLO-01 GLO-02 GLO-03 GLO-04
12 Sept. '94	GLO-10 datum stake	GLO-10 GLO-11 GLO-12
13 Sept. '94	Galveston State Park	BEG-01 BEG-02 GLO-07 GLO-08 GLO-09
24 Sept. '94	GLO-17, GLO-23	no profiles surveyed
25 Sept. '94	GLO-17 datum stake	BEG-09 GLO-13 GLO-14 GLO-15 GLO-16 GLO-19
26 Sept. '94	GLO-23 datum stake	BEG-10 GLO-20 GLO-21 GLO-22 GLO-23 GLO-24
27 Sept. '94	GLO-17 datum stake	GLO-17 GLO-18

Methods

Static Surveys (Base Stations)- The Galveston Island and Bolivar Peninsula GPS surveys were conducted using identical techniques: a static solution was estimated for each stationary base station with respect to the Houston RRP, and then a rapid-static solution was estimated with respect to the base station for points on the transect surveyed by a mobile receiver.

Table 2 shows the base station used for each day and the beach profiles surveyed relative to that base station. Three of the base stations were the datum stakes at beach profiles GLO-10, GLO-17, and GLO-23. One base station was the National Coast and

Geodetic Survey benchmark *M460, 1951* located near San Luis Pass on Galveston Island. The fifth base station was the top of a plastic cap installed on a concrete pillar located on the Galveston State Park parking area. The position of this base station was known from previous GPS surveys in the park (Morton, et al., 1993).

The position of each base station was estimated using GPS data recorded at the base station and the Houston RRP. The coordinates for the Houston RRP were held fixed while the coordinates of the base station were estimated using the National Geodetic Survey's OMNI software. All base stations, except for GLO-10, were occupied by GPS at least twice. GLO-10, on Galveston's East Beach, was occupied for just one day so there is only a single daily solution for this station. In addition, because of technical difficulties, data from the Houston RRP was not available for 10 September therefore no base station solution is available for Galveston State Park on that day. If the base station was occupied more than once then a weighted average of the daily solutions was used to compute the final base station position.

The overall RMS of fit to the GPS data, a direct measure of precision, varied between 2 cm for the Galveston State Park base station and less than 1 cm for GLO-17 and GLO-23 on Bolivar Peninsula (Table 2). Why the RMS for the Bolivar Peninsula base stations should be consistently lower than the Galveston sites, especially the State Park is unknown. Weather may contribute; tropospheric variability during the observation session may be hard to model with a single tropospheric scale height for the entire session. Weather during the Galveston survey was certainly more unstable than during the Bolivar survey. Multi-pathing may also be a factor. The station with the highest RMS is Galveston State Park, where the static receiver was located in a parking area. The paved parking surface may be significantly more reflective than the vegetation covered surfaces encountered at other stations.

Rapid Static Surveys- The rapid-static method was used to estimate the position between the base station and the mobile receiver that occupied selected points on each beach profile. The mobile or "rover" receiver was carried in a backpack and powered by a small 12 volt battery and the rover antenna was mounted on a 6-foot range pole. The operator carried the receiver and antenna along the beach profile and placed the range pole over the survey point. A bipod and spirit level on the range pole allowed the operator to stabilize the antenna directly over the survey point.

The dune protection line and the vegetation line on each profile were occupied by GPS except for BEG-9 (Caplan) and BEG-5 (Terramar). On BEG-9 the datum stake was occupied, but not the dune protection line. On some Galveston Island profiles, additional points were occupied, such as the dune crest. Each GPS survey point was typically occupied twice by the GPS rover. During each occupation, at least ten minutes of GPS data was collected at the sampling rate of 5 sec (the base station also recorded at a 5 sec sampling rate). The two occupations were separated by at least ten minutes to allow the GPS satellites to change position. Two ten-minute occupations, ten minutes apart was considered a minimum requirement that would allow a precise solution to be estimated with as few as four satellites visible.

The rapid-static data were reduced with the National Geodetic Survey's OMNI software version 2.10. Version 2.10 instead of version 3.22 was used because the more recent version does not have kinematic nor rapid-static capabilities. To minimize the effects of multi-pathing and tropospheric refraction, all data below an elevation of 20° were discarded. In addition, no rapid-static surveys were conducted over a distance greater than 10 km from a base station.

Results

The GPS solutions provided the x, y, and z coordinates of each survey point relative to the center of the earth in an earth-fixed reference frame. These x, y, and z coordinates were transformed to latitude, longitude, and height above the WGS-84 ellipsoid using an algorithm created by Dr. Clyde Goad at the National Geodetic Survey (NGS). The latitude and longitude were in turn converted to State Plane coordinates using Trimble's PFinder GPS software. The NAD27 datum and the Clarke 1866 ellipsoid were used in the state plane coordinate transformation. The coordinate units used were "survey feet."

We were able to extend geodetic control over a large area in a relatively short time using a combination of static and rapid-static GPS techniques. The horizontal and vertical position of each survey point on Galveston Island and Bolivar Peninsula is precisely located relative to the Houston RRP. Because of time constraints, none of the rapid-static surveys were repeated. Therefore the true precision of these points are unknown. However, comparisons between the relative heights of points measured by both GPS and the total station agree within 1-3 cm. The static surveys show a baseline repeatability of ± 1-2 cm. These internal verifications indicate that the precision of the combined static and rapid-static surveys should be about ± 2-3 cm in the horizontal dimension and about ± 3-5 cm in the vertical dimension.

DUNE TYPES AND FUNCTIONAL RELATIONSHIPS

The functional relationships and criticality of dunes at a particular site are determined by three interrelated factors (White et al., 1978). The first factor is the physiographic setting of the site; whether it is a barrier island or some other coastal landform such as a mainland beach. The second factor involves dune characteristics such as dune height and width, amount and type of dune vegetation, and the continuity, orientation, and location of dunes with respect to the Gulf shoreline, washover channels, blowouts, and other features that influence the formation and stability of dunes. The third factor involves the types of dunes present and their response to storm flooding. The dune types and their functional relationships help establish general guidelines for the kinds of human activities that can occur at a site considering the expected extent of storm flooding and washover.

Different types of dunes serve different functions in protecting coastal developments as well as the natural environment.

Physiographic Setting

Coastal dunes of the Texas Gulf shore are directly related to sand supply and shoreline stability. Where sand supply is abundant and the shore is stable, dune fields are extensive and individual dune complexes are large. Where sand supply is minor and the beach is eroding, dunes are sparse or absent.

The dunes of Galveston County encompass a broad spectrum of conditions. At some sites there are moderately large dune ridges containing enough sand to minimize hurricane damage. At other sites, dunes are absent where beach retreat is rapid and the landward limit of the backbeach coincides with an erosional escarpment. Considering the entire Texas coast, Galveston Island and Bolivar Peninsula are relatively stable barriers that receive variable amounts of sand. In contrast, the mainland Gulf shore between Rollover Pass and High Island is an erosional headland where dunes are poorly developed. All along the upper Texas coast, there is sufficient rainfall to promote the rapid growth of vegetation that stabilizes the dunes. Consequently, most of the dunes are densely vegetated, and mounds of sand placed in the backbeach after beach scraping are quickly vegetated.

Dune Characteristics

Dune characteristics are the fundamental attributes that together define the different dune types. The physical attributes of the dunes include lateral continuity, sand volume, orientation, density of vegetation, and location. By using this checklist of attributes, dune types can be determined at any coastal site.

Lateral continuity of the dunes parallel to the beach is an important characteristic. This is because a continuous dune ridge can block rising storm waters, thus protecting back-island areas from hurricane surge and washover more effectively than do discontinuous dunes. A high, continuous dune ridge with discontinuous dunes seaward offers the best protection against storm erosion and flooding. If the discontinuous hummocky foredunes are extensive, they can dissipate storm waves and currents before they reach the continuous dune ridge.

Dunes oriented with their long axis parallel to the shoreline are most effective in blocking high storm waters and sheltering back dune areas from high winds. Discontinuous longitudinal dunes with their long axis perpendicular to the shore can actually funnel storm surge into interdune areas.

Dune height and width together determine the volume of sand stored in the dunes above the backbeach. Dune height is an indicator of how effective the dunes will be in preventing storm overwash. Records compiled by the Galveston District Corps of Engineers indicate that hurricane surge rarely exceeds 15 feet along the Texas coast. Therefore, dunes less than 12 ft high are vulnerable to complete destruction in a major storm. Dune height alone is insufficient for complete protection because the dunes are subject to erosion. Therefore, the total volume of sand stored in the dunes is an important consideration at each coastal site. The degree of protection is directly related to the volume of sand. High, wide dunes are much more effective as storm barriers than are low, narrow dunes.

The amount of vegetative cover is another basic dune attribute. Surface vegetation acts as a baffle that traps blowing sand and the extensive underground root systems of dune grasses act as binding agents to retard the movement of loose sand exposed to erosion by wind and water. Both vegetated and barren dunes serve important functions. Along some beach segments, the only dunes present are unvegetated blowout dunes that are critical to protecting inland areas. Although both vegetated and unvegetated dunes are important, vegetated dunes are more desirable because of their greater stability.

Dune location with respect to the Gulf shoreline is a consideration because dunes far from the water are generally less vulnerable to storm attack than those close to the water. The increased distance from the Gulf also affords a greater area for wave and current dissipation before storm waters reach the dune ridge. Dunes located near washover channels and beach access roads can be severely eroded during high storm flooding.

Dune Types

An idealized profile of a sandy barrier island illustrates the various dune types and their spatial arrangement (fig. 2). There are six major dune types present along the Texas coast. Beginning at the backbeach and progressing landward they are: (1) low unvegetated or sparsely vegetated coppice mounds, (2) hummocky, discontinuous vegetated foredunes, (3) continuous vegetated foredune ridge, (4) active dunes and blowouts, (5) stable blowouts, and (6) back-island dunes.

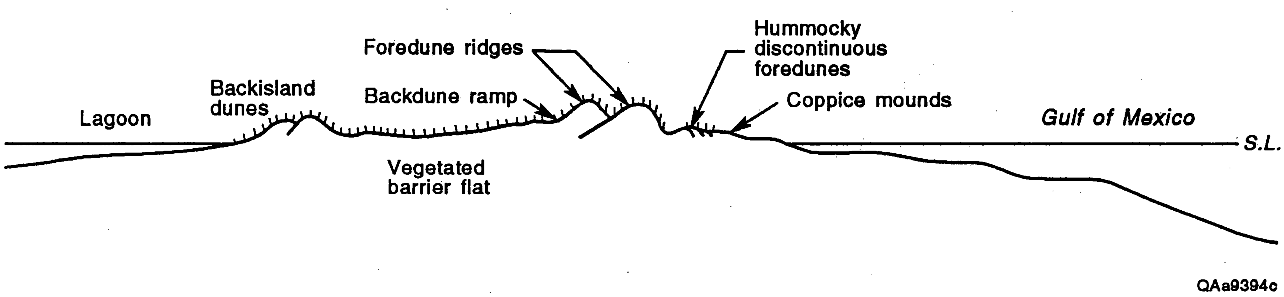

Figure 2. Generalized barrier island profile showing the locations of different dune types. Modified from White et al., 1978.

Coppice mounds represent the initial stage of dune formation and are a source of sand that can be exchanged with the beach during storms. They form by accumulation of sand on the downwind side of vegetation or other small irregularities on the beach. In their latter stages of development, they enlarge and merge to form low, hummocky isolated dunes. Coppice mounds are generally absent from the beaches of Galveston County because of beach traffic and beach maintenance.

Discontinuous vegetated foredunes commonly form landward of the coppice mounds and seaward of the foredune ridge. They represent the second stage in the evolution of dune types. In Galveston County, they attain heights of about 10 ft above sea level.

During storms, waves and currents erode the upper beach, coppice mounds, and discontinuous foredunes, transporting the sand offshore where it is stored temporarily on the shoreface. By producing a wide lowered beach, wave energy is dissipated over a broad area. Although the dunes may be obliterated by storm erosion, the sand is transferred to the beach and shoreface to compensate for the high wave energy. The discontinuous hummocky foredunes also dissipate wave and current energy by offering resistance to the flow of water across the area between the beach and foredune ridge.

The continuous foredune ridge is capable of blocking most storm surges and preventing inland penetration of washover into the back-island area. Landward of the foredune ridge is a backdune ramp that slopes down and merges with the vegetated barrier flat. Storm waters can breach the dune ridge where it is weakened either by devegetation or deflation, or where roads or paths have been cut through the dunes. Continuous foredune ridges are present along some segments of Galveston Island and Bolivar Peninsula.

Active dunes and blowouts form where the foredunes are weakened and unstable sand migrates landward. Eventually the blowout may become so large that the active dunes detach from the foredunes and migrate across the island. When the blowout enlarges and the dunes detach, the deflation flat formed at the base of the dune ridge is a potential washover channel and site for breaching of the foredune ridge. Currently there are no large active dunes and blowouts in Galveston County. On East Beach, dune ridges and isolated hummocky dunes located far inland from the foredunes are remnants of foredunes that were preserved when the beach accreted.

Stable blowouts are hummocky, vegetated surfaces found landward of the foredunes that are remnants of active blowouts and deflation flats. The blowouts are stabilized by vegetation that covers the surface of the sand and prevents further migration. However, the stable blowouts may become reactivated if the stabilizing vegetation is weakened or destroyed. Currently there are no stable blowouts in Galveston County.

Back-island dunes, as the name implies, are located in the back-island areas of barrier islands (fig. 2). They form there as a result of migration across the barrier, normally during severe droughts. There are no back-island dunes in Galveston County.

Ordinal Ranking of Dunes

Assessments of dune criticality should be based not only on the physiographic setting, dune characteristics, and types of dune present, but also on the function that the dunes serve. To state that continuous dunes are more critical than discontinuous dunes is misleading because each serves a different function. If only discontinuous dunes are present, then clearly they are the most critical dunes that provide protection and therefore require preservation from any human activities that would alter their function or cause their destruction.

Dune types on or near the beach are ranked according to their function and the role each type plays with respect to the other dune types:

1. High continuous foredune ridge.
2. High discontinuous foredune ridge.
3. Low continuous foredune ridge.

4. Low discontinuous foredune ridge.

5. Vegetated coppice mounds

6. Barren coppice mounds.

The relative ranking of dunes varies according to location on the coast and the specific conditions that prevail at any particular time and place. As presented here, the ordinal ranking of dunes is idealized and contains all the possible dune types observed along the Gulf shoreline. The entire ranking is most applicable to the south Texas coast where there is abundant sand supply and the semi-arid climate promotes eolian processes and the accumulation of wind-blown sand (White et al., 1978). Nevertheless, the ranking is easily adapted to any setting along the coast where dunes are present.

RECENT HISTORY OF DUNE DEVELOPMENT, GALVESTON COUNTY

In 1961, an extremely large and intense hurricane (category 4) named Carla caused severe property damage and beach erosion all along the Texas Coast. Hurricane Carla obliterated the foredunes of Galveston County, and the Carla erosional escarpment can still be observed at numerous sites on West Beach of Galveston Island and at a few sites on Bolivar Peninsula. Aerial photographs taken by the U. S. Coast and Geodetic Survey immediately after Carla show the damage inflicted on the dunes. After Carla, vehicular traffic, beach maintenance, and public recreation did not prevent reformation of the dunes or advancement of the vegetation line in either developed or undeveloped areas of Galveston County where the beach is relatively stable (Morton and Paine, 1985).

High waves and backbeach flooding associated with hurricanes in 1980 (Allen) and 1983 (Alicia) again destroyed the dunes on Galveston Island and damaged those on Bolivar Peninsula. After Hurricane Alicia, the most recent storm, several different techniques were used to construct artificial dune ridges along the Gulf beaches of Galveston County (Morton and Paine, 1985). One technique involved lining the backbeach with sand fences that create wind shadows causing deposition of wind-blown sand and forming low, unvegetated sand ridges parallel to the beach. Another technique involved placement of bundled Christmas trees and other debris on the backbeach to trap sand blown landward by prevailing winds. By themselves, these techniques have not added substantial volumes of sand to the dune system, but they have contributed some sand when combined with other techniques that add much larger volumes of sand to the foredune complex.

Post-Alicia artificial dune ridges were constructed along segments of Jamaica Beach, Acapulco Village, Sea Isle, and Terramar subdivisions on Galveston Island and at scattered localities on Bolivar Peninsula. In these areas, heavy equipment (dump trucks, front-end loaders) was used to construct linear sand ridges about 6 ft wide at the base and 2 ft above the beach surface (Morton and Paine, 1985).

Artificial dunes composed of loose sand offer some immediate protection from abnormally high tides, but they are vulnerable to wave attack. Another disadvantage of artificial dunes is their tendency to prevent aggradation of the backbeach if they are constructed seaward of and separated from the vegetation line. During post-storm recovery, elevations of the backbeach normally are raised by minor flooding and sand deposition, but the area between the vegetation line and an artificial dune ridge remains a topographic low that ponds water. Artificial dune ridges at Sea Isle and Terramar caused this type of interference with backbeach recovery (Morton and Paine, 1985).

Artificial dunes that offer the greatest resistance to erosion achieve their height by enlarging in concert with plant growth. These dunes have a network of roots that minimize erosion. The erosional resistance of planted experimental dunes was demonstrated by Dahl and others (1982) along north Padre Island after Hurricane Allen.

During periods of low storm frequency, eolian processes can deposit substantial volumes of sand along the backbeach as both natural and artificially nourished dunes.

This accumulated sand has buried low concrete and wooden bulkheads, fences, and posts that subsequently have been uncovered by Hurricane Alicia or other major storms.

Construction of dunes and advancement of the vegetation line are enhanced by increasing backbeach elevation, blocking eolian sand transport, changing backbeach morphology, planting native dune vegetation, and watering and fertilizing the plants. Gulf-front property owners along West Beach of Galveston Island used these techniques to artificially reestablish a vegetation line near its pre-storm position or to promote its recovery. Nearly 80% of the beach front lots with buildings were filled and sodded after Hurricane Alicia (Morton and Paine, 1985). Artificial sand dunes built with heavy equipment or created by beach maintenance changed the backbeach shape and raised the land surface. Native grasses either planted or growing naturally on these sand mounds have flourished making it difficult to distinguish between artificial and natural dunes without close examination.

Widespread manipulation of the backbeach and vegetation line were observed after Alicia in developed areas and were detected by comparing beach width and beach shape in developed and adjacent undeveloped areas (Morton et al., 1994). Measurements at unaltered lots within subdivisions showed that artificial dunes, sand fences, and other obstructions were placed 75 to 130 ft seaward of the natural post-storm vegetation line. In some areas, such as Sea Isle subdivision, these modifications covered about half of the beach width (Morton and Paine, 1985).

Immediately after Hurricane Alicia, manipulation of the dunes and vegetation line were restricted to developed areas, but during the past 12 years, the dunes and vegetation line along most of the Galveston County Gulf beaches have been altered by scraping and dumping activities (fig. 3).

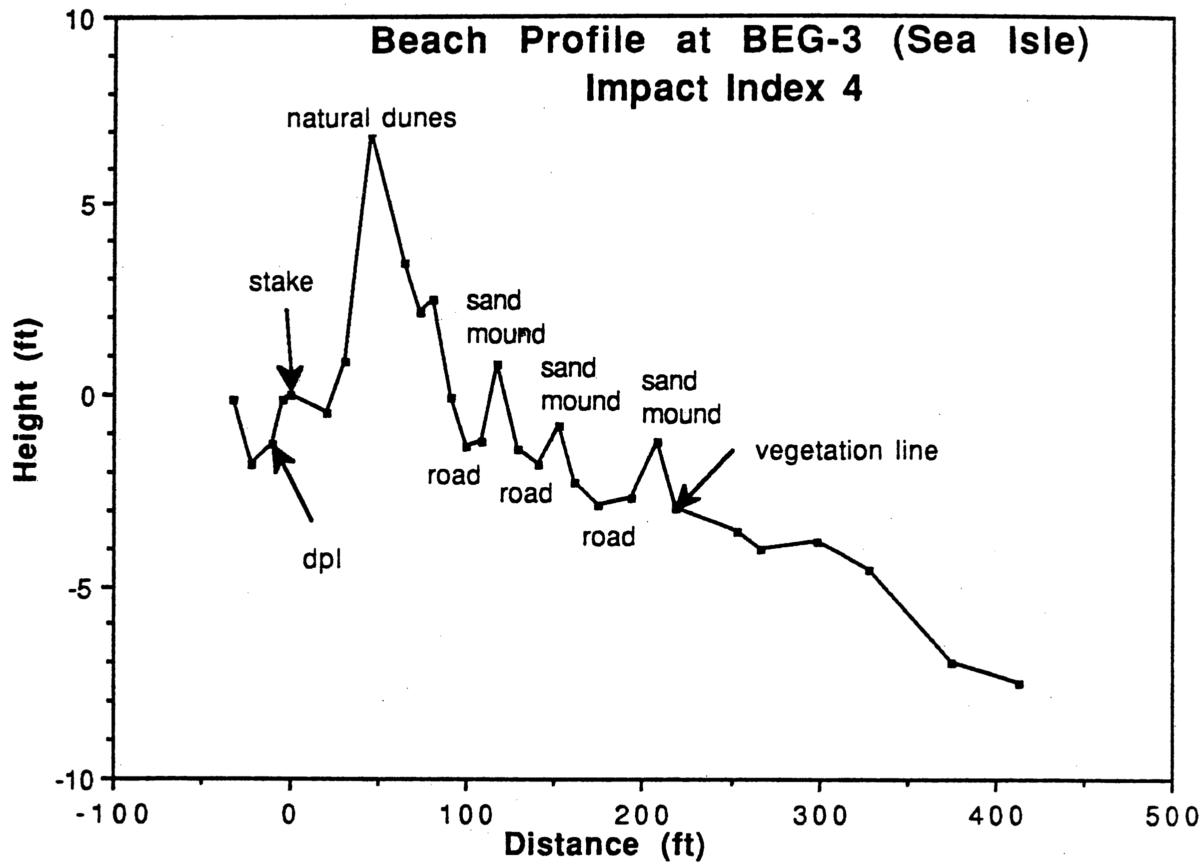

Figure 3. Beach and dune profile at BEG-3 showing substantial modifications to the dune system caused by beach maintenance activities. The high natural dunes formed after Hurricane Alicia. Subsequent construction of sand mounds seaward of the backbeach road and episodic seaward movement of the road and sand mounds have resulted in major modifications to the backbeach and dune system.

HUMAN MODIFICATION OF DUNES

Public Beach Access and Dune Alterations

The preceding discussion emphasizes the function and importance of foredunes in geological processes and natural hazards. Equally important is an understanding of alterations in the natural beach-dune system as a result of increased use of the beach. Little has been done to prevent adverse effects of beach maintenance and vehicular traffic because of a lack of scientific data documenting the adverse impacts. During the past 50 years, beach traffic and maintenance have increased from only occasional occurrences with no lasting adverse effect on the dunes to practically continuous use and maintenance with possible unforeseen impacts on dune stability.

Unique political and social conditions in Texas permit easy vehicular access to many of the Gulf beaches. Although beach access is controlled, the amount of traffic up and down the beach is not controlled except in certain densely populated areas. In Texas, increased demands for beach recreation partly translates to increased beach traffic.

From field observations and beach profiles (Appendix A) it is apparent that beach scraping and vehicular traffic along the backbeach prevent the formation of coppice mounds and thus eliminate most of the sparse vegetation. Prevention of natural sand accumulation and concomitant decreases in backbeach elevation enhance erosion of the foredunes by lower storm surges. Furthermore, a given storm will probably cause greater damage to the dunes because of the increased erosion that results from eliminating the reserve of sand provided by the coppice mounds.

The beaches of Galveston County are scraped frequently to remove the natural accumulation of seaweed and other debris that wash ashore from the Gulf. The sand and debris scraped from the beach is usually placed just seaward of the natural dunes or in low interdune areas. Beach cleaning can create artificial dunes and cause unnatural advancement of the vegetation line. These activities can redistribute substantial volumes of sand on the beach. Some of the post-Alicia dune development and accumulation of sand attributed to sand fences and natural accumulation partly reflect the beach cleaning activities.

Cars typically drive on the dry beach between the berm crest and the dunes, whereas beach scraping typically is concentrated between the water line and the dunes. Together beach traffic and beach maintenance partly control the position of the dunes and vegetation line. If the dunes are eroded by a major hurricane, beach traffic and cleaning following the storm can slow or prevent post-storm dune recovery and natural seaward advance that normally follows. In that case the beach activities would artificially maintain the dunes and vegetation line in a more landward position. This impact of human activities on the dune system can be observed at Malaquite Beach, Padre Island National Seashore on adjacent beaches with and without beach traffic.

Ranking of Human Impacts

The "Index of Human Impact on Dunes and Vegetation" (Table 3) is a conceptual classification that ranks the degree to which the beach and foredunes have been modified by human activities. The ranking is based on physical criteria such as (1) width of the area impacted, (2) type of fill and consistency of the fill material with the natural dune system, (3) ratio of trash to sand in the fill, (4) total volume of the fill, and (5) the degree of profile alteration. The classification scheme was developed to provide a basis for distinguishing natural dunes from vegetated or barren sand piles containing trash and other beach debris. The classification can be applied to any coastal segment and it is not restricted by geographic area. The classification was used to grade all beach profile sites from San Luis Pass to High Island as part of the GLO/NRI dune surveys conducted in September, 1994.

Table 3. Index of human impact on dunes and vegetation.

Index	Description
0	No visible impact of beach scraping or evidence of backbeach dumping. Dune morphologies and plant communities are natural. Essentially no modification of beach and dune profile.
1	Low, small-volume mounds of sand containing some minor beach trash such as *Sargassum*. Trash represents less than 20% of mound volume. Altered zone is narrow relative to the entire beach width.
2	Low, small-volume mounds of sand and some minor beach trash such as *Sargassum* and small pieces of wood. Trash represents less than 33% of mound volume. Altered zone is narrow relative to the entire beach width.
3	Moderately large mounds of sand at least 3 ft high. Mounds composed of approximately 33% trash including moderately large pieces of wood or other debris. Several rows (2-3) of modified dunes or sand mounds. Altered zone is moderately wide relative to the entire beach width.
4	Moderately large mounds of sand greater than 3 ft high. Mounds composed of more than 33% trash. Multiple rows of modified dunes or sand mounds forming moderately wide zone relative to the entire beach width. Modified area may include bypass zone(s) representing former backbeach road(s).
5	Large mounds of sand up to 6 ft high. Mounds composed of as much as 50% trash containing large logs, cut wood, tires, appliances, and concrete or other rubble. Multiple rows of modified dunes or sand mounds forming wide zone relative to the entire beach width. Modified area may include bypass zone(s) representing former backbeach road(s).

The 1994 beach and dune topography at BEG profile 3 (undeveloped segment northeast of Sea Isle) was annotated from field observations at the time the survey was conducted (fig. 3). There is a broad zone of backbeach area that has been "removed" from the public beach by massive manipulation of the backbeach topography. The line of vegetation covering the sand piles formed by beach scraping is about 115 ft seaward of the toe of natural dunes that formed after Alicia. The survey indicates that each successive sand-pile ridge is lower and farther seaward from the succeeding ridge. It appears that this may be an attempt to bring the modified vegetation line to the same position on the undeveloped beach as the artificial vegetation line seaward of the houses at Sea Isle. This is only one of many examples where the foredunes and position of the vegetation line are artificially controlled by beach cleaning activities.

At most profile sites, there are close correlations among development density, beach stability, and the impact index of beach and dune modification. Impact indices generally are low where the beach segment is undeveloped and the beach is retreating. At those sites there is little pressure to clean the beach, and the backbeach is narrow and incapable of preserving sand piles placed there in conjunction with beach cleaning. Examples of this are at profiles BEG-4 to GLO-3 (Table 1). There are several examples of low impact indices where erosion is minor or the beach is stable. Beaches are scraped infrequently at Galveston Island State Park (GLO-6 and BEG-2), consequently, the impact index is low. The impact index is also low at BEG-6 and GLO-13 because these beach segments are far from any residential development. Impact indices generally are high where the beach is stable or accreting and the beach is so wide that several rows of sand piles and intervening abandoned roads are preserved on the former backbeach (fig. 3). Good examples of this setting are at BEG-3, GLO-7, and GLO-11. Exceptions to this relationship are found at GLO-23 and 24 (Appendix A) where the beach is eroding, but the sand and shell piles pushed up on the backbeach dominate the beach morphology.

The cumulative impact of beach cleaning activities in Galveston County is reflected in the distribution of impact indices. Of the 32 profile sites, only 9 sites have rankings of 2 or less, whereas 23 sites have impact rankings greater than 3 (Table 1). The low impact rankings are uniformly distributed with three each. The most common levels of beach and dune impact are 3 and 4 (Table 1), which indicates significant human alterations to the backbeach and dune morphologies all along the shore.

DISTRIBUTION OF DUNE TYPES, GALVESTON COUNTY

Dune development is limited in Galveston County because of the relatively high annual rainfall and limited supply of sand to Gulf beaches. The climate is the most significant limiting factor as demonstrated by the lack of high dunes even where sediment supply is abundant. East Beach on Galveston Island and Bolivar Flats on Bolivar Peninsula receive so much sand that the beach is either stable or accreting. Despite the abundant supply of sand, the dunes of both beach segments are no more than 11 ft high. The highest natural dunes in Galveston County are located along the undeveloped segment of West Beach northeast of the Sea Isle subdivision (fig. 3).

The Gulf beaches of Galveston County offer a spectrum of natural and humanly altered conditions (Appendix A). At one extreme are beach segments where there is no visible evidence that the beach morphology has been altered by vehicular traffic or beach cleaning operations. On the other extreme are long beach segments in subdivisions and in undeveloped areas where the highest accumulations of sand in the backbeach are almost entirely an artifact of human activities.

The following account describes the dunes along the Gulf shore between San Luis Pass and High Island (Appendix A). At the southwestern end of Galveston Island (BEG-4), the highest elevations near the backbeach of about 10 ft are associated with a washover terrace constructed during Hurricanes Carla and Alicia. Discontinuous and sparsely vegetated dunes with a maximum elevation of about 8 ft are forming seaward and below the post-Alicia erosional escarpment. To the northeast, from GLO-1 to GLO-3, the dunes are low, discontinuous, and poorly developed. Maximum elevations of the dune crests range from about 7 to 11 ft, and maximum elevations and dune development generally decrease to the northeast. At Terramar and Sea Isle subdivisions, the vegetated sand mounds forming the seaward edge of the developed lots are almost entirely artificial. These densely vegetated sand mounds were largely constructed by filling the lots, constructing sand ridges with heavy equipment, and placing sand fences on the ridges to increase their mass and elevation (Morton and Paine, 1985).

A moderately high, continuous, densely vegetated foredune ridge has formed naturally since Hurricane Alicia along the undeveloped beach northeast of Sea Isle. The dune ridge is the highest and most continuous dune complex on Galveston Island, and is typified by profiles at GLO-4 and BEG-3 (fig. 3). These dunes rise about 12 ft above the backbeach and have maximum elevations of about 15 ft.

Natural post-Alicia dunes in the vicinity of GLO-5 are about 10 ft high, continuous, and densely vegetated. The natural foredunes also have been supplemented with several rows of large vegetated sand mounds containing abundant wood. The zone of sand mounds seaward of the foredunes is about 75 ft wide. A zone of vegetated sand mounds also occupies the seaward edge of lots in the Indian Beach, Acapulco Village, and Jamaica Beach subdivisions.

A narrow, continuous, densely vegetated natural foredune ridge has formed along the Gulf beach of Galveston Island State Park. These post-Alicia foredunes, which have maximum elevations of about 10 ft, have been supplemented with low, vegetated sand mounds derived from beach scraping. The low dunes and sand mounds in the park are illustrated at GLO-6 and BEG-2.

The low vegetated sand mounds along the seaward edge of the Pirates Beach subdivision are almost entirely artificial, and were constructed after Hurricane Alicia in a manner similar to the artificial dunes in other subdivisions on West Beach. Just northeast of Pirates Beach at GLO-7, the backbeach morphology has an impact index of 5 because the hummocky zone seaward of the Alicia escarpment is composed almost entirely of dumped trash (logs, tires) and several rows of large sand mounds and debris. The zone is about 100 ft wide and maximum elevations of the sand mounds are about 9 ft.

The rows of low, vegetated sand mounds along the seaward edge of the Bermuda Beach subdivision are mostly artificial. They were formed by the same dune construction activities that occurred in the other beach-front subdivisions after Hurricane Alicia. At GLO-8, which is an undeveloped beach segment just northeast of Bermuda Beach, a narrow natural dune ridge about 10 ft high has formed. Seaward of the dune ridge is a hummocky zone of sand mounds containing some wood and other beach debris. The piles of sand and debris were placed in the backbeach in conjunction with beach cleaning operations.

Continuous beach erosion have prevented the formation of large foredunes at BEG-1 and GLO-9. Some wind blown sand has accumulated above the Alicia erosional escarpment (Morton and Paine, 1985), and the elevation of the narrow natural foredune ridge is about 11 ft.

The profiles at GLO-10, 11, and 12 show that the foredunes on East Beach are variable in height and in the degree of human modification. The natural foredunes are narrow, moderately continuous, densely vegetated, and range in height from 8 to 11 ft. Beach cleaning activities have created several rows of large sand mounds containing wood and other beach debris. The substantial alterations to the backbeach, which have artificially advanced the vegetation line, have an impact index of 3.

On the southern end of Bolivar Peninsula (GLO-13), the natural foredune ridge is narrow and about 10 ft high. The broad zone of low, sparsely-vegetated hummocks between the foredune ridge and barren backbeach is a product of long-term beach accretion (Paine and Morton, 1989). The accumulation of sand at the berm crest and on the forebeach has prevented the formation of large dunes despite the surplus of sand supplied to the beach. The impact index is low (1), and with the exception of this site, all the other beach segments on Bolivar Peninsula have impact indices of 3 to 4.

Backbeach and dune morphology are similar along the undeveloped beach segments represented by GLO profiles 14-17. At all four sites the foredunes are narrow, densely vegetated and separated from the barren backbeach by a zone of vegetated sand mounds produced by beach cleaning activities. Heights of the natural foredunes rise from 8 ft at GLO-14 to 11 ft at GLO-17. The total volume of sand in the foredune complex consisting of natural eolian accumulation and beach scraping also is greatest at GLO-17.

The profiles at GLO-18 and GLO-19 are within developed beach segments and they both exhibit similar characteristics. The backbeach is substantially altered by the artificial construction of sand mounds containing abundant beach debris. The multiple rows of sand mounds are covered by moderately dense vegetation except the most recent mounds, which are barren. The mounds are about 9 ft high at GLO-18 and only about 7 ft high at GLO-19. The impact indices at these two sites are 3.5 and 4.0 because most of the elevated sand accumulation is the result of beach maintenance operations.

The beach profile at Caplen (BEG-9) is unique in its morphology and recent history. The highest elevations, which are about 10 ft, are associated with the barrier flat. An erosional escarpment formed in 1961 by Hurricane Carla, separates the barrier flat from the vegetated hummocky zone of eolian sand. This undeveloped beach segment contains abundant shell material and has a high backbeach elevation, consequently the impact of beach scraping is insignificant.

The profile at GLO-20 reflects overwash processes and long-term beach erosion. The beach is narrow and steep, and it is composed mostly of oyster shells. The highest elevation above the washover ramp coincides with a low mound of eolian sand. A few low sand mounds of beach trash form the landward edge of the backbeach.

The profile at GLO-21 reflects storm processes, moderately high erosion rates, and some beach cleaning activities. There are no natural dunes at this site, and the highest elevations (about 6 ft) coincide with a washover terrace that forms the vegetated barrier flat. An erosional escarpment separates the barrier flat from a narrow zone of beach trash that forms the landward edge of the backbeach. This beach segment is just southwest of Rollover Pass where recent erosion rates have averaged about 1.5 ft/yr (Paine and Morton, 1989).

Profiles GLO-22, GLO-23, High Island (BEG-10), and GLO-24 all represent undeveloped beach segments east of Rollover Pass. Along this beach segment the beach is narrow, steep, and contains abundant shell and caliche nodules. Natural dunes are poorly developed and the vegetated coastal plain is separated from the beach by low, densely vegetated sand mounds constructed from beach cleaning. The sand mounds have trapped some eolian sand to form a more continuous ridge or row of mounds. The highest elevations on the sand mounds are about 8 ft.

CONCLUSIONS

The foredunes of Galveston County range from low, isolated, sparsely vegetated coppice mounds to continuous, densely vegetated foredune ridges that are as much as 15 ft high. Natural dune development is directly related to beach stability (erosion, accretion), sediment supply, and recent storm history. Most of the natural dunes and beach morphology have been modified by beach maintenance whereby sand and beach debris (wood and other trash) are scraped from the beach and dumped in the backbeach seaward of the natural dunes. These activities add volume to the dune complex and artificially advance the vegetation line seaward.

The degree of artificial dune modification can be evaluated using an impact index, which is a ranking from 0 to 5. The impact index is based on the composition of the fill, width and height of the fill, and the extent of the fill compared to the entire beach width. A zero ranking indicates that there is no visible evidence of dune alteration, whereas a 5 indicates that the alterations are major and typically consist of multiple rows of large mounds containing sand and abundant debris or other unnatural fill such as tires, appliances, and trees. Most beach segments in Galveston County have impact indices of at least 3.

In general, the foredunes of Galveston County are narrow, relatively continuous, densely vegetated, and less than 11 ft high. These characteristics mean that the dunes provide adequate protection from washover and flooding by weak to moderately strong hurricanes (< category 3), but are vulnerable to complete destruction by more intense storms (category 3-5). The dunes have been either severely damaged or totally destroyed twice in the past 35 years. Dune reformation is a slow process that can be enhanced or limited by human activities.

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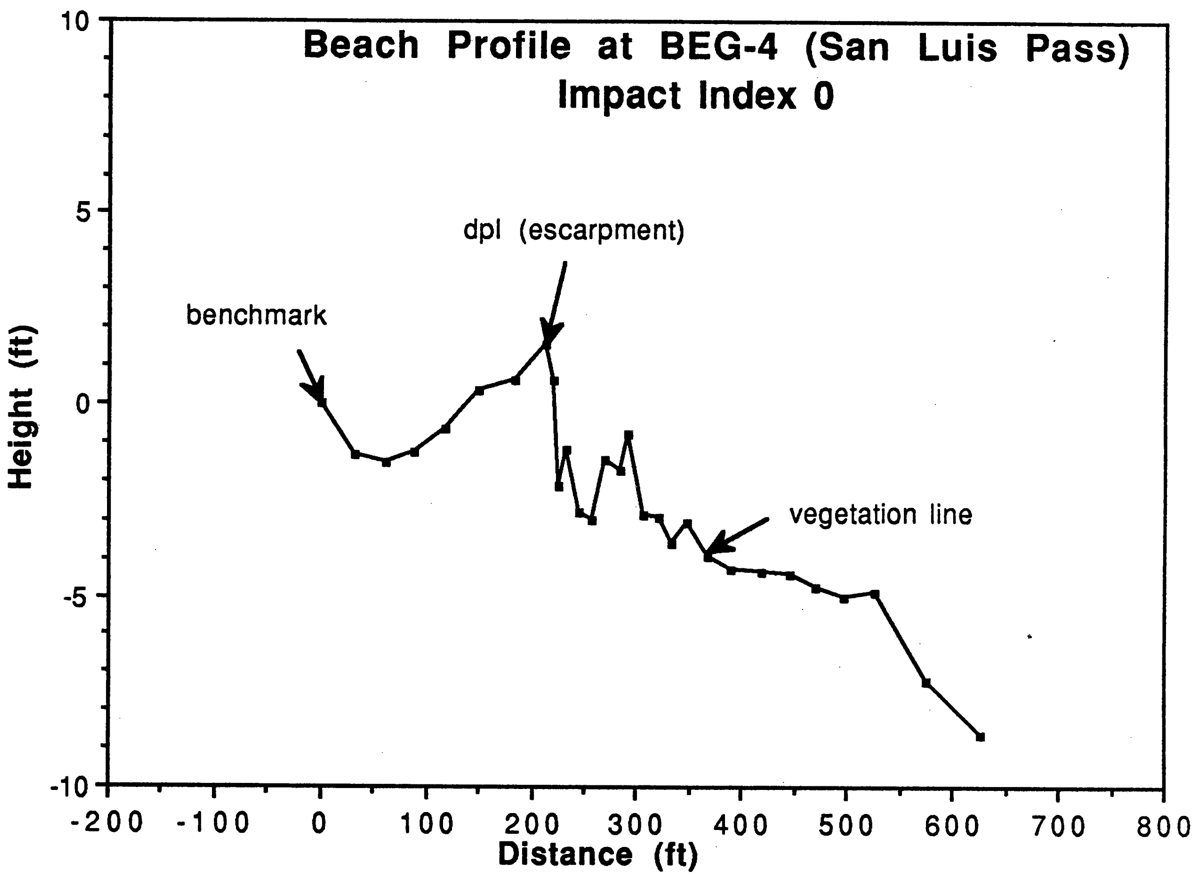
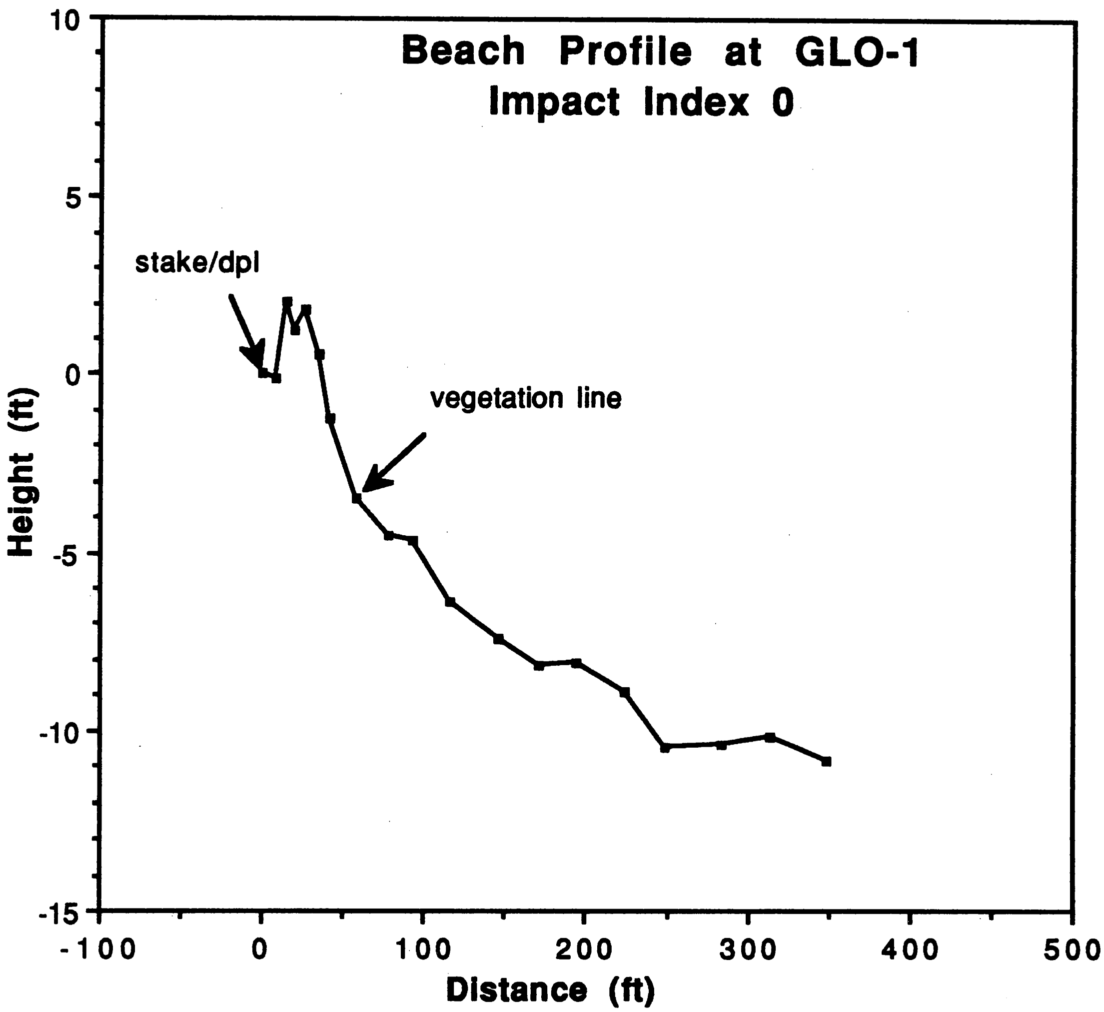
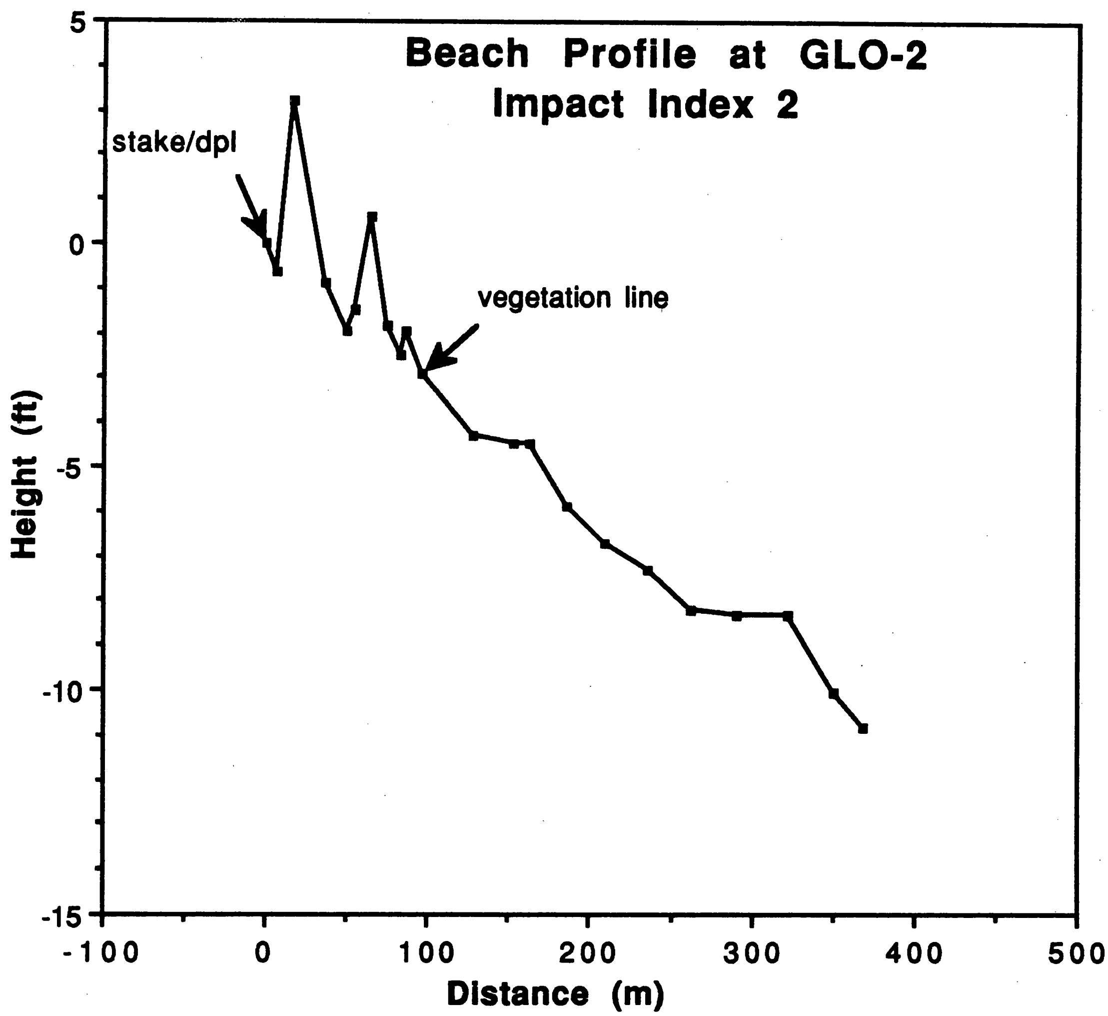
APPENDIX A

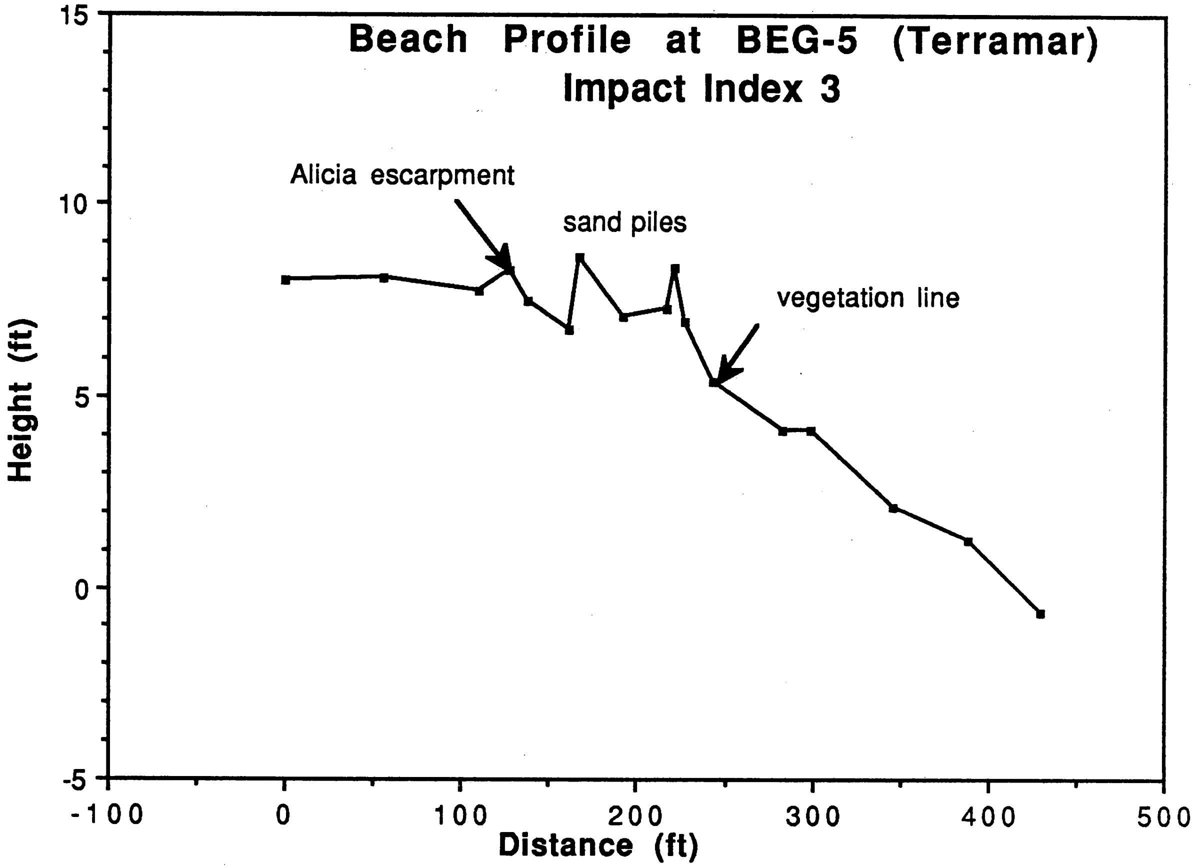
Beach and Dune Profiles of Galveston County
Recorded September, 1994


Beach Profile at BEG-4 (San Luis Pass)
Impact Index 0
dpl (escarpment)
benchmark
vegetation line
Height (ft)
Distance (ft)
10
5
0
-5
-10
-200
-100
0
100
200
300
400
500
600
700
800

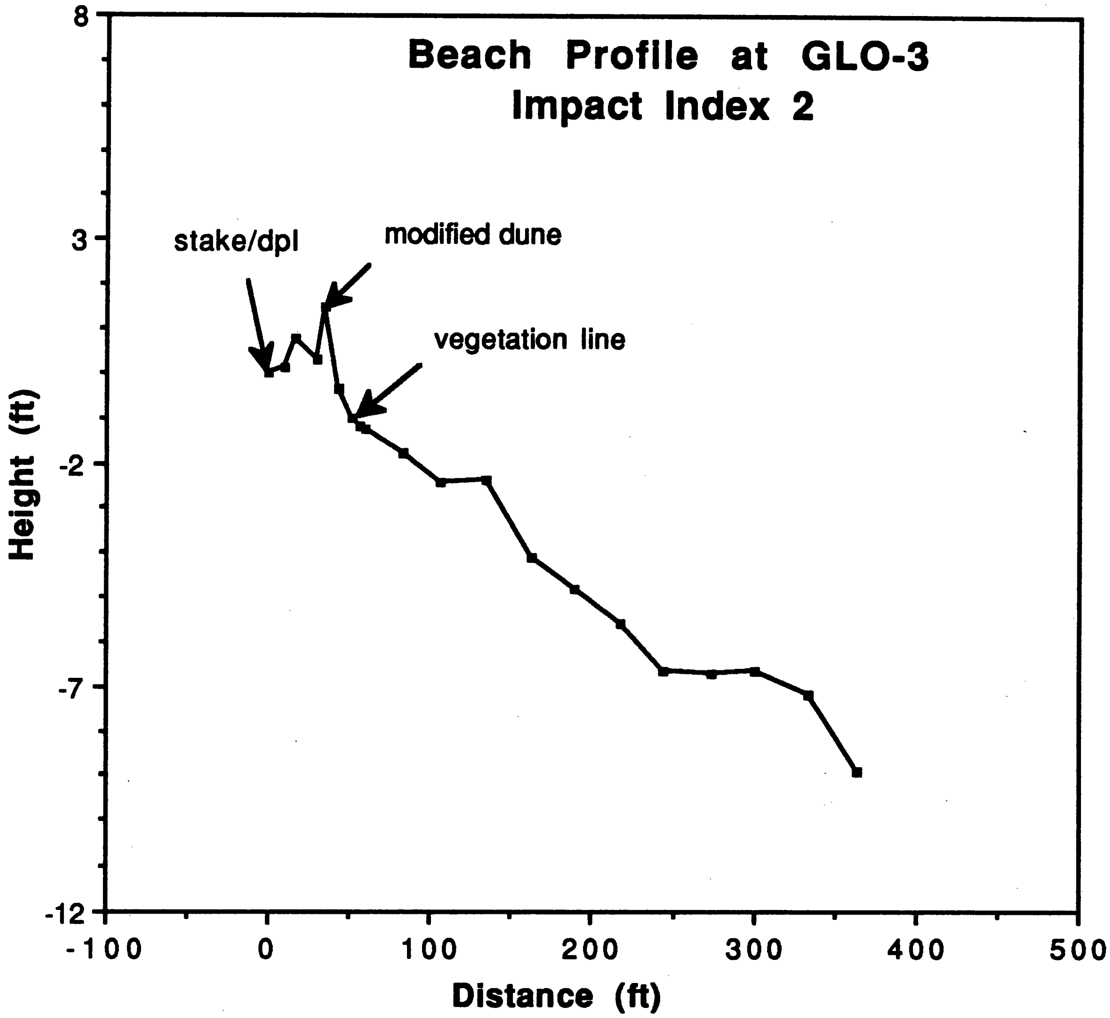


Beach Profile at GLO-1
Impact Index 0
stake/dpl
vegetation line
10
5
0
-5
-10
-15
Height (ft)
-100
0
100
200
300
400
500
Distance (ft)

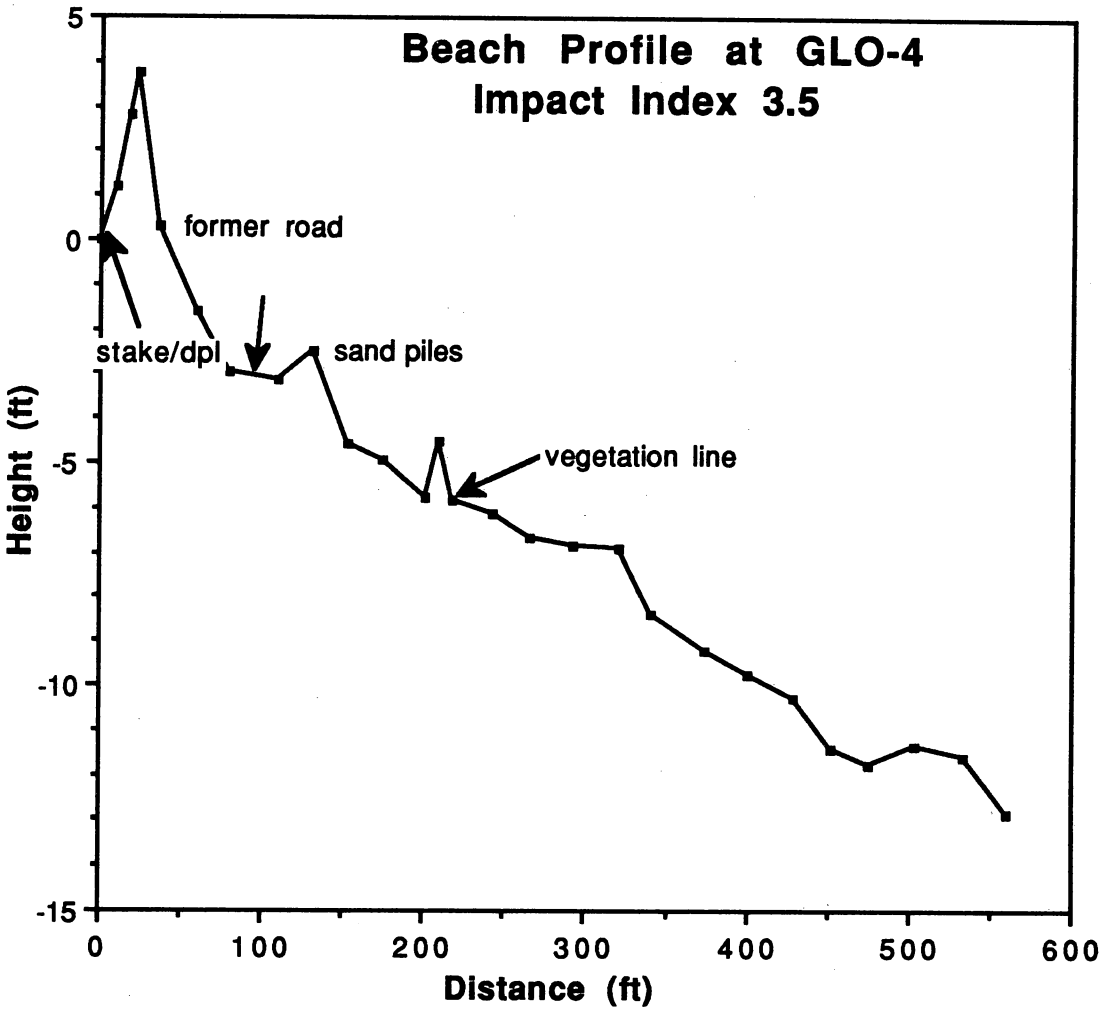

Beach Profile at GLO-2
Impact Index 2
stake/dpl
vegetation line
Height (ft)
5
0
-5
-10
-15
-100
0
100
200
300
400
500
Distance (m)

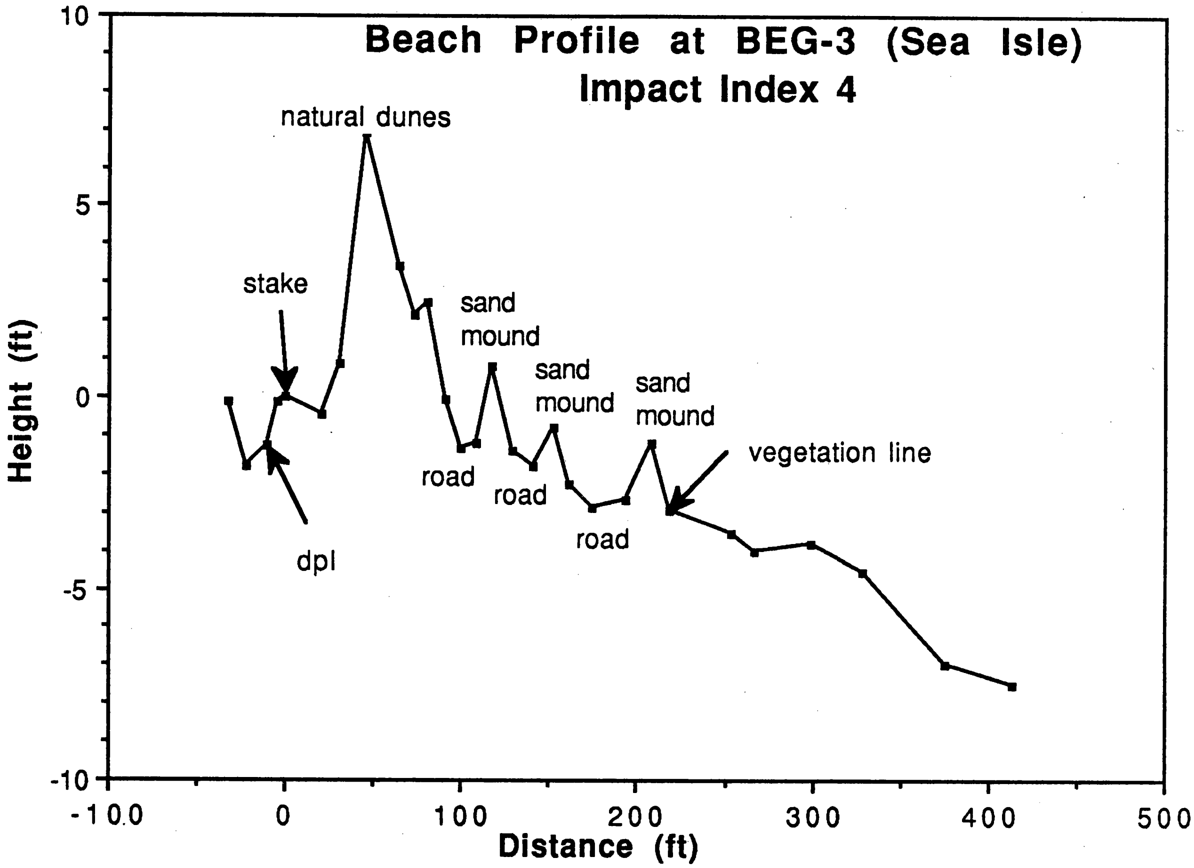


Beach Profile at BEG-5 (Terramar)
Impact Index 3
Alicia escarpment
sand piles
vegetation line
Height (ft)
15
10
5
0
-5
-100
0
100
200
300
400
500
Distance (ft)

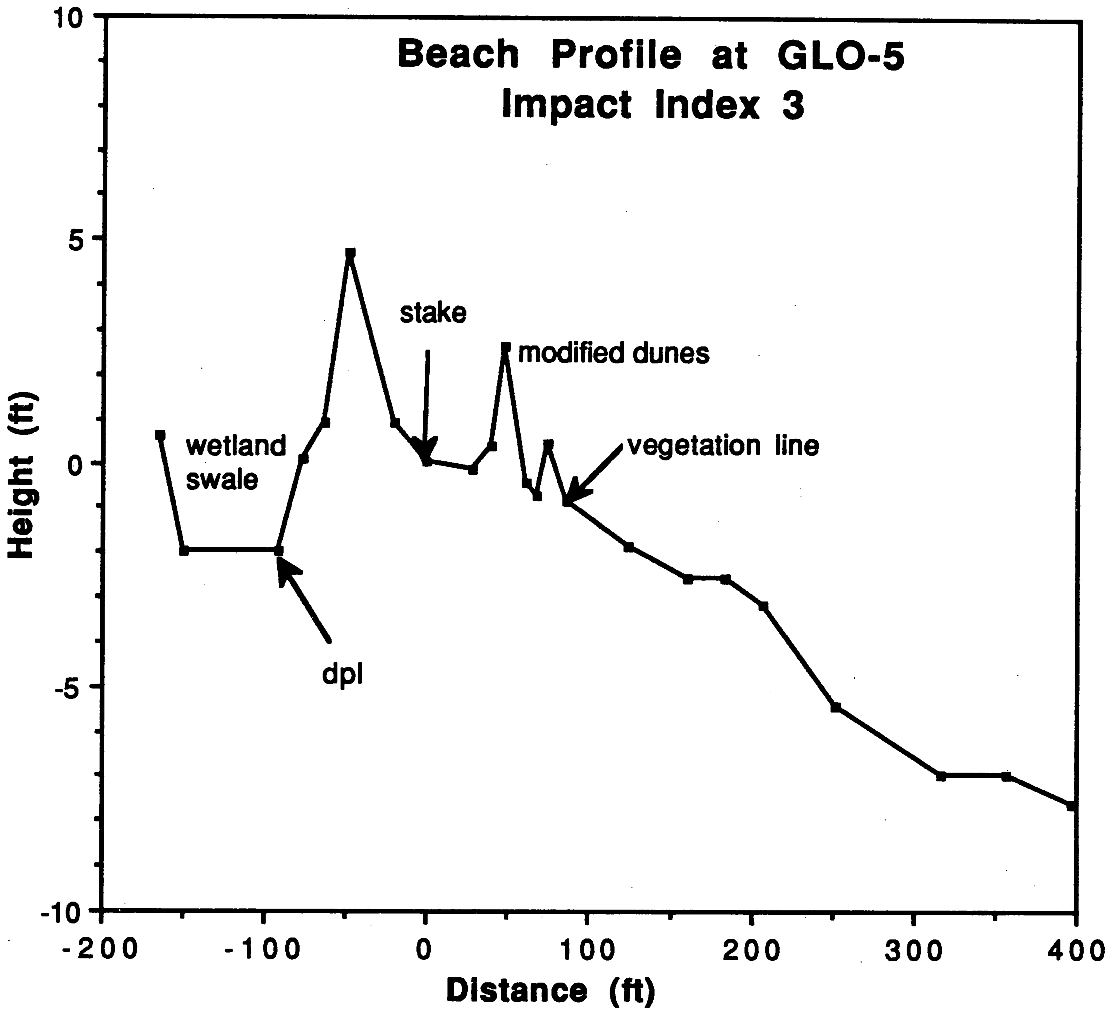


Beach Profile at GLO-3
Impact Index 2
stake/dpl
modified dune
vegetation line
8
3
-2
-7
-12
Height (ft)
-100
0
100
200
300
400
500
Distance (ft)

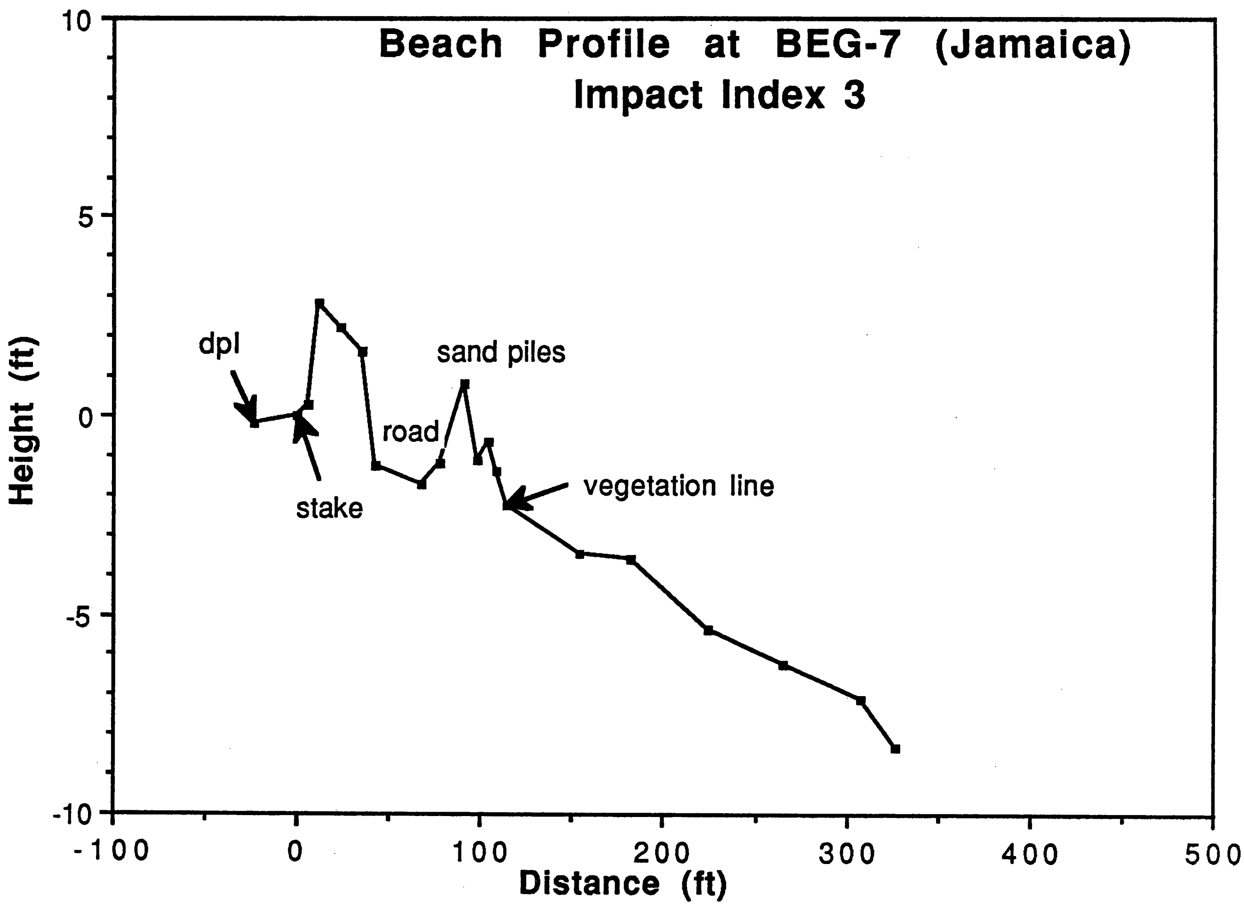

Beach Profile at GLO-4
Impact Index 3.5
former road
stake/dpl
sand piles
vegetation line
Height (ft)
5
0
-5
-10
-15
0
100
200
300
400
500
600
Distance (ft)



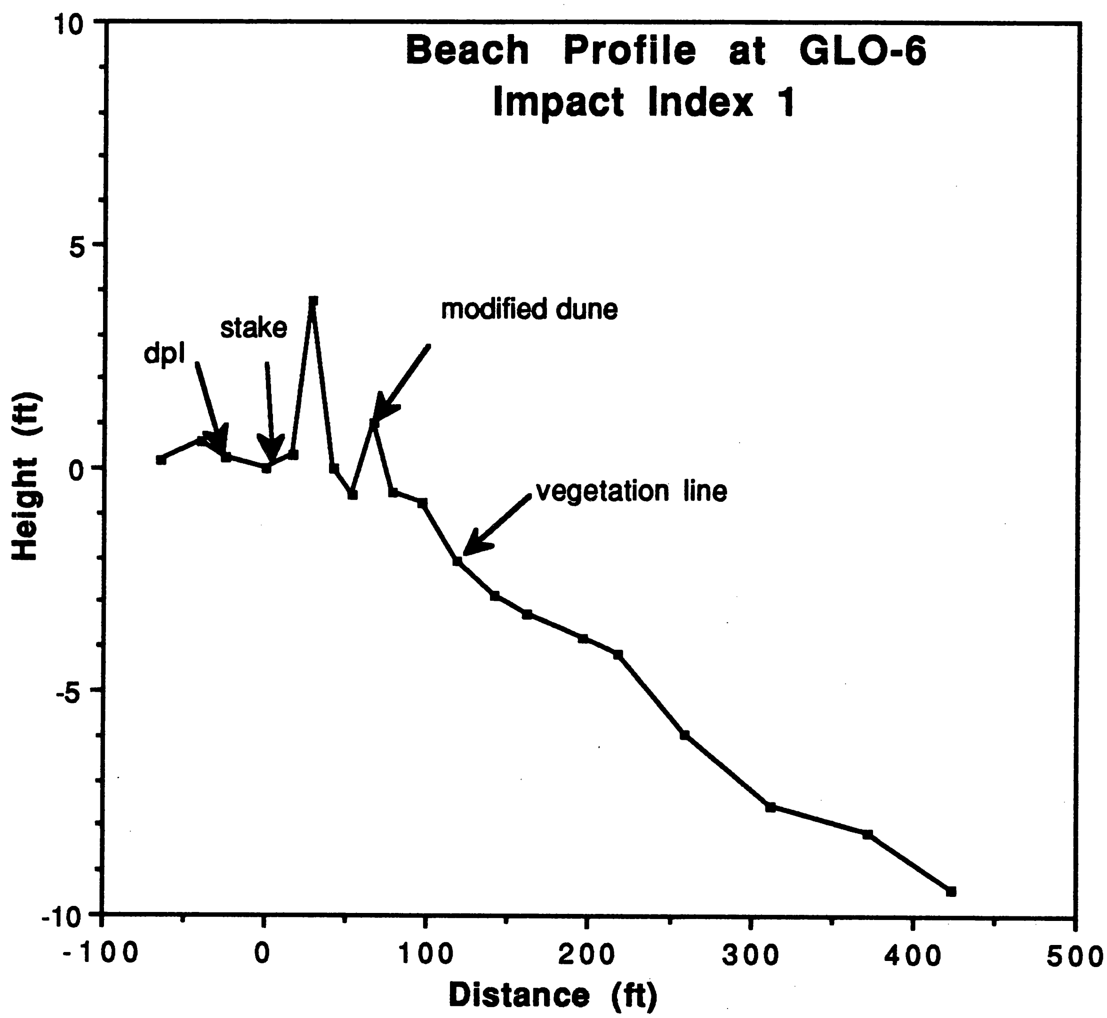
Beach Profile at BEG-3 (Sea Isle)
Impact Index 4
natural dunes
stake
dpl
sand mound
sand mound
sand mound
road
road
road
vegetation line
Height (ft)
10
5
0
-5
-10
-100
0
100
200
300
400
500
Distance (ft)



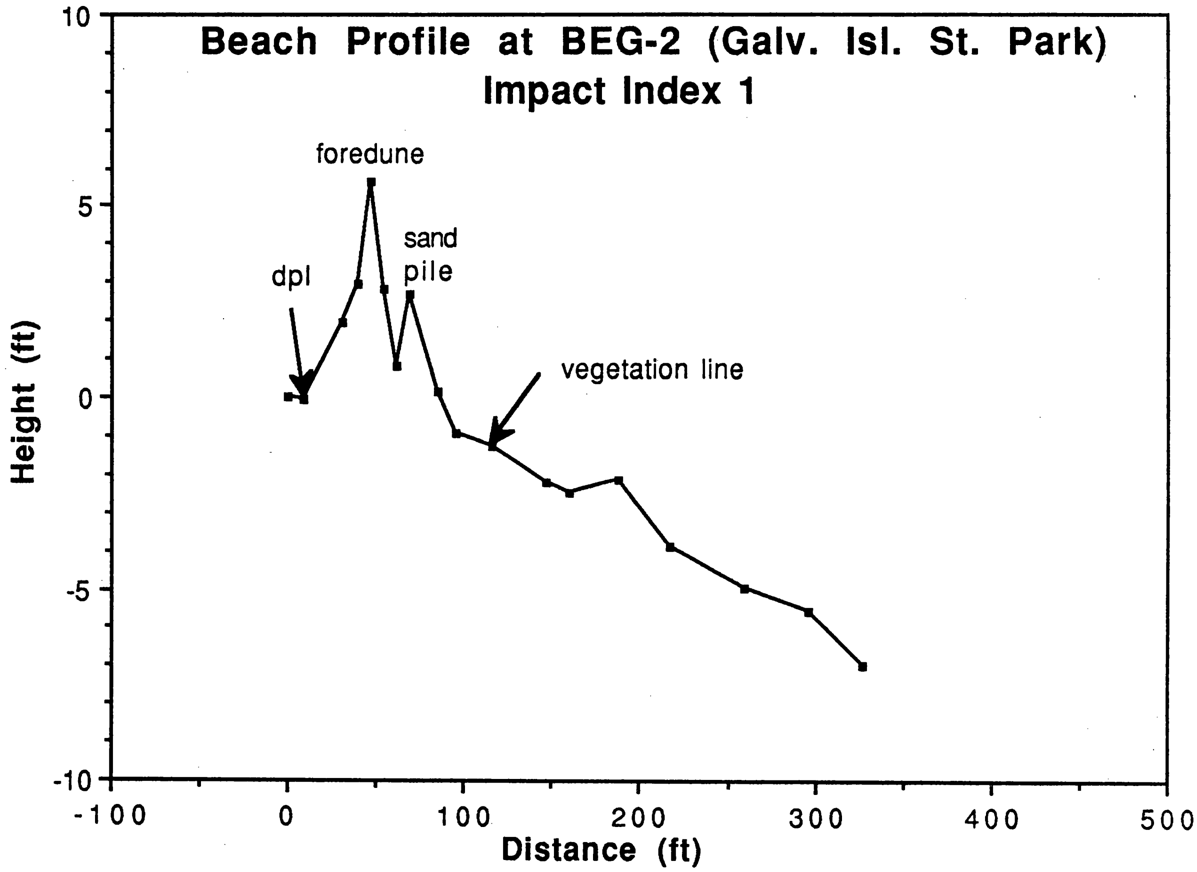
Beach Profile at GLO-5
Impact Index 3
Height (ft)
Distance (ft)
wetland
swale
dpl
stake
modified dunes
vegetation line
10
5
0
-5
-10
-200
-100
0
100
200
300
400



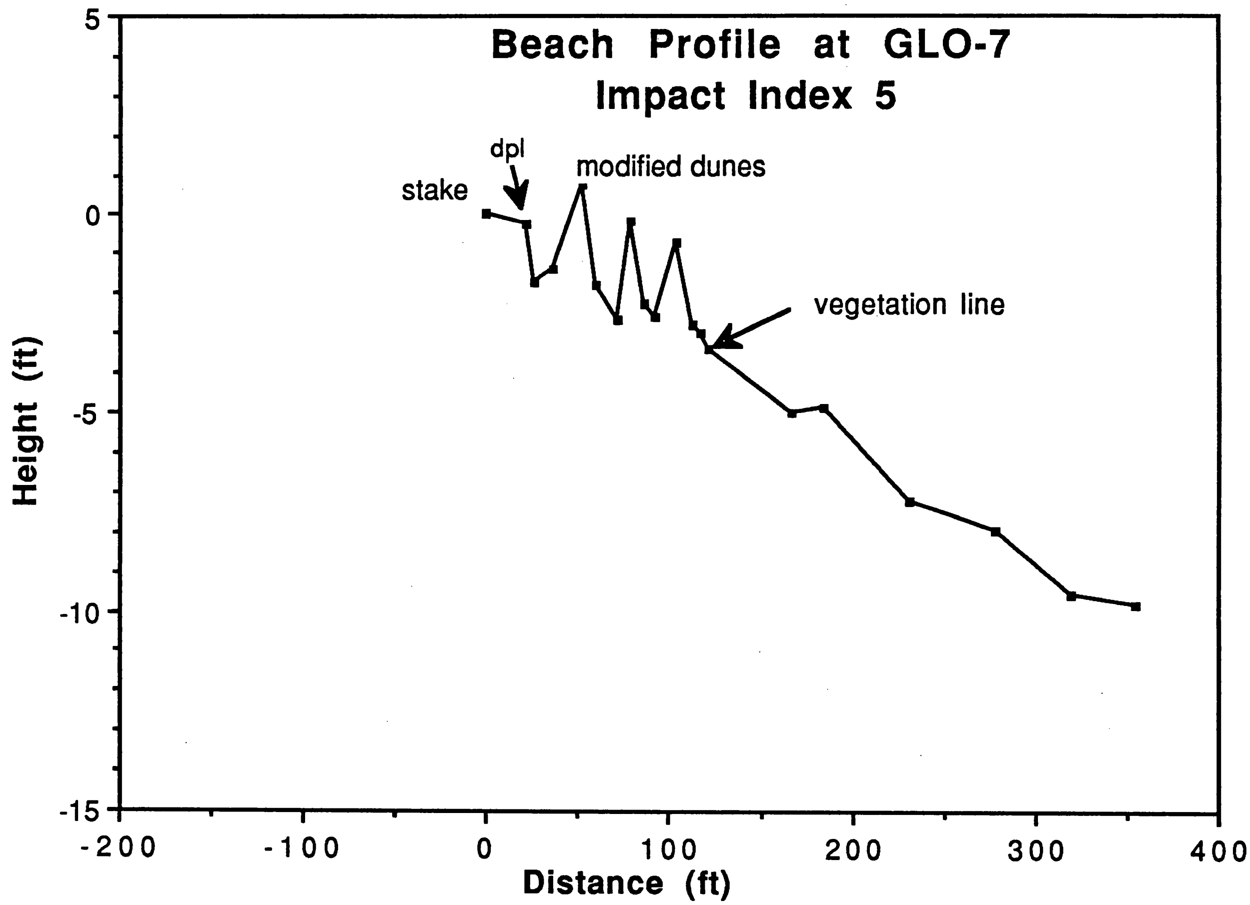
Beach Profile at BEG-7 (Jamaica)
Impact Index 3
10
5
0
-5
-10
Height (ft)
dpl
stake
road
sand piles
vegetation line
-100
0
100
200
300
400
500
Distance (ft)



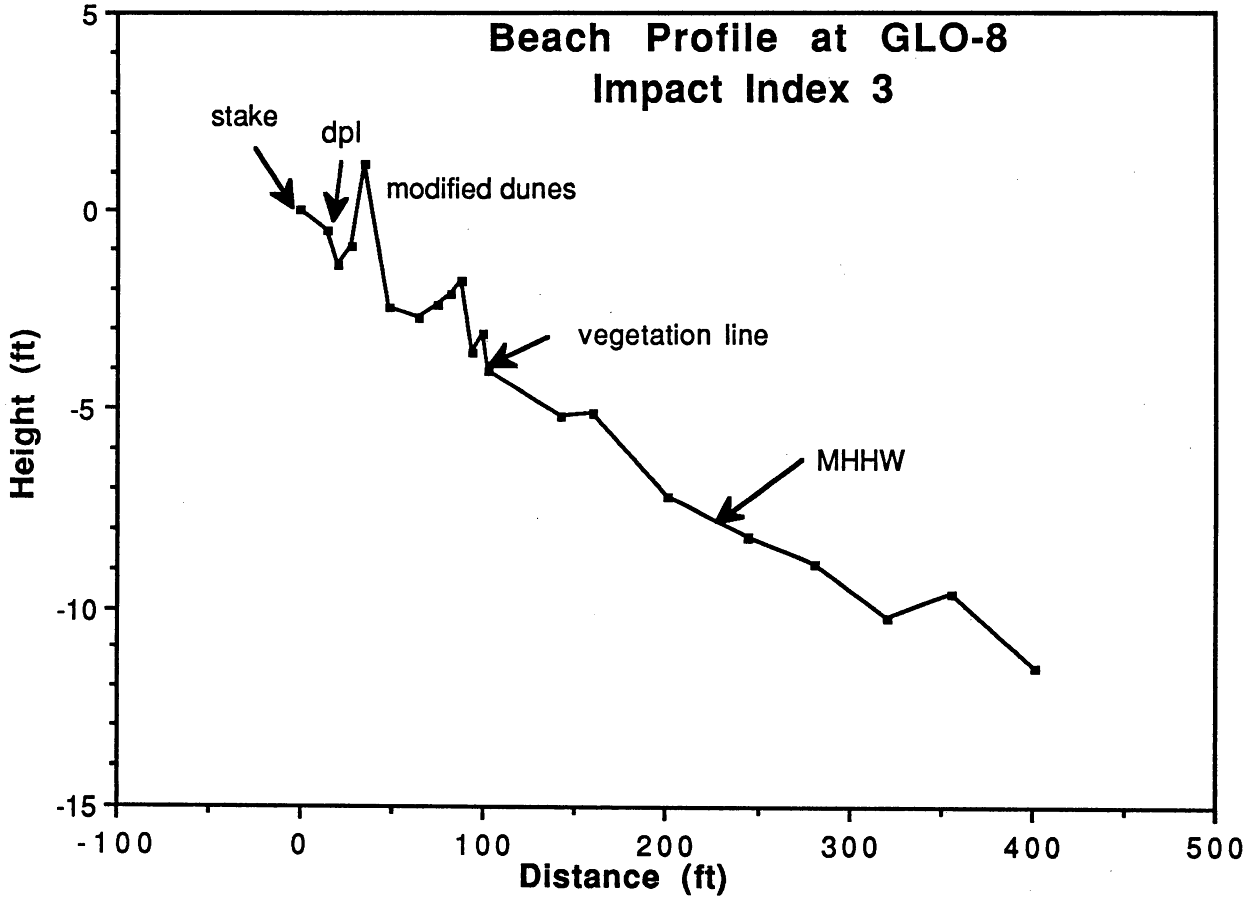
Beach Profile at GLO-6
Impact Index 1
modified dune
stake
dpl
vegetation line
Height (ft)
Distance (ft)
10
5
0
-5
-10
-100
0
100
200
300
400
500



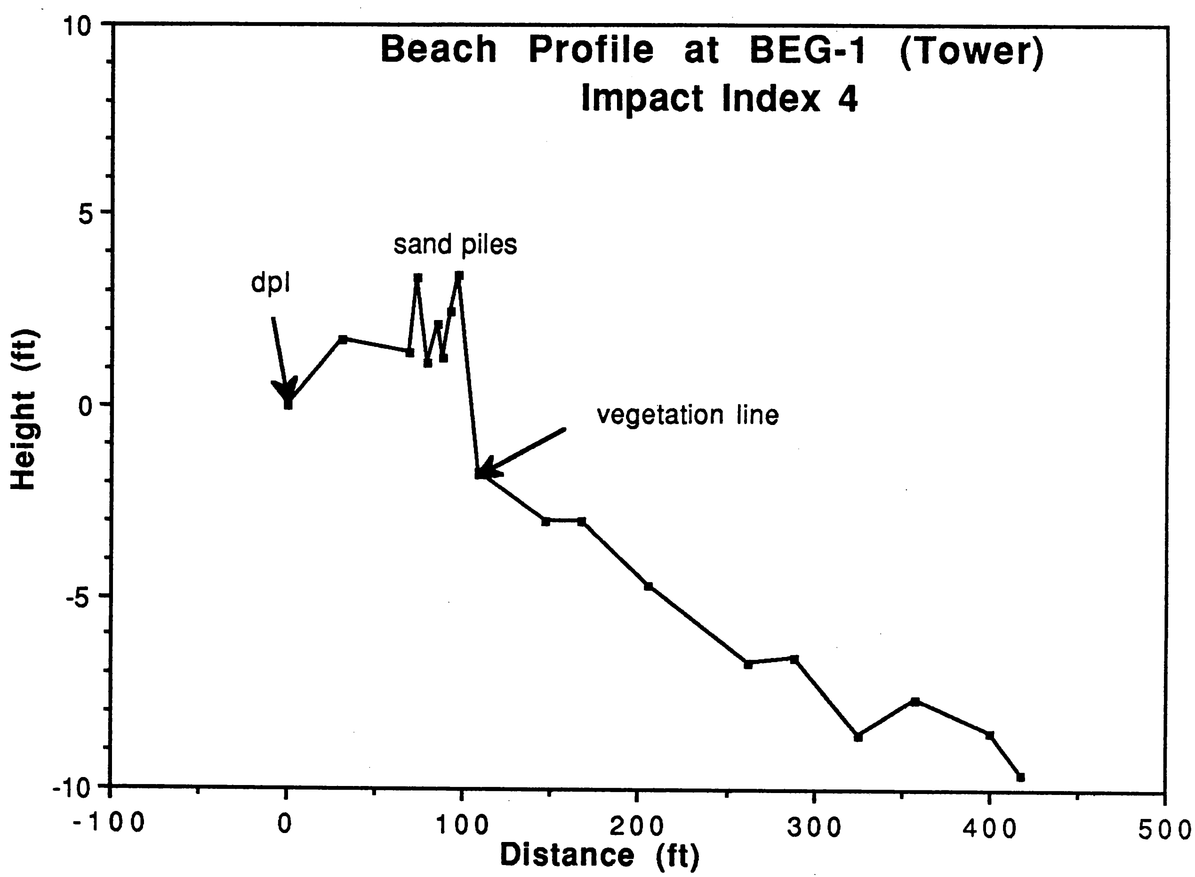
Beach Profile at BEG-2 (Galv. Isl. St. Park)
Impact Index 1
foredune
sand pile
dpl
vegetation line
10
5
0
-5
-10
Height (ft)
-100
0
100
200
300
400
500
Distance (ft)

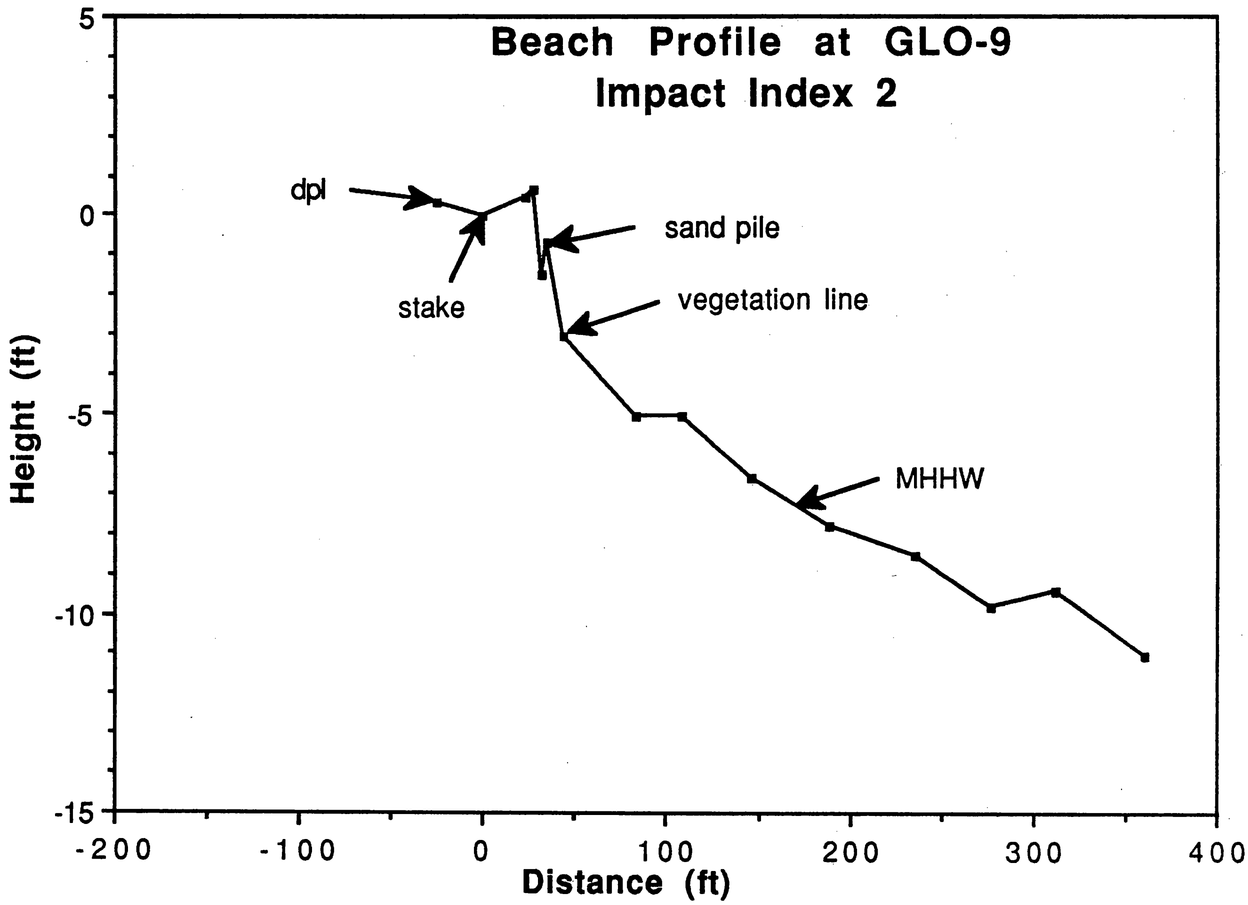


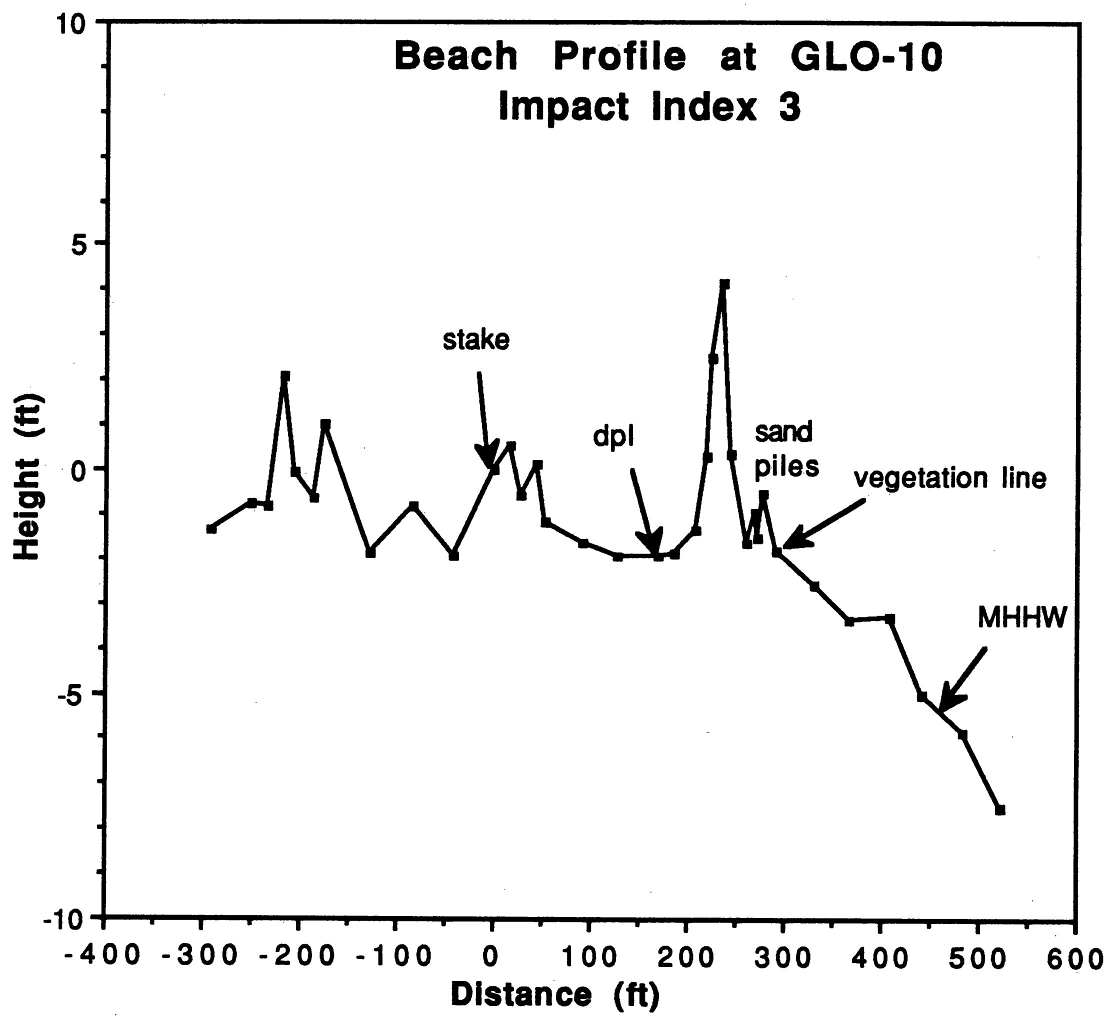
Beach Profile at GLO-7
Impact Index 5
dpl
stake
modified dunes
vegetation line
5
0
-5
-10
-15
Height (ft)
-200
-100
0
100
200
300
400
Distance (ft)

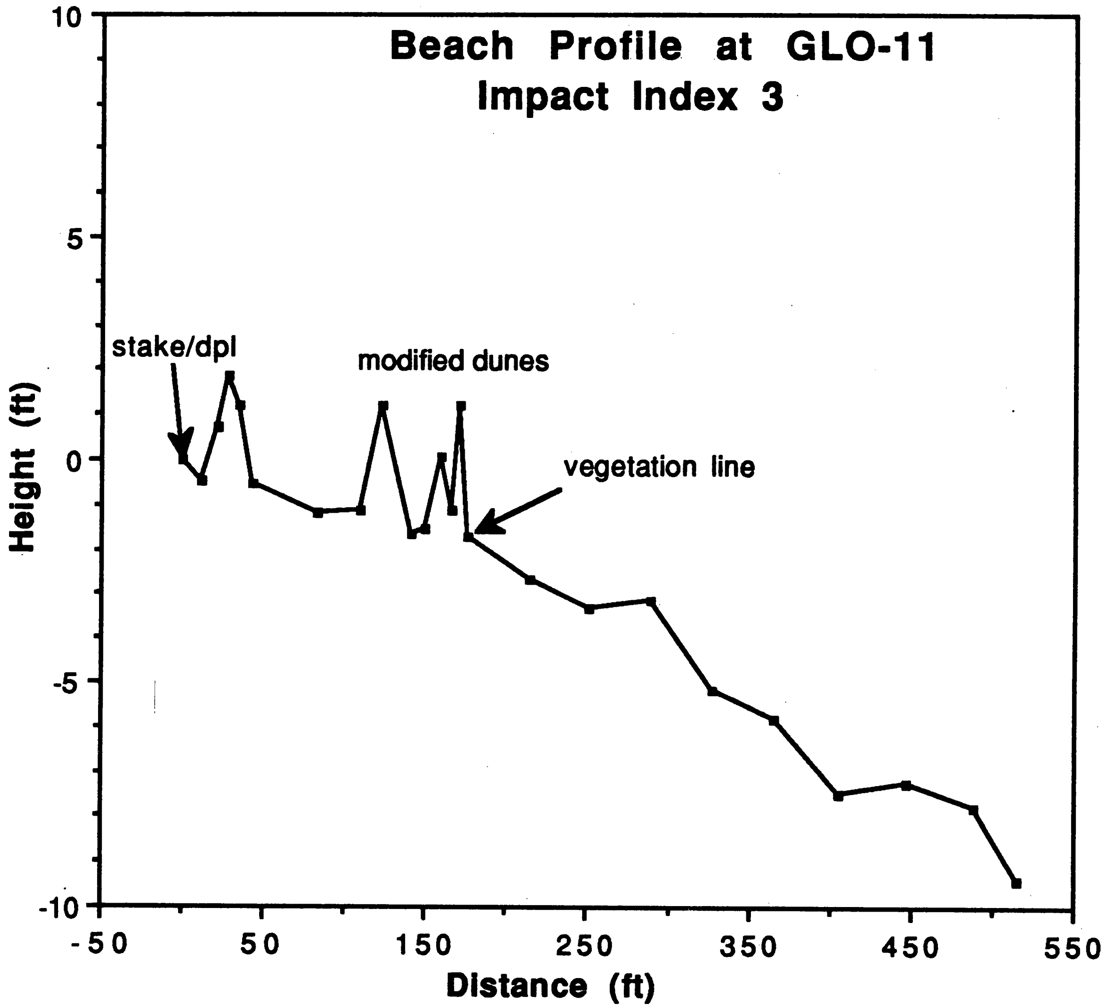


Beach Profile at GLO-8
Impact Index 3
stake
dpl
modified dunes
vegetation line
MHHW
Height (ft)
Distance (ft)
5
0
-5
-10
-15
-100
0
100
200
300
400
500

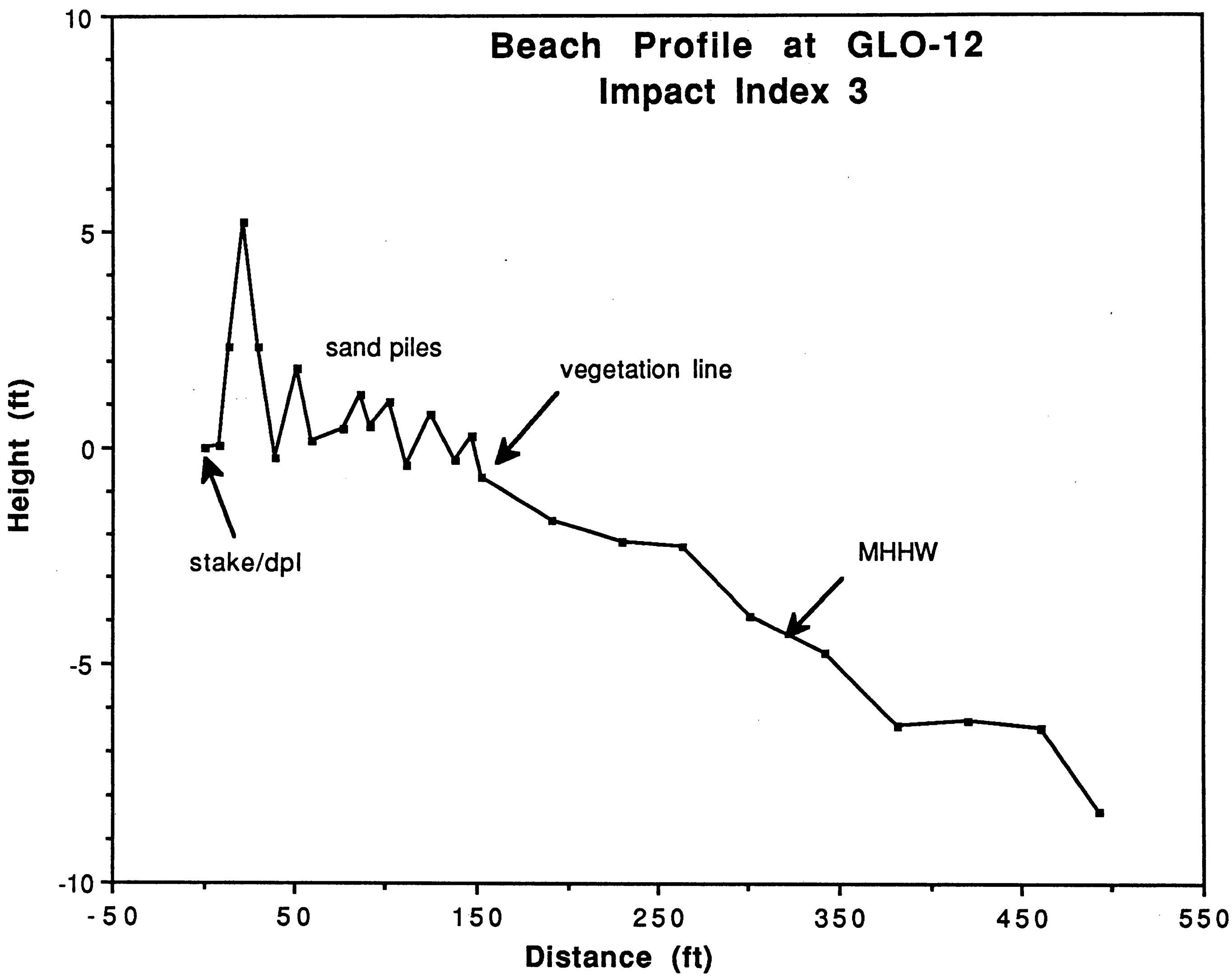

Beach Profile at BEG-1 (Tower)
Impact Index 4
sand piles
dpl
vegetation line
Height (ft)
Distance (ft)
10
5
0
-5
-10
-100
0
100
200
300
400
500


Beach Profile at GLO-9
Impact Index 2
dpl
stake
sand pile
vegetation line
MHHW
Height (ft)
Distance (ft)
5
0
-5
-10
-15
-200
-100
0
100
200
300
400

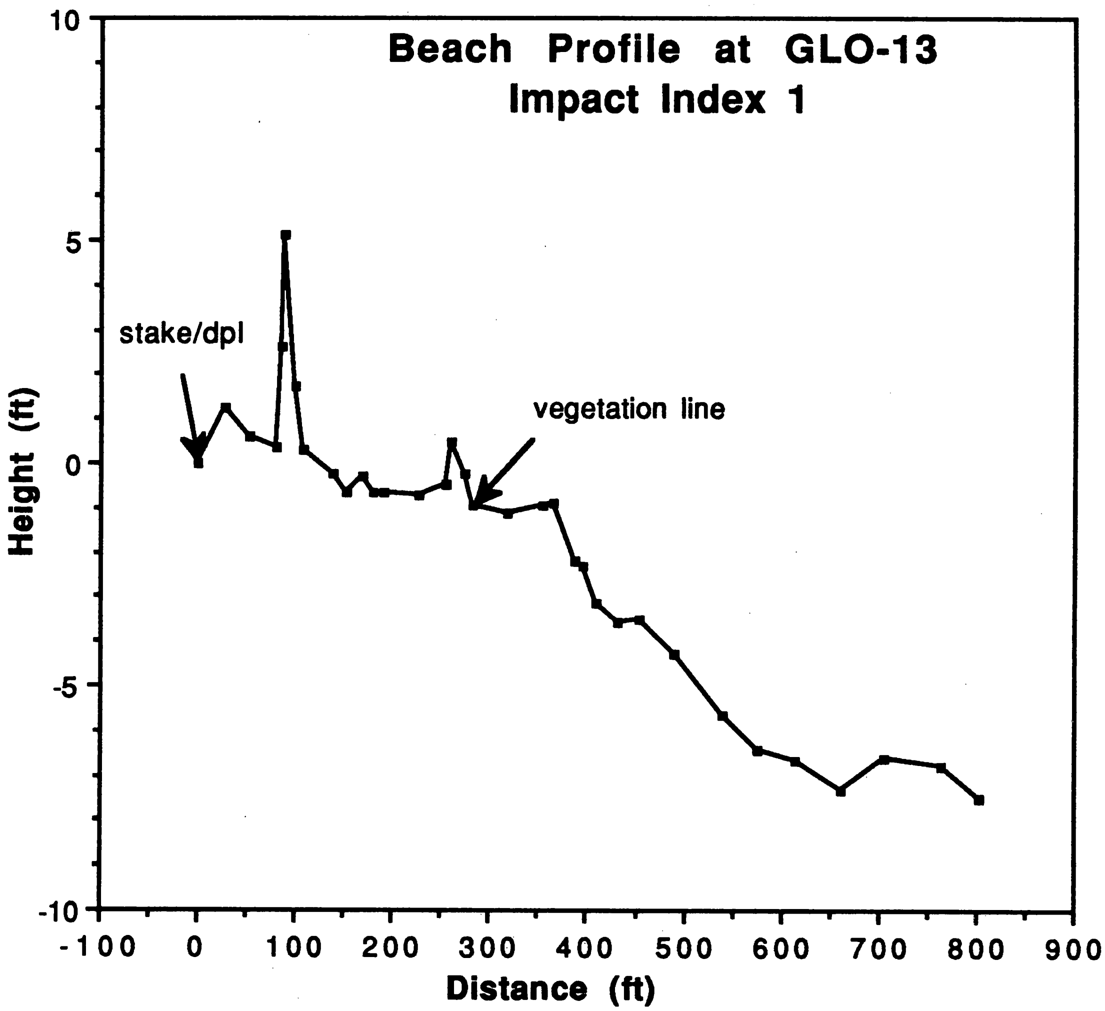

Beach Profile at GLO-10
Impact Index 3
10
5
0
-5
-10
Height (ft)
stake
dpl
sand
piles
vegetation line
MHHW
-400 -300 -200 -100 0 100 200 300 400 500 600
Distance (ft)



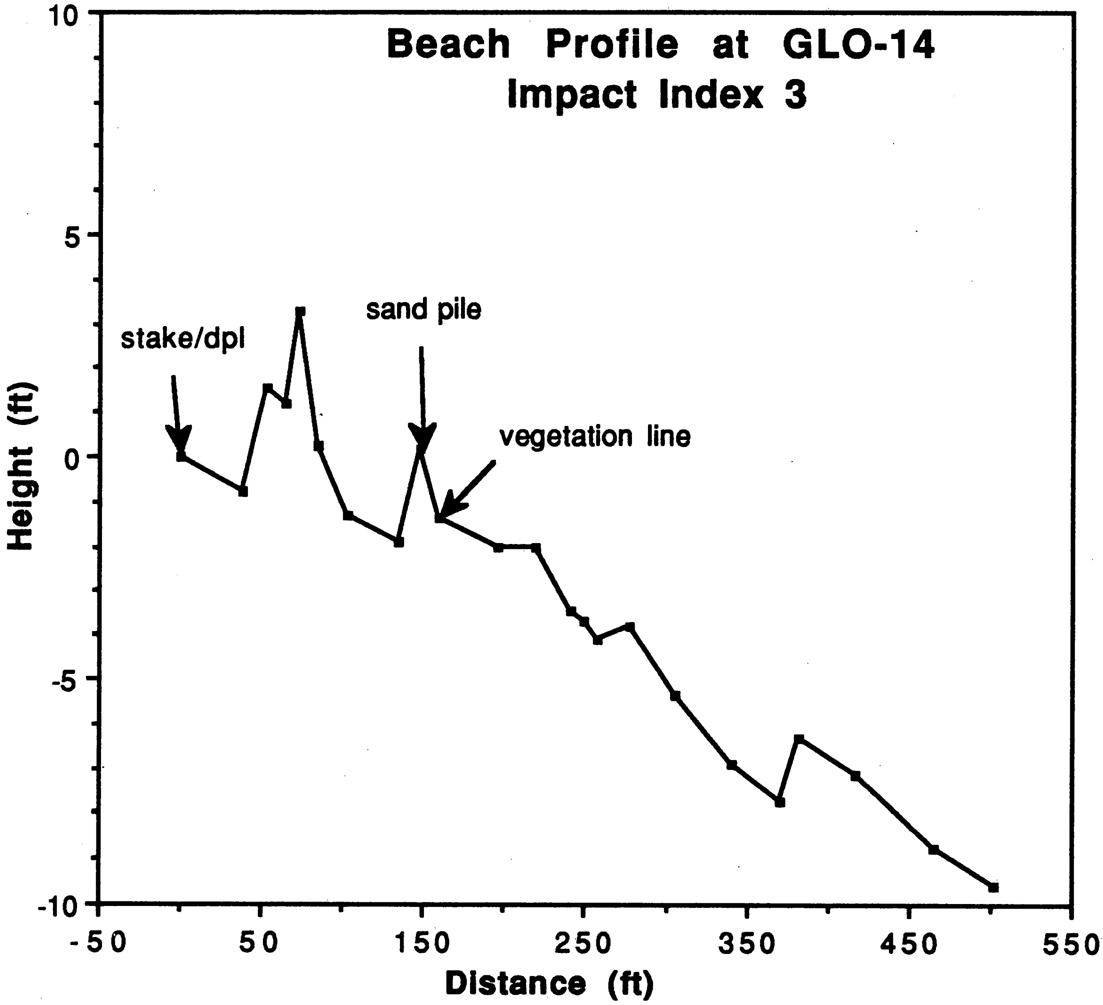
Beach Profile at GLO-11
Impact Index 3
stake/dpl
modified dunes
vegetation line
Height (ft)
10
5
0
-5
-10
-50
50
150
250
350
450
550
Distance (ft)



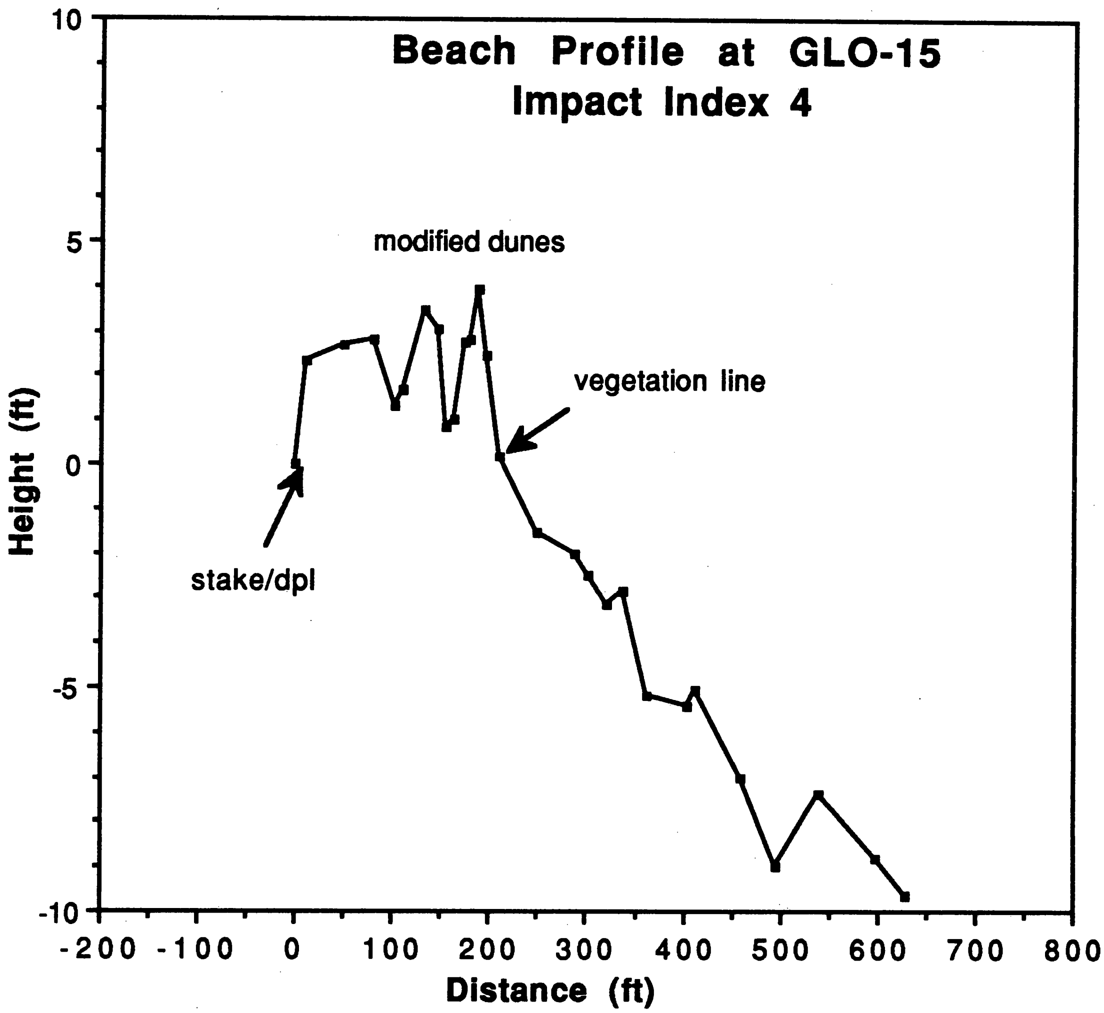
Beach Profile at GLO-12
Impact Index 3
sand piles
vegetation line
stake/dpl
MHHW
Height (ft)
Distance (ft)
10
5
0
-5
-10
-50
50
150
250
350
450
550

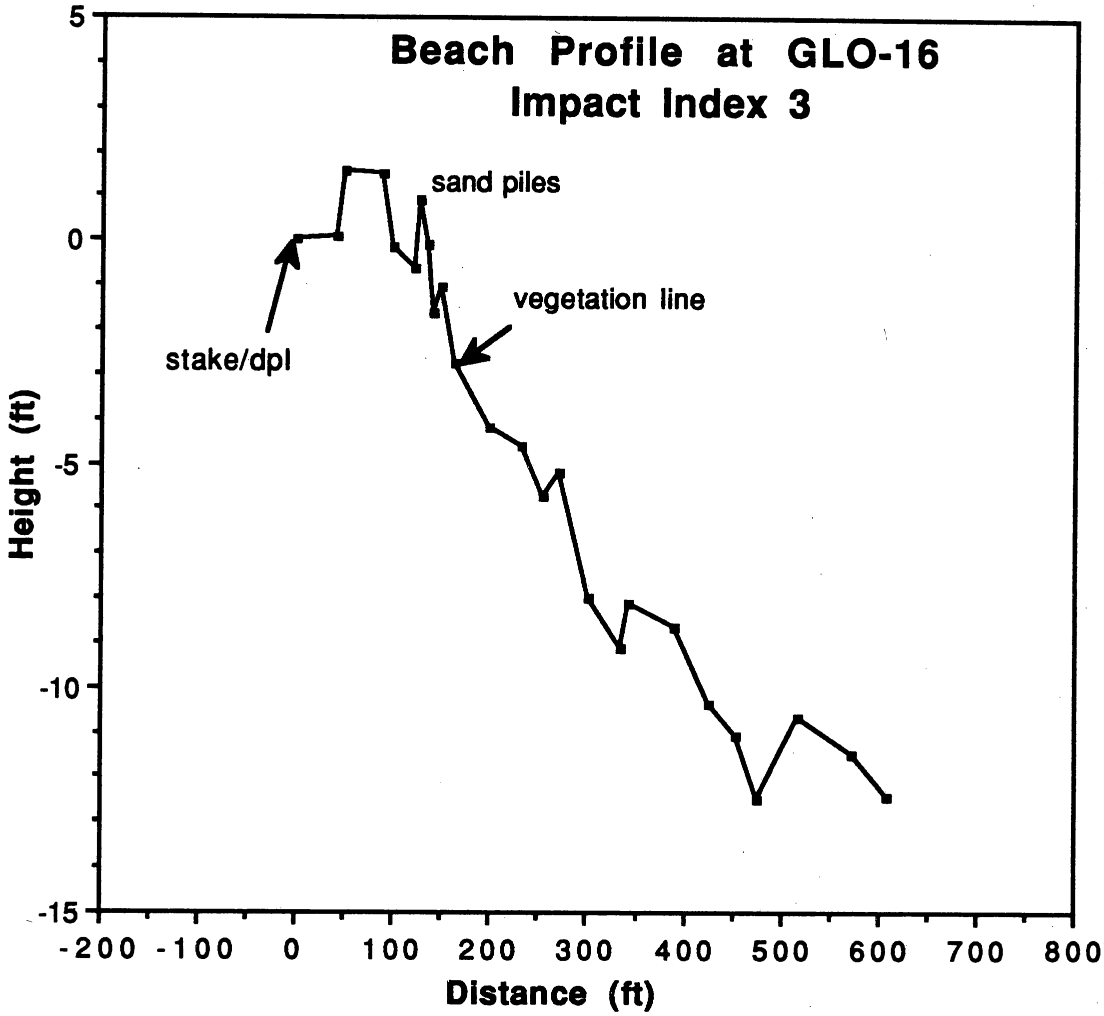


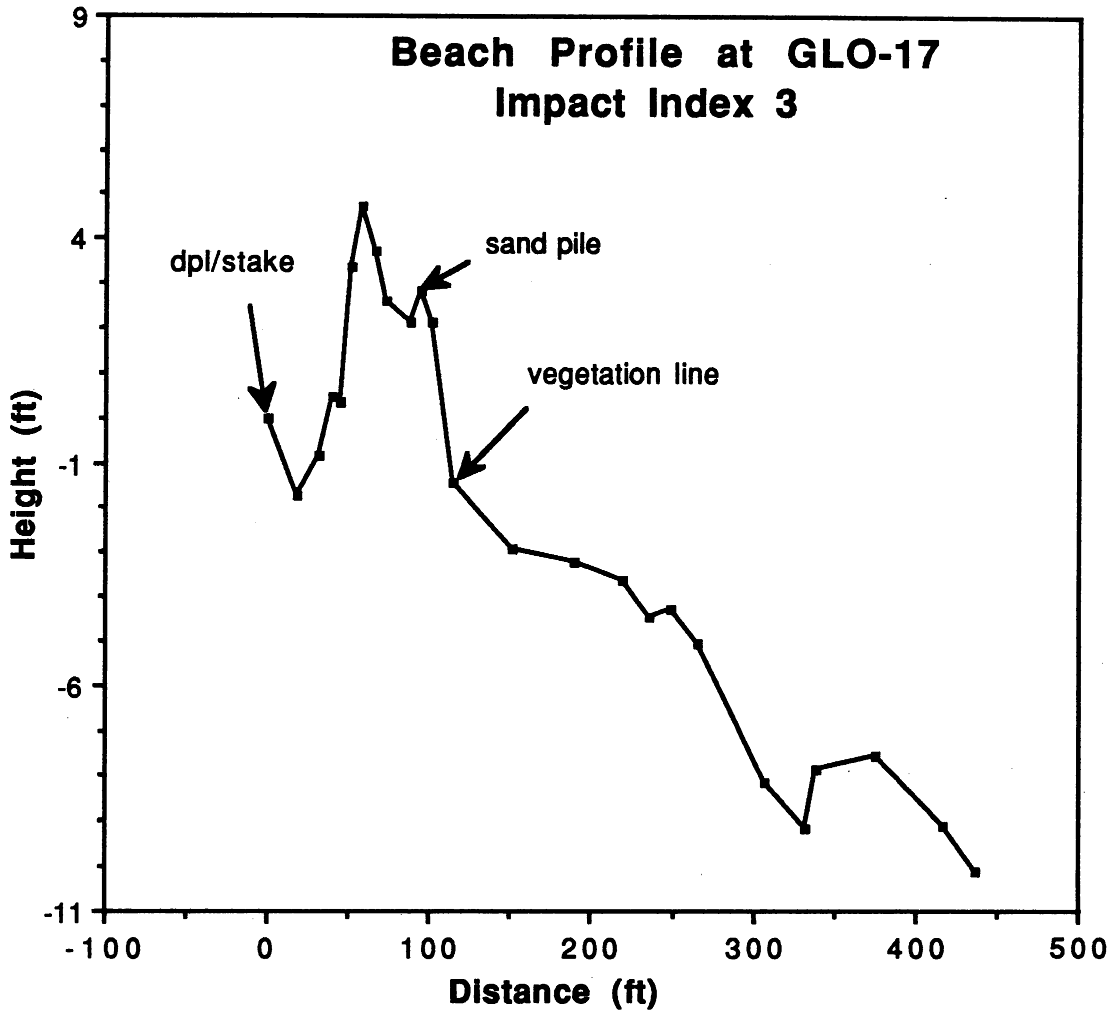
Beach Profile at GLO-13
Impact Index 1
stake/dpl
vegetation line
Height (ft)
Distance (ft)
10
5
0
-5
-10
-100
0
100
200
300
400
500
600
700
800
900

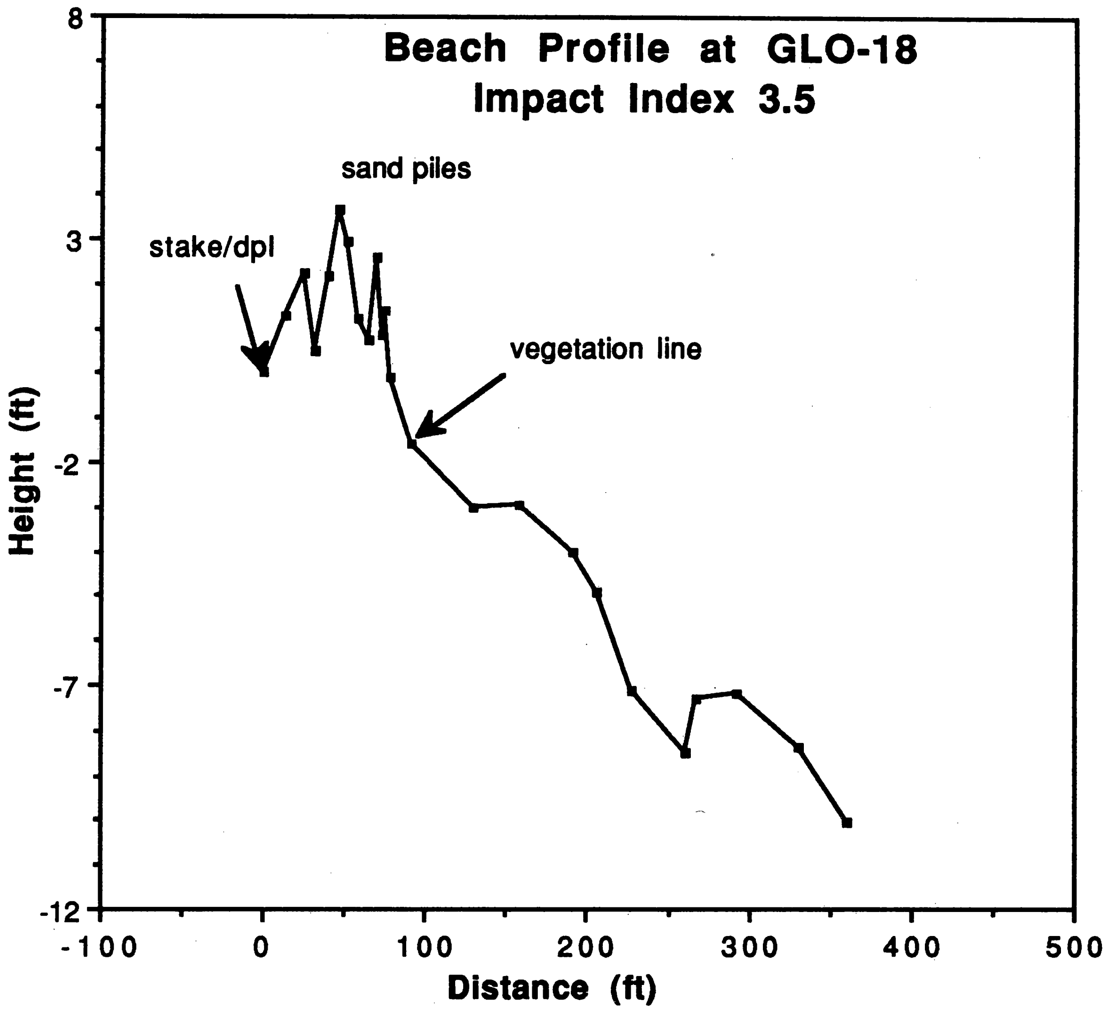


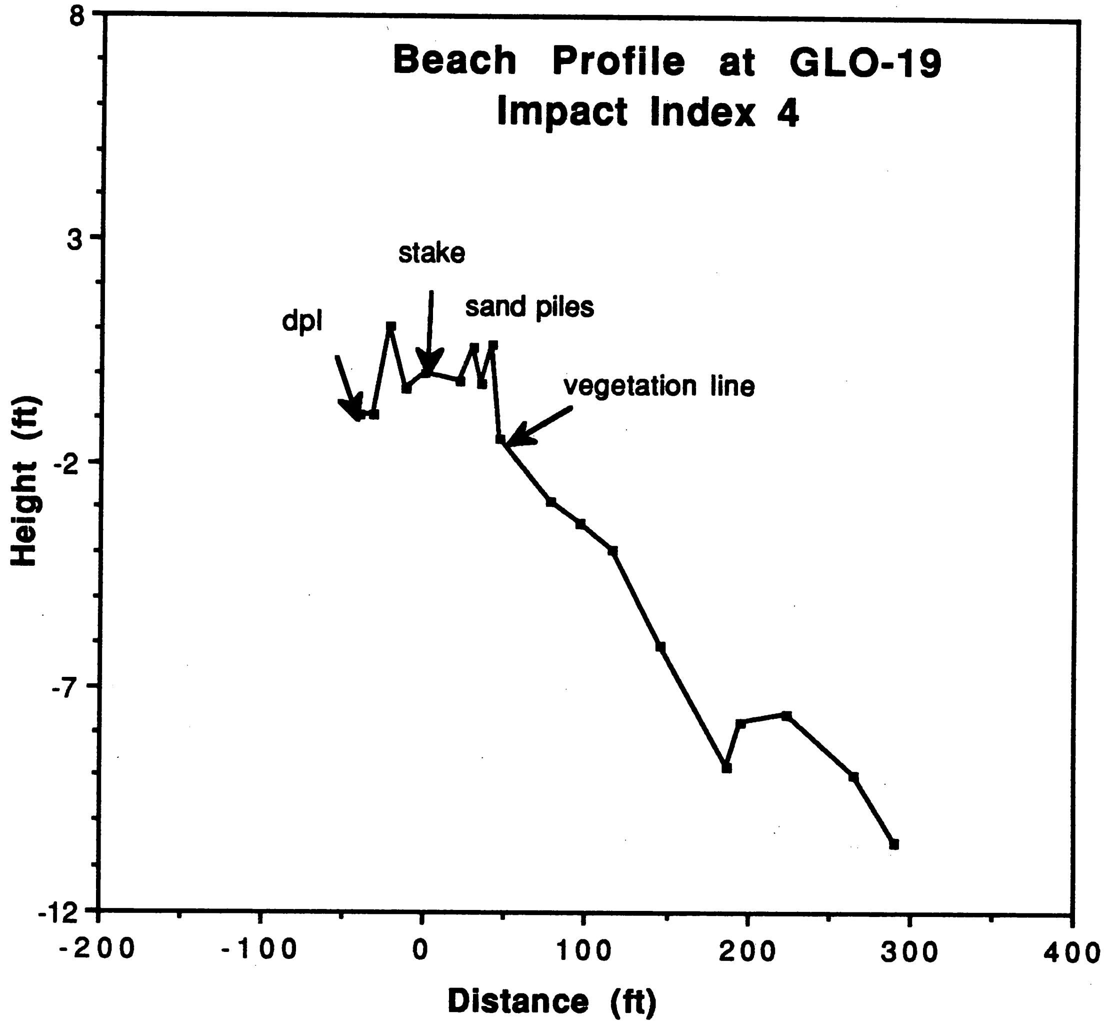
Beach Profile at GLO-14
Impact Index 3
stake/dpl
sand pile
vegetation line
Height (ft)
10
5
0
-5
-10
-50
50
150
250
350
450
550
Distance (ft)


Beach Profile at GLO-15
Impact Index 4
modified dunes
vegetation line
stake/dpl
Height (ft)
Distance (ft)
10
5
0
-5
-10
-200
-100
0
100
200
300
400
500
600
700
800

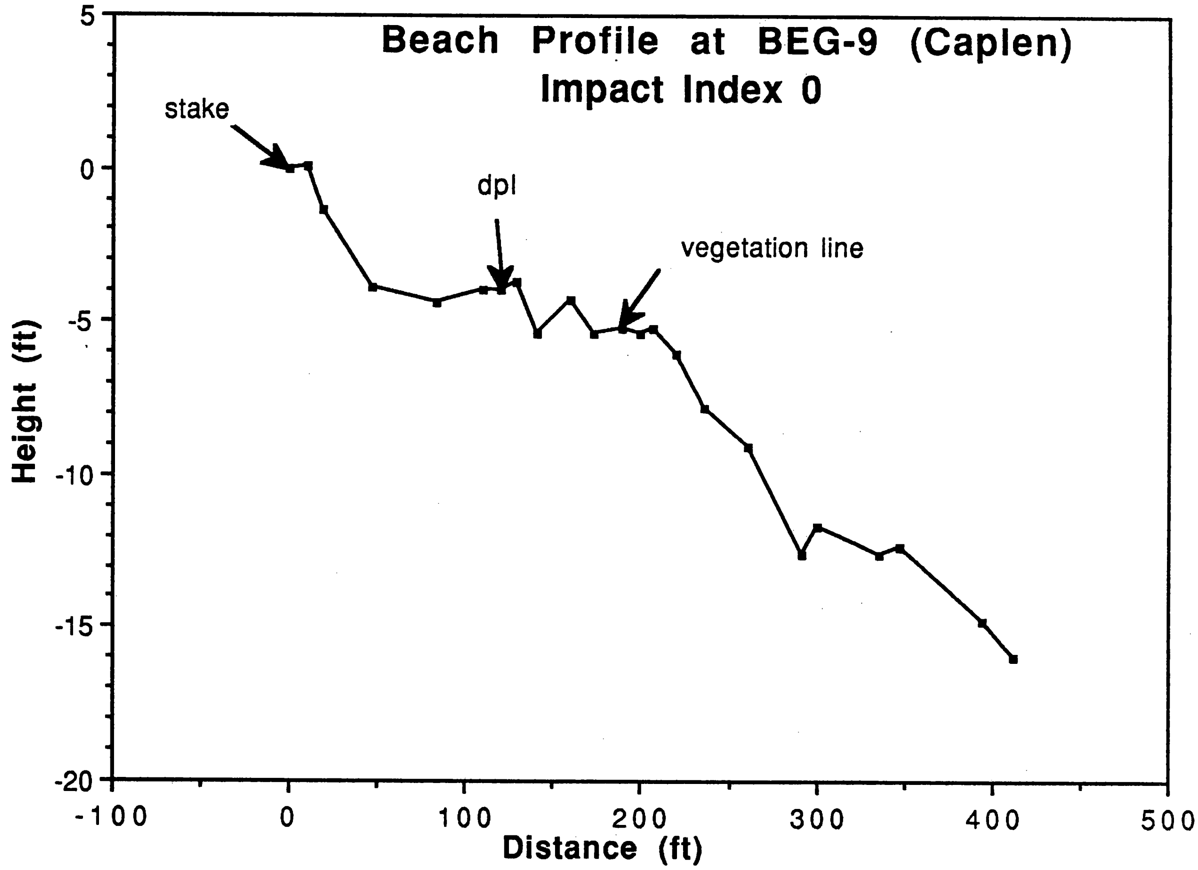

Beach Profile at GLO-16
Impact Index 3
sand piles
vegetation line
stake/dpl
Height (ft)
5
0
-5
-10
-15
-200 -100 0 100 200 300 400 500 600 700 800
Distance (ft)


Beach Profile at GLO-17
Impact Index 3
dpl/stake
sand pile
vegetation line
Height (ft)
Distance (ft)
9
4
-1
-6
-11
-100
0
100
200
300
400
500

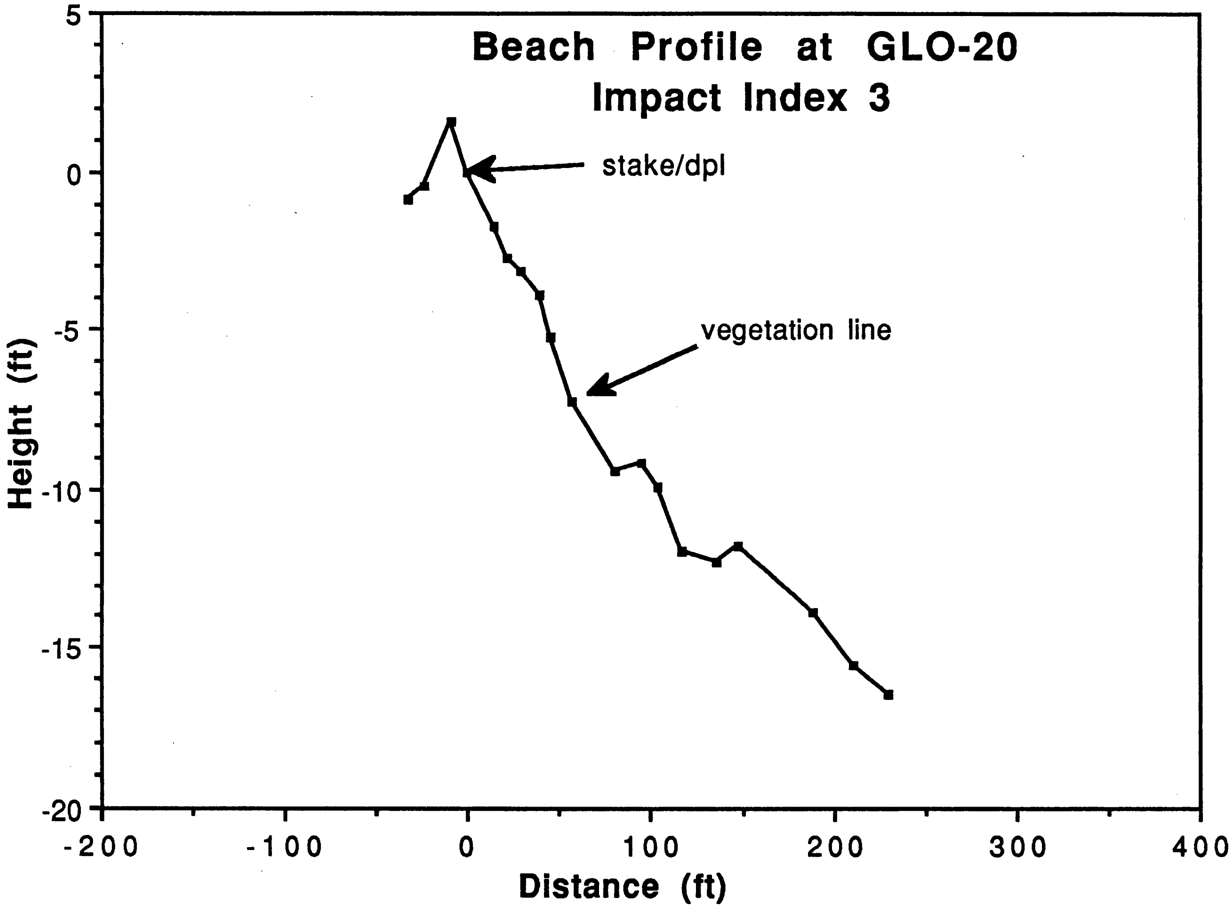

Beach Profile at GLO-18
Impact Index 3.5
sand piles
stake/dpl
vegetation line
8
3
-2
-7
-12
Height (ft)
-100
0
100
200
300
400
500
Distance (ft)

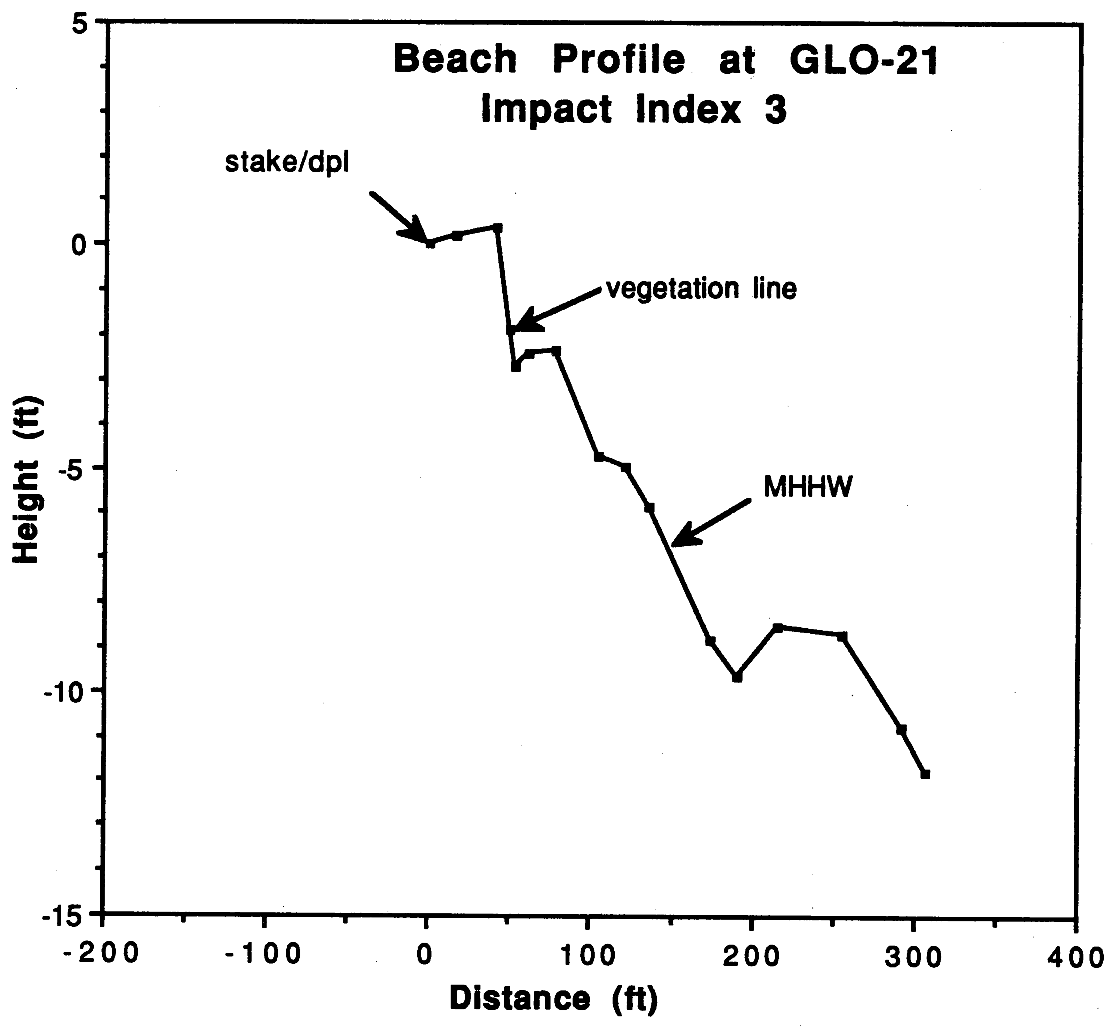


Beach Profile at GLO-19
Impact Index 4
stake
dpl
sand piles
vegetation line
Height (ft)
8
3
-2
-7
-12
-200
-100
0
100
200
300
400
Distance (ft)

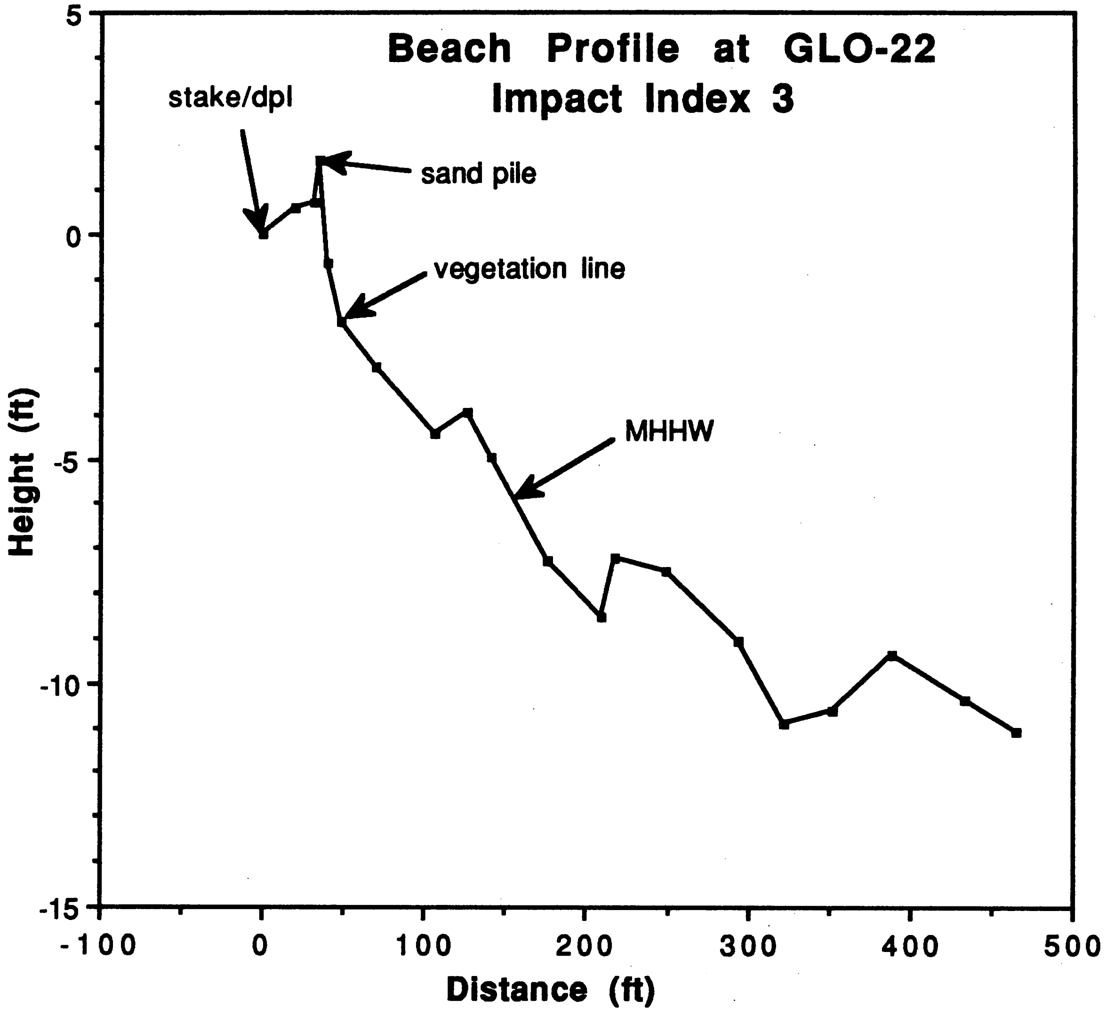


Beach Profile at BEG-9 (Caplen)
Impact Index 0
stake
dpl
vegetation line
Height (ft)
5
0
-5
-10
-15
-20
-100
0
100
200
300
400
500
Distance (ft)

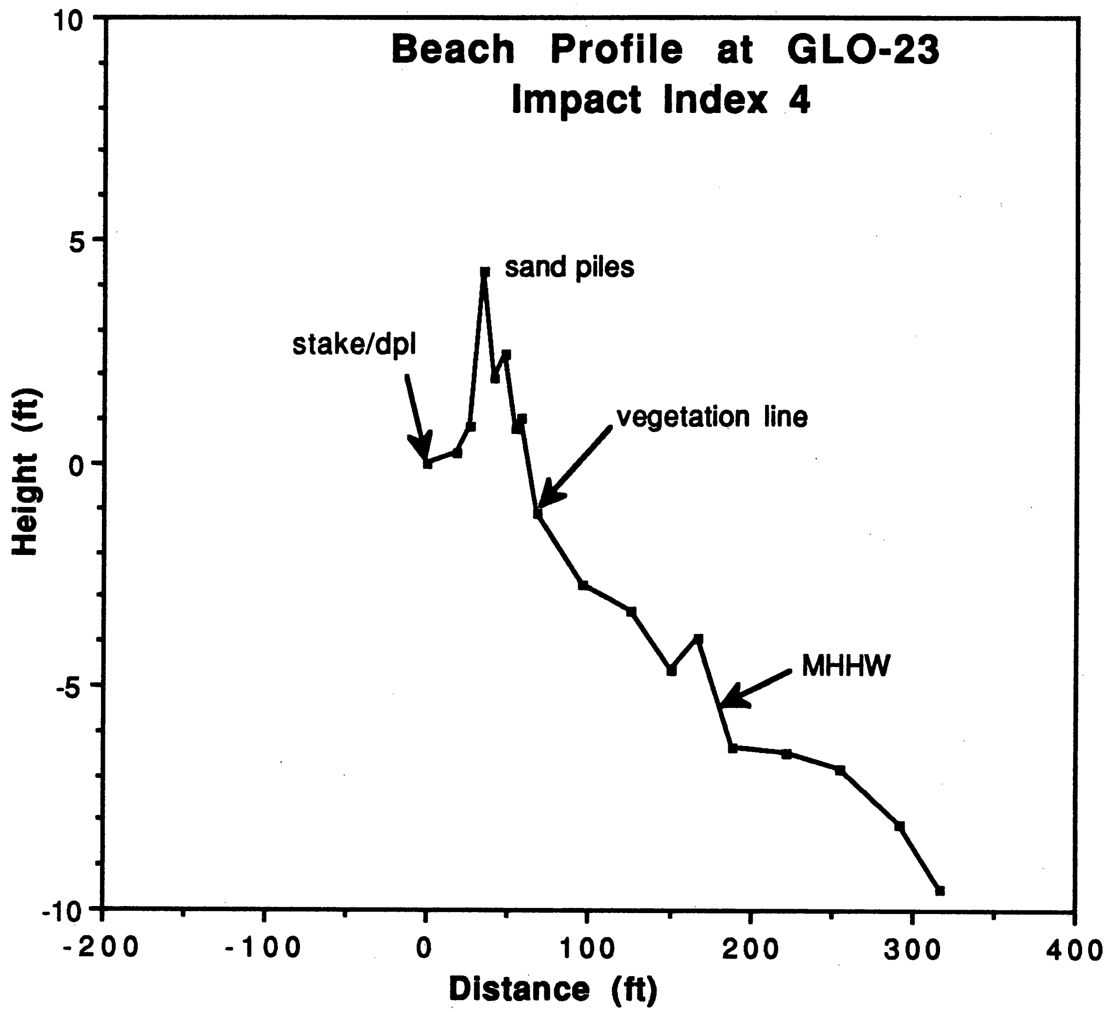

Beach Profile at GLO-20
Impact Index 3
stake/dpl
vegetation line
Height (ft)
Distance (ft)
5
0
-5
-10
-15
-20
-200
-100
0
100
200
300
400

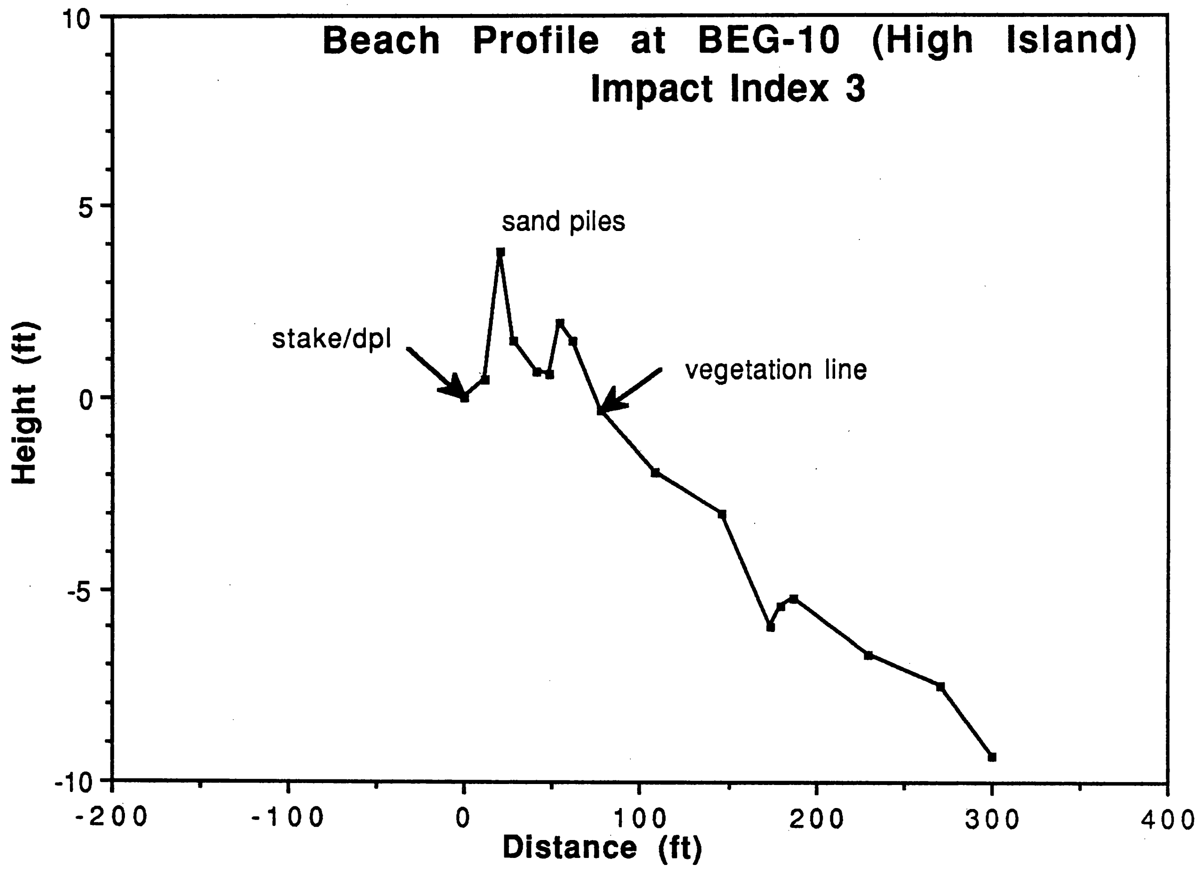


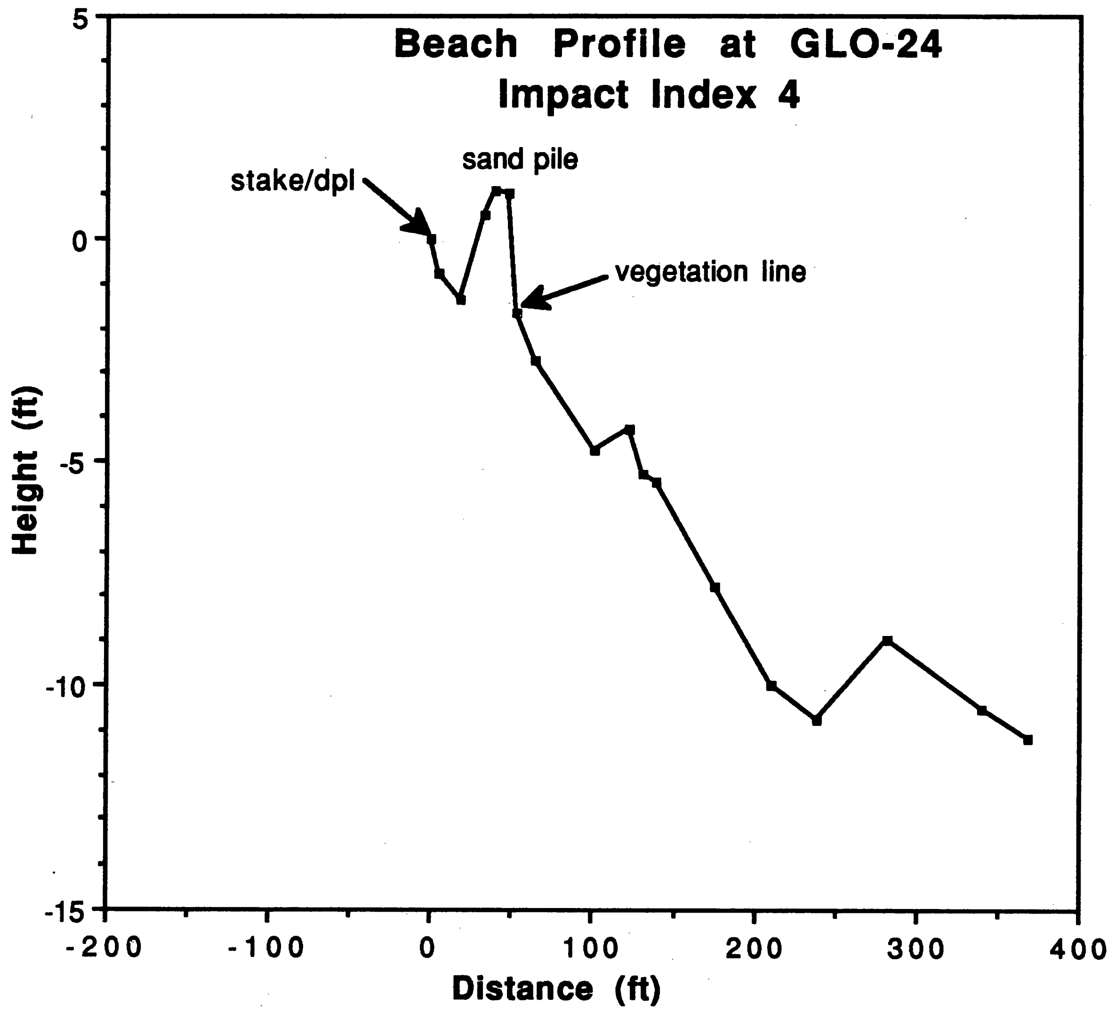
Beach Profile at GLO-21
Impact Index 3
stake/dpl
vegetation line
MHHW
Height (ft)
5
0
-5
-10
-15
-200
-100
0
100
200
300
400
Distance (ft)



Beach Profile at GLO-22
Impact Index 3
stake/dpl
sand pile
vegetation line
MHHW
Height (ft)
5
0
-5
-10
-15
-100
0
100
200
300
400
500
Distance (ft)


Beach Profile at GLO-23
Impact Index 4
sand piles
stake/dpl
vegetation line
MHHW
Height (ft)
Distance (ft)
10
5
0
-5
-10
-200
-100
0
100
200
300
400


Beach Profile at BEG-10 (High Island)
Impact Index 3
sand piles
stake/dpl
vegetation line
Height (ft)
Distance (ft)
10
5
0
-5
-10
-200
-100
0
100
200
300
400


Beach Profile at GLO-24
Impact Index 4
stake/dpl
sand pile
vegetation line
Height (ft)
5
0
-5
-10
-15
-200
-100
0
100
200
300
400
Distance (ft)

APPENDIX B

Data Sheets and Comments for
Beach and Dune Profiles of Galveston County

BEG-4 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	214.186	-1.555	0.000	8.927	0.000	0.000	benchmark
2	214.370	-0.551	32.051	7.566	32.051	-1.362	vegetated barrier flat
3	182.136	-2.917	61.030	7.375	61.030	-1.552	vegetated barrier flat
4	153.156	-3.107	89.167	7.661	89.167	-1.266	vegetated barrier flat
5	125.020	-2.822	118.468	8.241	118.468	-0.686	vegetated barrier flat
6	95.719	-2.241	150.682	9.265	150.682	0.338	vegetated barrier flat
7	63.504	-1.217	183.215	9.557	183.215	0.630	vegetated barrier flat
8	30.971	-0.925	214.186	10.482	214.186	1.555	dpl and dune crest
9	0.000	0.000	220.026	9.498	220.026	0.571	Alicia escarpment
10	-5.840	-0.984	225.515	6.791	225.515	-2.136	Base Alicia escarpment
11	-11.329	-3.691	233.842	7.720	233.842	-1.207	First nat. foredune crest
12	-19.656	-2.762	245.653	6.125	245.653	-2.802	road as seen on aerial
13	-31.467	-4.357	257.211	5.915	257.211	-3.012	
14	-43.025	-4.567	269.308	7.451	269.308	-1.476	crest of nat. hummock
15	-55.121	-3.031	284.639	7.182	284.639	-1.745	low area w/in hummock
16	-70.453	-3.301	291.217	8.140	291.217	-0.787	hummock crest
17	-77.031	-2.343	305.525	6.060	305.525	-2.867	
18	-91.339	-4.423	320.568	5.951	320.568	-2.976	crest of low hummock
19	-106.381	-4.531	332.671	5.308	332.671	-3.619	
20	-118.484	-5.174	348.317	5.856	348.317	-3.071	crest seawardmost hummock
21	-134.131	-4.626	366.286	4.984	366.286	-3.944	vegetation line
22	-152.100	-5.499	389.560	4.636	389.560	-4.291	
23	-175.374	-5.846	418.114	4.560	418.114	-4.367	backbeach/no recent sargass
24	-203.927	-5.922	444.892	4.505	444.892	-4.423	backbeach/roadway
25	-230.705	-5.978	470.292	4.186	470.292	-4.741	driftline /sargass
26	-256.106	-6.296	497.530	3.881	497.530	-5.046	backbeach
27	-283.343	-6.601	526.867	3.996	526.867	-4.931	upper berm
28	-312.680	-6.486	573.970	1.657	573.970	-7.270	swash
29	-359.783	-8.825	626.316	0.295	626.316	-8.632	breakers
30	-412.129	-10.187					

GLO-1 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	25.590	-1.780	-25.590	-1.780	-0.000	-0.000	stake/dpl
2	25.610	-1.551	-17.797	-1.889	7.793	-0.109	leeward base of natural dune
3	17.797	-1.889	-11.262	0.243	14.328	2.023	crest-landwardmost foredune
4	11.262	0.243	-5.413	-0.538	20.177	1.242	inter-foredune swale
5	5.413	-0.538	0.000	0.000	25.590	1.780	crest-seaward foredune
6	0.000	0.000	8.784	-1.236	34.374	0.544	
7	-8.784	-1.236	15.708	-2.993	41.298	-1.213	windward base of foredune
8	-15.708	-2.993	32.774	-5.239	58.364	-3.459	vegetation line
9	-32.774	-5.239	51.793	-6.289	77.383	-4.509	backbeach
10	-51.793	-6.289	66.646	-6.456	92.236	-4.676	berm crest
11	-66.646	-6.456	91.105	-8.154	116.695	-6.374	foreshore-mixed shells
12	-91.105	-8.154	120.479	-9.164	146.069	-7.384	swash
13	-120.479	-9.164	145.203	-9.938	170.793	-8.158	
14	-145.203	-9.938	169.056	-9.859	194.646	-8.079	bar
15	-169.056	-9.859	197.856	-10.692	223.446	-8.912	trough
16	-197.856	-10.692	224.105	-12.275	249.695	-10.495	
17	-224.105	-12.275	259.023	-12.184	284.613	-10.404	bar
18	-259.023	-12.184	287.430	-11.908	313.020	-10.128	bar
19	-287.430	-11.908	323.915	-12.607	349.505	-10.827	
20	-323.915	-12.607					

GLO-2 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	16.639	-3.193	-16.639	-3.193	-0.000	-0.000	stake/dpl
2	16.498	-2.921	-9.643	-3.823	6.996	-0.630	leeward base-natural dune
3	9.643	-3.823	0.000	0.000	16.639	3.193	crest
4	0.000	0.000	19.698	-4.075	36.337	-0.882	
5	-19.698	-4.075	32.305	-5.157	48.944	-1.964	intra-foredune swale
6	-32.305	-5.157	38.600	-4.702	55.239	-1.509	leew. base-new nat. foredune
7	-38.600	-4.702	48.275	-2.613	64.914	0.580	crest-new nat. foredune
8	-48.275	-2.613	58.164	-5.043	74.803	-1.850	windw. base of foredune
9	-58.164	-5.043	66.977	-5.692	83.616	-2.499	leeward of sandpile
10	-66.977	-5.692	69.659	-5.164	86.298	-1.971	crest of sand pile
11	-69.659	-5.164	79.570	-6.108	96.209	-2.915	vegetation line
12	-79.570	-6.108	110.800	-7.495	127.439	-4.302	drift line
13	-110.800	-7.495	135.833	-7.675	152.472	-4.482	backbeach
14	-135.833	-7.675	145.141	-7.672	161.780	-4.479	berm crest
15	-145.141	-7.672	168.607	-9.079	185.246	-5.886	foreshore
16	-168.607	-9.079	193.121	-9.898	209.760	-6.705	foreshore
17	-193.121	-9.898	219.466	-10.508	236.105	-7.315	swash
18	-219.466	-10.508	245.128	-11.433	261.767	-8.240	breakers
19	-245.128	-11.433	273.774	-11.505	290.413	-8.312	bar (top)
20	-273.774	-11.505	304.751	-11.544	321.390	-8.351	
21	-304.751	-11.544	334.495	-13.223	351.134	-10.030	trough
22	-334.495	-13.223	352.000	-14.036	368.639	-10.843	trough
23	-352.000	-14.036					

BEG-5 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	Comments
1	227.507	1.056	0.000	8.005	
2	172.123	1.145	55.384	8.094	
3	117.060	0.784	110.446	7.733	
4	100.177	1.348	127.329	8.297	Alicia escarpment
5	89.678	0.564	137.828	7.513	
6	66.969	-0.226	160.538	6.722	
7	59.856	1.663	167.651	8.612	
8	35.620	0.102	191.886	7.051	
9	10.062	0.335	217.444	7.283	
10	6.604	1.391	220.902	8.340	
11	0.000	0.000	227.507	6.949	
12	-16.385	-1.555	243.891	5.394	vegetation line
13	-55.614	-2.805	283.120	4.144	runnel
14	-71.339	-2.815	298.845	4.134	berm crest
15	-117.867	-4.849	345.374	2.100	
16	-161.558	-5.676	389.065	1.273	
17	-201.985	-7.608	429.491	-0.659	

GLO-3 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	59.843	1.262	-59.843	1.262	0.000	0.000	stake/dpl
2	59.941	1.725	-49.738	1.374	10.105	0.112	base-leeward side of foredune
3	49.738	1.374	-43.925	2.007	15.918	0.745	crest
4	43.925	2.007	-30.364	1.574	29.479	0.312	windw. base of nat. foredune
5	30.364	1.574	-25.508	2.754	34.335	1.492	crest of modified dune
6	25.508	2.754	-16.770	0.882	43.073	-0.380	windw. base of modif. dune
7	16.770	0.882	-7.777	0.213	52.066	-1.049	vegetation line
8	7.777	0.213	-2.803	0.069	57.040	-1.193	backbeach
9	2.803	0.069	0.000	0.000	59.843	-1.262	
10	0.000	0.000	22.836	-0.554	82.679	-1.816	
11	-22.836	-0.554	45.541	-1.203	105.384	-2.465	drift line
12	-45.541	-1.203	74.502	-1.128	134.345	-2.390	berm crest
13	-74.502	-1.128	102.154	-2.866	161.997	-4.128	foreshore
14	-102.154	-2.866	129.197	-3.564	189.040	-4.826	
15	-129.197	-3.564	157.318	-4.302	217.161	-5.564	swash
16	-157.318	-4.302	184.652	-5.377	244.495	-6.639	plunge step
17	-184.652	-5.377	214.466	-5.469	274.309	-6.731	breakers
18	-214.466	-5.469	240.321	-5.367	300.164	-6.629	bar
19	-240.321	-5.367	273.898	-5.938	333.741	-7.200	bar
20	-273.898	-5.938	303.430	-7.636	363.273	-8.898	trough
21	-303.430	-7.636					

GLO-4 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	23.649	-3.764	-23.649	-3.764	-0.000	0.000	stake/dpl
2	23.620	-2.921	-13.462	-2.557	10.187	1.207	
3	13.462	-2.557	-4.554	-0.938	19.095	2.826	broad top of dune
4	4.554	-0.938	0.000	0.000	23.649	3.764	crest
5	0.000	0.000	12.495	-3.485	36.144	0.279	in bowl of blowout-upper
6	-12.495	-3.485	36.043	-5.367	59.692	-1.603	in bowl of blowout -lower
7	-36.043	-5.367	56.705	-6.764	80.354	-3.000	windw. base of nat. dune
8	-56.705	-6.764	85.325	-6.938	108.974	-3.174	
9	-85.325	-6.938	107.666	-6.256	131.315	-2.492	crest of sand pile
10	-107.666	-6.256	128.662	-8.321	152.311	-4.557	low area in sand pile
11	-128.662	-8.321	151.630	-8.725	175.279	-4.961	windward base of sand pile
12	-151.630	-8.725	177.934	-9.557	201.583	-5.793	bare sand & flat
13	-177.934	-9.557	185.357	-8.302	209.006	-4.538	crest of sand pile
14	-185.357	-8.302	193.485	-9.603	217.134	-5.839	vegetation line
15	-193.485	-9.603	218.885	-9.911	242.534	-6.147	backbeach
16	-218.885	-9.911	242.725	-10.403	266.374	-6.639	driftline
17	-242.725	-10.403	268.866	-10.607	292.515	-6.843	backbeach
18	-268.866	-10.607	296.990	-10.646	320.639	-6.882	berm crest
19	-296.990	-10.646	316.639	-12.131	340.288	-8.367	foreshore
20	-316.639	-12.131	350.780	-12.970	374.429	-9.206	swash
21	-350.780	-12.970	377.433	-13.505	401.082	-9.741	
22	-377.433	-13.505	404.495	-14.036	428.144	-10.272	breakers
23	-404.495	-14.036	428.866	-15.177	452.515	-11.413	
24	-428.866	-15.177	451.446	-15.525	475.095	-11.761	
25	-451.446	-15.525	480.436	-15.131	504.085	-11.367	
26	-480.436	-15.131	510.298	-15.344	533.947	-11.580	
27	-510.298	-15.344	536.705	-16.593	560.354	-12.829	
28	-536.705	-16.593					

BEG-3 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	77.408	-7.034	193.678	7.257	-32.211	-0.148	Carla escarpment
2	66.919	-8.730	204.167	5.561	-21.722	-1.844	swale
3	55.988	-8.146	215.098	6.145	-10.791	-1.260	dpl
4	50.046	-7.034	221.040	7.257	-4.849	-0.148	dune terrrace
5	45.197	-6.886	225.889	7.405	0.000	0.000	stake
6	24.997	-7.326	246.089	6.965	20.200	-0.440	base leeward side of nat. dune
7	14.236	-6.040	256.850	8.251	30.961	0.846	
8	0.000	0.000	271.086	14.291	45.197	6.886	dune crest
9	-18.701	-3.432	289.787	10.860	63.898	3.455	
10	-27.175	-4.721	298.261	9.570	72.372	2.165	
11	-35.686	-4.429	306.772	9.862	80.883	2.457	crest of foredune
12	-45.016	-6.936	316.102	7.356	90.213	-0.049	
13	-54.413	-8.212	325.499	6.079	99.610	-1.325	middle of old road
14	-63.684	-8.107	334.770	6.184	108.881	-1.220	
15	-71.814	-6.056	342.900	8.235	117.011	0.830	crest of sand pile
16	-84.068	-8.301	355.154	5.991	129.265	-1.414	
17	-96.066	-8.707	367.152	5.584	141.263	-1.821	middle of another road
18	-106.411	-7.671	377.497	6.621	151.608	-0.784	crest of sand pile
19	-116.437	-9.147	387.523	5.144	161.634	-2.260	
20	-129.642	-9.783	400.728	4.508	174.839	-2.897	another road middle
21	-148.829	-9.541	419.915	4.751	194.026	-2.654	
22	-162.175	-8.127	433.261	6.165	207.372	-1.240	crest of sand pile
23	-172.779	-9.816	443.865	4.475	217.976	-2.930	vegetation line
24	-207.618	-10.469	478.704	3.822	252.815	-3.583	back beach
25	-221.677	-10.906	492.762	3.386	266.873	-4.019	
26	-253.652	-10.745	524.738	3.547	298.848	-3.858	upper berm
27	-282.730	-11.434	553.816	2.858	327.927	-4.547	lower berm
28	-330.013	-13.868	601.099	0.423	375.210	-6.982	breakers
29	-368.045	-14.383	639.131	-0.092	413.241	-7.497	

GLO-5 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	115.269	-4.082	-115.269	-4.082	-164.371	0.607	Modified Carla escarpment
2	100.613	-6.679	-100.613	-6.679	-149.715	-1.990	base of escarpment
3	43.456	-6.695	-43.456	-6.695	-92.558	-2.006	dpl
4	28.610	-4.593	-28.610	-4.593	-77.712	0.096	terrace
5	14.269	-3.748	-14.269	-3.748	-63.371	0.941	base leeward side of dune
6	0.000	0.000	0.000	0.000	-49.102	4.689	dune crest
7	-28.243	-3.784	28.243	-3.784	-20.859	0.905	base windward side of dune
8	-49.102	-4.689	49.102	-4.689	-0.000	0.000	stake
9	-49.115	-3.970	77.187	-4.836	28.085	-0.147	windward base modified dune
10	-77.187	-4.836	89.223	-4.305	40.121	0.384	
11	-89.223	-4.305	96.502	-2.043	47.400	2.646	modif. dune crest
12	-96.502	-2.043	109.856	-5.131	60.754	-0.442	low area in hummocks
13	-109.856	-5.131	116.341	-5.452	67.239	-0.763	leeward side modif. sand mound
14	-116.341	-5.452	123.495	-4.259	74.393	0.430	crest of modified sand mound
15	-123.495	-4.259	135.744	-5.538	86.642	-0.849	vegetation line
16	-135.744	-5.538	173.049	-6.587	123.947	-1.898	backbeach
17	-173.049	-6.587	209.554	-7.279	160.452	-2.590	backbeach
18	-209.554	-7.279	233.567	-7.279	184.465	-2.590	upper berm (modif. by tractor)
19	-233.567	-7.279	256.315	-7.875	207.213	-3.186	lower berm
20	-256.315	-7.875	301.069	-10.098	251.967	-5.409	water line
21	-301.069	-10.098	365.833	-11.669	316.731	-6.980	breaker
22	-365.833	-11.669	405.934	-11.659	356.832	-6.970	bar
23	-405.934	-11.659	445.866	-12.308	396.764	-7.619	trough
24	-445.866	-12.308					

BEG-7 94 Data (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	34.678	-3.045	-34.678	-3.045	-23.234	-0.204	dpl
2	11.444	-2.841	-11.444	-2.841	0.000	-0.000	stake
3	6.106	-2.585	-6.106	-2.585	5.338	0.256	dune crest
4	0.000	0.000	0.000	0.000	11.444	2.841	seaward of crest
5	-11.302	-0.630	11.302	-0.630	22.746	2.211	top of escarpment
6	-24.042	-1.257	24.042	-1.257	35.486	1.584	windward base of dune
7	-30.666	-4.140	30.666	-4.140	42.110	-1.299	seaward edge of road
8	-56.342	-4.616	56.342	-4.616	67.786	-1.775	leeward base of modif. dune
9	-65.922	-4.058	65.922	-4.058	77.366	-1.217	crest of modif. dune
10	-79.908	-2.064	79.908	-2.064	91.352	0.777	low interd. dune swale
11	-87.260	-3.980	87.260	-3.980	98.704	-1.139	sand pile
12	-93.123	-3.524	93.123	-3.524	104.567	-0.683	GPS pt for veget. line
13	-97.231	-4.236	97.231	-4.236	108.675	-1.395	vegetation line
14	-102.510	-5.121	102.510	-5.121	113.954	-2.280	backbeach
15	-143.048	-6.332	143.048	-6.332	154.492	-3.491	berm crest
16	-170.604	-6.453	170.604	-6.453	182.048	-3.612	foreshore wash
17	-212.090	-8.179	212.090	-8.179	223.534	-5.338	breakers
18	-253.944	-9.072	253.944	-9.072	265.388	-6.231	
19	-297.001	-9.938	297.001	-9.938	308.445	-7.097	
20	-314.872	-11.142	314.872	-11.142	326.316	-8.301	

GLO-6 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	93.387	-3.580	-93.387	-3.580	-65.341	0.171	shower
2	68.639	-3.174	-68.639	-3.174	-40.593	0.577	
3	53.026	-3.498	-53.026	-3.498	-24.980	0.253	dpl
4	28.046	-3.751	-28.046	-3.751	0.000	0.000	stake
5	28.036	-3.157	-11.751	-3.479	16.295	0.272	base leeward side of dune
6	11.751	-3.479	0.000	0.000	28.046	3.751	crest of natural dune
7	0.000	0.000	13.131	-3.725	41.177	0.026	base widward side of dune
8	-13.131	-3.725	25.603	-4.341	53.649	-0.590	low area in modif. dunes
9	-25.603	-4.341	38.108	-2.731	66.154	1.020	modified dune crest
10	-38.108	-2.731	50.387	-4.298	78.433	-0.547	windward side of modif. dune
11	-50.387	-4.298	67.915	-4.508	95.961	-0.757	nat. hummock crest
12	-67.915	-4.508	89.839	-5.852	117.885	-2.101	vegetation line
13	-89.839	-5.852	113.259	-6.613	141.305	-2.862	seaward edge of sargass. pile
14	-113.259	-6.613	133.587	-7.030	161.633	-3.279	drift line
15	-133.587	-7.030	167.475	-7.538	195.521	-3.787	upper berm
16	-167.475	-7.538	189.685	-7.889	217.731	-4.138	lower berm
17	-189.685	-7.889	230.338	-9.698	258.384	-5.947	water line
18	-230.338	-9.698	283.866	-11.289	311.912	-7.538	breakers brake in slope
19	-283.866	-11.289	344.574	-11.882	372.620	-8.131	bar in surf zone
20	-344.574	-11.882	394.974	-13.151	423.020	-9.400	
21	-394.974	-13.151					

BEG-2 94 Data (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	46.844	-5.627	0.000	5.873	0.000	0.000	base of concrete meas @gr base
2	38.337	-5.669	8.507	5.830	8.507	-0.043	dpl
3	15.705	-3.688	31.138	7.812	31.138	1.939	1/2 way up leeward slope
4	7.802	-2.687	39.042	8.812	39.042	2.940	3/4 " " " " " " " " "
5	0.000	0.000	46.844	11.499	46.844	5.627	Alicia erosional escarpment
6	-7.388	-2.795	54.232	8.704	54.232	2.831	1/2 down windward slope
7	-14.639	-4.843	61.483	6.657	61.483	0.784	interdunal swale
8	-21.542	-2.913	68.386	8.586	68.386	2.713	crest of modified dune
9	-37.552	-5.512	84.396	5.988	84.396	0.115	windward slope
10	-48.950	-6.581	95.794	4.918	95.794	-0.955	base of windw slp of modif dune
11	-69.245	-6.900	116.089	4.600	116.089	-1.273	vegetation line
12	-99.977	-7.871	146.821	3.629	146.821	-2.244	drift line
13	-112.192	-8.084	159.035	3.415	159.035	-2.457	swale
14	-140.610	-7.776	187.454	3.724	187.454	-2.149	berm crest
15	-170.220	-9.534	217.064	1.965	217.064	-3.907	foreshore swash
16	-212.047	-10.594	258.891	0.906	258.891	-4.967	breakers-waves plunging from SE
17	-248.924	-11.220	295.768	0.279	295.768	-5.594	breakers (bar?)
18	-279.321	-12.582	326.165	-1.083	326.165	-6.955	waist deep

GLO-7 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	103.836	1.285	-103.718	0.685	-0.000	0.000	stake
2	103.718	0.685	-81.728	0.472	21.990	-0.213	Alicia escarpment/dpl
3	81.728	0.472	-78.377	-1.020	25.341	-1.705	
4	78.377	-1.020	-67.849	-0.708	35.869	-1.393	crest of first debris pile
5	67.849	-0.708	-51.944	1.452	51.774	0.767	
6	51.944	1.452	-44.275	-1.098	59.443	-1.783	
7	44.275	-1.098	-32.905	-1.941	70.813	-2.626	leeward edge of 2nd debris pile
8	32.905	-1.941	-24.777	0.528	78.941	-0.157	crest of 2nd debris pile
9	24.777	0.528	-18.203	-1.557	85.515	-2.242	windward edge of 2nd debris pil
10	18.203	-1.557	-12.134	-1.928	91.584	-2.613	leew. base of 3rd debris pile
11	12.134	-1.928	0.000	0.000	103.718	-0.685	crest of 3rd debris pile
12	0.000	0.000	8.311	-2.125	112.029	-2.810	windw. base of 3rd debris pile
13	-8.311	-2.125	13.797	-2.282	117.515	-2.967	crest of sand pile
14	-13.797	-2.282	17.662	-2.725	121.380	-3.410	veget. line
15	-17.662	-2.725	62.600	-4.334	166.318	-5.019	backbeach/swale scraped
16	-62.600	-4.334	81.298	-4.167	185.016	-4.852	berm crest
17	-81.298	-4.167	127.433	-6.518	231.151	-7.203	swash
18	-127.433	-6.518	174.072	-7.285	277.790	-7.970	top of bar
19	-174.072	-7.285	215.521	-8.869	319.239	-9.554	trough
20	-215.521	-8.869	251.295	-9.161	355.013	-9.846	bar
21	-251.295	-9.161					

GLO-8 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	34.705	-0.489	-34.603	-1.197	-0.000	0.000	stake
2	34.603	-1.197	-19.567	-1.672	15.036	-0.475	top of Alicia escarpment/dpl
3	19.567	-1.672	-14.446	-2.584	20.157	-1.387	base of escarpment
4	14.446	-2.584	-7.026	-2.089	27.577	-0.892	leeward base of modif. dune
5	7.026	-2.089	0.000	0.000	34.603	1.197	crest
6	0.000	0.000	13.193	-3.649	47.796	-2.452	windw. base of modif. dune
7	-13.193	-3.649	29.895	-3.931	64.498	-2.734	swale
8	-29.895	-3.931	40.079	-3.548	74.682	-2.351	crest of modified dune
9	-40.079	-3.548	46.964	-3.311	81.567	-2.114	crest of sand pile
10	-46.964	-3.311	53.013	-3.003	87.616	-1.806	crest of sd. pile aff. by aeoli
11	-53.013	-3.003	59.685	-4.774	94.288	-3.577	low intra sand pile area
12	-59.685	-4.774	64.239	-4.348	98.842	-3.151	sand pile crest
13	-64.239	-4.348	68.105	-5.246	102.708	-4.049	vegetation line
14	-68.105	-5.246	108.066	-6.416	142.669	-5.219	backbeach
15	-108.066	-6.416	125.210	-6.357	159.813	-5.160	berm crest
16	-125.210	-6.357	165.774	-8.443	200.377	-7.246	foreshore
17	-165.774	-8.443	210.249	-9.420	244.852	-8.223	crest of low tide bar
18	-210.249	-9.420	247.164	-10.095	281.767	-8.898	trough
19	-247.164	-10.095	286.577	-11.459	321.180	-10.262	
20	-286.577	-11.459	321.941	-10.810	356.544	-9.613	bar crest
21	-321.941	-10.810	367.718	-12.731	402.321	-11.534	
22	-367.718	-12.731					

BEG-1 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	-92.057	-2.510	-261.683	7.520	0.000	0.000	dpl
2	-61.158	-0.771	-230.784	9.259	30.899	1.739	
3	-23.504	-1.112	-193.130	8.917	68.553	1.398	leeward base modif. dune
4	-18.386	0.830	-188.012	10.860	73.671	3.340	crest
5	-13.786	-1.358	-183.412	8.671	78.271	1.152	inter modif. dune swale
6	-7.408	-0.374	-177.034	9.656	84.649	2.136	crest of sand mound
7	-4.003	-1.224	-173.629	8.806	88.054	1.286	
8	0.000	0.000	-169.626	10.030	92.057	2.510	instrument
9	4.967	0.909	-164.659	10.938	97.024	3.419	crest of sand mound
10	15.630	-4.288	-153.996	5.741	107.687	-1.778	veg. line @windwrd base of pile
11	53.934	-5.548	-115.692	4.482	145.991	-3.038	backbeach
12	74.925	-5.499	-94.701	4.531	166.982	-2.989	berm crest
13	113.025	-7.205	-56.601	2.825	205.082	-4.695	foreshore
14	169.626	-9.209	0.000	0.820	261.683	-6.699	tower base
15	169.409	-3.862	26.768	0.951	288.451	-6.568	top of intertidal bar
16	196.394	-9.078	64.055	-1.070	325.738	-8.589	trough
17	233.681	-11.099	95.545	-0.138	357.228	-7.657	bar crest
18	265.171	-10.167	139.219	-1.014	400.902	-8.533	
19	308.845	-11.043	156.033	-2.047	417.717	-9.567	trough/chest deep
20	325.659	-12.077					

GLO-9 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	48.443	-0.141	-48.443	-0.141	-25.010	0.272	dpl
2	23.433	-0.413	-23.433	-0.413	0.000	-0.000	stake
3	23.541	0.184	0.000	0.000	23.433	0.413	
4	0.000	0.000	4.525	0.210	27.958	0.623	top erosional escarpment
5	-4.525	0.210	8.207	-1.918	31.640	-1.505	windw. base of escarpment
6	-8.207	-1.918	11.325	-1.105	34.758	-0.692	top of sargassum sd pile
7	-11.325	-1.105	20.511	-3.456	43.944	-3.043	vegetation line
8	-20.511	-3.456	59.098	-5.475	82.531	-5.062	backbeach
9	-59.098	-5.475	84.695	-5.492	108.128	-5.079	berm crest
10	-84.695	-5.492	123.259	-7.049	146.692	-6.636	foreshore
11	-123.259	-7.049	165.866	-8.233	189.299	-7.820	low tide swale/swash
12	-165.866	-8.233	212.702	-8.957	236.135	-8.544	breakers
13	-212.702	-8.957	253.295	-10.272	276.728	-9.859	trough
14	-253.295	-10.272	289.220	-9.836	312.653	-9.423	bar
15	-289.220	-9.836	337.230	-11.469	360.663	-11.056	
16	-337.230	-11.469					

GLO-10 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	527.243	-5.508	-527.243	-5.508	-291.961	-1.364	
2	484.643	-4.911	-484.643	-4.911	-249.361	-0.767	leeward base of lndwrd. dune
3	467.682	-4.944	-467.682	-4.944	-232.400	-0.800	leew. base of second dune
4	452.954	-2.049	-452.954	-2.049	-217.672	2.095	crest
5	439.449	-4.216	-439.449	-4.216	-204.167	-0.072	blowout bowl
6	420.016	-4.767	-420.016	-4.767	-184.734	-0.623	windward base
7	410.718	-3.148	-410.718	-3.148	-175.436	0.996	crest
8	362.816	-6.049	-362.816	-6.049	-127.534	-1.905	vegetated barrier flat
9	318.433	-4.961	-318.433	-4.961	-83.151	-0.817	crest-small mound
10	275.630	-6.072	-275.630	-6.072	-40.348	-1.928	leew. base of 2nd dune cplx.
11	235.249	-3.597	-235.282	-4.144	0.000	-0.000	stake
12	235.282	-4.144	-217.505	-3.610	17.777	0.534	crest in 2nd dune cplx.
13	217.505	-3.610	-208.866	-4.748	26.416	-0.604	windward base
14	208.866	-4.748	-190.341	-4.010	44.941	0.134	crest
15	190.341	-4.010	-183.249	-5.341	52.033	-1.197	windward base
16	183.249	-5.341	-144.584	-5.800	90.698	-1.656	vegetated barrier flat
17	144.584	-5.800	-108.023	-6.098	127.259	-1.954	
18	108.023	-6.098	-66.285	-6.115	168.997	-1.971	dpl
19	66.285	-6.115	-49.925	-6.013	185.357	-1.869	leew. base of spillover lobe
20	49.925	-6.013	-26.230	-5.482	209.052	-1.338	
21	26.230	-5.482	-15.049	-3.839	220.233	0.305	
22	15.049	-3.839	-9.056	-1.659	226.226	2.485	level area
23	9.056	-1.659	0.000	0.000	235.282	4.144	crest
24	0.000	0.000	9.256	-3.800	244.538	0.344	
25	-9.256	-3.800	26.085	-5.780	261.367	-1.636	low interdune area
26	-26.085	-5.780	33.387	-5.079	268.669	-0.935	sand pile crest
27	-33.387	-5.079	37.725	-5.705	273.007	-1.561	low w/in sand piles
28	-37.725	-5.705	43.731	-4.698	279.013	-0.554	crest of sand pile
29	-43.731	-4.698	57.649	-5.990	292.931	-1.846	vegetation line
30	-57.649	-5.990	94.098	-6.728	329.380	-2.584	backbeach
31	-94.098	-6.728	131.272	-7.508	366.554	-3.364	swale
32	-131.272	-7.508	171.990	-7.433	407.272	-3.289	berm crest
33	-171.990	-7.433	207.551	-9.200	442.833	-5.056	swash
34	-207.551	-9.200	247.298	-9.977	482.580	-5.833	breakers
35	-247.298	-9.977	286.564	-11.639	521.846	-7.495	bar
36	-286.564	-11.639					

GLO-11 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	28.489	-1.820	-28.489	-1.820	0.000	0.000	stake/dpl
2	28.466	-1.252	-16.269	-2.298	12.220	-0.478	leeward base of modif. dune
3	16.269	-2.298	-7.305	-1.085	21.184	0.735	
4	7.305	-1.085	0.000	0.000	28.489	1.820	crest
5	0.000	0.000	6.538	-0.607	35.027	1.213	
6	-6.538	-0.607	14.941	-2.364	43.430	-0.544	windward base of modif. dune
7	-14.941	-2.364	53.993	-2.987	82.482	-1.167	veg. barrier flat-hummocky
8	-53.993	-2.987	80.784	-2.948	109.273	-1.128	leeward base of modif. dune
9	-80.784	-2.948	94.630	-0.646	123.119	1.174	crest
10	-94.630	-0.646	112.734	-3.489	141.223	-1.669	interdune swale
11	-112.734	-3.489	120.230	-3.351	148.719	-1.531	leeward base of sand pile
12	-120.230	-3.351	130.708	-1.731	159.197	0.089	crest of sand pile
13	-130.708	-1.731	137.089	-2.954	165.578	-1.134	leeward base of new sand pile
14	-137.089	-2.954	141.810	-0.613	170.299	1.207	crest
15	-141.810	-0.613	147.338	-3.554	175.827	-1.734	vegetation line
16	-147.338	-3.554	185.590	-4.502	214.079	-2.682	backbeach
17	-185.590	-4.502	222.954	-5.177	251.443	-3.357	swale (approx)
18	-222.954	-5.177	260.797	-5.003	289.286	-3.183	berm crest
19	-260.797	-5.003	299.230	-6.997	327.719	-5.177	foreshore
20	-299.230	-6.997	337.574	-7.646	366.063	-5.826	
21	-337.574	-7.646	376.580	-9.344	405.069	-7.524	bar breakers
22	-376.580	-9.344	418.823	-9.062	447.312	-7.242	
23	-418.823	-9.062	459.826	-9.633	488.315	-7.813	
24	-459.826	-9.633	486.007	-11.203	514.496	-9.383	
25	-486.007	-11.203					

GLO-12 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	21.410	-5.213	-21.410	-5.213	0.000	-0.000	stake/dpl
2	21.449	-4.475	-12.895	-5.157	8.515	0.056	leeward base of modif. dune
3	12.895	-5.157	-6.980	-2.885	14.430	2.328	
4	6.980	-2.885	0.000	0.000	21.410	5.213	crest
5	0.000	0.000	9.138	-2.875	30.548	2.338	
6	-9.138	-2.875	18.233	-5.426	39.643	-0.213	base of windward slope
7	-18.233	-5.426	29.702	-3.367	51.112	1.846	modif. dune crest
8	-29.702	-3.367	37.774	-5.030	59.184	0.183	windward base of modif. dune
9	-37.774	-5.030	54.731	-4.761	76.141	0.452	interdune swale
10	-54.731	-4.761	64.010	-3.977	85.420	1.236	modif. dune crest
11	-64.010	-3.977	70.449	-4.738	91.859	0.475	low area w/in sand piles
12	-70.449	-4.738	80.092	-4.138	101.502	1.075	crest of sand piles
13	-80.092	-4.138	89.387	-5.616	110.797	-0.403	low area w/in sand piles
14	-89.387	-5.616	103.311	-4.433	124.721	0.780	aeolian sd. pile (crest)
15	-103.311	-4.433	116.866	-5.502	138.276	-0.289	
16	-116.866	-5.502	126.466	-4.915	147.876	0.298	
17	-126.466	-4.915	131.311	-5.856	152.721	-0.643	vegetation line
18	-131.311	-5.856	169.334	-6.905	190.744	-1.692	backbeach
19	-169.334	-6.905	208.033	-7.361	229.443	-2.148	
20	-208.033	-7.361	241.925	-7.472	263.335	-2.259	berm crest
21	-241.925	-7.472	278.682	-9.111	300.092	-3.898	foreshore
22	-278.682	-9.111	321.069	-9.951	342.479	-4.738	crest of low tide bar
23	-321.069	-9.951	359.997	-11.593	381.407	-6.380	
24	-359.997	-11.593	399.715	-11.498	421.125	-6.285	bar
25	-399.715	-11.498	439.751	-11.682	461.161	-6.469	
26	-439.751	-11.682	471.420	-13.525	492.830	-8.312	
27	-471.420	-13.525					

GLO-13 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	89.489	-5.131	-89.489	-5.131	0.000	-0.000	stake/dpl
2	89.485	-4.439	-62.643	-3.862	26.846	1.269	crest of natural historic dune
3	62.643	-3.862	-37.089	-4.557	52.400	0.574	interdunal swale
4	37.089	-4.557	-9.610	-4.774	79.879	0.357	leew. base of natural foredune
5	9.610	-4.774	-3.908	-2.498	85.581	2.633	
6	3.908	-2.498	0.000	0.000	89.489	5.131	crest
7	0.000	0.000	9.131	-3.433	98.620	1.698	
8	-9.131	-3.433	19.049	-4.846	108.538	0.285	base windw. side of foredune
9	-19.049	-4.846	50.023	-5.390	139.512	-0.259	top aeolian mound
10	-50.023	-5.390	63.269	-5.793	152.758	-0.662	low area on former backbeach
11	-63.269	-5.793	78.577	-5.416	168.066	-0.285	former backbeach
12	-78.577	-5.416	89.279	-5.784	178.768	-0.653	landward edge of road
13	-89.279	-5.784	101.892	-5.761	191.381	-0.630	seaward edge of road
14	-101.892	-5.761	136.866	-5.826	226.355	-0.695	hummocky area
15	-136.866	-5.826	163.843	-5.620	253.332	-0.489	leeward base of aeolian mound
16	-163.843	-5.620	171.902	-4.669	261.391	0.462	crest of aeolian mound
17	-171.902	-4.669	185.052	-5.384	274.541	-0.253	
18	-185.052	-5.384	192.115	-6.098	281.604	-0.967	vegetation line
19	-192.115	-6.098	228.308	-6.266	317.797	-1.135	backbeach
20	-228.308	-6.266	265.872	-6.082	355.361	-0.951	normal high berm
21	-265.872	-6.082	277.000	-6.030	366.489	-0.899	edge of berm
22	-277.000	-6.030	296.941	-7.315	386.430	-2.184	toe of erosional feature
23	-296.941	-7.315	307.495	-7.423	396.984	-2.292	crest of midlevel berm
24	-307.495	-7.423	320.010	-8.266	409.499	-3.135	drift line
25	-320.010	-8.266	341.498	-8.695	430.987	-3.564	lowest area of runnel
26	-341.498	-8.695	365.875	-8.652	455.364	-3.521	low berm crest
27	-365.875	-8.652	400.069	-9.423	489.558	-4.292	foreshore/swash
28	-400.069	-9.423	449.197	-10.787	538.686	-5.656	breakers
29	-449.197	-10.787	486.856	-11.584	576.345	-6.453	flat nearshore
30	-486.856	-11.584	525.007	-11.803	614.496	-6.672	flat nearshore
31	-525.007	-11.803	571.846	-12.482	661.335	-7.351	
32	-571.846	-12.482	616.223	-11.738	705.712	-6.607	bar
33	-616.223	-11.738	676.118	-11.934	765.607	-6.803	flat nearshore
34	-676.118	-11.934	713.354	-12.626	802.843	-7.495	
35	-713.354	-12.626					

GLO-14 94 DATA (ft)

	9/94 XRAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	73.000	-3.246	-73.000	-3.246	0.000	0.000	stake/dpl
2	72.944	-2.836	-35.102	-4.020	37.898	-0.774	leew. base of natural foredune
3	35.102	-4.020	-20.374	-1.679	52.626	1.567	interforedune low area
4	20.374	-1.679	-8.285	-2.039	64.715	1.207	
5	8.285	-2.039	0.000	0.000	73.000	3.246	crest
6	0.000	0.000	12.102	-2.990	85.102	0.256	
7	-12.102	-2.990	29.082	-4.541	102.082	-1.295	windw. base of foredune
8	-29.082	-4.541	60.744	-5.157	133.744	-1.911	leew. base of sand pile
9	-60.744	-5.157	75.066	-3.095	148.066	0.151	top of sand pile
10	-75.066	-3.095	86.148	-4.593	159.148	-1.347	vegetation line
11	-86.148	-4.593	122.616	-5.272	195.616	-2.026	backbeach
12	-122.616	-5.272	146.443	-5.298	219.443	-2.052	upper berm
13	-146.443	-5.298	168.469	-6.679	241.469	-3.433	toe of erosional feature
14	-168.469	-6.679	176.525	-6.908	249.525	-3.662	mid-level berm
15	-176.525	-6.908	183.767	-7.325	256.767	-4.079	runnel-low
16	-183.767	-7.325	204.367	-7.052	277.367	-3.806	lower berm
17	-204.367	-7.052	232.728	-8.616	305.728	-5.370	foreshore
18	-232.728	-8.616	267.498	-10.141	340.498	-6.895	runnel
19	-267.498	-10.141	298.154	-11.003	371.154	-7.757	landward base of bar
20	-298.154	-11.003	308.430	-9.554	381.430	-6.308	top of bar/swash
21	-308.430	-9.554	343.954	-10.367	416.954	-7.121	breakers
22	-343.954	-10.367	392.170	-12.023	465.170	-8.777	
23	-392.170	-12.023	428.590	-12.810	501.590	-9.564	flat nearshore
24	-428.590	-12.810					

GLO-15 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	188.131	-3.938	-188.131	-3.938	-0.000	0.000	stake/dpl
2	188.138	-3.407	-178.590	-1.600	9.541	2.338	top of escarpment/dune terrace
3	178.590	-1.600	-138.161	-1.249	49.970	2.689	
4	138.161	-1.249	-107.620	-1.121	80.511	2.817	crest
5	107.620	-1.121	-85.833	-2.652	102.298	1.286	interdunal swale
6	85.833	-2.652	-77.430	-2.252	110.701	1.686	leew. base of foredune
7	77.430	-2.252	-57.043	-0.469	131.088	3.469	crest of foredune
8	57.043	-0.469	-40.508	-0.918	147.623	3.020	
9	40.508	-0.918	-33.872	-3.098	154.259	0.840	windw. base of foredune
10	33.872	-3.098	-25.105	-2.918	163.026	1.020	leew. base of modif. dune
11	25.105	-2.918	-7.925	-1.157	180.206	2.781	
12	7.925	-1.157	0.000	0.000	188.131	3.938	crest of modif. dune
13	0.000	0.000	7.993	-1.521	196.124	2.417	
14	-7.993	-1.521	-12.918	-1.180	175.213	2.758	top of sand pile
15	12.918	-1.180	20.987	-3.748	209.118	0.190	vegetation line
16	-20.987	-3.748	60.115	-5.459	248.246	-1.521	backbeach
17	-60.115	-5.459	98.711	-5.954	286.842	-2.016	
18	-98.711	-5.954	113.784	-6.439	301.915	-2.501	upper berm
19	-113.784	-6.439	133.875	-7.102	322.006	-3.164	swale
20	-133.875	-7.102	149.616	-6.820	337.747	-2.882	mid-level berm
21	-149.616	-6.820	174.495	-9.105	362.626	-5.167	runnel
22	-174.495	-9.105	215.026	-9.380	403.157	-5.442	top of low-tide bar
23	-215.026	-9.380	223.515	-9.000	411.646	-5.062	crest of low-tide bar
24	-223.515	-9.000	270.741	-10.948	458.872	-7.010	breakers
25	-270.741	-10.948	308.357	-12.944	496.488	-9.006	trough
26	-308.357	-12.944	352.174	-11.338	540.305	-7.400	top of bar
27	-352.174	-11.338	410.134	-12.777	598.265	-8.839	
28	-410.134	-12.777	439.993	-13.580	628.124	-9.642	
29	-439.993	-13.580					

GLO-16 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	126.236	-0.895	-126.236	-0.895	-0.000	-0.000	stake/dpl
2	126.223	-0.387	-85.748	-0.846	40.488	0.049	leew. base of modif. dune
3	85.748	-0.846	-75.656	0.646	50.580	1.541	top (not crest) of modif. dune
4	75.656	0.646	-38.964	0.597	87.272	1.492	
5	38.964	0.597	-27.938	-1.049	98.298	-0.154	inter-dune swale
6	27.938	-1.049	-4.984	-1.505	121.252	-0.610	leew. base of sand pile
7	4.984	-1.505	0.000	0.000	126.236	0.895	crest
8	0.000	0.000	7.584	-0.980	133.820	-0.085	
9	-7.584	-0.980	15.361	-2.515	141.597	-1.620	windw. base of sand pile
10	-15.361	-2.515	23.331	-1.931	149.567	-1.036	crest-another sand pile
11	-23.331	-1.931	35.511	-3.662	161.747	-2.767	vegetation line
12	-35.511	-3.662	71.328	-5.095	197.564	-4.200	backbeach
13	-71.328	-5.095	105.472	-5.518	231.708	-4.623	upper berm
14	-105.472	-5.518	127.682	-6.662	253.918	-5.767	toe of erros. feature/swale
15	-127.682	-6.662	144.833	-6.111	271.069	-5.216	mid-level berm
16	-144.833	-6.111	176.423	-8.895	302.659	-8.000	landward edge of runnel
17	-176.423	-8.895	207.495	-10.026	333.731	-9.131	
18	-207.495	-10.026	217.744	-9.016	343.980	-8.121	top of low-tide bar
19	-217.744	-9.016	262.793	-9.544	389.029	-8.649	
20	-262.793	-9.544	300.377	-11.279	426.613	-10.384	
21	-300.377	-11.279	327.538	-11.967	453.774	-11.072	
22	-327.538	-11.967	349.066	-13.410	475.302	-12.515	
23	-349.066	-13.410	391.692	-11.584	517.928	-10.689	
24	-391.692	-11.584	447.348	-12.370	573.584	-11.475	
25	-447.348	-12.370	483.554	-13.315	609.790	-12.420	
26	-483.554	-13.315					

GLO-17 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	57.869	-4.718	-57.869	-4.718	0.000	-0.000	stake/dpl
2	57.790	-4.456	-40.239	-6.446	17.630	-1.728	
3	40.239	-6.446	-26.944	-5.597	30.925	-0.879	
4	26.944	-5.597	-18.505	-4.252	39.364	0.466	
5	18.505	-4.252	-13.105	-4.361	44.764	0.357	
6	13.105	-4.361	-6.246	-1.377	51.623	3.341	
7	6.246	-1.377	0.000	0.000	57.869	4.718	crest
8	0.000	0.000	7.538	-0.990	65.407	3.728	
9	-7.538	-0.990	15.190	-2.154	73.059	2.564	
10	-15.190	-2.154	30.577	-2.574	88.446	2.144	
11	-30.577	-2.574	35.833	-1.889	93.702	2.829	sand pile
12	-35.833	-1.889	42.469	-2.607	100.338	2.111	
13	-42.469	-2.607	56.377	-6.164	114.246	-1.446	vegetation line
14	-56.377	-6.164	92.613	-7.643	150.482	-2.925	
15	-92.613	-7.643	130.951	-7.964	188.820	-3.246	
16	-130.951	-7.964	160.770	-8.351	218.639	-3.633	
17	-160.770	-8.351	177.708	-9.180	235.577	-4.462	
18	-177.708	-9.180	191.852	-9.013	249.721	-4.295	upper berm?
19	-191.852	-9.013	207.213	-9.767	265.082	-5.049	
20	-207.213	-9.767	249.600	-12.856	307.469	-8.138	
21	-249.600	-12.856	274.023	-13.859	331.892	-9.141	
22	-274.023	-13.859	281.721	-12.548	339.590	-7.830	
23	-281.721	-12.548	317.830	-12.272	375.699	-7.554	lower berm
24	-317.830	-12.272	358.538	-13.826	416.407	-9.108	
25	-358.538	-13.826	378.187	-14.852	436.056	-10.134	
26	-378.187	-14.852					

GLO-18 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	51.725	-2.961	-51.725	-2.961	0.000	0.000	stake/dpl
2	51.754	-2.446	-38.377	-1.679	13.348	1.282	crest of sand pile
3	38.377	-1.679	-27.679	-0.725	24.046	2.236	east side of another sd. pile
4	27.679	-0.725	-20.010	-2.466	31.715	0.495	leew. base of sd.&trash mound
5	20.010	-2.466	-11.531	-0.774	40.194	2.187	
6	11.531	-0.774	-4.718	0.718	47.007	3.679	crest of mound
7	4.718	0.718	0.000	0.000	51.725	2.961	
8	0.000	0.000	6.800	-1.728	58.525	1.233	windw. base of mound
9	-6.800	-1.728	13.354	-2.230	65.079	0.731	
10	-13.354	-2.230	17.085	-0.387	68.810	2.574	crest of topsoil/trash pile
11	-17.085	-0.387	20.643	-2.121	72.368	0.840	
12	-20.643	-2.121	23.407	-1.564	75.132	1.397	crest of topsoil/trash pile
13	-23.407	-1.564	26.344	-3.082	78.069	-0.121	
14	-26.344	-3.082	39.656	-4.528	91.381	-1.567	vegetation line
15	-39.656	-4.528	78.111	-5.964	129.836	-3.003	backbeach
16	-78.111	-5.964	106.177	-5.908	157.902	-2.947	backbeach
17	-106.177	-5.908	139.387	-6.990	191.112	-4.029	mid-level berm
18	-139.387	-6.990	154.203	-7.889	205.928	-4.928	foreshore
19	-154.203	-7.889	175.587	-10.056	227.312	-7.095	swash
20	-175.587	-10.056	208.459	-11.446	260.184	-8.485	landward base of lowtide bar
21	-208.459	-11.446	216.190	-10.256	267.915	-7.295	top of bar
22	-216.190	-10.256	240.115	-10.151	291.840	-7.190	
23	-240.115	-10.151	278.515	-11.315	330.240	-8.354	
24	-278.515	-11.315	309.197	-12.997	360.922	-10.036	
25	-309.197	-12.997					

GLO-19 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	117.892	1.892	-117.892	1.892	-41.089	-0.983	dpl
2	109.010	1.921	-109.010	1.921	-32.207	-0.954	leeward base of nat. dune
3	99.518	3.928	-99.518	3.928	-22.715	1.053	crest
4	88.659	2.485	-88.659	2.485	-11.856	-0.390	windw. base of nat. dune
5	76.803	2.875	-76.803	2.875	-0.000	0.000	stake
6	76.731	3.354	-56.446	2.702	20.357	-0.173	base of sand pile
7	56.446	2.702	-46.964	3.472	29.839	0.597	crest
8	46.964	3.472	-41.889	2.610	34.914	-0.265	inter-sand pile swale
9	41.889	2.610	-36.177	3.495	40.626	0.620	crest of sand pile
10	36.177	3.495	-30.852	1.380	45.951	-1.495	vegetation line
11	30.852	1.380	0.000	0.000	76.803	-2.875	backbeach
12	0.000	0.000	18.875	-0.482	95.678	-3.357	
13	-18.875	-0.482	39.485	-1.062	116.288	-3.937	top of foreshore
14	-39.485	-1.062	68.443	-3.220	145.246	-6.095	swash
15	-68.443	-3.220	110.180	-5.898	186.983	-8.773	low-tide runnel
16	-110.180	-5.898	119.128	-4.908	195.931	-7.783	low-tide bar (top)
17	-119.128	-4.908	147.764	-4.738	224.567	-7.613	low-tide bar (top)
18	-147.764	-4.738	188.439	-6.098	265.242	-8.973	
19	-188.439	-6.098	213.761	-7.590	290.564	-10.465	
20	-213.761	-7.590					

BEG-9 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	199.560	5.374	60.039	9.846	0.000	0.000	stake
2	189.613	5.446	69.987	9.918	9.948	0.072	
3	180.217	3.967	79.383	8.438	19.344	-1.407	
4	152.910	1.509	106.690	5.981	46.650	-3.865	aeolian terrace
5	116.637	1.001	142.963	5.472	82.923	-4.373	aeolian terrace
6	89.190	1.358	170.410	5.830	110.371	-4.016	aeolian terrace
7	79.203	1.385	180.397	5.856	120.358	-3.990	dpl/base humm. aeolian dune
8	70.682	1.621	188.917	6.093	128.878	-3.753	crest aeolian hummock
9	59.108	-0.066	200.492	4.406	140.453	-5.440	interdunal swale
10	39.724	1.033	219.875	5.505	159.836	-4.341	crest aeolian hummock
11	26.827	-0.033	232.772	4.439	172.733	-5.407	windward base of hummock
12	10.686	0.177	248.914	4.649	188.875	-5.197	vegetation line
13	0.000	0.000	259.600	4.472	199.560	-5.374	instrument@washover terrace
14	-7.129	0.171	266.729	4.642	206.690	-5.203	seaward edge of washover ter
15	-19.721	-0.715	279.321	3.757	219.281	-6.089	
16	-35.725	-2.428	295.325	2.044	235.285	-7.802	toe of high berm escarpment
17	-61.339	-3.694	320.938	0.778	260.899	-9.068	lower berm
18	-92.815	-7.251	352.415	-2.779	292.375	-12.625	swale
19	-101.493	-6.280	361.093	-1.808	301.053	-11.654	crest of low-tide bar
20	-136.627	-7.208	396.227	-2.736	336.188	-12.582	swash
21	-147.700	-6.982	407.300	-2.510	347.260	-12.356	flat nearshore
22	-194.977	-9.400	454.577	-4.928	394.537	-14.774	trough
23	-212.861	-10.630	472.461	-6.158	412.421	-16.004	trough

GLO-20 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1			-54.455	1.780	-33.005	-0.750	
2			-45.958	2.230	-24.508	-0.450	
3			-30.833	4.229	-9.383	1.549	
4	21.436	2.679	-21.450	2.680	0.000	0.000	stake/dpl
5	21.479	3.239	-7.949	0.988	13.501	-1.692	washover ramp
6	7.944	0.987	0.000	0.000	21.450	-2.680	ramp
7	0.000	0.000	7.405	-0.466	28.855	-3.146	relict drift line
8	-7.400	-0.466	17.749	-1.184	39.199	-3.864	crest
9	-17.738	-1.184	23.901	-2.552	45.351	-5.232	
10	-23.885	-2.551	34.797	-4.531	56.247	-7.211	veg. line, erosion escarpment
11	-34.774	-4.528	59.308	-6.781	80.758	-9.461	runnel w/in backbeach
12	-59.269	-6.777	72.871	-6.512	94.321	-9.192	upper berm
13	-72.823	-6.508	82.566	-7.293	104.016	-9.973	mid-level berm
14	-82.511	-7.289	96.043	-9.239	117.493	-11.919	
15	-95.980	-9.233	114.360	-9.567	135.810	-12.247	lowest part of runnel
16	-114.285	-9.561	125.505	-9.114	146.955	-11.794	lower berm or low-tide bar
17	-125.423	-9.108	167.526	-11.165	188.976	-13.845	breakers
18	-167.416	-11.157	189.511	-12.897	210.961	-15.577	
19	-189.387	-12.889	209.078	-13.819	230.528	-16.499	
20	-208.941	-13.810					

GLO-21 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	60.433	2.403	-60.433	2.403	0.000	0.000	stake/dpl
2	60.479	3.105	-43.695	2.577	16.738	0.174	washover terrace
3	43.695	2.577	-18.839	2.761	41.594	0.358	nat. erosional escarpment
4	18.839	2.761	-10.511	0.495	49.922	-1.908	vegetation line
5	10.511	0.495	-7.121	-0.295	53.312	-2.698	
6	7.121	-0.295	0.000	0.000	60.433	-2.403	backbeach
7	0.000	0.000	17.374	0.062	77.807	-2.341	upper berm
8	-17.374	0.062	42.911	-2.318	103.344	-4.721	
9	-42.911	-2.318	60.928	-2.577	121.361	-4.980	mid-level berm
10	-60.928	-2.577	75.997	-3.433	136.430	-5.836	lower berm
11	-75.997	-3.433	112.826	-6.420	173.259	-8.823	trough
12	-112.826	-6.420	130.262	-7.249	190.695	-9.652	
13	-130.262	-7.249	154.416	-6.138	214.849	-8.541	low-tide bar top
14	-154.416	-6.138	194.184	-6.302	254.617	-8.705	bar top/brakers
15	-194.184	-6.302	230.915	-8.384	291.348	-10.787	seaward edge of bar
16	-230.915	-8.384	246.626	-9.390	307.059	-11.793	trough
17	-246.626	-9.390					NGVD adj=+9.12 ft

GLO-22 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	68.839	2.941	-68.839	2.941	-0.000	-0.000	stake/dpl
2	68.787	3.787	-49.462	3.528	19.377	0.587	washover terrace
3	49.462	3.528	-37.046	3.689	31.793	0.748	
4	37.046	3.689	-33.852	4.630	34.987	1.689	
5	33.852	4.630	-28.672	2.318	40.167	-0.623	sand/sargassum mound
6	28.672	2.318	-20.675	1.003	48.164	-1.938	vegetation line
7	20.675	1.003	0.000	0.000	68.839	-2.941	backbeach
8	0.000	0.000	36.790	-1.515	105.629	-4.456	seaward edge of runnel
9	-36.790	-1.515	56.452	-1.049	125.291	-3.990	upper berm
10	-56.452	-1.049	72.479	-2.016	141.318	-4.957	mid-level berm
11	-72.479	-2.016	106.416	-4.328	175.255	-7.269	runnel
12	-106.416	-4.328	139.682	-5.590	208.521	-8.531	landward toe of low-tide bar
13	-139.682	-5.590	148.800	-4.272	217.639	-7.213	landward top of low-tide bar
14	-148.800	-4.272	179.646	-4.567	248.485	-7.508	breakers
15	-179.646	-4.567	224.341	-6.148	293.180	-9.089	seaward base of low-tide bar
16	-224.341	-6.148	254.118	-7.941	322.957	-10.882	trough
17	-254.118	-7.941	282.439	-7.672	351.278	-10.613	
18	-282.439	-7.672	320.259	-6.420	389.098	-9.361	top of 2nd bar
19	-320.259	-6.420	365.108	-7.410	433.947	-10.351	seaward sid eof 2nd bar
20	-365.108	-7.410	395.770	-8.134	464.609	-11.075	flat nearshore
21	-395.770	-8.134					

GLO-23 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	34.243	-4.275	-34.243	-4.275	0.000	-0.000	stake/dpl
2	34.177	-3.997	-15.925	-4.066	18.318	0.209	leeward base of modif. dune
3	15.925	-4.066	-7.502	-3.466	26.741	0.809	leew. base of escarped m.d.
4	7.502	-3.466	0.000	0.000	34.243	4.275	crest
5	0.000	0.000	7.115	-2.341	41.358	1.934	interdunal swale
6	-7.115	-2.341	13.711	-1.810	47.954	2.465	crest of sand pile
7	-13.711	-1.810	20.387	-3.485	54.630	0.790	
8	-20.387	-3.485	22.915	-3.269	57.158	1.006	windward slope of sandpile
9	-22.915	-3.269	32.521	-5.410	66.764	-1.135	vegetation line
10	-32.521	-5.410	61.213	-7.003	95.456	-2.728	backbeach
11	-61.213	-7.003	91.574	-7.633	125.817	-3.358	upper berm
12	-91.574	-7.633	116.544	-8.892	150.787	-4.617	runnel (bottom)
13	-116.544	-8.892	132.367	-8.220	166.610	-3.945	lower berm
14	-132.367	-8.220	154.800	-10.633	189.043	-6.358	swash
15	-154.800	-10.633	188.485	-10.748	222.728	-6.473	breakers
16	-188.485	-10.748	221.266	-11.095	255.509	-6.820	flat nearshore top of bar
17	-221.266	-11.095	257.125	-12.390	291.368	-8.115	trough
18	-257.125	-12.390	282.269	-13.774	316.512	-9.499	flat nearshore
19	-282.269	-13.774					NGVD adj=+8.264 ft

BEG-10 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjx	adjy	Comments
1	54.393	-1.932	-7.218	-0.656	0.000	-0.000	stake/dpl
2	54.449	-0.945	4.672	-0.154	11.890	0.502	leeward base modif. dune
3	42.503	-1.430	12.999	3.146	20.217	3.802	crest modif. dune
4	34.177	1.870	19.990	0.807	27.208	1.463	windward base modif dune
5	27.185	-0.469	33.202	0.007	40.420	0.663	swale
6	13.973	-1.270	41.401	-0.030	48.619	0.626	leeward base of modif. dune
7	5.774	-1.306	47.175	1.276	54.393	1.932	instrument @crest
8	0.000	0.000	53.668	0.807	60.886	1.463	crest of sand pile
9	-6.493	-0.469	70.390	-1.017	77.608	-0.361	vegetation line
10	-23.215	-2.293	100.666	-2.605	107.884	-1.949	backbeach
11	-53.491	-3.881	138.688	-3.684	145.906	-3.028	lower berm
12	-91.512	-4.961	167.100	-6.601	174.318	-5.945	runnel (bottom)
13	-119.925	-7.877	172.100	-6.106	179.318	-5.450	top seaward runnel edge
14	-124.925	-7.382	179.452	-5.902	186.670	-5.246	low tide berm
15	-132.277	-7.178	222.090	-7.365	229.308	-6.709	breakers
16	-174.915	-8.642	264.081	-8.189	271.299	-7.533	flat nearshore
17	-216.906	-9.465	292.690	-9.970	299.908	-9.314	
18	-245.515	-11.247					

GLO-24 94 DATA (ft)

	9/94 X RAW	9/94 Y RAW	9/94 X CORR	9/94 Y CORR	adjX	adjY	Comments
1	64.849	2.764	-64.849	2.764	-0.000	-0.000	stake/dpl
2	64.879	3.374	-59.856	1.964	4.993	-0.800	base of escarpment
3	59.856	1.964	-47.292	1.393	17.557	-1.371	low area w/in escarpment
4	47.292	1.393	-32.790	3.308	32.059	0.544	
5	32.790	3.308	-26.056	3.830	38.793	1.066	crest
6	26.056	3.830	-17.430	3.764	47.419	1.000	mound crest
7	17.430	3.764	-12.462	1.102	52.387	-1.662	vegetation line
8	12.462	1.102	0.000	0.000	64.849	-2.764	backbeach
9	0.000	0.000	36.531	-1.993	101.380	-4.757	runnel
10	-36.531	-1.993	57.082	-1.505	121.931	-4.269	top of erosional escarpment
11	-57.082	-1.505	65.282	-2.541	130.131	-5.305	
12	-65.282	-2.541	73.790	-2.692	138.639	-5.456	lower berm
13	-73.790	-2.692	111.144	-5.010	175.993	-7.774	breakers
14	-111.144	-5.010	145.705	-7.210	210.554	-9.974	
15	-145.705	-7.210	174.193	-8.003	239.042	-10.767	
16	-174.193	-8.003	216.649	-6.210	281.498	-8.974	bar (top)
17	-216.649	-6.210	274.869	-7.770	339.718	-10.534	
18	-274.869	-7.770	302.889	-8.403	367.738	-11.167	trough
19	-302.889	-8.403					

APPENDIX C

GPS State Plane Coordinates for
Dune Protection Line and Vegetation Line, Galveston County

State Plane (Tx, SCen Zone)Clarke 1866, NAD27
Survey Feet, 1m=3.2808333 ft

PROFILE/FEATURE	EASTING	NORTHING
BEG-04 Dune Line	3243372.98	479373.42
BEG-04 Veg. Line	3243479.16	479265.10
GLO-01 Dune Line	3248646.71	484144.48
GLO-01 Veg. Line	3248683.17	484098.83
GLO-02 Dune Line	3253986.14	488701.01
GLO-02 Veg. Line	3254046.99	488626.74
GLO-03 Dune Line	3258729.16	492521.81
GLO-03 Veg. Line	3258761.75	492481.17
GLO-04 Dune Line	3266377.18	498666.59
GLO-04 Veg. Line	3266511.09	498495.74
BEG-03 Dune Line	3270760.46	501959.37
BEG-03 Veg. Line	3270899.02	501777.54
GLO-05 Dune Line	3275592.15	505485.72
GLO-05 Veg. Line	3275705.65	505347.17
BEG-07 Dune Line	3282371.03	510457.05
BEG-07 Veg. Line	3282453.04	510354.58
GLO-06 Dune Line	3286582.72	513529.85
GLO-06 Veg. Line	3286668.82	513415.73
BEG-02 Dune Line	3291448.74	517013.08
BEG-02 Veg. Line	3291512.04	516926.18
GLO-07 Dune Line	3299772.76	523012.93
GLO-07 Veg. Line	3299833.69	522934.64
GLO-08 Dune Line	3305314.24	527023.70
GLO-08 Veg. Line	3305364.44	526952.02
BEG-01 Dune Line	3308584.21	529462.54
BEG-01 Veg. Line	3308644.48	529373.41
GLO-09 Dune Line	3312420.47	532300.57
GLO-09 Veg. Line	3312461.37	532245.07
GLO-10 Dune Line	3349864.55	560985.66
GLO-10 Veg. Line	3349943.62	560890.31
GLO-11 Dune Line	3352826.24	563467.21
GLO-11 Veg. Line	3352936.43	563330.32
GLO-12 Dune Line	3356599.79	566478.63
GLO-12 Veg. Line	3356696.84	566360.62
GLO-13 Dune Line	3360941.99	586972.70
GLO-13 Veg. Line	3361208.80	586881.97
GLO-14 Dune Line	3365683.99	595391.10
GLO-14 Veg. Line	3365815.03	595300.61
GLO-15 Dune Line	3371276.92	601561.18
GLO-15 Veg. Line	3371421.25	601409.52
GLO-16 Dune Line	3378965.89	607555.78
GLO-16 Veg. Line	3379053.01	607419.51
GLO-17 Dune Line	3387521.08	613139.47
GLO-17 Veg. Line	3387587.50	613046.54
GLO-18 Dune Line	3396677.71	618488.96

GLO-18 Veg. Line	3396727.89	618412.46
GLO-19 Dune Line	3403789.58	622332.62
GLO-19 Veg. Line	3403809.66	622291.28
BEG-09 Dune Line	3412954.54	627048.89
BEG-09 Veg. Line	3412985.88	626987.91
GLO-20 Dune Line	3421607.22	631368.72
GLO-20 Veg. Line	3421632.34	631318.56
GLO-21 Dune Line	3428830.04	635108.97
GLO-21 Veg. Line	3428853.16	635064.64
GLO-22 Dune Line	3437975.79	639453.74
GLO-22 Veg. Line	3437996.98	639410.32
GLO-23 Dune Line	3446293.28	643442.19
GLO-23 Veg. Line	3446320.83	643381.34
BEG-10 Dune Line	3456407.03	648217.04
BEG-10 Veg. Line	3456440.23	648146.84
GLO-24 Dune Line	3465635.60	652550.45
GLO-24 Veg. Line	3465660.17	652504.09