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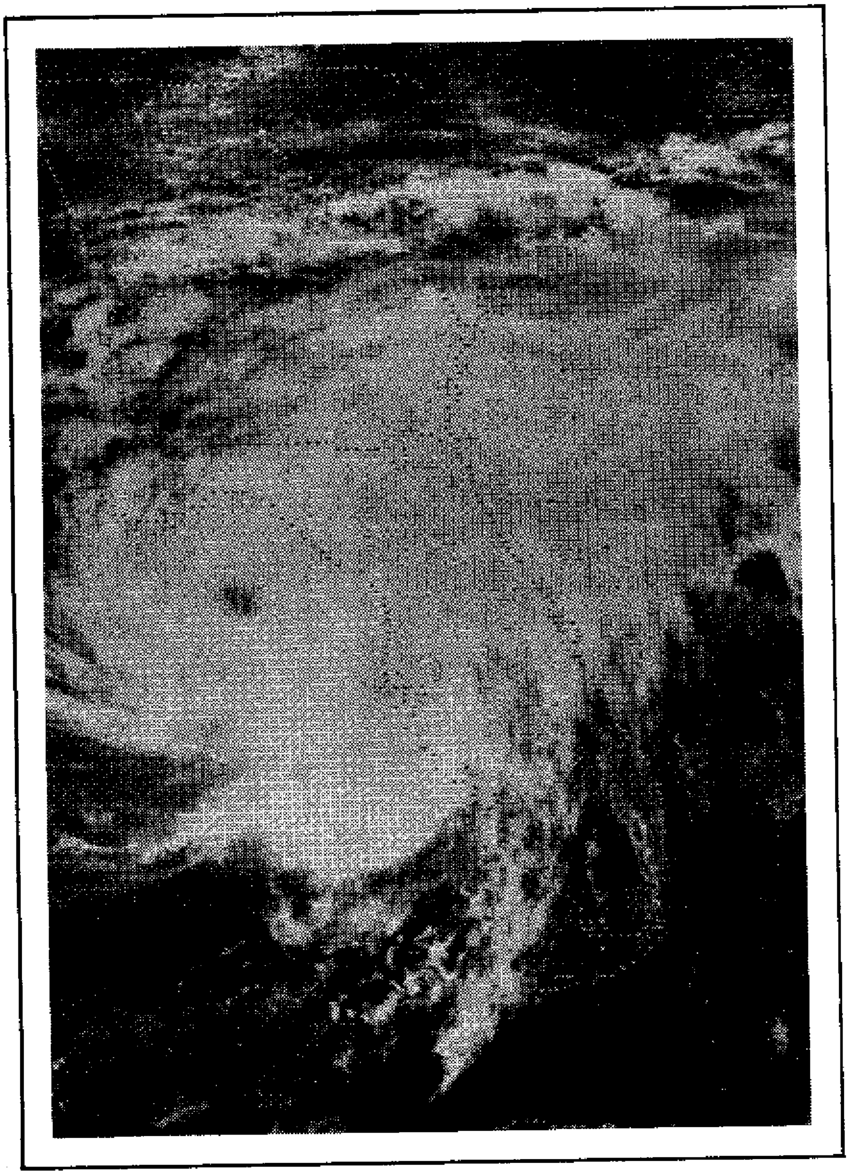
Technical Paper No. 51

Impact of Hurricanes on Pinellas County, Florida 1985



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FLORIDA SEA GRANT COLLEGE PUBLICATION

IMPACT OF HURRICANES ON PINELLAS COUNTY, FLORIDA, 1985

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IMPACT OF HURRICANES ON PINELLAS COUNTY, FLORIDA, 1985

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ABSTRACT

Three hurricanes had impact on the west-central coast of Florida during the fall of 1985; Elena, Juan and Kate. Although each caused damage, Elena was by far the most significant. It caused considerable damage to coastal structures, buildings and necessitated evacuation of virtually the entire coastal community of Pinellas County. Preparation and the modest energy from Elena limited the financial loss and injury and prevented any deaths in this area.

Hurricane Elena developed in late August and passed to the west of Pinellas County, stalled near Cedar Key and then moved to the northwest. Hurricane Juan formed in late October far to the west of the Pinellas coast and moved northward to the Mississippi Delta, then proceeded to the east with landfall near Pensacola. The final hurricane, Kate, followed a path similar to that of Kate but moved directly onshore near Tallahassee.

Considerable damage to various coastal structures and buildings was caused by Elena with the Indian Rocks and northern Sand Key area particularly hard hit. Most of damage to these structures by subsequent hurricanes was the result of exposure caused by damage during Elena or damage to facilities under repair and reconstruction from Elena.

Washover was minor and local from Elena and one new tidal pass was generated on the northern part of Caladesi Island. Beaches exhibited much erosion during Elena but most of this sediment returned as the result of Hurricane Juan. There was little beach change related to Hurricane Kate.

Beaches in front of seawalls exhibited more apparent erosion than adjacent natural beach profiles. These sites also experienced the most rapid recovery with the net change being one of apparent accretion.

The Pinellas County coast was generally spared from disaster during the 1985 hurricane season. The financial loss was modest considering the potential and there was minimal direct impact on people. The preparation and the generally distant nature of the storms both contributed to this situation. The beaches suffered little net loss by the end of the hurricane season and the winter season was mild thus helping to maintain the beaches.

IMPACT OF HURRICANES ON PINELLAS COUNTY, FLORIDA, 1985

Introduction

The west-central coast of Florida is among the most developed coasts on the Gulf of Mexico. Pinellas County in particular is the most developed reach of coast along this major water body. This county has a population of over 800,000 and includes the major metropolitan centers of St. Petersburg and Clearwater along with numerous smaller incorporated local governmental units. Although there is a rather broad spectrum of industries and residential complexes, the largest single industry is tourism.

The open coast includes several barrier islands with intervening inlets. It is essentially a continuous barrier system throughout except for about 6 km near the northern end of the county. All of these barriers are either completely developed or are various types of recreational parks and sanctuaries. The central two-thirds of this coast or a total of 35 km is developed in a complex of hotels, motels, high-rise buildings and single family residential dwellings. Various types of retail businesses, restaurants and other commercial establishments that support the tourist industry are also present.

Virtually all of this development has taken place since the 1920s when the first causeways were completed between the mainland and the barrier islands. Coincidently, the last major hurricane to impact this portion of the west peninsular coast of Florida was in 1921. A tremendous explosion of development has taken place in this area since about the late 1950s and is continuing. This means that virtually all of the development and population on these barrier islands has come during a period without any major impact from a hurricane. To be sure, there have been hurricanes in the eastern Gulf of Mexico since 1921, but all have either passed too far away from this area or have been of small enough magnitude so as not to cause serious damage.

The hurricane season of 1985 was quite unusual in a variety of ways. It produced not one but three hurricanes that had an impact on Pinellas County. These had a variety of strengths and they developed over a period of nearly three months. Additionally, the last one (Kate) was the latest hurricane on record in this part of the world and the first November hurricane in 50 years. Hurricane Elena impacted the west-central Florida coast on Labor Day weekend, Hurricane Juan passed rather far away from Pinellas County but caused some intense weather in late October and Hurricane Kate passed to the west of Pinellas County on November 20 with landfall two days later.

This report will document the nature and extent of the damage and changes that took place along and adjacent to the beaches of Pinellas County as the result of these three storms. The primary aim is to not only show the changes and their distribution, but also to monitor the beaches over several months to keep a record of their subsequent recovery. The study was initiated immediately after the passage of Hurricane Elena with data collection continuing for one year.

The primary objectives of the study were to document:

1) the distribution of beach changes including both erosion and accretion with special attention given to development of intertidal ridges.
2) locations of damage to coastal structures including seawalls, groins, jetties and other shoreline stabilization structures.
3) damage to buildings as the result of the storms.
4) washover sites where significant quantities of beach and nearshore sand had been transported landward onto the barrier island.
5) locations if any, where the barrier islands had been breeched and new tidal passes formed.
6) relative effects of storm impact on natural beach profiles as compared to those fronting seawalls or other hardened structures.
7) any other changes of note that could be related to the passage of the storms.

Study Area

The Pinellas County coast extends for 65 km along the west-central peninsula of Florida. This dominantly barrier island coast includes Mullet Key, North and South Bunces Keys, Long Key, Treasure Island, Sand Key, Clearwater Beach Island, Caladesi Island, Honeymoon Island and Anclote Key from south to north. The four islands in the central area are not only the longest but are also the ones where development is essentially continuous. The barriers at both the south and north ends of the county are parks and recreation areas with essentially no commercial or residential development.

Several reconnaissance visits, both on the ground and by air, were conducted throughout the study to all sections of the Pinellas coast. Because of the nature of this project, the detailed surveying was concentrated in the central portion of the county where development is most extensive. Initially, nine beach profile sites (figure 1) were established and surveyed at predetermined intervals in order to document beach configuration and recovery after Hurricane Elena. In February, 1986, two additional sites were added to the survey network. Additional profiles were surveyed at Caladesi Island and Anclote Key at irregular intervals.

Coastal Processes -

The west-central Florida coast is considered to be one of relatively low energy, even within the Gulf Coast. Wave energy is low and weather is dominated by the occasional hurricane and by the passage of regular frontal systems during the winter months.

Weather - The Florida peninsula occupies part of a subtropical climatic belt with distinctly seasonal and bimodal weather patterns. During the spring and summer months (March-September) this area is dominated by the Bermuda high. This situation produces a counterclockwise atmospheric

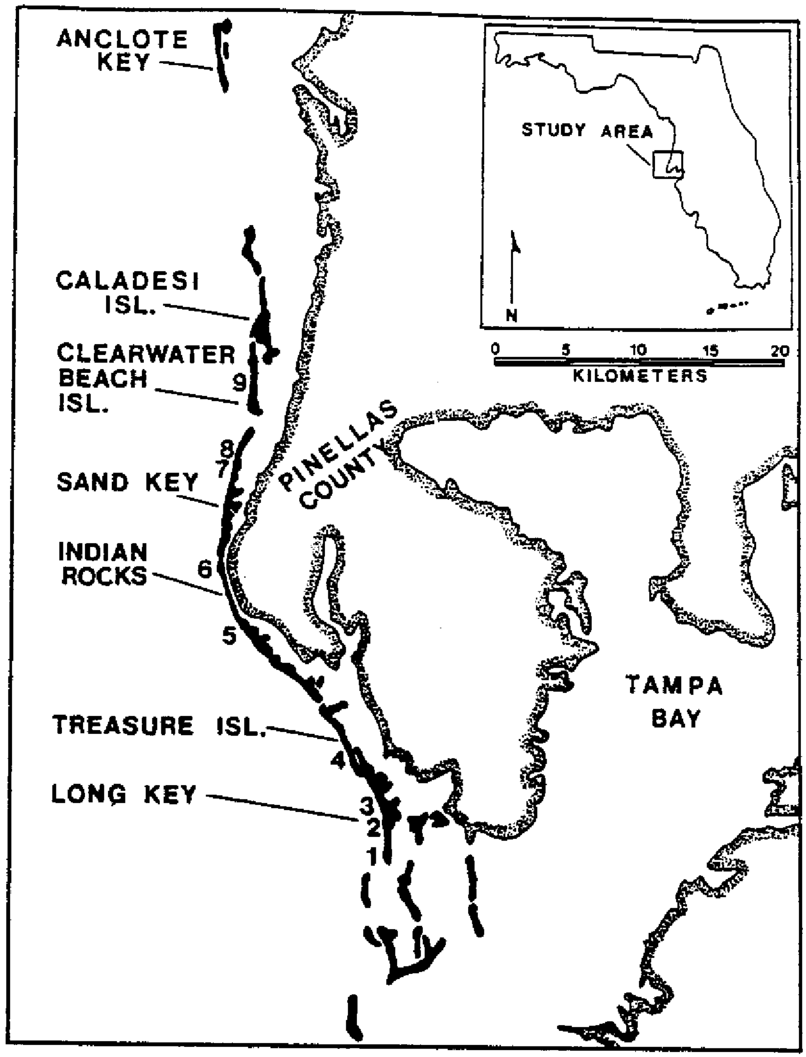

Figure 1 - Location map showing the Pinellas County barrier coast and the profile sites monitored in the beach study.

circulation with winds on the Pinellas coast being dominantly from the southeast during this time of year. Such climatic conditions cause the build-up of thermal convection cells over the peninsula with severe and common thunderstorms during June to September (Jordan, 1973).

During the winter months, the northern Gulf of Mexico in general, and the west coast of the Florida peninsula in particular, is subjected to the passage of frontal systems that move onto the Gulf in Texas and then proceed eastward over the Pinellas County coast. These cold fronts commonly pass far enough to the south to affect this area from about late October through February or early March.

Seasonal situations in weather produce a bimodal wind pattern for Pinellas County with northerly winds being prevalent during the winter and southerly winds most common during the summer (figure 2). This pattern is also reflected in the strength of winds. The stronger and dominant winds occur during winter and the weak winds are in the summer (figure 3).

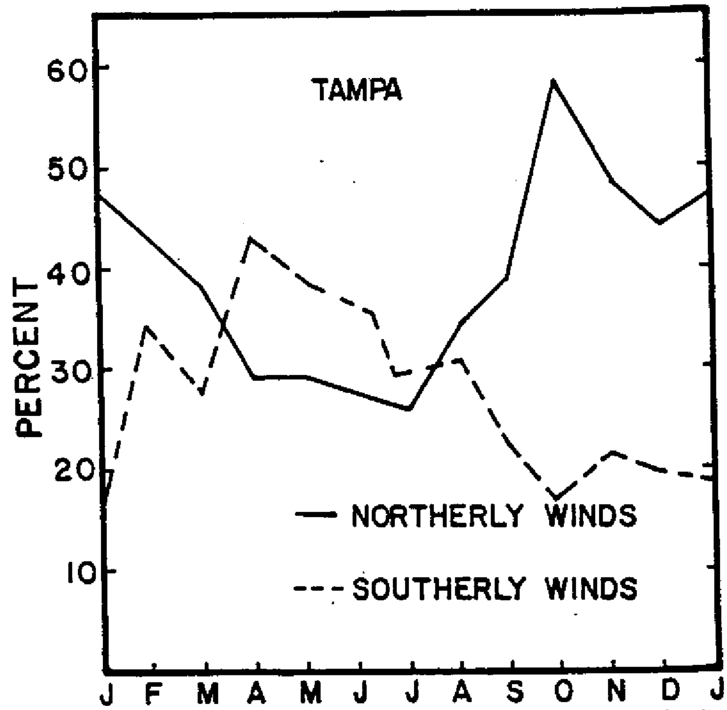

Figure 2 - Distribution of southerly and northerly winds by month and duration for the Pinellas coast. (from Rosen, 1976.)

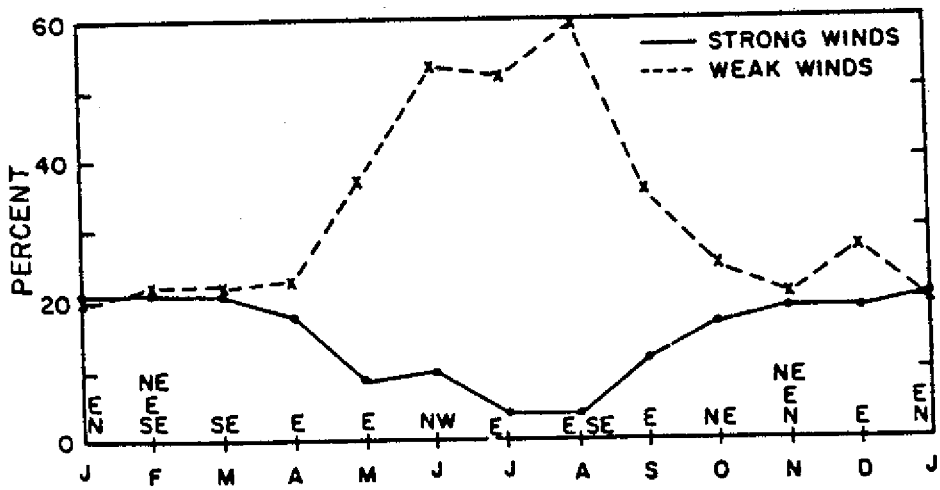

Figure 3 - Mean monthly distribution of strong winds (9 knots) and weak winds (3 knots) for Pinellas County. (from Rosen, 1976)

Although hurricanes may have a profound effect on the west-central Florida coast, they are relatively infrequent and certainly unpredictable. The dominant weather systems impacting this coast on a regualr basis are therefore the frontal systems that pass during the winter. As these weather systems approach the Florida peninsula the wind blows from the southwest with increasing speed as the front comes closer. Almost immediately upon passage, the wind shifts to the north or even the northeast, and is strong. This is the highest energy time of the passage of the system. These weather fronts actually dominate the yearly weather patterns in terms of intensity and therefore they impact severely on coastal processes.

Hurricanes are relatively infrequent on the west peninsular part of Florida because this is essentially in the shadow zone of the typical path for tropical storms in the Gulf of Mexico. The two most common avenues for hurricanes that move to the northwest through the Caribbean Sea are to trend to the north along the eastern coast of the United States or to move into the Gulf of Mexico between the southern tip of Florida and the Yucatan Peninsula of Mexico. Once in the Gulf, the typical path for hurricanes is within a north to westerly quadrant. It is not common for such storm to turn back toward the northeast and move onto the west coast of the Florida peninsula. The most common path for hurricanes that impact on the west coast of peninsular Florida is essentially a northerly one, more or less parallel to the coast. Several hurricanes have taken this course in recent years but will little influence on the west-central coast of Florida. Examples are hurricanes Alma in 1966, Eloise in 1975 and Frederick in 1979.

In 1960, Hurricane Donna actually did move toward the northeast and directly impact the west-central coast with landfall near Ft. Myers. The storm then moved diagonally across the peninsula and offshore near St. Augustine. As it passed near the Pinellas County coast, Hurricane Donna was producing strong offshore winds which produced a negative storm tide or set down. Such phenomena do not result in major wave-generated damage to the beach and related coastal environments.

During historical times, two major hurricanes have impacted the Pinellas County coast. The first was in 1848 when storm tides of about 4 m above normal were produced and Johns Pass was cut. The actual location of landfall for this storm is not known. The other hurricane was in 1921 and was probably the most devastating storm in recorded history as far as the Pinellas County coast is concerned. Storm tides reached 3 m above normal and Hurricane Pass was cut separating Caladesi and Honeymoon Islands which were originally called Hog Island. This storm moved along much of the west peninsular coast cutting Redfish Pass at the north end of Captiva Island and another tidal inlet which was the ancestor to Midnight Pass in Sarasota County. Landfall was near Tarpon Springs.

<u>Tides</u> - The Pinellas County coast is within the microtidal range with astronomical spring tidal range of 70-80 cm on the open coast. The tidal patterns are mixed with semi-diurnal conditons of unequal heights during most of the lunar month. The general configuration of the continental shelf adjacent to the coast is one of a broad and gently sloping surface with a gradient of less than 1:1200. Such a configuration facillitates set up during storms and can lead to extreme storm tides if strong onshore winds persist for long periods of time. Storm tides of 3-4 m as mentioned above would provide a devastating impact on the Pinellas barrier coast which has a natural profile with a maximum elevation of only 4-6 m.

The tidal prism carried by the various inlets in Pinellas County shows great variation due to the variety in the coastal bays that are served by these inlets. Some, such as Dunedin Pass and Blind Pass are distinctly wave-dominated due to the small prism that they carry. These unstable inlets have prisms of about 1 x 106 m3. By contrast, Johns Pass is quite stable and carries a large tidal prism of about 1.4 x 107 m3 (Mehta et al, 1976).

The large rainfall that commonly accompanies these storms is an aspect of hurricane conditions that is commonly overlooked and that can be a serious factor in producing flooding conditions. Amounts of tens of centimeters can fall in a day or two. Especially in Florida, this creates severe problems of runoff with streams required to carry virtually all of it to the coast. But the onshore storm winds have generated significant storm surge which tends to push water upstream in the rivers emptying into the coastal areas. The result is that drainage is severely impaired and flooding is widespread, not only along the coast where storm surge occurs but along the floodplains of the streams near the coast.

Littoral Processes - The most dominant coastal processes along the beaches of Pinellas County are the waves and wave-generated longshore currents, both of which are driven by the weather. The bimodal wind patterns described earlier result in a bimodal orientation of wave approach and therefore in longshore current. As is typical of all coasts, the longshore current and therefore littoral transport of sediment, displays a bimodal pattern with sediment moving both up the coast and down the coast during different weather and wave conditions.

The west peninsular coast experiences wave approach from the southwest during most of the summer months with the result being a northerly littoral drift. During times when winds are from the north, sediment is transported to the south along the coast. The resultant is a dominantly southerly drift of sand throughout. These are the general trends for this entire reach of coast. Pinellas County has a somewhat different patterns due largely to its coastal orientation. A glance at the coast (figure 1) shows that there is a broad headland near the center of the county with the shoreline trending to the NNE and SE away from it. The result is that wave refraction produces longshore current patterns that cause a net transport of sediment to the north and to the south away from this headland. There are some local reversals of these trends that are related to the sand bodies associated with some of the inlets.

Overall wave energy on this coast is quite low with mean annual wave height being less than 30 cm (Tanner, 1960). In a time-series study on Caladesi Island, Rosen (1976) measured breakers of 6-30 cm and periods of 2-4 sec during non-storm conditions. When the frontal systems pass during the winter, wave heights of 50-60 cm and periods of 5 sec are common. Open water wave measurements indicate that 65 % of waves are less than 1 m during the winter and during summer this reaches 90 % (U. S. Weather Command, 1975).

1985 Hurricanes

The hurricane season of 1985 was unusual for the west-central coast of Florida because three storms has an effect on this coast including the latest on record. Although Pinellas County was no closer than about 100 km from any of these storms, each had its effect on the area.

Hurricane Elena -

The storm that eventually became Hurricane Elena was formed in the western Sahara Desert of Africa on August 23. It did not become a true tropical cyclone until it approached Cuba on August 27 when it was named. Elena became a hurricane on August 29 as it passed near the latitude of Key West into the Gulf of Mexico (figure 4). Hurricane Elena continued

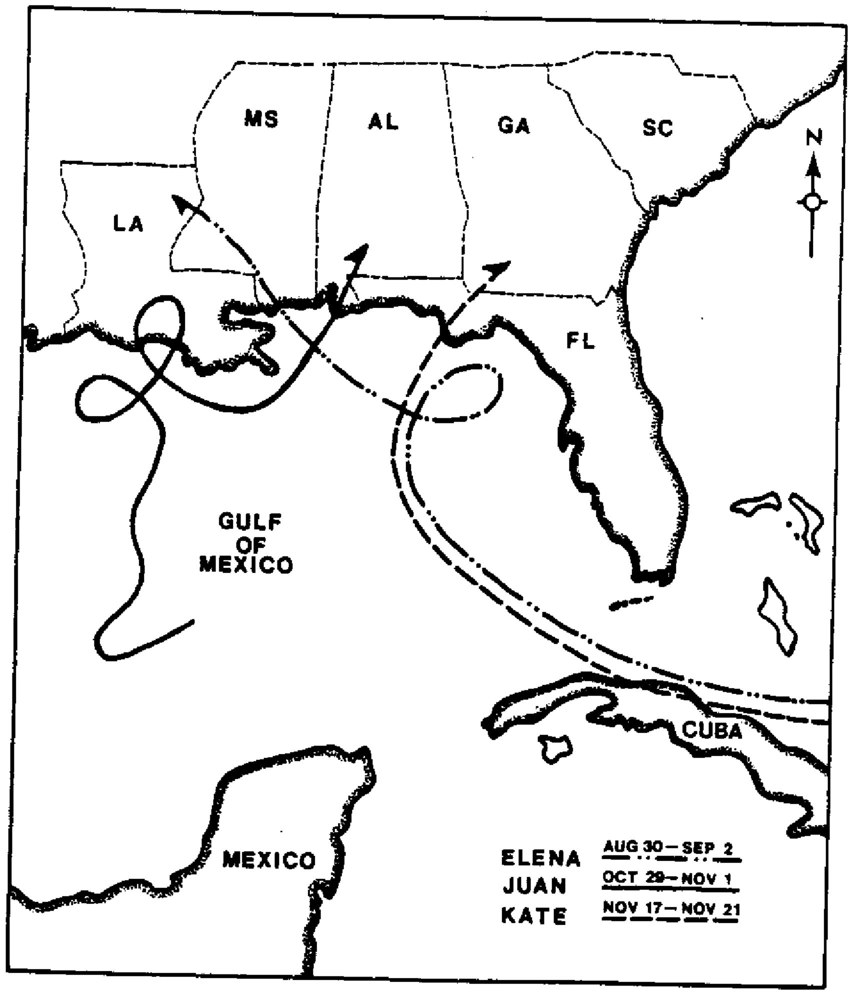

Figure 4 - Map of the Gulf of Mexico showing general paths of Hurricanes Elena, Juan and Kate.

in a northwesterly path at a speed of about 8 knots until about noon on August 30 when the storm changed to a northeasterly direction. It then moved to an area about 80 km west of Cedar Key, Florida and stalled somewhat for about 24 hrs. It was during this time, from noon on August 31 until the same time the next day, that the highest energy conditions from the storm impacted Pinellas County. After stalling west of Cedar Key, the storm moved toward the Louisiana coast on September 1 at a speed of 9 knots.

Elena had a minimum barometric pressure of 953 mb on September 2 with maximum winds of 110 knots at that time. This occured about 2 hrs prior to landfall on the east coast of Louisiana, well away from the west-central coast of Florida.

Weather conditions in the Pinellas County area included a minimum barometric pressure of 1003 mb and maximum winds of 24 knots at the National Weather Station in Tampa (figure 5). The strongest winds in this area were from the south and southwest, the directions of persistent winds during passage of the storm.

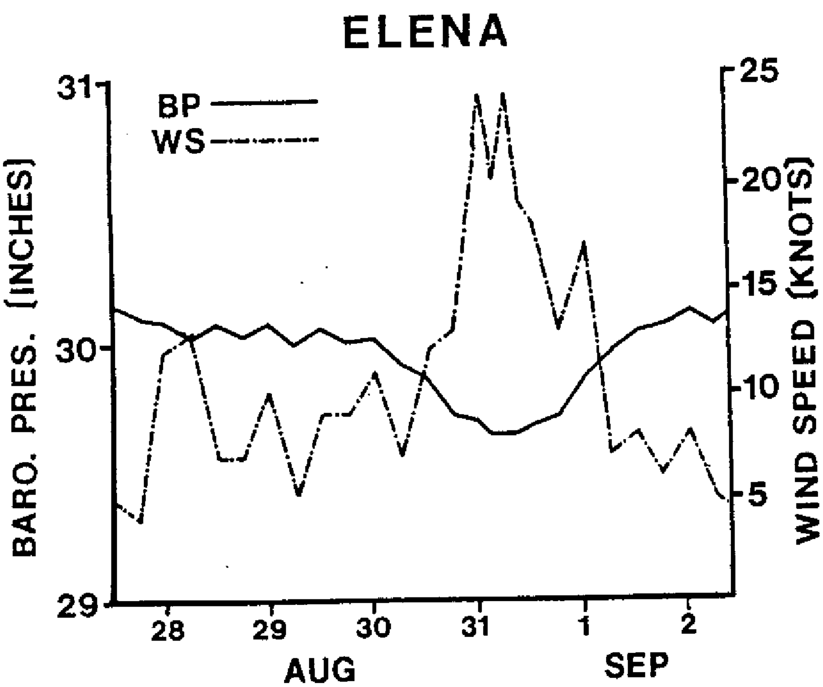

Figure 5 - Plot of barometric pressure and wind speeds recorded at the Tampa airport during the passage of Hurricane Elena.

The onshore component of these winds caused a significant storm surge and increase in wave energy over a several day period. These persistent winds resulted in a maximum open water surge of 1.4 m at Clearwater on August 31 (figure 6). This compares with surges of 2.5 m at Franklin County in the panhandle (Balsillie, 1985). The storm tides inside Tampa Bay during this period exceeded 2 m. Tide gauge records from the mouth of the Anclote River show elevated water levels due to set up for a period of at least two days (figure 7). These storm tide data indicate that Hurricane Elena is only a 10 yr storm (figure 8); that is, its recurring frequency is once in ten years. Its storm surge of 1.4 m is well below the 100 yr amount of 4 m as established by federal flood insurance studies.

Waves generated during the passage of Elena were nominal in terms of size (figure 9). The maximum significant wave height recorded at the wave gaging station offshore of Clearwater was 2.5 m with a period of 13 sec (Bodge and Kreibel, 1985) at 1400 hrs on August 31. Data from throughout Florida show that largest waves were near Jacksonville where

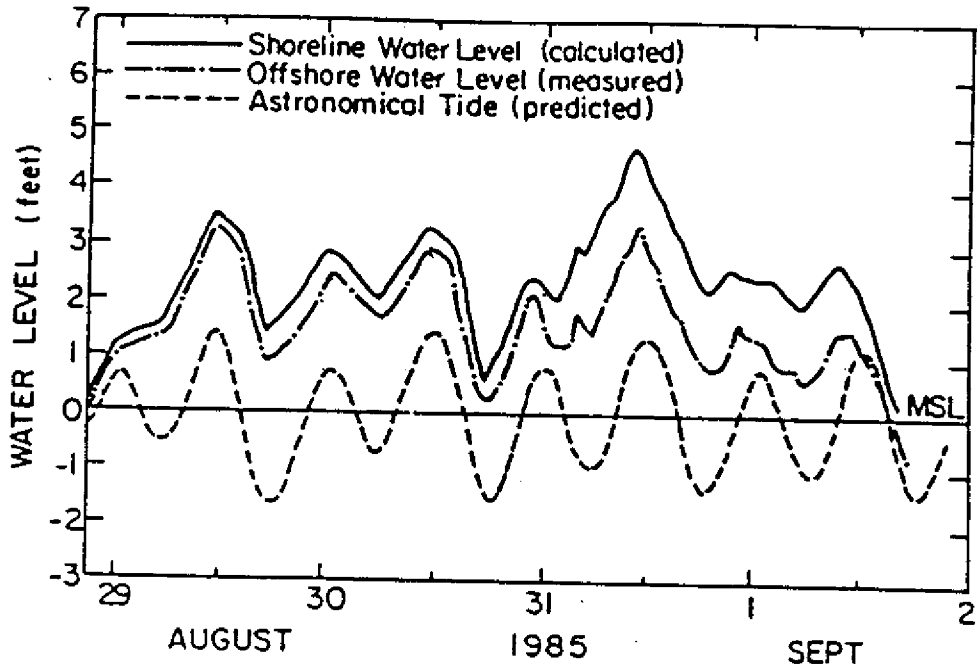

Figure 6 - Storm surge data for Hurricane Elena showing comparison of predicted tides with actual water levels. (from Bodge and Kreibel, 1985.)

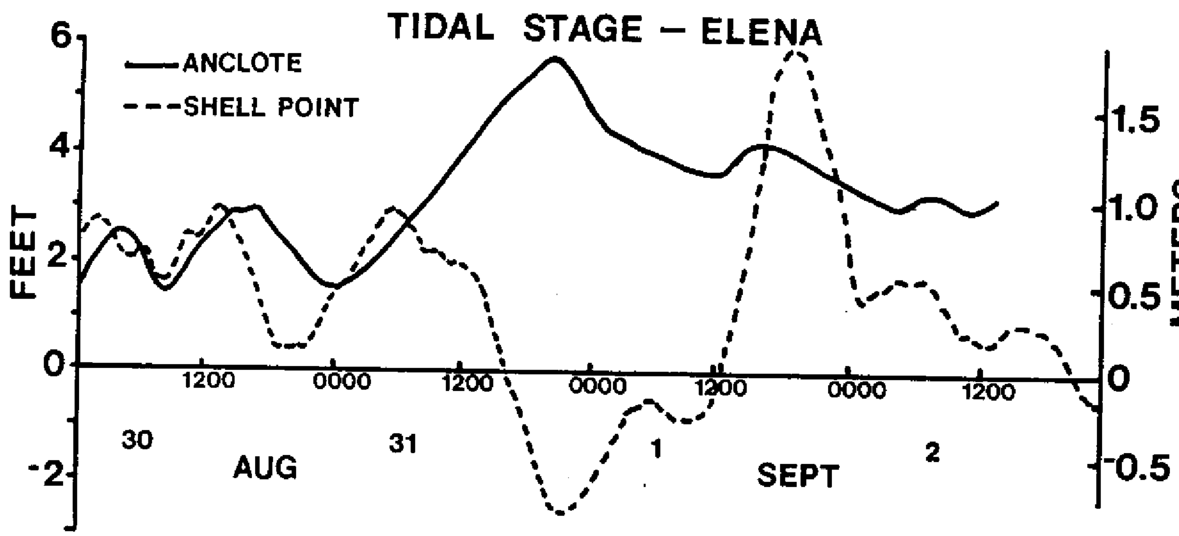

Figure 7 - Water levels during passage of Hurricane Elena as recorded by tide gauges at the mouth of the Anclote River and at Shell Point in Tampa Bay.

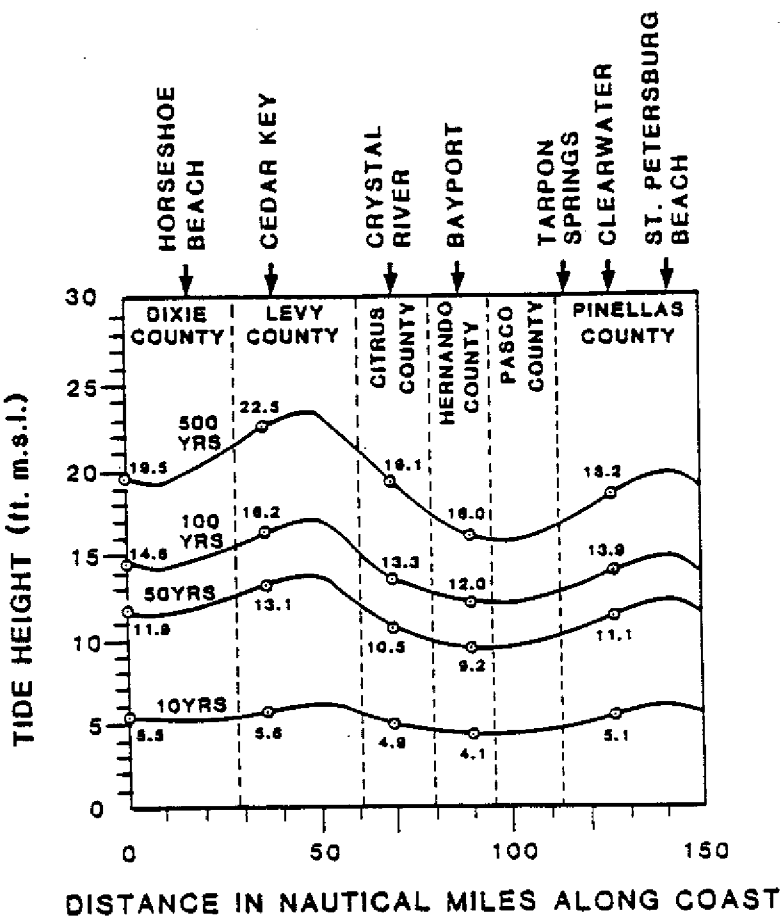

Figure 8 - Storm recurrence curves for the northeastern Gulf Coast including Pinellas County. Note that Hurricane Elena was only about a once in 10 yr storm. (from Hine et al, 1986.)

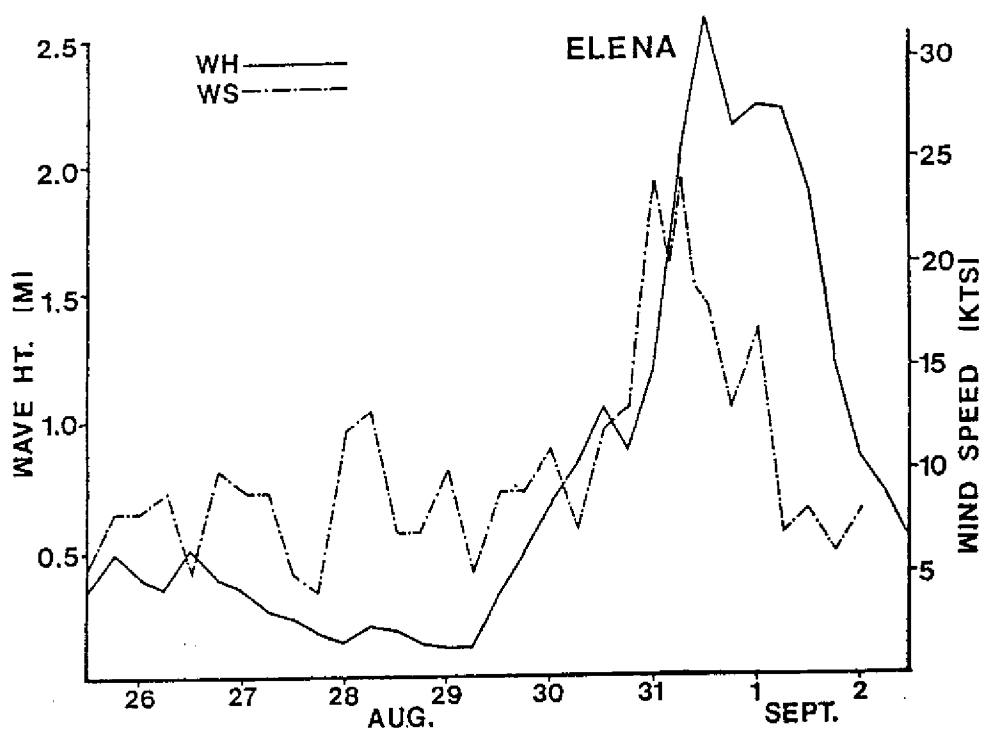

Figure 9 - Plot of wind speed and offshore wave height at Clearwater during the passage of Hurricane Elena.

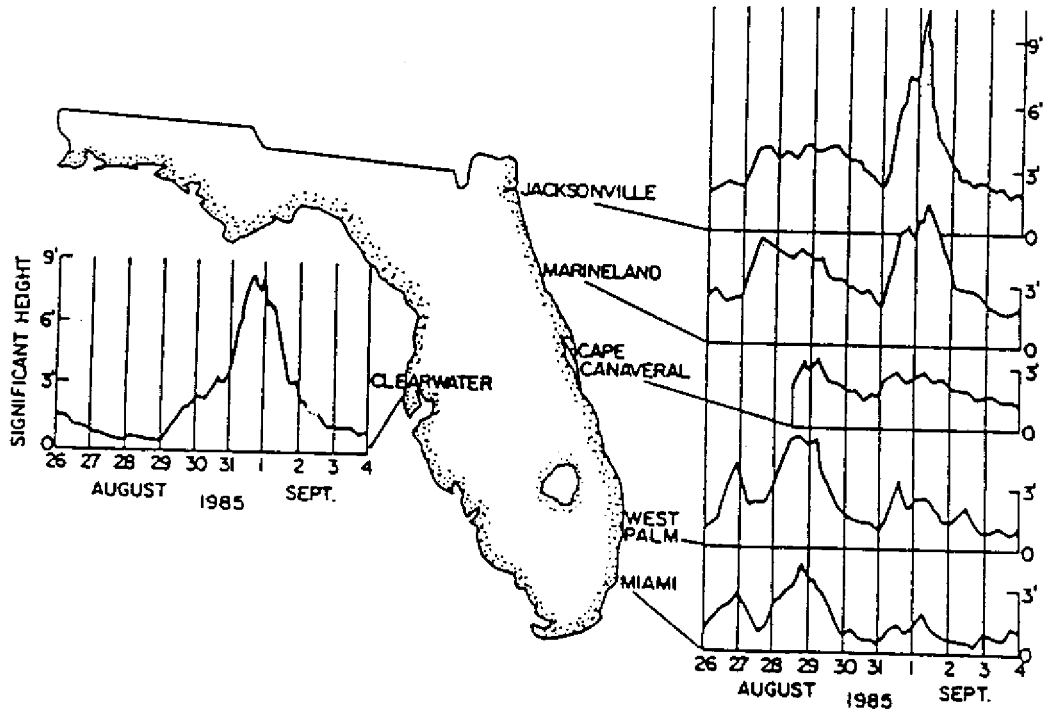

Figure 10 - Wave heights during Elena as recorded on both the Atlantic and Gulf coasts of Florida. Note that highest values are at Jacksonville. (From Bodge and Kreibel, 1985.)

the significant wave height was over 3 m (figure 10). The reasons for this distribution of wave energy are the wind directions and fetch relative to the eye of the storm and also the narrow and steep shelf on the northeast coast of Florida.

Hurricane Juan -

The subtropical depression that eventually became Hurricane Juan formed in the central Gulf of Mexico on October 25. It became a tropical storm the next day and then on October 27 started a northeasterly path which became northwesterly by afternoon when Juan achieved hurricane strength. The storm made two counterclockwise loops during its movement, one south of the Louisiana coast and the second just onshore. Juan moved offshore and around the Mississippi Delta with landfall near Pensacola on October 31 (figure 4).

Juan barely made hurricane levels with maximum sustained winds of 75 knots and a low pressure of 971 mb. Significant effects from Juan were felt from the east Texas coast through the Florida panhandle with tides from 1-2 m above normal. The Pinellas County coast received little impact from this storm. Highest sustained winds were 15 knots near Tampa with the minimum barometric pressure of 999.7 mb (figure 11).

Storm surge in the study area was from 0.3 to 0.9 m on the open coast but tide gauge records from Shell Point in Tampa Bay show a negative storm tide (figure 12). The offshore wave gage at Clearwater was damaged during Hurricane Elena and was inoperative during Juan. Only estimates are therefore available for wave heights. Data from other

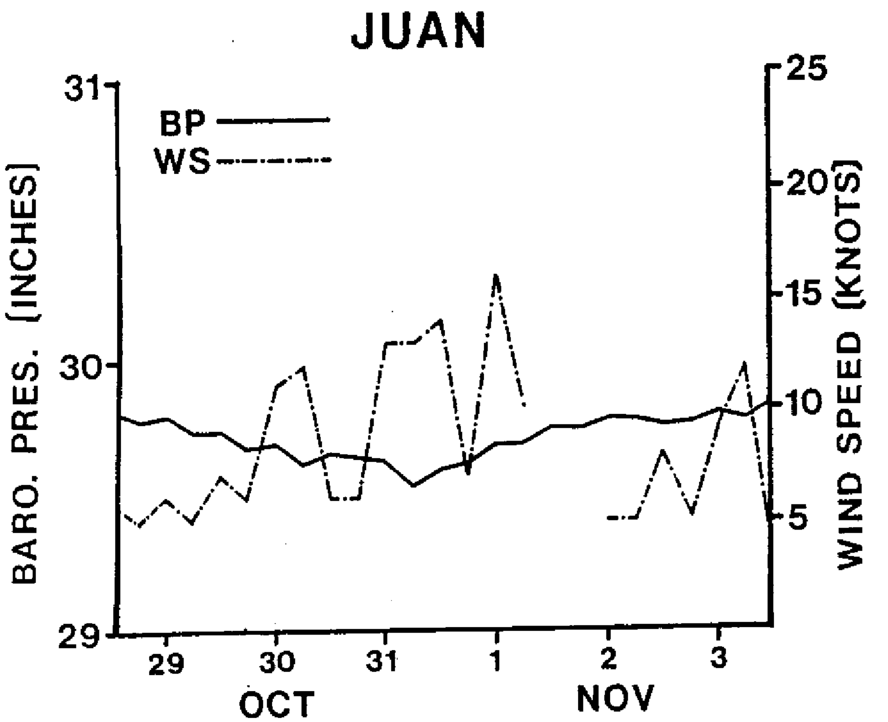

Figure 11 - Plot of barometric pressure and wind speed from the Tampa airport during the passage of Hurricane Juan.

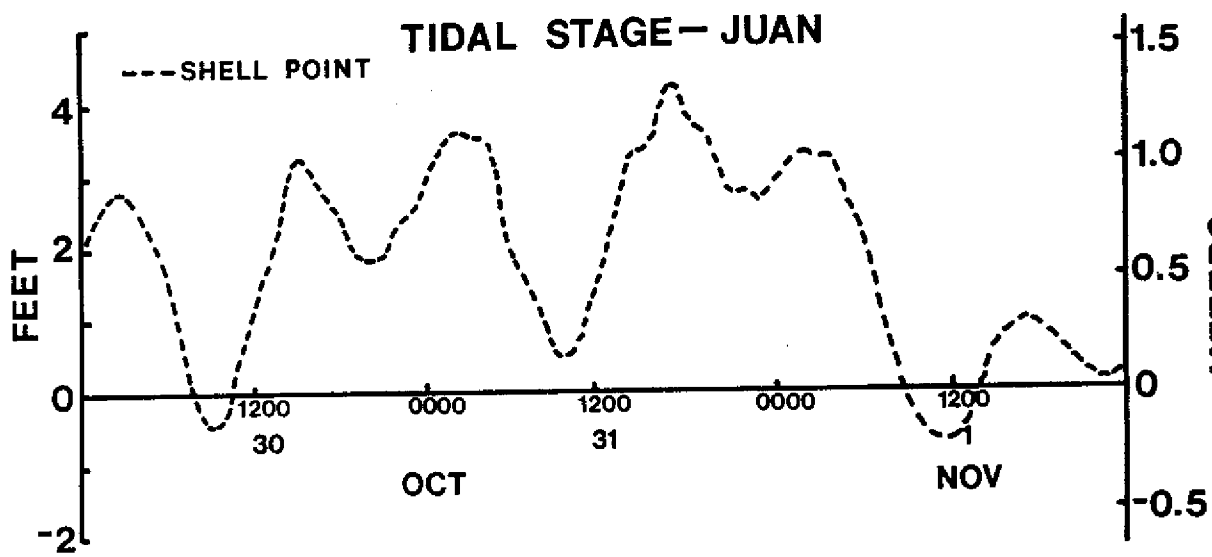

Figure 12 - Tide curve from Shell Point in Tampa Bay during Hurricane Juan. The Anclote River gage was inoperable.

storms indicate that maximum significant wave heights of 1.0-1.4 m are realistic.

Hurricane Kate -

The development of a hurricane in the Gulf of Mexico in late November came about due to unusual circumstances which produced weather conditions that resembled late September rather than October. This storm became organized near the Virgin Islands on November 13-14 and was named a day later. Kate became a hurricane at 1800 hrs on November 16. The storm passed southwest of Key West early on November 19 and headed in a northwesterly direction until it was almost west of Pinellas County where it turned toward the northeast (figure 4). Kate's path followed closely that of Elena but Kate continued toward the panhandle with landfall south of Tallahassee on November 22.

Minimum barometric pressure in the storm was 953 mb on November 20 during which time winds were 110 knots. Kate was about the same size and intensity as Elena but because Kate move much faster, it had less effect on the west-central Florida coast.

Highest sustained winds during Hurricane Kate at Tampa were 15 knots with a barometric low of 1012.5 mb (figure 13). Tides on the open coast were 0.3-0.6 m above normal for about two days however, those recorded in Tampa Bay show unexpectedly high levels (figure 14). Maximum significant wave height off Clearwater was 1.05 m (figure 15) with a period of 9 sec.

Hurricane Damage

The 1985 hurricane season was quite expensive for the Pinellas County coast and west-central Florida in general. The dollar amount of damage was among the highest for all years, the number of evacuees was very high and several counties were declared disaster areas. Although monetary losses were great, death and injuries were minimized as the result of preparation and organization of local governmental authorities.

Hurricane Elena -

Elena was both the first and most damaging of the three 1985 hurricanes to impact Pinellas County. Considerable information has been gathered on the losses resulting from Hurricane Elena, principally by the Division of Beaches and Shores, Department of Natural Resources (Balsillie, 1985) but also by others (Bodge and Kriebel, 1985; Hine et al, 1986). The present study also included various aspects of damage assessment with efforts concentrated on the beaches and adjacent buildings.

Information from the National Hurricane Center in Miami indicates that monetary losses incurred as the result of Elena approach one billion dollars. Insurance claims exceeded 0.5 billion dollars making it the fourth most expensive storm on record. Seven Gulf Coast counties were declared Federal Disaster areas including Pinellas, Hillsborough and Manatee on the west-central Florida coast.

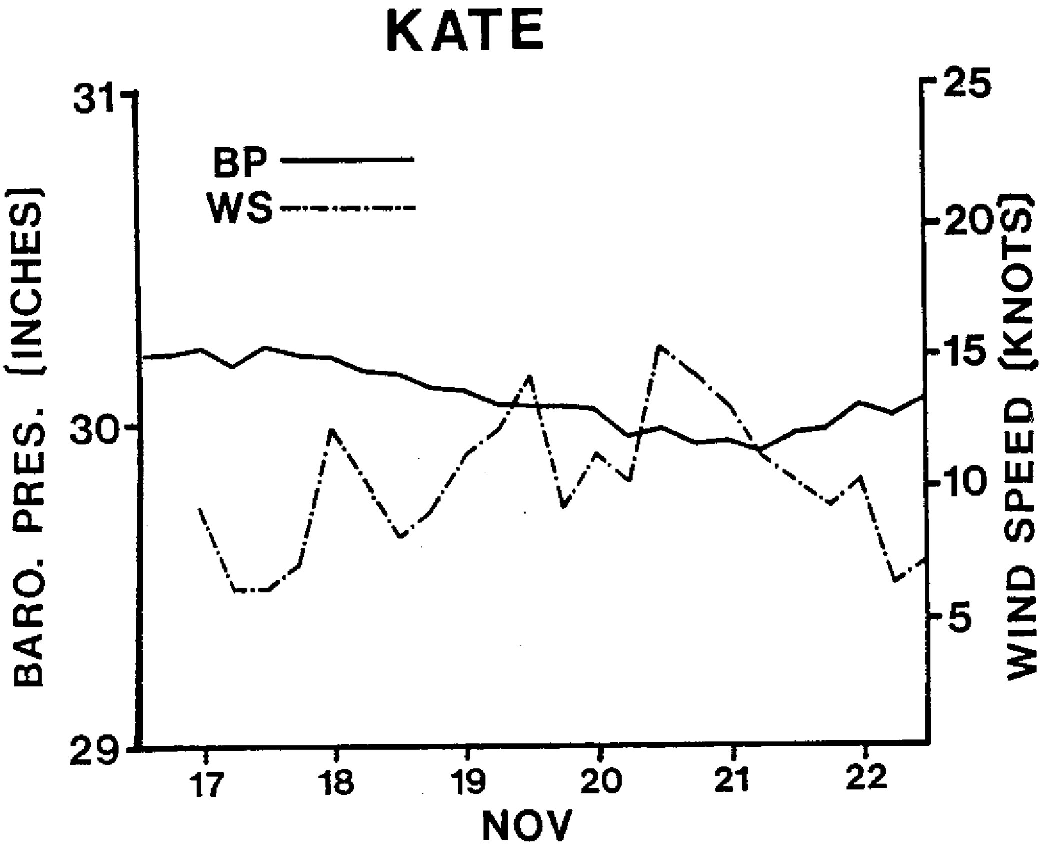

Figure 13 - Barometric pressure and wind speed data from the Tampa Airport during the passage of Hurricane Kate.

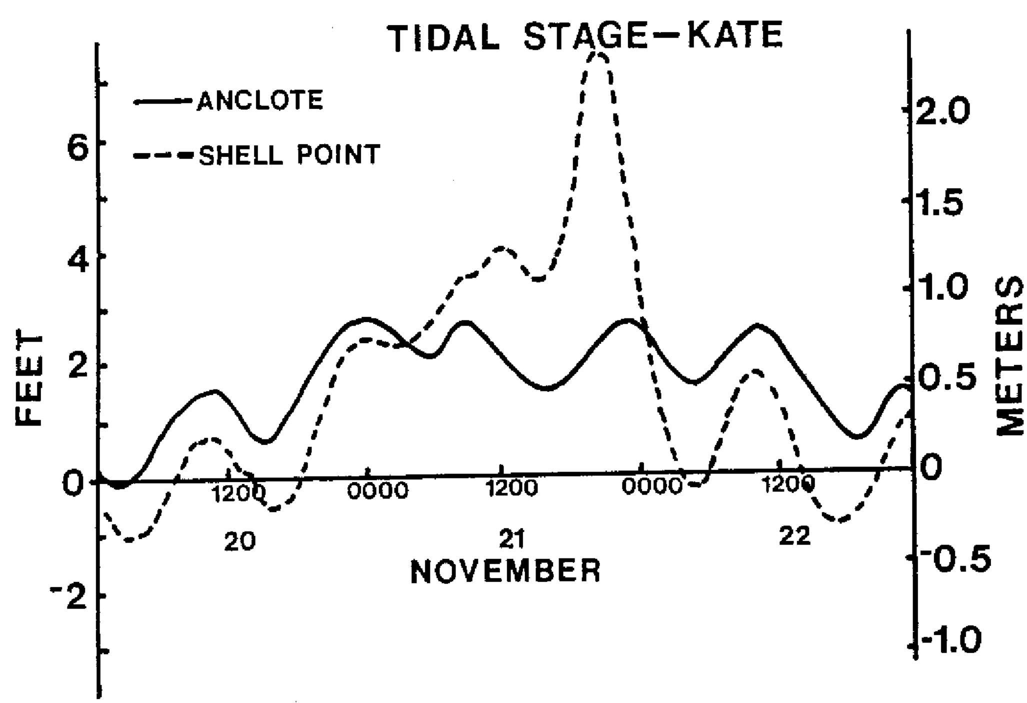

Figure 14 - Tidal curves during the passage of Hurricane Kate for the mouth of the Anclote River and Shell Point in Tampa Bay. The peak at Shell Point is the result of high water in the Manatee River which is adjacent to the tide gage.

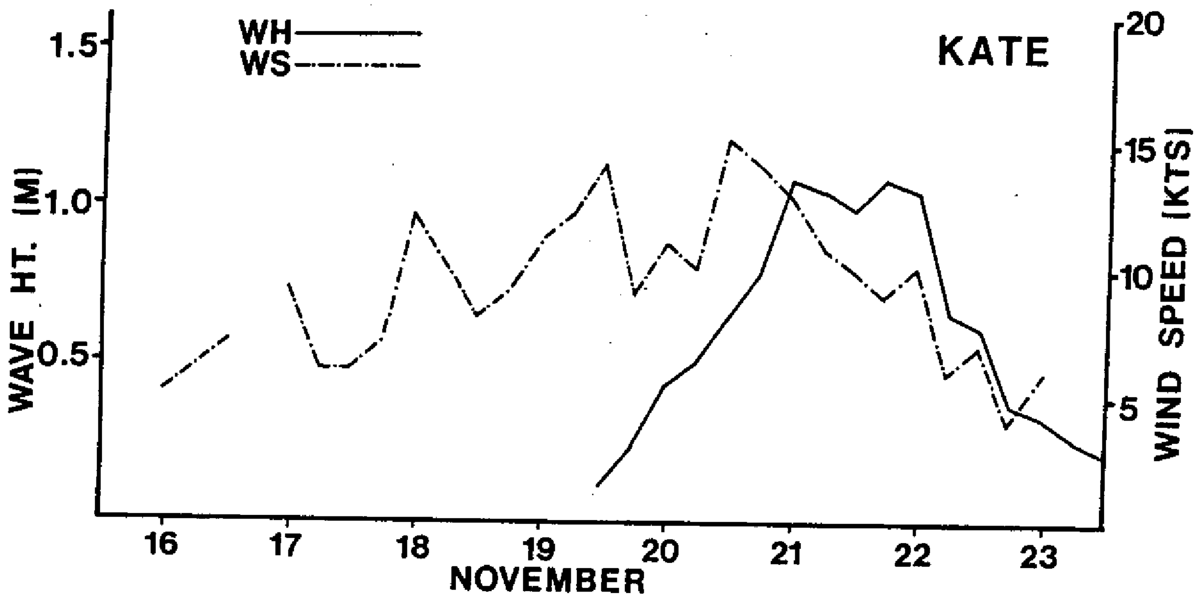

Figure 15 - Wind speed and offshore wave height at Clearwater during the passage of Hurricane Kate.

Four lives were lost as the result of Hurricane Elena, all due to falling trees, automobile accidents and heart attacks. None took place in Pinellas County. There were 134 people reported as hospitalized with 98 of these as the direct result of the storm and the remainder due to stress-related problems. Less than half of these were in Pinellas County (Federal Hurricane Center, 1985a). Much of the credit for the absence of deaths and the few injuries due to the storm is due to the orderly and rather complete evacuation of the barrier islands of Pinellas County. Nearly 250,000 people were removed well in advance of the storm and although this created problems of overcrowding in shelters and inconvenience for the people, it produced excellent results.

The property damage along the Pinellas coast can be placed into three major categories; 1) beach erosion, 2) damage or destruction to seawalls and other similar structures, and 3) damage or destruction to buildings. No significant damage was incurred by any public roadways in Pinellas County.

Erosion was essentially continuous throughout the Gulf beaches of Pinellas although the severity ranged rather widely (figure 16). Extensive development of ridge and runnel morphology was also associated with the post-storm beach profiles (figure 17). The most extensive and severe erosion took place on the southern two-thirds of Long Key and Treasure Island, central and northern Sand Key, most of Anclote Key and small reaches of Clearwater Beach Island, Caladesi Island and Mullet Key (figure 16).

Unfortunately there are no pre-storm beach surveys available except those from the Department of Natural Resources that were measured in connection with the coastal control line of about 11 years prior to Elena. The general absence of severe weather during this interim period

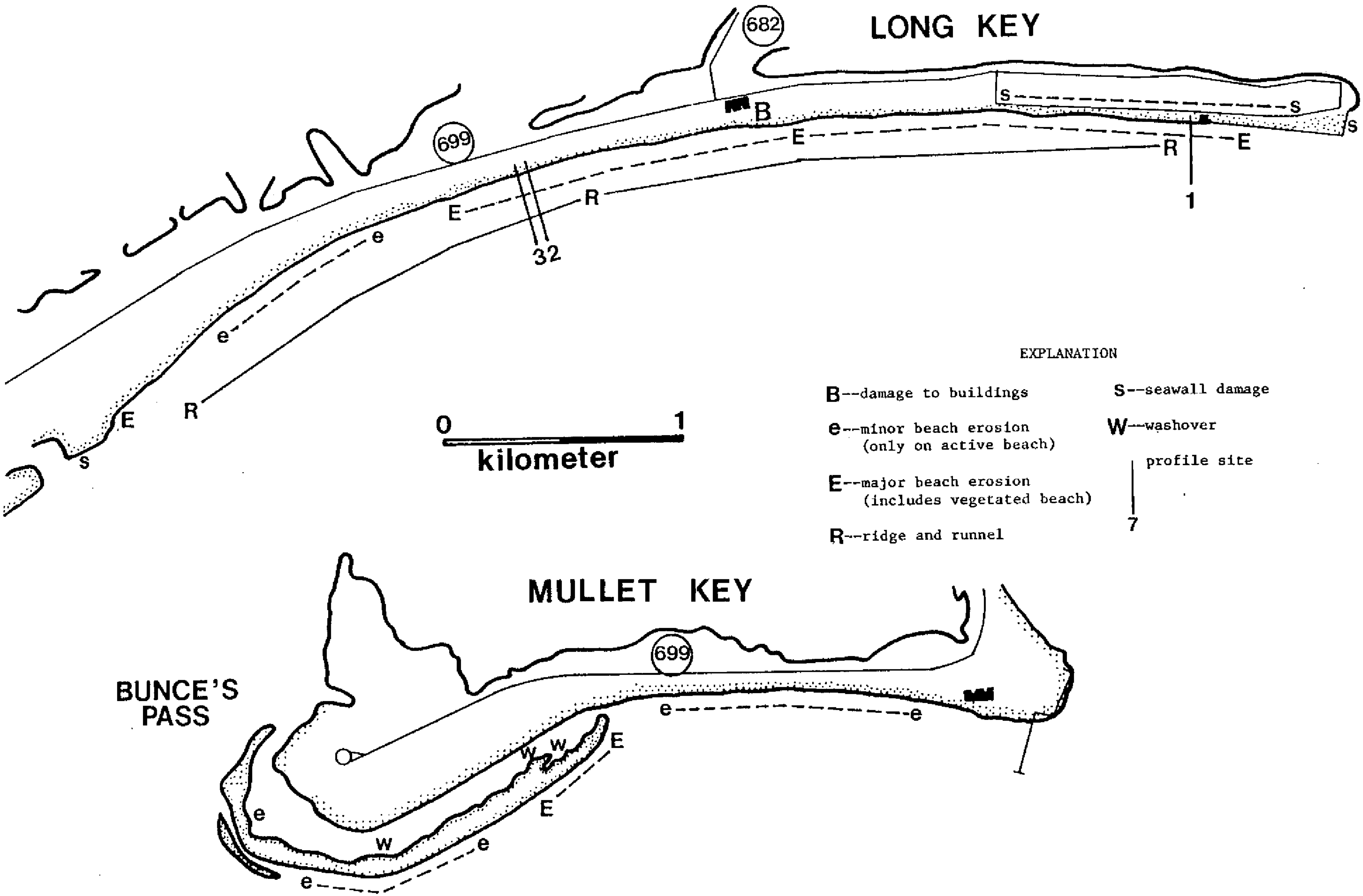

Figure 16a-e - Maps of the Pinellas County barrier islands showing beach changes and damage as the result of Hurricane Elena.

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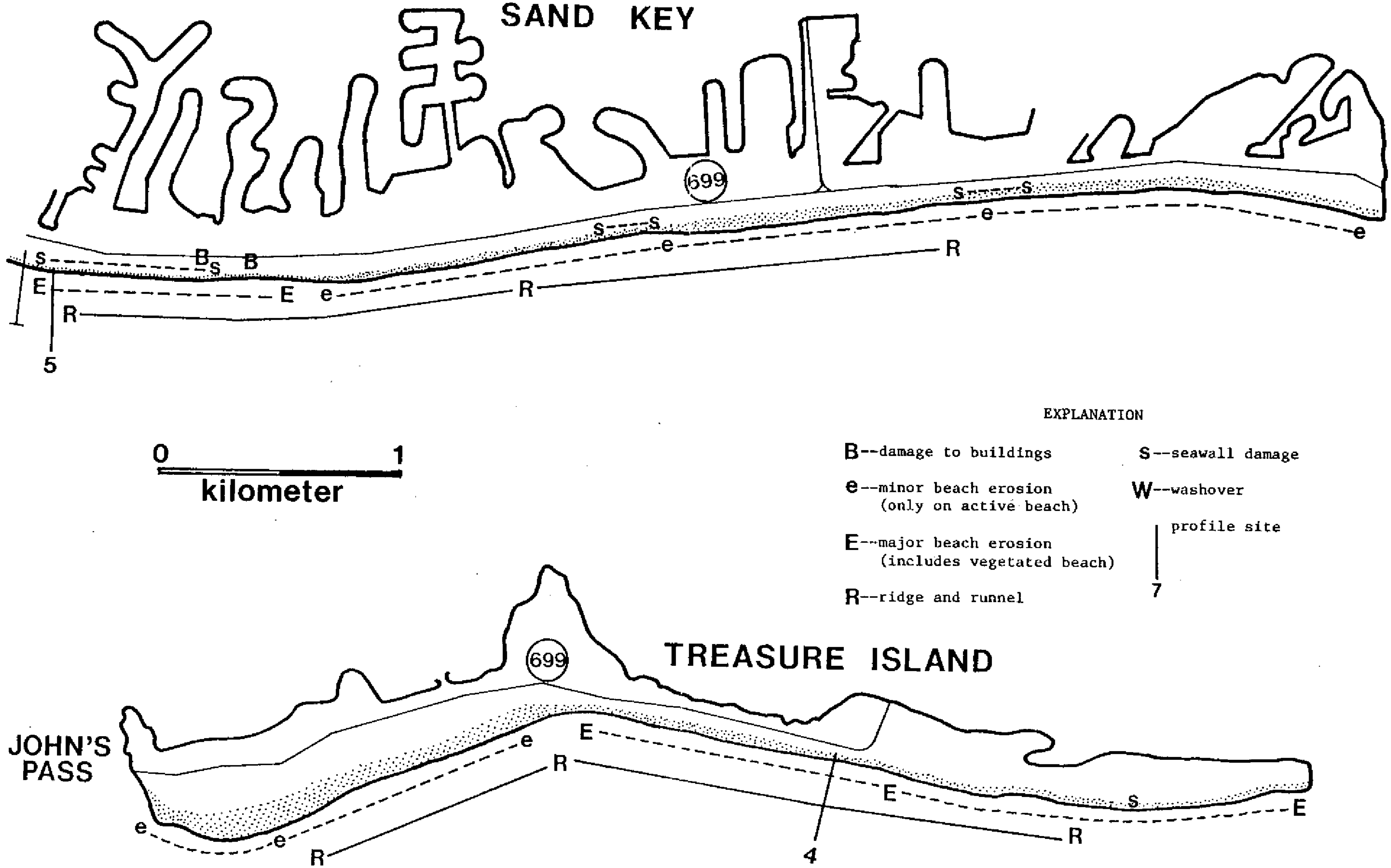

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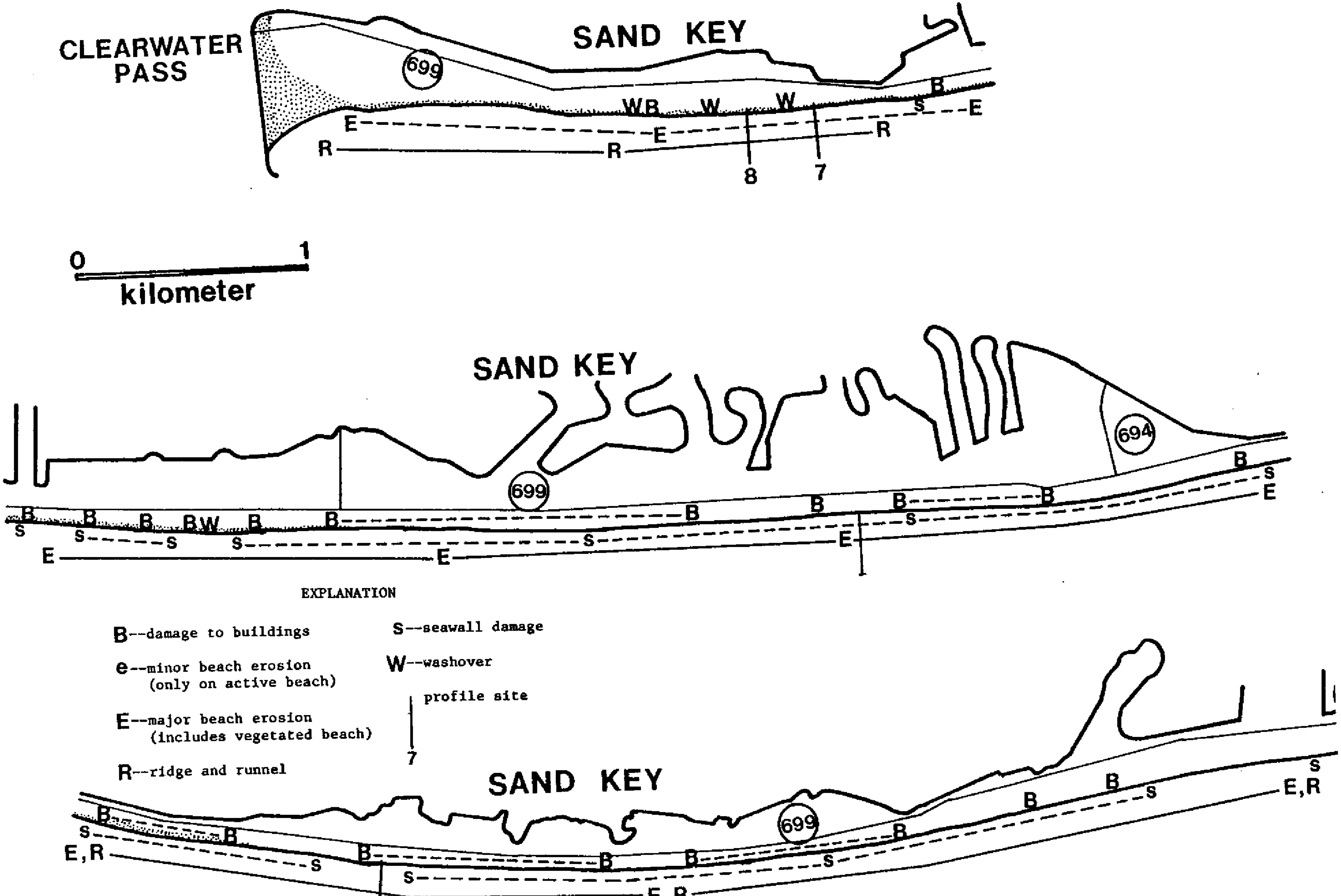

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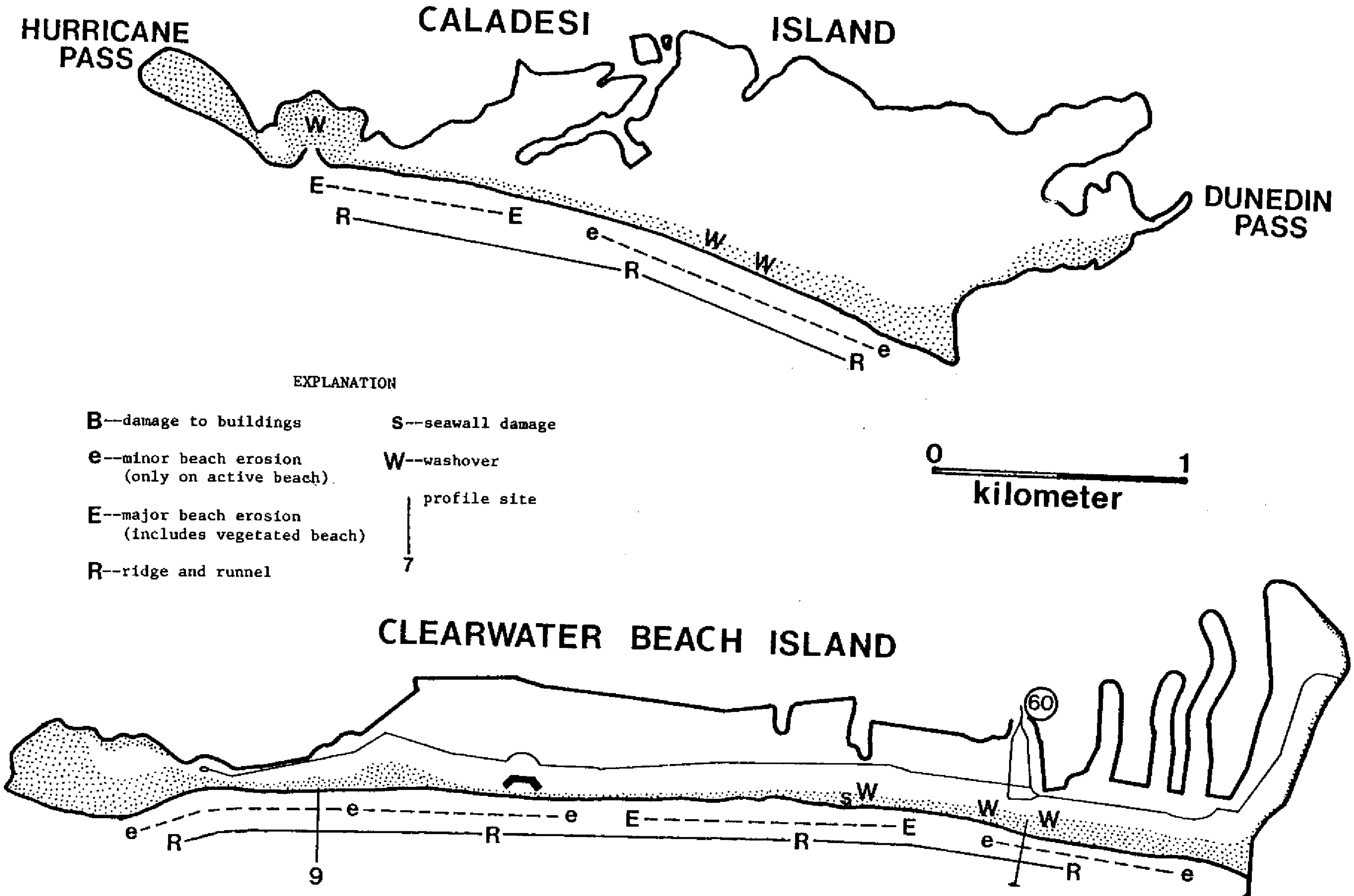

Figure 16 cont'd.

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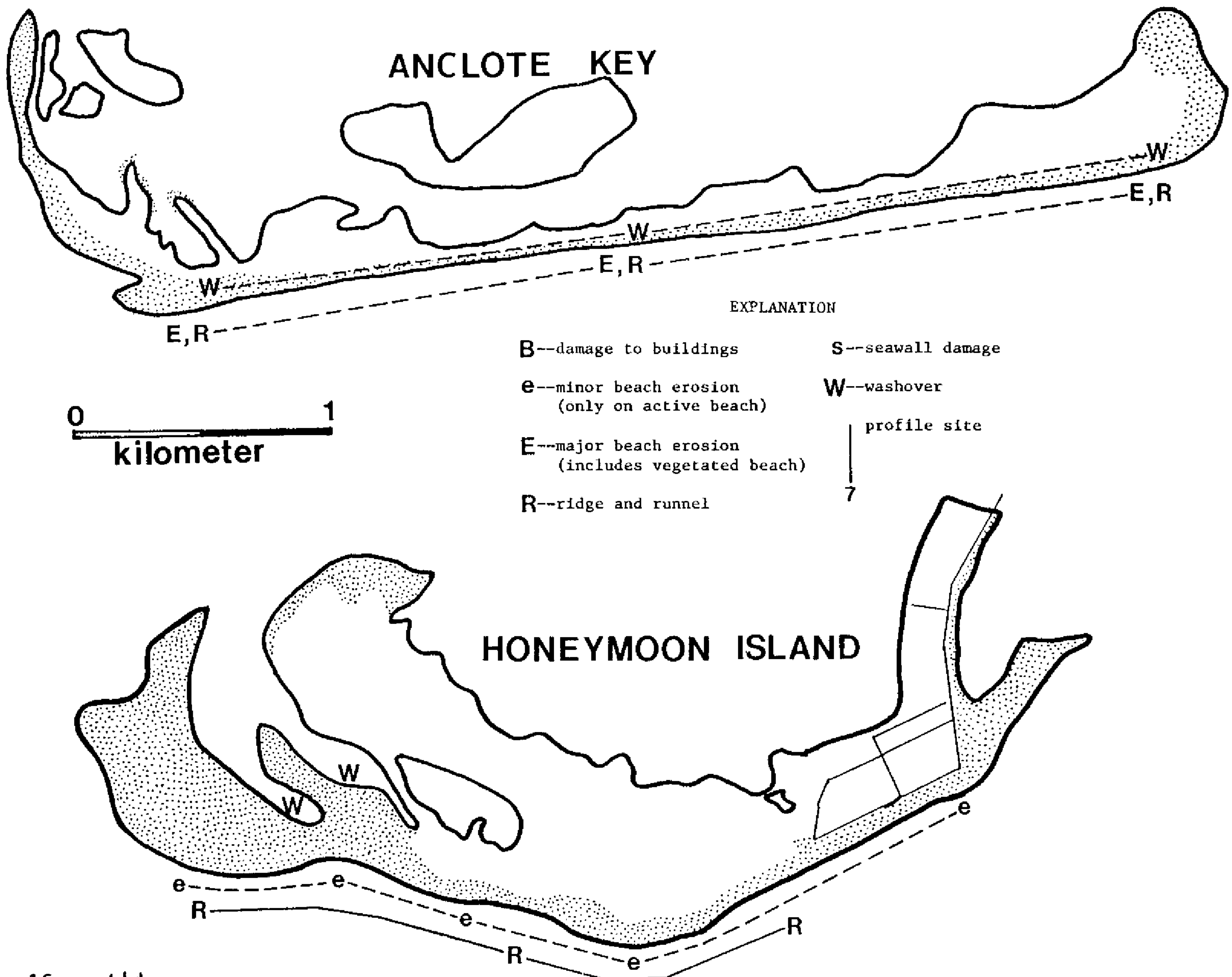

Figure 16 cont'd.

e

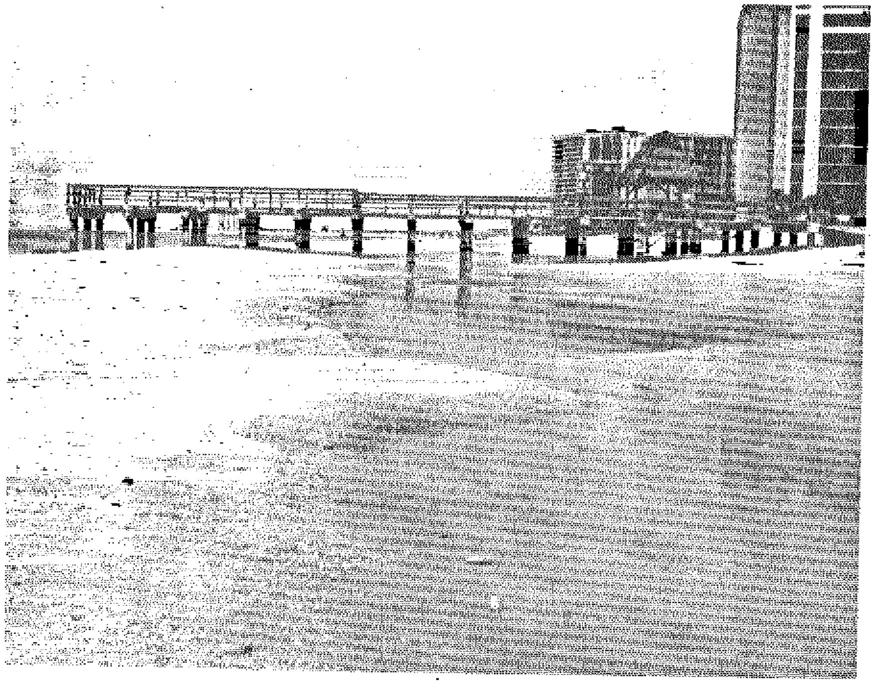

Figure 17a - Large high relief ridge and runnel feature formed as the result of Hurricane Elena on Sand Key near Location 8.

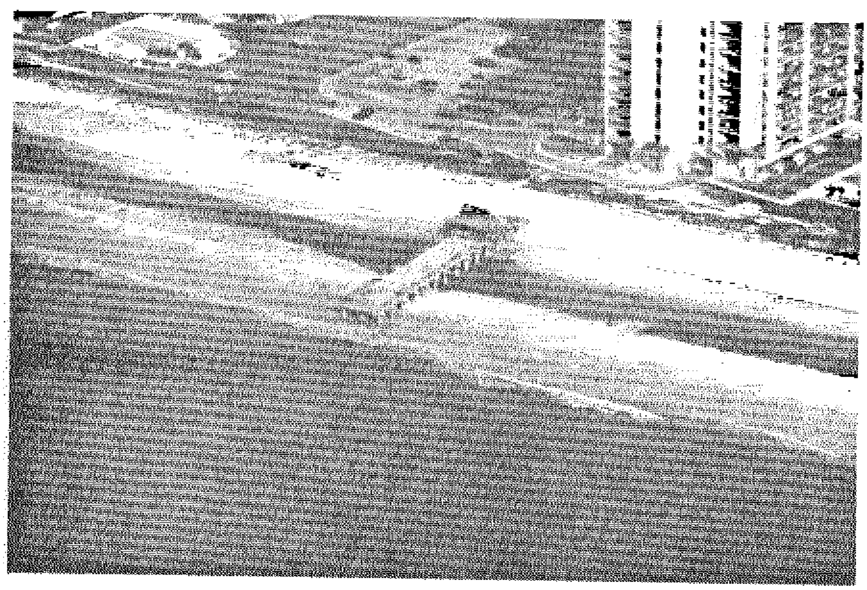

Figure 17b - Oblique aerial view of ridge and runnel feature on Sand Key.

and the presence of extensive seawalls in Pinellas County minimizes the effect of the long interval between surveys.

It is apparent that even during storms conditions, while most beaches experience erosion, some show accretion. Measurement of both is necessary to assess the net changes along a coastal reach as the result of storm activity. This type of analysis for Pinellas County shows that the change attributed to Hurricane Elena is about 6 cubic yards of erosion per linear foot of beach or 15 cubic meters per linear meter (Balsillie, 1985). Assuming a replacement cost of $6 per cubic yard, the damage assessment for beach erosion as the result of Hurricane Elena is $1,240,000 for Pinellas County. This is almost 4 times the amount lost from Manatee County beaches but is less than each of the panhandle counties affected except for Gulf County.

Damage to seawalls or similar protection structures was extensive but was confined to a rather small portion of the coast. The seawall on southern Long Key at Pass-a-Grille was damaged to the point that it had to be replaced (see Appendix A). The remainder of Long Key and all of Treasure Island was essentially free from seawall damage. The most extensive and severe damage to hardened shorelines was on Sand Key, locally in the southern portion and continuously beginning at North Redington Beach and continuing through Bellaire Beach on the north (figure 16). Most of the seawall-type structures along this reach were completely destroyed or were damaged to the point that major repair was necessary. Very little seawall damage took place in the City of Clearwater and to the north. Data from the DNR study (Balsillie, 1985) show that although there was considerable damage to seawalls and other protective structures, there was about 30 % less erosion at beaches that were fronting such structures. This study showed that a total of 4.55 km of vertical seawalls was destroyed or heavily damaged and another 3.46 km sustained minor damage.

Damage and destruction of buildings was largely confined to the same areas where seawall damage took place. A tennis court near the Don Cesar Hotel on Long Key was the only significant structural damage of this type south of the North Reddington Beach area. From there on to the north there was considerable damage to buildings through Bellaire Beach with no major damage of this type north of that area. The most severe damage to buildings took place at Indian Rocks Beach and just to the north (figure 18). A complete listing of building damage can be found in table 1.

Hurricane Juan -

Hurricane Juan was a very damaging hurricane to the northern Gulf coast but did relatively little damage to the Pinellas County coast. A total of 12 lives were lost, 9 of which were related to the offshore oil industry near the Mississippi Delta. These nine lives were lost as the result of offshore rigs being toppled or boats that were lost at sea transporting workers. The authorities reported 1,357 injuries; most of a minor nature.

Table 1 - Structural Damages for Buildings - Hurricane Elena (data from Balsillie, 1985)

44	single family dwellings destroyed
31	single family dwellings sustained major structural damage
3	condominium units destroyed
3	condominium units sustained major structural damage
2	townhours buildings sustained major structural damage
1	motel unit destroyed
5	motel structures sustained major damage
1	cabana-recreation unit sustained major damage
5	swimming pools destroyed
3	swimming pools sustained major damage
3	fishing piers destroyed
2	fishing piers sustained major damage

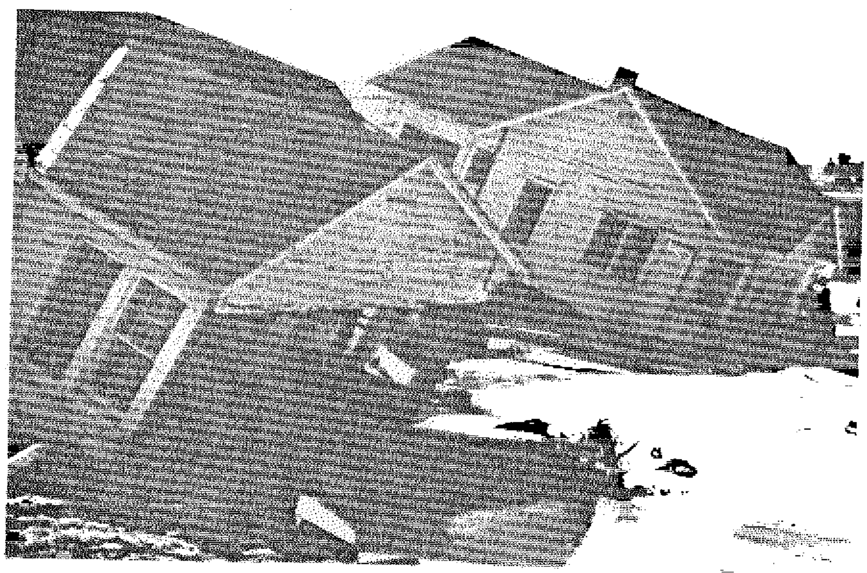

Figure 18 - Extensive damage to houses at Indian Rocks after passage of Hurricane Elena.

Total monetary losses related to Hurricane Juan were nearly 1.5 billion dollars, most of which was also along the north-central Gulf coast. A large portion of this was the result of very expensive offshore oil rigs being damaged. Considerable flooding in southern Louisiana causes damage to crops and livestock (Federal Hurricane Center, 1985b).

Pinellas County was essentially free from serious injuries as the direct result of Juan. Monetary losses along this coast totaled about 2.5 million dollars; an insignificant sum compared to Hurricane Elena. Much of the damage was inflicted on structures that were in the process of being repaired from Elena. This total included $1,500,000 from Indian Shores, $500,000 from St. Petersburg Beach and $265,000 from North Redington Beach, all areas that were hard hit during Elena.

Beach erosion associated with Juan was nominal throughout Pinellas County. Extremely low-lying areas experienced some washover due to the modest storm surge. Most of the county beaches were still protected by the large ridge system that developed during Hurricane Elena nearly two months previously. This ridge served to protect most beaches from erosion.

Hurricane Kate -

Monetary losses associated with Hurricane Kate are only $300 million; only a small fraction of that associated with either of the previous hurricanes. Of this amount, the vast majority was inclurred in the panhandle of Florida in the vicinity of Appalachicola Bay where the storm made landfall. Not included in this figure is the major loss of the oyster crop in the bay and the related loss of employment (National Hurricane Center, 1985c). The industry was essentially wiped out for a year due to siltation and disruption of beds caused by the storm. There were also 6 lives lost in Florida as the result of the storm. Numbers of injuries are not available but are assumed to be modest.

Some minor damage was incurred to buildings and to seawalls, primarily those still being repaired and rebuilt as the result of Hurricane Elena. Monetary losses specific to Pinellas County and this storm are not available.

Beach damage from Hurricane Kate was also nominal. Although there was some removal of sediment it was primarily a small amount at the base of the foreshore in the plunge step area. The typical profile change was the production of a small step in this part of the profile. Local and small areas of washover were also present. No calculations of sediment loss were made due to the minor changes to the beach.

Beach Profile Changes

Shortly after passage of Hurricane Elena, a reconnaissance trip was conducted along the entire Pinellas County coast in order to locate and establish sites for beach profile surveying. The locations were chosen in order to monitor that portion of the county where impact on human development was severe and also to provide at least subequal coverage of this coastal reach. A secondary factor was to locate proximal natural and seawall-impacted profiles in order to assess the relative roles of seawalls under essentially similar conditions as nearby natural profiles.

Nine profiles were established with initial surveys conducted on September 10, 1985. The planned schedule for surveys was to be weekly for the first month, biweekly for the next 3 months and monthly thereafter for a total of one year. This produced a total of 18 surveys at each of the locations. All profile locations, selected photographs of the profiles and the surveyed profiles are in Appendix A.

Each of the profiles was surveyed from permanent monuments or other permanent structures. Surveys were traversed essentially perpendicular to the shore and included the entire beach out to a depth that could be reached by wading. A Topcon AT-F4 autolevel and a metric stadia rod were employed for survey measurements. Elevations were recorded at 5 m intervals or less if noticeable topographic changes were present. Sea level was determined by measuring water depth at the end of each profile and adjusting that value to predicted tides. Although there is surely some error in this approach, it is probably only a few centimeters.

Field data were stored in Visi-Calc spread sheet files and adjusted to the appropriate datum. Computations and plots of the profile surveys were accomplished using the Harris H-800 minicomputer and a Hewlett-Packard plotter.

Pass-a-Grille (Loc. 1) -

This profile is located approximately 125 m north of a concession building on the public beach and it is just south of the intersection of Gulf Ave. with 11th St. (Appendix A). The profile extends from the seawall adjacent to the road across the entire beach. This seawall was destroyed during Hurricane Elena and much sand washed over from the beach to the road (Appendix A). It has subsequently been replaced. This location contains a well-developed beach with most profiles extending about 80 m.

The initial profile here showed a well-developed ridge high in the profile. It had relief of near a meter and was located about 30 m from the seawall (Appendix A). In 9 days time this ridge had migrated 5 m landward maintaining the same relief. The ridge remained in this position until the passage of Hurricane Juan about six weeks later. The primary changes to the profile as the result of Juan were to migrate the ridge landward to smooth the profile. Energy from Hurricane Kate in late November was approximately equivalent to a winter frontal system. It did little to the beach profile except for a small erosional step (Appendix A).

There was little significant change to the profile at Pass-a-Grille through April, 1986. Reconstruction of the seawall took place in late April and had little effect on the beach profile except for bulldozing of sand against the seawall (see May, 1986 profile). Little change took place during the summer of 1986 although there are some indications of decreasing profile width. This was alleviated as the result of a large scale beach renourishment project to the north of Location 1. Approximately 25 m of beach width was added by September, 1986 as the result of this project.

Long Key (Loc. 2) -

The profile at Location 2 is located adjacent to the southwest corner of the Colonial Gateway Motel on Gulf Blvd. just south of 64th St. The profile is 60 m south of the seawall at the Silver Sands condominium. This natural profile has a broad backbeach which extends 50-60 m landward of the berm (Appendix A). The profile typically was 80-100 m wide.

This location experienced little change as the result of Hurricane Elena. A small ridge and runnel was present during the initial survey however it does not show on the plot due to poor location of survey points. This ridge had a relief of about 0.3 m and persisted until passage of Hurricane Juan in late October (Appendix A). There was some change in profile of this ridge and modest landward movement.

A lower and broader ridge developed as the result of Hurricane Juan (see Nov. 2, 1985 survey) which subsequently migrated landward. Juan also caused the initial ridge to migrate up onto the berm area of the foreshore. During the following two weeks this ridge steepened and migrated on to the lower foreshore. Hurricane Kate planed off the ridge and caused it to migrate about 5 m seaward.

No significant changes took place at this location from December, 1985 through the end of the study period. Its general profile was maintained with small steps cut by minor wave action. Some grooming by bulldozers took place on the backbeach but with little impact on the general profile.

<u>Long Key - Wall (Loc. 3)</u> -

The profile at Location 3 was established in front of the seawall located adjacent to the Silver Sands condominiums which are at the Gulf end of 64th St. (Appendix A). The seawall which serves as the monument for the profile is fronted by boulder size rip-rap. The surveyed and plotted portion of the profile begins just Gulfward of the rip-rap. This profile was located here in order to provide comparative data with a closely proximal natural profile (Loc. 2). This is a very narrow profile with only a foreshore beach present.

The post-Elena profile shows no ridge and runnel development. The general width and shape of the profile did not change until the passage of Hurricane Juan in late October (Appendix A). After Juan the beach was somewhat wider and less steep. The profile included a wide and low-relief ridge which persisted throughout the winter and spring. There was no noticeable change in the profile as the result of Hurricane Kate.

A major change in the profile took place in July, 1986 when a beach nourishment project increased the level of the profile over a meter and also increased the beach width (Appendix A). This project completely covered the rip-rap and raised the level of the back portion of the beach to that of the seawall (see photo in Appendix A).

<u>Treasure Island (Loc. 4)</u> -

Profile #4 is located addjacent to the wooden boardwalk just north of the Island Inn condominium which is situated just to the north of 100th St. (Appendix A). The beach at this site is quite broad with a gently landward sloping backbeach and a broad foreshore. Much of the backbeach is artificially groomed so that only the portion of the profile Gulfward of the berm is truly natural.

The post-Elena profile on September 10, 1985 showed a large and well-developed ridge and runnel. The ridge has a relief of about 1 m and was approximately 25 m seaward of the berm (Appendix A). This ridge migrated landward over the following six weeks until passage of Hurricane

Juan in late October. After Juan the profile shows that at least some of the ridge did migrate landward. A very subtle ridge was present during early November but was not apparent after Hurricane Kate as shown on the November 26 profile.

There was little change to the beach profile from late fall of 1985 until termination of the study in September, 1986. The only discernable differences were small apparent accumulations of sediments on the foreshore.

Redington Beach (Loc. 5) -

This profile is located adjacent to a seawall which is 125 m south of the Redington Beach fishing pier, essentially opposite 175th Terrace on Gulf Blvd. The sea wall was badly damaged as a consequence of Hurricane Elena and was subsequently rebuilt. This construction had no major effect on the natural beach profile.

After Hurricane Elena the profile was low, narrow and had a pronounced ridge about 0.3 m high. A low relief and slightly subtidal ephemeral bar Gulf ward of this ridge. Both of these features persisted until Hurricane Juan in late October. (Appendix A). After Hurricane Juan the profile changed remarkeably. The ridge and the ephemeral bar were no longer present and there had been considerable accretion immediately in front of the seawall. More than 1 m of vertical accretion had taken place as waves generated by Hurricane Juan caused the ridge and ephemeral bar to move landward with the seawall acting as a barrier to further migration. A small and low relief ridge was present after the passage of Juan but was removed during Hurricane Kate (Appendix A).

This profile remained essentially the same throughout the remainder of the study period. It was rather narrow throughout with no readily discernable berm (Appendix A).

Indian Shores (Loc. 6) -

The profiles at Indian Shores is located adjacent to a seawall in front of the Redwood Apartments on the south side of 199th Ave. (Appendix A). This sea wall sustained damage during Hurricane Elena but was not destroyed. This profile is in the area which experienced the most severe damage as the result of this storm. The beach here is narrow and generally resembles the one at Redington Shores (Loc. 5).

After Hurricane Elena this profile exhibited a ridge and runnel topography with about 0.6 m of relief. Like the Redington Shores location, this morphology persisted until passage of Hurricane Juan. Juan cause landward migration of the ridge with eventual deposition of considerable sediment against the seawall which prevented further landward transport. After Juan the profile was rather narrow and steep with a concave upward shape. More than a meter of sediment was accreted to the landward portion of the beach. A rather well-developed ridge and runnel system developed as the result of passage of winter frontal systems during November. This configuration persisted through the passage of Hurricane Kate.

During the winter and ensuing months of the study this profile was rather stable but narrow and steep (Appendix A). There was no apparent ridge and runnel nor was there erosion during the typically high energy winter season.

Sand Key Wall (Loc. 7) -

The profile at Location 7 is situated adjacent to the northwest corner of the seawall that surrounds the Dan's Island Condominium which is near the southern boundary of the City of Clearwater. This profile is paired with Loc. 8, a natural profile located a few hundred meters to the north. The beach at this site is narrow and not unlike the two sites to the south (Locs. 5 & 6).

The profile just after impact of Hurricane Elena showed a very large ridge and runnel system. The ridge had a relief of 1.5 m with the crest above high tide. This profile configuration remained unchanged for several weeks afterward largely because the crest of the ridge was not overtopped by tides and waves thereby causing landward migration (Appendix A). After Hurricane Juan the profile showed marked change which included nearly a meter of accretion immediately in front of the seawall and a change in the shape and size of the ridge. The ridge migrated landward and although apparently unaffected by Hurricane Kate, it welded to the profile by early December.

The profile showed little change throughout the remainder of the study period. It was steep and narrow with the large amount of accretion in front of the seawall persisting throughout the duration of the study. Slow removal of sediment was apparent duing the spring and summer of 1986 (Appendix A). The beach was only about 15 m wide by September.

Sand Key (Loc. 8) -

This profile is located near the southwest corner of the property surrounding the South Bay condominiums on Gulf Blvd. in the City of Clearwater. It is a few hundred meters north of Dan's Island and is 63 m south of the short fishing pier associated with the South Bay complex. The profile is now a natural one however there is a buried seawall near its landward end and some artificial plantings have been set in the area. The profile has a noticeable berm and was at least 50 m wide throughout the study. This profile is paired with Loc 7 to provide comparison of natural and seawall profiles.

The initial profile after Hurricane Elena displayed a well developed ridge and runnel but without the great relief displayed by Loc. 7 a few hundred meters to the south. Although the relief on this ridge was near 1 m it did permit some overtopping during high tide conditions and consequently there was a bit of lanward migration (Appendix A). The most significant change to this profile took place as the result of Hurricane Juan. The ridge that had persisted for the previous several weeks had migrated onto the upper beach and a new but smaller ridge had developed lower on the profile. The resulting profile showed considerable accretion in the backbeach area. This ridge migrated onto the beach quickly and after Hurricane Kate another small ridge was present. This feature also welded onto the beach quickly.

From December, 1985 until the completion of the study in September of the following year there was little natural change to the beach with only minor changes in the foreshore due to passage of winter frontal systems. In early summer a small man-made dune was constructed and planted with grasses in an attempt to stabilize the back beach (Appendix A).

North Clearwater (Loc. 9) -

The northernmost of the regularly surveyed profiles is located on the northern part of Clearwater Beach Island opposite the Carlouel Yacht Club on El Dorado Drive. The profile is just north of the end of a boardwalk over the dunes (Appendix A). This is one of the widest beaches in the study area and certainly is the one displaying the greatest long-term accretion.

Immediately after Hurricane Elena there was a ridge and runnel as well as a large ephemeral bar on this profile. Although its relief was similar to that on profile #7 it was lower on the profile. Water covered the bar during high tide conditions and caused a slight shoreward migration. After Juan, this profile displayed a markedly different appearance. The ridge had migrated up onto the beach and a new ridge and runnel was present. This broad ridge showed some shoreward migration and persisted through the passage of Hurricane Kate (Appendix A).

There has been little change to this beach since December, 1985. Small ridge and runnel features along with minor erosional features were present on the profile over the remainder of the study period. There was a subtle but regular decrease in beach width from early 1986 through the end of the study.

Summmary of Beach Profile Changes -

Generalizations about beach changes caused by the hurricanes of 1985 can be placed into two major categories; those that were geographic in nature and those that occurred in association with a specific storm. A secondary type of consideration is the comparison of changes associated with natural profiles as compared to those adjacent to hardened shore structures such as seawalls. In consideration of beach changes reported here, it should be remembered that no pre-storm profile surveys are available except for a few that the Dept. of Natural Resources measured 11 years prior to the 1985 hurricane season. Because of the time gap and the lack of geographic match, these profiles are not considered in this discussion.

Without question, Hurricane Elena had the greatest impact on Pinellas County beaches of the 1985 storms. Much obvious change to the profiles occurred in the form of erosion, washover and especially development of large ridge and runnel features (Appendix A). Hurricane Juan caused more accretion than erosion as the result of its facilitation of shoreward migration of the ridge formed during Elena. There was little change caused by Hurricane Kate except for some isolated locations.

The southern beaches (Locs. 1-4) of Pinellas County experienced the least change during Hurricane Elena although a large ridge and runnel feature did form at Loc. 4 (see Appendix A). Erosion was prevalent from Location 5-8 which was from Redington Beach to northern Sand Key. Little erosion occurred at the northernmost site however this profile also displayed a large ridge and runnel after Elena.

This pattern of beach change is largely to the combination of the shoreline pattern of Pinellas County in combination with the dominantly southwesterly wind and wave direction during Elena. Longshore transport of sediment was undoubtedly to the north throughout the storm but at a low rate in the southern portion of the county as compared to the north. This was due to the angle of wave approach and the lower gradient of the inner shelf as well as protection from the Egmont Shoal in the southern area. The broad headland area was relatively vulnerable to wave attack and longshore transport from this area to the north was higher than the southern part of the county. This produced erosion in the central headland area and facilitated the development of the ridge and runnel system which was most prominent in the central and northern part of the county. The northernmost profile on an accreting spit of Clearwater Beach Island showed little apparent erosion but did develop a very large ridge and runnel morphology.

These general patterns suggest that there was a net northerly transport of beach sediments with a net gain of sediments in the northernmost part of this barrier system. Long term profiles, aerial photographs and the results of the year-long profile study support this pattern of shoreline sedimentation.

Although no quantitative data are available to assess the relative erosion on the natural profiles as compared to those adjacent to seawalls, there does seem to be more vertical erosion in front of the seawalls. This may not be a greater volume of sand removal from the profile because erosion did not occur landward of the structure in most cases. There is no question however, that recovery took place more rapidly in front of the seawalls than on natural profiles. This also may have been somewhat exaggerated due to the circumstances mentioned above.

Summary and Conclusions

The storms of 1985 presented an unusual set of circumstances for the Pinellas County coast; 1) there were three in one hurricane season, 2) one was probably the most severe storm to impact the coast since extensive development occurred, 3) the net change to the beaches of the county was nominal, 4) considerable property loss was incurred however there was no loss of life and injuries were few and 5) it was the first time there has been detailed studies associated with hurricanes on the west-central Florida coast.

Erosion during Hurricane Elena was modest but was largely ameliorated as the result of the second storm and the third did little damage to beaches. The extremely large ridges produced by Elena were generally above high tide and therefore persisted until the passage of Juan. They protected the beach from further erosion and actually migrated landward and welded onto the beach. The generally low energy winter season that followed the hurricanes also fostered the recovery of the beaches.

Data on seawall effects on the beach profiles are inconclusive. Erosion in front of these structures was indeed great and scour was apparent. On the other hand, the beaches at these sites recovered more rapidly and completely in a shorter time than did the natural profiles. It is very likely that the circumstances of the sucessive storms contributed to this phenomenon.

Damage to property was quite high as the result of Hurricane Elena but was comparatively nominal for the last two storms. Most of the damage was to coastal protection structures and buildings and was due to waves. Few buildings were completely destroyed. The damage to property was largely confined to the central portion of the county on the headland and just to the north of it. Much of the damage cuased by Hurricanes Juan and Kate was incurred to protective structures under repair and reconstruction after Elena or to buildings exposed by destruction of protective structures as the result of Elena.

It is possible that the most serious aspect of the hurricanes of 1985 may be psycological. Hurricane Elena was the first hurricane to have a major impact on Pinellas County since major development has taken place. The fact that even though there was substantial loss of property, little else other than evacuation, caused serious inconvenience to residents could result in false confidence.

Hurricane Elena did not come within 100 km of Pinellas County, winds and waves generated along this coast were nominal and the storm surge was less than 2 m on the open coast. Too many people are now of the opinion that because this area escaped major disaster from Elena it is a safe coast. It is possible that Elena did not cause enough destruction to teach us a lesson!

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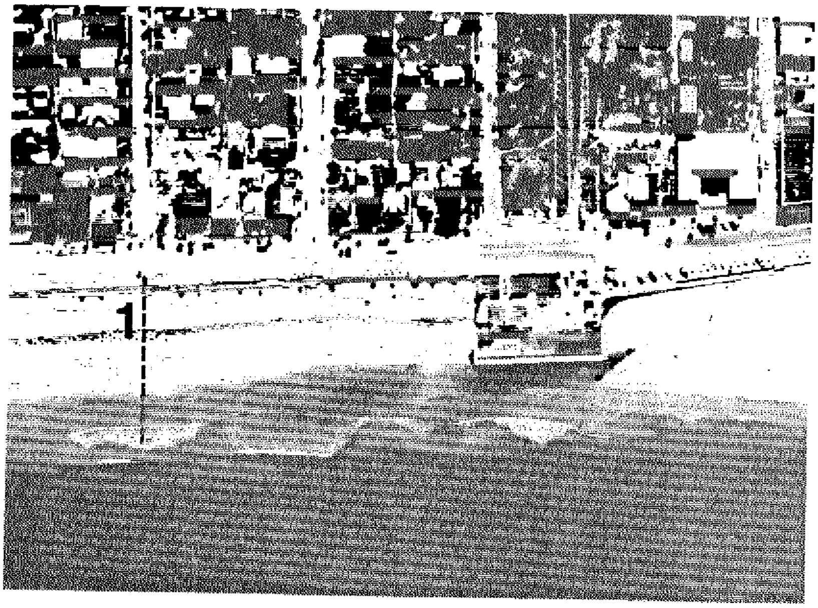
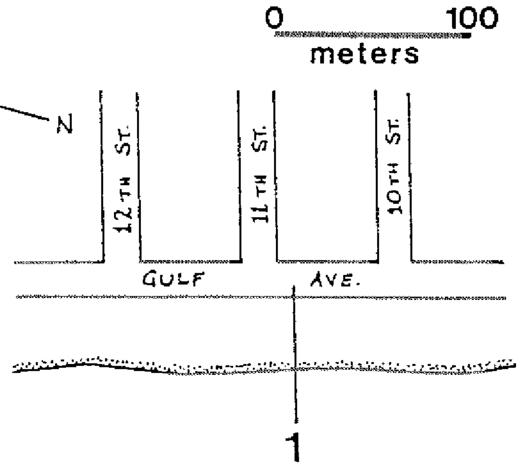
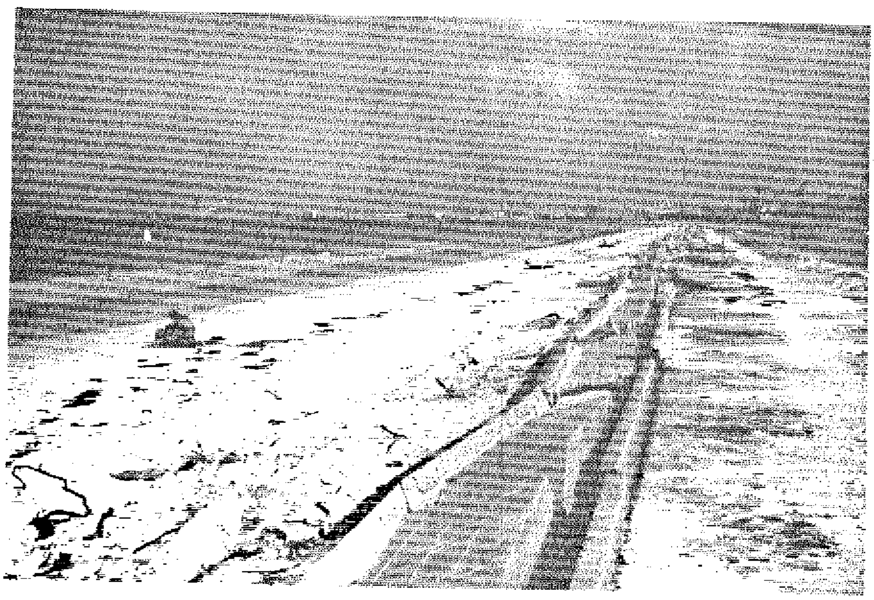
APPENDIX A

Location maps, aerial photographs, beach photographs and beach profiles for each of the surveyed beach locations. See figure 1 for general location of each profile.

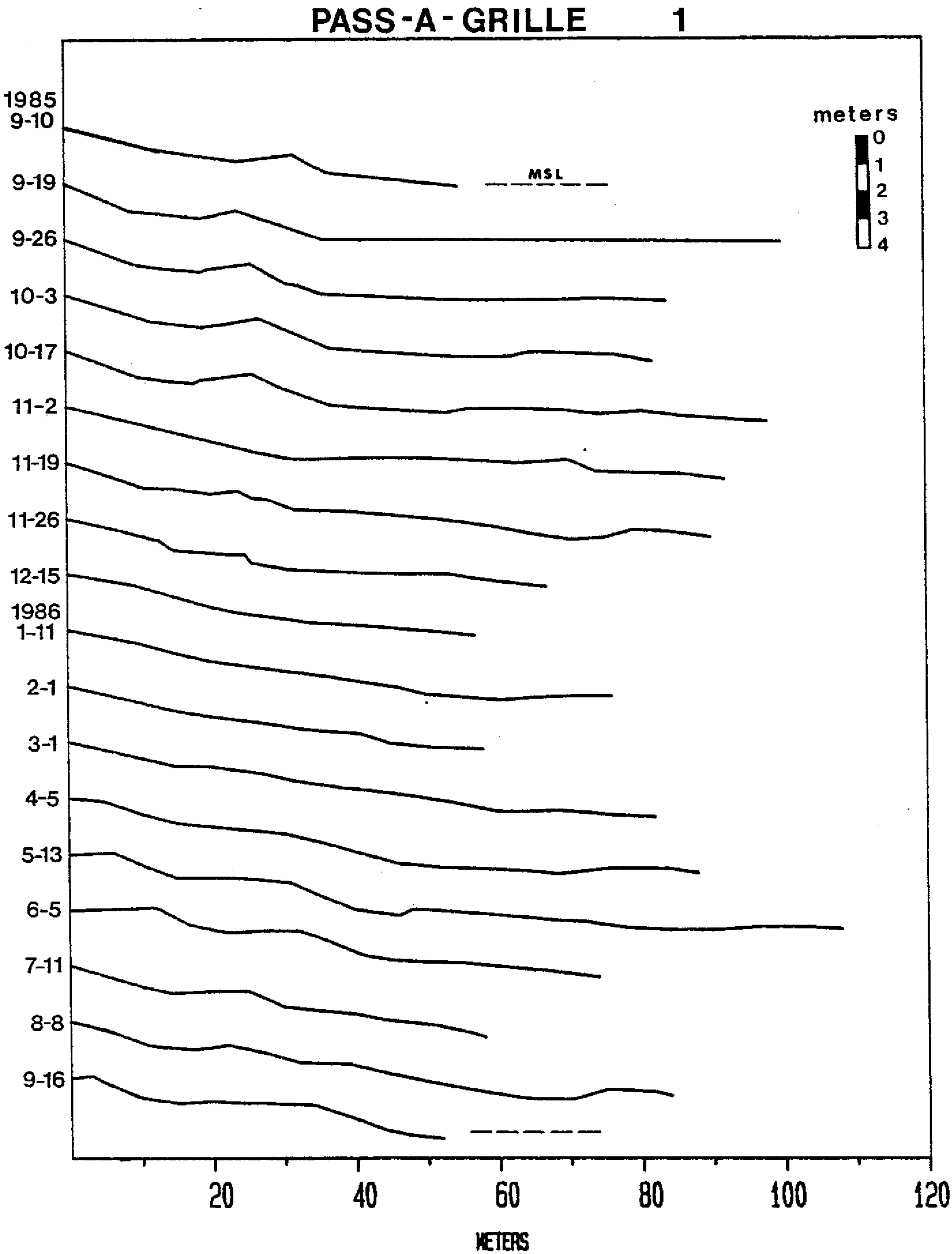






September 10, 1985

July 11, 1986


PASS-A-GRILLE 1
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11-26
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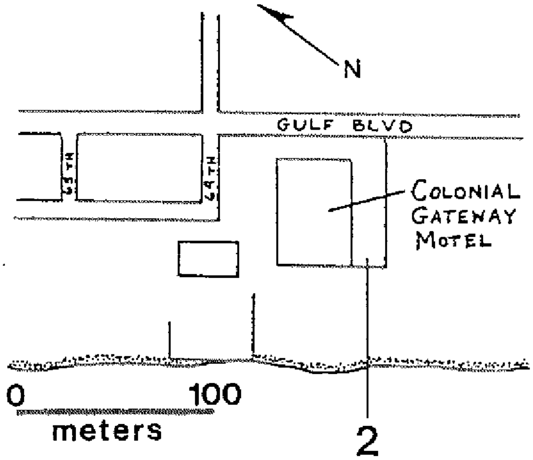
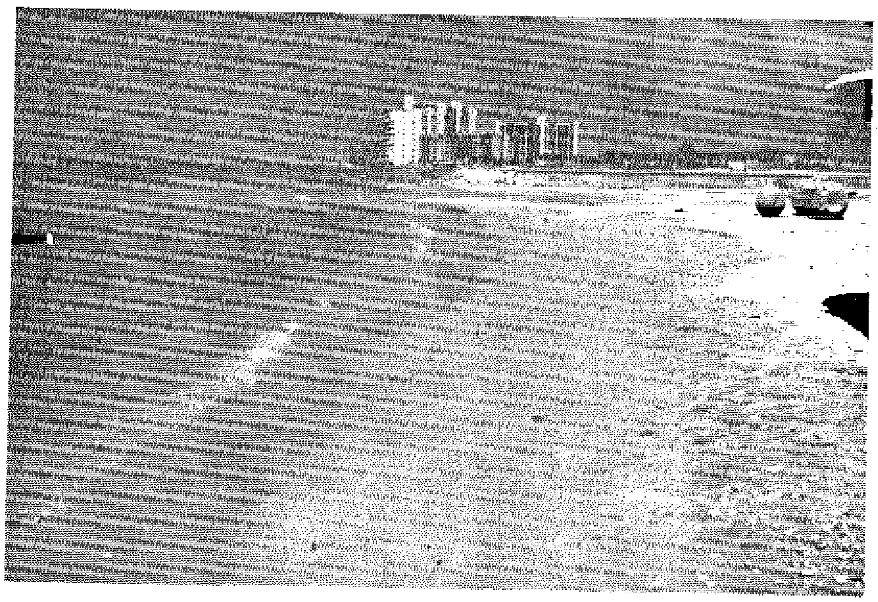
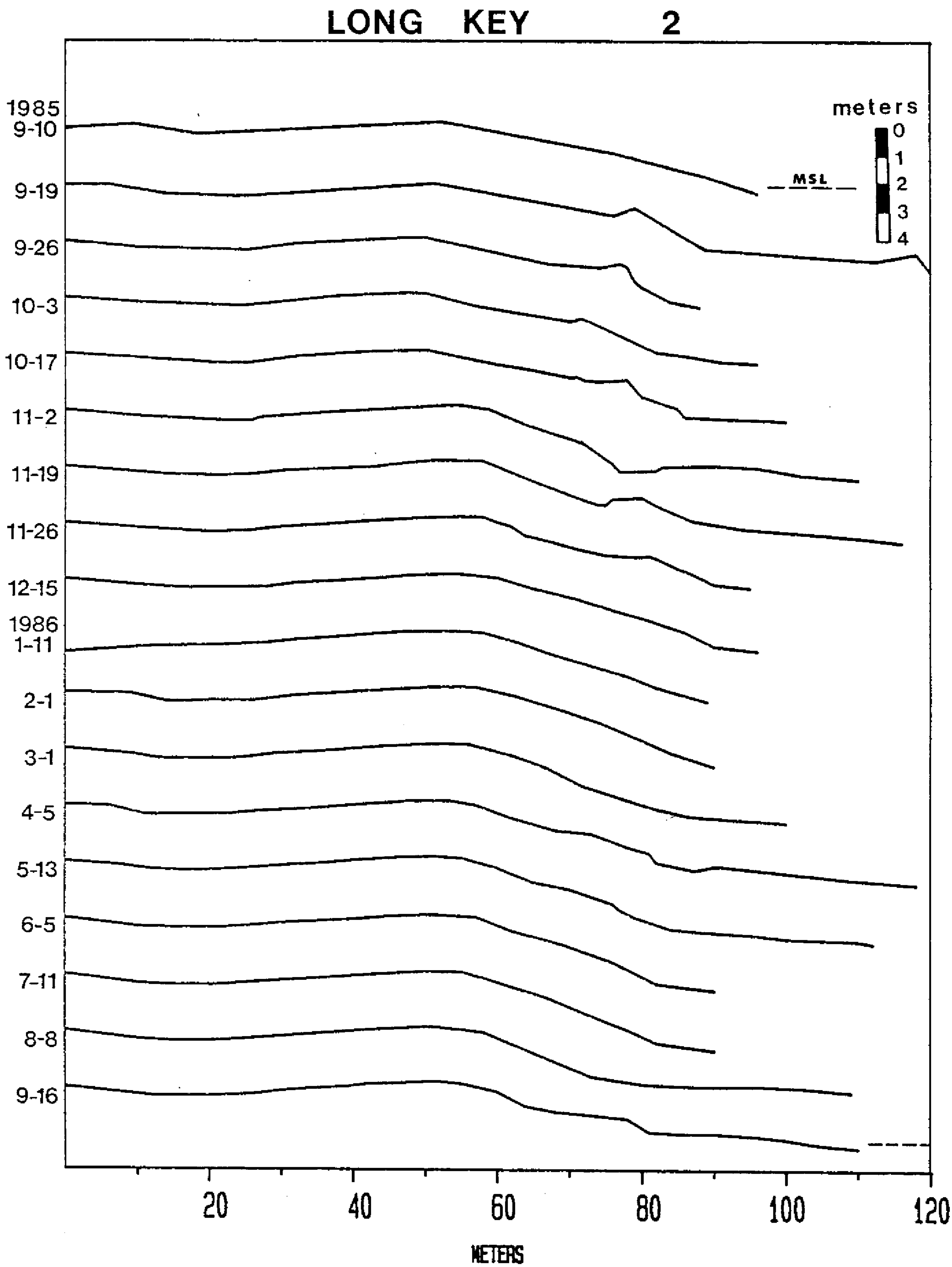




September 10, 1985

September 16, 1986


LONG KEY 2
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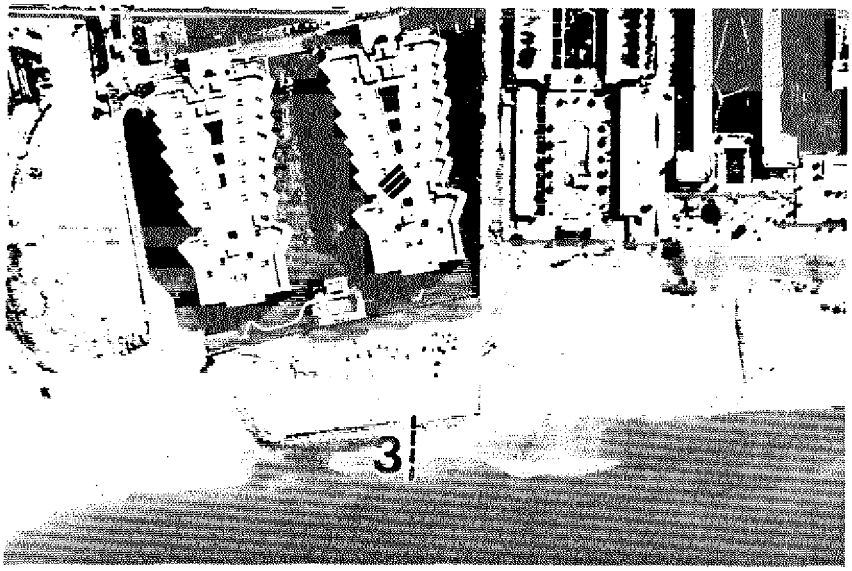
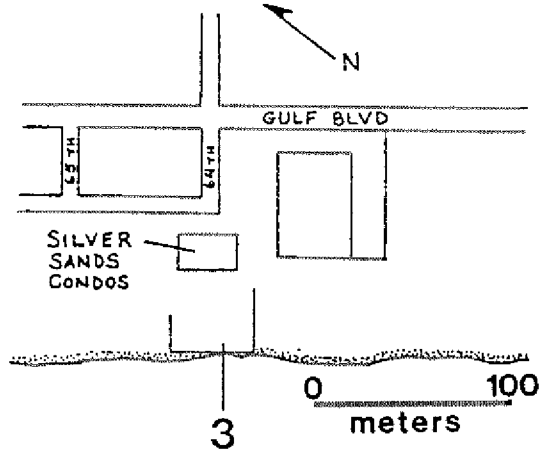
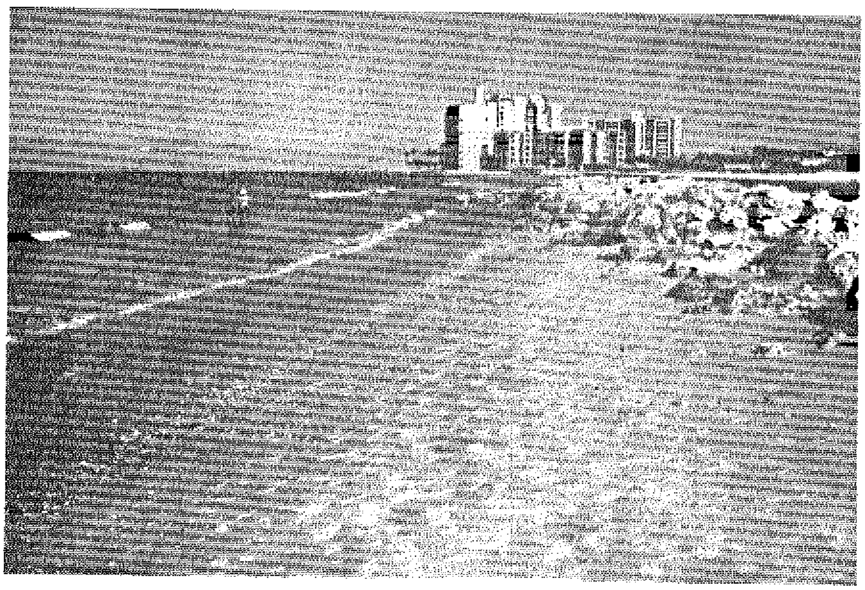


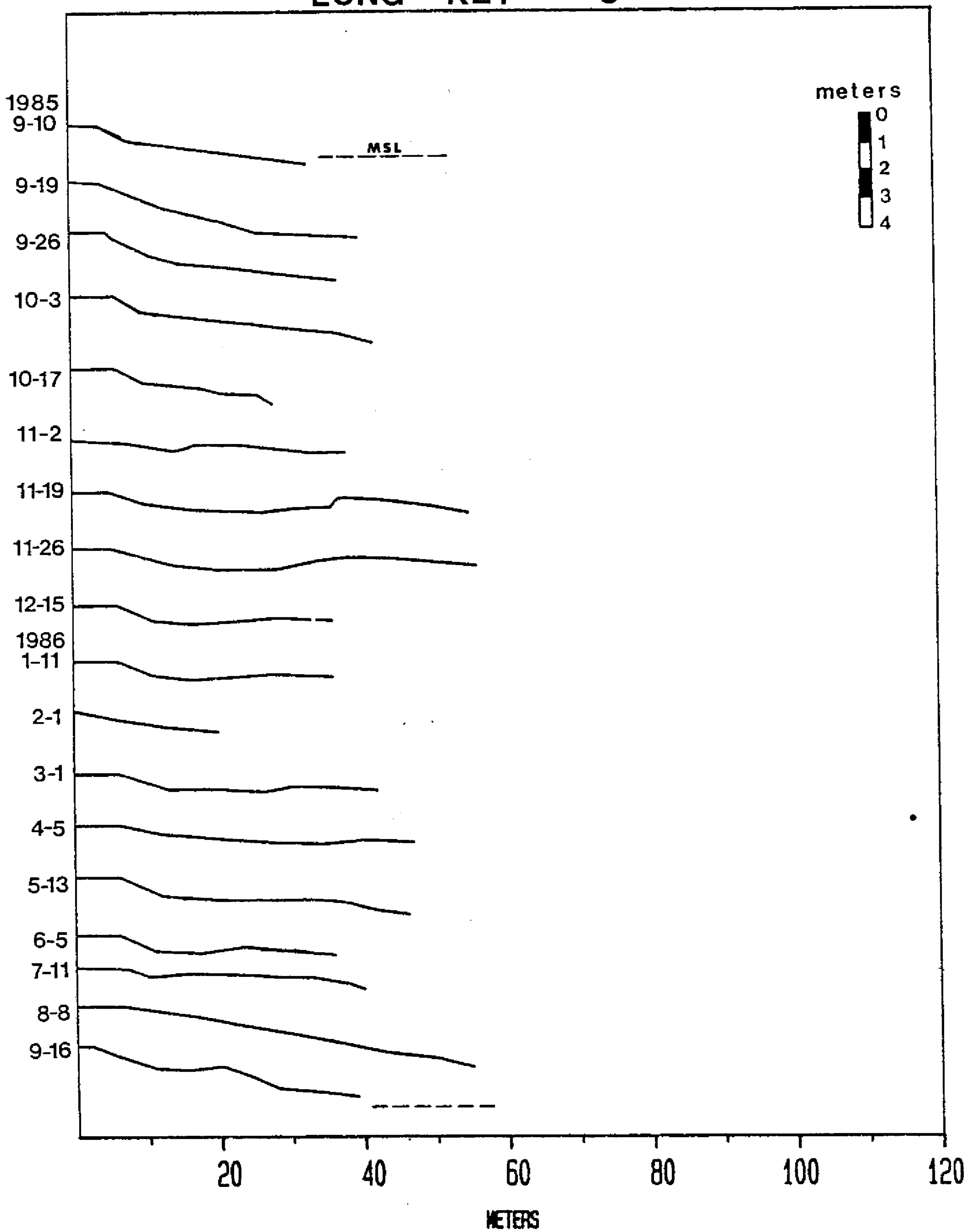




October 3, 1985

September 16, 1986

LONG KEY 3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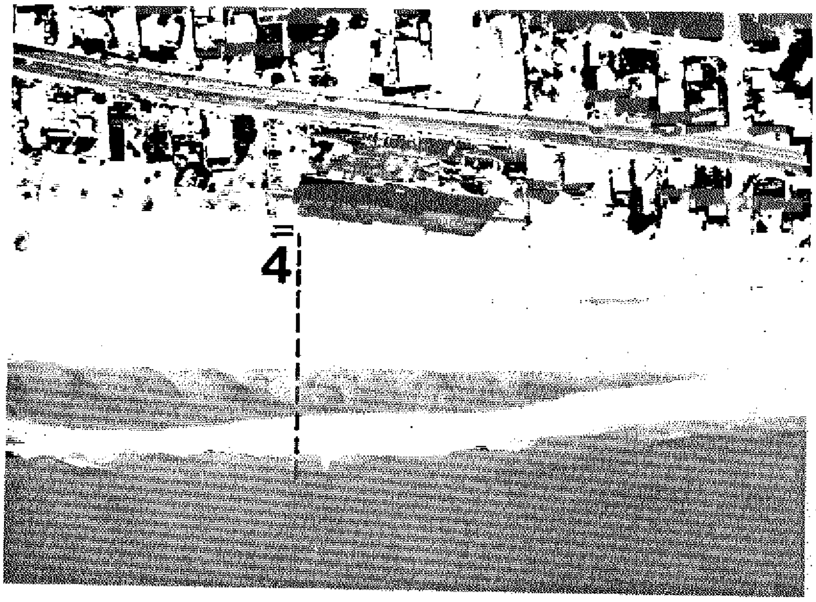
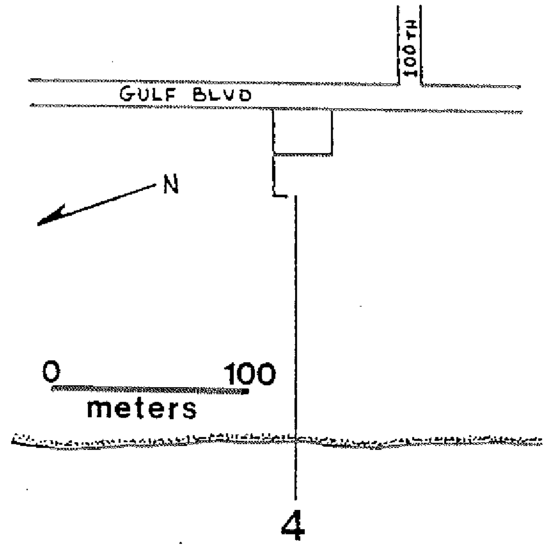
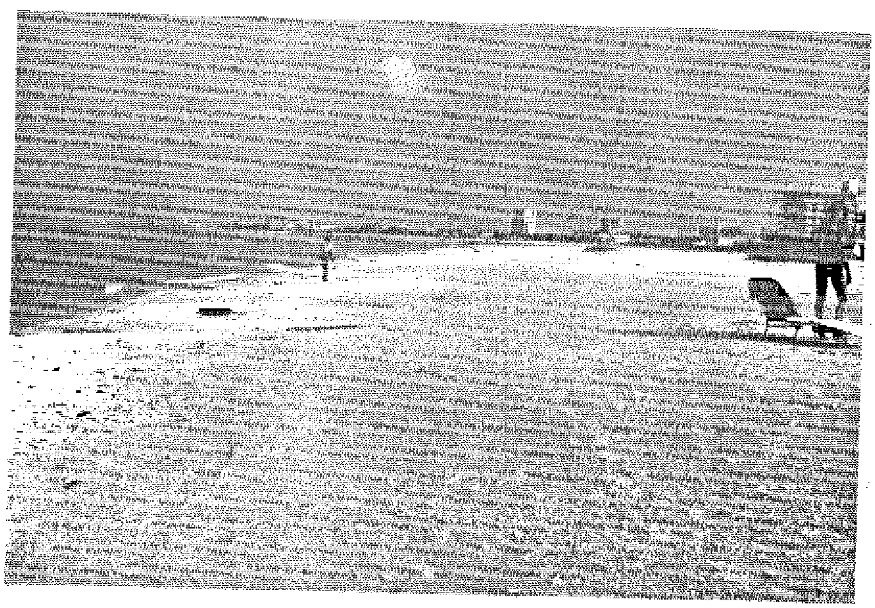
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
20
40
60
80
100
120
METERS







September 12, 1985

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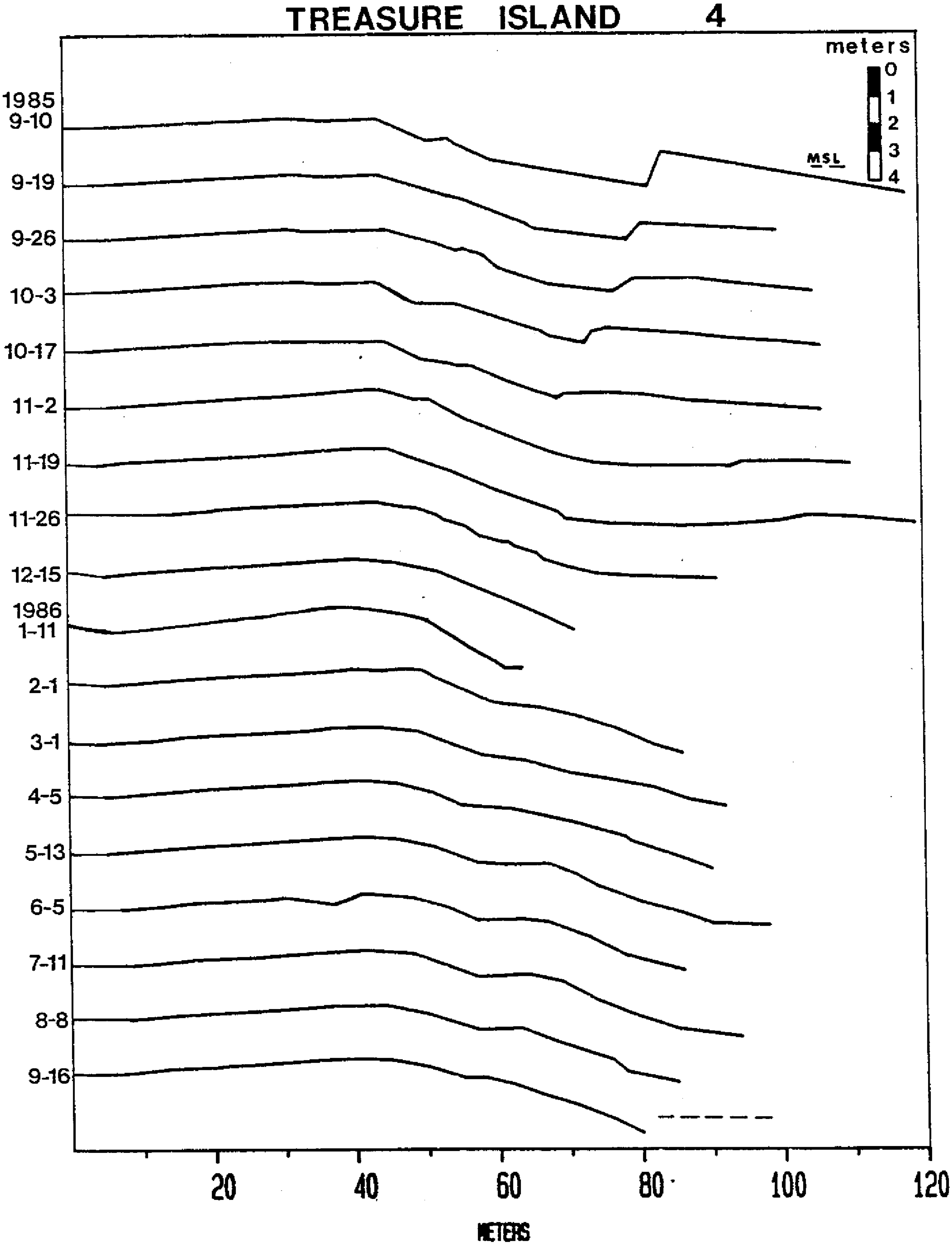
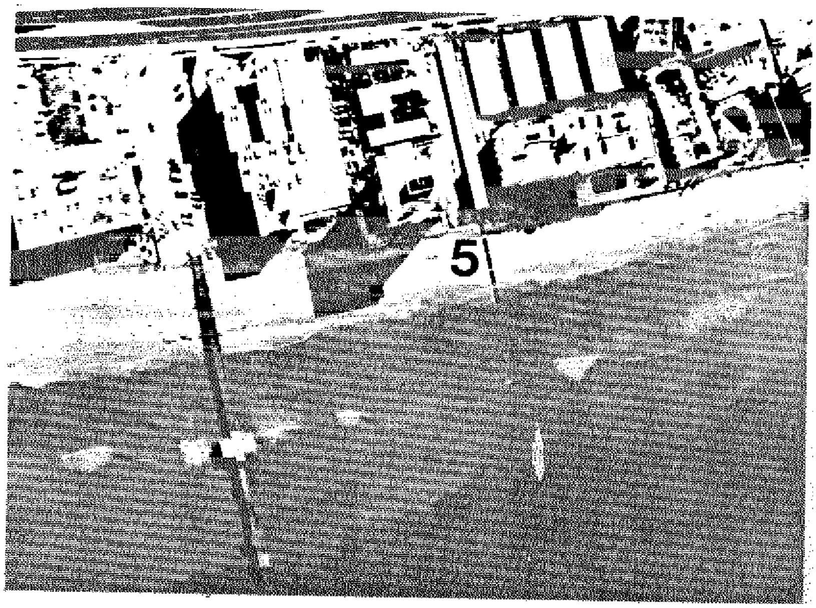
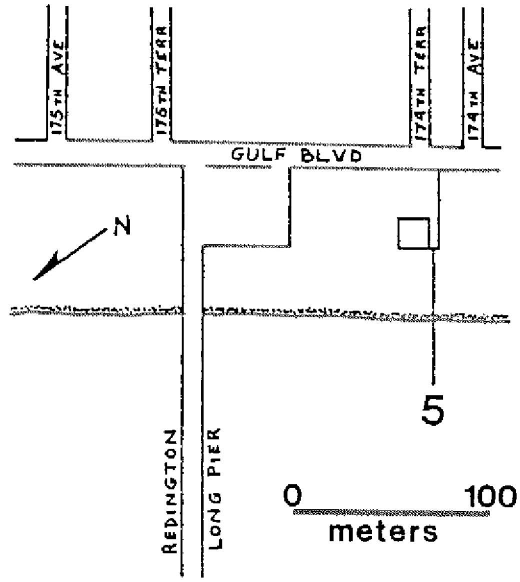
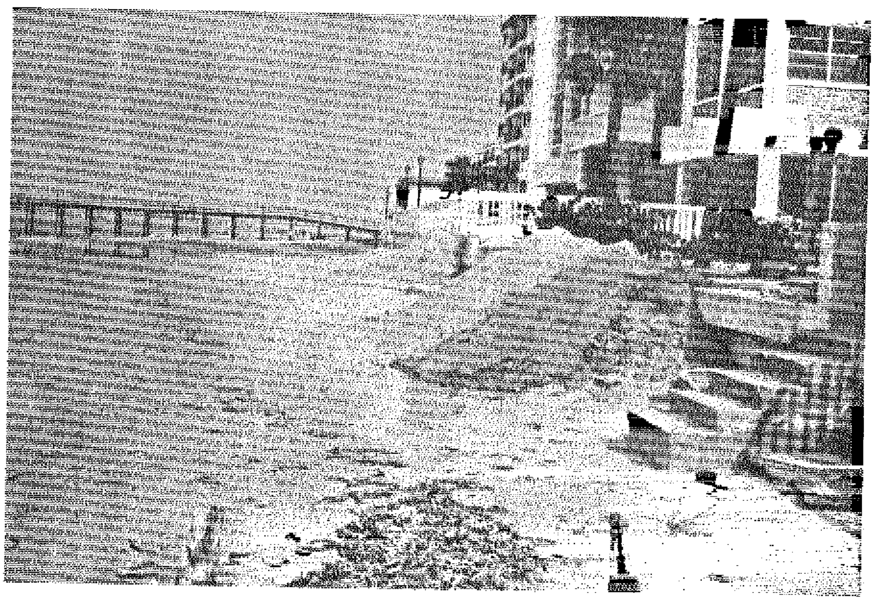
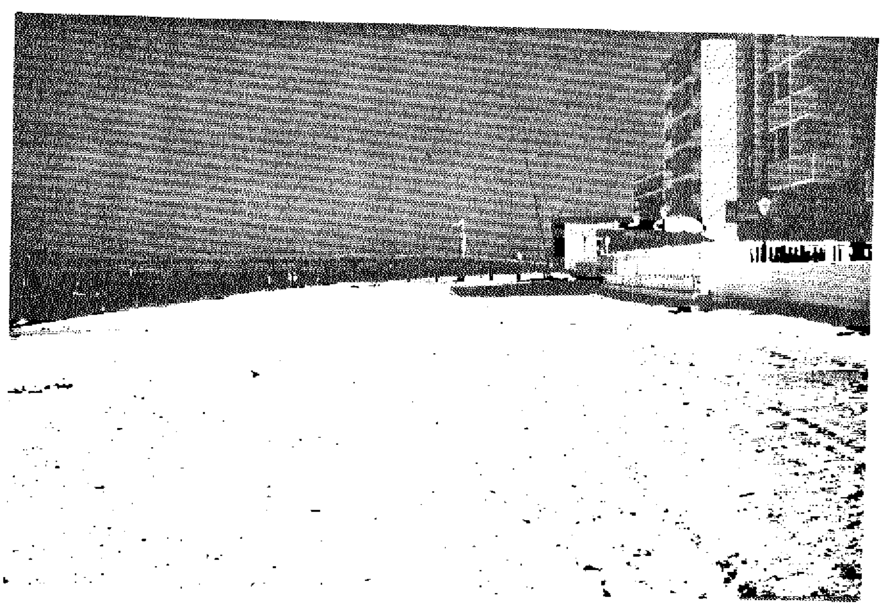

TREASURE ISLAND 4
meters
0
1
2
3
4
MSL
1985
9-10
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
20
40
60
80
100
120
METERS



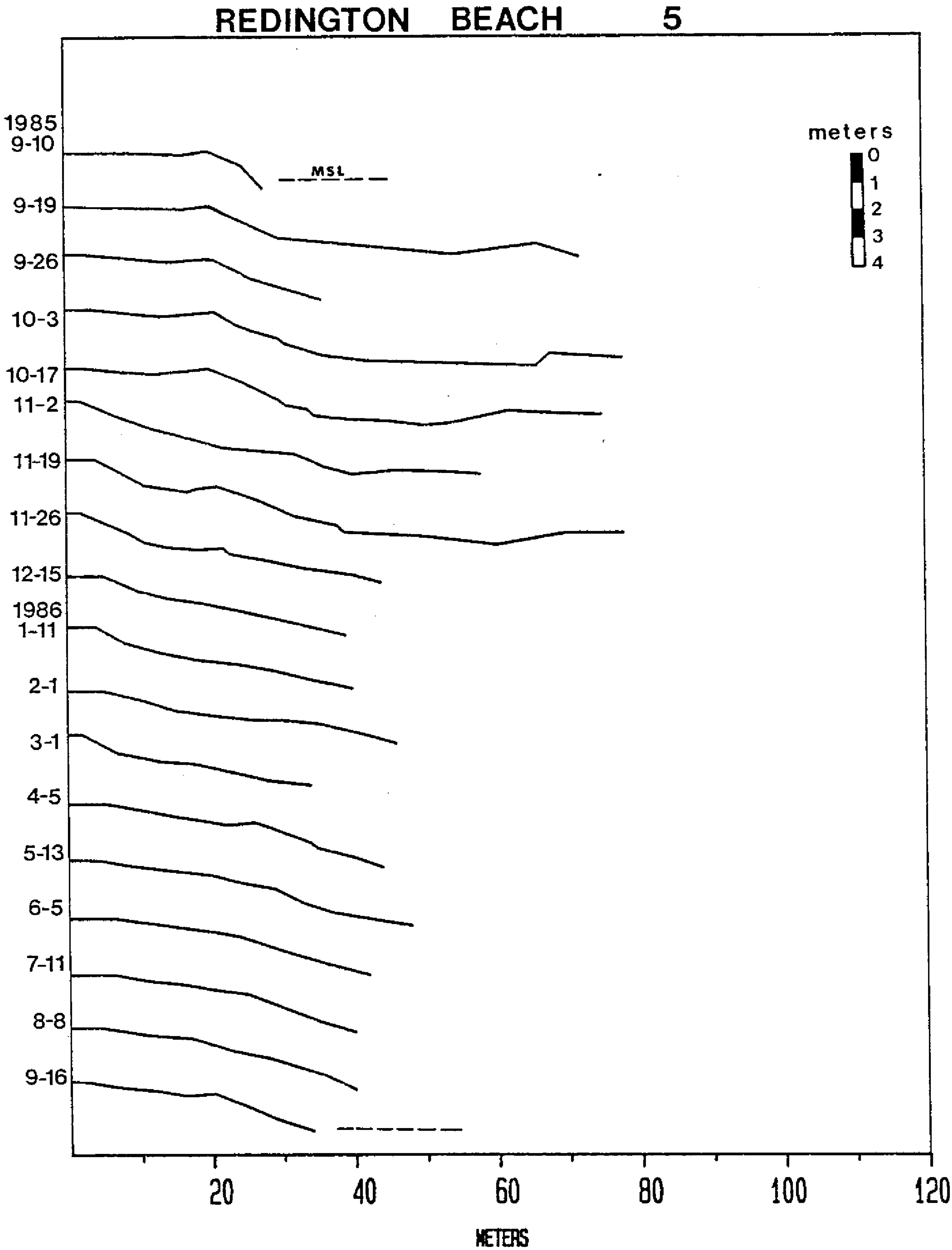


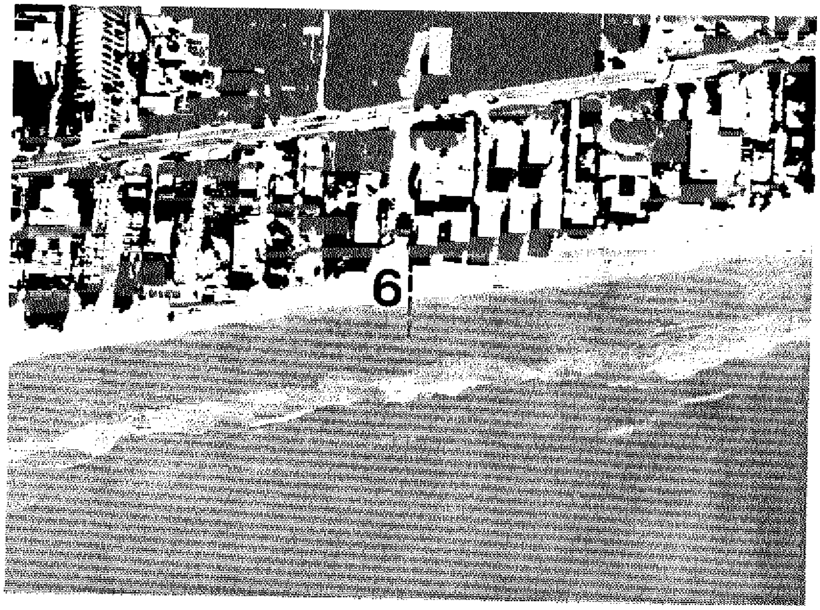


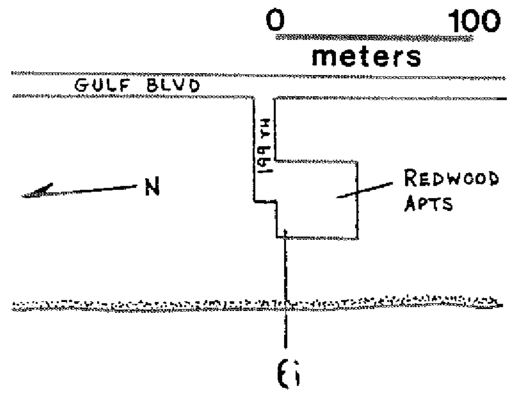
September 12, 1985

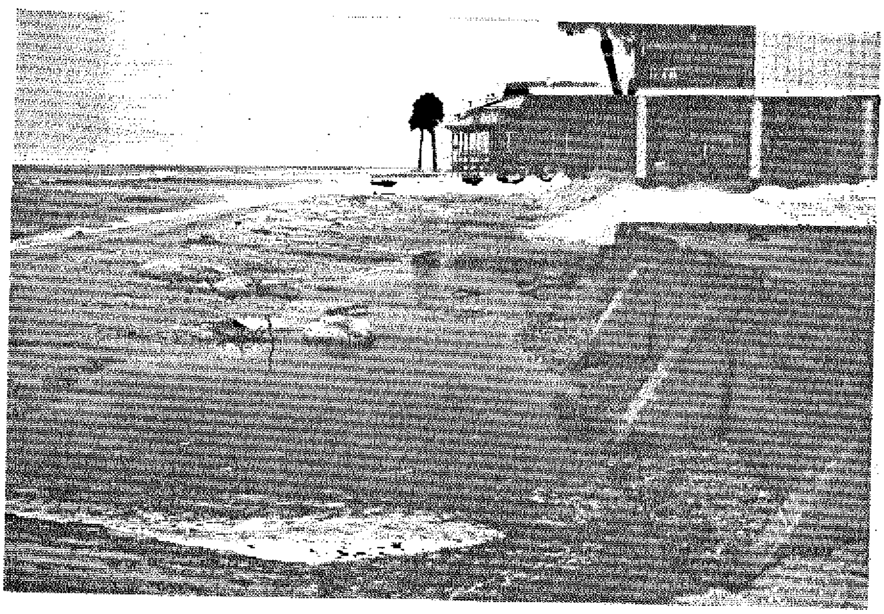


September 16, 1986


REDINGTON BEACH 5
1985
9-10
MSL
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
meters
0
1
2
3
4
20
40
60
80
100
120
METERS

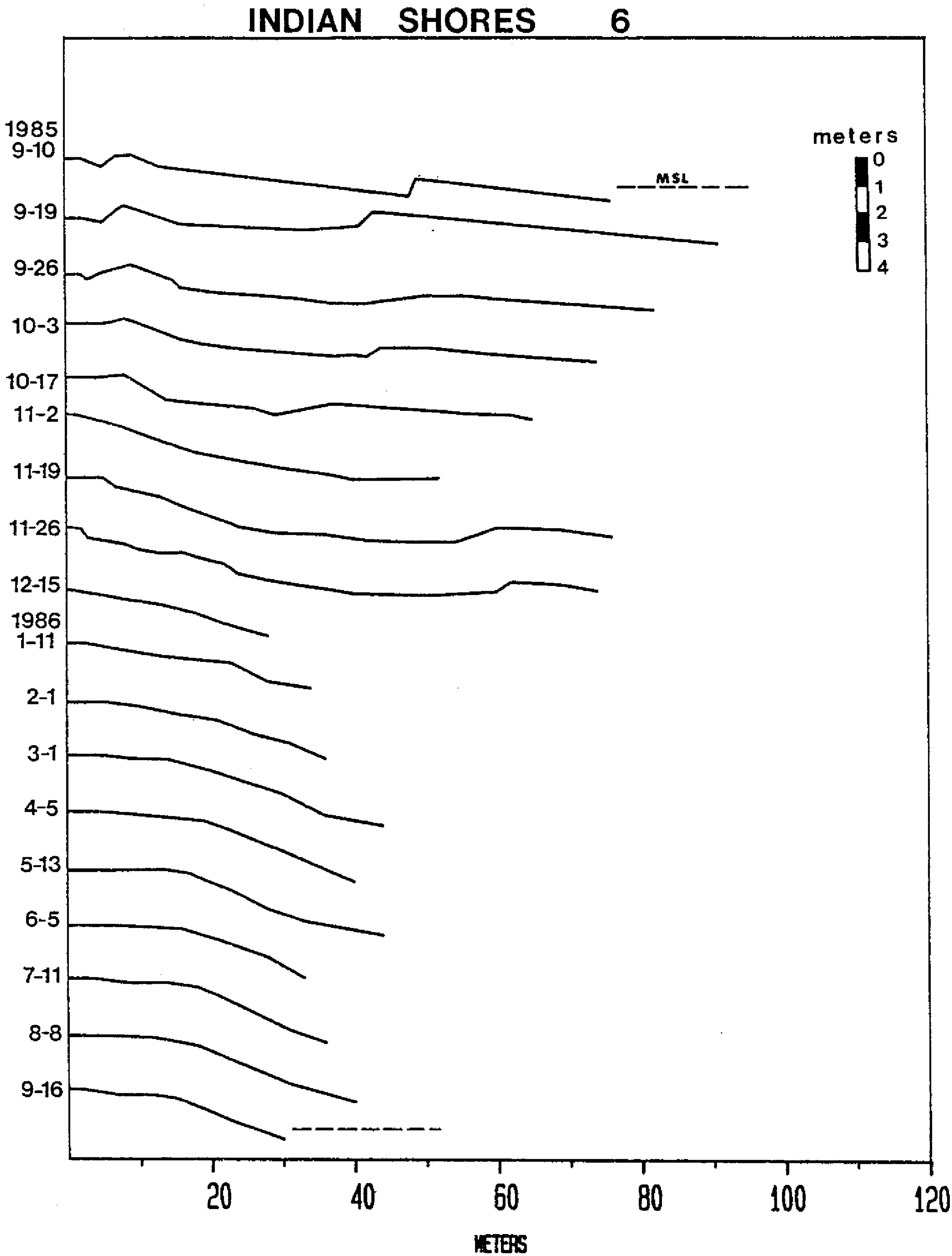






September 26, 1985

July 11, 1986



INDIAN SHORES 6
1985
9-10
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
MSL
meters
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1
2
3
4
20
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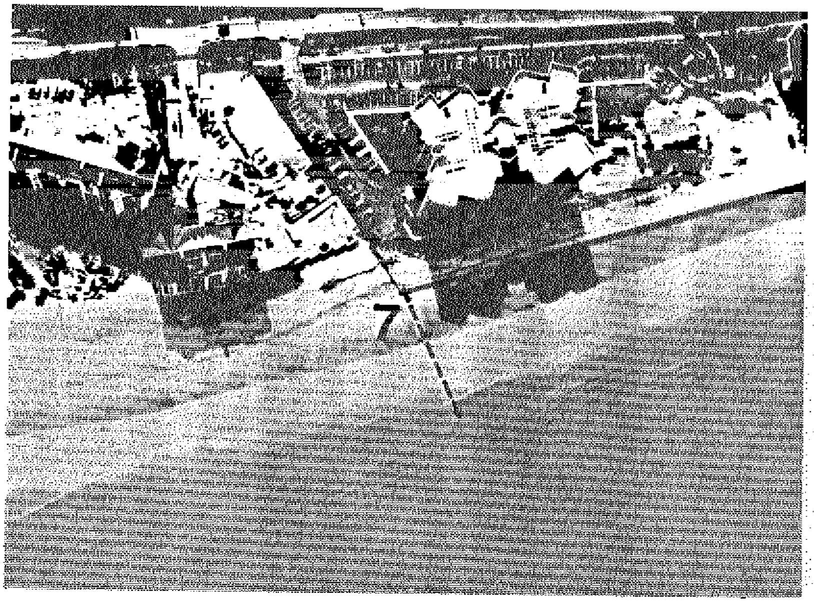
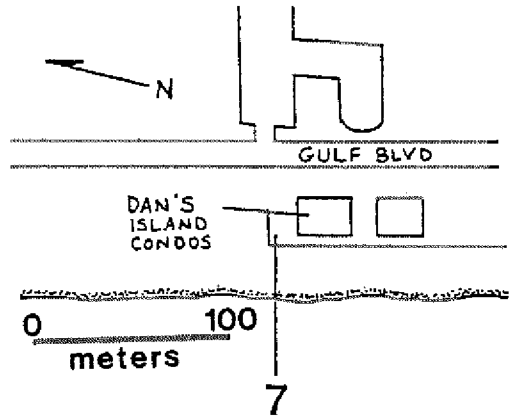
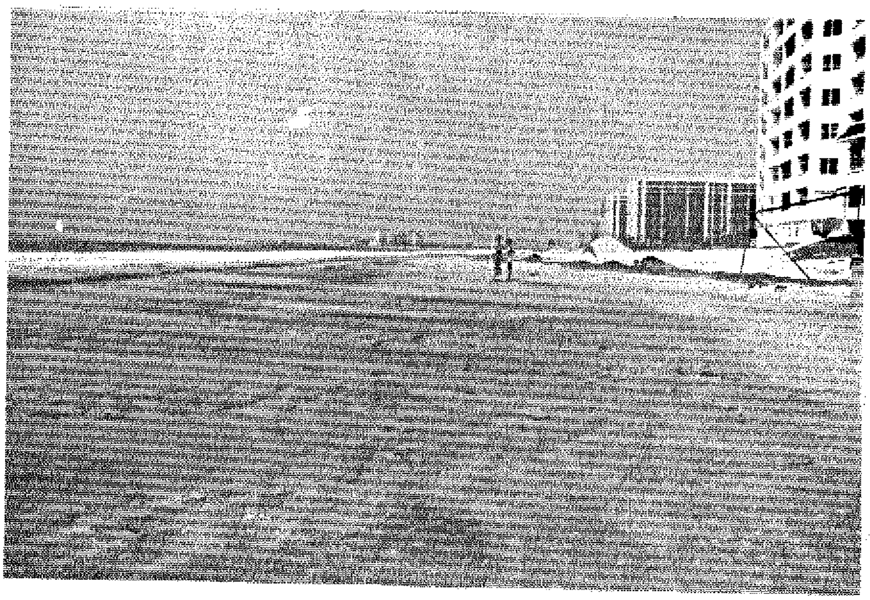
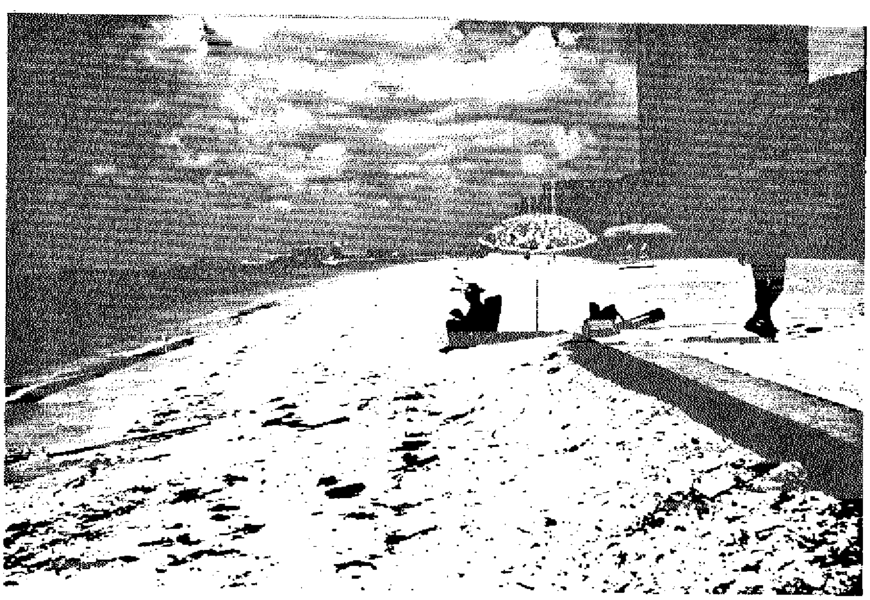
60
80
100
120
METERS



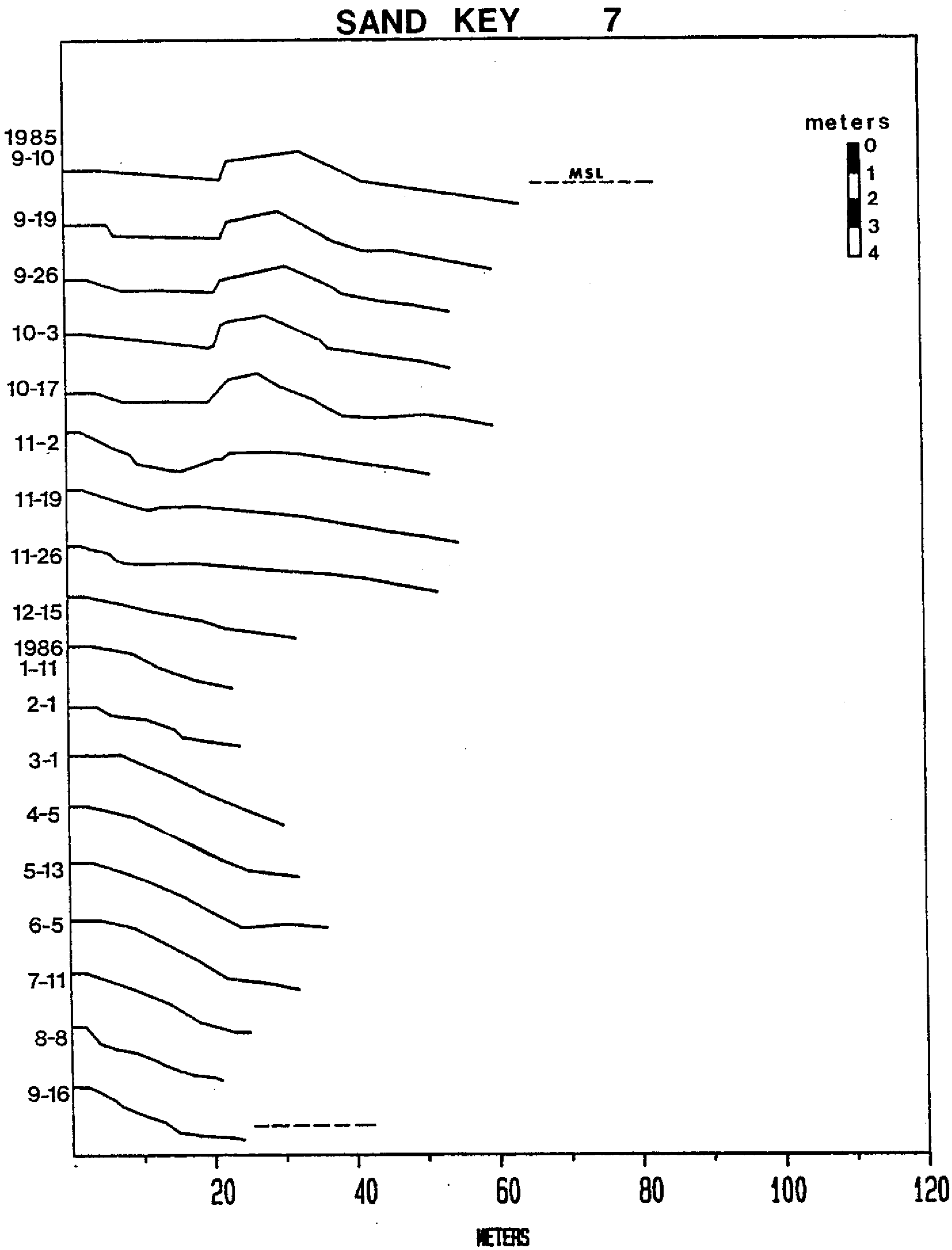


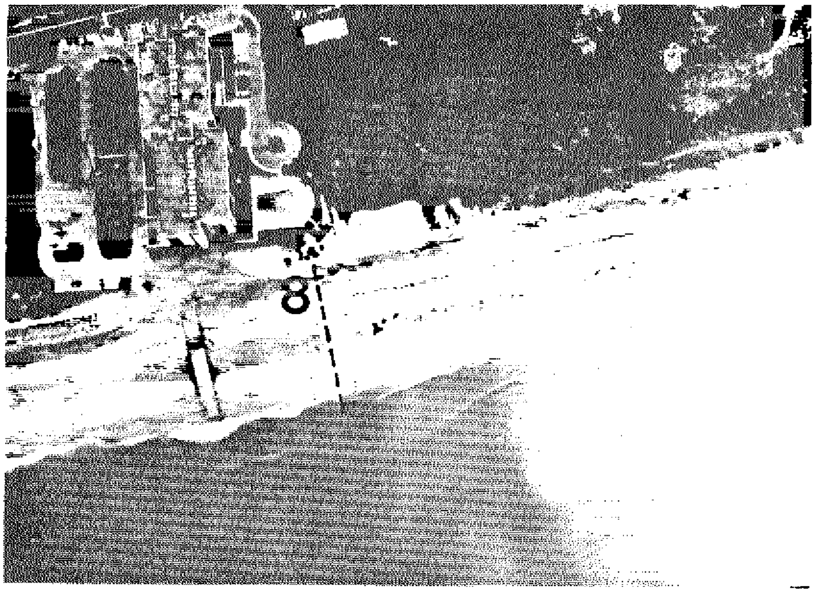


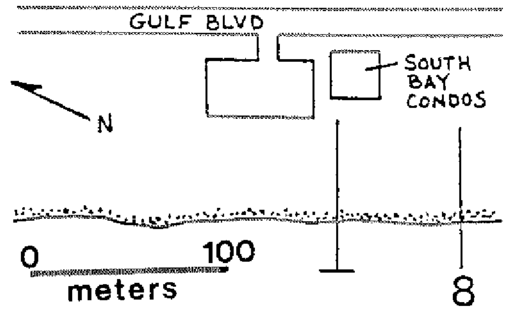
September 10, 1985

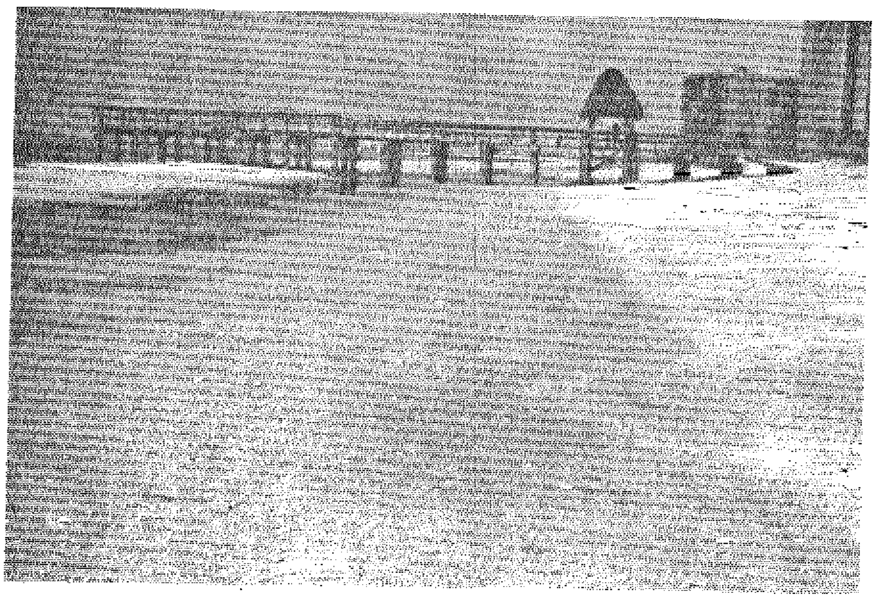


September 16, 1986

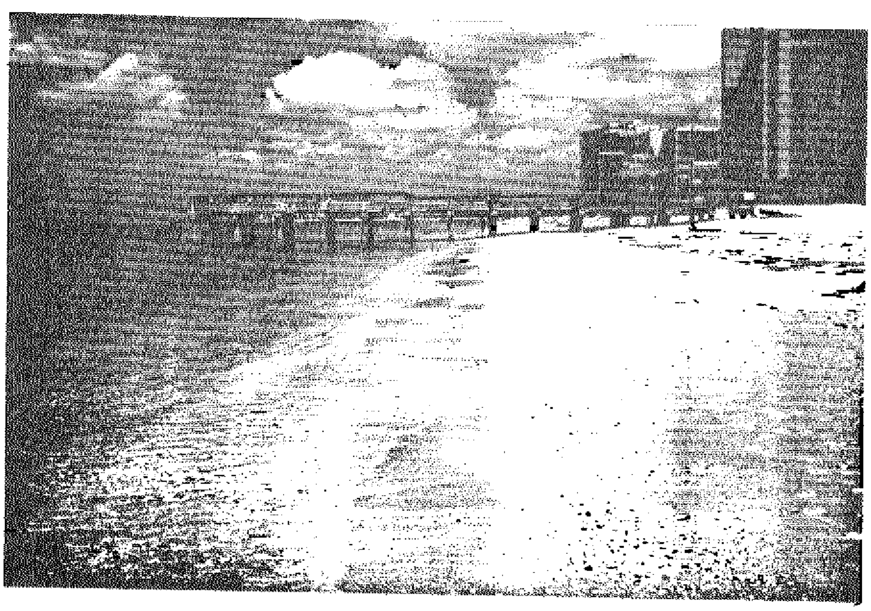

SAND KEY 7
1985
9-10
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
MSL
meters
0
1
2
3
4
20
40
60
80
100
120
METERS



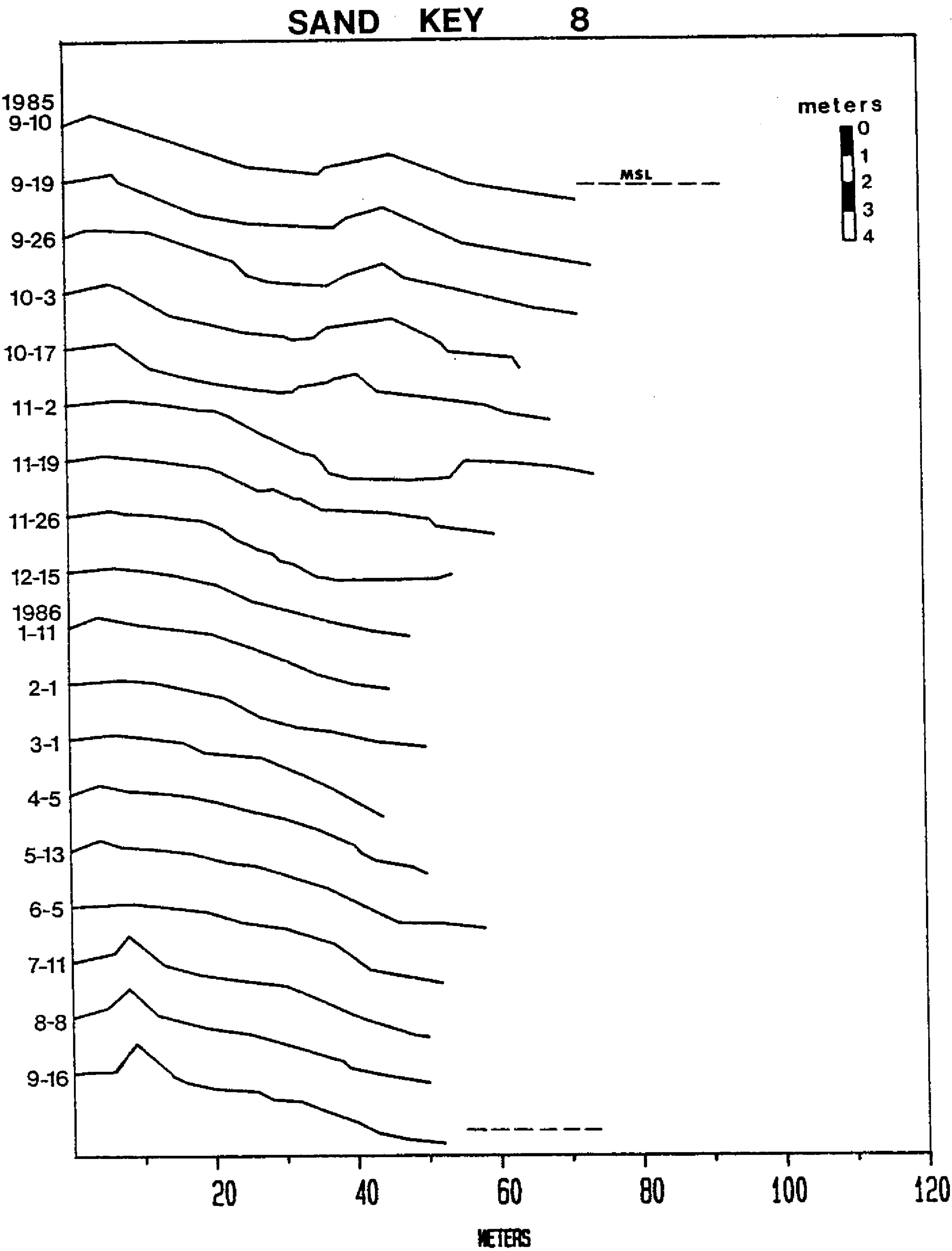


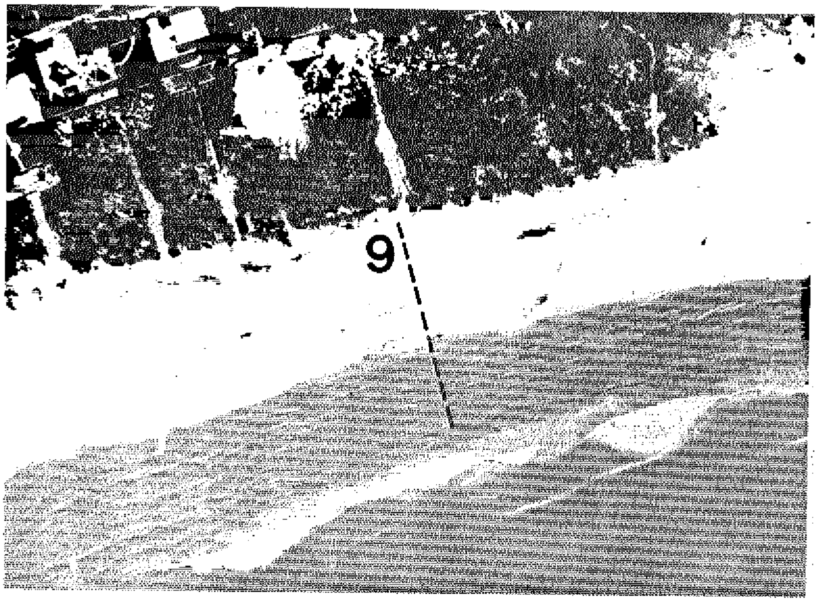


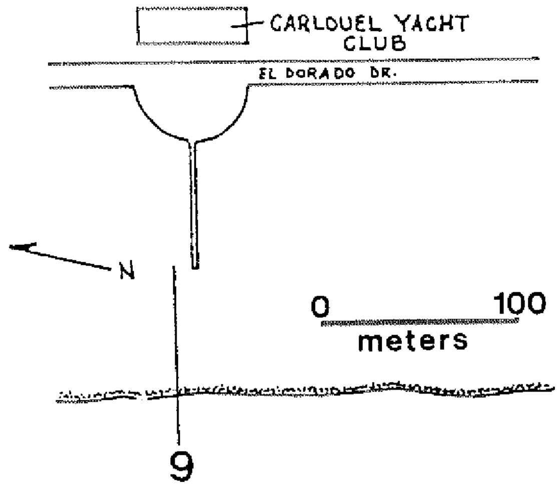
September 10, 1985

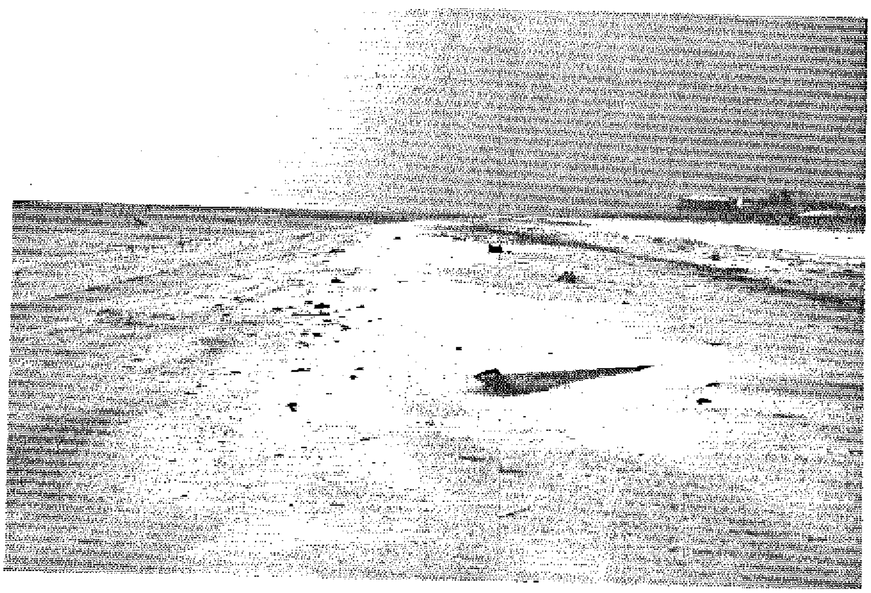


September 16, 1986


SAND KEY 8
meters
0
1
2
3
4
MSL
1985
9-10
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
20
40
60
80
100
120
METERS

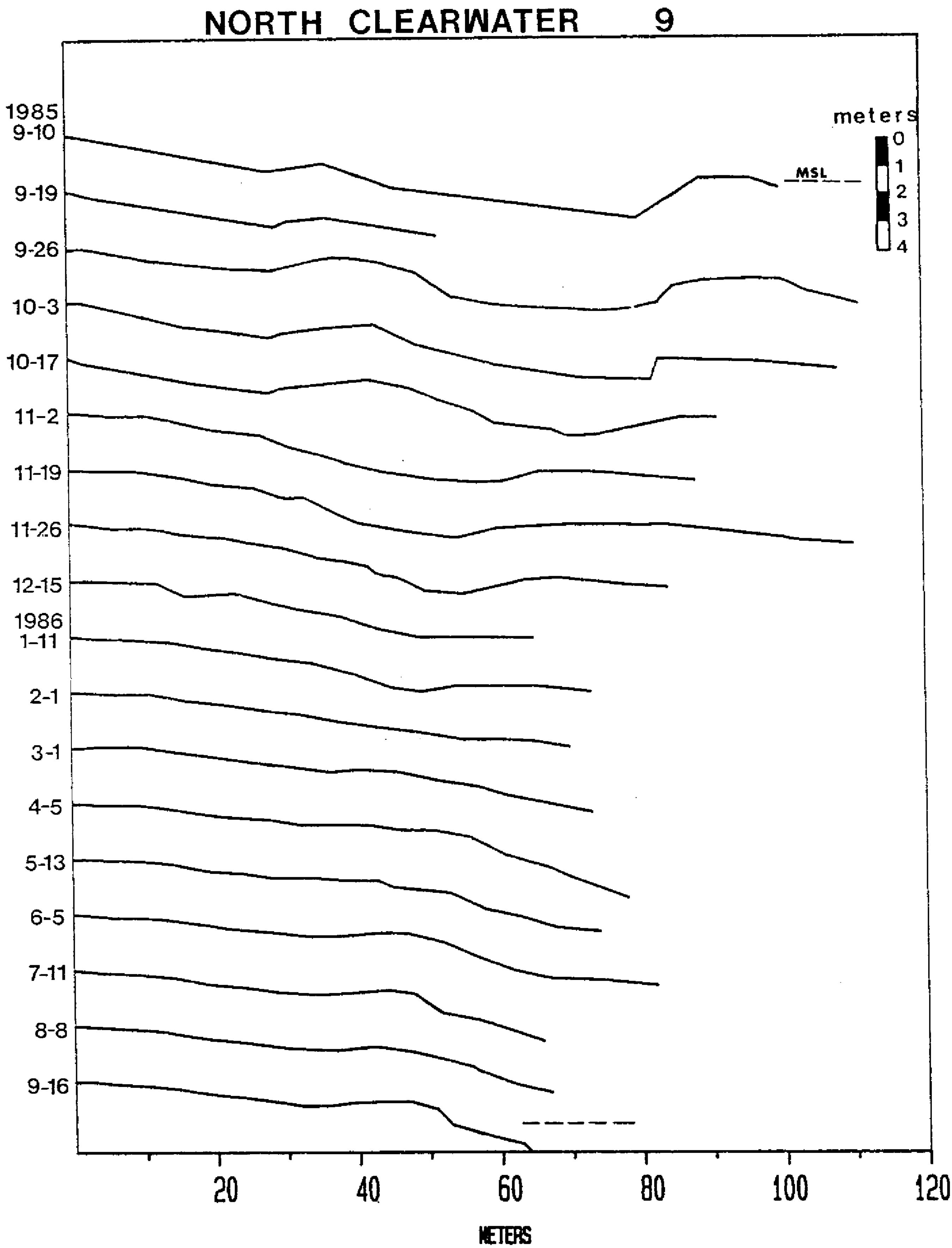






September 10, 1985

August 8, 1986


NORTH CLEARWATER 9
1985
9-10
9-19
9-26
10-3
10-17
11-2
11-19
11-26
12-15
1986
1-11
2-1
3-1
4-5
5-13
6-5
7-11
8-8
9-16
meters
0
1
2
3
4
MSL
20
40
60
80
100
120
METERS