THE NECESSITY OF AN ADEQUATE DUNELINE TO OVERALL BARRIER ISLAND BEACH STABILITY

by

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ABSTRACT

As can be seen from the extremeness of their property values, barrier island beaches are of the rarest and most desired of all recreational lands. Of equal or greater importance is how perfectly these beaches serve as natural buffers between the land and the sea. Vital to the stability of these islands is the existance of adequate dune structures. These dunes serve two important functions. They act as a dike to prevent exceptionally high storm waves from flooding the land, and more importantly, they hold a reserve of sand which allows for bar formation and beach replenishment during times of severe erosion. Man has created two situations that are detrimental to the effectivenes of the dunes. The first problem is the destruction of dune vegetation by pedestrian and vehicular traffic. The second is the critical amount of material that is removed from these dunes to make room for waterfront construction. All coastal states have seashore-management programs, but few single out barrier islands as areas whose preservation deserves special concern. To prevent loss of these islands or the establishment of a Dutch-style of total engineered coastline, it is recommended that something should be done to preserve these vital landforms.

1 INTRODUCTION

Barrier island beaches like on Galveston Island are one of our nation's most valued resources. Not only do these beaches provide much needed locations for people to relax and recreate, they are also optimum forms of defense in the never-ending battle between the land and the sea. In recent decades the extensive development that has taken place on the nation's coast and inland waterways has been detrimental to the beaches. Ironically, even a majority of the engineering projects designed to save the shoreline have caused more damage than repair.

Through an analysis of the barrier island beach environment, this research will determine how necessary adequate duneline structures are to their overall stability. The study will cover dunes from formation processes, through modification and on to the functions they perform in maintaining the shoreline. Also, there will be an attempt to put forth recommendations that might help coastal engineers, developers, and common beachgoers preserve the dunes, beaches, and ultimately barrier islands themselves.

It should be noted that "overall stability", not the erosion or accretion of the barrier island beach, is being studied. Barrier islands by their nature are not stationary landforms, but their migration and configuration changes can be considered part of a dynamic equilibrium state.

2 BARRIER ISLAND BEACHES

2.1 Stable Beach Characteristics

Before discussing ways to increase the stability of barrier island beaches, it is first necessary to define the stable beach. Beaches are "accumulations of rock fragments subject to the movement by ordinary wave action." (BASCOM,1964) They are gnerally considered to extend from the edge of the permanent vegetation line to as far offshore as sand particles are affected by ordinary wave action. Figure 1 is an illustration of a typical barrier island beach divided into its different subparts. The NEARSHORE area is subdivided into the BACKSHORE, the FORESHORE, and the BREAKER ZONE.

The backshore is the zone of the beach between the foreshore and the coastline. It is acted upon by waves only during severe storms. The BERM is the most significant feature in the backshore. It is the nearly horizontal part of the beach formed at the high water line by the deposition of wave transported sediment. In the summer, the berm's low wide configuration offers an excellent place for recreation. During the winter, steep waves cut back and steepen the berm, repositioning the sand in the breaker zone in the form of a bar.

The FORESHORE is that part of the beach between the berm crest and the water's edge at low water. Here, the breaking of waves sends a rush of water up the beach slope, called RUNUP. The berm crest is the upper limit of this wave wash.

As waves approach the beach they steepen and break in the BREAKER ZONE. In this region sand is moved shoreward by the waves in small orbital currents. The return flow is laminar and against the friction of the bottom. These sand grains are moved by some eight to twelve thousand waves a day. Therefore a tenth of an inch displacement per wave would result in a seventy foot movement in one day (BASCOM, 1964). Of course, not all of this movement is normal to the shoreline. Waves generally strike the coast at an angle causing the transport to be directed along the shore. This LITTORAL process is called LONGSHORE TRANSPORT. Figure 2 diagrams the zigzag movement of a sand particles under influence of littoral currents and gravity.

At the most inland part of the beach, vegetation begins to appear. Dried sand blown off the berm is trapped in this vegetation and dune structures develop. The dunes serve two important functions. During severe weather conditions, the sand serves as a dike to hold back the storm waves from flooding inland property. They are also an important reservoir of sand that is used to nourish the beach face after the waves become calmer. The processes by which dunes are developed and destroyed as well as their functions will be discussed in much greater detail later in this paper.

It is important to emphasize that a stable beach is not a static piece of real estate, but one that is in a state of dynamic equilibrium. The higher energy of steep winter waves cut away at the beach slope creating a sharper beach profile with narrow, high berms. The sand taken form the beach face is not lost from the system, but is transported offshore and deposited as bar formations in an attempt to better combat the sea. Then summer comes, bringing smoother, lower energy waves that slowly transport the sand back to the beach. A wide berm is formed (just in time for summer's sunbathers and picnickers) and the underwater profile usually becomes smooth and barless.

The beach may be thought of as "a small closed system in which sand moves either on and offshore at the whim of the waves, or alongshore in accordance with currents." (BASCOM, 1964) There exists a certain budget of littoral sediments (KOMAR, 1976). Some processes remove sand from the shoreline, while others replace it. A stable beach is one where over the long run the loss and gain terms basically balance out.

2.2 Beach Functions

Beaches have two very important functions. First, and most important in the layperson's mind is its unique features which make it a optimum place to live or play (SENSABAUGH, 1975). Anyone who lives near the coast, or has been there on a holiday, can quickly name several obvious recreational uses of the beach: swimming, surfing, sunbathing, beachcombing, walking, jogging, fishing, or picnicking (KOMAR, 1976). Presently about two-thirds of the world's population lives with a narrow belt directly landward from the seashore (BROWER,1978). The crowded public beaches and the abundance of seaside condominiums, trailer parks, motels and gas stations, all which tend to destroy the aesthetic beauty that originally drew the people, are several examples of this population pressure (SENSABAUGH,1975). But the beach and the dunes are much more than a place for recreation, they form the first line of defense against the endless attack of the sea. In fact, upon the well-being of the beach rest the very existence of the barrier island (KAUFMAN and PILKEY,1979). Waves exert a continuous barrage of high energy and great force on the coast. As the ultimate form of defense that nature has developed, the beach dissipates wave energy as no manmade structure can. If the shoreline were vertically sloped, the energy in the waves would be reflected creating partial standing waves that would be of sufficient strength to remove the large boulders from the seafloor. Thus the sediment would be quickly eroded away in a fatal blow to the barrier island. With a gently sloping beach the wave energy is expended over a long distance, from hundreds of feet offshore to the berm crest. As the wave moves up the foreshore, its speed is greatly reduced as the beaches permeable surface absorbs the uprush and the sand's gritty texture exerts an opposing frictional force.

The beach is also constructed so that it can change forms in an effort to best counteract the immediate wave conditions. Figure 3 shows three of the types of waves that approach beaches, SPILLING, SURGING, and PLUNGING BREAKERS, and the beaches upon which they are found. For the spilling breakers the beach will be found to be nearly horizontal, whereas steep beaches are characteristic of plunging breakers, and surging breakers occur at very steep beaches. Offshore bars are created and destroyed, and berms steepened and leveled off all to create the optimum defense from the current sea conditions.

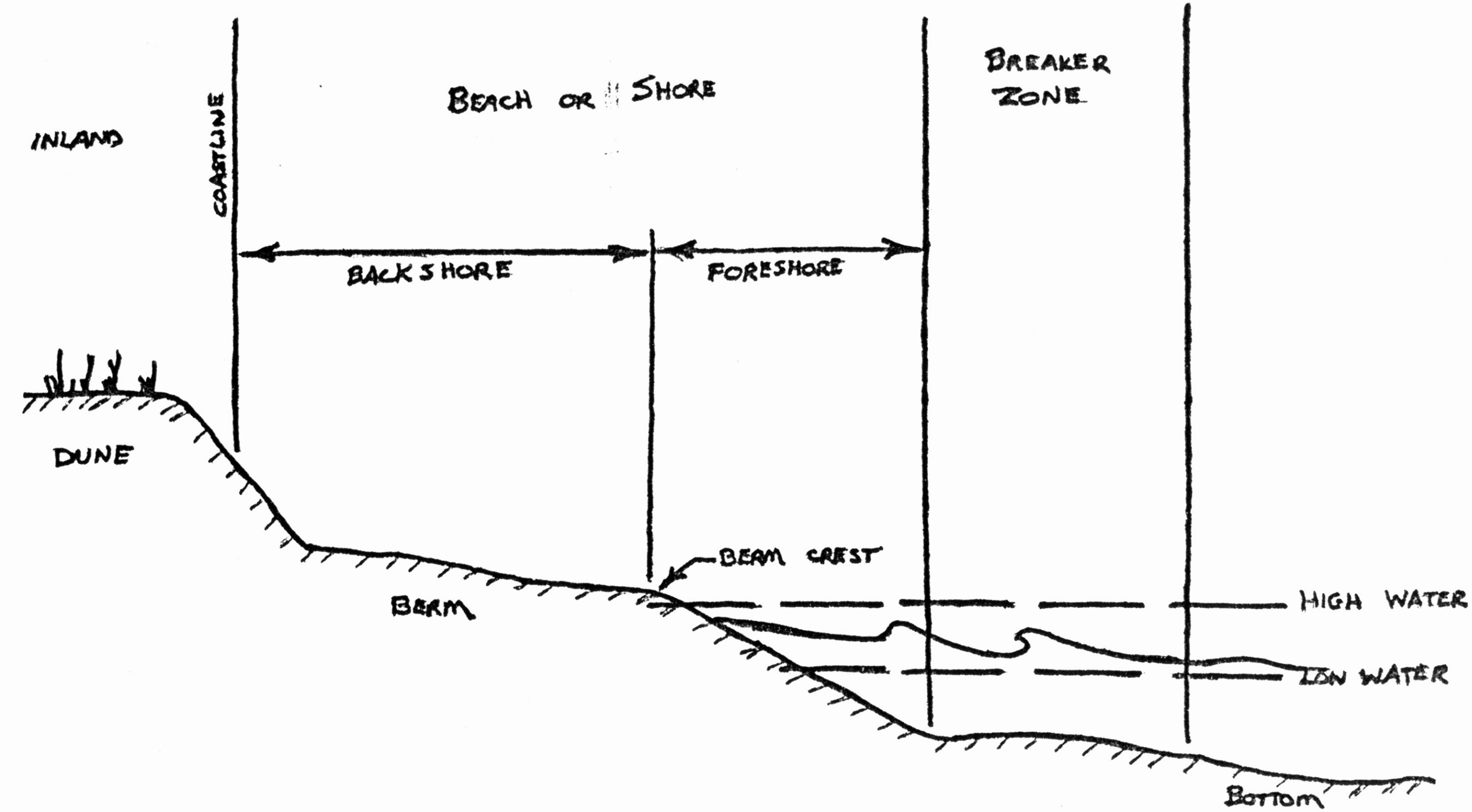


FIGURE No. 1 TYPICAL BEACH PROFILE

1. SAND RESERVES STORED IN DUNE
2. SWELLS BREAK AND RUN-UP FORESHORE

FIGURE No. 2

SEDIMENT MOTION ALONG A STEEP BEACH FACE

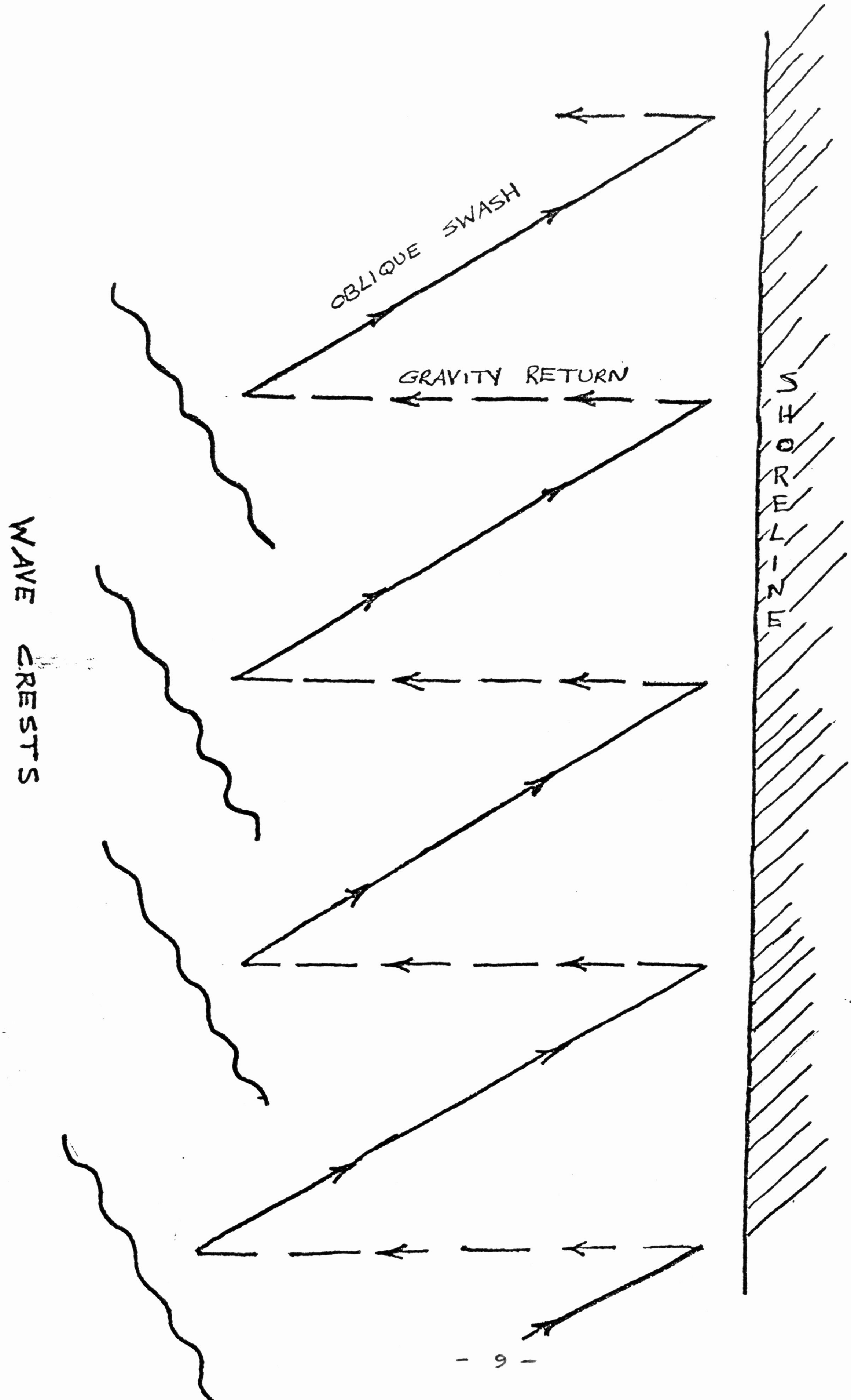
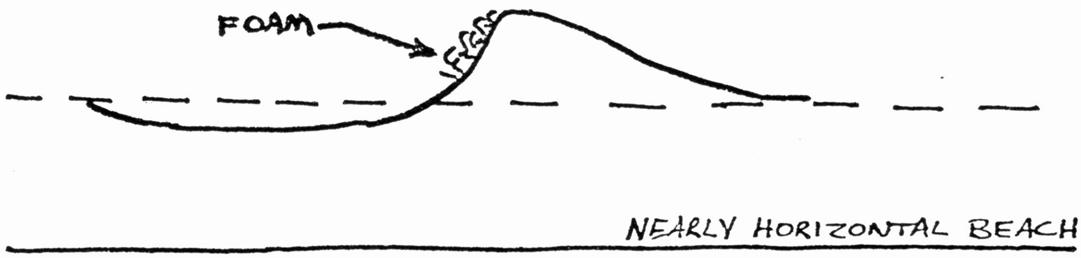
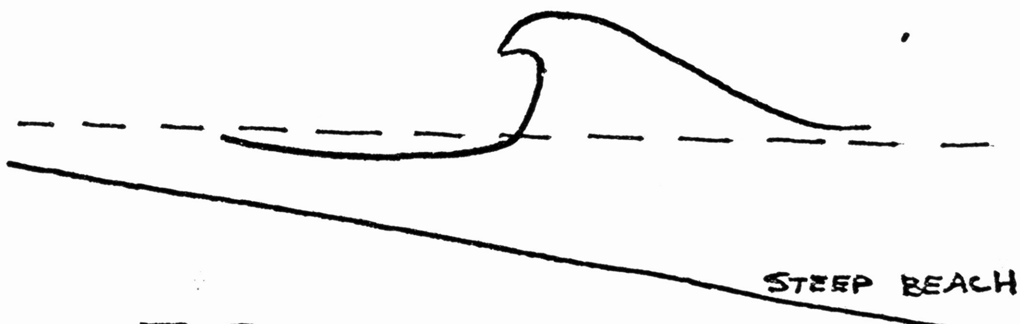


FIGURE No. 3

THREE TYPES OF BREAKING WAVES

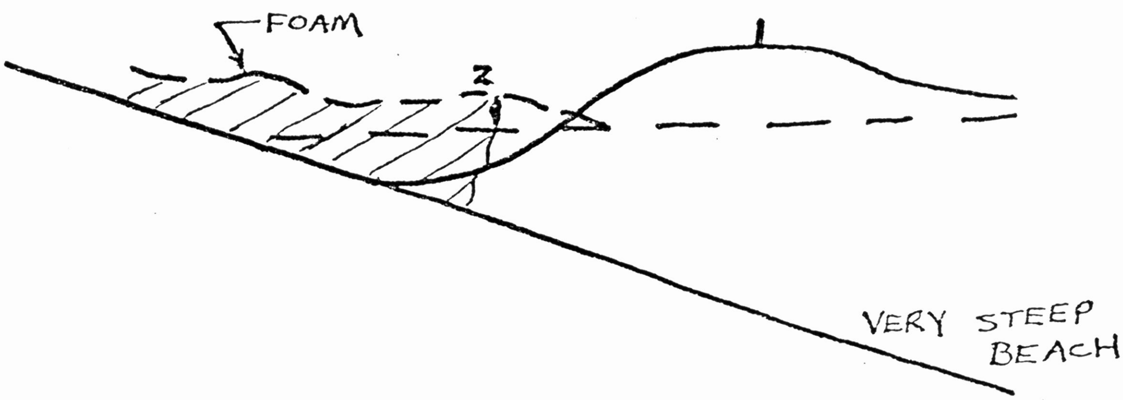


I. SPILLING BREAKERS



II. PLUNGING BREAKERS

III. SURGING BREAKERS



3 ADEQUATE DUNE STRUCTURES

3.1 Formation Processes

Between periods of high water, the sand of the berm is dried by the sun. Steady offshore winds blow this dried sand loose from the beach face, and transport it to the back of the beach where if vegetation is present it will collect around plant clumps creating mounds of sand called COPPICE DUNES. In addition, wind shadow dunes sometimes develop in areas protected from the wind (behind logs or debris). Composed of fine dry sand the coppice dunes normally remain small (less than 3 feet), but under the right conditions they may continue to develop and become part of the fore-island dune ridge (WEISE and WHITE,1980).

The FORE-ISLAND DUNE RIDGE is a row of high grass-covered dunes immediately landward of the back of the beach and parallel to the shoreline. Although generally consisting of fine, very well-sorted sand, fairly coarse pieces of shell are sometimes carried onto the foredunes by strong onshore winds. The bulk of material in the dunes were transported by suspension, saltation, and creep.

SUSPENSION is the process where small or light grains are transported large distances suspended in the air flow. SALTATION occurs when the force of the wind is not strong enough to retain the sand particles in suspension, and the travel path of the particles is a series of hops and bounds. CREEP is where the sand are rolled along the beach surface by wind forces or the impact of saltating grains.

In the initial stages of dune development, when most of the blown sand is being lost from the beach environment, the wind flow becomes disturbed as it passes over obstacles in its path causing the deposition of the sand. Eventually, many grains come to rest inside the relatively stagnant shadow zone, accumulating into a growing mound with slopes that reflect the angle of repose of the sediments. This area, generally in the supratidal zone, is colonized by plants as it develops into a dune structure (GOLDSMITH,1978).

Two plant types associated with dunes of the Texas Gulf Coast, panic beach grass and sea oats, each perform functions vital to the survival of the barrier island dunes. Sea oats are tall with foliage that disturbs air flow causing sand deposition. They have short roots that tend to stabilize the surface layers of the dune. Panic beach grass has short foliage that retards surface air flow,. Its long roots have a important binding effect on the interior structure of the dune. It can be seen that this vegetation has an immense effect on the stabilization of the whole dune structure.

3.2 Damaging Modifications

Frequently the duneline structures of a barrier island are destroyed or critically damaged by factors other than high energy storm waves. The two most common ways are both the doings of humans. One is the devegetation caused by beachgoers crossing to get to the water, and the other is the removal of sand by developers to level the land for construction.

The damage to duneline vegetation caused by the extensive transversing of humans, animals, and machinery is probably the most common reason for dune failure. Even though the plants that stabilize the dunes are highly tolerant of the harsh coastal environment, they can not survive even moderate amounts of traffic. A footpath quickly develops across a dune after only a few times of being walked or driven on. And without the bonding effects of the roots and the wind retardation effects of the foliage, the sand on the footpaths will be quickly blown from the dune face in a process called DEFLATION. Even just one or two footpaths on a dune structure can greatly reduce the storm wave resistance ability. These weakened points give out quickly allowing for the flooding of the inner part of the island. Victor Goldsmith wrote that, "The most important contribution that humans can make toward the preservation of barrier islands is to prevent damage to dune vegetation." Dunes are far more stable than piles of sand. Dunes that become devegetated, like sand piles, will be quickly eroded by constant onshore winds. This sand will be carried further inland

and eventually deposited in the marshes and shallow low-energy bays that often exist on the landward side of barrier islands. The permanent loss of this material from the nearshore region, if not corrected, will eventually cause the barrier island beach to become unstable.

Dunes are also damaged and destroyed by the heavy equipment of beach property developers. In an effort to level the land to build hotels, condominiums, and parking lots, construction crews bulldoze large sections of dunes. What nature has taken decades to maticuously build, a man and a bulldozer can tear down in just a few short hours. While visiting West Florida in March 1984, I was appalled to see that the extensive dune structures on Panama City Beach had all but been destroyed to make room for hotels and condominiums. One of the few large expanses of dunes left had a large billboard placed on it. The sign had a depiction of an elaborate resort and stated, "Coming Soon the Dunes of Panama." The dunes were already there and thriving, but it looked as though they would soon be removed to make room for the resort.

3.3 Functions of an Adequate Duneline

Dunes represent an accumulation or capital asset of sand from which the beach makes deposits and withdrawals depending on weather conditions. The existence of the dunes helps to preserve the amount of sand in the nearshore area. During the winter months, large storm fronts tend to produce steep high-energy waves. The foreshore is steepened and the berm crest is pushed back as sand is taken from the beach face and used to build a bar in the breaker zone. During periods of higher water levels, sand is taken from the dunes and is used to nourish the depleted beach. Lower energy waves of the summer return this material of the bar to the beach, and the sand after reaching the berm is dried by the hot sun and carried by the wind to replenish the duneline.

If the duneline did not exist the steady onshore winds would transport the dried sand of the beach face further inland. This permanent deflation of the beach, as mentioned previously, could cause the beach to become critically unstable. Also, this removal of sand from the littoral processes would also be detrimental to the beaches further downcoast.

Most visable of the dunes functions is the protection they provide against the destruction of large storm waves and tides that would otherwise flood the lower area inland of the beach. The high energy of these storm waves that could potentially cause excessive damage to inland property and structures, is reduced as the large dunes are eroded. As shown in figure 4, the sand taken from the dune structure is used to develop a bar formation at the edge of the breaker zone. This bar grows to a size where it can steepen and break the incoming storm waves. "Once this wave dissipation develops fully, erosion of the beach ceases, since only the broken and turbulent surge proceeds shorewards." (SILVESTER,1974) Once the storm conditions pass, the sand that was stockpiled in the dunes is moved ashore to nourish the eroded beach as shown in figure 5. Only this provision of sufficient sedimentary material in the dunes for the bar formation can assure the ultimate stability of the barrier island beach.

Figure 6 shows two of the common natural dune types found on barrier islands of the Texas Gulf Coast. A deflation flat exists on the windward side of both the barchan and transverse dunes, moving into a gently sloping front face. At the brink or highest point of the dune, the ridge slopes steeply downward to the leeward side.

Figure 7 diagrams the disturbed air flow around an obstruction similar to a sand fence plank. Dunes formed in this way usually have a profile reversed of those occurring naturally.

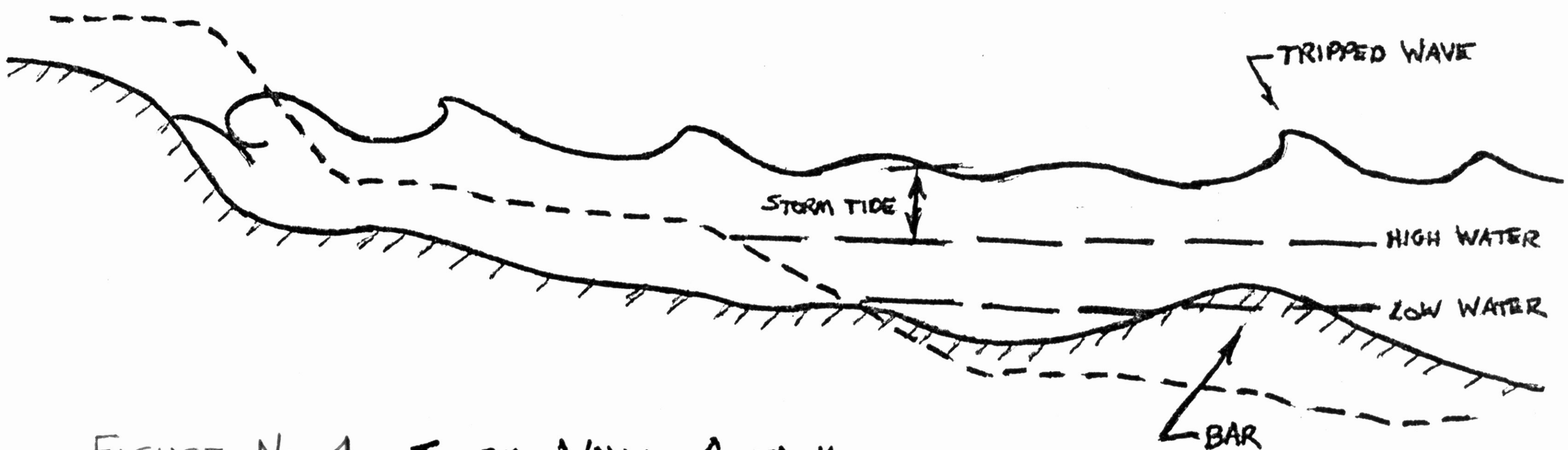


FIGURE No. 4 STORM WAVE ATTACK

1. DUNE AND BERM SAND DEPOSITS ERRODED
2. OFFSHORE BAR FORMS
3. BAR TRIPS WAVES PREMATURELY

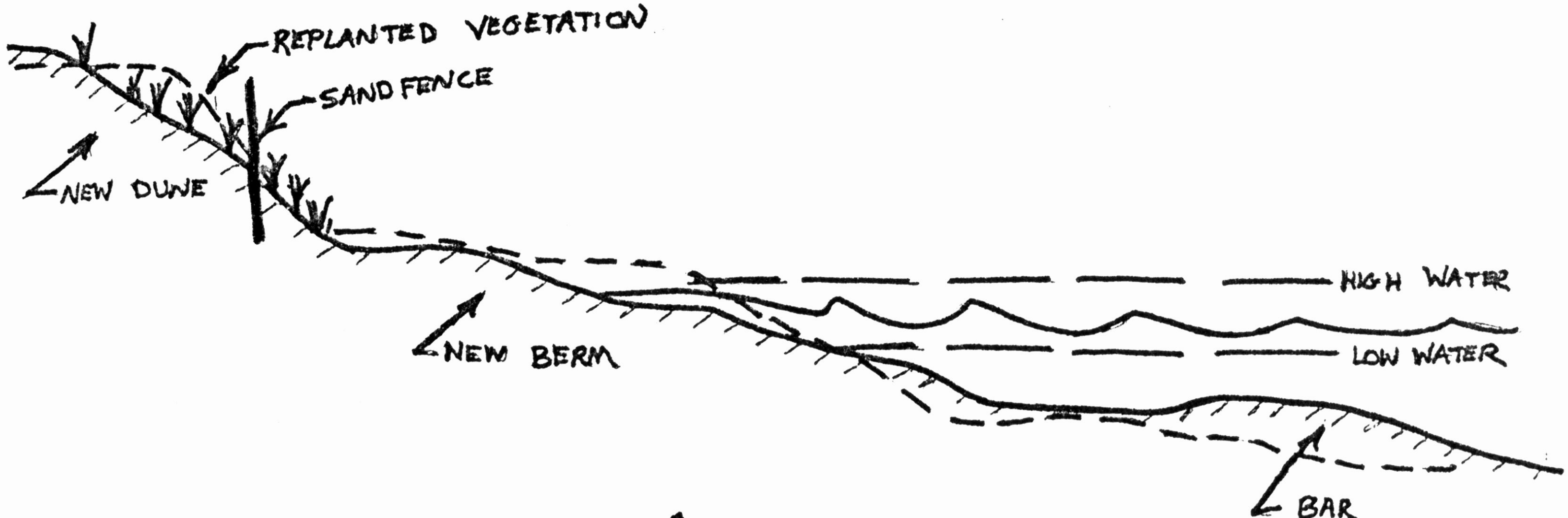


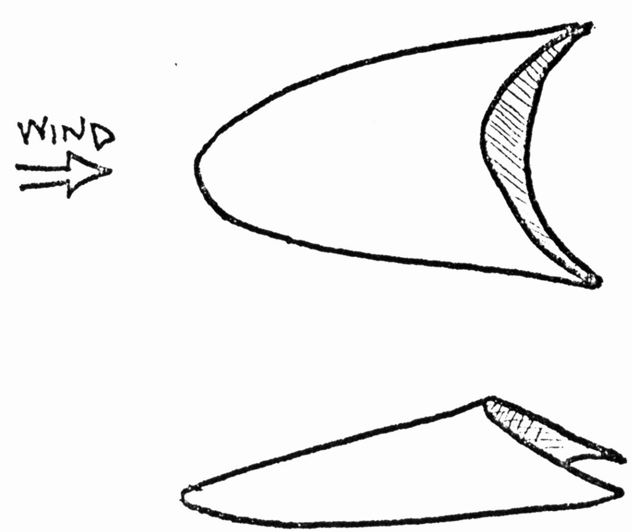
FIGURE No. 5 AFTER STORM ATTACK

1. NORMAL WAVE ACTION BUILDS NEW BERM
2. BAR SAND DEPOSIT MOVED INLAND BY CALMER WAVES
3. REPLANTED VEGETATION AND SAND FENCE REBUILD DUNE

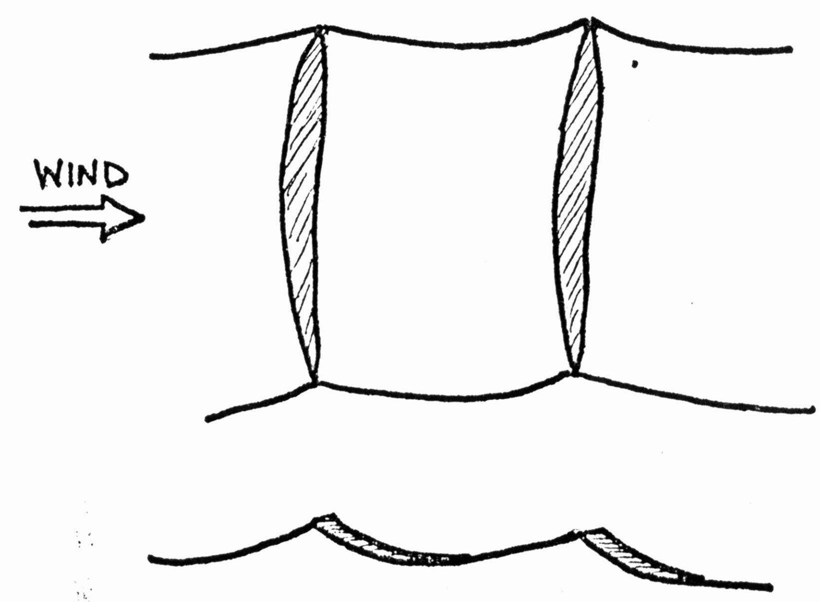
FIGURE No. 6

GENERAL CHARACTERISTICS OF DUNES

COMMON TYPES OF DUNES



BARCHAN DUNES



TRANSVERSE DUNES

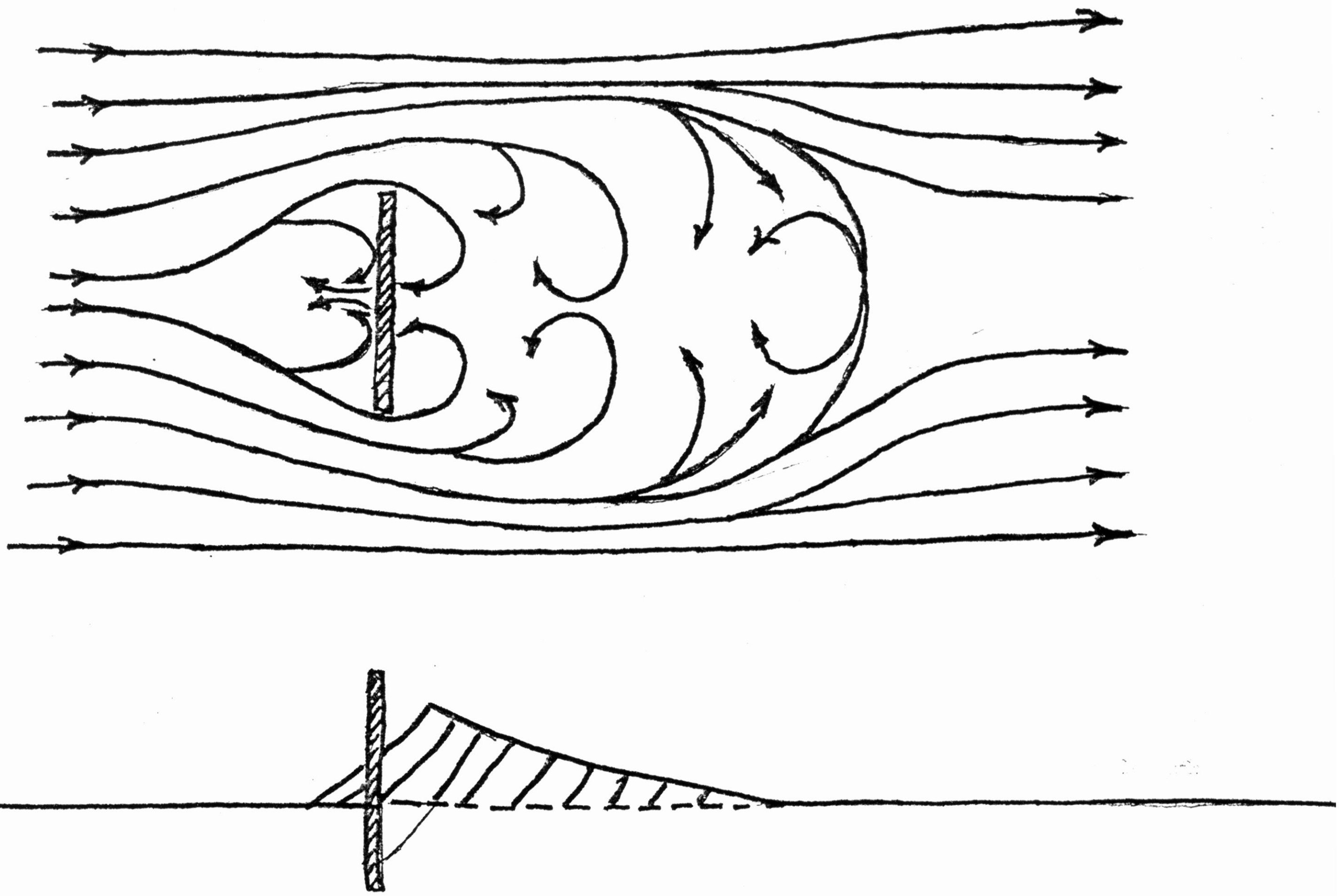


FIGURE NO. 7 SAND AND WIND FLOW PAST OBSTRUCTION

1. DECREASED AIR FLOW IN FRONT OF AND BEHIND
2. SAND DEPOSIT FORMS DUNE STRUCTURE

4 METHODS OF APPROACH

4.1 Laboratory Considerations

When this research was first begun last fall, it was proposed that a model beach would be constructed and tested in the wave tanks located on the campus of Texas A&M University at Galveston. Sand ridges to represent foredune structures were to be built up at the back of the model beach, and by inflicting different wave conditions the role of dunes in the stabilization of the beach under storm wave attack would be investigated.

Fortunately, soon after research began it was realized that an accumulation of sand at the back of the beach face does not in itself constitute an adequate duneline. Under natural conditions dunes develop by processes previously discussed over an extended period of time. The importance of the time factor is shown when it is realized where the strength of the dune structure comes from. In the slow depositional process the sediment becomes well-refined and graded. And more importantly, the roots of the stabilizing vegetation are given to become well-developed in each of its parallel layers. A sand mound that has not undergone this refinement and is lacking vegetation cannot be expected to exhibit the same characteristics as the naturally formed dune.

For these same reasons, it was decided that the proposed lab tests should not be performed. Although the TAMUG laboratory facilities are well equipped, model tests would be inherently distorted and unreliable. Silvester in Coastal Engineering commented that, "Because of the difficulties of verifying theoretical analyses, either in model (due to necessary distortions) or in the field (due to the changeable energy input and the magnitude of the measurements), some of the views expressed can be termed tenative. They should be tested against observations of nature and it is hoped, indicate fruitful lines of research." In an effort to test the hypothesis that adequate dunelines are directly related to the overall stability of barrier island beaches, the author decided to compile a geologically recent history of a barrier island. From this a comparison between the duneline conditions and the stability of the beach was to be drawn.

4.2 History of Galveston Island Dunes

It was decided that the past history of the dunes on Galveston Island and their relationship to the state of the beach environment would offer the neceesary data and results. The following is a historical discussion compiled from old newspaper articles and the memories of citizens of the island.

In the early to middle nineteenth century, Galveston Island had an extensive fore-island dune system. Rising to heights of 20 to 30 feet above sealevel and well-stabilized by vegetation, these dunes offered a more than adequate means of protection from all but the largest of storms. Most development was wisely placed behind the large dunes. Because of the pleasures inherent in a barrier island beach environment, Galveston Island became a very popular place for the well-to-do to recreate. In an unwise move, it was decided to level the dunes in order that the tourists might be provided better access to the sights and sounds of the beach and surf. With the dunes gone, development of the east end expanded to the edge of the shoreline.

Then in 1900 a large hurricane struck the island. Without the protection of the dunes the city was quickly inundated. The only warning anyone had of the approaching storm was a wire received the day before from the weather bureau in New Orleans which informed the Galveston Weather Bureau of thunderstorms approaching from the south that could possibly bring "some" rainfall. With no fore-warning, the citizens of the city were not prepared. Six thousand people died that night and in the following days as the city of Galveston was all but completely destroyed.

Unknowledgeable of the nature of barrier islands and unwilling to give up their land, citizens pushed for legislation that called for the construction of a seawall on the east end of the island and for the raising of the city by ten feet. Designed to "protect and preserve" the island, the seawall and the series of groins that soon accompanied it stifled the processes that were its life's blood. With the seawall in place there was no way for the natural development of dunes to occur. The standing waves that soon developed in front of the vertical face of the seawall during storm conditions soon washed away all the beach material in front of the wall. To "protect" the seawall from being undermined large granite blocks were placed at the foot of the structure.

In an effort to trap the sand that was bypassing the island, a groin system was designed and built in the 1930's and 40's. What was once a beautiful and "stable" barrier island beach which offered endless recreational possibilities, was quickly transformed by coastal engineers into a concrete fortress that resembled a mid-evil castle. As it will later be seen this engineered coast cut off large amounts of longshore transport that is vital to the nourishment of the beaches further down the island and the Texas coast. A majority of this sediment load was dredged out of the channel and "ingeneously" to create a large landfill at the eastern tip of the island. This material could just as easily been reintroduced to the littoral system further downcoast. As it was the longshore transport that reached the western end of the island was greatly depleted.

This lack of material getting to the western end was something that would be felt in the long run. The beaches on this part of the island were still in good condition in the 1950's and 60's. The dunes were well-stabilized and there was a lot of asthetic beauty. Because of this the west end was quicky sought after by real estate developers. As little sub-divisions like Jamaica and Pirate's Beach began to grow in the late 1960's and 70's, roads were cut through the dunes and large amounts of sand were removed to level off roughed lots. In some places, the entire dune structure was bulldozed down in order that houses could be built as close to the water's edge as possible. Much like the pre-turn-of-the-century east end, the west end became a popular spot for well-off families to spend their weekends and holidays. Provided only with the protection of inadequate dunes, many beach houses were damaged when the fringes of Hurricane Allen crossed the island in 1978. In an article that appeared in the "Houston Post" on August 13, 1980, Ray Quay, Galveston's City Planner, remarked after touring the West Beach area,

> The storm was a lot worse than I thought it was, ...Where the dunes were in good shape they survived ...where there had been erosion or roads and paths cut through the dunes, they are almost completely wiped out ...to have your dune structure destroyed by such a small storm, I think is a warning.

It was a warning not taken. The next five years saw a dramatic increase in the development and usage of the western end of the island. The critically weakened dunes were further exploited for construction and recreational purposes. What little stabilizing vegetation existed was quickly being destroyed by beachgoers, causing increased erosion. By 1983, there was little left of the duneline structure except a few scattered coppice mounds.

On the night of August 17 of that year, Hurricane Alicia struck land at the western end of the Galveston Island. Her severe storm waves inflicted large amounts of damage to this virtually unprotected shoreline. Almost two hundred feet of property, valued in some places at $100,000 a lot, was removed in just a few hours time. If the protection of an adequate duneline had existed on this part of the island millions of dollars in losses might have been prevented. Even so no provision was made after the storm to leave room for the dunes to rebuild. Even with this dramatic display of the distructive force of nature's fury fresh on their minds, developers and beach house owners indignently set about building and rebuilding on the water's edge. In an attempt to enforce laws that set aside land from the water's edge to the vegetation line for public use, State Attorney General, Bill Mattox ordered all construction in this area to come to a halt. But people who attempt to defy the laws of nature cannot be expected to regard state laws with anything but contempt. In blatantly illegal actions, these home owners continued construction almost beyond the average high water lines. For protection they have constructed long, expensive wooden bulkheads infront of the houses. These are the same type of untied back structure that offered no protection from Hurricane Alicia's storm waves. In fact, these bulkheads amplify the erosional force of even ordinary high tide waves. Figure 8 shows how vertical structures like these bulkheads and seawalls, and paved surfaces like the roads and house foundations are responsible for the accelerated erosion of beaches like that on the west end of the island. These structures cause large volumes of water to be pured on concentrated sections of the beach face during storm conditions. The beach becomes saturated and the water table rises. As the increased groundwater flow is returning to the sea a quicksand effect developes which sets the stage for the rapid removal of beach material. Under these conditions, "it is little wonder that large slices of beach can disappear within hours of the inception of a storm." (SILVESTER,1974)

Also of significance is the fact that no room is being left for the stabilzing vegetation to re-establish itself. As fast as nature can return sand to renourish the beach, it is being dried and blown from the beach face. This sand that is intended for use in reconstruction of damaged dune structures now covers roads and driveways, and piles up against the sides of buildings. Seeing this as only a nuisance, many beach house owners do not seem to realize that this sand is being, for all practical purposes, lost permanently form the already starved littoral budget of material that exists off of the western part of the island.

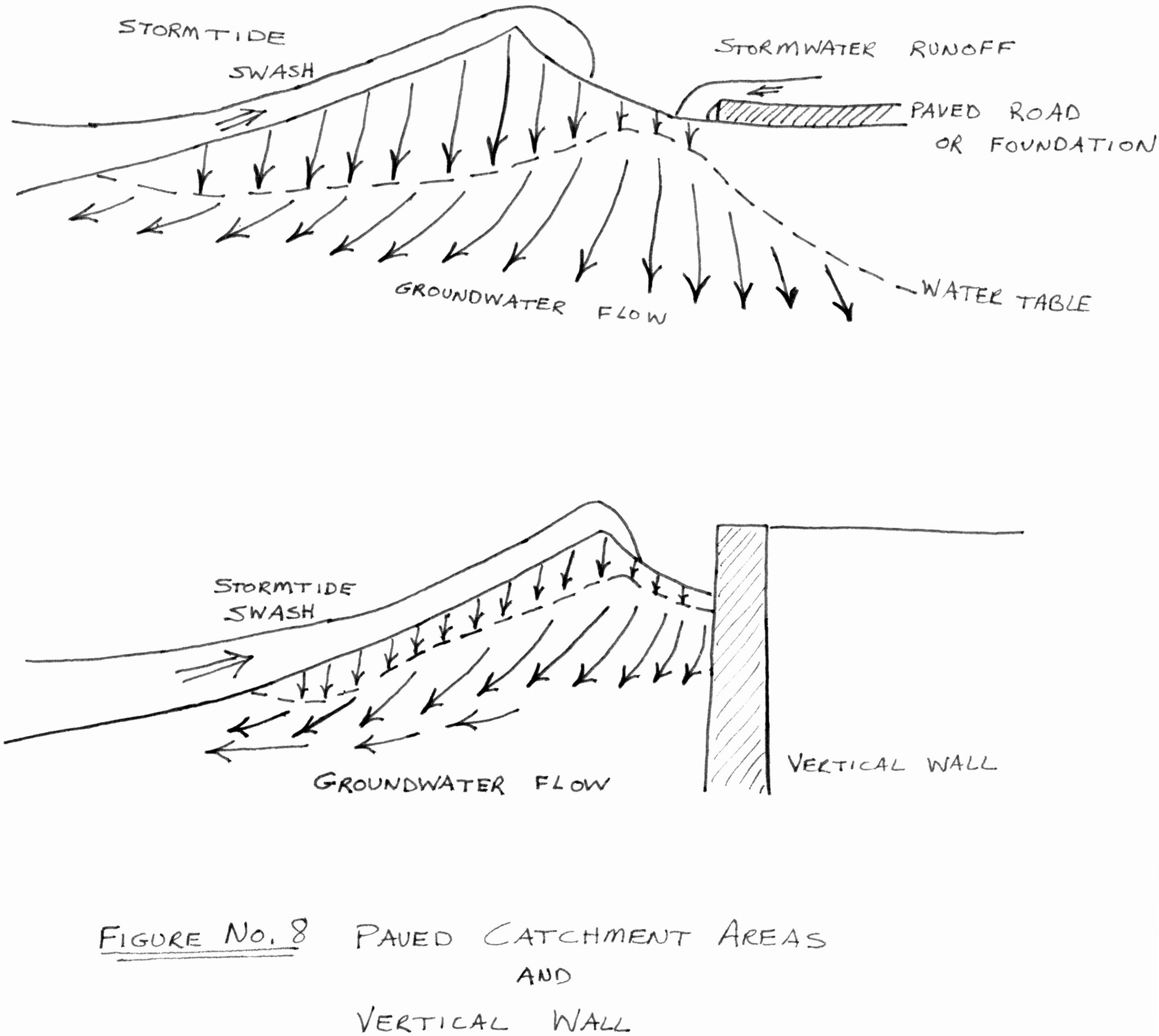


FIGURE NO. 8 PAVED CATCHMENT AREAS
AND
VERTICAL WALL

5 SOURCES OF INFORMATION

5.1 Literature

A large majority of the information used to draw the conclusions on this research was obtained, because of time and money limitations, from published material on beach processes, and coastal engineering. The complete list of literature used to get the author up-to-speed on the subject as well as to support the ideas set forth is given in the bibliography in Appendix B.

Valueable information was found in books written by marine geologists, coastal managers, and coastal engineers. All of these groups seem to approach the subject from a different viewpoint. Books by geologist emphasize the mechanisms, ancient and recent, responsible for beach existance and deterioration. Coastal management texts concentrated on the interfacement with the human element. Coastal engineers presented chapters on the importance fo beaches, but then offered instruction into the design of seawalls, rock groins, and similar structures that tend to be detrimental to the beach environment.

The U.S. Army Corps of Engineers is responsible for most of the practical material on coastal projects. They have been behind design and construction of a majority of the projects that have been presented in this paper as harmful to the long term conditions of

Galveston Island. The Corps of Engineers has been delegated "the unenviable task of protecting our coasts from erosion, maintaining our beaches, and at the same time building jetties, boat harbors, and other similar structures on the coast. In general these tasks are not compatible with one another." (KOMAR,1976)

5.2 Input from Experts

This research project could not have been completed without the valuable input of several people knowledgeable of the coastal environment. My interest in beach processes was iniated by several technical papers loaned to me last summer by Dr. Yu-Hwa Wang, who was also there to guide me thoughout my research.

A large amount of my information on the Galveston Island area and Texas Coast in general was obtained from books loaned to me by Paul C. Wilson, the chief engineer of the regional planning section of the Galveston office of the U.S. Army Corps of Engineers, and Dr. Ernest L. Estes, assistant professor of marine sciences at TAMUG and my instructor for Geological Oceanography.

While taking profiles of the beach on the west end of the island, I had the opportunity to discuss my research with several beach house owners. These men and women related to me their efforts, successful and otherwise, to protect their property from erosion. One in particular, Al Anderson, the owner of APEC construction company that builds bulkheads and beach houses, showed his interest by coming up to talk several times. He was able to save us a lot of trouble by giving us the location of a marker that had been referenced to sealevel. Unable to locate any nearby benchmarks, without Mr. Anderson's assistance I would not have been able to reference the beach profiles to sealevel.

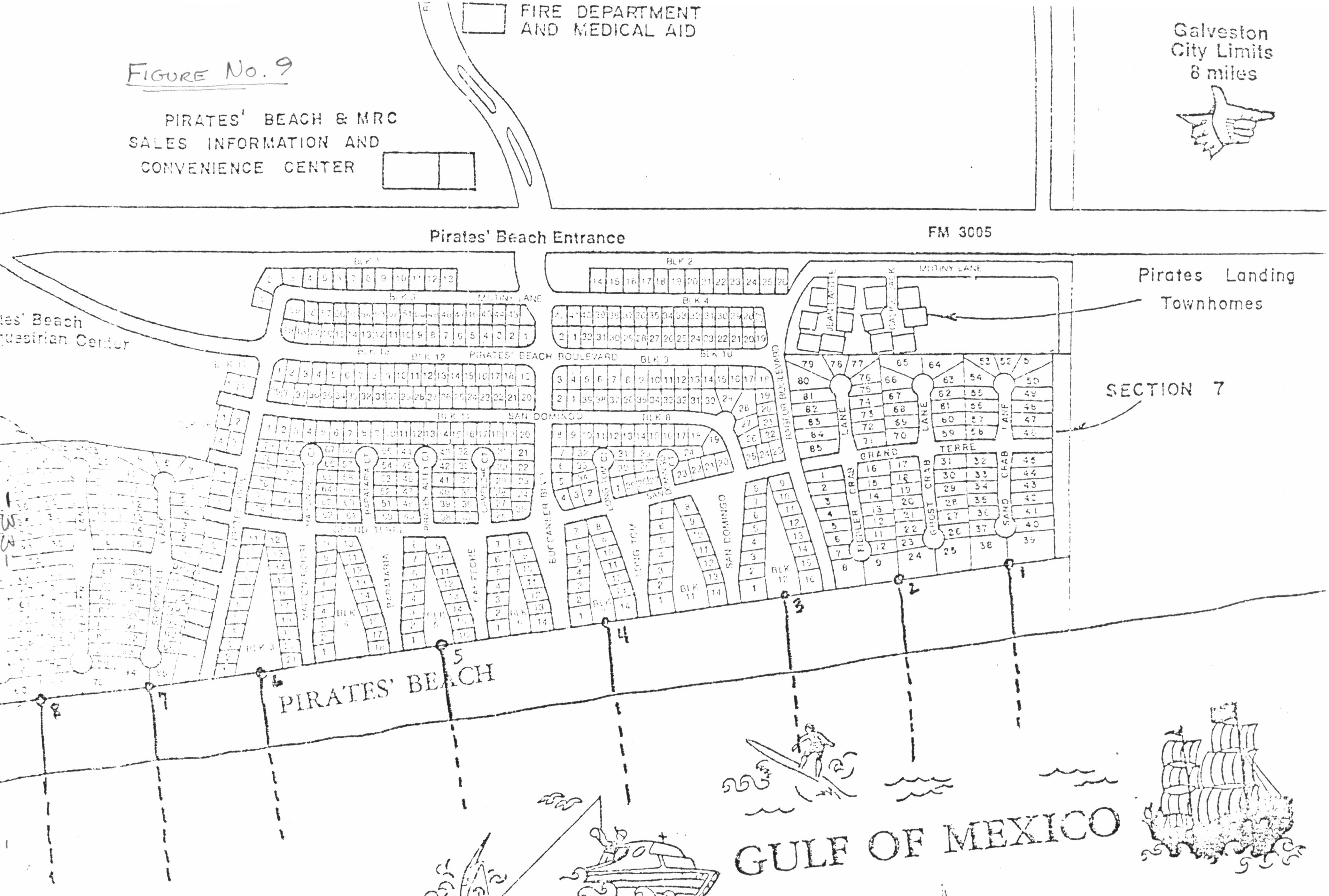
5.3 Field Techniques

From October to March, a one mile stretch of shoreline on the west beach area of Galveston Island was surveyed to monitor changes in the beach configuration. Using a transit, beach profiles were taken intermittenly at eight stations along this stretch of Pirate's Beach, see figure 9. These stations were chosen in locations away from breakwater structures, beach houses and roads to exclude these outside influences. Wooden posts placed at each station were clearly marked with bright paint and numbers.

To ease comparisions, all the beach profiles were taken at 140" true to North, which in most cases was approximately perpendicular to the shoreline. The transit was set up on a tripod and the distance from the lens to the top of the post and to the ground was measured. Using the differential levelling technique diagrammed in figure 10, relative heights were taken at points about ten feet apart. A computer program (given in Appendix A) was written by the author to draw the profiles attached at the end of this paper.

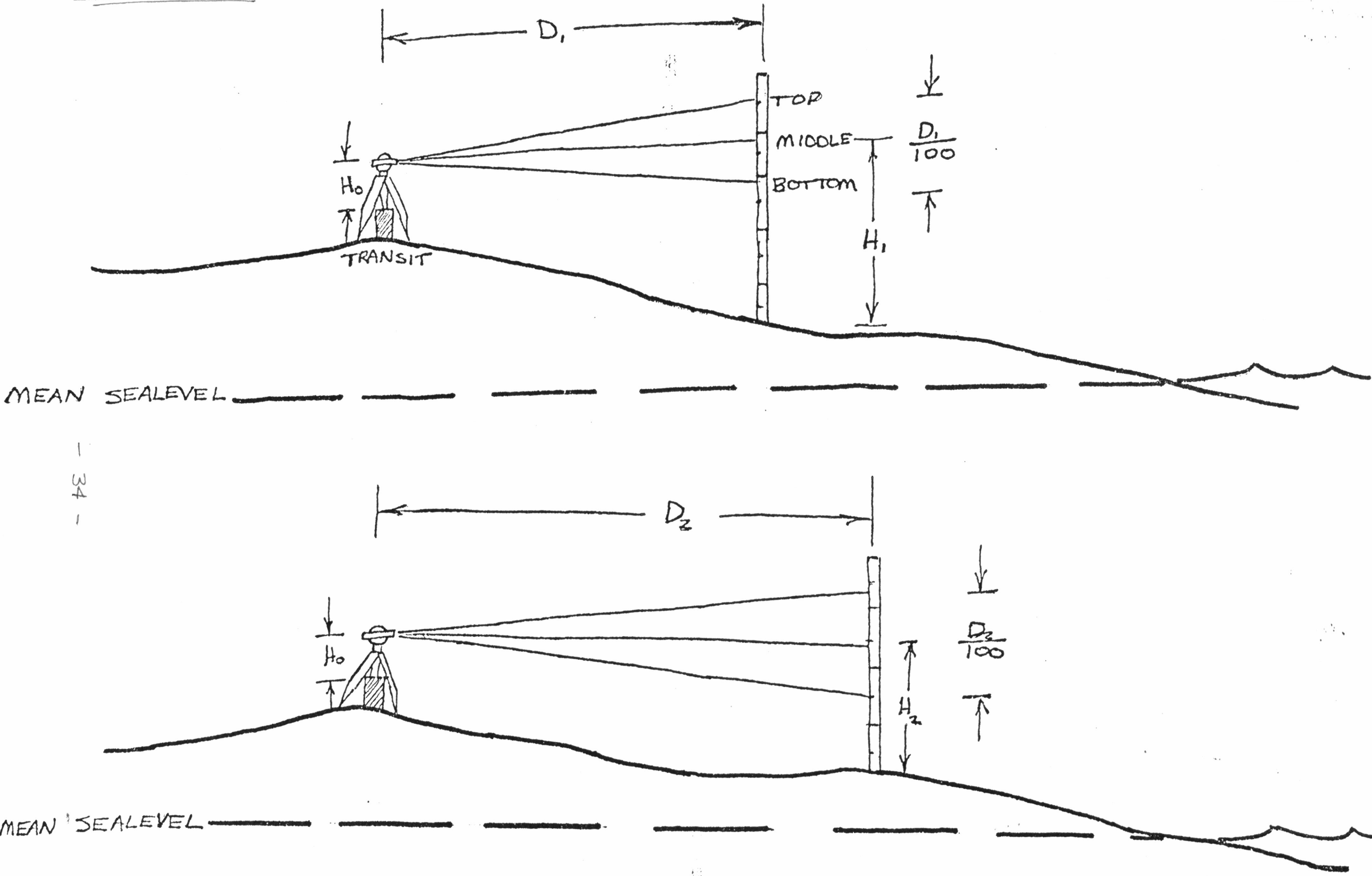
Because of the short time frame, these profiles do not at this time give much valuable information, but they will offer a base with which to reference later additions to research on this topic.

FIGURE No. 9



Obtain HUD property report from developer and read it before signing anything. HUD neither approves the merits of the offering nor the value of the property as an investment, if any.

FIGURE NO. [illegible] DIFFERENTIAL LEVEL SURVEYING



6 RESULTS AND CONCLUSIONS

The ultimate defense of barrier islands is the provision of sufficient material to build a bar during storm wave conditions. An adequate duneline represents this capital of material and is therefore directly related to barrier island beach stability. As this entire paper has been devoted to the proof of these facts, this section of result and conclusions shall be utilized to present a series of recommendations the author has for geologists, coastal engineers, beachgoers and shoreline developers.

Though it sounds logical, my first recommendation, where adequate dune structures exist they should be pampered and protected, is seldomn common practice. Barrier islands are of such value and rarity that they should be protected, by federal legislation if necessary. In the past few years the amount of sand taken from the dunes by developers has reached a critical point. Further exploitation of the coast should be halted and the coast should be protected under the national seashore system. Beachgoers should be forbidden from driving and walking on the dune vegetation for reasons explained earlier.

My second suggestion is that coastal engineers should make a greater effort to work with the natural processes by which shorelines maintain themselves. Barrier islands by their very name are designed to defend the coast from erosion by taking the brunt of storm wave attacks. Coastal engineers have a tendency to try and stabilize (with reinforced concrete and granite blocks) every piece of real estate. Barrier islands base their existance on an ability to migrate and change forms in attempts to best resist present conditions. Starved of littoral material and restrained from shifting, they are unable to serve their purposes properly.

Islands are by nature a hazardess places to inhabit. My third suggestion is that developers take economically valueable projects further inland. Not only are buildings, roads and other structures in danger along the water's edge, but by being there they create an unstable beach environment and take away from the natural beauty which makes them want to be there.

My forth and final suggestion is that geologists and coastal engineers that understand these processes should come forth in an effort to preserve the few remaining natural coastlines. They should quit being content to write articles that will only be read by fellow professionals and concentrate on increasing the public's awareness of the problem. Timely articles in "Shore and Beach" and similar journals have a purpose, but greater results could be obtained from popular magazines read by the general public. Only then is the necessary pressure going to be placed on the government to prohibit developers from destroying any more stable barrier island coasts like Miami Beach, Atlantic City, and Galveston Island.

7 APPENDIX A -- COMPUTER PROGRAM

```
      DIMENSION BOTTOM(100),CENTER(100),TOP(100),DIST(100),HEIGHT(100)
       CALL PLOTS(0,0,36)
       MMM=3
       CALL PLOT(0,.5,-3)
       CALL TNOUA('ENTER THE SIZE FACTOR:',22)
       READ(1,*)FACTO
       WRITE(1,1)
 1     FORMAT('ENTER THE NUMBER OF PROFILES')
       READ(1,*)K
      L=K+4
      DO 200 J=5,L
     READ(J,*)NUMBER
     READ(J,*)POSTSL
     READ(J,*)POSTLN
     READ(J,*)N
     SEALVL=POSTSL+POSTLN
      DO 100 I=1,N
          READ(J,*)BOTTOM(I),CENTER(I),TOP(I)
          DIST(I)=100.0*(TOP(I)-BOTTOM(I))
          HEIGHT(I)=SEALVL-CENTER(I)
           WRITE(1,10)DIST(I),HEIGHT(I)
 10        FORMAT('DIST=',F10.4,'HEIGHT=',F10.4)
100   CONTINUE
      NP1=N+1
      NP2=N+2
          MMM=MMM+1
          IF(MMM.GE.4)MMM=1
     IF(J.GT.5)GO TO 300
      CALL PLOTS(0,0,36)
      CALL PLOT(0,.5,-3)
C  SET SIZE FACTOR OF PLOT.
     CALL FACTOR(FACTO)
      CALL AXIS(0.,0.,13HBEACH-PROFILE,-13,9.0,0.,-160.,40.)
      CALL AXIS(0.,0.,9HABOVE-MSL,+9,4.0,90.,0.,2.)
       CALL NEWPEN(MMM)
 300    CONTINUE
      JM5=J-5
      CALL FLINE(DIST,HEIGHT,-N,1,4,JM5)
      IF (J-6) 5,6,7
 5    CALL PLOT(6.0,3.4,3)
      CALL SYMBOL(7.0,3.4,.14,8HNOV 1983,0.0,8)
      CALL SYMBOL(6.5,3.4,.14,JM5,0.0,-1)
      GO TO 200
 6    CALL PLOT(6.0,3.7,3)
      CALL SYMBOL(7.0,3.7,.14,8HJAN 1984,0.0,8)
      CALL SYMBOL(6.5,3.7,.14,JM5,0.0,-1)
```

```
      GO TO 200
  7   CALL PLOT(6.0,4.0,3)
      CALL SYMBOL(7.0,4.0,.14,8HFEB 1984,0.0,8)
      CALL SYMBOL(6.5,4.0,.14,JM5,0.0,-1)
 200    CONTINUE
C TERMINATION OF PLOT SUBROUTINES
      CALL PLOT(0.0,0.0,999)
       STOP
      END
```

8 APPENDIX B -- SELECTED REFERENCES

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9 APPENDIX C -- TERMINOLOGY

ACCRETION -- the buildup of land, by the action of nature or because of an act of man, on a beach be deposition of waterborne or airborne material.

BACKSHORE -- the zone of the beach lying between the foreshore and the coastline and acted upon only by waves during severe storms, especially when combined with exceptionally high water.

BAR -- a submerged or emerged embankment of sand, or other unconsolidated material built on the sea floor in shallow water by waves and currents.

BARRIER BEACH -- a bar essentially parallel to the shore, the crest of which is above normal high water level.

BEACH -- the zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves).

BEACH BERM -- a nearly horizontal part of the beach or backshore formed by the deposit of material by wave action.

BEACH EROSION -- the carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BEACH FACE -- the section of the beach normally exposed to the action of the wave uprush.

BEACH WIDTH -- the horizontal dimension of the beach measured normal to the shoreline.

BERM CREST -- the seaward limit of a berm.

DEFLATION -- the removal of loose material from a beach or other land surface by wind action.

DUNES -- ridges or mounds of loose, wind-blown material, usually sand.

EOLIAN SANDS -- sediments of sand size or smaller which have been transported by winds.

FEEDER BEACH -- an artifically widened beach serving a nourish downdrift beaches by natural littoral currents or forces.

FOREDUNE -- the front dune immediately behind the backshore.

FORESHORE -- the part of the shore lying between the crest of the seaward berm and the ordinary low water mark.

GROIN -- a shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

INSHORE -- the zone of the beach from the low water line through the breaker zone.

JETTY -- a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials.

LITTORAL DRIFT -- the sedimentary material moved in the zone extending seaward from the shoreline to just beyond the breaker zone, under the influence of waves and currents.

LONGSHORE CURRENT -- the littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

NOURISHMENT -- the process of replenishing a beach by longshore transport, or artifically by the deposition of dredged material.

OVERWASH -- that portion of the uprush that carries over the crest of a berm or of a structure.

RECESSION -- a net landward movement of the shine

RUNUP -- the rush of water up a beach on the breaking of a wave.

SALTATION -- particle travel by a series of hops and bounds because the motion of the fluid is not strong or turbulent enough to retain them in suspension.

SCARP -- an almost vertical slope along the beach caused bywave action erosion.

SEAWALL -- a structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

SHOAL -- to become gradually shallower.

STORM SURGE -- a rise above normal water level on the open coast due to the action of wind stress on the water surface.

SURF ZONE -- the area between the outermost breaker and the limit of wave uprush.

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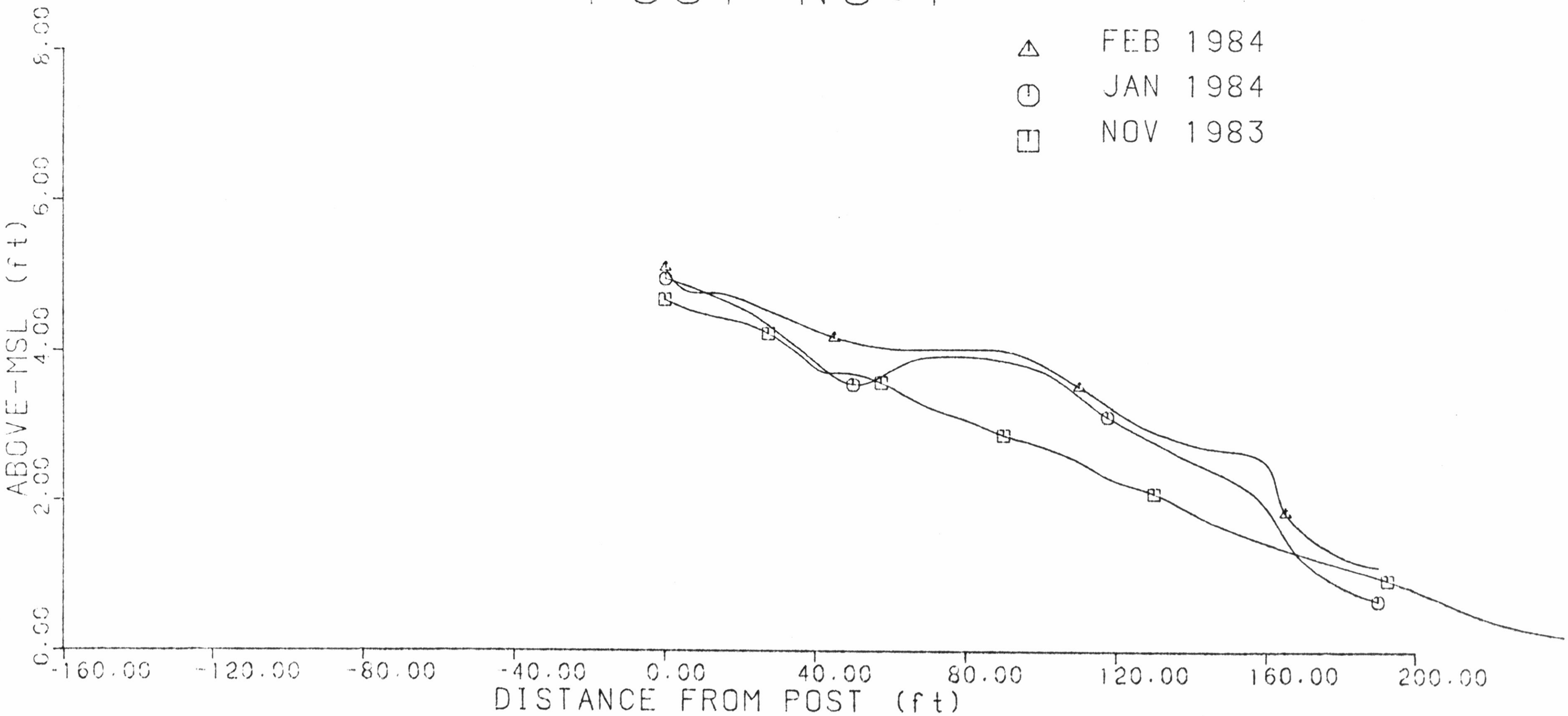

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0.00
40.00
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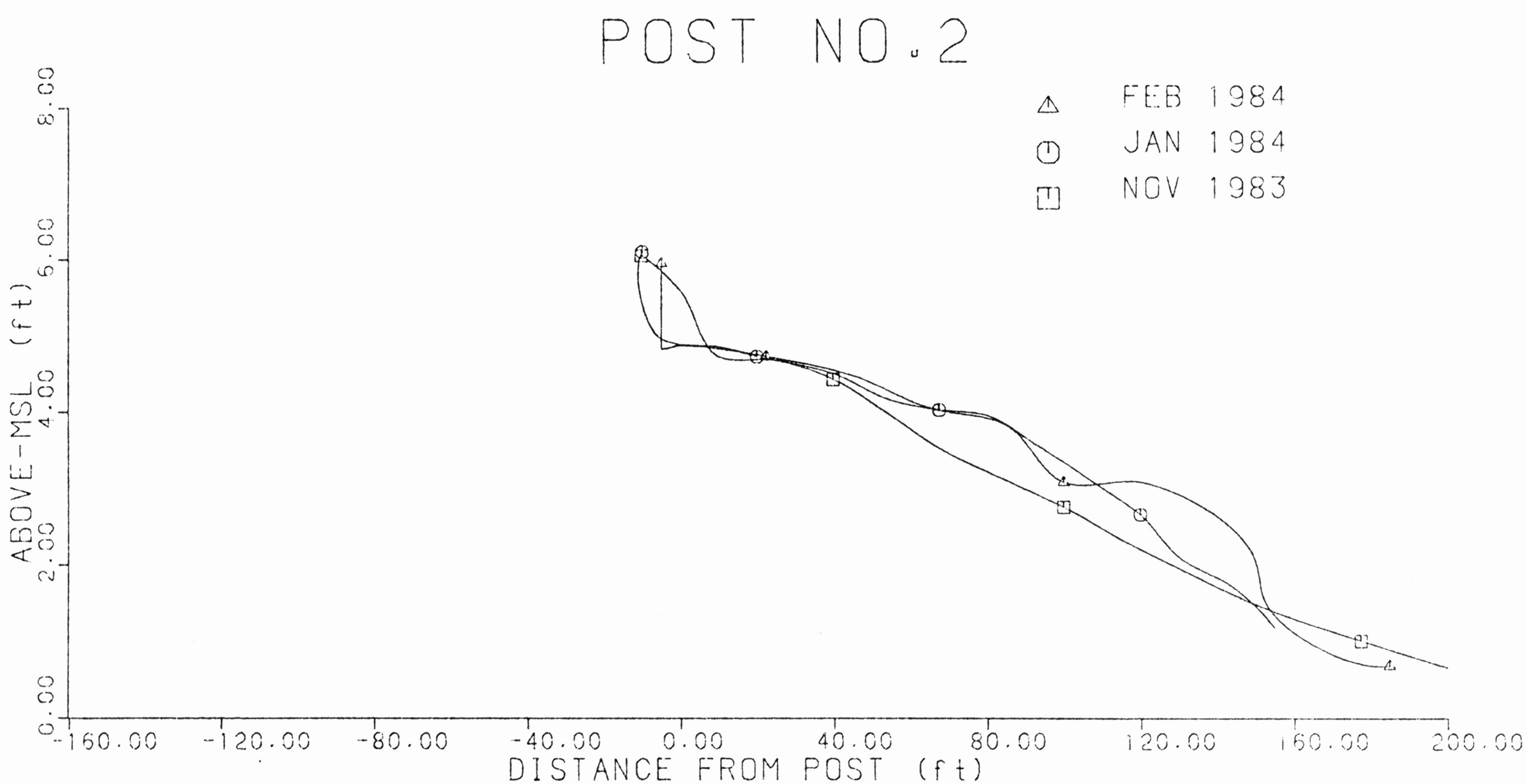
DISTANCE FROM POST (ft)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160.00
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DISTANCE FROM POST (ft)

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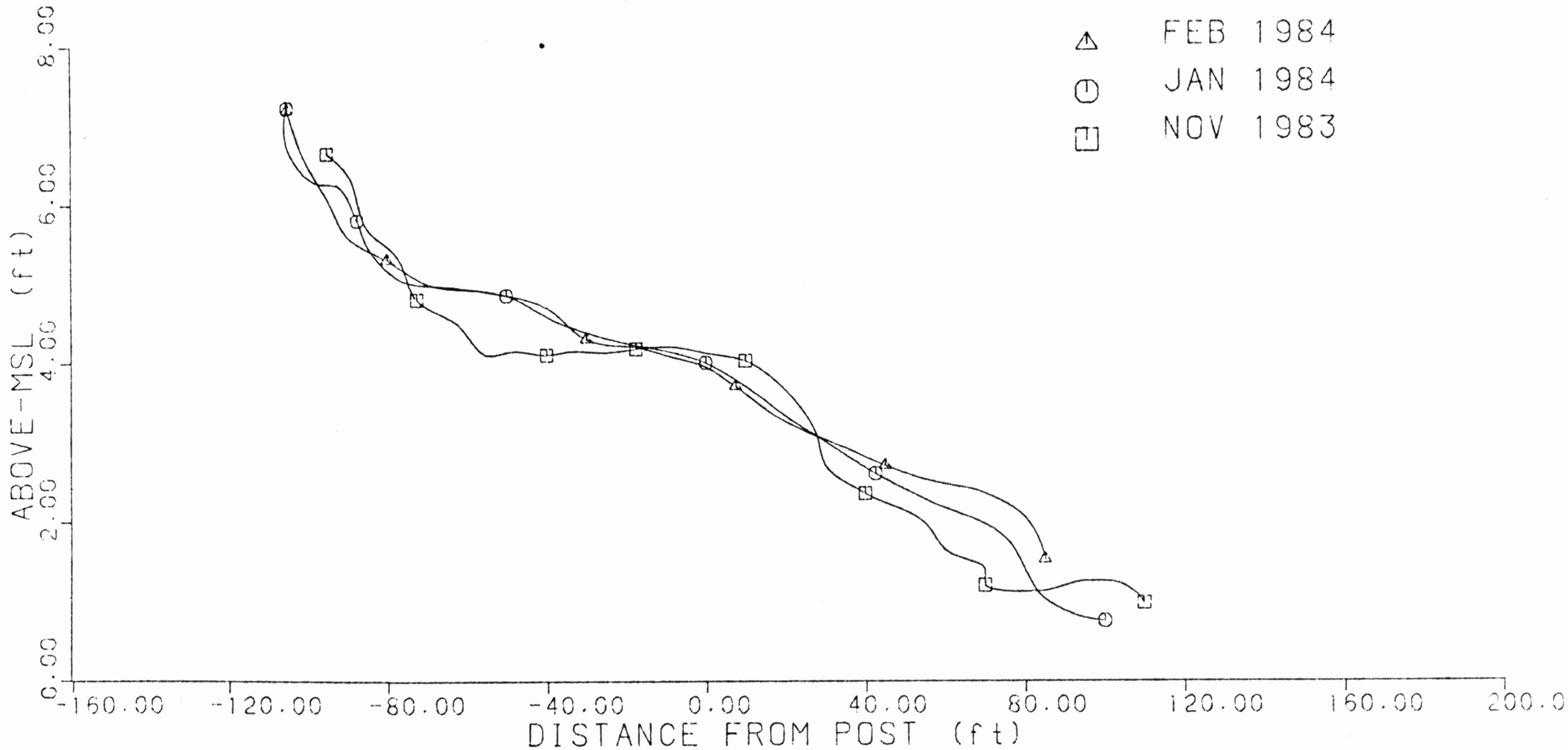
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DISTANCE FROM POST (ft)

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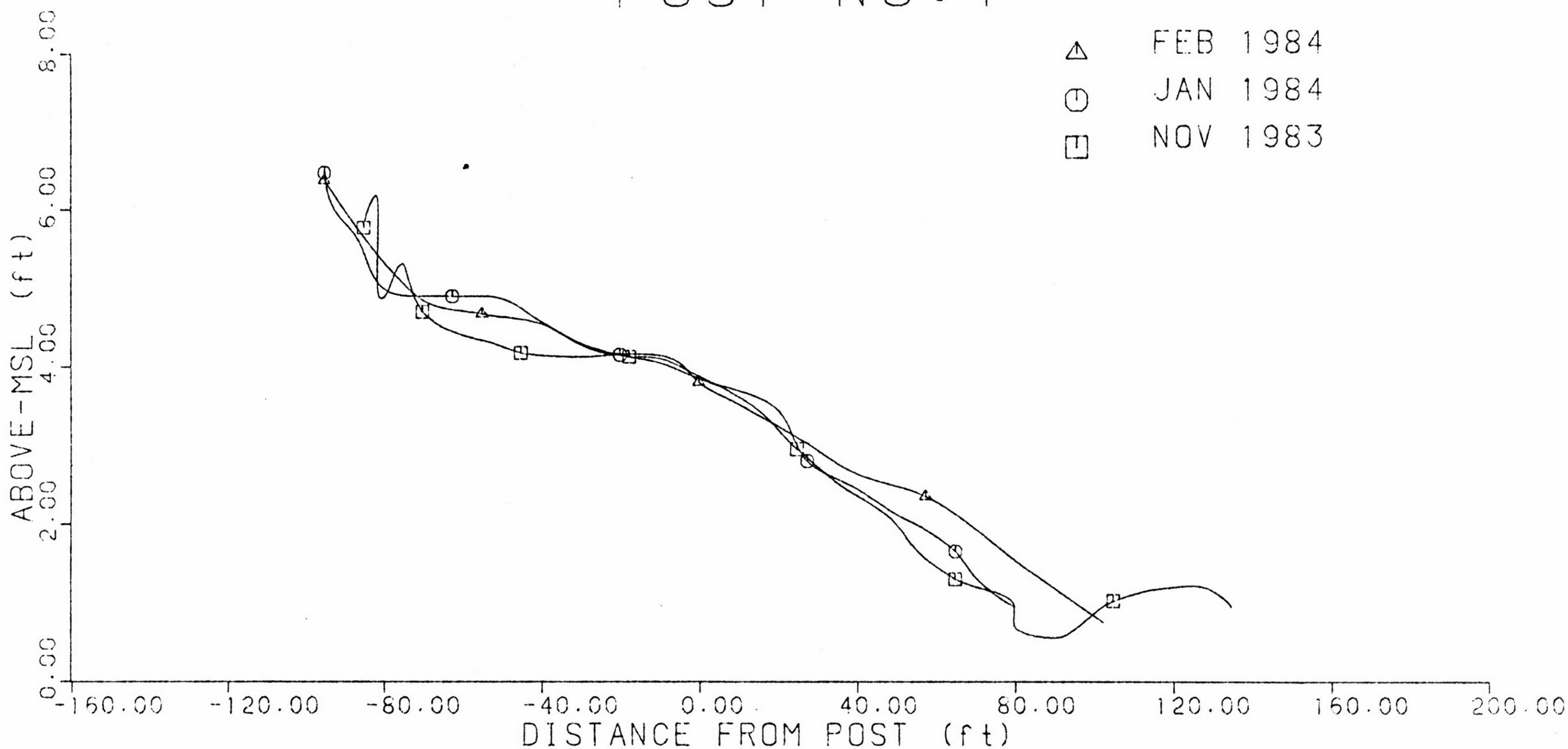

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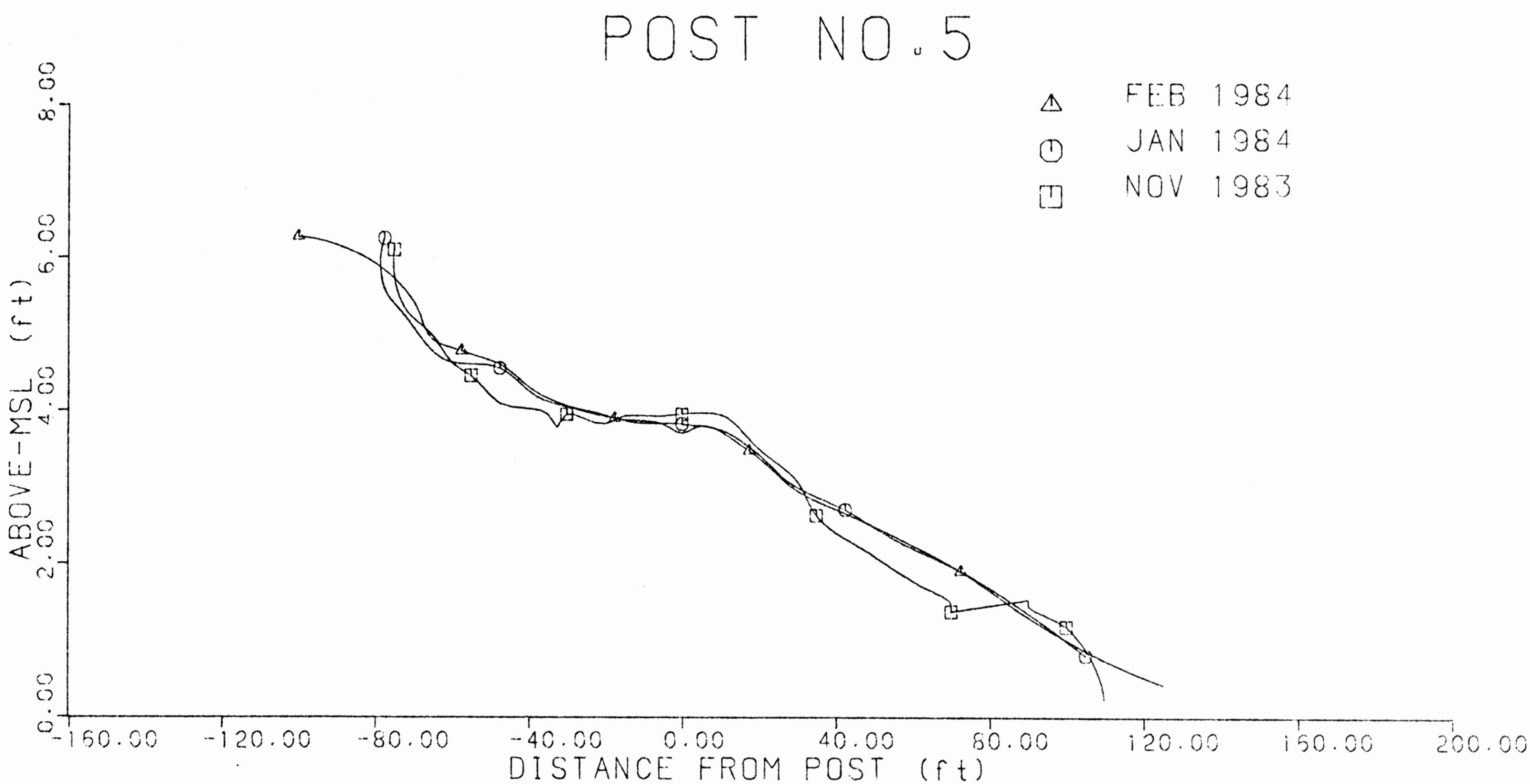
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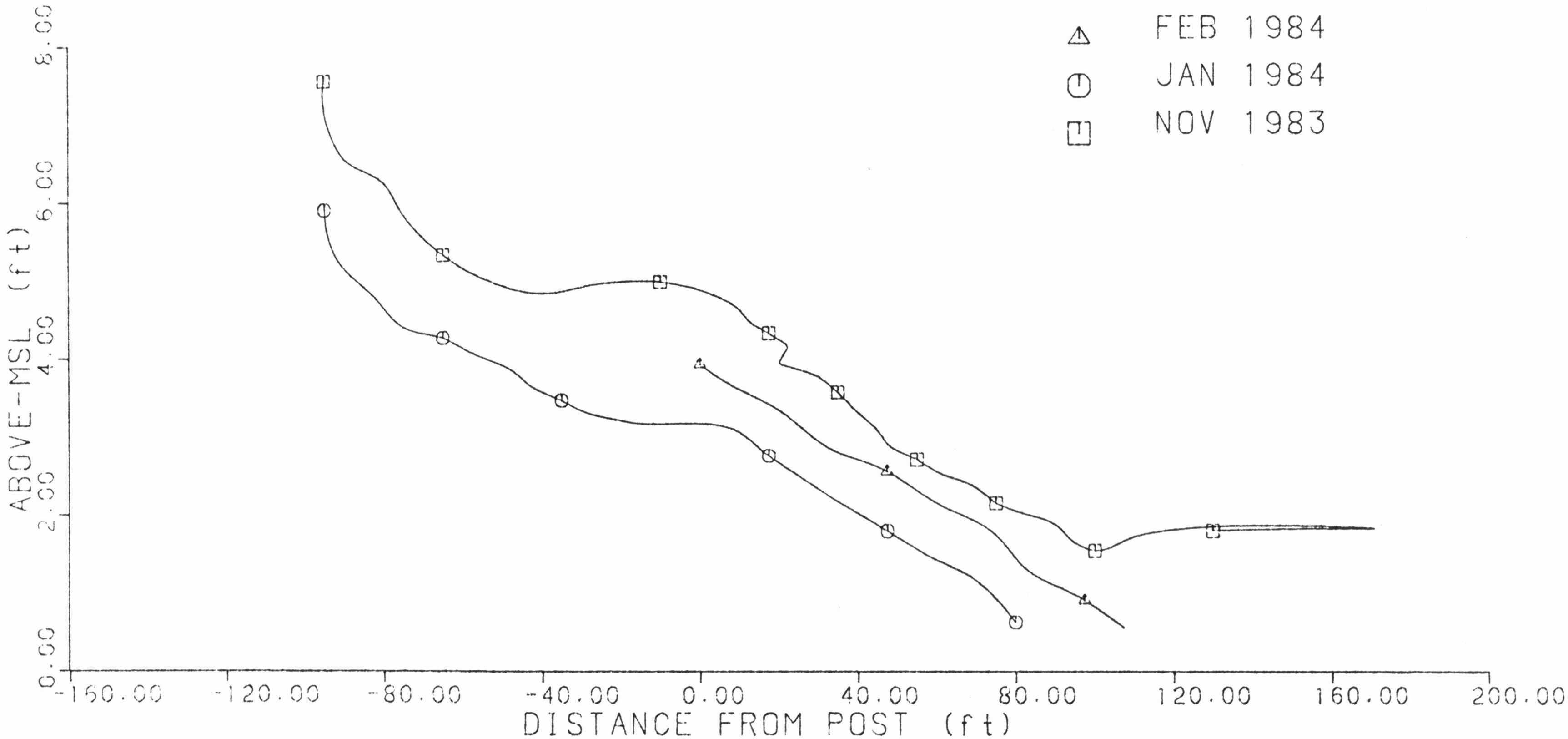
DISTANCE FROM POST (ft)

POST NO.6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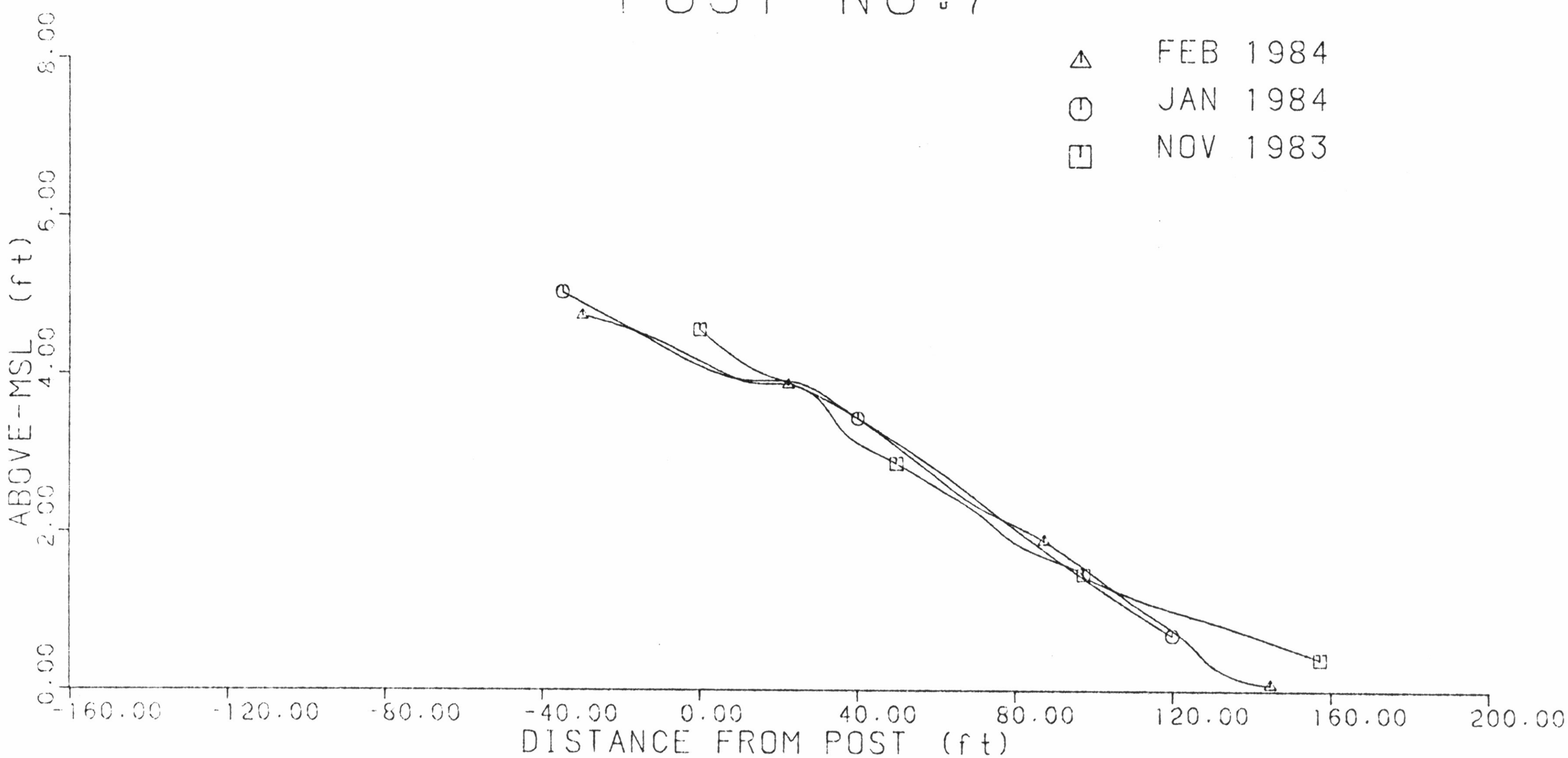

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DISTANCE FROM POST (ft)

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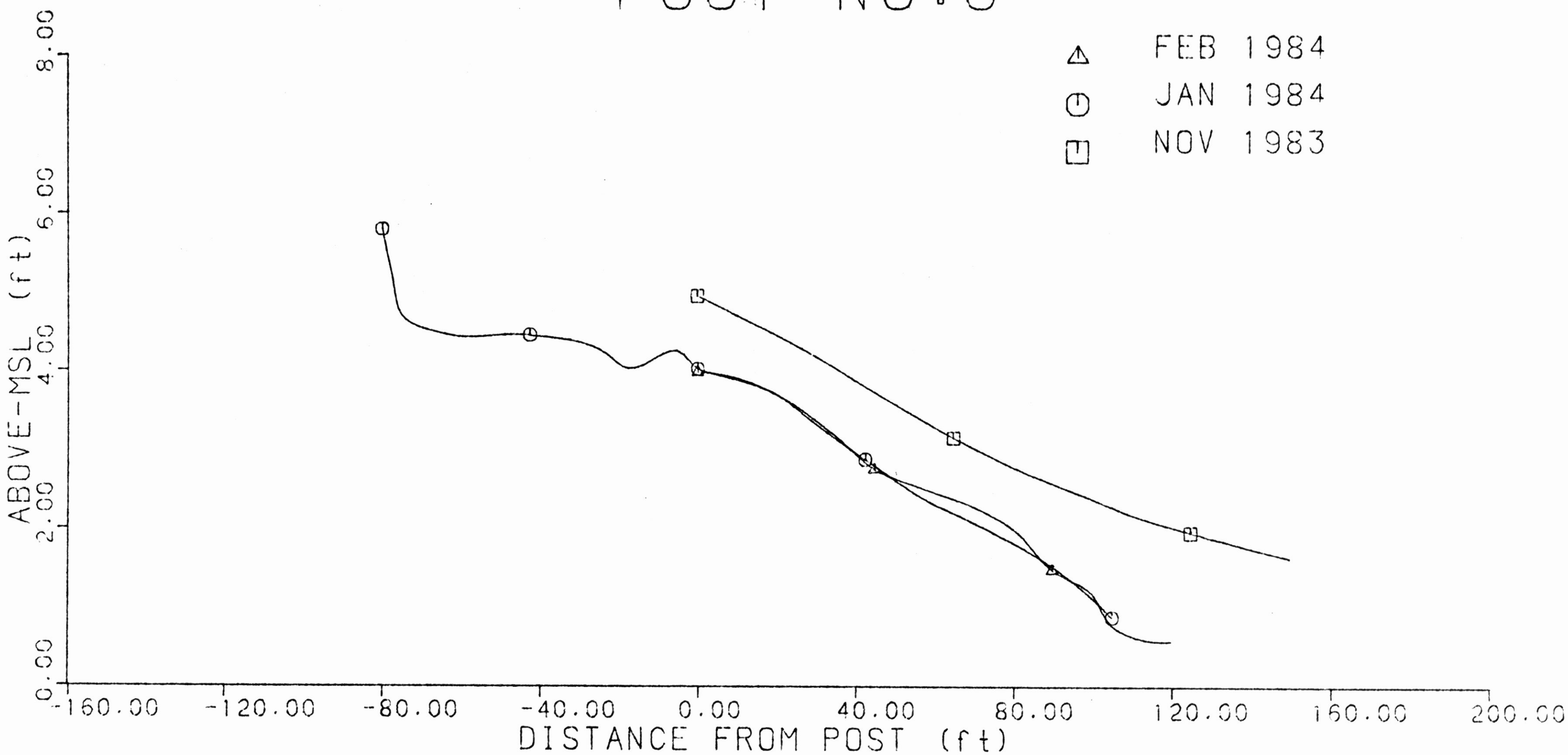
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-40.00
0.00
40.00
80.00
120.00
160.00
200.00
DISTANCE FROM POST (ft)