DEMONSTRATION PROJECT IN LOW-COST SHORELINE EROSION CONTROL

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FINAL REPORT

TO

County Administrator
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ABSTRACT

Low cost erosion control structures were installed at ten shoreline sites located in the lower Chesapeake Bay and on the Potomac and Rappahannock Rivers to further test the applicability of the perched beach concept under diverse littoral environments. The perched beach is achieved via installation of a low sill parallel to the shoreline. The objective of the sill is to provide a partial barrier behind which an elevated (perched) beach is accreted. When successful, the perched beach backshore and foreshore acts to reduce the frequency of direct wave attack against the fastland and thereby reducing the erosion rate. In this study, sills were used in conjunction with existing groins as well as alone. Some testing was performed on the use of a spur with existing groins as a device to prevent the formation of a downdrift erosion notch where the groin intersects the fastland. The sills were formed with a series of large PVC-coated nylon bags hydraulically filled with sand or with stone filled gabions. In one case compacted used auto tires were utilized as fill for a gabion. Evaluation of the response to the structures was based upon a series of surveyed beach profiles at each site and sequential photography. At each site the beach profiles were surveyed for several months prior to and following the installation of the various structures. Additional profiles were run adjacent to the treated areas. The structures were emplaced between late March and early June of 1978.

The post-installation monitor period ended in late July. Given the short post-installation monitoring period, it is not possible to make a complete judgement of the effectiveness of the installations. However, the characteristics of the early beach response to the structures do provide a reasonable basis for estimating the longer term. Four of the ten sites exhibited a weak initial response with respect to accretion. Those sites represent the joint condition of low to moderate littoral drift supply and the influence of groin fields. Site locations with larger littoral drift supply responded rapidly, particularly if the structures were placed in front of an indentation in the shoreline. The test with compacted used auto tires as gabion fill was encouraging and further research is suggested.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

The Commonwealth, having a tidal shoreline exceeding 5,000 miles in length, is graced with a wide diversity of shore types which include the low-lying barrier islands on the oceanside of the Eastern Shore, the ocean front headland-barrier spit of southeastern Virginia, and the shores of the Chesapeake Bay and its estuary tributaries which range from high bluffs to tidal marshes. Along much of this extensive shoreline erosion of the fastland is a baneful problem which victimizes occupants of the shorelands. In addition, the sediment stripped from the fastland by tidal shoreline erosion impacts the marine biological resources and leads to added expense in maintenance of navigable waterways. The purpose of the demonstration project herein reported was to test the applicability of some low-cost erosion control techniques to various physiographic conditions found along the shoreline of the Chesapeake Bay System. However, before going into the details of the study design it is essential to review the erosion processes acting in the system.

The Erosion Processes. The principal natural processes responsible for erosion are the long term changes in the level of the sea, the waves generated by local or distant winds and short term water level fluctuations occurring during storms. About 14,000 years ago the polar ice caps, formed indirectly from water of the world's oceans, were extensive, and sea level was about 300 feet lower than its present elevation. The ocean shorelines off what is now Virginia were then located near the edge of the continental shelf, about 60 nautical miles from the entrance to the Chesapeake Bay. Of course, the Bay and its rivers were not estuaries at that time but were an upland drainage network leading to the sea. The gorges of the rivers were deeper than now because the fluvial action tended to scour channels as the rivers flowed down to the sea. As the ice caps began to melt and recede, the elevation of the sea started to rise. This world-wide rise of sea level is called the eustatic sea level rise. Local changes of relative sea level, however, are the result of two components, the eustatic sea level rise and the isostatic changes which are due to local subsidence or uplift of the earth's crust. According to Rosen (1976), the best estimates for local, relative sea level rise are obtained from comparison of long term marograph data. Using data from Hicks and Crosby (1974) and Holdal and Morrison (1974), Rosen computed rates of sea level change for several Chesapeake Bay System locations. His results varied from an average rise to 5.43 mm per year at Old Point Comfort in the City of Hampton to a fall of 0.46 mm in the City of Richmond. (These rates are 21 and 1.8 inches per century, respectively.)

An "average" for sea level rise in the Chesapeake Bay area is about 0.01 feet per year or 1 foot per century (Hicks, 1972). This average includes shorter term variations of several years duration which may be appreciably larger or smaller. Although this rate of sea level rise is small, its effect is dramatic. The fringes of the ocean and the Bay have, generally, very gentle slopes, so a small increase vertically covers an appreciable horizontal distance. Thus, each decade brings constant encroachment against the fastland. Whereas the slow sea level rise may be considered as a pervasive but passive influence of erosion, wave action is the active erosional force. An analogy with a sawmill is fitting; wave action represents the cutting teeth and sea level rise represents the belt advancing the saw blade.

Another important aspect of sea level rise is its effect on the sedimentation characteristics of the Chesapeake Bay and its tributary rivers. When sea level was lower, the fluvial action of the freshwater rivers tended to carry sand and silt to the edge of the sea. The present condition, however, represents a sediment trap wherein coarse grained materials, sand and gravel, are deposited in the tributary reaches near the fall line which separates the Piedmont from the Coastal Plain. This zone is approximated by a line connecting Richmond, Fredericksburg and Washington. Moreover, saline oceanic waters now enter the Bay and tributaries. The net effect of the circulation between the entering oceanic waters and freshwater introduced from the rivers (James, York, etc.) is to trap the fine grained sediments, the silts and clays, within the estuaries. Thus, very little of the sediment delivered to the estuary system, either from the tributary freshwater rivers or from shoreline erosion, escapes the mouth of the Chesapeake Bay to the ocean.

When visiting the ocean shores of Virginia, an observer may notice wave conditions ranging between "fair weather" and those of a storm. Fair weather waves are characterized by generally well defined gentle undulations which break on the beach face with apparent regularity. These waves are generated by wind fields relatively far offshore and then travel to distant shores. During a storm, however, strong local winds generate waves which mix with those generated offshore. The result is an apparent maelstrom with waves of all sizes and shapes. Generally speaking "fair weather" waves (called swell) carry sand from the immediate nearshore bottom and deposit it on the beach. Storm waves, on the other hand, tend to remove sand from the beach itself and to deposit it in nearshore waters in accumulations called bars. When the fair weather swell waves return, the material stored in the bars is driven back to the beach face. Thus, there is a periodic shift of sand between the beach and the nearshore. Another very important aspect of wave behavior on beaches is that waves drive sand alongshore. This occurs when, as is usually the case, the breaking wave crests approach at an angle to the shoreline. This action of the waves provides the principal source of sand which works along the shore and is deposited in the entrances to inlets and creeks.

An observer visiting the shore of the Chesapeaker Bay and the wider parts of the tributary estuaries would witness the same wave behavior except the wave heights would be smaller and the time between successive waves shorter. This is due to the fact that the degree of wave development is strongly dependent on fetch, the "over the water" distance the wind blows. Of course the distances across the Bay are much smaller than those found on our ocean coast.

The beaches fringing our coastline are natural formations formed by wave action as the waves expend their energy. Beaches are, in fact, recognized as the most efficient dissipators of wave energy. Thus, aside from their intrinsic attractiveness to man, beaches are a protective structure which inhibit erosion of the fastland.

During storms (northeasters) and hurricanes, the strong winds push additional water against the ocean coast and into the Bay. As a result, the normal rise and fall of the tide oscillates around an elevated mean water level. While this storm surge generally ranges between one and two feet, it may be several feet in magnitude. For example, the extremely severe northeast storm of March, 1962 resulted in water elevations at Norfolk of 6.1 feet higher than predicted.

Aside from the obvious hazard of flooding low-lying areas, the surge permits the erosive action of the waves to directly attack the fastland, above the usual buffer provided by the beach. The effect is further accentuated if the storm occurs in conjunction with the higher, or spring, tides of the lunar month.

Tidal currents, the water movements resulting from the rise and fall of the tide, play a secondary role in shoreline erosion since the current speeds are small except near inlets where their influence is a dominate force. Away from inlets the tidal currents tend to move the sand stirred up by waves slowly along the coast. In some areas within the estuaries, local conditions result in strong currents not associated with inlets and which directly influence bank erosion. One example of this occurs at bends in the rivers.

It is of interest to see how these elements interact during the passage of a typical northeast storm. With the onset of the storm, the northeast or easterly winds generate large waves which impinge on the open coast beaches. Due to the large, steep waves and accompanying storm surge, it may be expected that large volumes of sand will be removed from the ocean beaches. Some of this material will be moved offshore for temporary storage in sand bars while some will be driven alongshore to storage in inlets or to beach areas on the fringe of that storm's influence. Within the Bay and tributary rivers, the intensity of erosion will depend on the path and strength of the storm. When the local easterly winds in the Bay are sustained at 20 knots or greater, the waves become quite large and the attack is focused on the western side of the Chesapeake Bay and the lower reaches of the tributary estuaries. After the storm center has passed offshore or to the north, the winds shift to the northwest quadrant. These winds, accompanied by a clear sky, are frequently stronger and of longer duration than those of earlier experience during the "storm". Now the ocean front beaches tend to recover some of the sand from the offshore bar. But in the Bay the focus of wave attack simply shifts. Now the eastern side of the Bay receives wave attack. Since the major tributary estuaries have a northwest-southeast orientation, their banks also receive substantial wave attack during northwest winds.

The Magnitude of Erosion. In order to gain a first order insight of the magnitude of shoreline changes within the Bay System, Byrne and Anderson (1977) compared the earliest reliable maps (1850's) with a series of 1940-1960 maps and charts for 2,365 miles of the Bay System. Byrne (1973) made a similar study of the barrier islands and the Corps of Engineers (1970) studied the coastline between Cape Henry and the Virginia-North Carolina border. The summarized results (Table 1) show that over 28,000 acres of land were lost during the recent past century (1850-1950).

Table 1

Areas Losses Due to Erosion (Circa 1850-1950)

Atlantic Coast SE Virginia	27 miles	- 40 acres
Atlantic Coast Eastern Shore	84 miles	- 7,228 acres
Virginia Chesapeake Bay and Tributaries	2,365 miles	-21,079 acres
TOTAL	2,476 miles	-28,347 acres

The ocean coastline segments show characteristically different erosion responses as compared to the Bay System. The barrier islands are, for the most part, sand starved islands segmented by tidal inlets. The net littoral drift is directed to the south. The northernmost section of the islands, Wallops, Assawoman, Metomkin and Cedar Islands have retreated in a fashion where the new shoreline parallels the older but with greater erosion rates on Metomkin and Cedar Islands. The central section of islands, Parramore, Hog and Cobb Islands, are flanked by deep inlets which strongly influence their gross behavior. Over recent times these islands exhibit accretion on the northern ends due to local trapping of sand which bypasses the adjacent inlet. The retreat of the southern portions of the islands is dramatic, up to 50 feet per year on Hog Island. The southern section of islands ending with Smith Island have retreated in a nearly parallel fashion, Smith Island at about 25 feet per year. Meanwhile, Fishermans Island, which is at the toe of the peninsula, has accreted with a four fold increase in area during the century studied.

The ocean coastline of Virginia south of Cape Henry is characterized by zones of alternating shoreline advancement and recession. If the total shoreline length between Cape Henry and North Carolina border (27.4 miles) is averaged over the long term, the annual recession rate is about 0.7 feet. This gross average masks a highly dynamic shoreline wherein some locations experienced erosion rates as high as 20 feet per year for several decades which then may have been followed by a period of accretion.

The lower Chesapeake Bay shoreline and that of its tributary estuaries, the James, York, Piankatank, Rappahannock, and Potomac Rivers, is highly dissected by entrances to creeks so that there is a high degree of variability in shoreline response within and between adjacent segments. Again referring to gross average, the eastern and western shores of the Chesapeake Bay lost about 12 acres per mile per century. The southern sides of the tributaries have experienced somewhat greater erosion due to the more direct attack from northwesterly winds. Although individual segments of the shoreline have experienced erosion rates exceeding 7 feet per year, one or two feet per year is more common. For the 2,365 miles of Bay System shoreline measured the average erosion rate was 0.7 feet per year. Slaughter (1964) estimated that the Chesapeake Bay has one of the nations highest rates of erosion for tidewater areas.

The products of shoreline erosion, sand, silt and clay, contribute a significant fraction of the total sediment load trapped in the Bay System. The sand fraction derived from erosion is the principal source of beach materials. The silt and clay fractions, however, contribute to the general sedimentation of the channels and flanks of the estuaries. Although the volume of suspended sediment entering the Virginia estuary system has not been determined precisely, interpretation of available records indicates that the input from the upland drainage basins of the Potomac, Rappahannock, York and James Rivers is about 4 million tons per year. If we assume that 30% of the material derived from shore erosion is silt and clay, then it appears that about 1 million tons per year are injected into the system via shoreline erosion. Thus, the total silt/clay input is about 5 million tons per year of which 20% is derived from shore erosion.

Byrne and Anderson (1977) estimated that the total amount of material eroded from the Virginia portion of the Chesapeake Bay System between 1850 and 1950 was over 270,000,000 cubic yards. This volume is about one third the volume of the entire York River estuary.

The Effects of Erosion. Tidal shoreline erosion is a problem only because its impacts compromise our perceived benefits of occupying the shore zone or of utilizing its contiguous waters and subaqueous bottoms. The attractions to the shores are manifold and the pressures for occupation are growing. The principal effects of tidal shore erosion in Virginia are, without rank of position:

1) Loss of fastland property and improvements thereon
2) Loss of taxable lands within localities
3) Influx of eroded sediments into the estuarine system and its flanking tidal creek entrances, and
4) Principal supply of sand to beaches fringing the Bay System and ocean shoreline.

The first two effects are generally perceived as adverse impacts. The third effect, while consequence of shore erosion, may be perceived as a disbenefit since the fine grained sediments contribute to the shoaling of navigational waterways, and the silting of oyster rocks whereas the sand size materials may deposit in the entrances to feeder creeks, thereby reducing navigability. The fourth effect, the supply of sand to the fringing beaches, is decidedly a beneficial aspect of shore erosion. Within the Chesapeake Bay System and along the ocean shoreline, the principal source of beach sand is that derived from fastland erosion. This fact complicates strategies to alleviate the impacts of erosion since isolation of the sediment sources by shoreline protection structures results in the diminution of the sand supply available to adjacent beaches.

CHAPTER 2

THE STUDY PLAN

Background. In the course of our past studies and advisory work it have been possible to examine the wide spectrum of erosion control structures in use throughout the Bay System and to at least partially assess the effectiveness of the various methods under varying shoreland conditions. At any given site the choice between various structures should be based upon consideration of several physical parameters:

1) The rate of erosion at and near the site
2) The height and composition of the fastland
3) The magnitude of the sand supply from the littoral drift system and that from the local retreat of the fastland
4) The exposure to wave action. For the most part this parameter is determined by the orientation of the shoreline and the fetch.

In response to these factors and the goals of the property owner the selection of a structure is generally made between two broad strategies. The first strategy may be considered a defensive approach. The structure is intended to provide a barrier between the sea and the fastland, wherein the barrier itself withstands the attack of wave energy. The principal example of this strategy is the bulkhead or seawall wherein the structure acts to support the fastland as well as to isolate the fastland from wave energy. The second strategy is to promote the formation of a beach in front of the fastland so that the breaking wave energy is expended on the beach rather than the fastland. The principal example of this strategy is a groin field in which the vertical structures are placed perpendicular to the shoreline to act as local traps for sand in the littoral drift system. Of course, the success of the groins is dependent upon the magnitude of the sand supply and the efficiency of design (groin spacing, length, and height).

Objectives. Most of the conventional approaches to erosion control are quite costly, ranging from $30 to $100 per foot of protection. Moreover a survey of the shoreline exposes numerous cases where structures have failed completely or are only partially effective. The intent of the project herein reported was to test the applicability of two techniques to various environmental circumstances:

1) The perched beach, wherein the central idea is to increase the elevation of the beach face so that the beach rather than the fastland absorbs the energy of the breaking waves

2) The use of a short spur perpendicular to groins wherein the central idea is cause, via wave diffraction, a small sand fillet to form at the intersection of the groin and the fastland

The perched beach concept is illustrated in Figure 1a. In practice a structure (a sill) is placed parallel to the beach near the

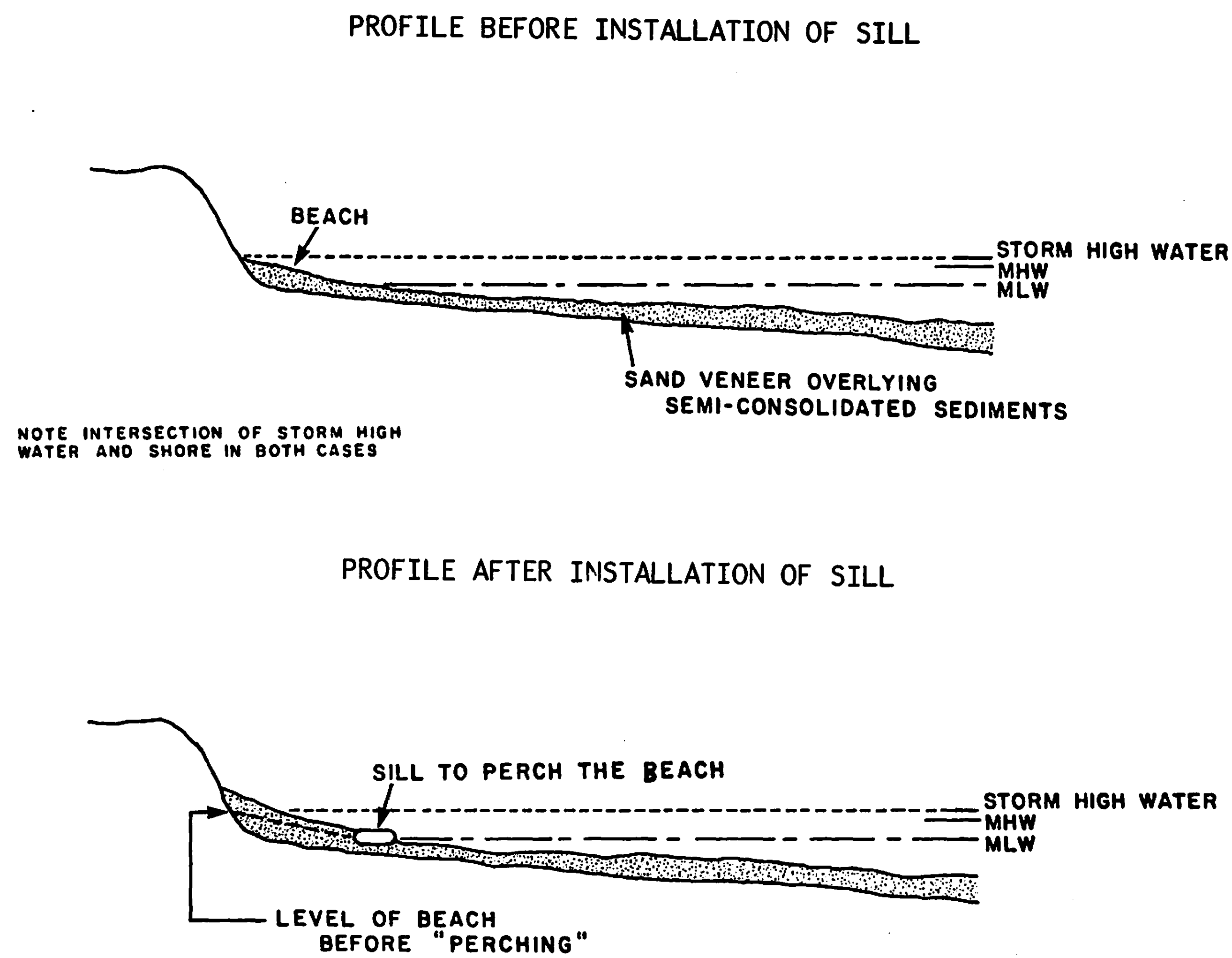


FIGURE 1a. Perched beach concept.

base of the foreshore slope where it will act as a hinge for the formation of an elevated beach face. When successful the backshore elevation is, as well, increased (Byrne and Anderson, manuscript in preparation). The effect of the "perched" beach is to provide an elevation increase which will reduce the number of occasions when the waves, in conjunction with storm surge, directly attack the fastland. Rather, the elevated beach acts to absorb the incoming wave energy.

The principle of the use of a spur on a groin is illustrated in Figure 1b. While a groin will trap sand on the updrift side there is, in almost all cases, a concommitent erosion on the downdrift side of the groin. The erosion is due to two effects. First, the littoral drift supply is interrupted by the groin itself. The second effect causing the downdrift erosion notch is due to wave diffraction at the tip of the groin. The process of diffraction causes the wave crests to bend and become perpendicular to the groin (as illustrated in Figure 1b). Wave action is thus concentrated at the junction of the groin with the fastland. If the erosion notch captures the junction of the groin and the fastland the structure will become isolated from the bank and fail to collect sand. The purpose of the spur is to utilize the diffraction of waves at the tip of the spur to drive a fillet of sand into the corner behind the spur. This sand fillet acts to prevent the encroachment of the erosion notch at the junctions of the groin and fastland.

Our previous experience with sills and spurs was derived at location where there was a substantial littoral drift and the

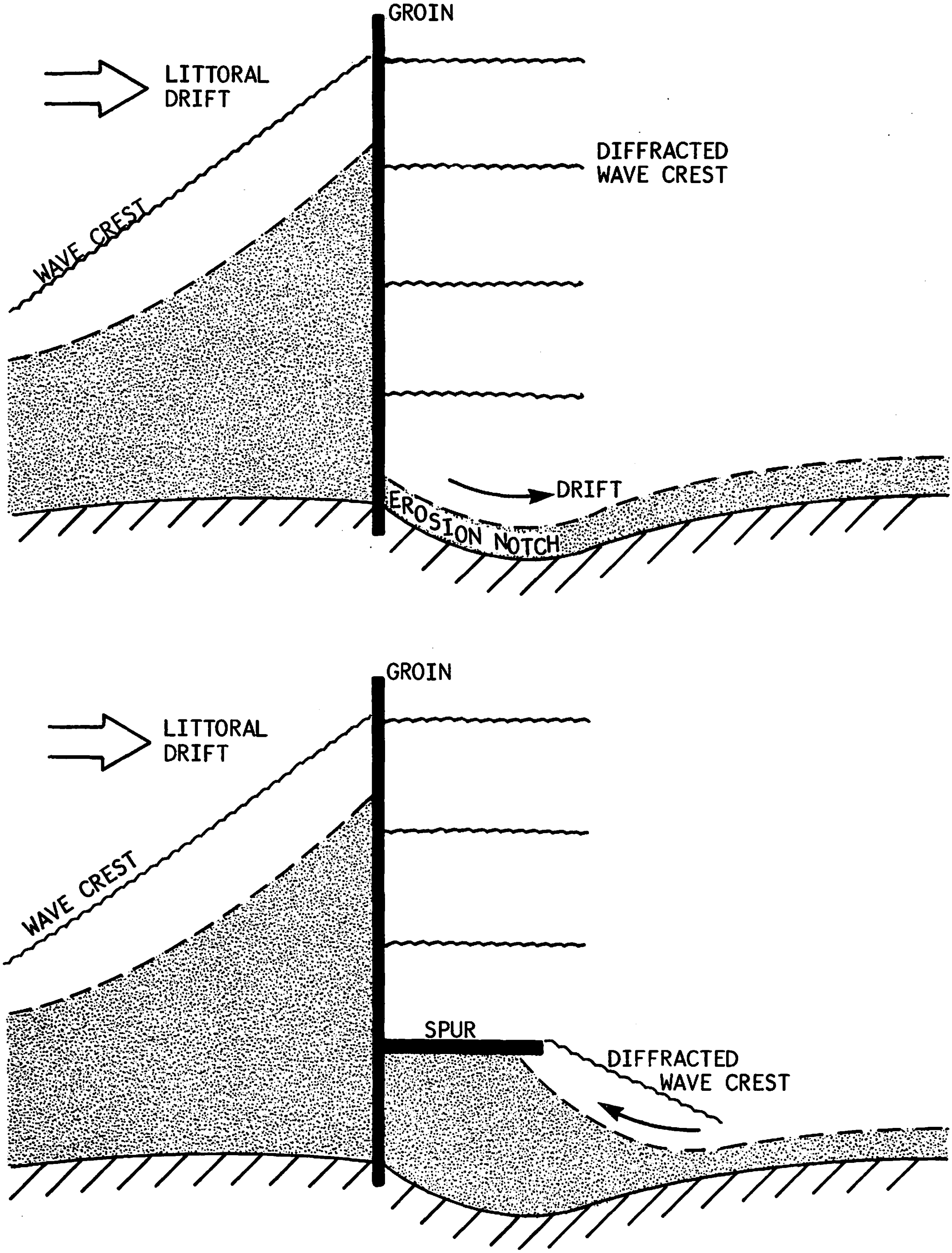


FIGURE 1b. The effect of a spur with a groin.

likelihood of success was strong. An additional objective of this demonstration project was to extend the application to areas of lower littoral drift in order to evaluate the limits of applicability. Finally the project offered the opportunity to test different materials for the construction of the sills. Prior experimentation utilized PVC-coated nylon bags hydraulically filled with sand. The alternate material to be tested was rock filled gabions. The PVC-coated nylon bags ("Durabag" marketed by Erosion Control, Inc., West Palm Beach, Florida) offer the advantage that they present no hazard to bathers transiting the beach. However, a contractor with an appropriate sand pump is generally required in the installation. In addition the sand bags are susceptible to damage from floating debris and ice. The gabions, constructed of PVC-coated heavy duty wire mesh (manufactured by Maccaferri Gabions, Inc.) and filled with rock or other materials, do present a hazard potential to bathers. On the other hand damage due to floating debris is minimized. Finally, gabions can be installed by the property owner without the use of heavy equipment.

Study Design. Site selection was based upon the need to achieve diversity among several factors:

1) Supply of sand from local erosion and the littoral drift system
2) Elevation and compostion of the fastland
3) Fetch distances
4) Presence and effectiveness of other erosion control

structures at or near the site

5) Applicability of the approach to other shoreline segments in the locality if the demonstration was successful

Specific sites within an area were chosen after review of the reach.

Eight areas were selected. These were (see Figure 2):

1) Saxis Island; Pocomoke Sound, bayside of the Eastern Shore, private property owners, Accomack County, Planning District 22.

2) Silver Beach, bayside of the Eastern Shore, several private property owners, Northampton County, Planning District 22.

3) Gloucester Point; north shore of the York River, state property, Gloucester County, Planning District 18.

4,5,6,7) Gwynn Island; confluence of the Piankatank River and Chesapeake Bay, several private property owners, Mathews County, Planning District 18.

8) Property of Mr. William Maynard; north shore of the Rappahannock River, private property, Lancaster County, Planning District 17.

9) Property of Mr. Eugene Dennis; south shore of the Potomac River, private property, Northumberland County, Planning District 17.

10) Town of Colonial Beach, Virginia; south shore of the Potomac River, private property, Northumberland County, Planning

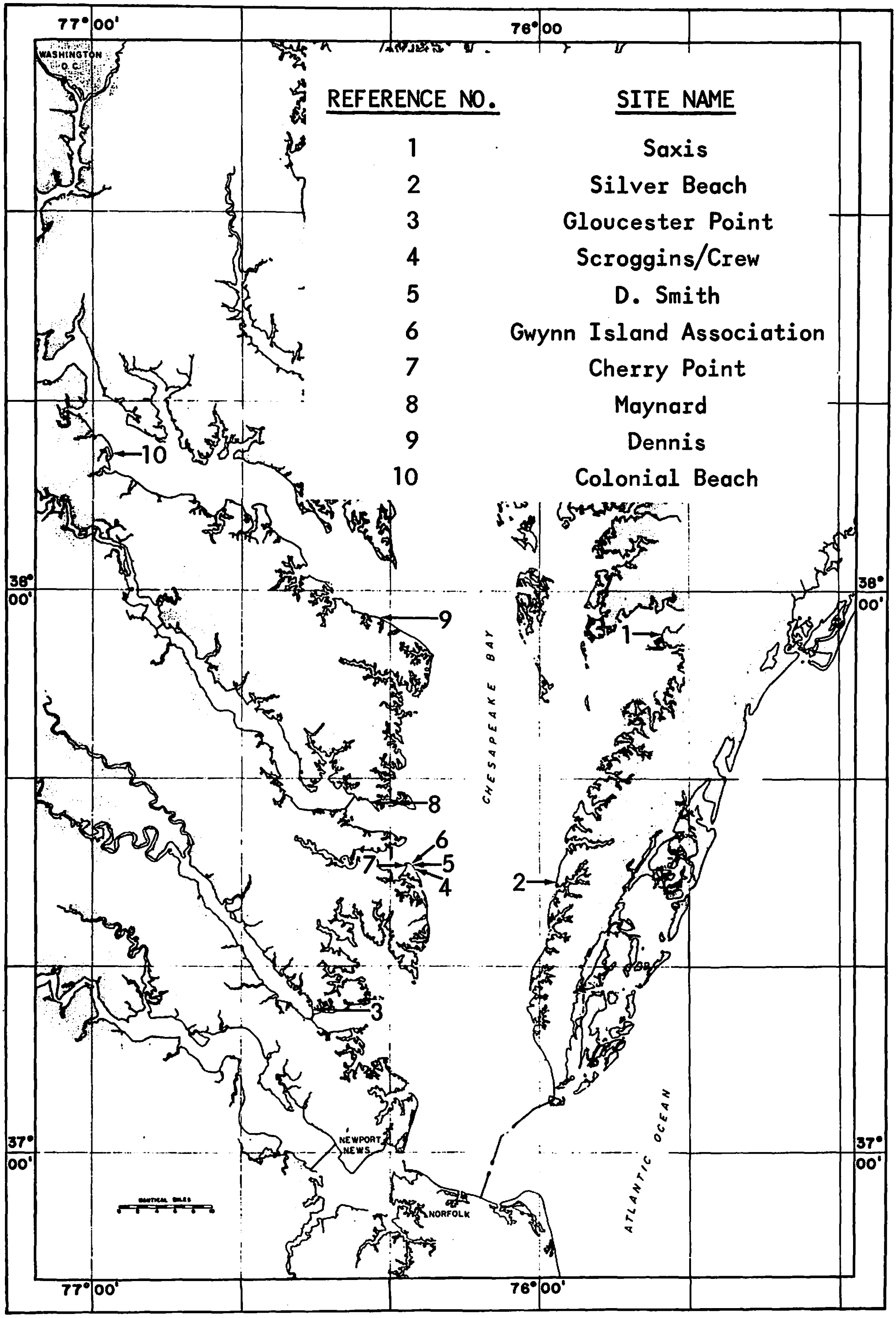


FIGURE 2. Site locations.

Distict 17.

11) Tangier Island; Accomack County, Commonwealth property, Planning District 22.

Saxis Island was chosen because the sand supply is quite limited due to the low elevation and solid characteristics of the eroding fastland. In this case, the perched beach was attempted to see whether the system could hold its own" once the perch was achieved.

Silver Beach, located on the bayside of the Eastern Shore, has been the subject of dramatic attempts to protect many homes and a roadway near a low bluff. The most recent attempt at stabilization was the installatin of a groin field. However, the severe ice conditions of the 1977 winter damaged many of the groins. A sill installation was proposed to test whether the sand trappaing ability of the groin system could be enhanced.

The two Gloucester Point sites are on the property of the Virginia Institute of Marine Science. One site proposed was to have a sill constructed from gabions filled with acrylic sand bags. The other site was to utilize a gabion spur to protect an existing groin undergoing flanking. The fill material for the gabion in this case was to be compacted automobile tires.

Gwynn Island in Mathews County offered the opportunity to test the proposed approaches in an area where extensive shoreline modifications exist due to bulkheading and groin fields. The sand supply from the littoral drift system is moderate to slight and this fact permitted a test under rather adverse conditions. Four experimental sites were selected at Gwynn Island. The treatments varied between sills with groins, sills alone, and spurs on groins.

The Scroggins/Crew site on Gwynn Island was selected because of the nonperformance of the existing structures and the vulnerable exposure to the northeast. A successful demonstration of the techniques selected could lead to the techniques being applied elsewhere in the area.

The Douglas Smith site provided the opportunity to use a different technique than those used at sites on either side. Although these adjacent structures are resisting erosion, they have not allowed the formation of a protective beach. This previously unprotected site would provide a good comparison to adjacent techniques.

The Gwynn Island Association (GIA) site offered a similar opportunity to the Douglas Smith site with the major difference being the nature of the fastland. The Gwynn Island Association site is backed by a small dune; while the Douglas Smith site is backed by a low clay fastland terrace. A successful demonstration at GIA would benefit all the members of the association without direct beach access.

The Maynard site was attractive because of the fastland characteristics and exposure. In addition a sill had been previously installed but it was showing a poor response. It was felt that the sill could be made to work with the addition of the experimental structures. The high bluff found at Maynard's extends throughout several miles of the Rappahannock River north shore.

The Dennis site was chosen because of the lack of adjacent structures, a large volume of sand in the littoral drift system and the extreme exposure to waves causing a high erosion rate.

Two sites representing different types of problems were selected at Colonial Beach. While in both cases public roadways were in jeopardy of being undermined the fastland elevation was dramatically different between the sites. The north Colonial Beach site was characterized by a high bluff with small sand supply and a very narrow, thin beach. The south Colonial Beach site along Irving Avenue is a selection which has a wide diversity of shoreline structures immediately fronting the roadway. Direct comparisons of three different approaches were planned. A successful demonstration would allow the extension of the best technique to other erosion plagued sections of south Colonial Beach.

Tangier Island was selected because of its extreme exposure, high erosion rate and the type of material being protected. The very long fetch from the NW makes Tangier Island very susceptible to wave erosion after passage of a cold front and after passage of an offshore low pressure area. The recent erosion rate for the west side of the island is in excess of 20 feet per year. The material to be protected was marsh with a very small frontal beach. Another selection reason was the nearness of the island's airport runway to the shoreline.

The project had $38,000 allotted for construction at the various sites. In order to reduce costs the installations at the Gloucester Point sites were to be performed by local manpower. The bids received for the remaining sites exceeded the allotted budget so the number of sites were reduced. Since the Tangier Island site was quite costly due to mobilization costs the decision was reached to drop that site. In addition, the north Colonial Beach site was dropped. Finally one of the Gloucester Point sites was dropped because the manufacturer of the acrylic sand bags failed to deliver the sewing machine required to seal the bags.

Methodology. The basic criterion used to assess the level of success of the installation at a particular site is the degree to which sand is trapped by the structure. More specifically the point of interest is the enhancement of the elevation of the backshore since that enhancement determines the degree to which the fastland proper is isolated from direct wave attack as the "storm" waves expend their energy on the beach.

The response of the system at each site was monitored by repetative surveys of a number of transects perpendicular to the shoreline. The number and location of transects was chosen so that the shore area fringing the "site" were included thereby permitting a comparison between the "treated" and "untreated" responses. The horizontal location of the transect origins were referenced to control points on the fastland. Vertical location for each transect origin was referenced to the same control points which were, in turn, referenced to the nearest permanent bench mark. An exception to this procedure was the Dennis site on the Potomac River where the control point was levelled to a mean tide level (MTL) tidal gauge datum at Hack Creek, approximately 2.8 miles down river from the Dennis site. The accuracy of the MTL is $\pm$ 0.1 ft. At those sites referenced to bench marks closure was considered acceptable if within $\pm$ 0.05 feet. The sites were tied into bench marks solely to establish a reference datum. Since the bench marks refer to a geodetic mean sea level (MSL) unconnected for sea level rise they should not be interpreted to approximate local mean tide level (MTL). To insure no confusion between the two the survey profiles are labeled as referenced to NGVD (National Geodetic Vertical Datum). In the course of conducting the surveys, estimated tidal data were observed and these were used in planning the location of structures and are occasionally used in the narrative of the response. Such designations are approximations.

In addition to the repetitive profiles ground level photographic recording was used. Periodic aerial photographic missions were flown, also, to document the regional response.

Beach sand sampling was undertaken on the mid-foreshore of the beaches prior to installation at each profile location. Samples were then split, weighed, and the sand (2 mm - .063 mm) fraction analyzed with a Rapid Sediment Analyzer. Descriptive terminology of grain size closely follows that of Wentworth (1922). A complete listing is offered in Appendix A.

Chronology of the Project. The following chronology outlines significant events as they occurred in the performance of the demonstration project. Several dates will include a discussion of decisions made at that time.

May 2, 1977 - Accomack County submitted the full proprosal for review by the Coastal Plains Regional Commission.

June 24, 1977 - In anticipation of immediate funding, profile lines at the sites were selected and first profiles were taken.

August 29, 1977 - Permit applications to the various agencies were submitted.

September 27, 1977 - The permits for the Gloucester Point and Maynard sites were received.

October 1, 1977 - CPRC notifies Accomack County that the demonstration project may begin.

October 14, 1977 - Severe "northeast" storm impacts the Chesapeake Bay.

October 17, 1977 - Silver Beach (P. C. Kellam) permits received.

December 12, 1977 - Douglas Smith permits received.

December 28, 1977 - Crew, Scroggins permits received.

January 18, 1978 - The request for construction proposals was published.

January 24, 1978 - Gwynn Island Property Owner's Association (GIA) and Cherry Point Property Owner's Association (CPA) permits received.

February 21, 1978 - Bids received in response to RFP were opened at 4:30 p.m. in the office of Mr. Walter Diggles, Business Manager, Virginia Institute of Marine Science. The following bids were received:

Coastal Erosion Control, Inc. (Mr. Morris)
all sites - 84,014.97
all sites; excluding Tangier Island - 53,307.97

Newington of Gloucester, Inc. (Mr. Shriver)
all sites - 64,095.00
all sites; excluding Tangier Island - 43,497.00

February 22, 1978 - After a review of the bid breakdowns by each contractor, it was decided to drop Tangier Island and Colonial beach North as sites.

At 10:30 a.m., Mr. Shriver was notified by phone that there was only $38,000 allotted to the construction budget. He was asked to consider completing the amended site list for the fixed price of $38,000.

At 10:45 a.m., Mr. Morris was notified by phone of the $38,000 allotment for construction. He was then asked to consider completing the amended site list for the fixed price of $38,000.

February 27, 1978 - Letters from Mr. Morris and Mr. Shriver were received stating whether or not they would complete the construction for the fixed price of $38,000. Both letters were opened at 10:45 a.m. Mr. Morris and Mr. Shriver each elected to construct the demonstration project for the fixed fee.

February 28, 1978 - Mr. Shriver was selected as the contractor for the project. The basis of this decision was his extensive local knowledge and his experience in installing gabion structures.

March 3, 1978 - Received Colonial Beach permits.

March 7, 1978 - Received Dennis permits.

March 21, 1978 - Gloucester Point West installation completed. Gloucester Point East installation was curtailed due to supply problems. A company which had agreed to loan the use of a portable sewing machine failed to supply that particular item.

April 18, 1978 - Maynard installation completed.

April 25, 1978 - Dennis installation completed.

April 26, 1978 - Major "northeaster" severely damages the shores of the Chesapeake Bay.

May 3, 1978 - Drewer-Dorn (Saxis) permit received.

May 5, 1978 - Douglas Smith installation completed.

May 9, 1978 - Gwynn Island Association installation completed.

May 10, 1978 - Cherry Point installation completed.

May 31, 1978 - Colonial Beach South installation completed.

June 10, 1978 - Drewer-Dorn (Saxis) installation completed.

June 12, 1978 - Silver Beach installation completed.

July 3, 1978 - Scroggins/Crew installation completed.

CHAPTER 3 SITE DESCRIPTIONS AND ANALYSES

SAXIS SITE

Easement:

Mr. Henry J. Dorn, 610 Nicholas Street, Frackville, Pennsylvania, 17931; and Mr. Vernon Drewer, Jr., Saxis, Virginia, 23427

Site Location:

Saxis, Accomack County, Eastern Shore, Virginia, on Pocomoke Sound, Chesapeake Bay.

Directions to Site:

From Temperanceville, Accomack County, take route 695 west for 10.1 miles into the town of Saxis. At the first four-corner intersection near the center of town turn right onto the gravel and dirt road. The site is located at the end of the road. Permission for access to the site is required from the owners.

Shoreline Physiography

Saxis Island is formed by a cap of sand overlying marsh at the tip of the extensive Freeschool Marsh in Pocomoke Sound (Fig. 3). The Town of Saxis is located on the topographic high of about 5 feet (MSL). The shoreline of Saxis which fronts Pocomoke Sound is about 9,000 feet in length. The Beach fronting the low fastland is composed of coarse to very coarse sand. Medium grain diameters varied from

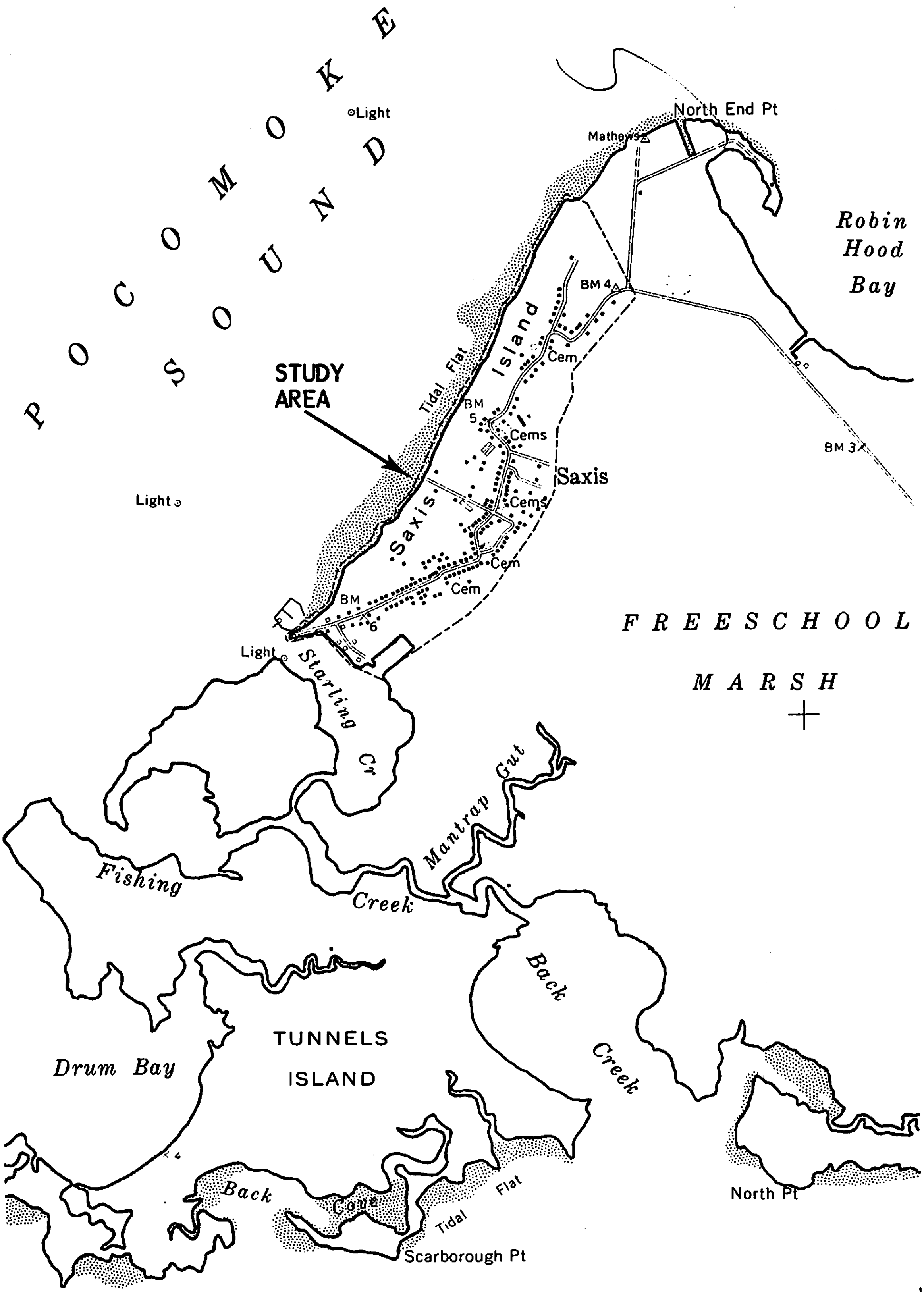


FIGURE 3. Saxis Site. From Saxis Quadrangle, Virginia-Maryland. Scale 1 inch = 2000 feet

0.52 mm to 1.59 mm among samples (see Appendix A) and mean gravel content was 40.4% by weight. Frontal erosion of the fastland appears to be the principal source of sand in the beach system. The beach is narrow and thin; in places the marsh peat erosion surface is exposed at the base of the foreshore. The average long term erosion rate is 4.9 feet per year (Byrne and Anderson, 1977). The shoreline morphology indicates that the direction of net littoral drift is to the northeast. This is consistent with the relatively long fetch to the southwest (Fig. 4) and the fact that the regional winds are from the southwest during the summer.

Aside from a limited amount of bulkheading at the southern and northern ends of the reach there were no erosion control structures at the start of the project. Although the higher density residential area is still several hundred feet from the shoreline several outlying residences are within the possible erosion zone over the next decade or two.

The fastland is densely vegetated. Reed grass is the dominant species with small trees, bushes, and short grass adding to the protective cover.

Structure Design

In circumstances such is found at Saxis the most reliable form of erosion control would be a continuous rock revetment or heavy duty bulkhead. This approach of course is very costly. One would predict that groins would have limited success due to the relatively scanty

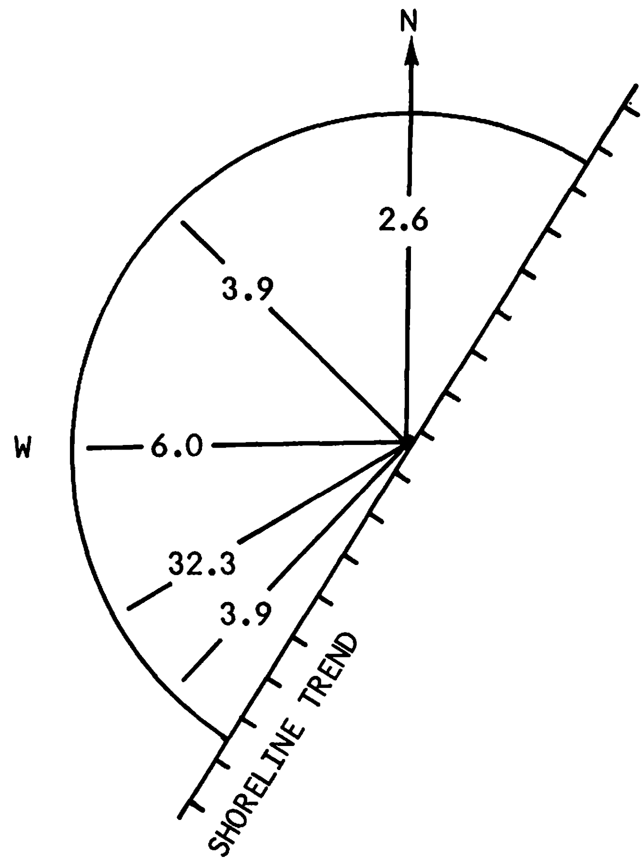


FIGURE 4. Fetch distances (nautical miles) at the Saxis site.

supply of sand in the littoral drift system. In such cases groins tend to be flanked fairly quickly and when in that condition the free standing remnants may locally increase the erosion rate as waves are redirected and focused by the structures.

The decision to attempt a perched beach at Saxis was based upon the desire to test the response under conditions of limited sand supply. In addition the perched beach allows by-passing across the beach face more readily than groins so down drift impacts may be expected to be less. The layout of the sill and the location of profile monitor transects are shown in plan in Figure 5. A 200 foot sill of alternating sandbags and stone filled gabions was installed parallel to the shoreline near the estimated mean low water line. Eight sandbags and eight gabions were used. The height of the filled bags and gabions is about 1.5 feet. A forty-foot return consisting of two sandbags and a gabion extends landward and perpindicular from the sill's northern end. The purpose of the return was to provide a partial blockage to the flow of sand. The purpose of the sill is to raise and widen the beach and thereby reduce the frequency of direct wave attack on the fastland edge. Alternating sandbags and gabions were used in the design so their relative longevity could be evaluated. Mean tide range is 2.2 feet.

Results and Effects

Installation of the gabion-bag sill was completed 10 June 1978. Plate 1 shows aerial views of the site in 1977 and one year later about two months after installation. An undulating accretion appears

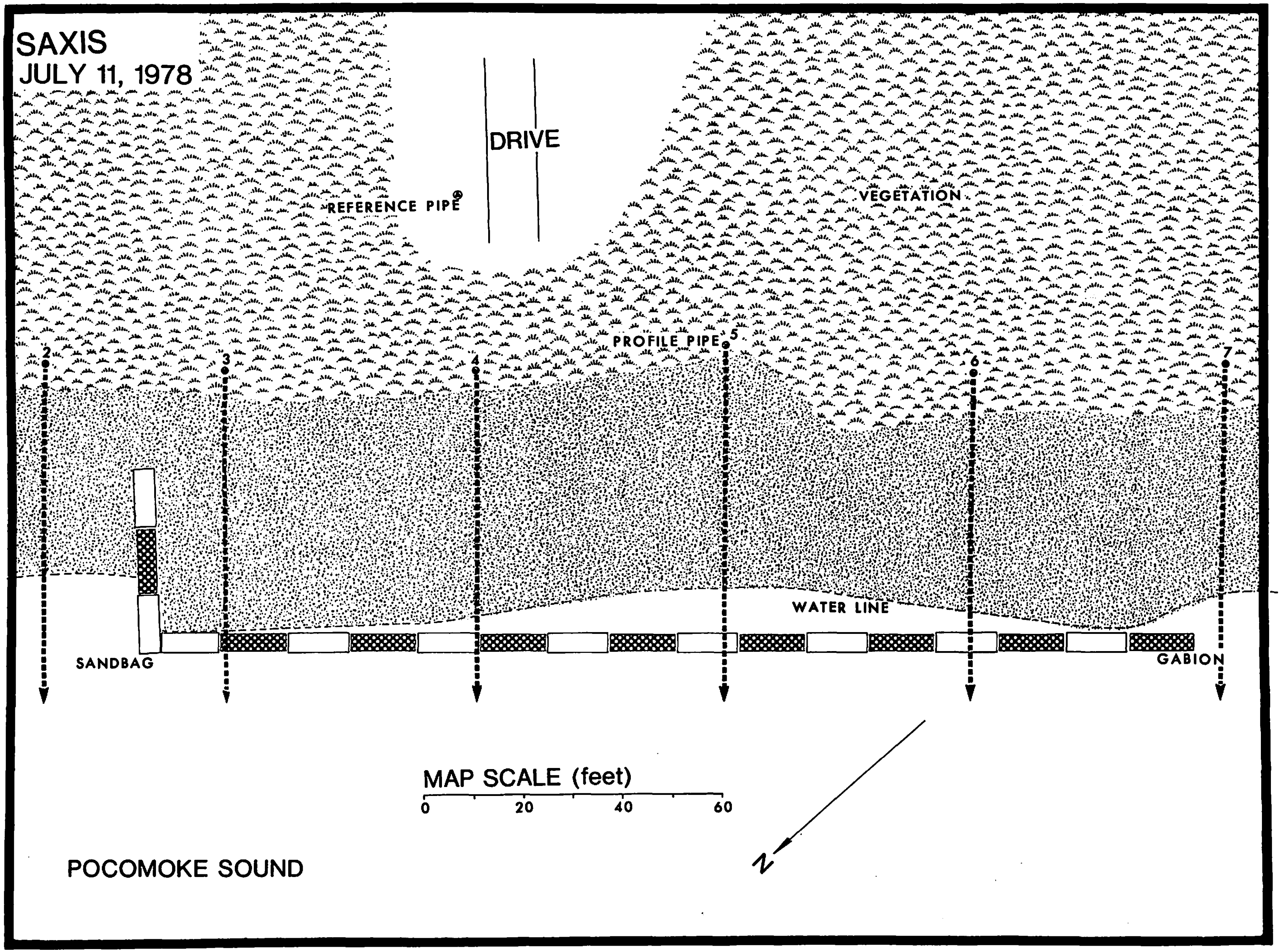


FIGURE 5. Plan view of the structure layout at the Saxis site.

to have formed behind the sill. Examination of the repetative surveys (shown in full in Appendix B) indicates that while accretion behind the sill was occurring there was a simultaneous diminution of sand volumes immediately to the north. The photographs of Plates 1B and 2A show this effect quite clearly. The effect is also documented in Figures 6A and 6B which show the comparative response of Lines 1 and 4. Line 1 (not shown in plan in Figure 5) is to the north of the sill while Line 4 is within the zone of the structure. This condition documents the northerly littoral drift during the summer and it represents the temporary diminution of sand supply to the downdrift beach while the sill fills. Profile Line 1, reflects the temporary decrease in sand supply by the retreating foreshore. During times of winds from northerly directions the littoral drift will tend to replace these volumes lost as material accretes against the return constructed at the north end of the sill. As of 26 July 1978 the results of Profile Line 1 show that the foreshore retreat has not resulted in erosion of the fastland. However, the downdrift foreshore retreat has extended for a considerable distance to the north. Far beyond in fact that which would be expected from a local response to the sill.

Since the post-installation monitor period was quite short and restricted to summer conditions, it is premature to predict the ultimate success of the installation. The early results do demonstrate that the sill is beginning to perch the beach. However, if over a period of a year or two the sill does result in lessened erosion rates of the zone intended for protection then the installation will be considered a success.

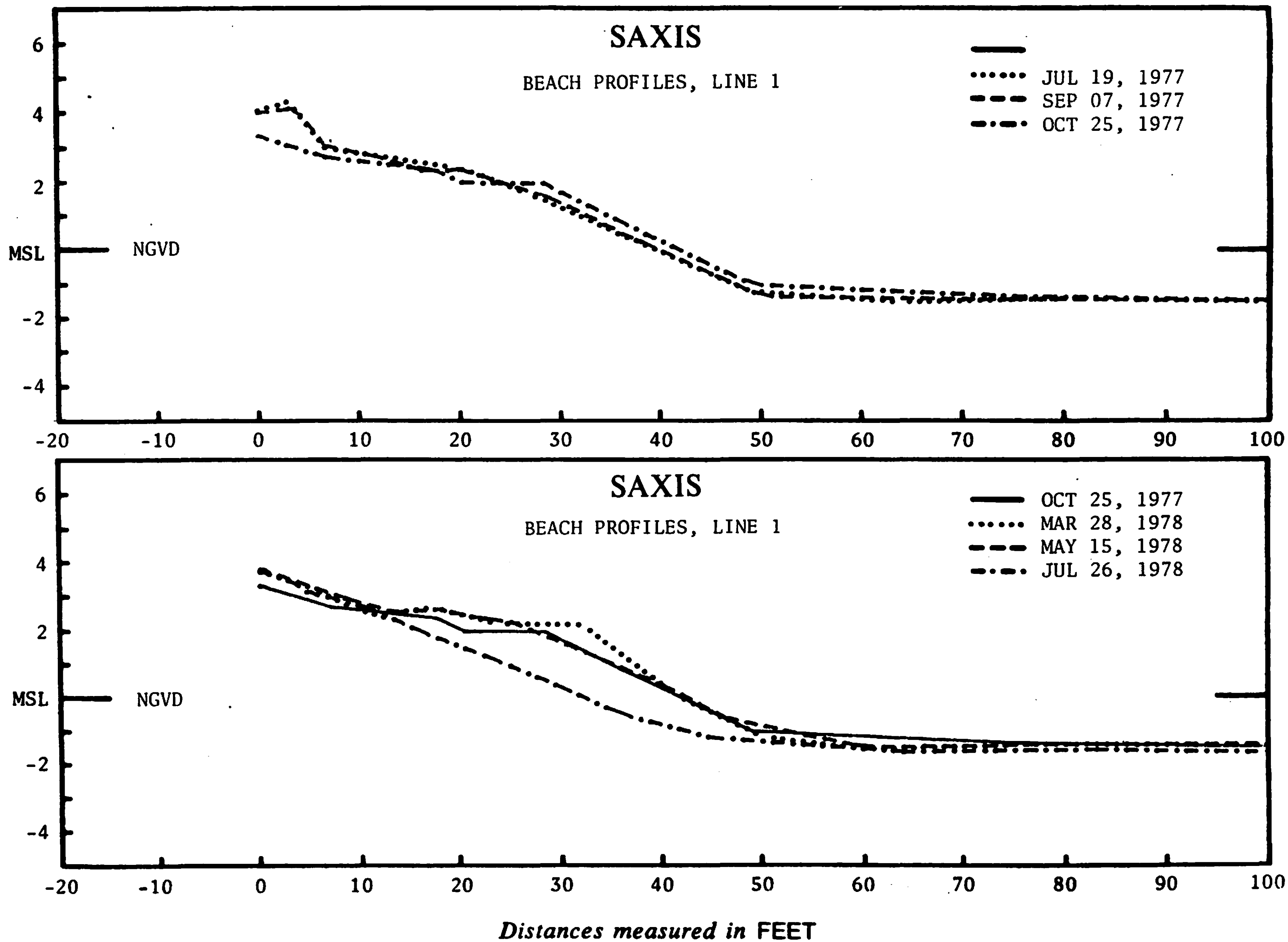


FIGURE 6A. Profile Line 1 at the Saxis site.

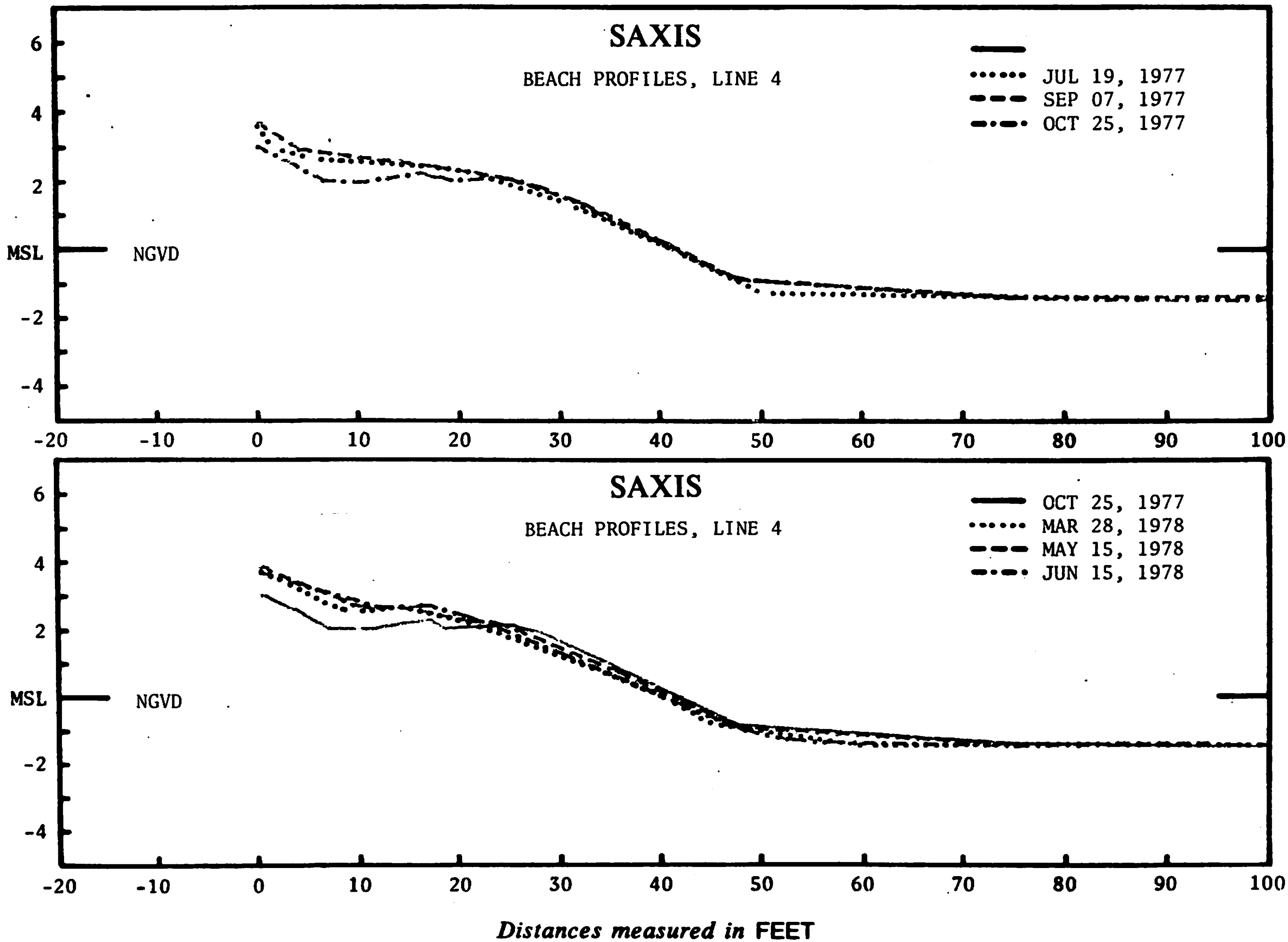


FIGURE 6B, Profile Line 4 at the Saxis site.

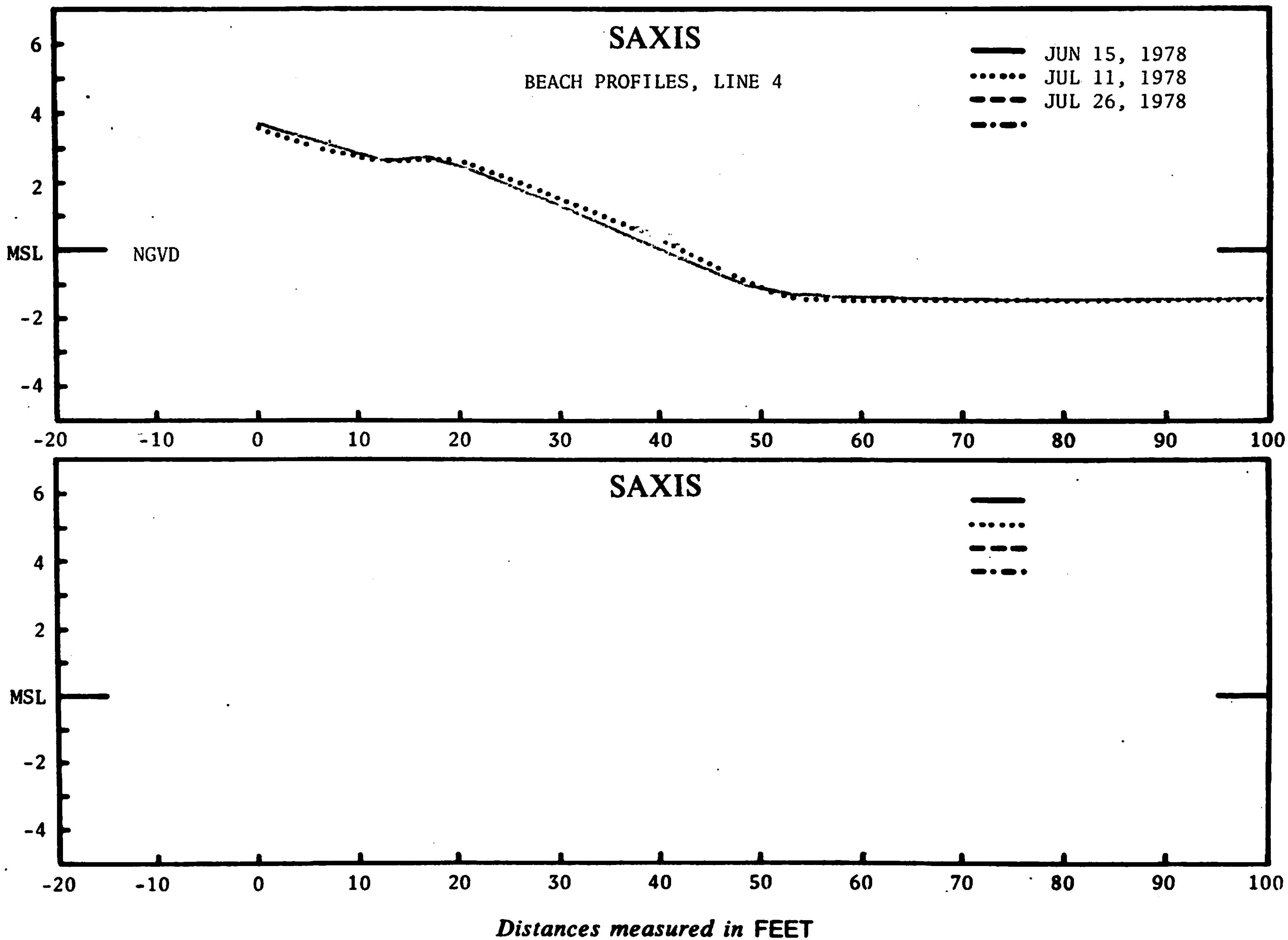


FIGURE 6B cont'd. Profile Line 4 at the Saxis site.

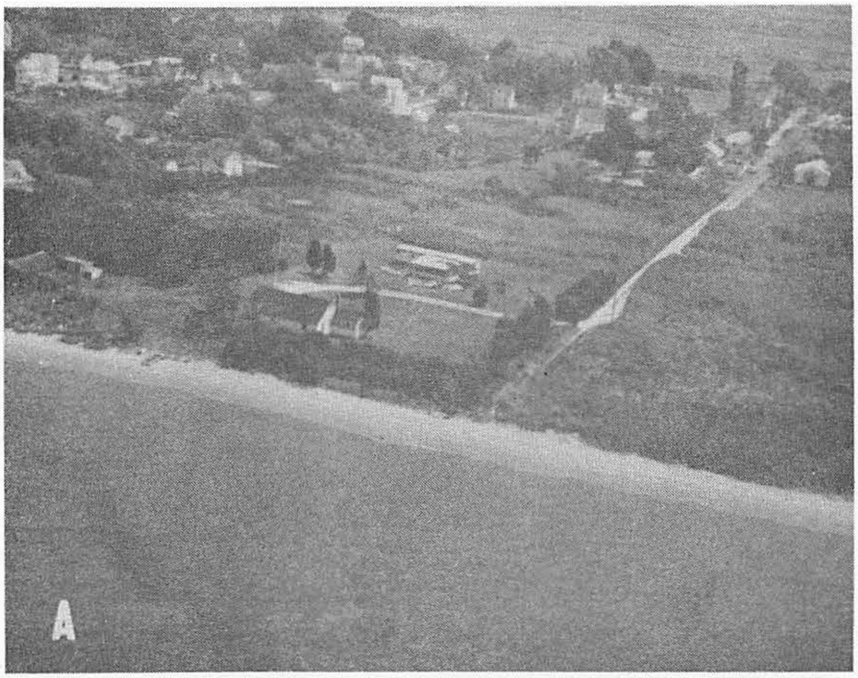
PLATE 1

A. SAXIS

This oblique aerial photograph illustrates the preinstallation site conditions on August 10, 1977 (North to the left).

B. SAXIS

This oblique aerial photograph of August 8, 1978 records the response of the sill system installed on June 10, 1978. The photograph reveals an apparent increase in the beach volume. It also illustrates the trend toward a net littoral transport to the north (left in this photo). (The illusion of a dramatic increase is enhanced by the retreat of the shore on the north side of the structure.) Profiles 3, 4, and 7 did register a net increase in volume.


A

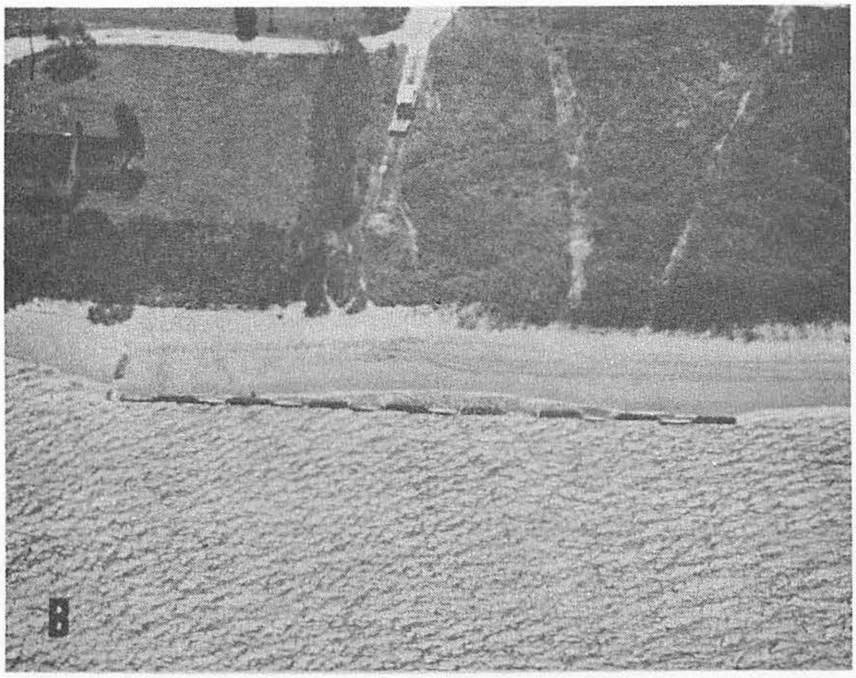

B

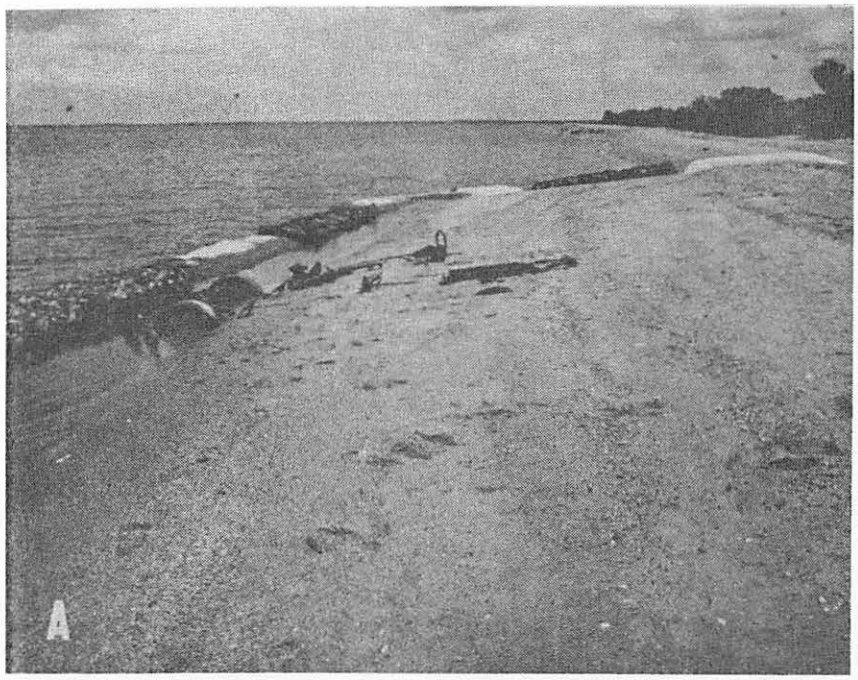
PLATE 2

A. SAXIS

A ground photograph of the beach conditions on July 26, 1978. The continued retreat of the beach to the north is very evident.

B. SAXIS

Looking south on July 26, 1978 the beach is approaching the structure and beginning to catch an updrift fillet of sand.



SILVER BEACH SITE

Easement:

Mr. P. C. Kellam, Exmore, Virginia 23350

Site Location:

Silver Beach, Northampton County, Eastern Shore, Virginia, on the eastern side of the Chesapeake Bay.

Directions to Site:

From Exmore, Northampton County, travel west to Silver Beach on Route 613. At Silver Beach, turn right onto Route 686. The site is located 0.3 mile further on the right. Permission for access is required from the landowner.

Shoreline Physiography

Silver Beach is a shoreline segment of approximately 4,000 feet at the southern end of Occohannock Neck in Northampton County (Figure 2 and Figure 7). The Chesapeake Bay shoreline of Occahannock Neck is about 5.3 miles in length. This entire reach is exposed to long fetch from the north to the south (Figure 8). Since Silver Beach is in the southern one-fifth of the reach the supply of littoral drift from the north far exceeds that from the south. Thus, the important wind events in moving sand into the area are those cases when the winds are from the north, northwest, and, to a lesser extent, from the west. These occasions generally embody conditions following the

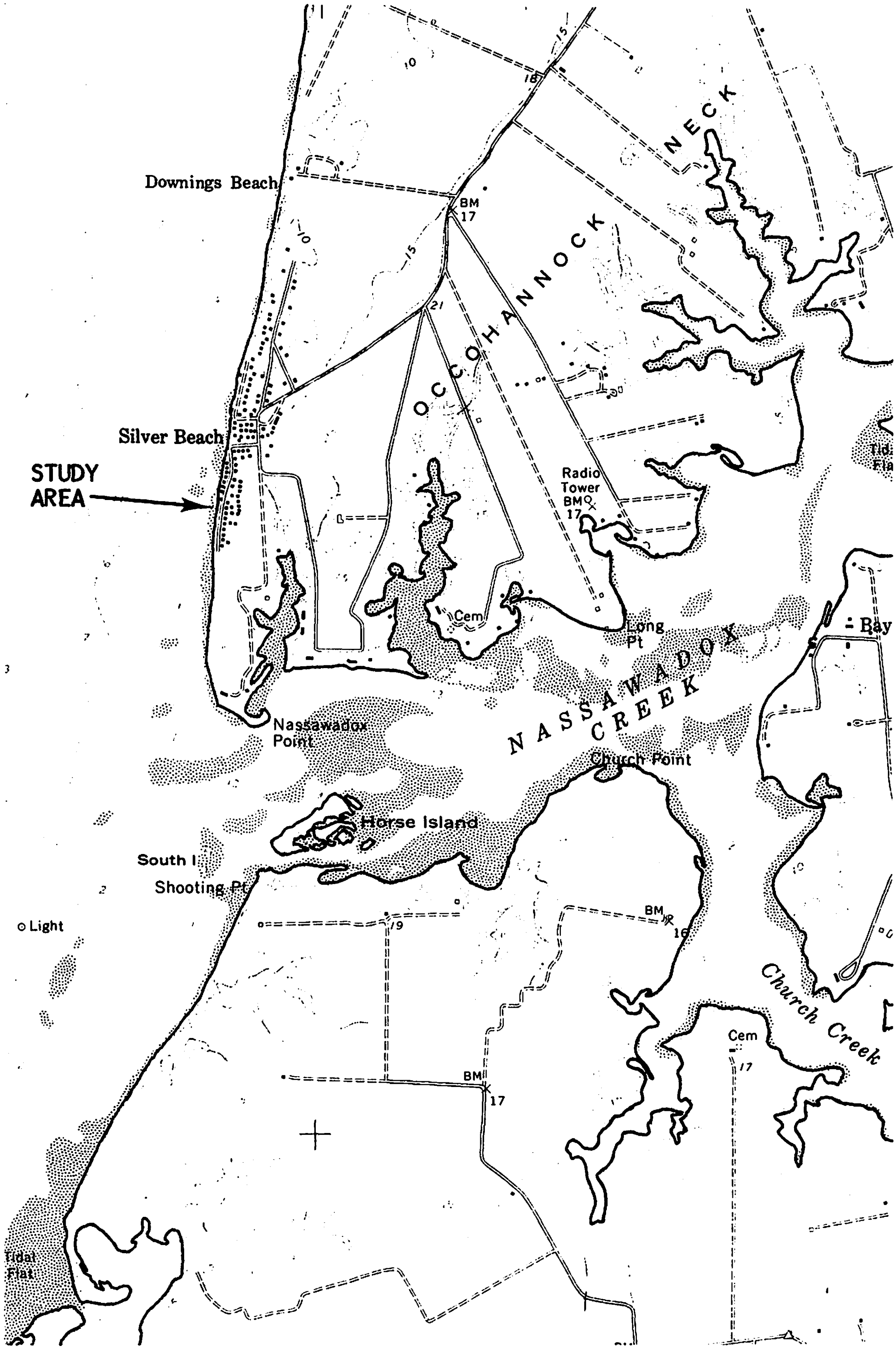


FIGURE 7. Silver Beach site. From Franktown Quadrangle.
Scale 1 inch = 2000 feet

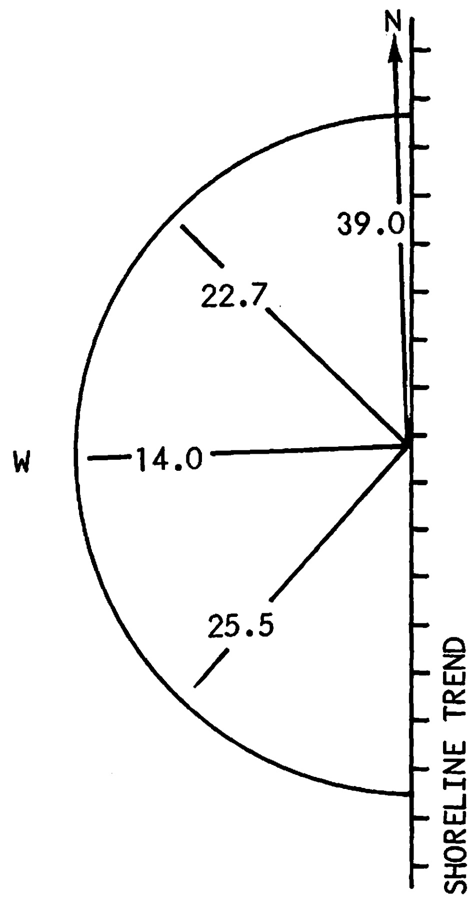


FIGURE 8. Fetch distances (nautical miles) at the Silver Beach site.

passage of low pressure cells (northeasters) and are characterized by strong winds from the northwest with accompanying wind set-up. Thus, these are the erosional events in the annual wind wave climate. Silver Beach receives only limited sand supply under the less severe wave conditions induced by southwest winds. The beach material is fine sand (median diameters ranged from 0.16 to 0.75 mm).

The fastland at Silver Beach is a bluff about 20 feet high. The average long-term (100 year) erosion rate for the lower 9,700 feet of the Occohannock Neck shoreline was 5.7 feet/year (Byrne and Anderson, 1977). In recent decades numerous attempts have been made to stabilize the fastland which include placing construction rubble on the bluff slope, bulkheads of various kinds, and groins of various construction. The Silver Beach history exemplifies the case of non-integrated design and construction. However, in 1976 a coordinated attempt was followed with the installation of high profile groins. Unfortunately the extreme ice conditions of 1977 severely damaged the groin field. Several residences and the road servicing these homes (Route 686) are in jeopardy.

Structure Design

The site is 300 feet in length and the location was chosen so that, if successful, it would offer additional protection to the service road paralleling the beach. A plan view is shown in Figure 9. Within the site area there are five groins with various levels of damage. The toe of the bluff is stabilized by a four foot high wooden

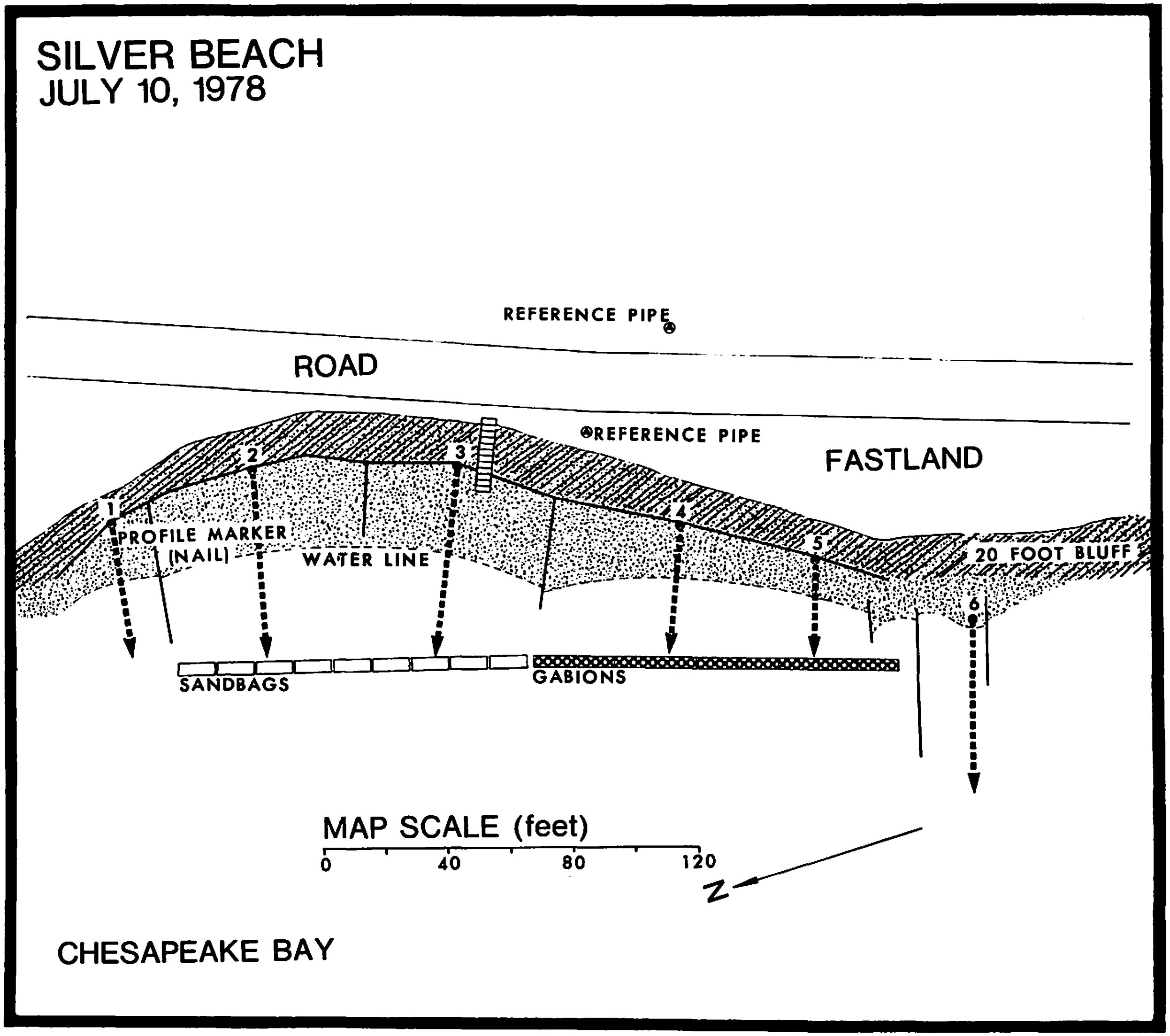


FIGURE 9. Plan view of the structure layout at the Silver Beach site.

bulkhead in disrepair. The principal function of the bulkhead is to act as toe stabilization for light weight riprap which faces the bluff.

The sill at Silver Beach is composed of two sections, 100 feet of sandbags and a 115 foot section formed by 9 gabions (each 12' x 3' x 1.5'). The sill was placed near the low water line and was located with the intention of enhancing the sand trapping characteristics of the remaining groin sections. If successful the combined structures would provide a wider and higher sand wedge to protect the bluff and toe bulkhead. In addition recreational use would be enhanced by increasing the beach width and by covering the rubble found on the beach.

The mean tide range in the area is 1.7 feet.

Results and Effects

The installation was completed on 12 June 1978. During the relatively short monitoring time between installation and this report preparation, accretion was noticeable in the deepest part of the indentation of the shore (Figure 9). This response is shown in Plates 3 and 4 and in Profile Line 3 (Figure 10). At Profile Line 3 the beach berm had advanced approximately 10 feet by 10 July. Although Profiles Lines 4 and 5 (see Appendix B) did not show as much advance some accretion did occur as shown in Plate 5. In contrast to the profiles within the treated zone, Profile 6, located just south of the site, showed essentially no change in the berm position during the same period (Figure 11).

While the post-installation elapsed time has been too short to pronounce the site treatment a success the early response has shown promise. The expectation is that the indented shore area will experience the greatest filling and the least modulation in sand volume through time.

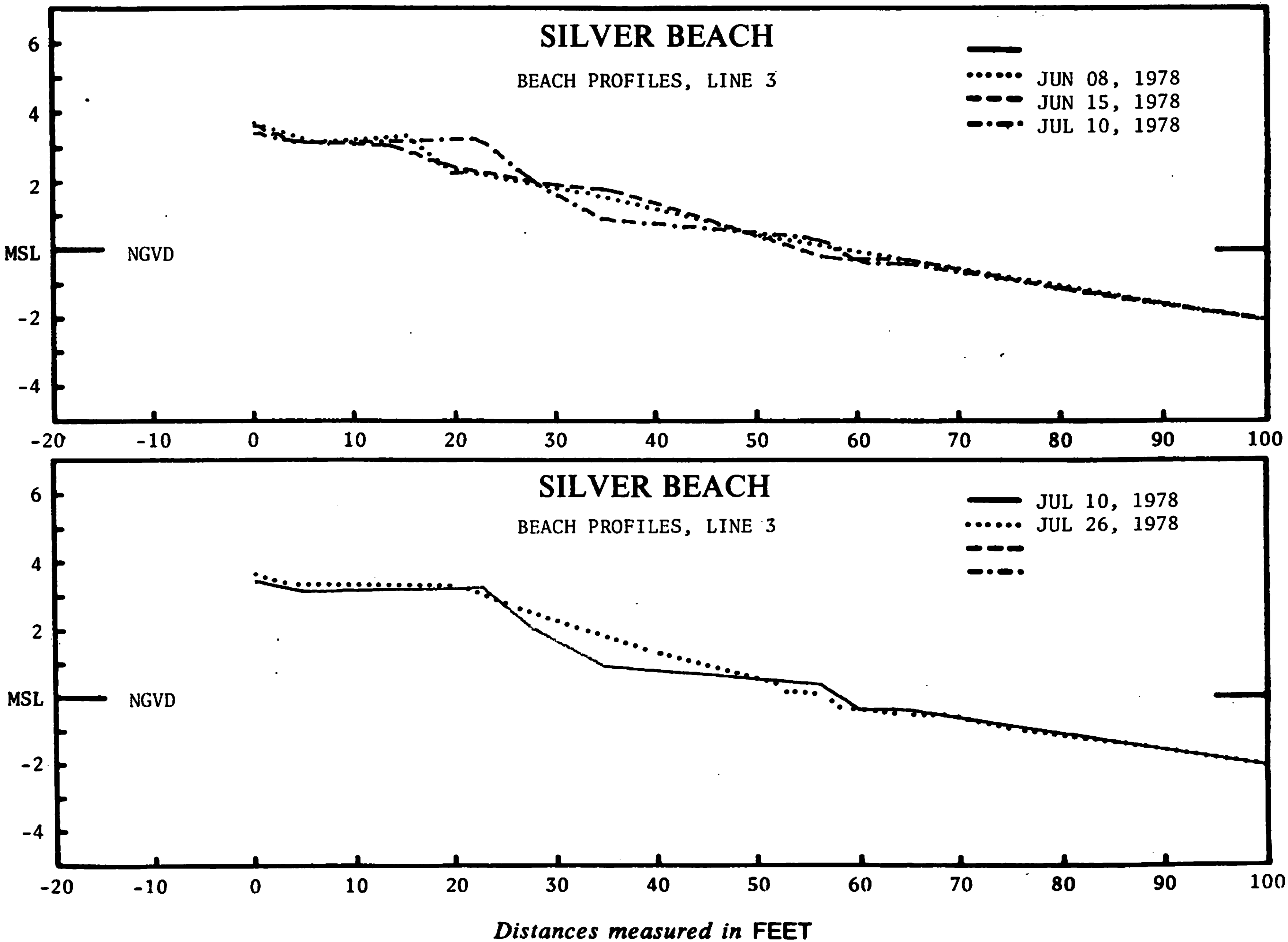


FIGURE 10. Profile Line 3 at the Silver Beach site.

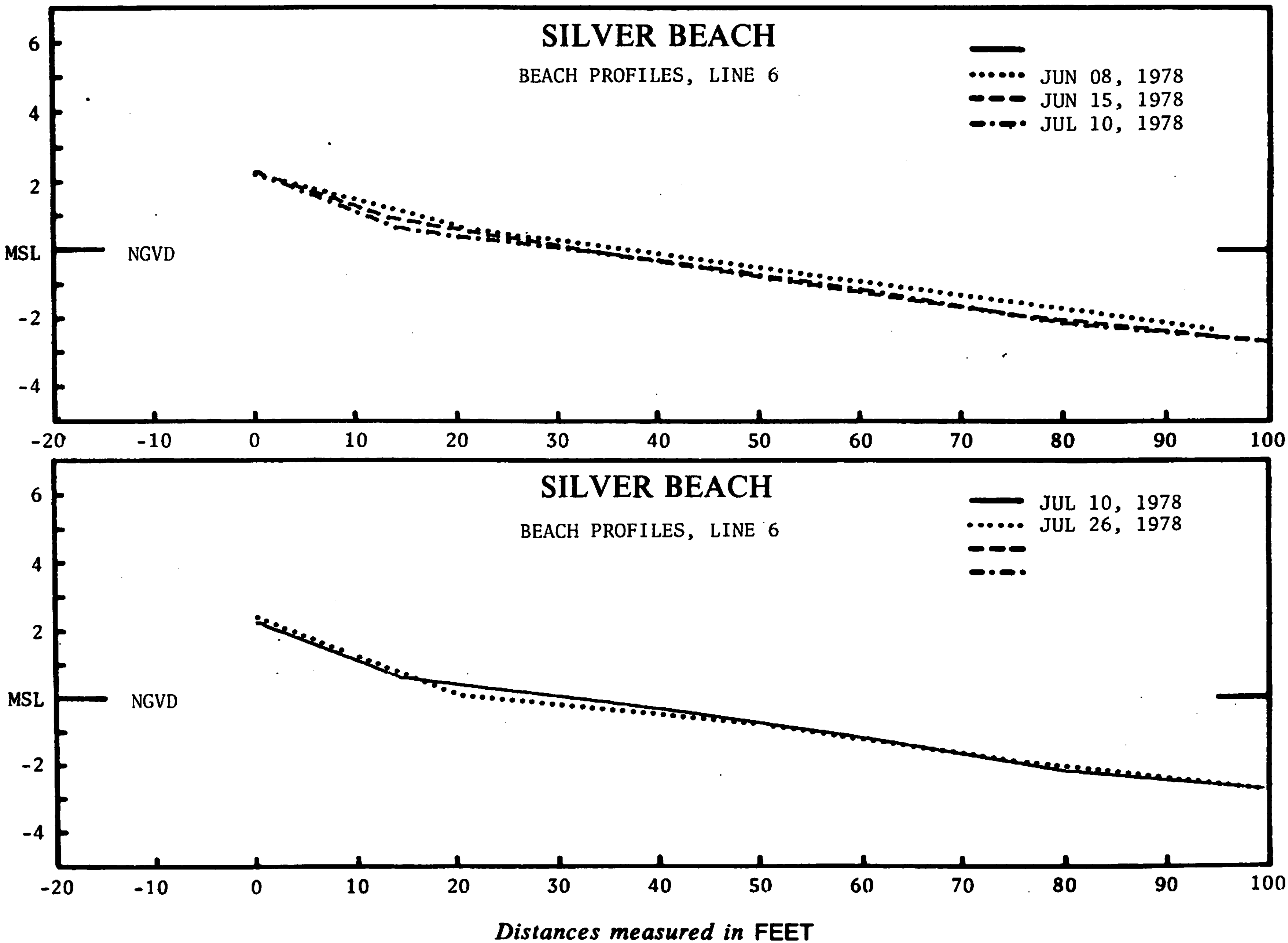


FIGURE 11. Profile Line 6 at the Silver Beach site.

PLATE 3

A. SILVER BEACH

This north looking ground photo from atop the bluff shows the preinstallation beach conditions on June 8, 1978. Note the deterioration of the bayward end of the groins.

B. SILVER BEACH

After the installation of the sandbag sill on June 12, 1978, the beach had increased in volume as recorded in this photograph of July 26, 1978. Of particular interest is the accretion of sand around the short groin in the center of the site.


A

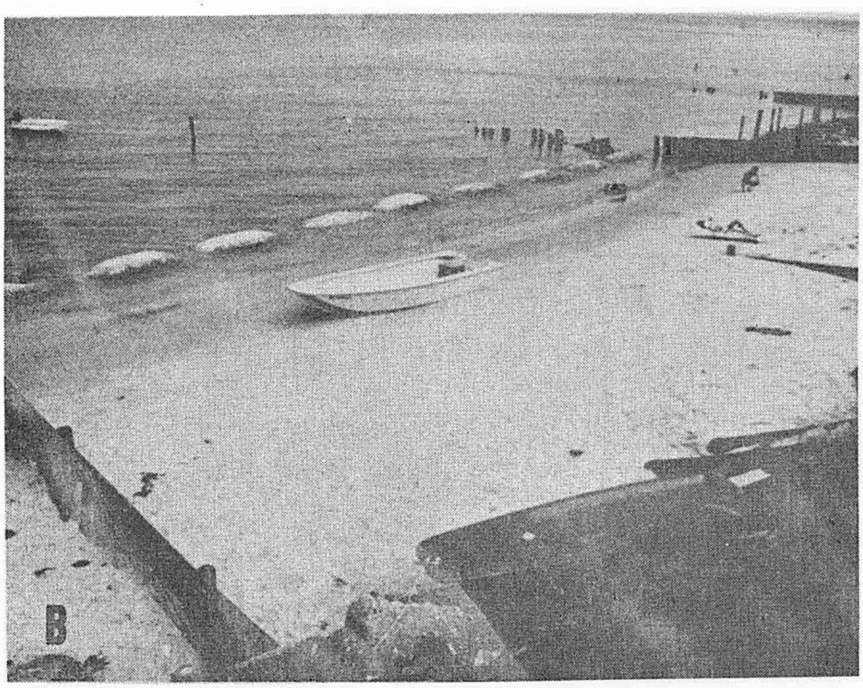

B

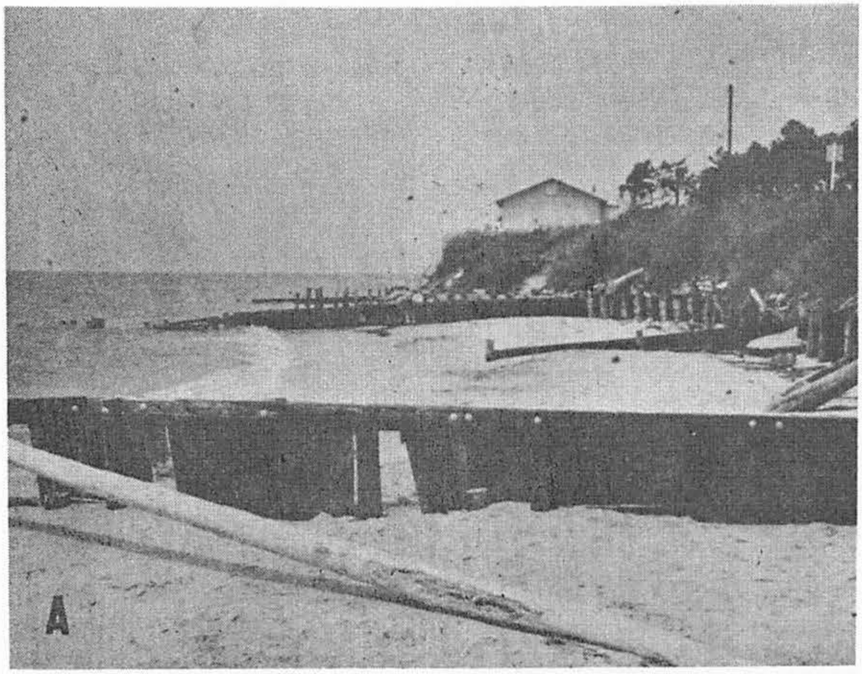
PLATE 4

A. SILVER BEACH

The preinstallation conditions of the sandbag sill section are recorded in this photograph of June 8, 1978. The cottage on the bluff edge is typical of the erosional conditions at Silver Beach.

B. SILVER BEACH

On July 26, 1978, the backshore of the beach had widened and had elevated. This is apparent when comparing sand levels adjacent to the short middle groin. In addition, the berm has translated bayward approximatley 10 feet.


A

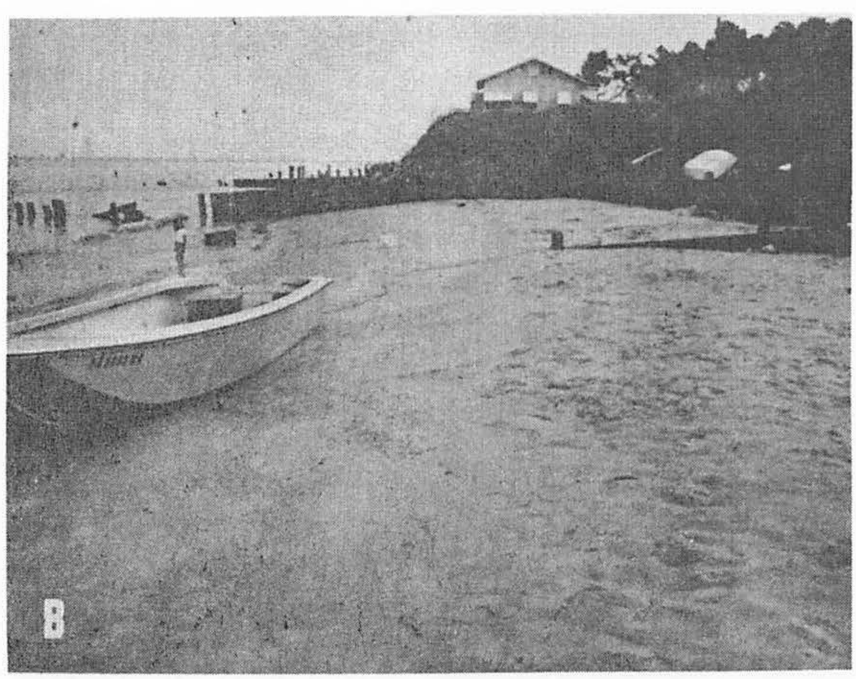

B

PLATE 5

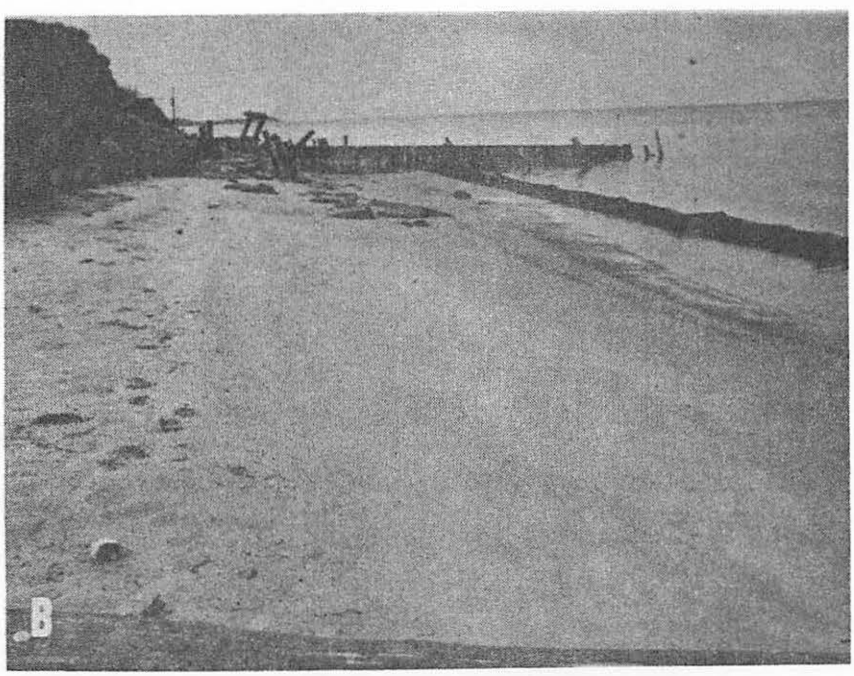
A. SILVER BEACH

This southward looking preinstallation photograph of June 8, 1978 illustrates various erosion control attempts by the landowners. The debris behind the low wooden bulkhead, broken groins and rubble on the beach are particularly noteworthy.

B. SILVER BEACH

This July 26, 1978 southward looking photograph demonstrates the beginning of accretion in the test cell. Sand is beginning to accumulate behind the gabion sill and starting to bury the rubble on the beach.


A


B

GLOUCESTER POINT SITE

Site Location:

Virginia Institute of Marine Science, Gloucester Point, Gloucester County, Virginia, on the northern shore of the York River.

Directions to Site:

From Yorktown, York County, take Route 17 north across the York River via the George P. Coleman Bridge. Immediately after crossing the bridge, turn right. Drive to the next intersection and turn right. At the base of the hill, veer to the right and go underneath the bridge. The site is located on the west site of the point on the York River between two wooden groins. The site is accessible without permission.

Shoreline Physiography

Gloucester Point is a low sand terrace formed on the north side of the York River by the convergence of littoral drift and tidal currents (Figure 12). East of the point the sand is forced toward the west under the combined influence of wave action from the east and flood tidal currents. West of the point the shoreline responds to wind waves from the northwest as they come down the axis of the York River and refract against the shoreline (Figure 13). In addition the ebb tidal currents sweep along the shallows along the north side of the river entraining sand toward the convergence at Gloucester Point.

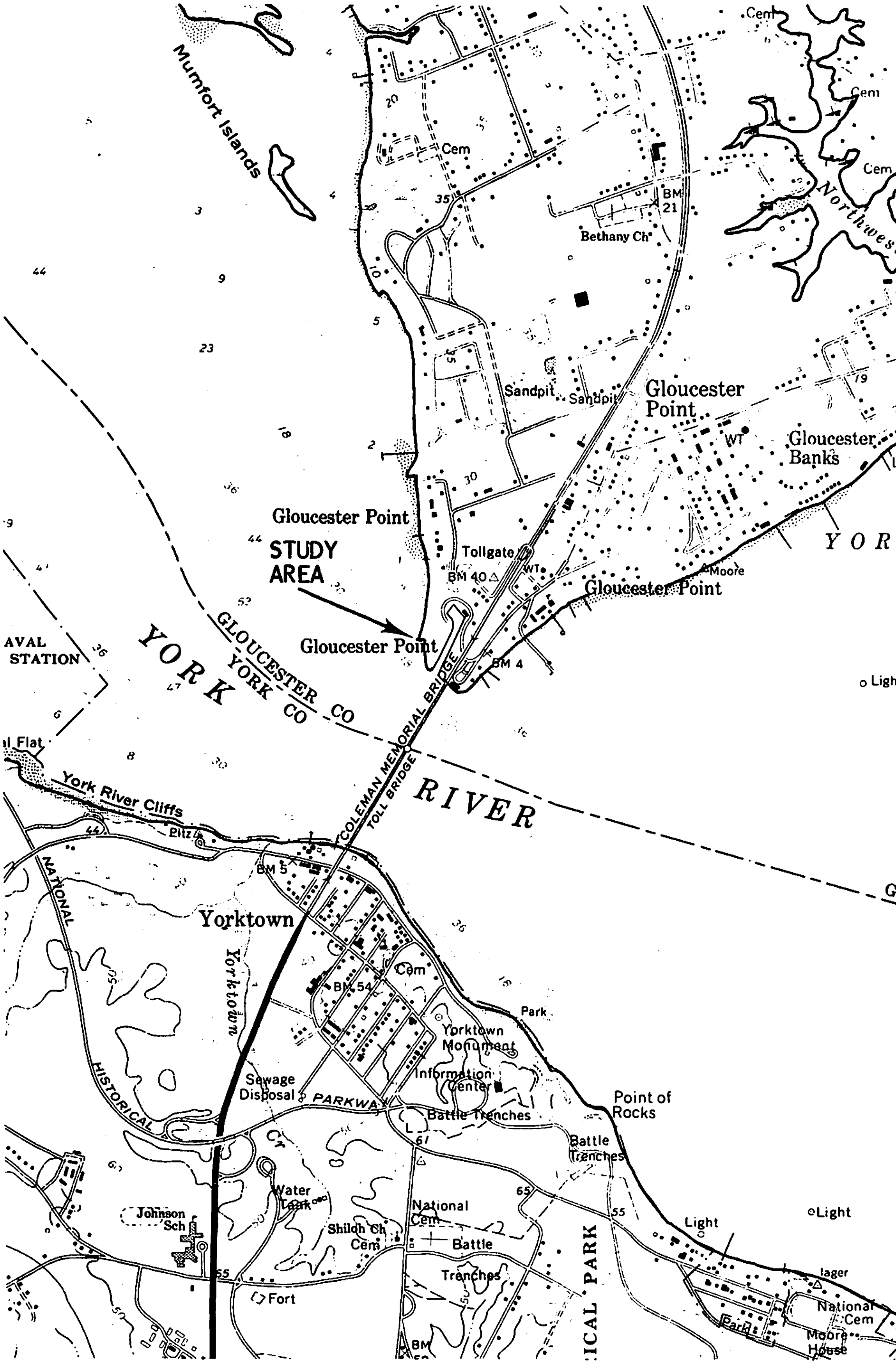


FIGURE 12. Gloucester Point Site. From Achilles, Clay Bank, Poquoson West, and Yorktown Quadrangles. Scale 1 inch = 2000 feet

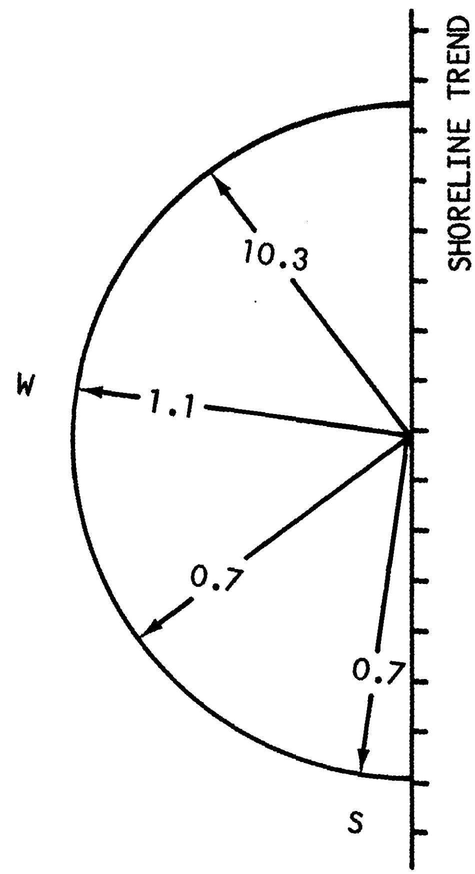


FIGURE 13. Fetch distances (nautical miles) at the Gloucester Point site.

The shorelines of this region are also subject to considerable boat wake activity from commercial freighters and Naval vessels using the U. S. Navy facilities on the York River.

The fastland at the point is a low (4 to 5 feet) vegetated sand terrace. The foreshore sands are fine to medium in grain sizes (0.26 to 0.74 mm median sizes). The historical erosion was less that 1 foot per year prior to stabilization. Three long groins were installed in the past to retard the sand drift into a small boat harbor which had been dredged into the terrace (Figure 12). These groins, about 120 feet in length, intercepted the easterly moving littoral drift and very pronounced sand fillets accumulated on the west (upriver) sides. Since these are high profile groins sand by-passing occurs only around their tips rather than overpassing the tops as well. As a consequence the by-passing sand has formed shoals at the tips rather than circulate the sand back to the foreshore drift system. The downdrift offset had progressed to the point where the landward ends of the groins had become isolated. The groins have not failed because the fillet caught on the updrift side (west) is so large and has become stabilized. Nevertheless the notching of the fastland was increasing so that ultimate failure could be expected.

Structure Design

The groins at Gloucester Point offered an ideal circumstance to test the efficacy of the spur concept in controlling the development of the erosion notch. The site plan is shown in Figure 14. The plan

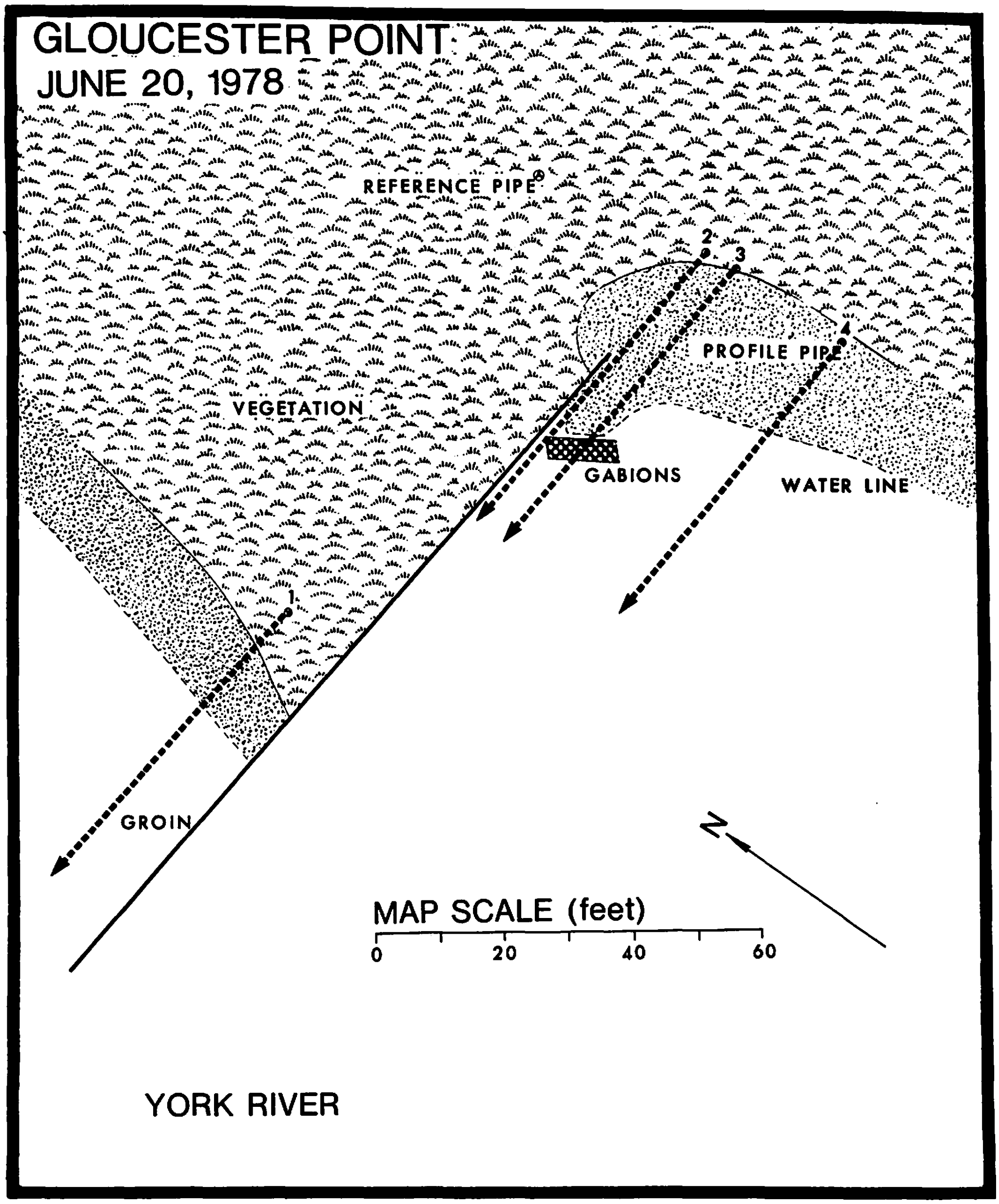


FIGURE 14. Plan view of the structure layout at the Gloucester Point site.

involved the placement of two gabions, each 6' x 3' x 3', tied together to form a spur near the low water line on the downdrift side of the groins. As explained earlier wave diffraction at the tip of the gabion would then force sand into the erosion notch and protect it from failure. In addition to testing the spur concept we had the opportunity to test the possibility of using expended tire casings as fill material. Tire casings are relatively chemically inert in the marine environments and they may offer the opportunity to utilize a waste product toward the erosion control goal. Approximately 130 rubber tires were compacted into two bundles of 65 tires each and bound together with 1 1/4 inch steel bands by the International Baler Corporation (Mr. John Laudis, vice president) of Jacksonville, Florida, and shipped to VIMS. Each bundle weighed about 1600 pounds in air. On 21 March, 1978 the bales were manually loaded into two gabions and crane-lifted to the site. Soon after installation the bands on one of the bundles were intentionally broken while the remaining bundle broke free of the bands due to corrosion approximately 18 weeks later.

Results and Effects

Two results warrant discussion; the effect of the spur on accretion in the downdrift erosion notch and the response of compacted tires used as gabion fill materials. The effect of the spur was to increase the sand volumes in the previous erosion notch. This is reflected in Profile Line 2 (Figure 15) where a steady increase of materials occurred between April 5, 1978 (installation 21 March 1978) and 24 August 1978. Profiles Lines 3 and 4 also show accumulations that exceed the summer beach accretion of the previous year (see profiles in Appendix B). Further illustration of the accretion is shown in Plates 6 and 7. Thus, this installation can be considered a success in spite of the relatively short monitor time. The response was immediate and the wave climate conditions are such that no reversal in behavior can be expected.

When the bands restraining the tires broke, the gabions underwent some deformation but with no apparent weakening of the structure. To avoid deformation a new compacting design may be appropriate. For the present case whole tires were compacted on the central axis so when the bands broke the interlaced ensemble of tires expanded in one direction. The gabion cross-section is square so the tire expansion tended to increase the width of the gabion and decrease its height. Another possibility would be to use stacked half tires which are sliced in the plane of the casing. This would reduce the tendency for expansion when the bands corroded. In addition a greater unit weight would be achieved. This greater unit weight might circumvent the problem encounted during the storm of 26 April 1978 when the gabions were rotated forty degrees landward by the strong wave action refracting east around Gloucester Point. This site demonstrates the potential worth of using expended tire casings as fill for gabions. However, further testing is needed with split tires which will reduce the post-binding failure expansion and which will increase the unit weight within the gabion.

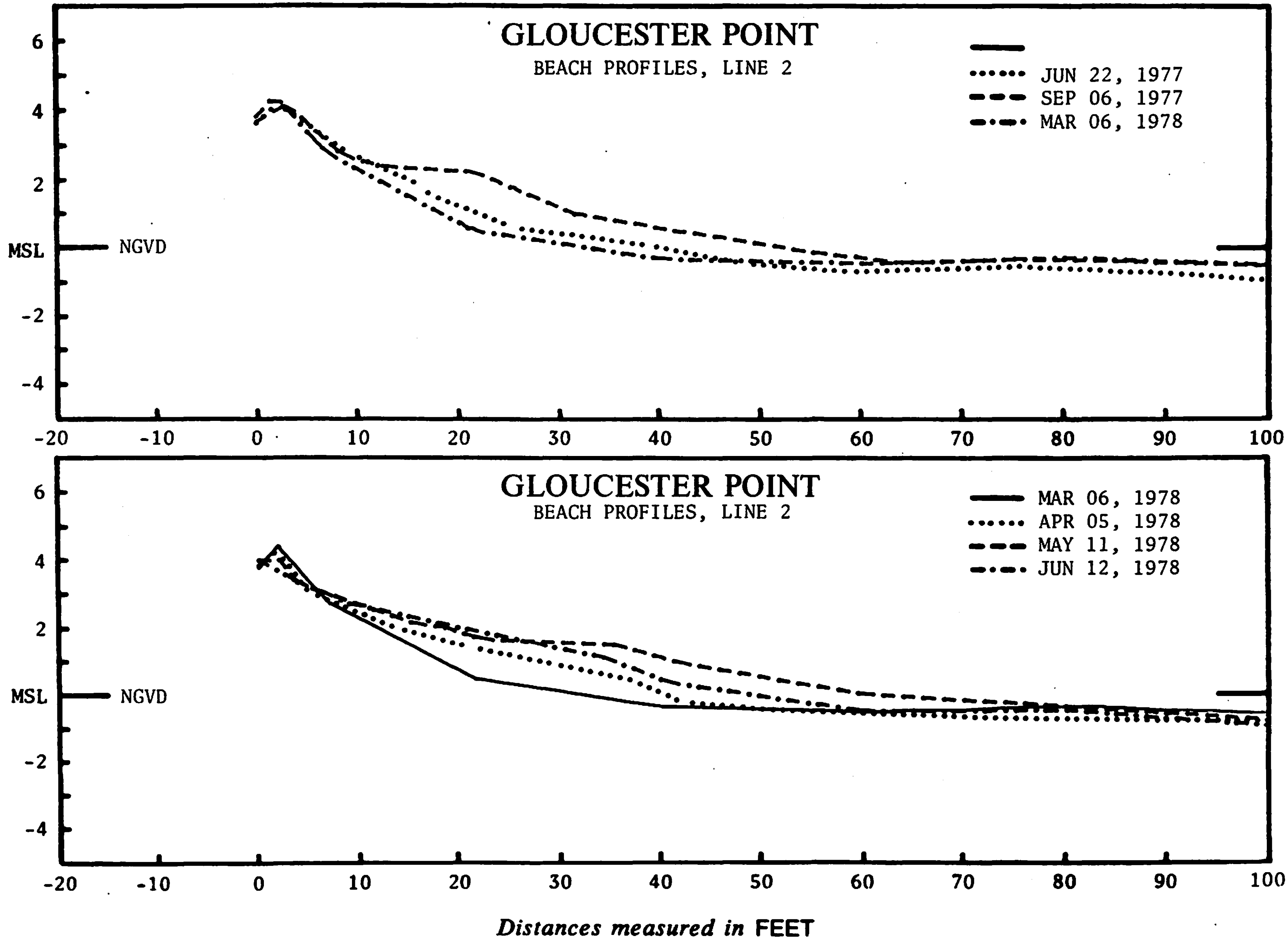


FIGURE 15. Profile Line 2 at the Gloucester Point site.

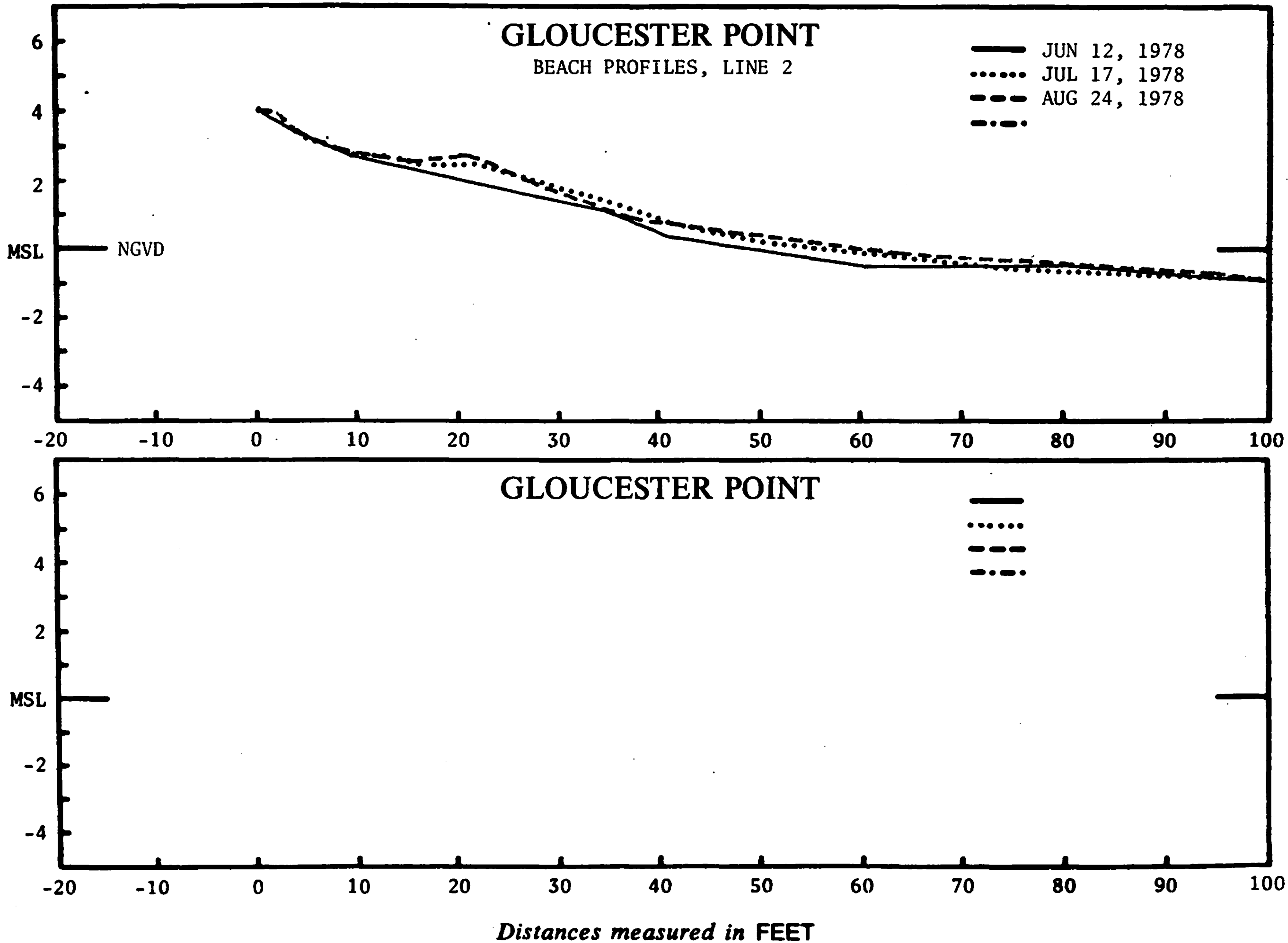


FIGURE 15 cont'd. Profile Line 2 at the Gloucester Point site.

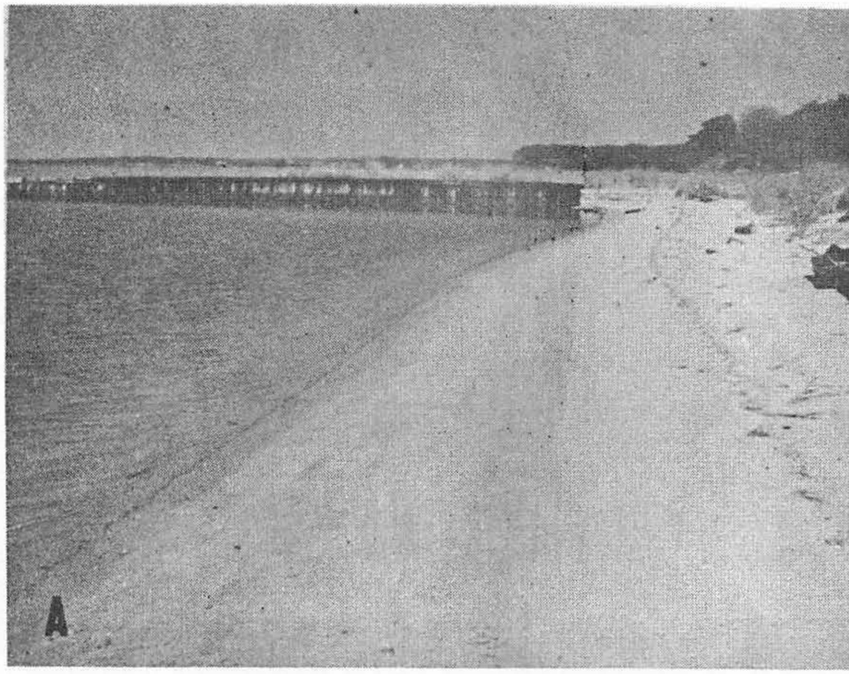
PLATE 6

A. GLOUCESTER POINT

The preinstallation conditions of March 15, 1978 are recorded in this photograph. The large groin is beginning to be flanked. Note the "erosion notch" present in the vacinity of the flank.

B. GLOUCESTER POINT

On March 21, 1978, two gabions filled with compacted automobile tires were installed as a spur. This March 23, 1978 photo illustrates the diffracting effect that the spoiler has on approaching waves.



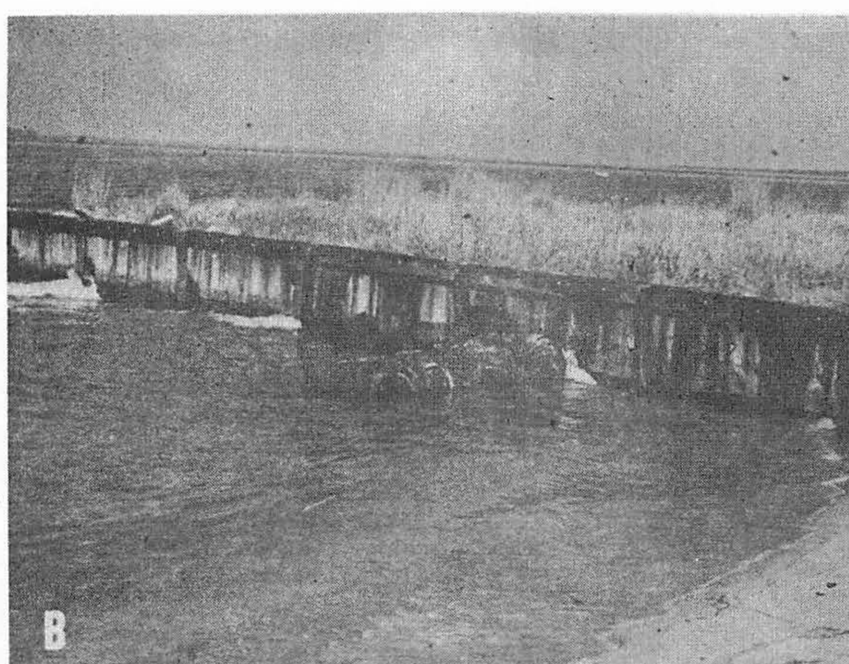


PLATE 7

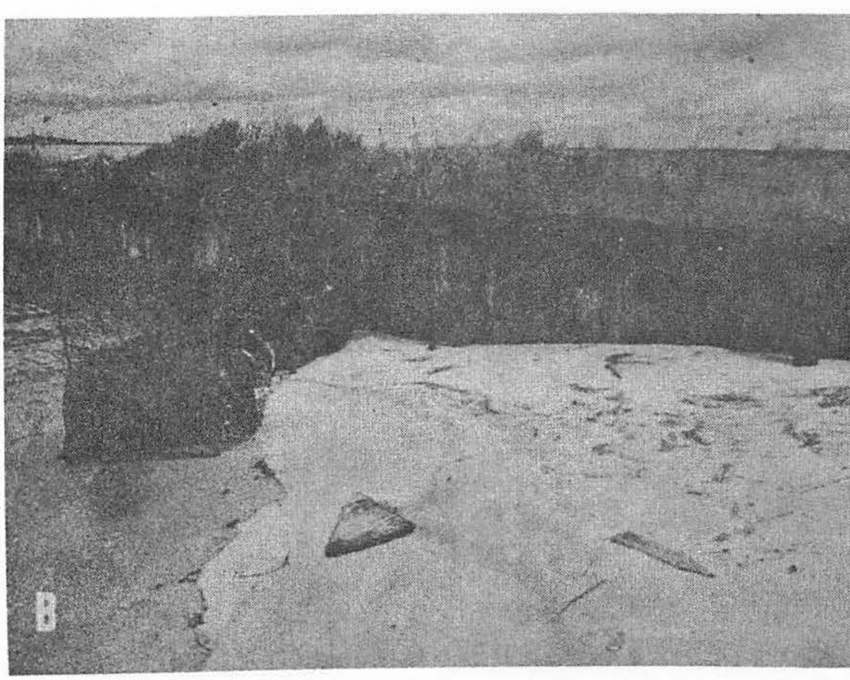
A. GLOUCESTER POINT

As illustrated in this photograph of April 20, 1978, the beach has accreted to the position of the spoiler filling the erosion notch. Of particular interest is the increase in backshore elevation and width of the foreshore.

B. GLOUCESTER POINT

The beach on June 7, 1978 had continued to widen and heighten accreting to half the diameter of the tires. Note the 40 degree rotation of the spoiler. This rotation occurred during the April 26, 1978 "Northeaster".


A


B

GWYNN ISLAND SITES

Four sites were selected on Gwynn Island:

1) Scroggins/Crew
2) D. Smith
3) Gwynn Island Association
4) Cherry Point

Gwynn Island, located in Mathews County, is bordered on the west by the Piankatank River and on the east by the Chesapeake Bay (Figure 16).

To reach Gwynn Island from Mathews Courthouse use Route 198 north to Hudgins, then turn right at Hudgins onto Route 223 and proceed to Gwynn Island. After crossing the bridge to Gwynn Island, Route 223 changes to Route 633.

Shoreline Physiography of Gwynn Island

The four sites named above are located in the northern most one-quarter of the Chesapeake Bay shoreline of Gwynn Island ending with the region adjacent to Cherry Point. Since these sites are subject to the wave driven processes acting along the frontage facing Chesapeake Bay a discussion of the shoreline processes along this side of the island is warranted. The total length of that shoreline is about 22,000 feet (4.17 statute miles). Inspection of the shoreline morphology shows that sand, derived from shoreline erosion, is driven both to the north and south. However the angle of the shoreline

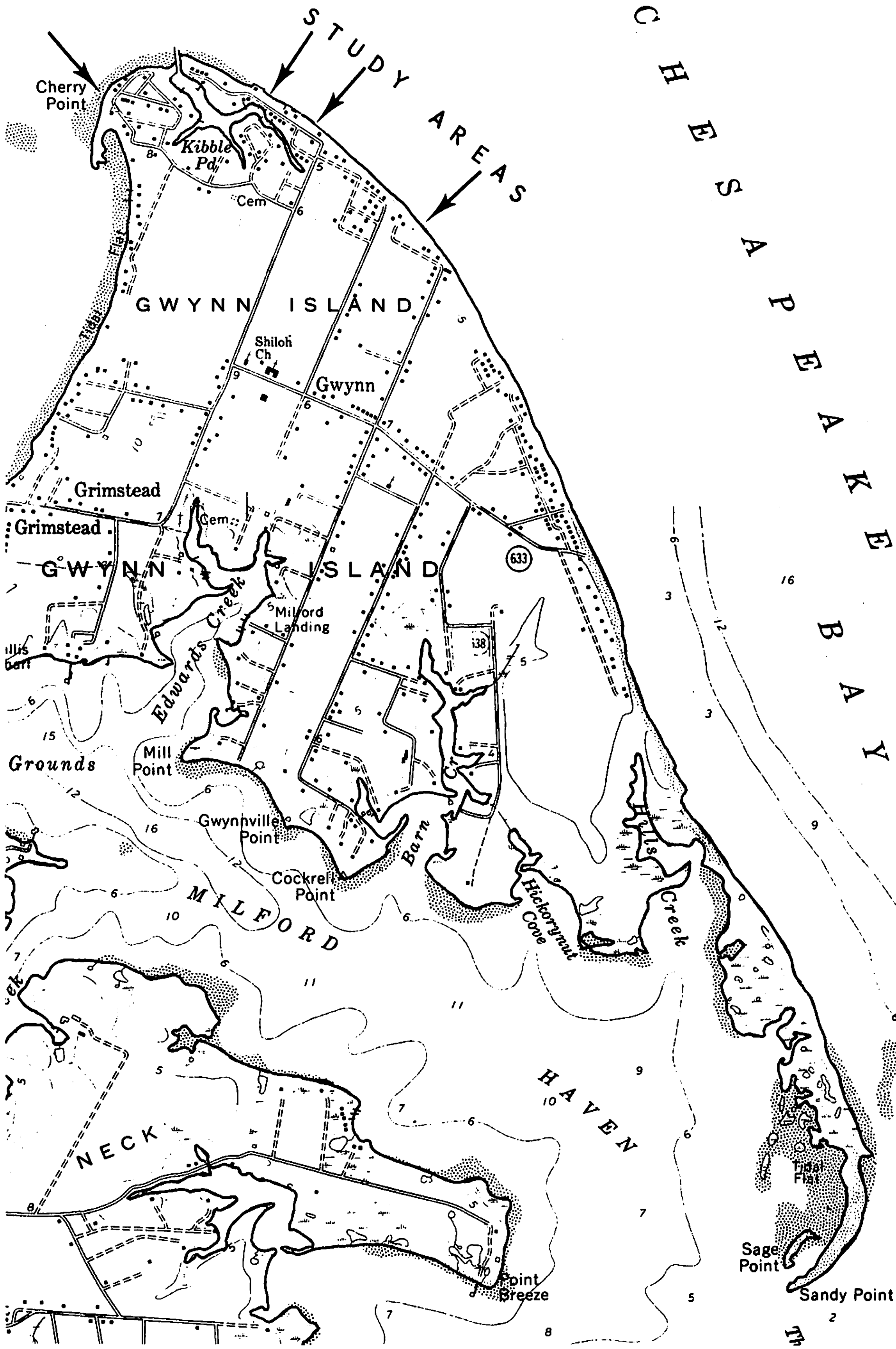


FIGURE 16. The four Gwynn Island sites; clockwise, Cherry Point, Gwynn Island Association, D. Smith, and Scroggins/Crew. From Deltaville and Mathews Quadrangles.
Scale 1 inch = 2000 feet

relative to offshore contours indicates that the northern part of the island finds its principal sand supply from the northern one half of the island. Thus, the sand supply to the sites in question must be considered limited. The historical erosion rate between 1850-1950 is 7.1 feet/year between Cherry Point and Sandy Point. This rate is based on a time period prior to most of the attempts to control erosion in the northern quarter of the island. Since erosion control strategies implicitly embody the reduction in sand supply via erosion it is predictable that those strategies based upon trapping sand will become less successful as the sand source, induced by erosion, becomes diminished. The direction of net littoral drift at the sites is to the northwest.

The fastland of Gwynn Island is low lying (about 5 feet MSL) so a unit distance of retreat supplies little sand to the system in terms of volume. In the northern one-third of Gwynn Island about 30% of the shore has been stabilized with little or no beach at high tide (mean tide range is about 1.2 feet). Four sites were selected in the northern quarter of Gwynn Island with a view toward testing whether the sill and/or spur application could improve sand trapping under conditions of limited sand supply or when the site was subject to signficant influence of structures in adjacent properties.

SCROGGINS/CREW SITE

Easement:

Mr. William F. Scroggins, P.O. Box 472, Gwynn, Virginia, 23066 and Mr. Randolph and Vicki S. Crew, 2802 Oakland Avenue, Richmond, Virginia 23228.

Site Location:

Gwynn Island, Mathews, Virginia, on the Chesapeake Bay.

Directions to Site:

From Hudgins in Mathews County, travel east to Gwynn Island on route 223. Route 223 changes to route 633 at the bridge connecting the island to the mainland. Continue on route 633 for 2 miles and then turn left just passed the post office onto route 636. Go to the end of route 636 and turn left onto the dirt road. the site is about 0.1 mile on the right. There is a sign saying "Eden" denoting the proper drive. Permission for access is required from the landowners.

Shoreline Physiography

The Scroggins/Crew site is a low shore area with fastland elevation less than 5 feet. The fastland is stabilized with a wooden bulkhead, 4 feet high, and two groins, 80 and 50 feet in length. Plate 8A illustrates site conditions on 10 August, 1977. The purpose of the groins is to trap sand in front of the bulkhead in order to isolate it from direct wave attack and possible undermining. This combination of structures is frequently used when the region is subject to long fetch distances (Figure 17). The bulkhead shown in Plate 8A was destroyed in the northeast storm of 26 April 1978. The level of damage is illustrated in Plate 10A as is the reconstruction phase.

The beach was composed of medium to coarse sand with median diameter ranging from 0.30 to 1.20 mm. There is no vegetation on the beach.

Structure Design

In this case the goal was to test whether the application of spurs with the groins would enhance the sand trapping characteristic of the system. The plan layout of the spurs is shown in Figure 18. Four spurs made from sand bags and gabions were installed. Two of these, on the inside of the groin cell, where each composed of three units; two gabions (12' x 3' x 1.5') and one sandbag. The third spur is a single sandbag off the northern groin. This set of three spurs were installed in an attempt to maintain a beach in front of the existing bulkhead.

The fourth spur is a single gabion placed on the backshore perpendicular to the southern corner wall of the bulkhead (at Profile Line 2 in Figure 18). It was installed to prevent flanking of the bulkhead at junction with the fastland during storm conditions.

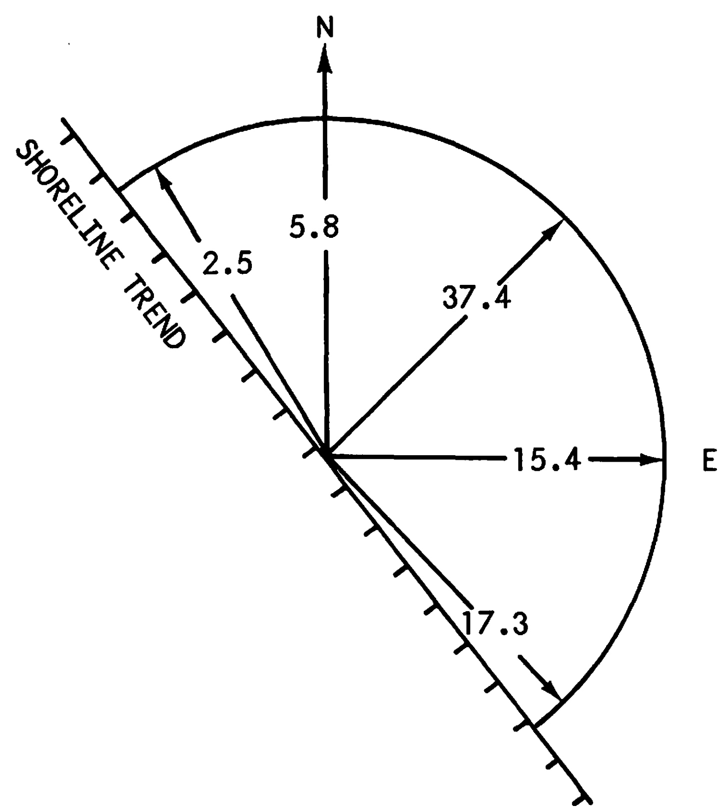


FIGURE 17. Fetch distances (nautical miles) at the Scroggins/Crew site.

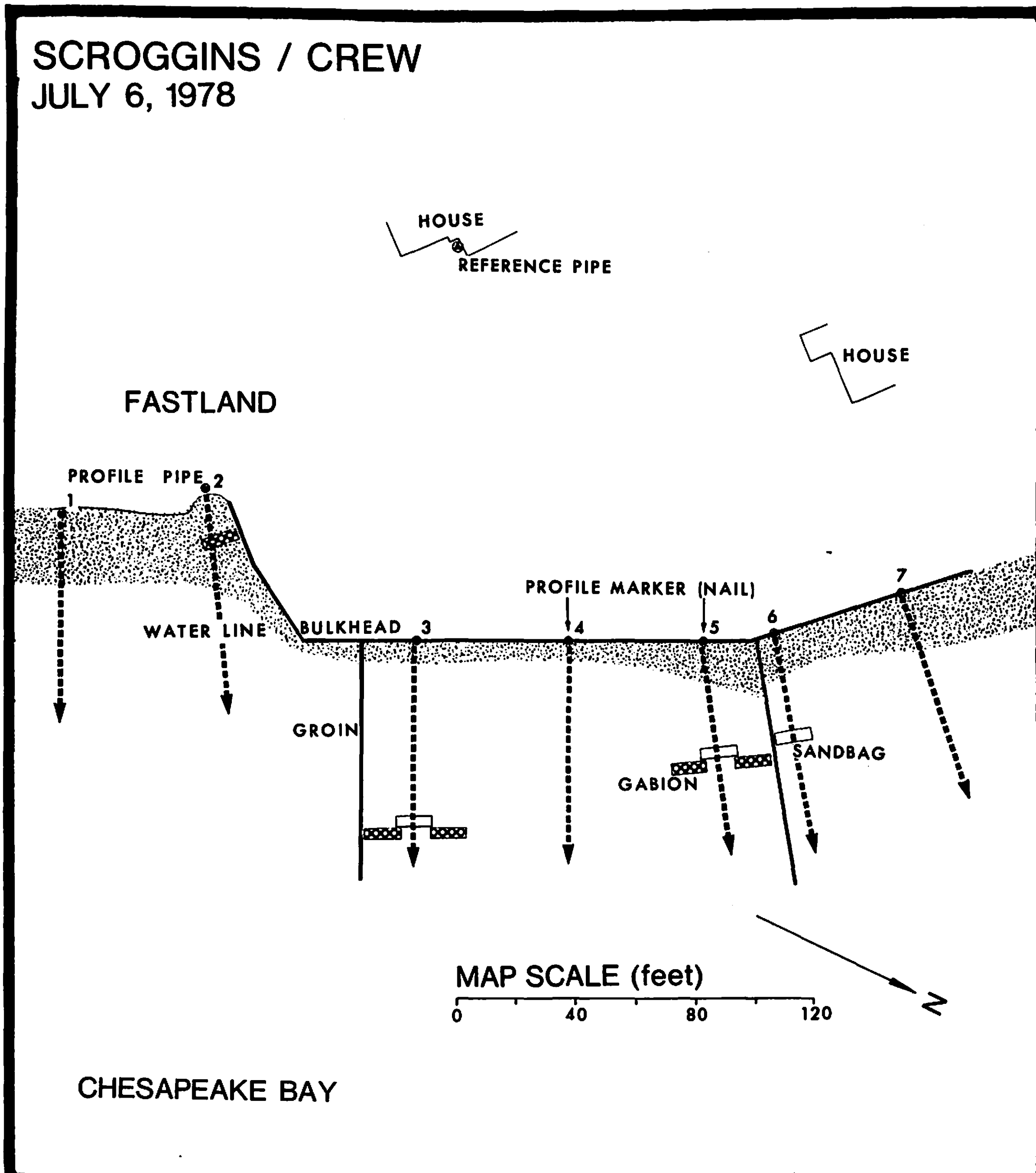


FIGURE 18. Plan view of the structure layout at the Scroggins/Crew site.

Results and Effects

The installation was delayed somewhat since our application necessarily had to follow the reconstruction of the bulkhead and groins destroyed in the April, 1978 storm. Reconstruction was completed in late June, 1978. The spurs were installed by 3 July, 1978.

The post-installation condition is shown in Plates 8B, 9, and 10. A local storm (2 July) just prior to completion of the spurs depleted the beach along the entire area. The most dramatic recovery to that event was monitored at Profile Lines 2 and 5. This accretion is attributable to the return of the post-storm waves from the southeast which moved sand to the north. Profile 2 responded quickly because the long return wall of the bulkhead acts as a groin and catches the northerly littoral transport.

The short-term response of the groin cell is exemplified by Profiles Lines 3 and 5 (Figures 19 and 20). The survey of 5 July 1978 shows a dramatic buildup at Line 3 and depletion at Line 5. However the post-storm conditions show a reversal as the material is shifted to the northern side of the compartment in response to waves from the south.

The post-installation period of monitoring has been too short to offer an objective assessment of the installation. A visit to the site in September, 1978 indicated the beach at Profile 5 remained and that the spur at Profile 2 was holding a beach. While these indications are positive more time will be required to assess the effectiveness of the spurs at this site.

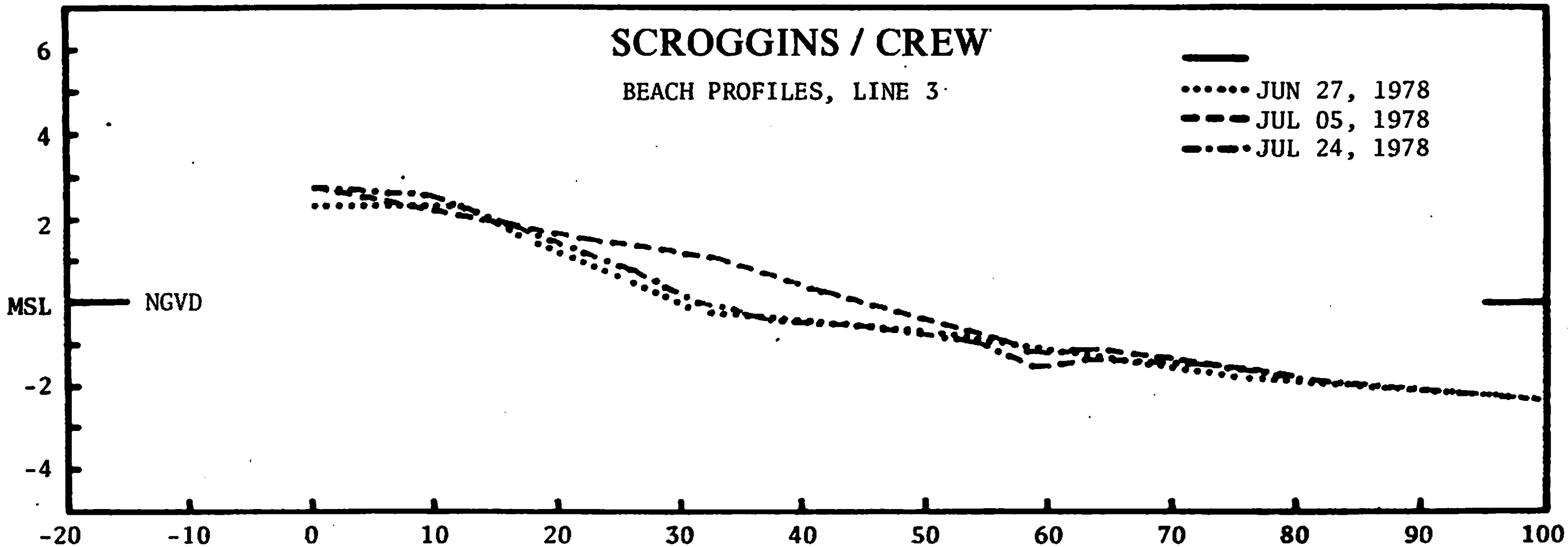


FIGURE 19. Profile Line 3 at the Scroggins/Crew site.

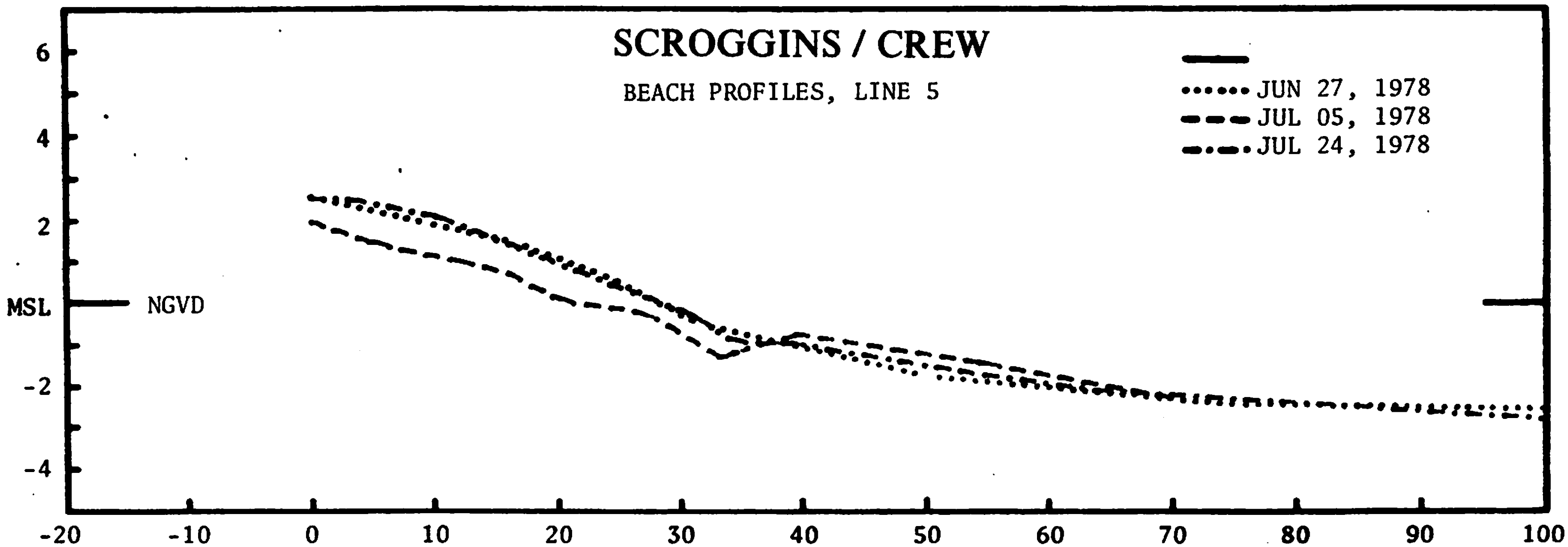


FIGURE 20. Profile Line 5 at the Scroggins/Crew site.

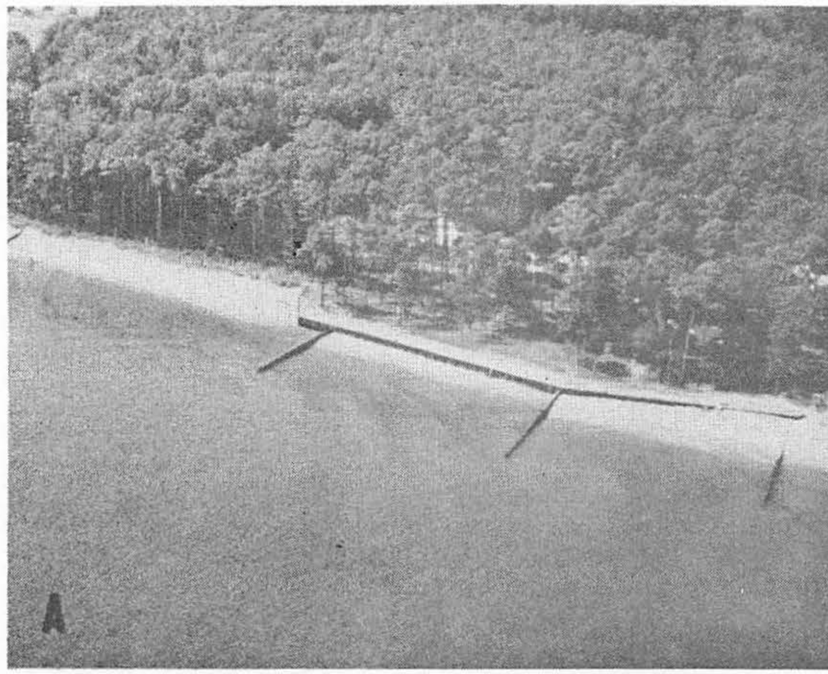
PLATE 8

A. SCROGGINS/CREW

This photograph of August 10, 1977 illustrates the pre-installation site conditions. The original bulkhead shown in this picture was destroyed by the April 26, 1978 storm.

B. SCROGGINS/CREW

The bulkhead in this photograph of August 1, 1978 replaced the demolished structure in the photo above. Note the positions of the sandbags and gabions which were installed on July 3, 1978.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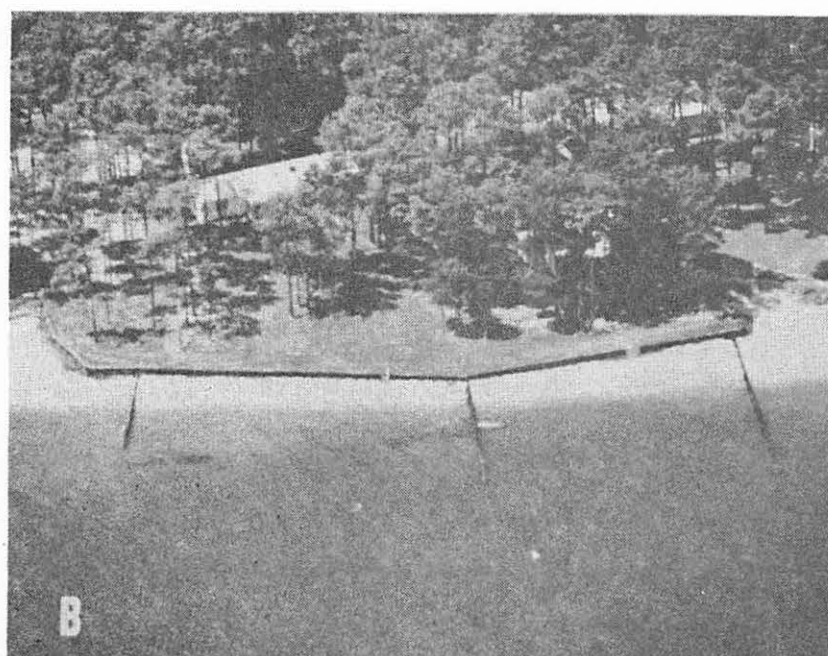

B

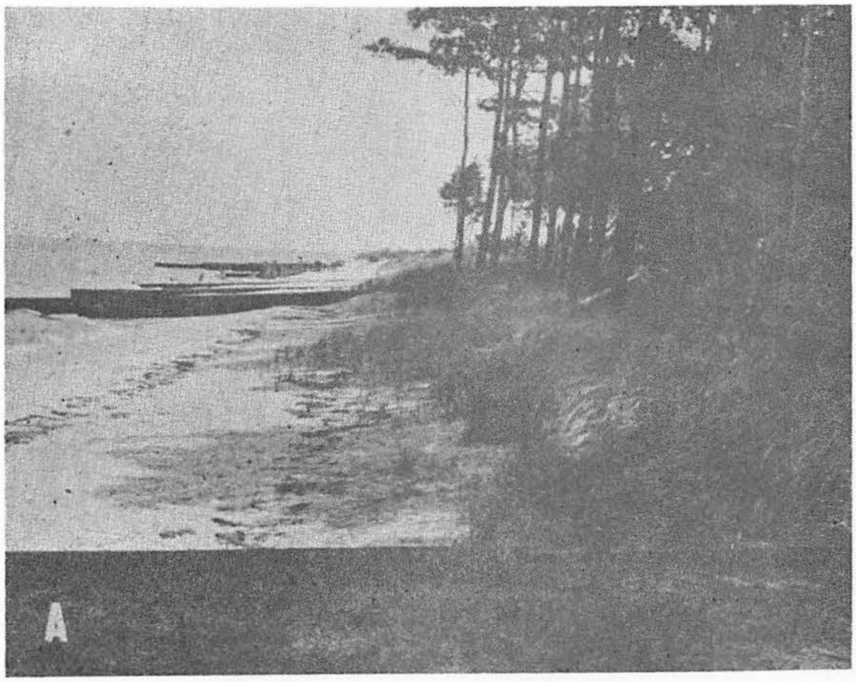
PLATE 9

A. SCROGGINS/CREW

On August 10, 1977 the backshore of the Crew property was well vegetated.

B. SCROGGINS/CREW

The April 26, 1978 storm removed the vegetation. This June 27, 1978 photograph illustrates the scarp cut into the fastland behind the beach.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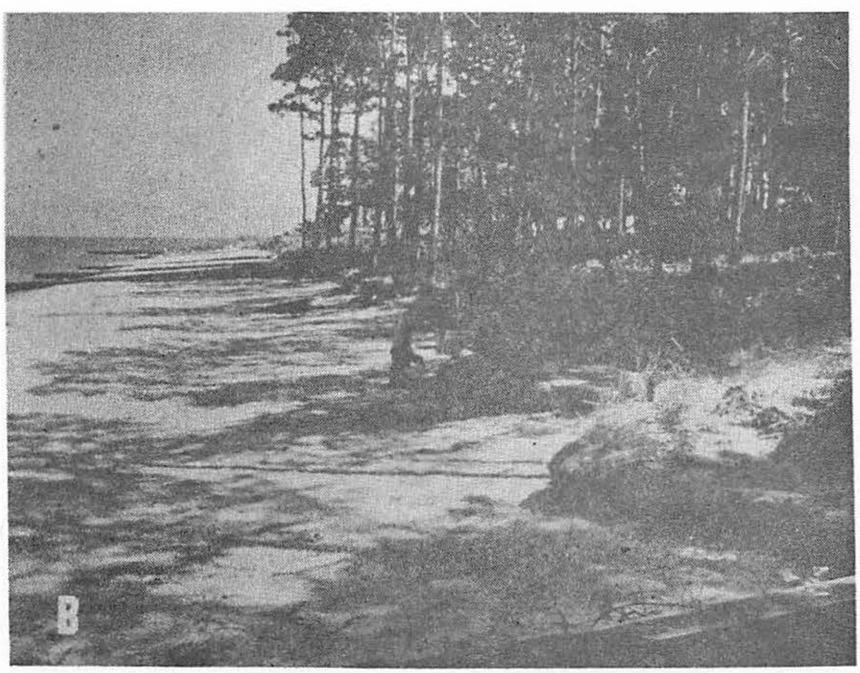

B

PLATE 10

A. SCROGGINS/CREW

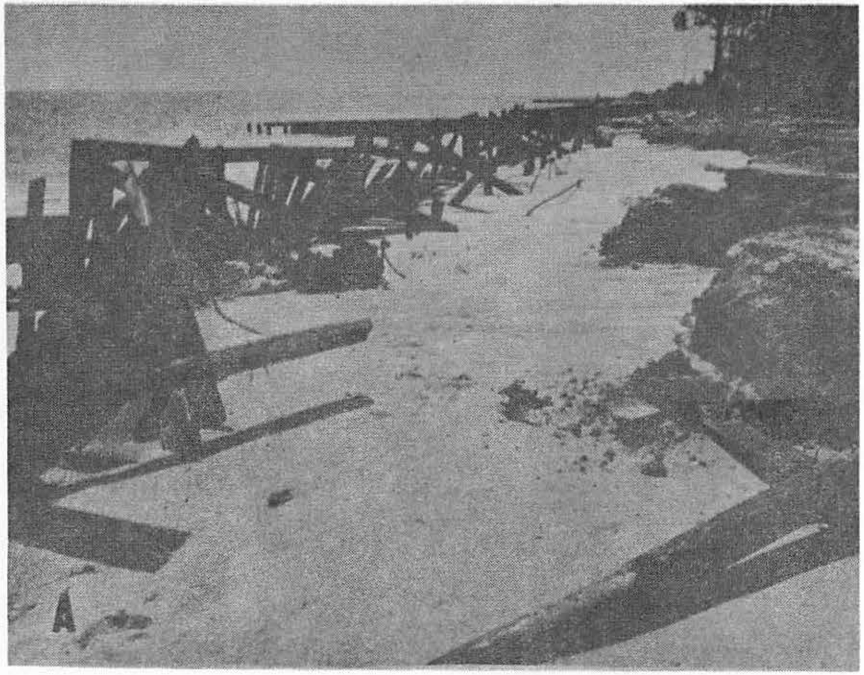
The destruction of the bulkhead at the site is well illustrated in this photograph of May 12, 1978.

B. SCROGGINS/CREW

On June 27, 1978 the new bulkhead is nearly completed. Note also the return of a sand beach in front of the wall.

C. SCROGGINS/CREW

On July 24, 1978, the site had continued to rebuild as witnessed in this north looking photograph.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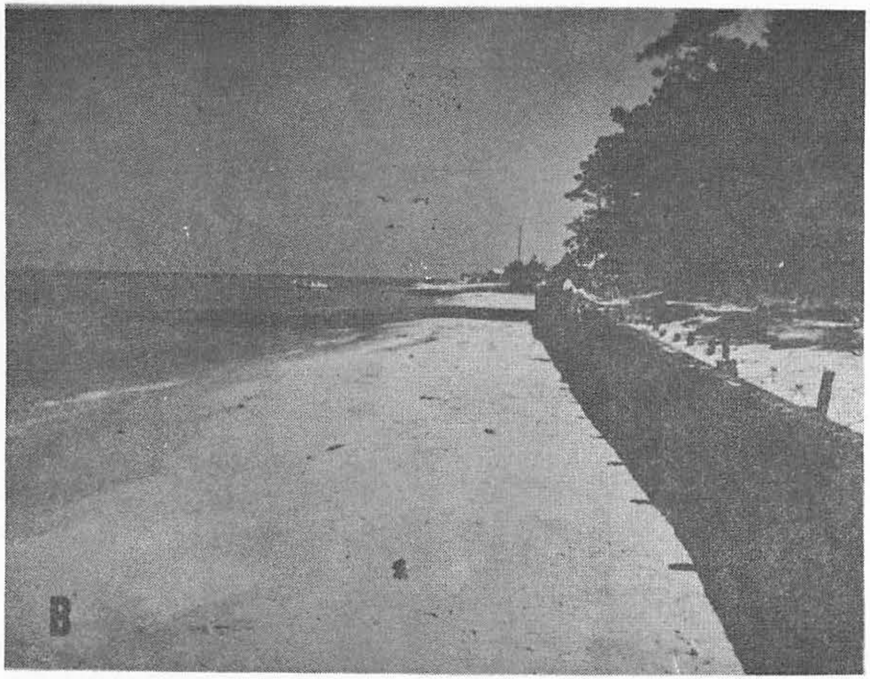
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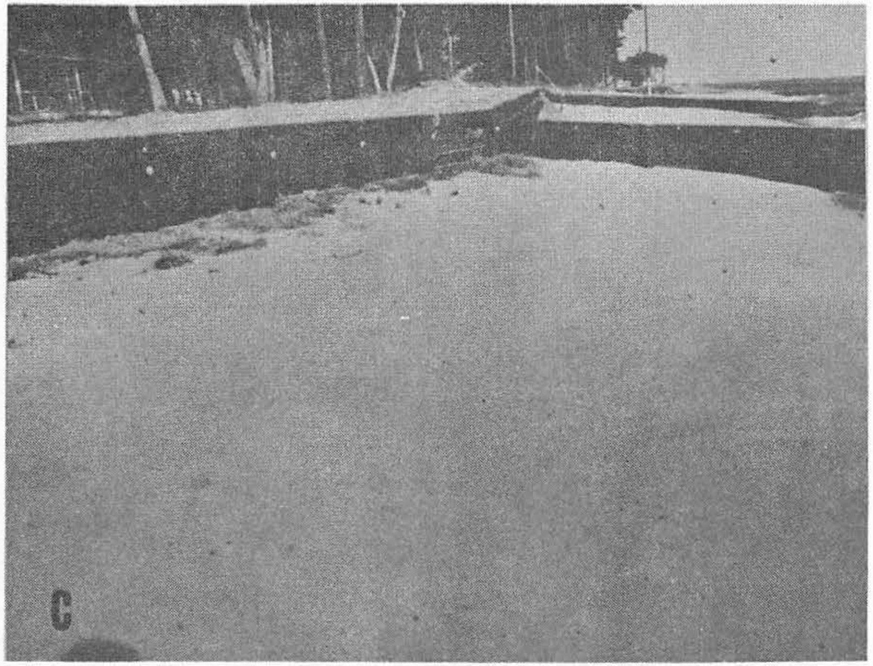

C

D. SMITH SITE

Easement:

Mr. Douglas D. Smith, 7511 Lisa Lane, Richmond Virginia, 23229.

Site Location:

Gwynn Island, Mathews, Virginia, on the Chesapeake Bay.

Directions to Site:

From Hudgins in Mathews County, travel east to Gwynn Island on route 223. Route 233 changes to route 633 at the bridge connecting the island to the mainland. Use 633 for 1.6 miles and continue straight onto route 664. Use route 664 for 0.4 mile and continue straight onto the dirt road. The site is located 0.3 mile further on the right. Permission for access is required from the owner.

Shoreline Physiography

The fastland at this site consists of loosely consolidated soils of a few feet thickness underlain by an impermeable clay layer. The fastland elevation is about 3 feet which is vegetated with pine trees, small bushes and short grasses. The shorelines of the properties on both sides have been stabilized with bulkheading and riprap revetment. An aerial pre-installation view is shown in Plate 11A. Several points are noteworthy. The transition from the fastland to the beach is a two foot erosional scarp. The beach was narrow and thin as the clay layer substrate extends out to nearshore. The sands on the beach are fine grained (0.16 to .24 mm median size).

The site has displayed pronounced erosion; during the observation year prior to installation the scarp retreated approximately 12 feet much of which occurred during the storm of 26 April, 1978. The dramatic history of recession at this site is due to the limited littoral drift passing the site, the impermeable nature of the substrate, and the exposure to the northeast winds (Figure 21). The principal reason for selection of this site was the proximity of a roadway which services the community and the desirability to test the perched beach concept under conditions where the site is recessed relative to adjacent properties.

Structure Design

The structure plan view is shown in Figure 22. A gabion sill, approximately 167 feet in length (13 gabions each 12' x 3' x 1.5') was placed parallel to the shoreline about 30 feet seaward of the estimated high water line. The site is divided by the remnants of a concrete pier which has, to a limited degree, acted as a groin.

The structure was designed to widen and raise the backshore of the beach in order to reduce direct wave attack on the fastland. In addition the widened beach would enhance the recreational usage of the beach area. At low water the sill itself would serve as a breakwater to dissipate wave energy. The installation was completed on 5 May 1978.

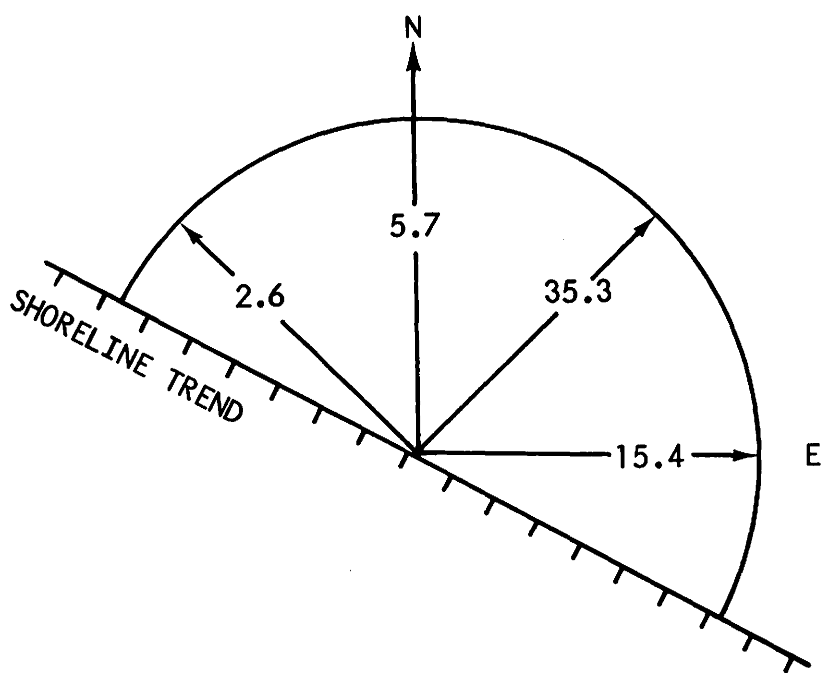


FIGURE 21. Fetch distances (nautical miles) at the D. Smith site.

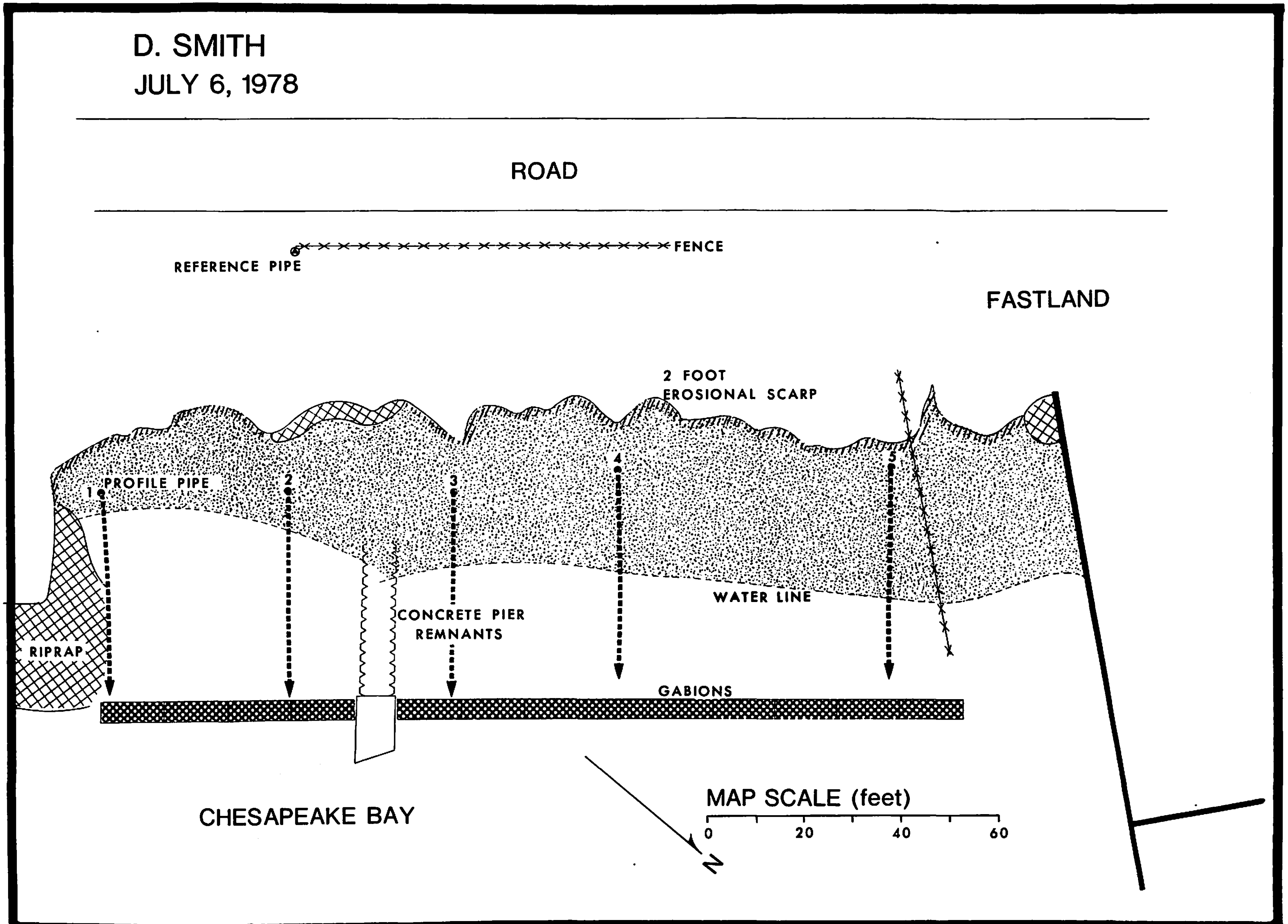


FIGURE 22. Plan layout of the D. Smith site.

Results and Effects

The response of the D. Smith site is the result of the direction of littoral transport and the relationship of the gabion sill to the adjacent bulkheading and groin. During the post-installation period, May 5, 1978 through July 27, 1978, littoral drift was apparently to the northwest. Beach material was transported in the direction of the bulkheading. It is believed that the bulkhead and groin initiated the restrain on the drift material and the gabion sill became the trapping agent. Alone, the bulkheading and groin had shown no significant change in the beach, but in combination with the sill the structures acted to accrete beach sand and to elevate and widen the northwest portion of the beach. As a result, accumulation progressed away from the bulkhead.

The beach showed signs of accumulation at the onset of gabion installation. Profiles of Line 5 (the line closet to the bulkhead and groin) taken May 9, 1978 and May 17, 1978 show a significant increase of beach material. In constrast, profiles of Line 4 of the same days show only slight accumulation. It is not until June 14, 1978 profile that Line 4 (see Figure 23) demonstrates marked accretion. This "delayed response" of Line 4 agrees with the idea of progressive accumulation away from the bulkhead.

Contrary to the accretion demonstrated at Lines 4 and 5, Lines 1 and 2 actually lost a considerable amount of sand. This is illustrated when profiles of the summer of 1977 and the summer of 1978 are compared (see Appendix B). One possible explanation for the loss is starvation. Immediately adjacent to Line 1, a revetment of riprap and a bulkhead exist. Sand being transported along shore may not enter the system until further updrift.

Finally, the response of Line 3 seems to be one of moderation lying somewhere between the accretion at 4 and 5, and the loss at 1 and 2. Line 3 is characterized by minor fluctuations of beach material. Losses and gains are a common occurrence, but in general the beach at Line 3 has maintained a similar profile over the 13 month period of June 27, 1977 to July 24, 1978. In addition, Line 3 clearly shows the pre-installation erosion of the fastland caused by the storm of April 26, 1978. Profile Line 4 (Figure 23) illustrates the kind of response desired wherein the foreshore is elevated and advanced seaward. Plates 11, 12, and 13 show pre and post-installation differences clearly.

The rapid response to the sill is encouraging. Given that the site is recessed relative to adjacent properties continuing retention of the sand behind the sill is expected. Over the longer term additional sand retention at the southern end of the installation (Profiles 1 and 2) is expected. At this point in time the installation is considered successful.

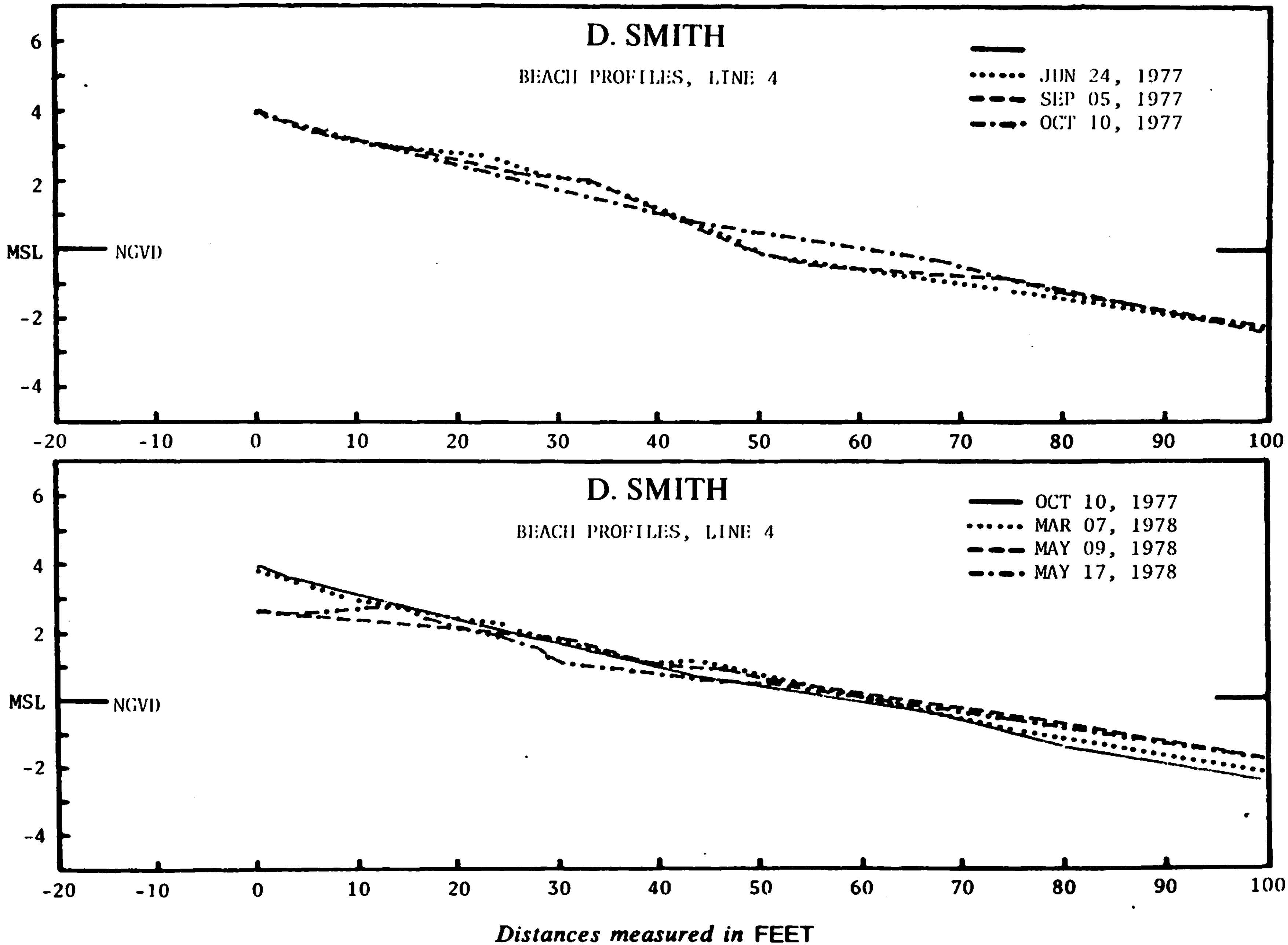


FIGURE 23. Profile Line 4 at the D. Smith site.

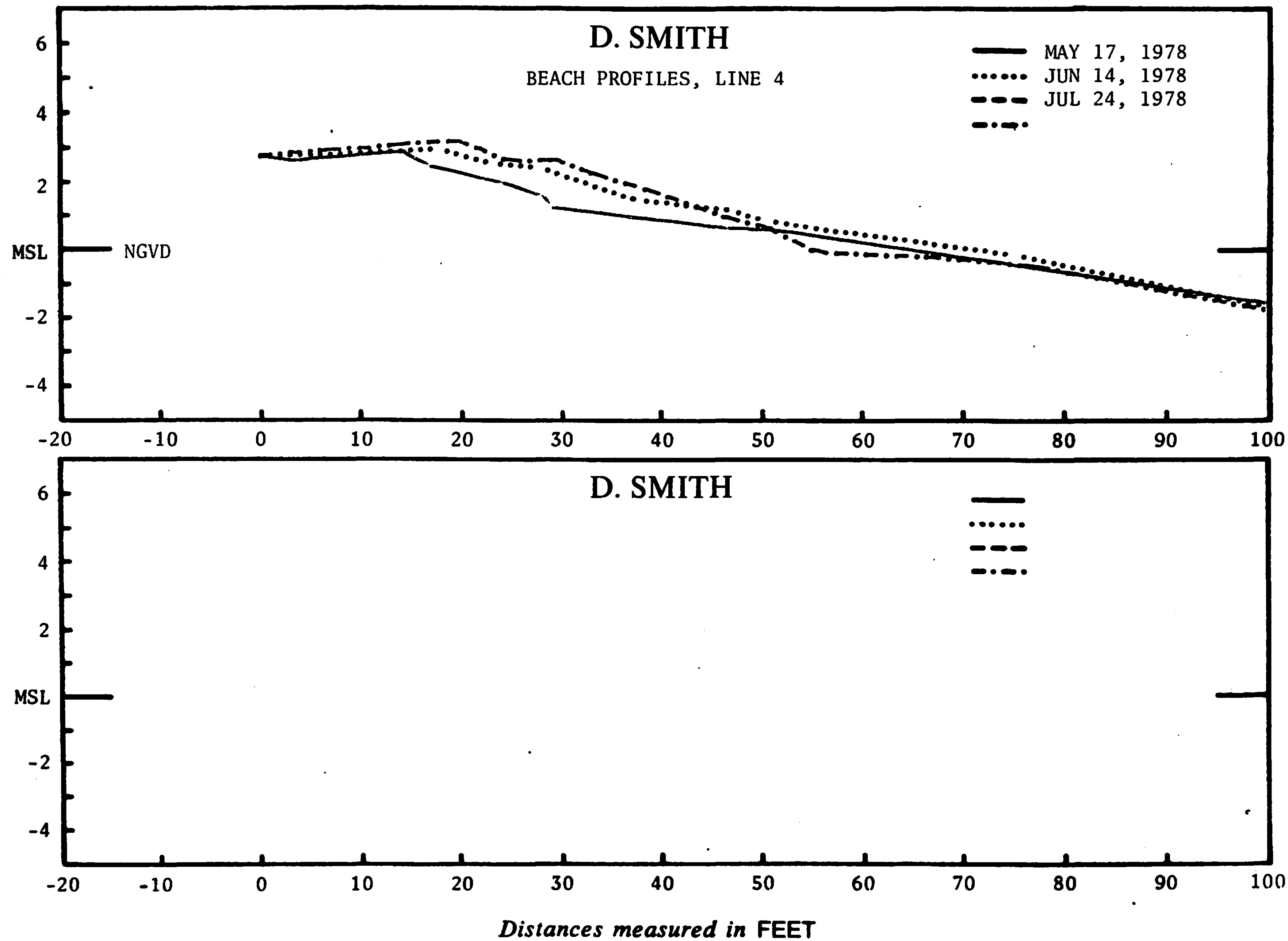


FIGURE 23 cont'd. Profile Line 4 at the D. Smith site.

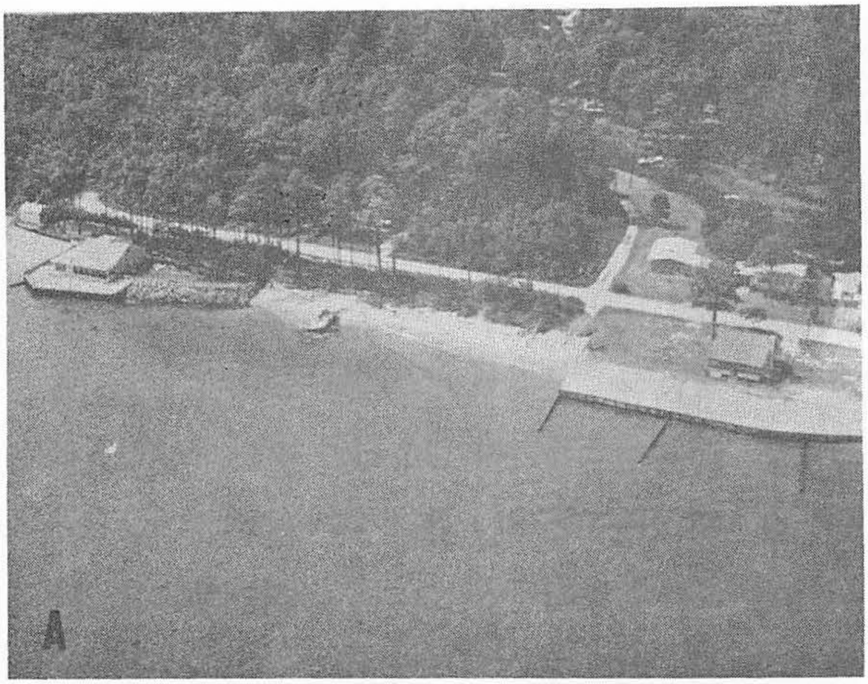
PLATE 11

A. D. SMITH

An oblique aerial photo of the preinstallation site conditions on August 10, 1977.

B. D. SMITH

This oblique aerial photo on August 1, 1978 demonstrates the dramatic recovery of this site. Of particular note is the recovery from the fastland scarp to a position beyond the gabion sill. This is particularly important considering the 10-15' retreat of the fastland scarp during the April 26, 1978 storm. The gabion sill was installed on May 5, 1978.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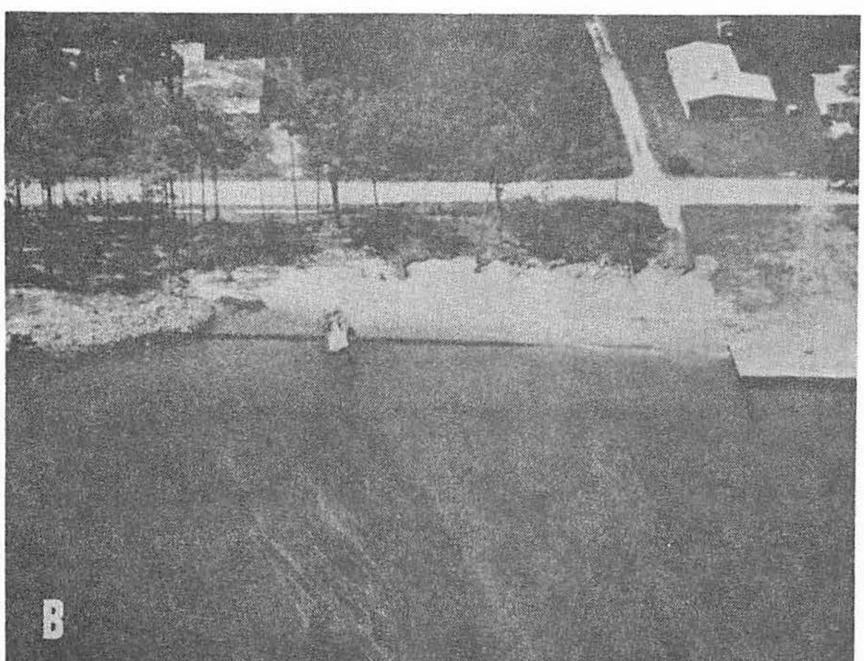

B

PLATE 12

A. D. SMITH

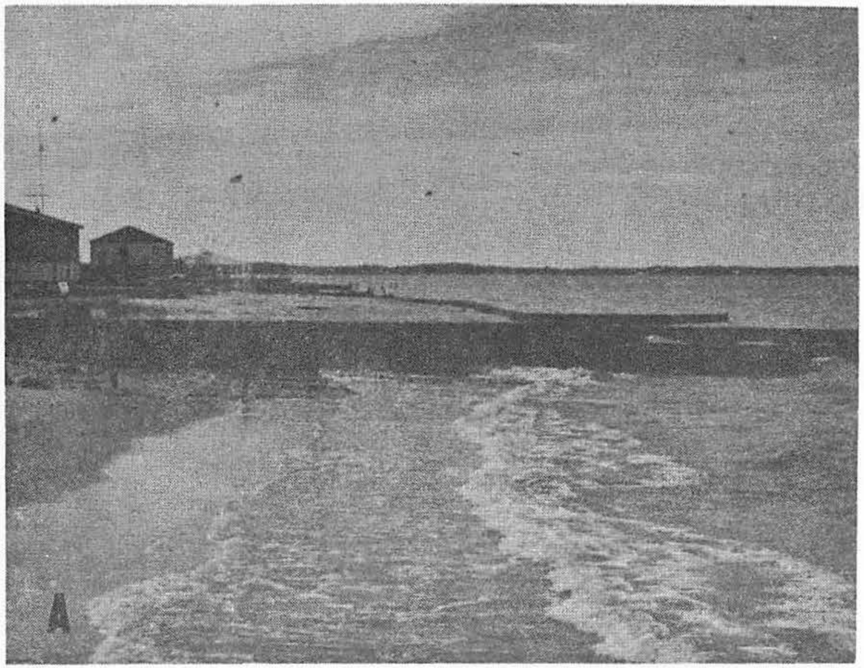
This northward looking photograph on July 26, 1977 records the preinstallation site conditions.

B. D. SMITH

This southward view illustrates the preinstallation site conditions as of March 7, 1978.

C. D. SMITH

The gabion sill was installed on May 5, 1978. By May 17, 1978 the beach had rebuilt dramatically. This is particularly in evidence at the north end of the beach adjacent the bulkhead. Pier remnants lie in the foreground.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B

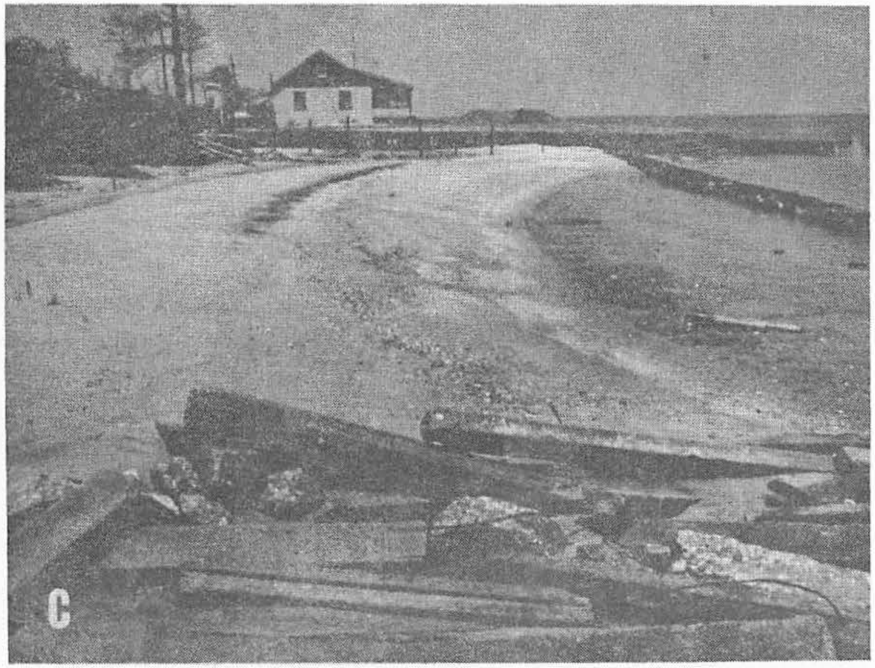

C

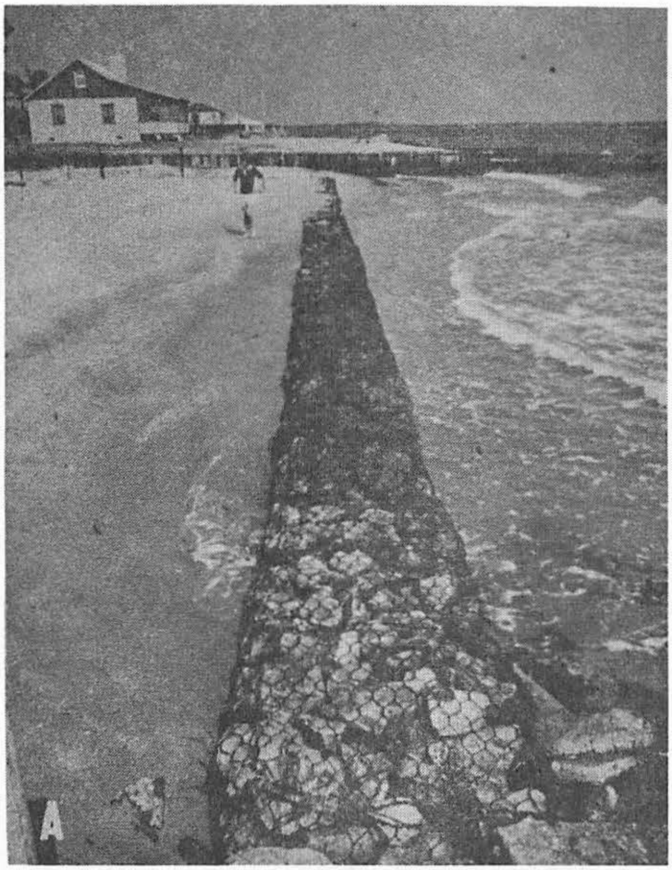
PLATE 13

A. D. SMITH

In this photograph of July 24, 1978, the beach has built to a point where it is covering the gabions.

B. D. SMITH

A closeup of the accretion at the north end of the property. This photo was taken on July 24, 1978.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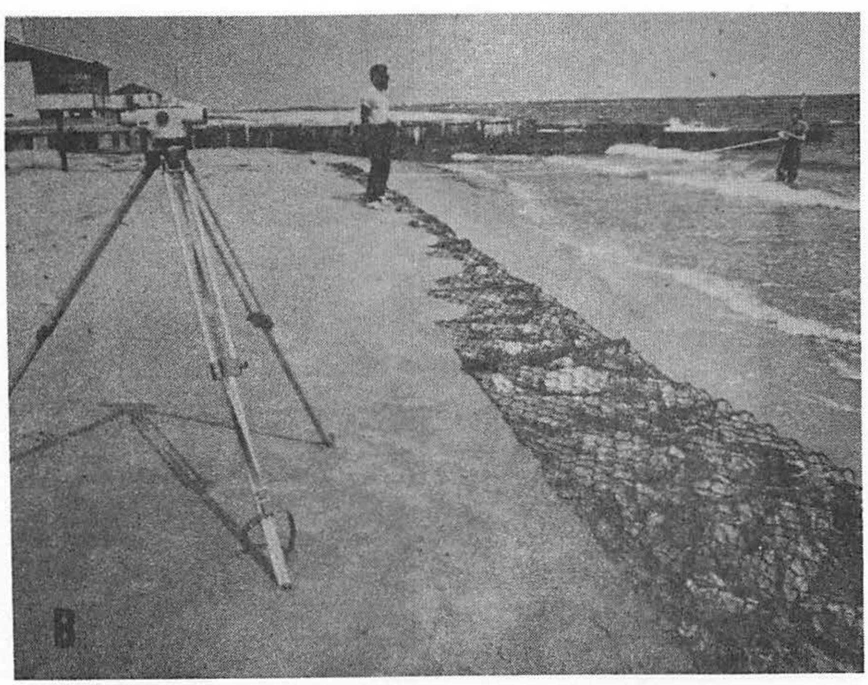

B

GWYNN ISLAND ASSOCIATION SITE

Easement:

Mr. Arthur W. Plummer, President, Gwynn Island Estates Property Owners Association, P.O. Box 797, West Point, Virginia, 23181.

Site Location:

Gwynn Island, Mathews, Virginia, on the Chesapeake Bay.

Directions to Site:

From Hudgins, Mathews County, travel east to Gwynn Island on route 223. Route 223 changes to route 633 at the bridge connecting the island to the mainland. Use 633 for 1.6 miles and continue straight onto route 664. Use 664 for 0.4 mile, then go straight onto the dirt road. Use this dirt road for 0.4 mile and the site is located on the right. Permission for access is required from the property owners association.

Shoreline Physiography

The GIA site is a beach segment 100 feet in length contained between two properties which have shorelines protected by bulkheads and groins. Like the previously described D. Smith site the nearby GIA shoreline is recessed relative to the adjacent hardened shoreline. However the GIA site has a more normal suite of beach features which include the foreshore, an elevated backshore, and a low vegetated foredune. The beach is composed of medium to coarse sands (median diameters ranging between 0.63 to 1.45 mm).

During the coarse of this study two significant pre-installation storms occured, 14 October 1977 and 26 April, 1978. The 14 October storm lowered the foreshore of the beach and caused a 10 foot recession of the vegetated backshore and dune. Following storms of this type the beach system exhibits some recovery as the nearshore sands are driven back into the beach and some trapping of the littoral drift supply occurs.

The GIA site is a community beach area. In addition a service road passes the site immediately behind the foredune. These two conditions were the principal factors in site selection as enhancement of the beach width and elevation would improve its recreational value and offer additional protection to the roadway.

Structure Design

Since the site is used as a bathing beach sandbags were selected over gabions as the materials for sill construction. The plan view of the site and sill location is shown in Figure 24. A gap was left in the sill to provide a valve for the hydraulic head created when waves break over the sill and inject water into the zone behind it prior to filling of the beach. In addition the gap permits unobstructed access to the nearshore. The installation was completed on 9 May, 1978.

Results and Effects

The degree of normal modulation of the beach profile prior to the sill installation is exemplified by the history at Profile Line 2

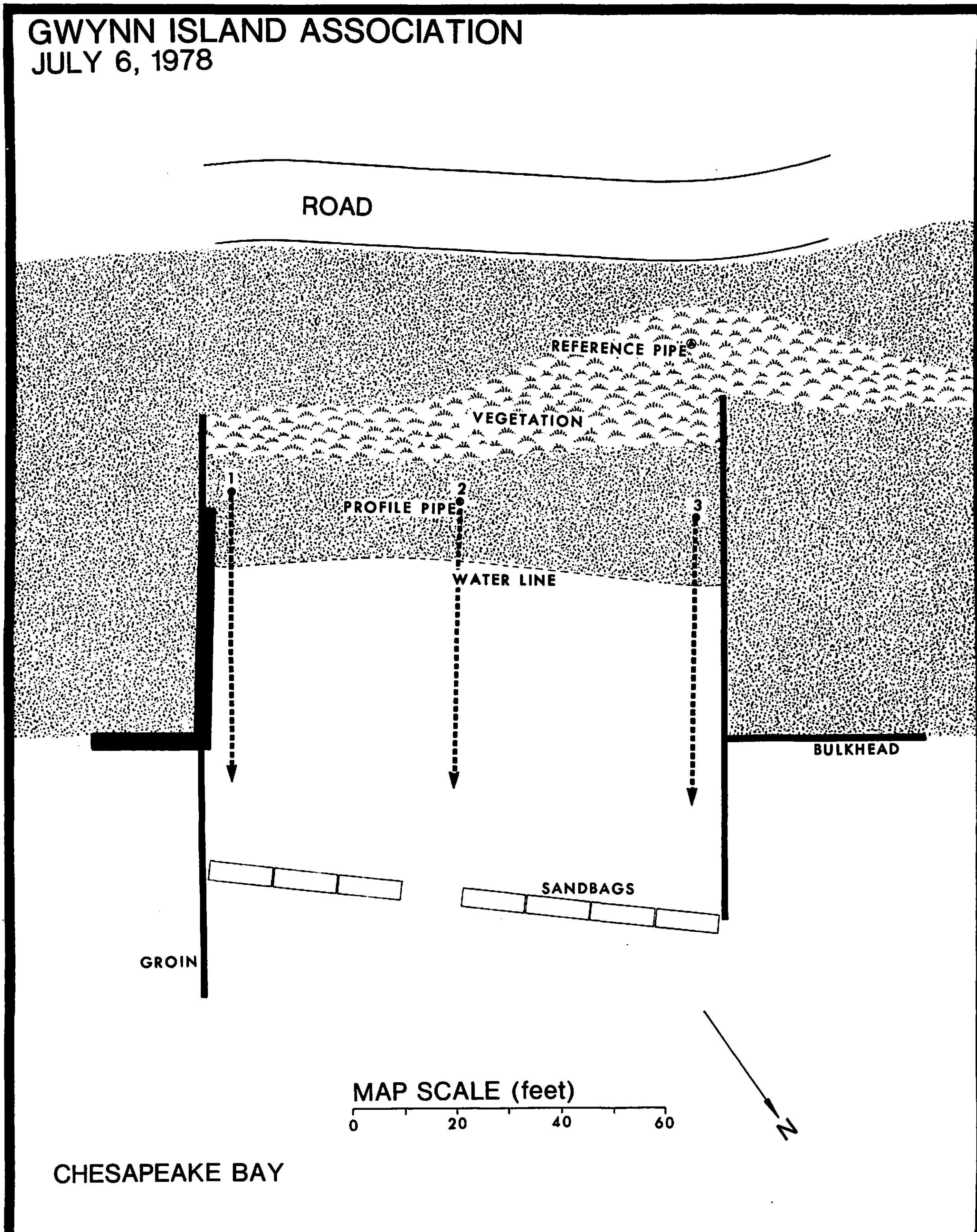


FIGURE 24. Plan view of the GIA site.

(Figure 25). The impact of the 26 April storm is shown by the comparison of the 7 March, 1978 and 10 May, 1978 profiles which indicate the cutting back of the foredune.

The post-installation response between 9 May and 24 July, 1978 shows accretion at all three profiles but the changes are not dramatic enough to claim the sill was responsible as opposed to normal modulations in beach volume. Plates 14 and 15 illustrate the pre and post-installation conditions.

The post-installation period, although showing potentially positive results, has been too short at this site to pass an objective judgement on the effectiveness of the sill. Continued observation over the next few years will be required.

In passing it should be noted that one or more of the local residents have been extracting sand from the backshore and dunes. On two occasions during our study volume reduction and equipment tracks on the beach have been observed. The adverse impact this may have on the beach response and the loss of protection to the roadway cannot be overemphasized. The practice should be stopped immediately.

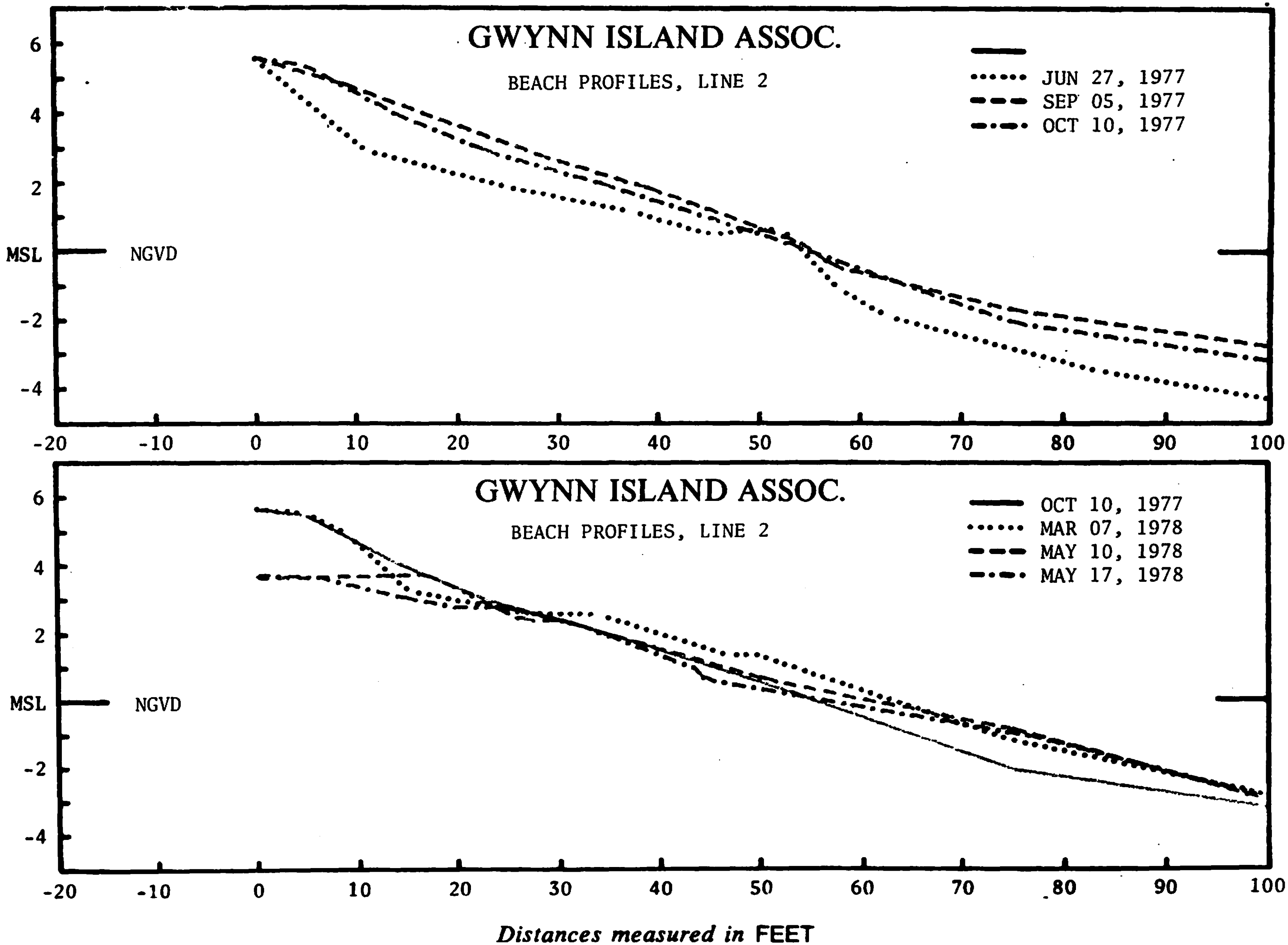


FIGURE 25. Profile Line 2 at the GIA site.

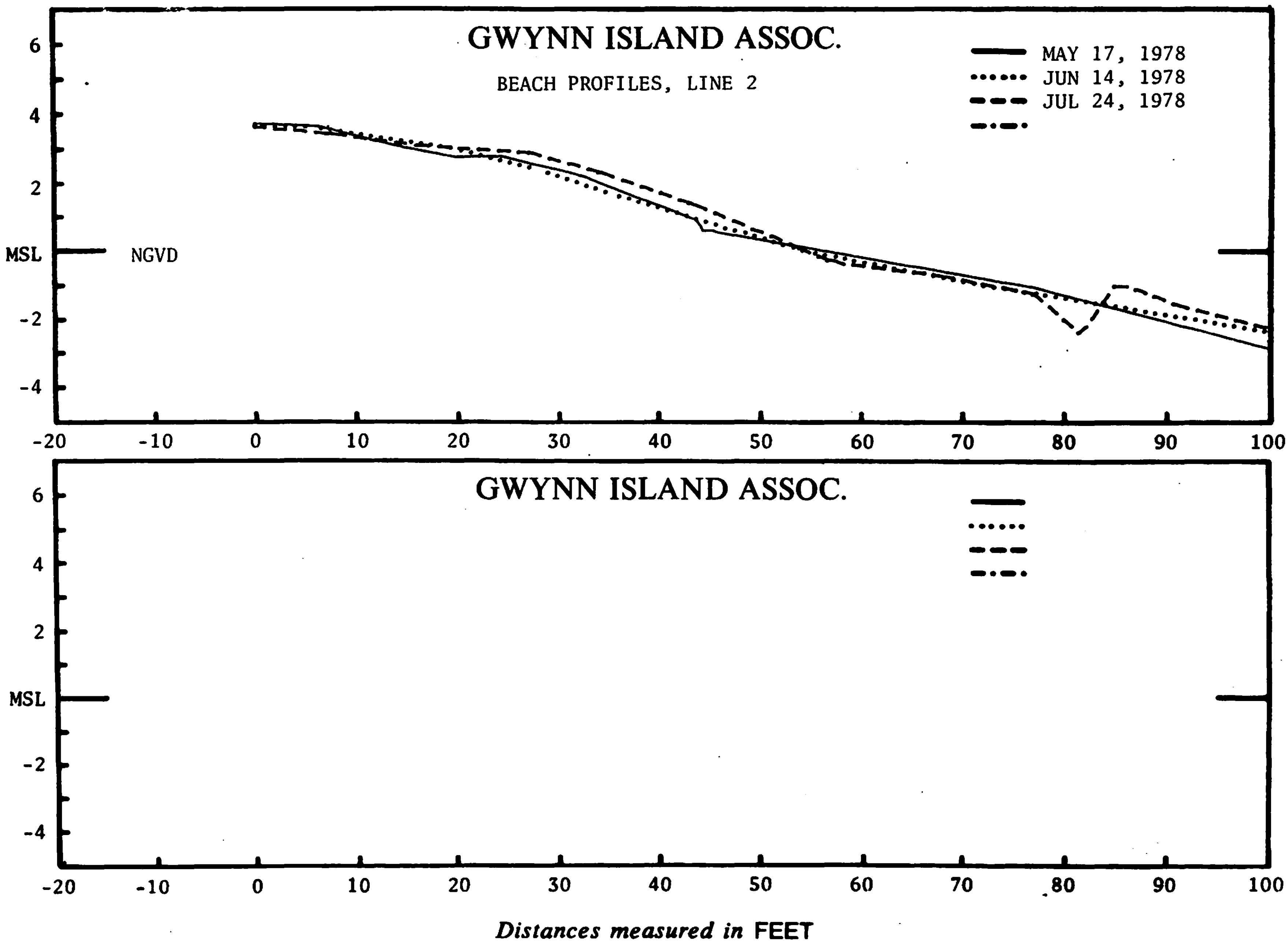


FIGURE 25 cont'd. Profile Line 2 at the GIA site.

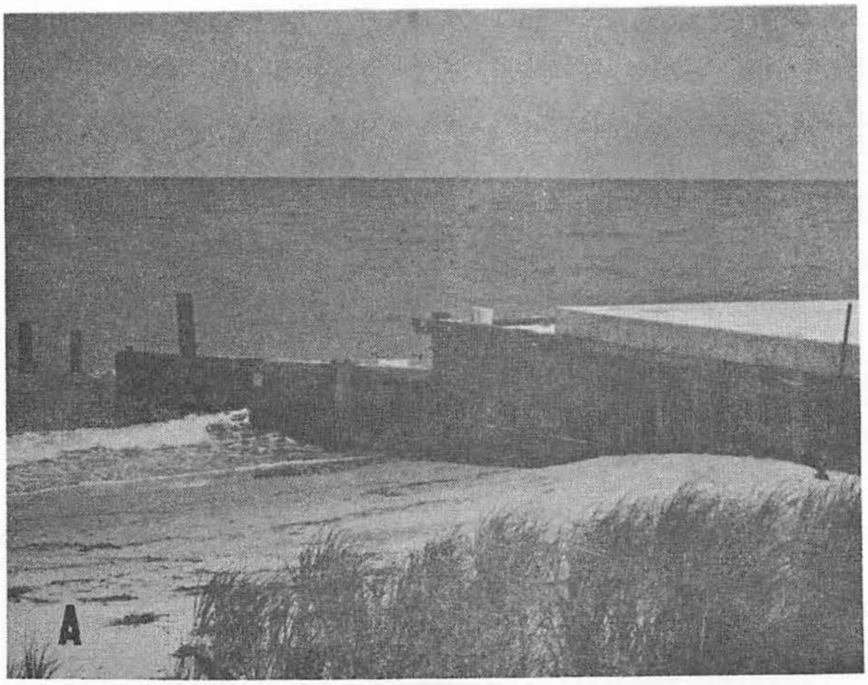
PLATE 14

A. GWYNN ISLAND ASSOCIATION

Preinstallation conditions as of July 26, 1977. Note the well vegetated backshore.

B. GWYNN ISLAND ASSOCIATION

This north looking view on July 26, 1977 illustrates the beach position relative to the adjacent groin.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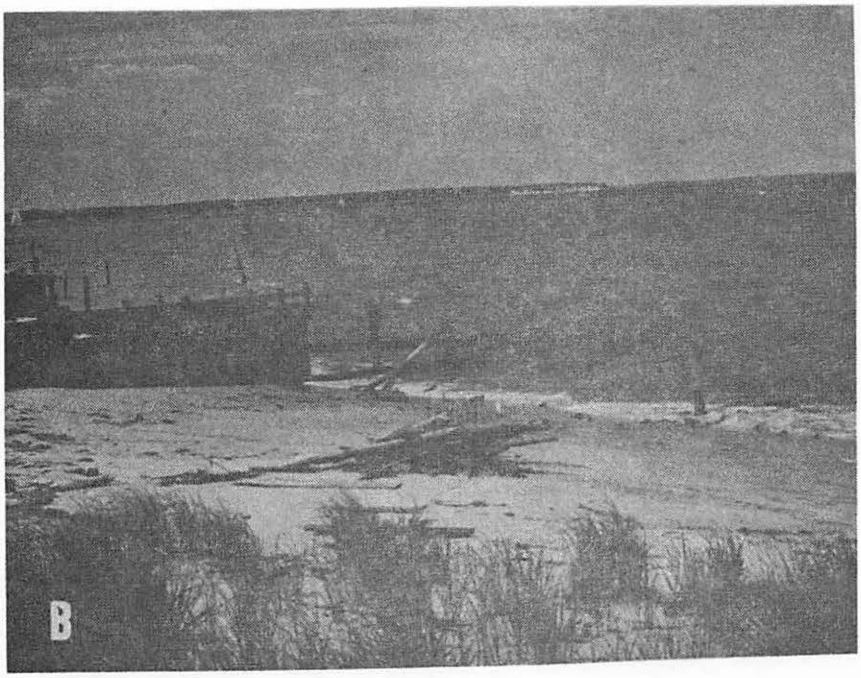

B

PLATE 15

A. GWYNN ISLAND ASSOCIATION

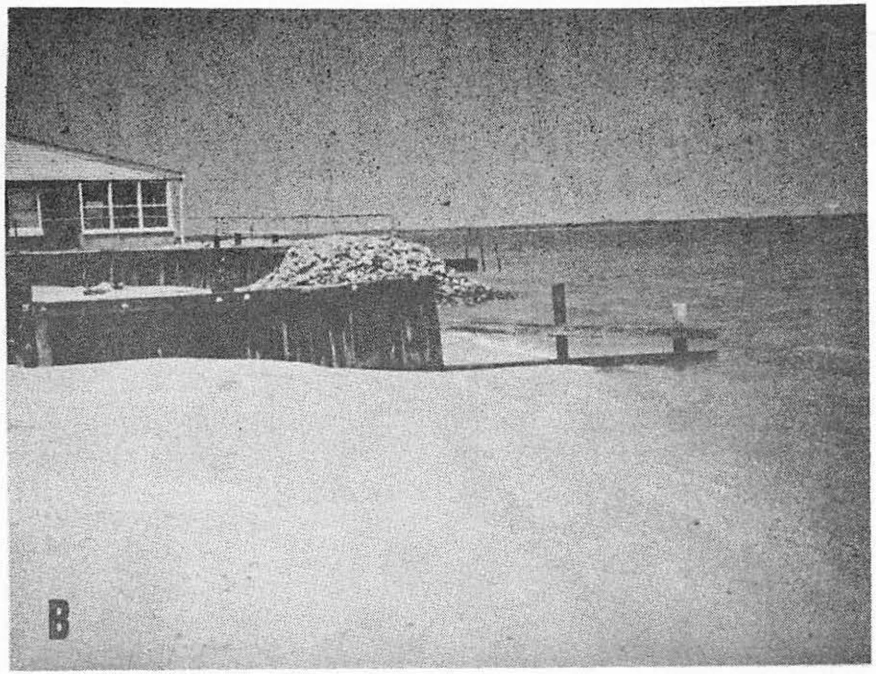
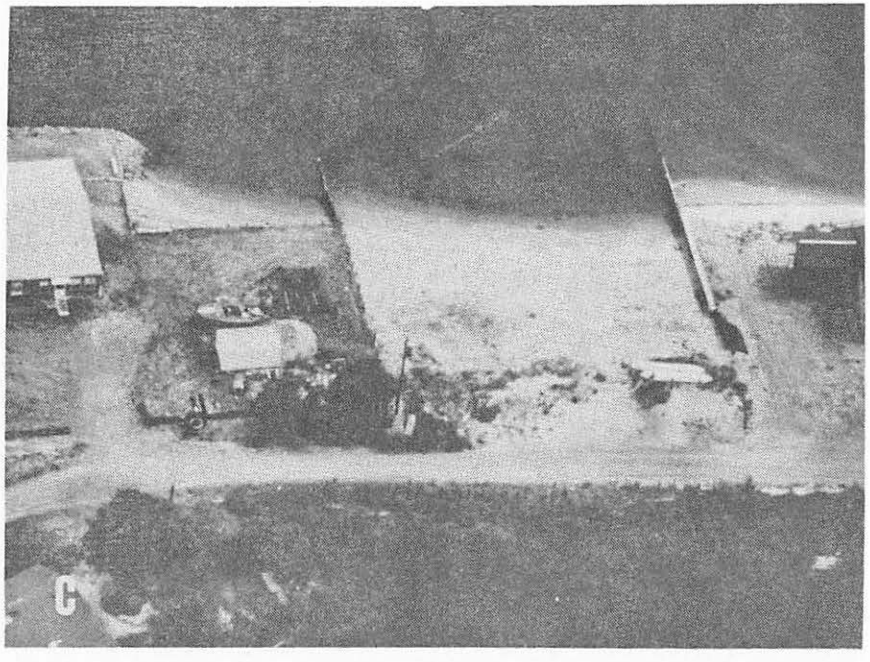
The installation of the sandbag sill was completed on May 9, 1978. Note the waves breaking on the bags in this June 28, 1978 photo.

B. GWYNN ISLAND ASSOCIATION

This view looking northward on June 28, 1978 illustrates the gradual accretion at the groin.

C. GWYNN ISLAND ASSOCIATION

This August 1, 1978 oblique aerial photograph reveals the position of the sandbag sill. Note the loss of vegetation from the backshore of the beach. Most of this vegetation was lost during the April 26, 1978 storm.


A

B

C

CHERRY POINT SITE

Easement:

Mr. Arthur W. Plummer, President, Gwynn Island Estates Property Owners Association, P.O. Box 797, West Point, Virginia, 23181.

Site Location:

Gwynn Island, Mathews County, Virginia, at Cherry Point bordered to the west by the Piankatank River and the Chesapeake Bay to the north.

Directions to Site:

From Hudgins in Mathews County, travel east to Gwynn Island on route 223. Route 223 changes to route 633 at the bridge connecting the island to the mainland. Use 633 for 1.6 miles and continue straight onto route 664. Use 664 for one mile and the site is on the left. Permission for access is required from the association of property owners.

Shoreline Physiography

The Cherry Point site is at the northwest end of Gwynn Island (Figure 16) which is the junction of the fastland and a large spit which had formed as a terminal spit in response to the northwest littoral drift along the shoreline of Gwynn Island facing Chesapeake Bay. In 1850 the spit was much larger; since 1942 the spit has undergone dramatic reductions in size and has migrated eastward tending to weld with the shoreline. Figure 16 shows the condition in 1964. Since then the spit has welded to the shoreline and the site in question has undergone erosion. Although the site has limited exposure to direct wind wave action (Figure 26) wave refraction and diffraction around Cherry Point control the local wave climate. Thus the site is indirectly susceptible to northeast storms. The reduction of the spit is, in part, due to the increasing amount of shore protection along the northern one-third of the shoreline facing Chesapeake Bay as each hardening of a segment of the shoreline removes a sand supply to downdrift beaches. In particular, the installation of a groin field immediately updrift interrupted the shoreface drift system. Erosion at the site eventually led to attempts at hardening the shoreline with rubble and finally the fastland had been hardened with a riprap revetment. The beach sand ranged from medium to coarse in median grain sizes (0.48 to 1.42 mm median diameter).

At the time of site selection this community beach was very narrow and unsightly due to the rubble from septic field remains and other debris.

Structure Design

A perched beach via a sandbag sill was designed as shown in Figure 27. The sill is approximately 150 feet in length. The attempt at this site was directed to local beach enhancement since the fastland boundary was hardened with a riprap revetment. It is of

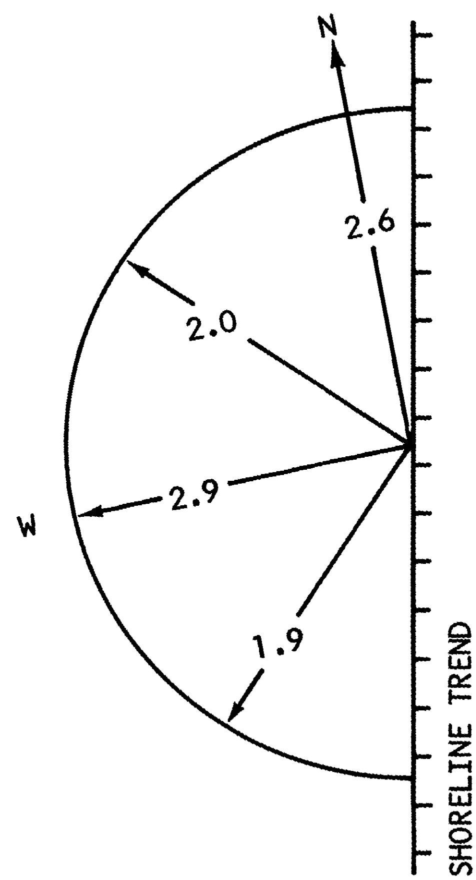


FIGURE 26. Fetch distances (nautical miles) at the Cherry Point site.

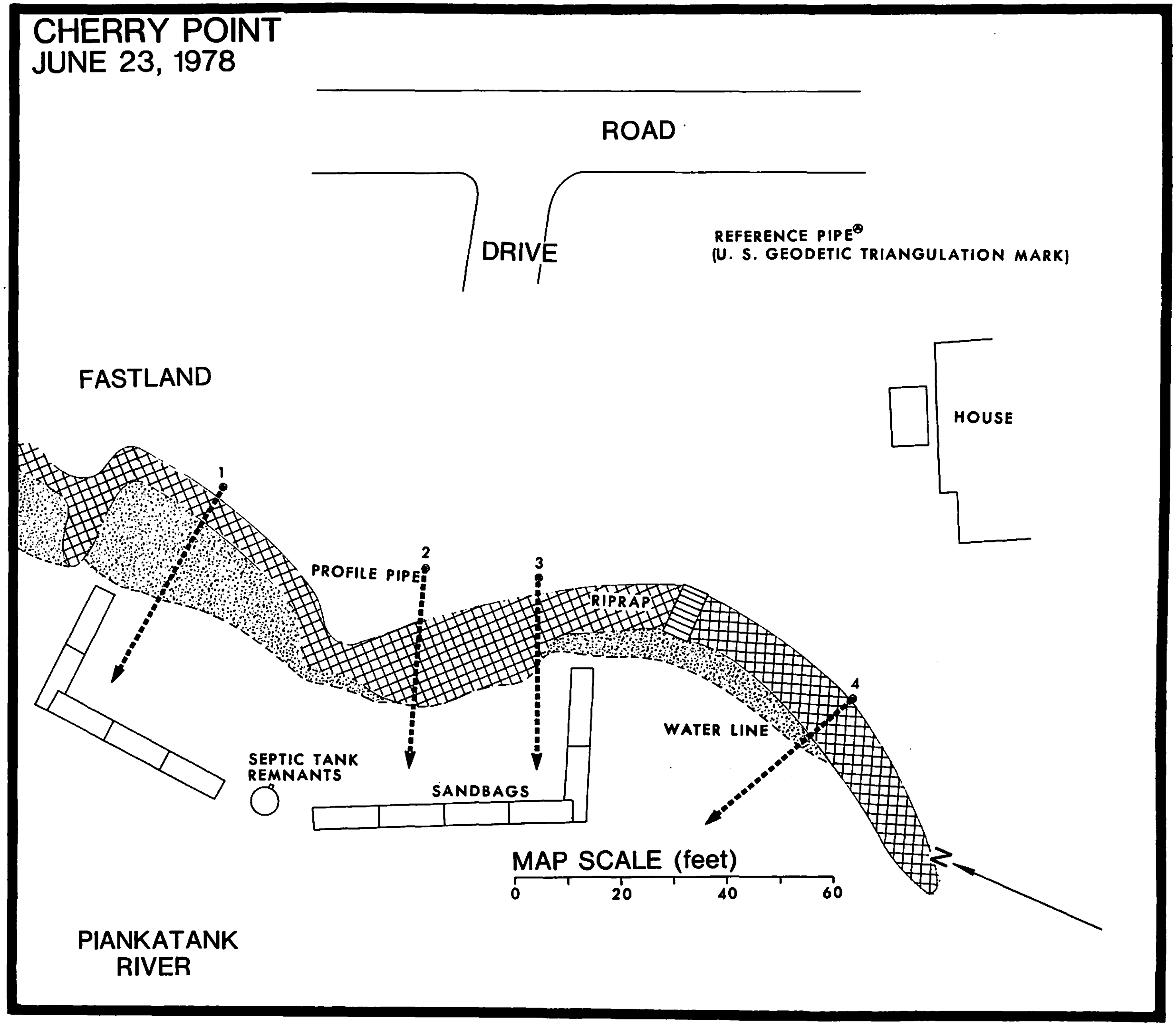


FIGURE 27. Plan view of the Cherry Point site.

interest to note that during the 26 April, 1978 northeaster, stone from the revetment was scattered about the fastland terrace. This response dramatizes the local response to northeast storms even though the local fetch in that direction is zero (Figure 26).

The installation was completed on 10 May, 1978.

Results and Effects

Examination of the pre-installation profiles (Appendix B) generally indicate only minor modulation in beach sand volumes although Profile Line 3 showed a strong response to the 26 April, 1978 storm. During the short post-installation profiling period (10 May - 24 July) only Profile Line 1 showed a strong positive response (Figure 28) wherein more than a foot of accretion occurred over a twenty foot zone (compare Profiles of 31 May with 24 July). Over the same time period very minor accretion or no change occurred at the other profile lines (as exemplified by Figure 29). Plates 16 and 17 show the pre and post-installation condition. In particular, Plate 17A shows the lobe of sand accretion reflected by Profile Line 1. A recent visit (25 October, 1978) since the termination of the profiling program revealed dramatic accretion since 24 July. For example, the culvert pipe shown exposed in Plate 17B was almost entirely covered. The beach had thus widened considerably but the backshore elevation had not responded to the same degree.

In summary, the site is beginning to respond to the sill with the formation of a perched beach. An extended period of observation will be necessary before a definitive judgement can be made on the site.

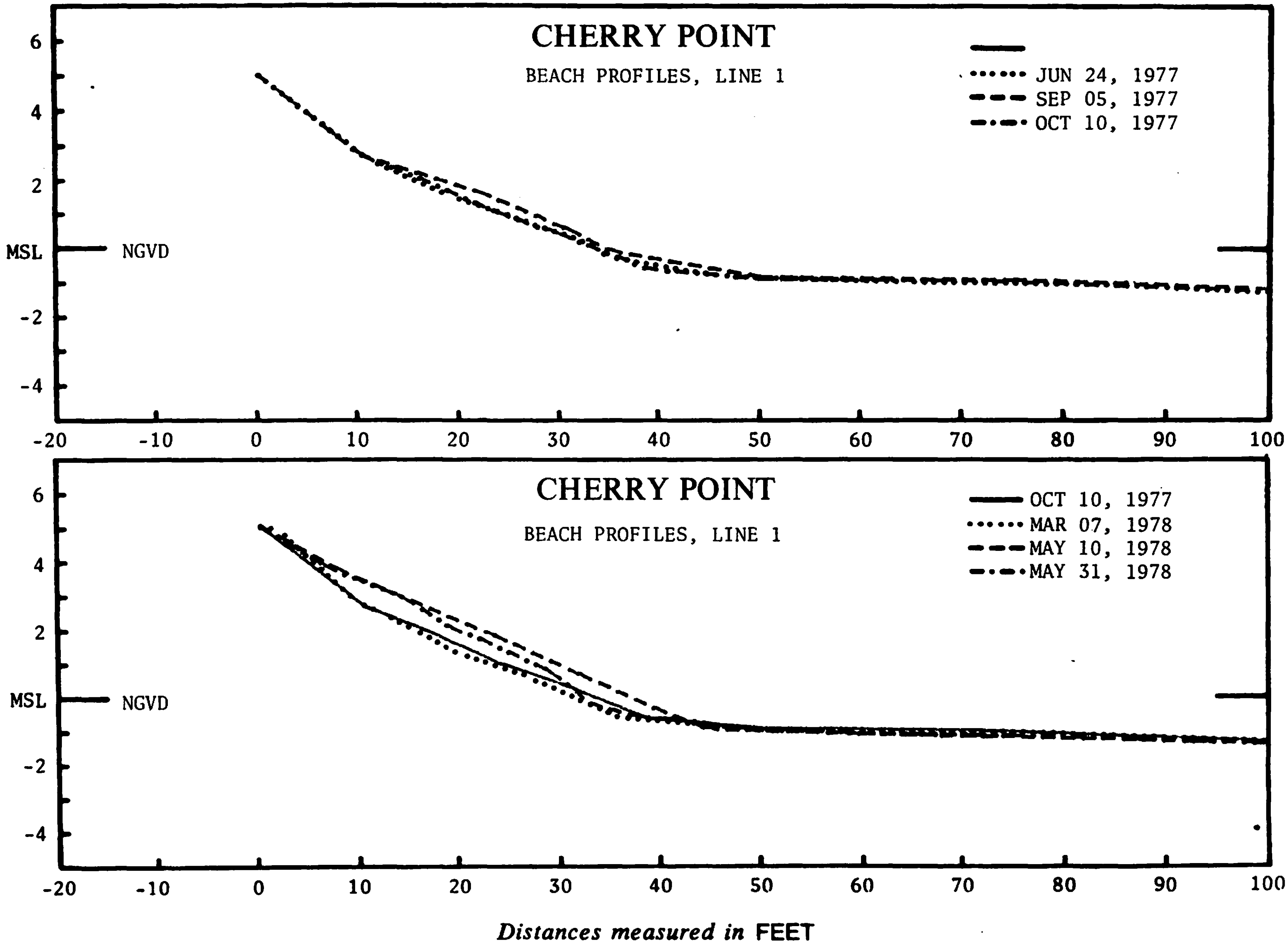


FIGURE 28. Profile Line 1 at the Cherry Point site.

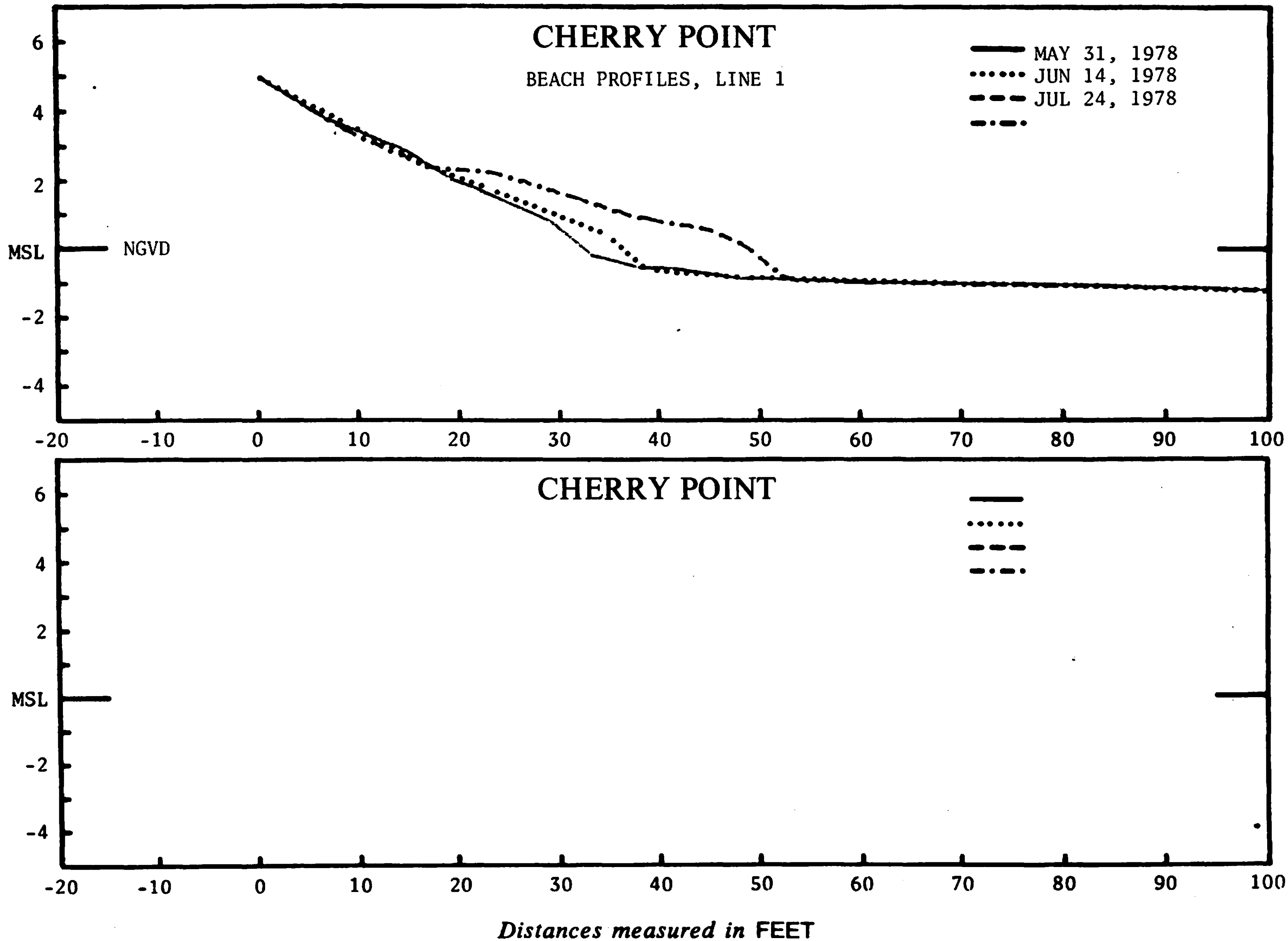


FIGURE 28 cont'd. Profile Line 1 at the Cherry Point site.

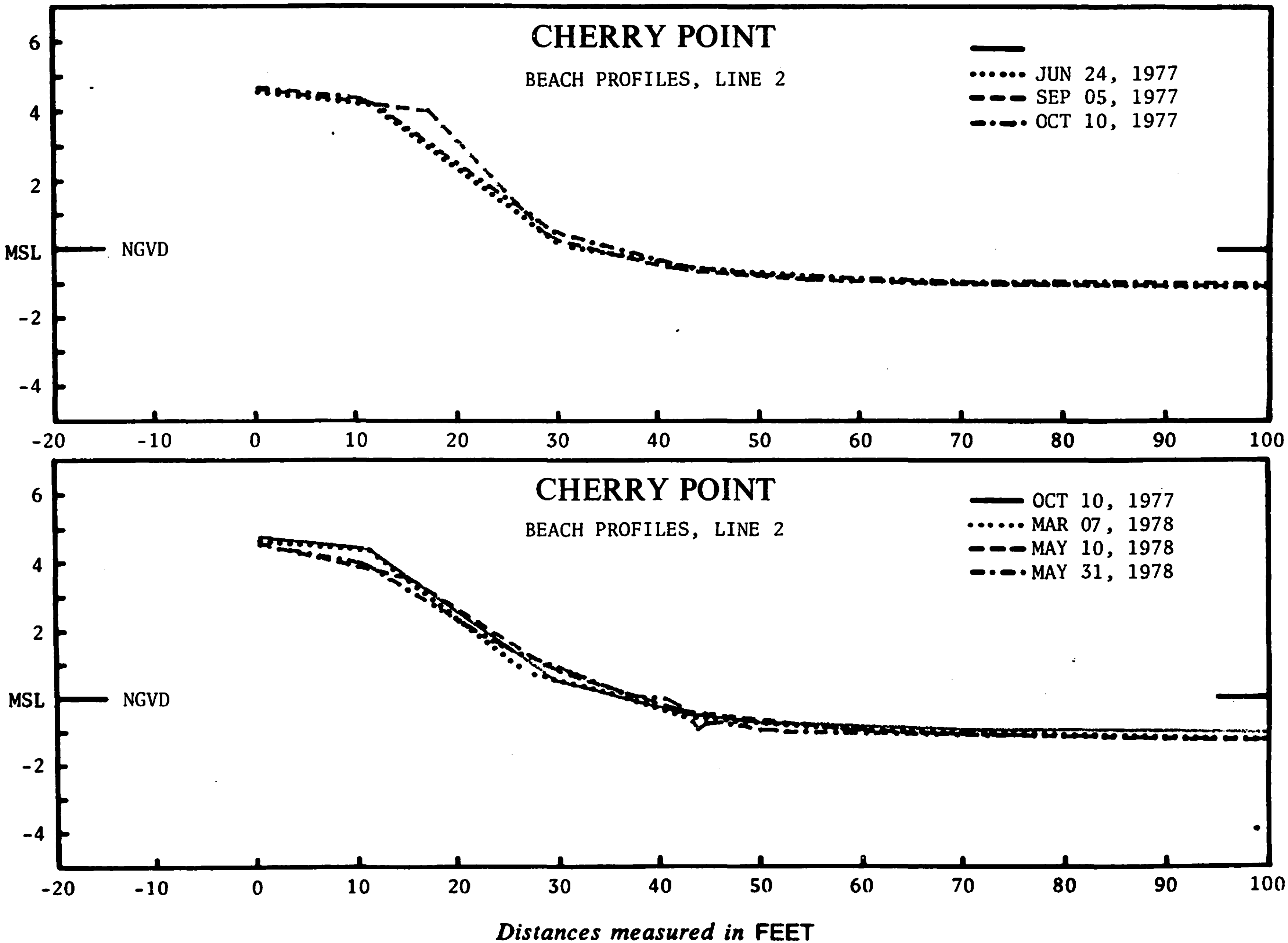


FIGURE 29. Profile Line 2 at the Cherry Point site.

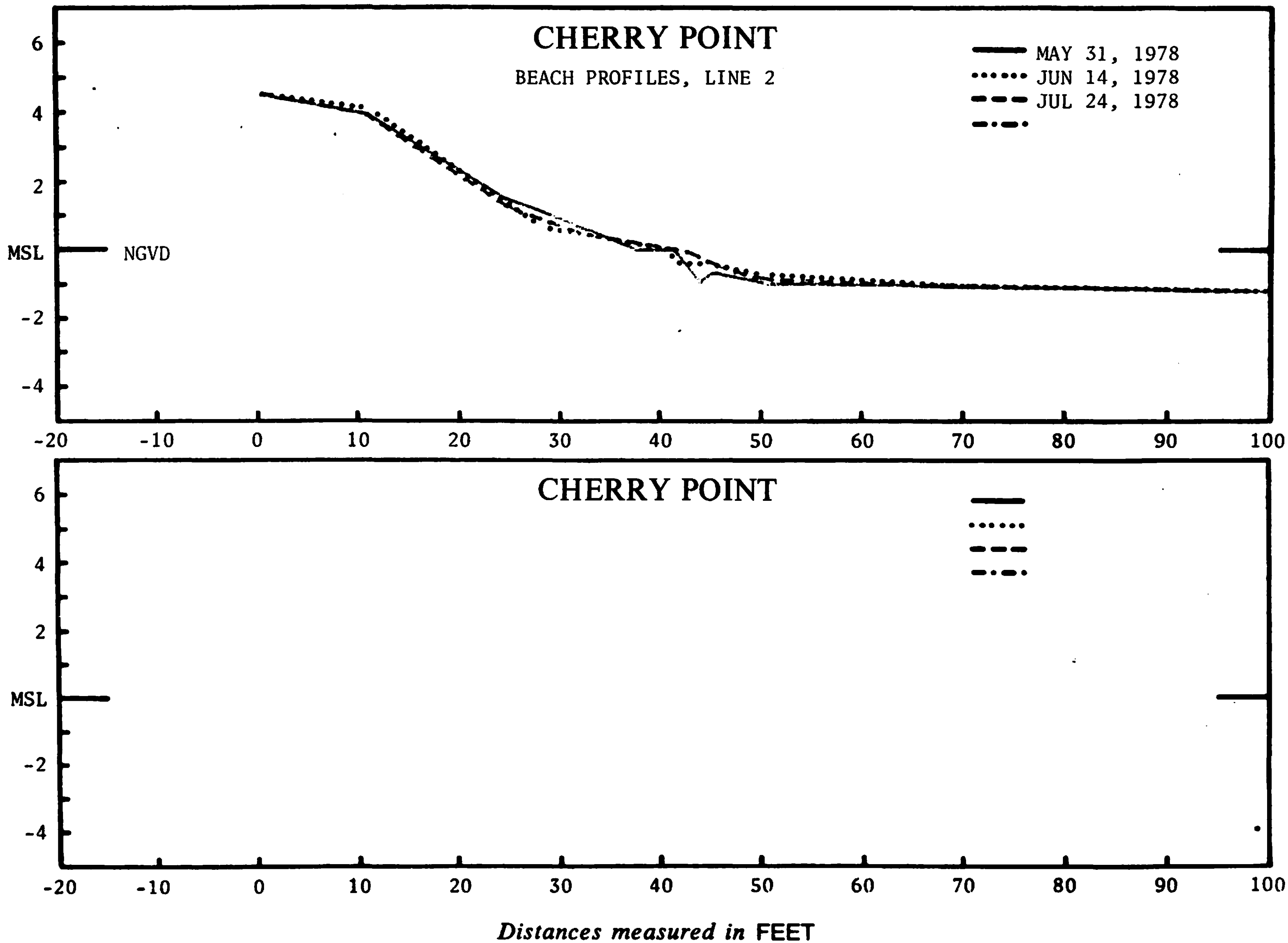


FIGURE 29 cont'd. Profile Line 2 at the Cherry Point site.

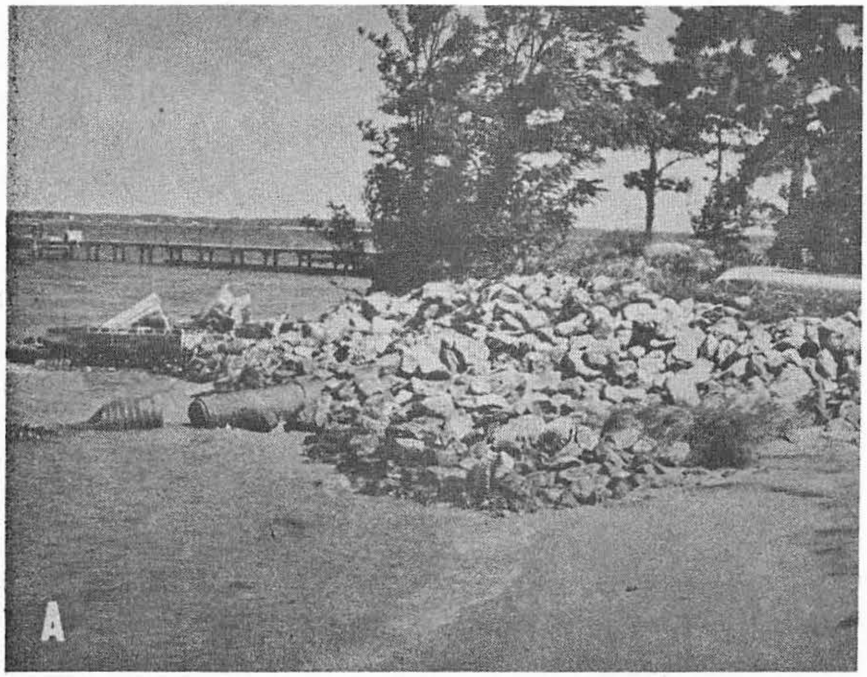
PLATE 16

A. CHERRY POINT ASSOCIATION

The pre-installtion of the site is illustrated in this photo of May 11, 1977. Note the lack of sand around the culvert pipe and the necessary emplacement of riprap to protect the adjacent fastland.

B. CHERRY POINT ASSOCIATION

This photograph of May 17, 1978 is just after the sandbag sill installation on May 10, 1978.



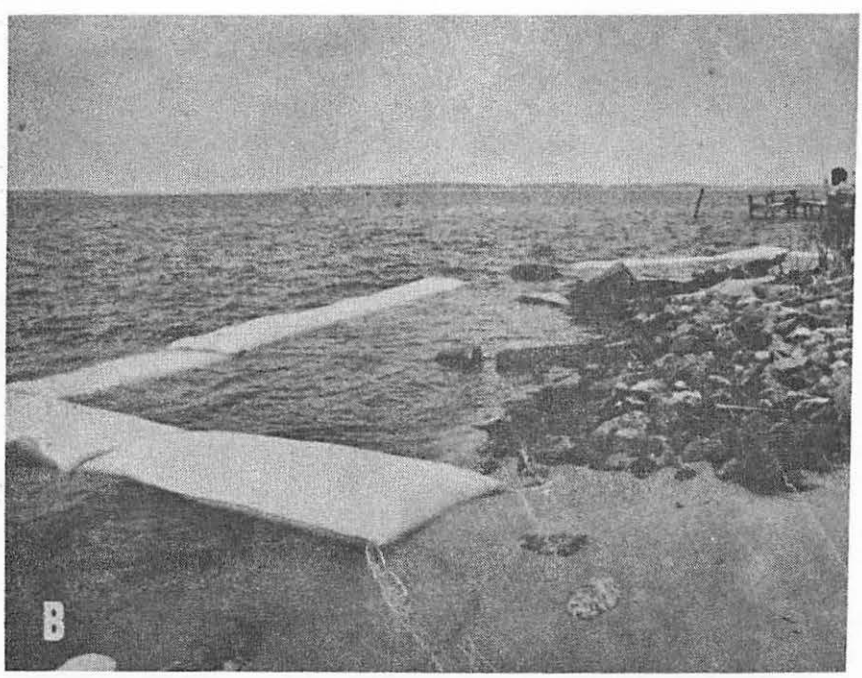


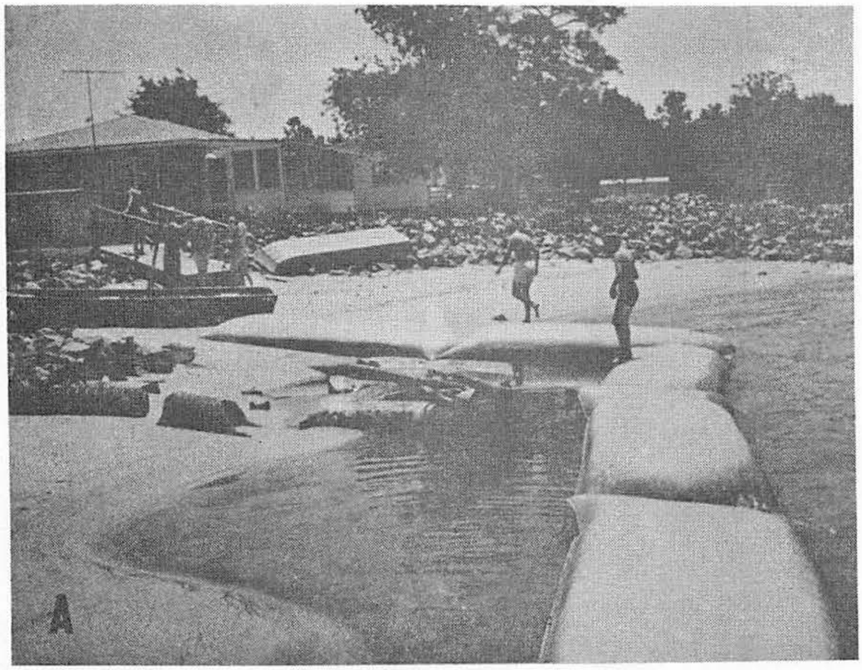
PLATE 17

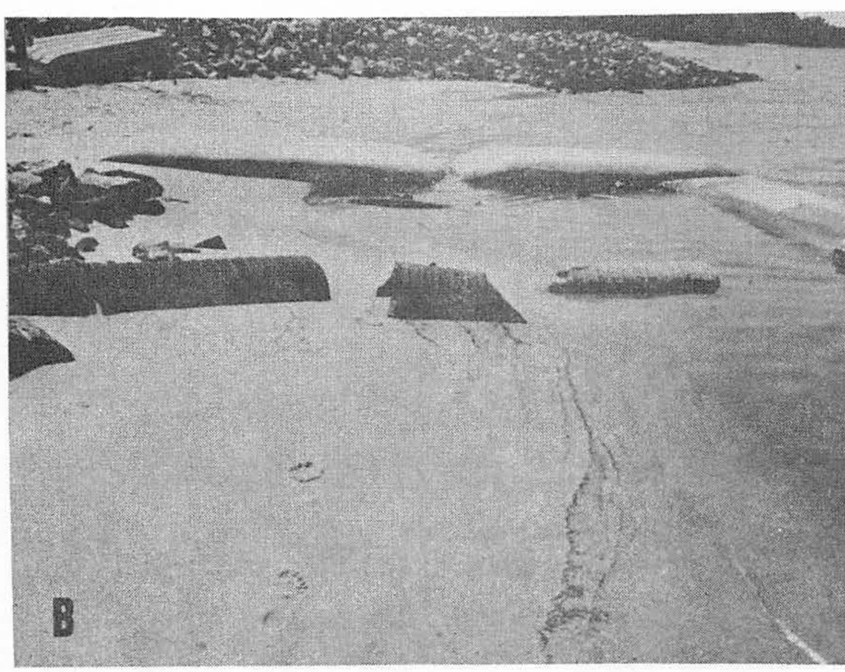
A. CHERRY POINT ASSOCIATION

As witnessed by the accretion around the culvert pipe, the beach has begun to build by June 28, 1978. Local residents will benefit from an increase in beach breadth as recreational activities will be enhanced as well as providing additional protection from storm waves.

B. CHERRY POINT ASSOCIATION

This photograph of July 24, 1978 reveals further beach accumulation around the culvert pipe.


A


B

MAYNARD SITE

Easement:

Mr. William G. Maynard, 8714 River Road, Richmond, Virginia.

Site Location:

White Stone, Lancaster County, Virginia, on the Rappahannock River.

Directions to Site:

From White Stone, Lancaster County, travel south on route 695 for 0.7 mile, then turn right onto route 641. Use route 641 for 1.1 miles. On the right is a drive leading to the site. The drive entrance has the sign "Maynard's Choice" hanging from a chain. Permission for access is required from the landowner.

Shoreline Physiography

The Maynard site rests approximately in the middle of a 3 mile shoreline reach which extends from Cherry Point to Mosquito Point (Figure 30). The eastern half of the reach has high bluffs (up to 50 feet), the erosion of which feeds littoral drift material to the western half of the reach and to a spit, Mosquito Point, formed by eastward moving littoral drift. The drift of material to the west has formed spits across creek mouths and a barrier spit ending at Cherry Point (not to be confused with the Cherry Point on Gwynn Island). The 100

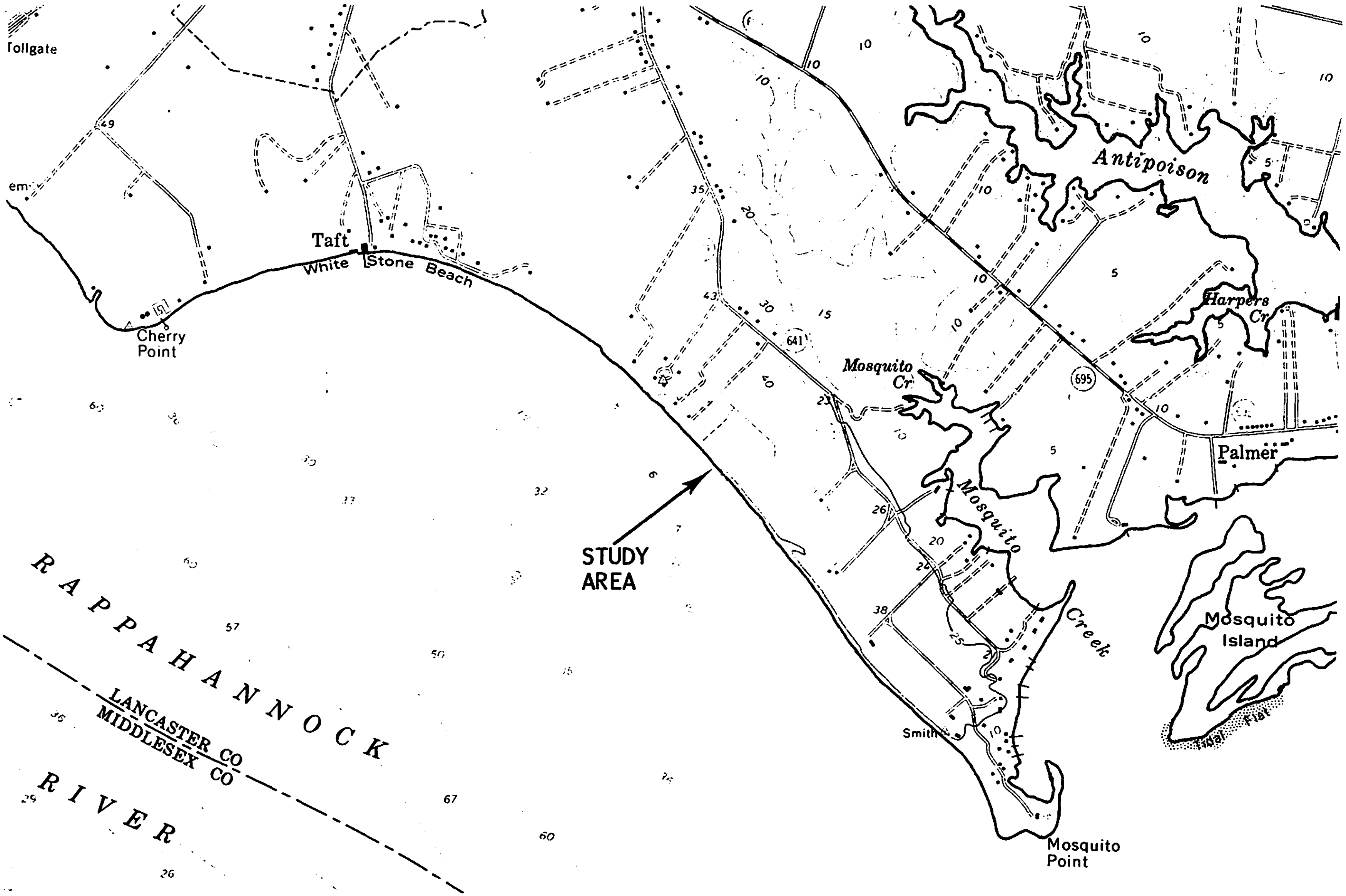


FIGURE 30. Maynard site. From Deltaville, Fleets Bay, Irvington, and Wilton Quadrangles.
Scale 1 inch = 2000 feet

year average erosion rate for the bluff section is less than 1 foot per year. The relatively low retreat is in part due to the presence of a peat and clay strata at the base of the bluff. Overlying this resistant strata is a thick deposit of relatively fine sand. Adjustment of the bluff face slope is a continuing process as runoff percolates down the sand and lubricates the interface at the clay layer. This leads to local slope failure which in turn causes adjustments higher on the bluff face. In addition, when tress become dislodged from the top and face of the bluff they carry large soil masses to the base of the bluff.

The beach fronting the bluff was quite narrow, less than 10 feet at high tide (mean tide range 1.2 feet). Even with a small storm surge wave action attacks the bluff toe. The beach material is medium to coarse sand (median diameters ranged between 0.36 to 0.70 mm). Although the fetch distances are not large (Figure 31) the site receives wave attack from easterly waves which refract around the nearshore terrace at Mosquito Point and from the west winds.

Structure Design

A previous attempt to inhibit erosion using a segmented sandbag sill (Figure 32) was unsuccessful in accreting enough sand to isolate the bluff toe from wave action. In order to enhance trapping, partial groins were installed using gabions at the center of each sill segment. The outboard gabions were each 12'x3'x3' while the inboard gabions were each 12'x3'x1.5'. Installation of the gabions was

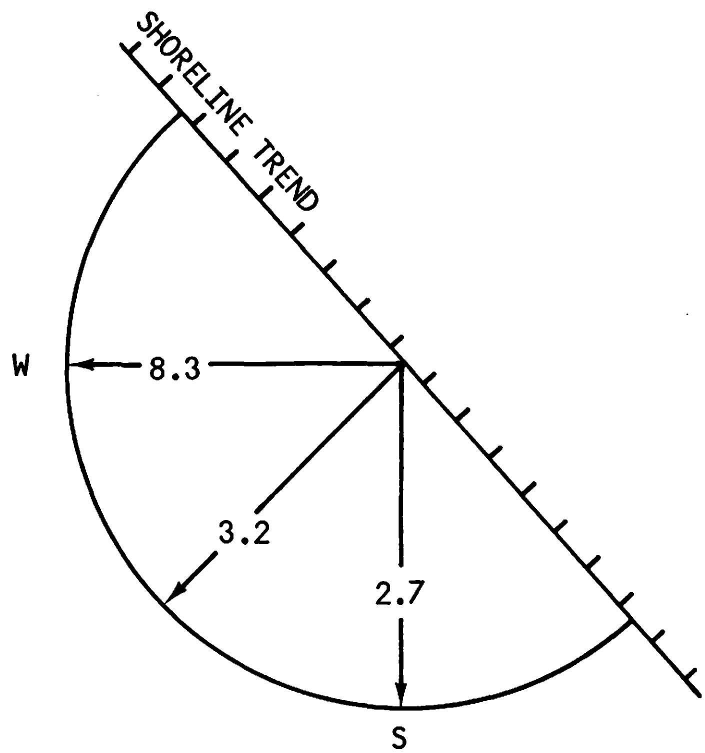


FIGURE 31. Fetch distances (nautical miles) at the Maynard site.

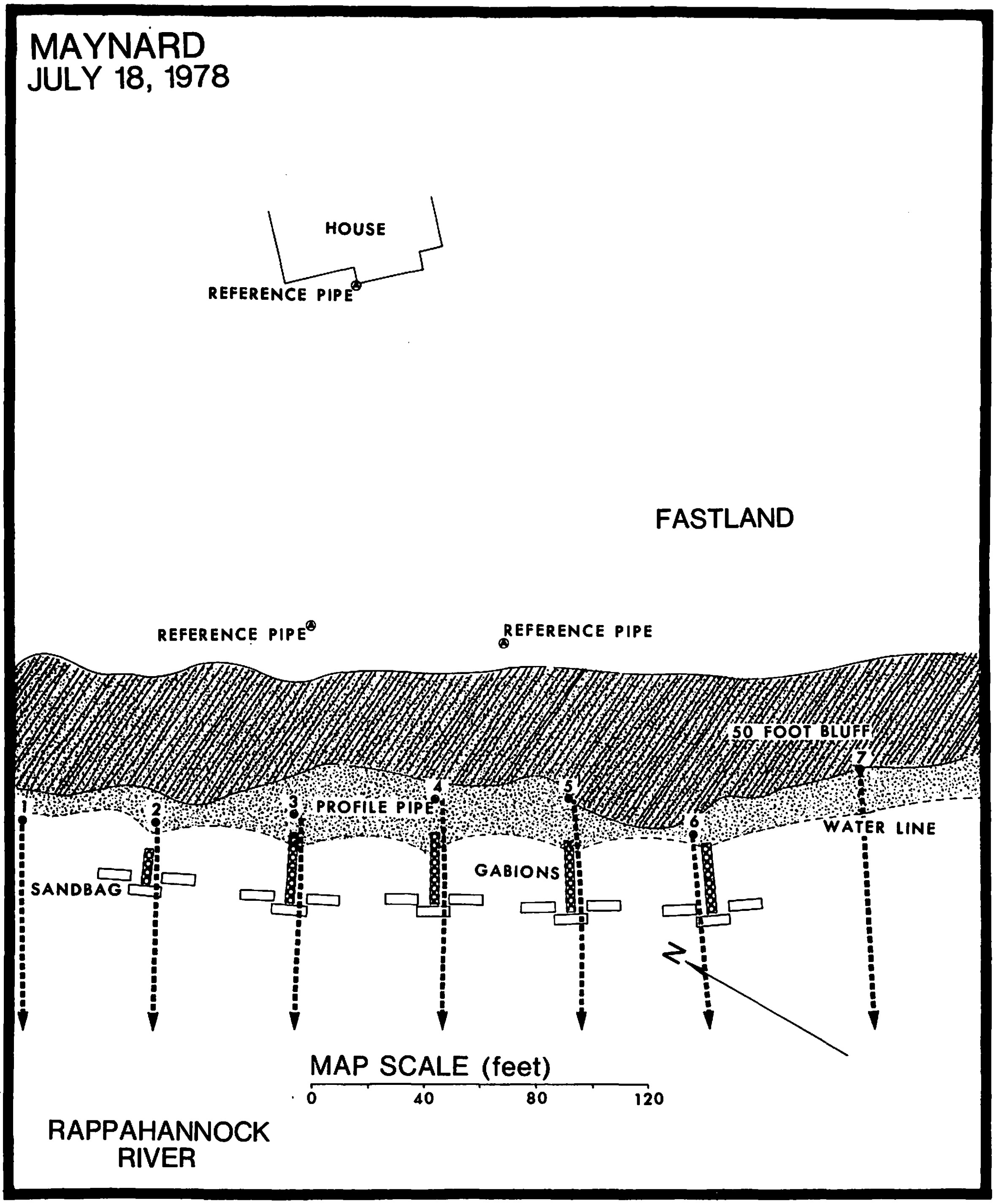


FIGURE 32. Plan view of the structure layout at the Maynard site.

completed on 18 April, 1978.

Results and Effects

The beach responded well to the groin-sill combination. Without exception, all profile lines within the test area accumulated a significant amount of sand. Line 2 showed oscillations in volume but the net result was accretion. Each sequential profile for Lines 3 though 6 represents an addition to the foreshore elevation and an increase in height and width of the backshore. This is exemplified by Line 5 (Figure 33) wherein local elevation increases of about two feet may be noted between 17 March and 18 July, 1978. The response of the beach is also illustrated in the photographs of Plates 18, 19, and 20.

The control lines 1 and 7 which are outside the treated area showed marked contrast. Line 1 (Figure 34) documents the continued loss of beach. Line 7 (Appendix B), however, marked increase in sand volumes. This adjustment might be attributed to a net westerly littoral drift during the observation period wherein Line 7 represents the updrift sand fillet caused by the groin system and Line 1 represents the downdrift beach retreat. If so, then the beach at locations of Lines 1 and 7 may be expected to shift back and forth in the future in response to temporal changes in the directions of littoral drift.

The results show that the addition of the gabions to the sandbag sill can be accredited for the accretion at the site. Given these results, the installation at this site can be considered a success.

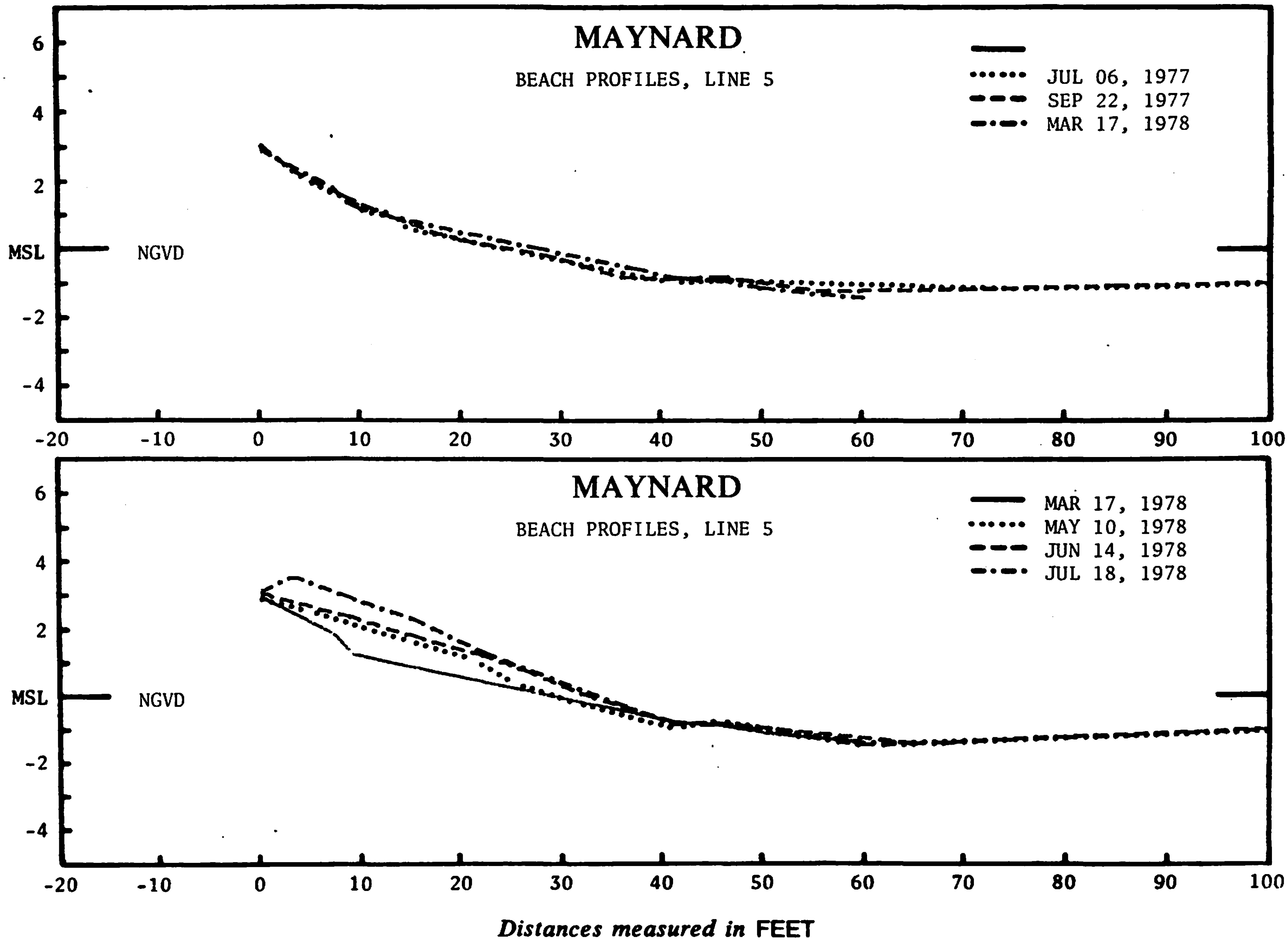


FIGURE 33. Profile Line 5 at the Maynard site.

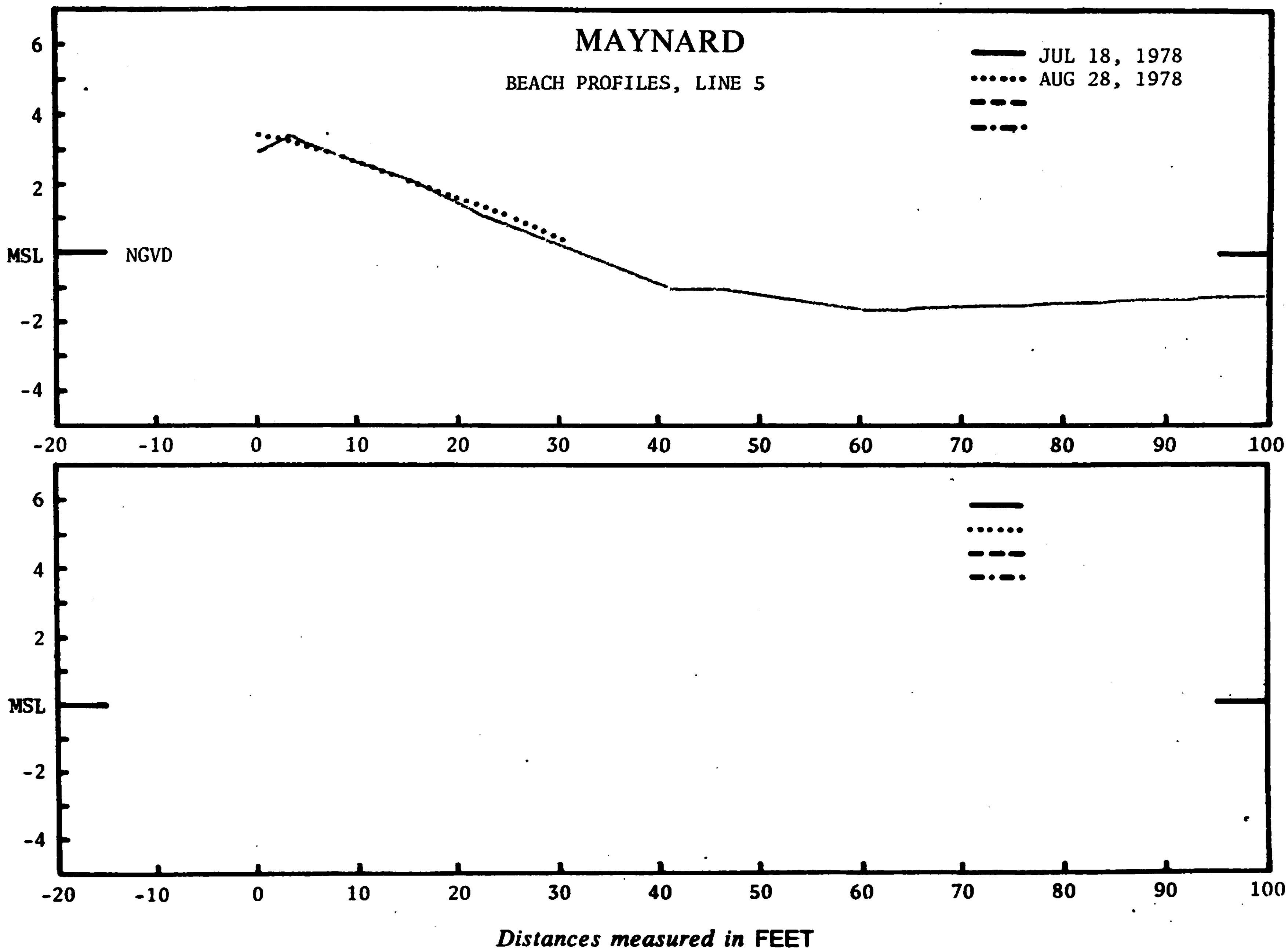


FIGURE 33 cont'd. Profile Line 5 at the Maynard site.

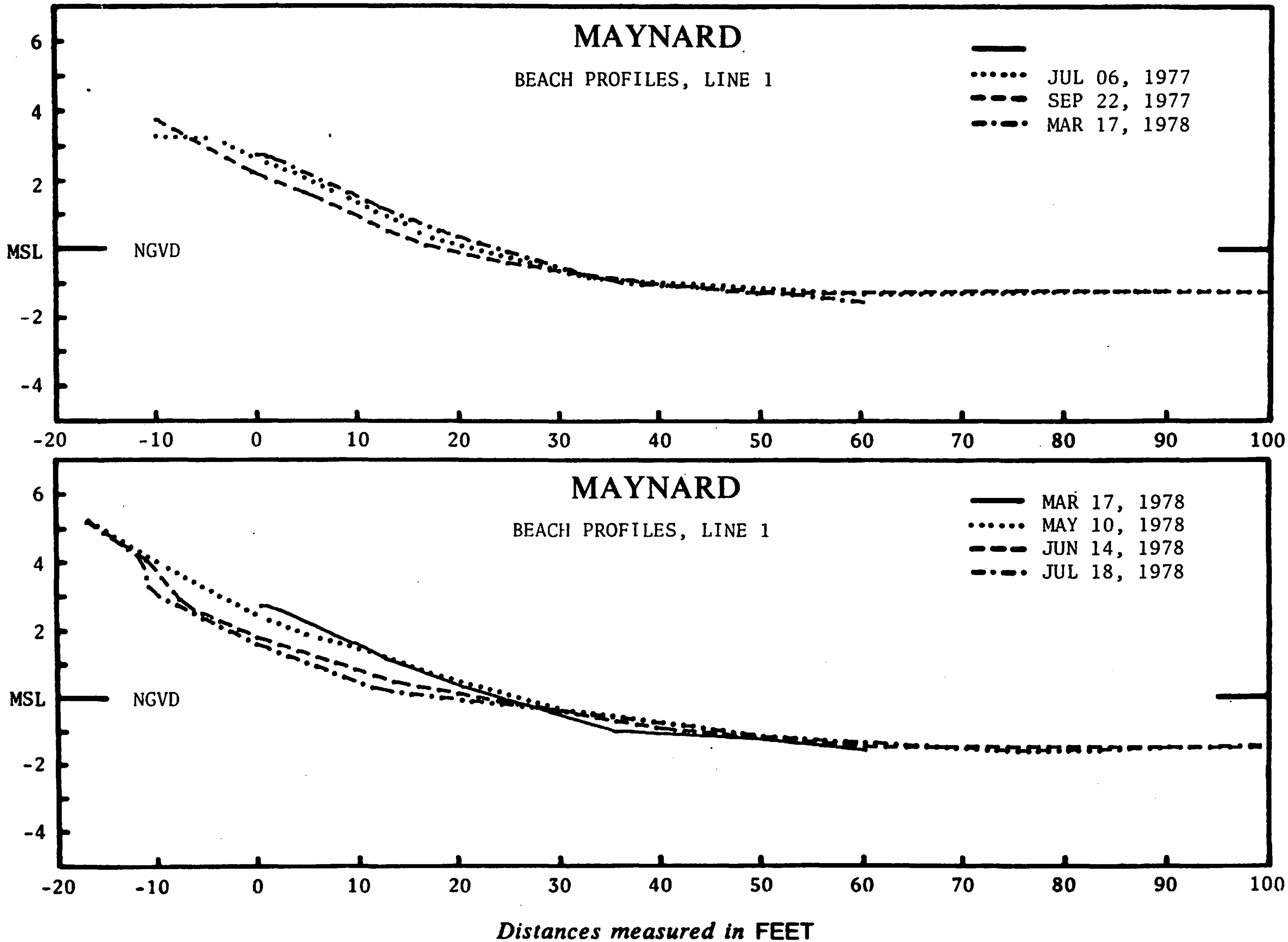


FIGURE 34. Profile Line 1 at the Maynard site.

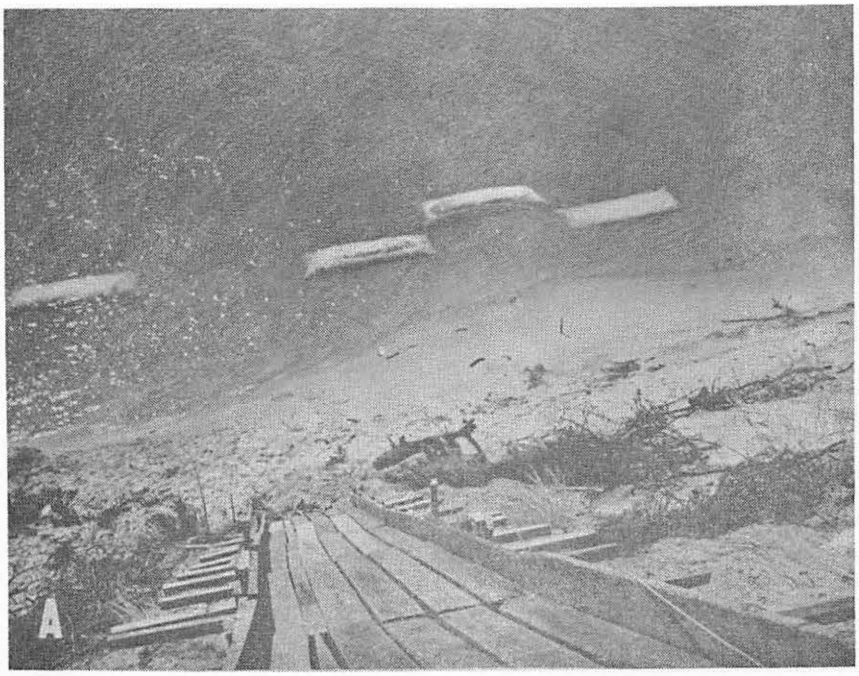
PLATE 18

A. MAYNARD

With the rock ramp in the foreground, this photograph of April 6, 1978 illustrates the pre-installation site conditions. The sandbag sill is the result of a previous attempt by the landowner to control erosion at the base of the 50 foot cliff. Profile pipe number 2 can be seen on the beach foreshore.

B. MAYNARD

By May 31, 1978, the system had begun to accrete after the installation of the gabions on April 18, 1978. Note the different gabion sizes used. Evidence of the accretion can be seen around the profile pipe exposed on the beach.



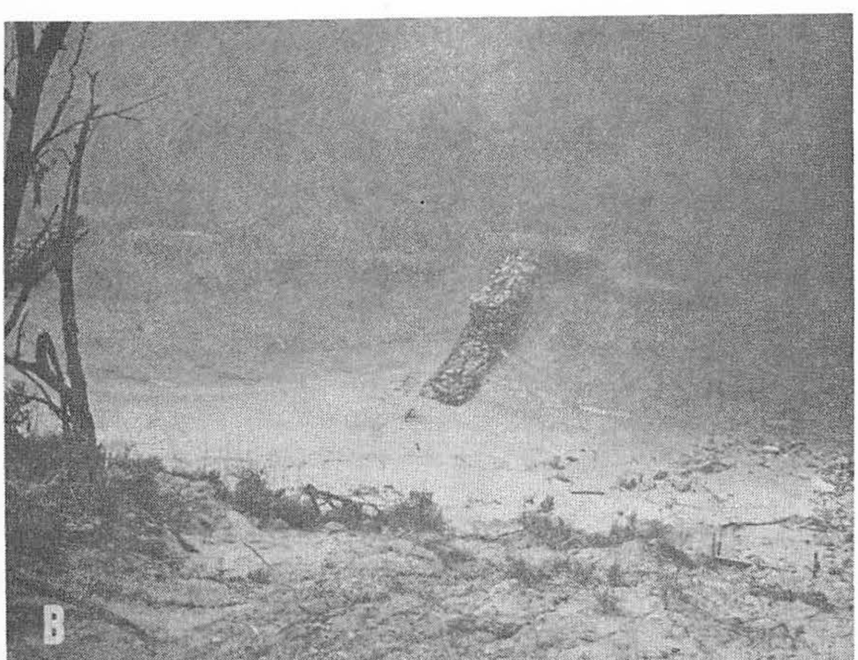


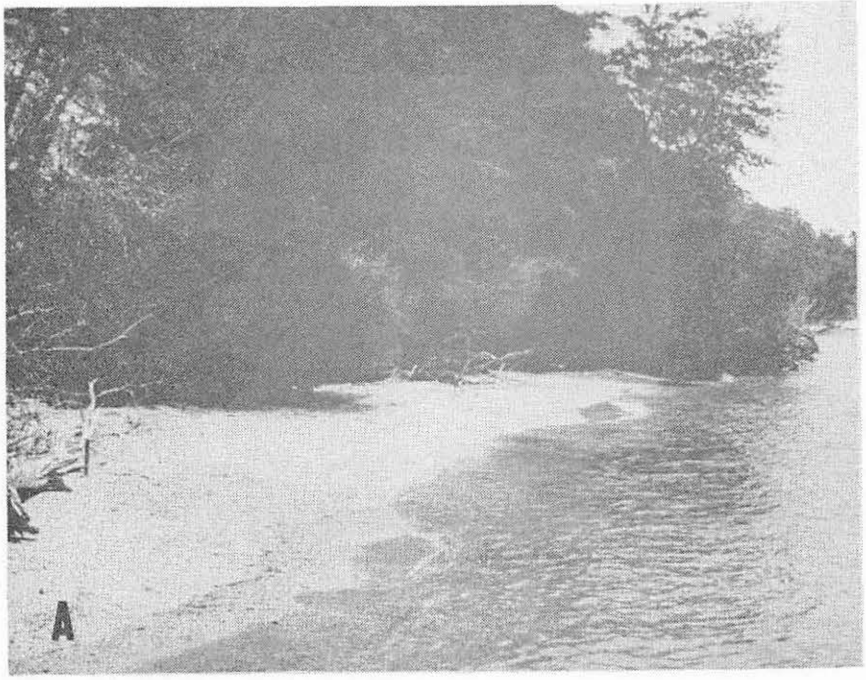
PLATE 19

A. MAYNARD

Beach level photograph looking east. This photo was taken on July 6, 1977.

B. MAYNARD

The same location on July 18, 1978. There has been an obvious increase in beach width and height.


A

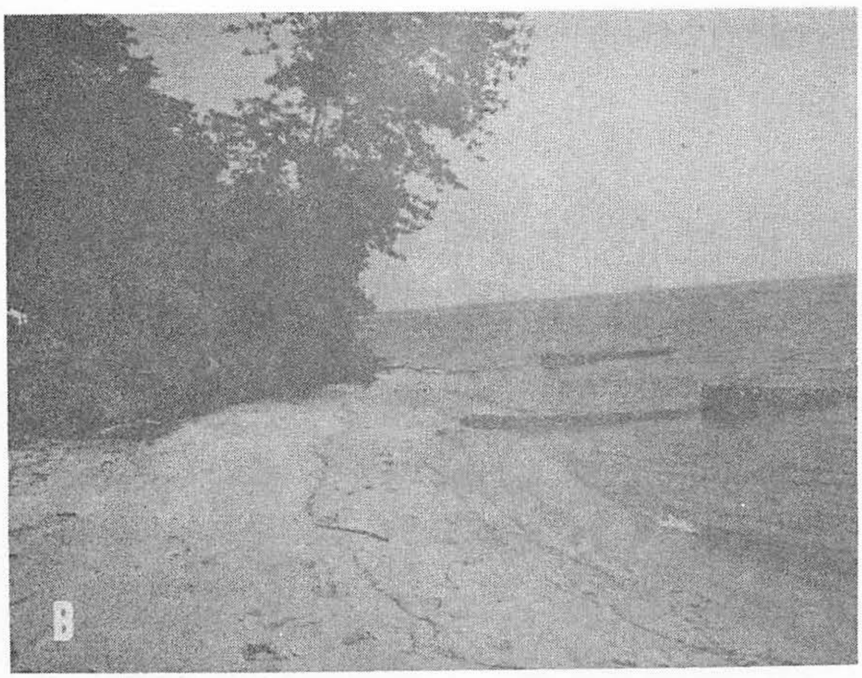

B

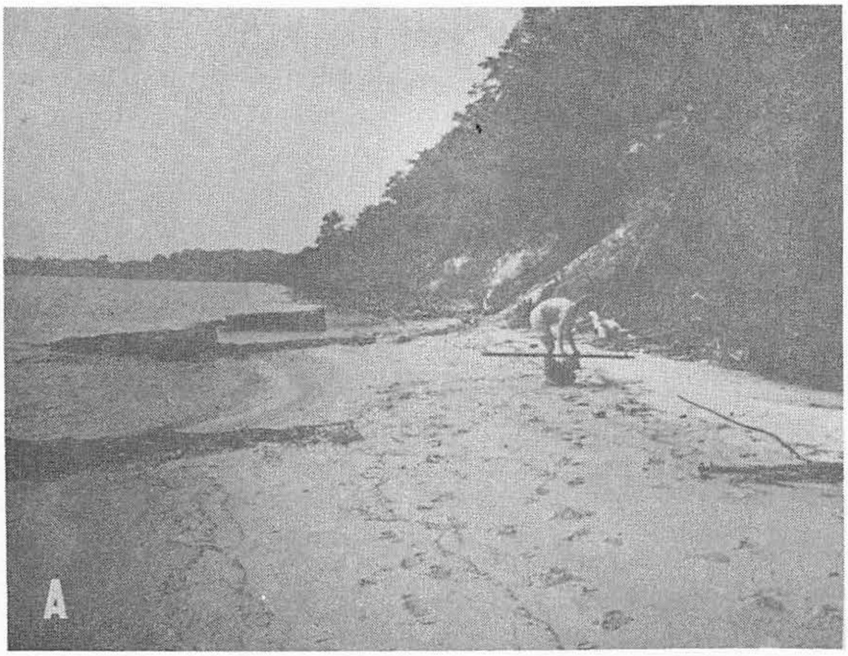
PLATE 20

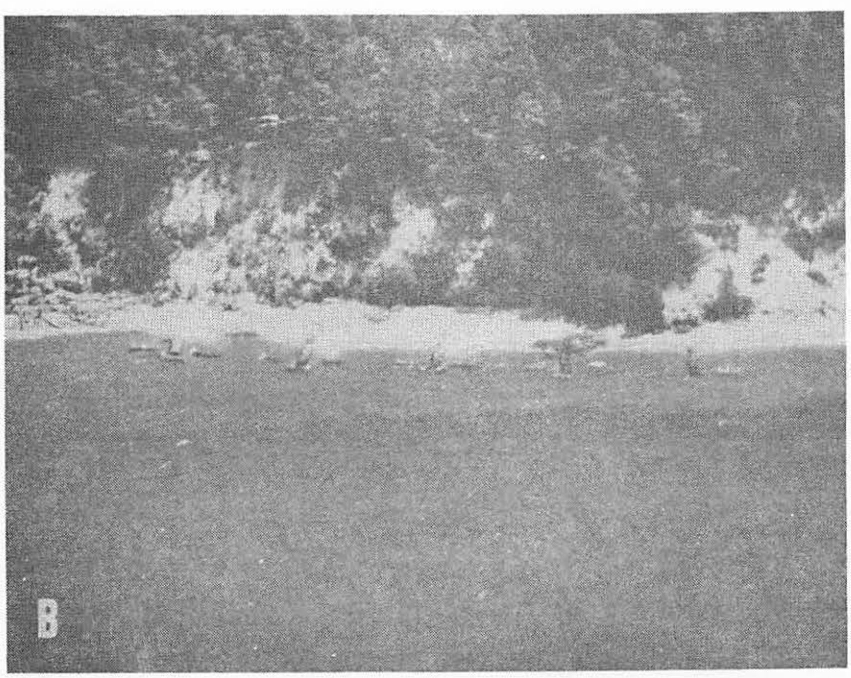
A. MAYNARD

Looking westward the beach has begun to bury the gabions by July 18, 1978.

B. MAYNARD

This oblique aerial photograph records the increase in beach width and height along the entire site. This photo was taken on August 8, 1978.


A


B

DENNIS SITE

Easement:

Mr. Eugene T. Dennis, 3319 Suffolk Road, Richmond, Virginia, 23228.

Site Location:

Marshalls Beach, Hull Neck, Northumberland County, Virginia, on the southern shore of the Potomac River.

Directions to Site:

From Burgess, Northumberland County, travel route 360 west to route 640. Use route 640 for four miles. Enroute to the site on 640, there are three ninety degree turns. After the third such turn, the second drive leads to the Dennis site. There is a sign 'DENNIS' at the start of the drive. Permission for access is required from the landowner.

Shoreline Physiography

The Dennis site at Marshalls Beach (Figure 35) is located about 1.5 miles east of Hull Creek which itself forms the western limit of a 9.5 mile reach ending on the east at Smith Point. The entire reach has a low bluff, 10 to 15 feet in height, composed of unconsolidated sands. The unconsolidated nature of the bank material and the long fetch to both the easterly and westerly wind quadrants (Figure 36) are

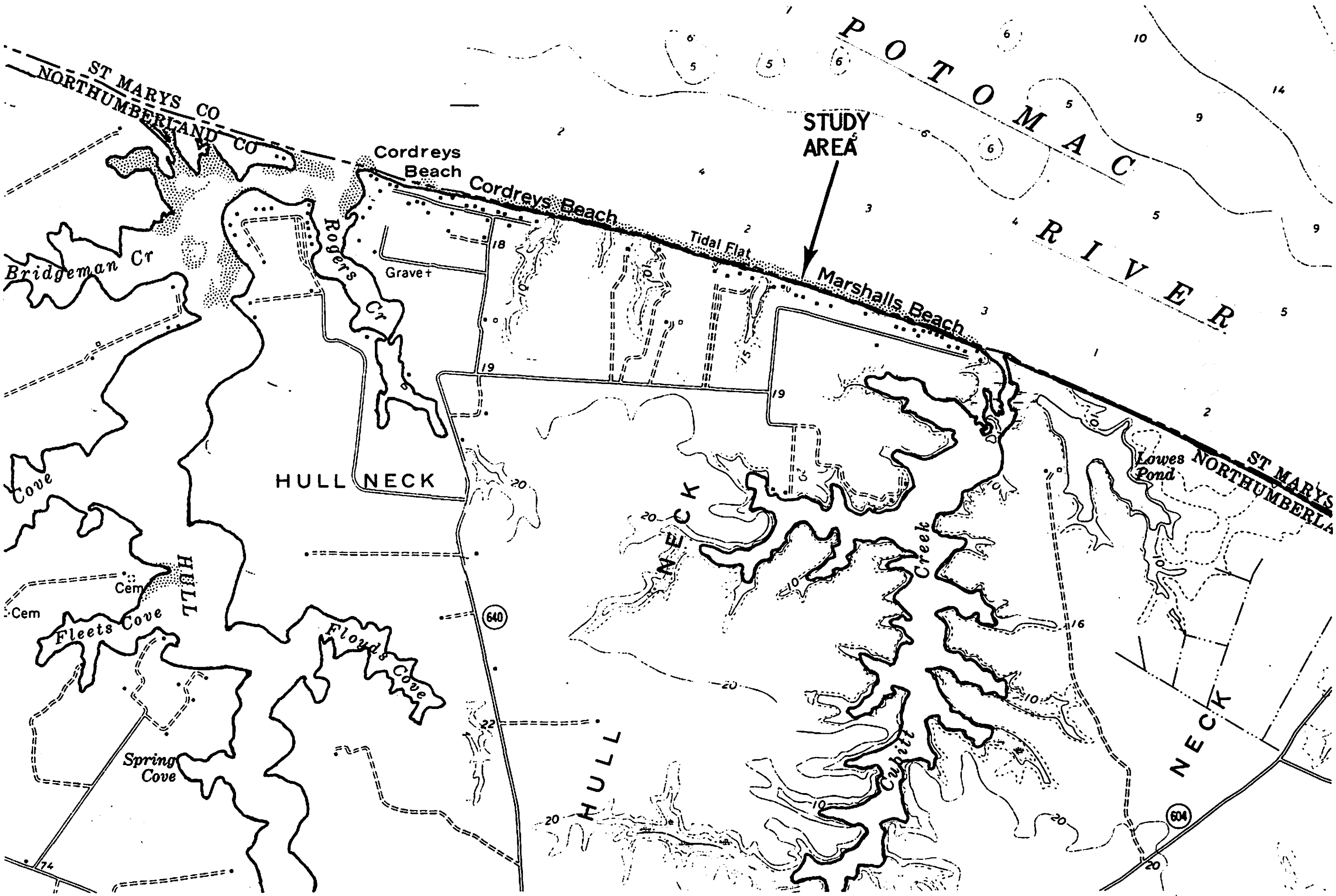


FIGURE 35. Dennis site. From Burgess and Heathsville Quadrangles.
Scale 1 inch = 2000 feet

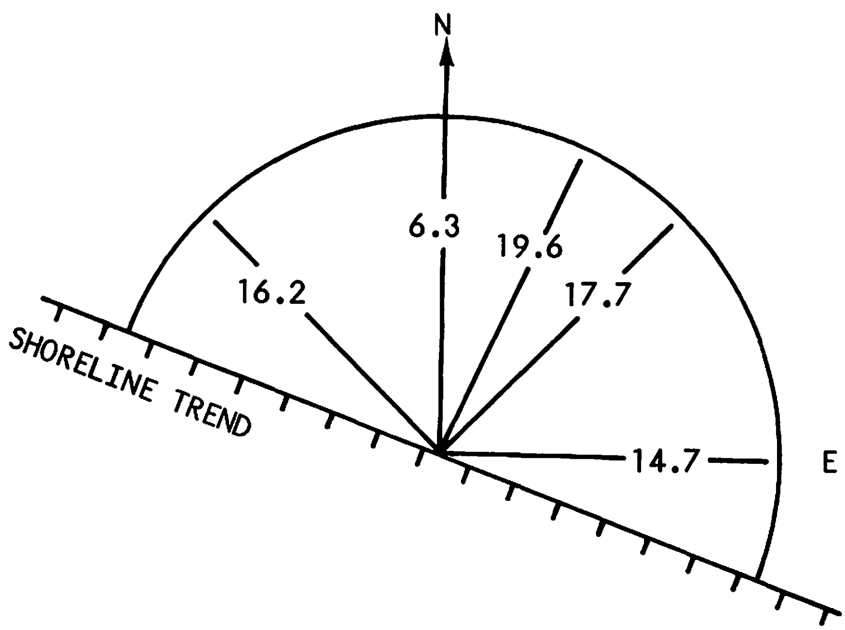


FIGURE 36. Fetch distances (nautical miles) at the Dennis site.

the principal factors contributing to the high erosion rate within the reach. The 100 year average rate is 4.9 feet per year (Byrne and Anderson, 1977). Conversely, the high erosion rate supplies a large volume of sand to the littoral drift system so strategies of erosion control using groin fields has met with reasonable success when properly designed and constructed. Since there are a number of dwellings close to the bluff the erosion rate is considered to be critical at Marshalls Beach. At the beginning of the observation period, the beach width at the Dennis site was 10 to 15 feet relative to the estimated mean tide line (mean tide range about 1.2 feet) and the beach was composed of medium sand sizes (median diameters ranged between 0.26 to 0.56 mm).

Structure Design

Since the rate of littoral transport is high in the region and there were no impeding structures nearby, a perched beach was attempted. The layout is shown in Figure 37. A total of 15 sandbags were used to construct a sill approximately 180 feet in length with partial returns at both ends. The sill was placed approximately parallel to the shoreline about twenty-five feet from the estimated mean tide level. The installation was completed on 25 April 1978.

Results and Effects

The date of installation was one day prior to the occurrence of the 26 April storm. The major storm did significant damage to the

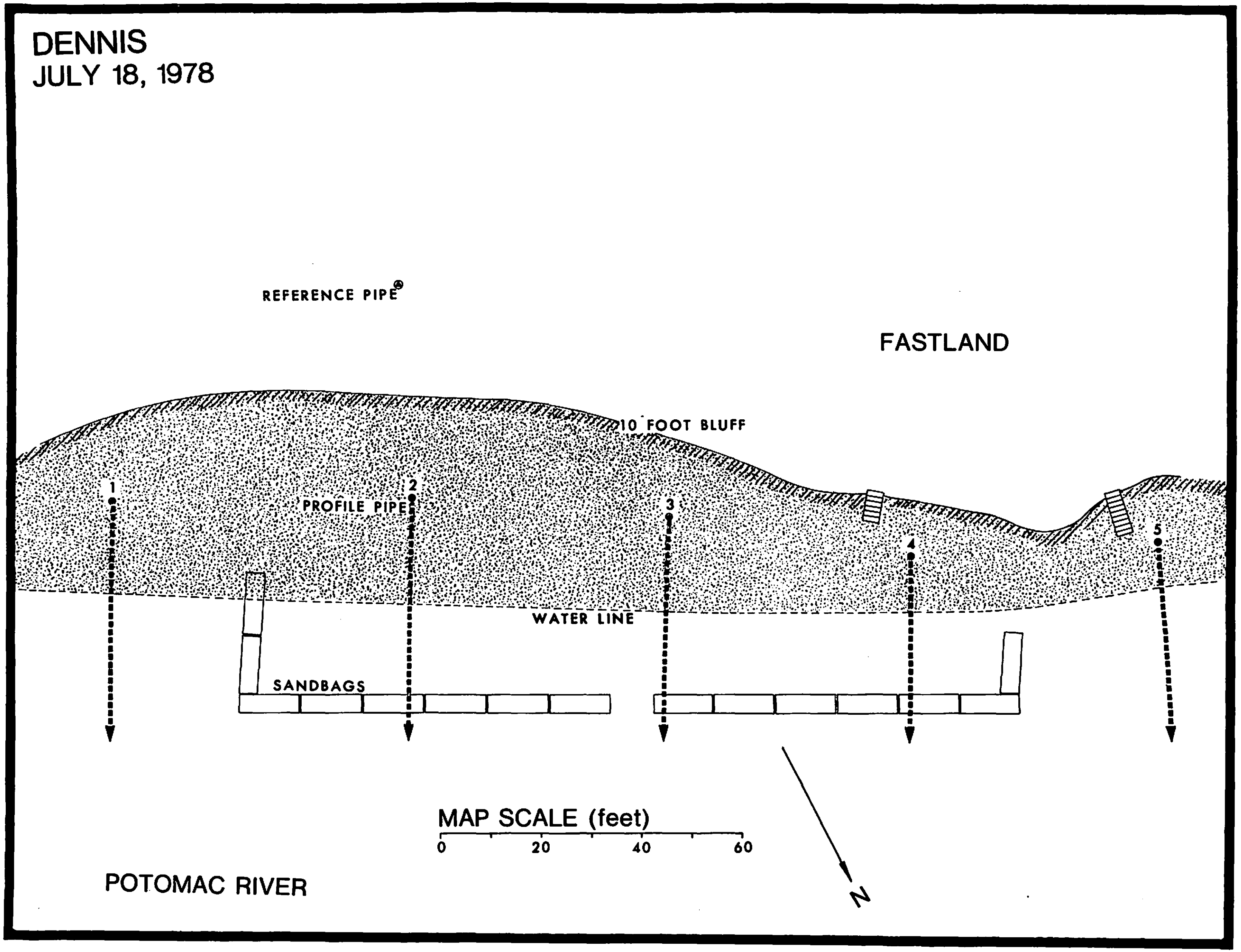


FIGURE 37. Plan view of the structure layout at the Dennis site.

shoreline immediately adjacent to the Dennis site. Bluff retreat was in excess of 15 feet. In comparison, the site itself suffered relatively minor bluff retreat amounting to losses between 1 and 5 feet. The storm did not move the sandbags.

Dramatic changes to the beach occurred at the Dennis site in response to the storm. Observations on 27 April, one day after the storm, showed the sill to be completely covered by sand and the beach to have been widened approximately 30 feet. An important point is that the shoreline trend no longer followed the concave-landward trend of the bluff, rather the beach zone had widened to form a linear segment continuous with the adjacent shorelines.

The beach profiles illustrate well the changing events of the beach. Figure 38, 39, and 40 show the response of Profile Lines 1, 2, and 5, respectively. The part of the site in the reentrant, Profile 1, 2, and 3, exhibited dramatic accumulations during the summer of 1977. Accumulation was also present at Lines 4 and 5 but to a much lesser extent. In March 1978, the profile was similar to the 1977 summer condition except at Line 5 where some deflation had occurred.

Immediately after the 26 April storm the beach had accreted approximately a foot elevation at all lines and, in some cases, (Line 2, Figure 39) nearly two vertical feet of sand had been added. The profile observations over the following two months illustrate a general tendency of the beach to maintain those elevations. This tendency is also reflected at Profile Line 1 which is located within the reentrant zone. This is probably due to the locally perched beach which has created an accretion shadow zone to the east. The response of the system is shown pictorially in Plates 21 and 22.

The fact the beach responded to a sill within the first season is very encouraging. The backshore elevation is now a few feet higher than that found at the end of the 1977 summer so the goals of the installation are considered as having been achieved. Although modulations in the sand volumes at the site can be expected in response to storms, the net effect of the installation will be to reduce the erosion.

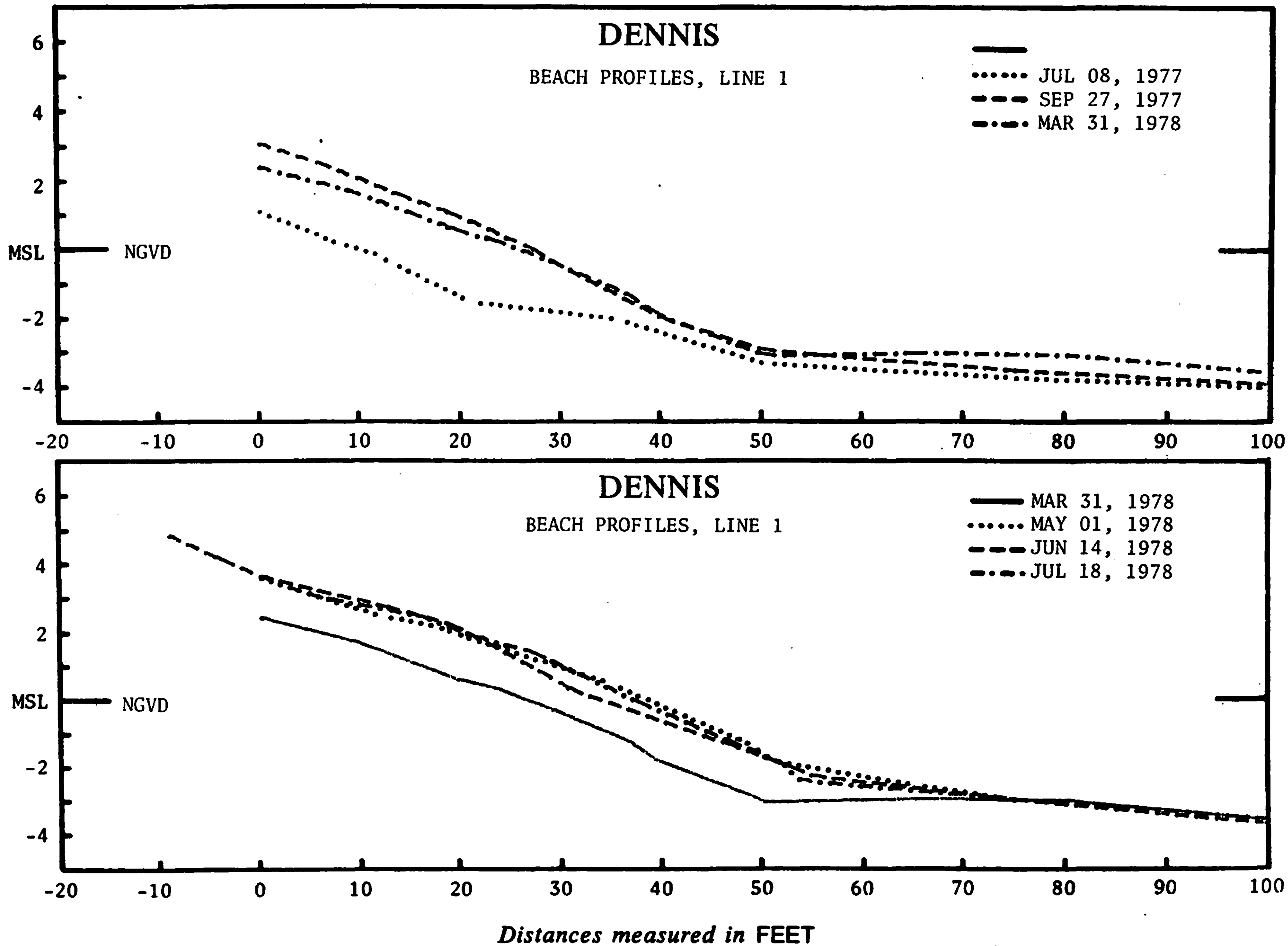


FIGURE 38. Profile Line 1 at the Dennis site.

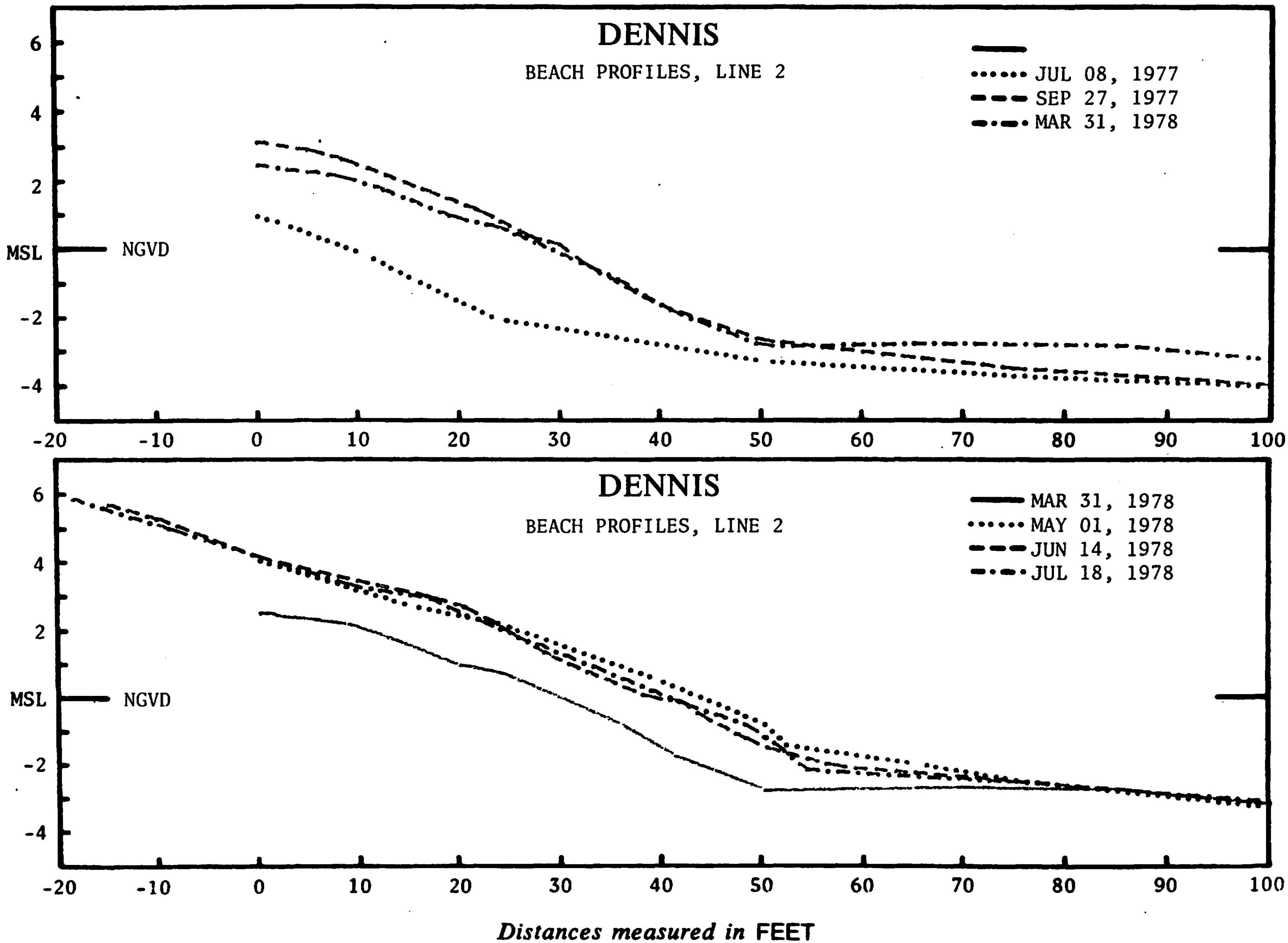


FIGURE 39. Profile Line 2 at the Dennis site.

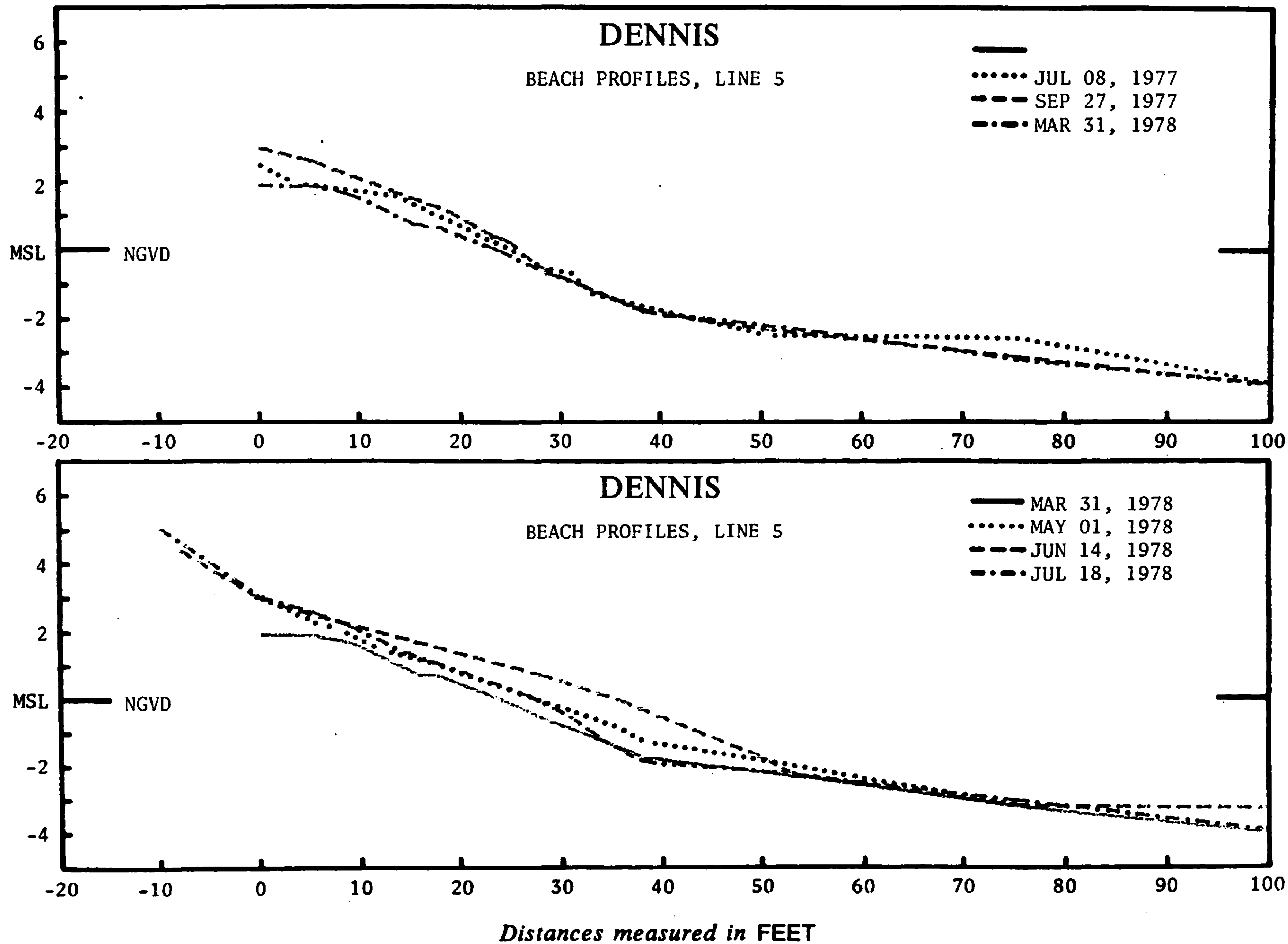


FIGURE 40. Profile Line 5 at the Dennis site.

PLATE 21

A. DENNIS

On July 7, 1977, the cliff scarp and fallen trees illustrate the recent rapid retreat of the shoreline. Note the concavity of the shoreline geometry.

B. DENNIS

Two profile pipes can be seen in the foreground of this picture. The larger was driven when the smaller had been buried by summer beach accretion. As a result of the storm of October 14, 1977, the buried pipe was exposed as illustrated in this October 27, 1977 photo.

C. DENNIS

This eastward looking photograph of May 1, 1978 records the dramatic recovery of the beach. The sandbag sill is now all but buried by the beach. The sill, installed on April 25, 1978, extends away from the exposed sandbags in the picture's foreground and parallels the waterline.

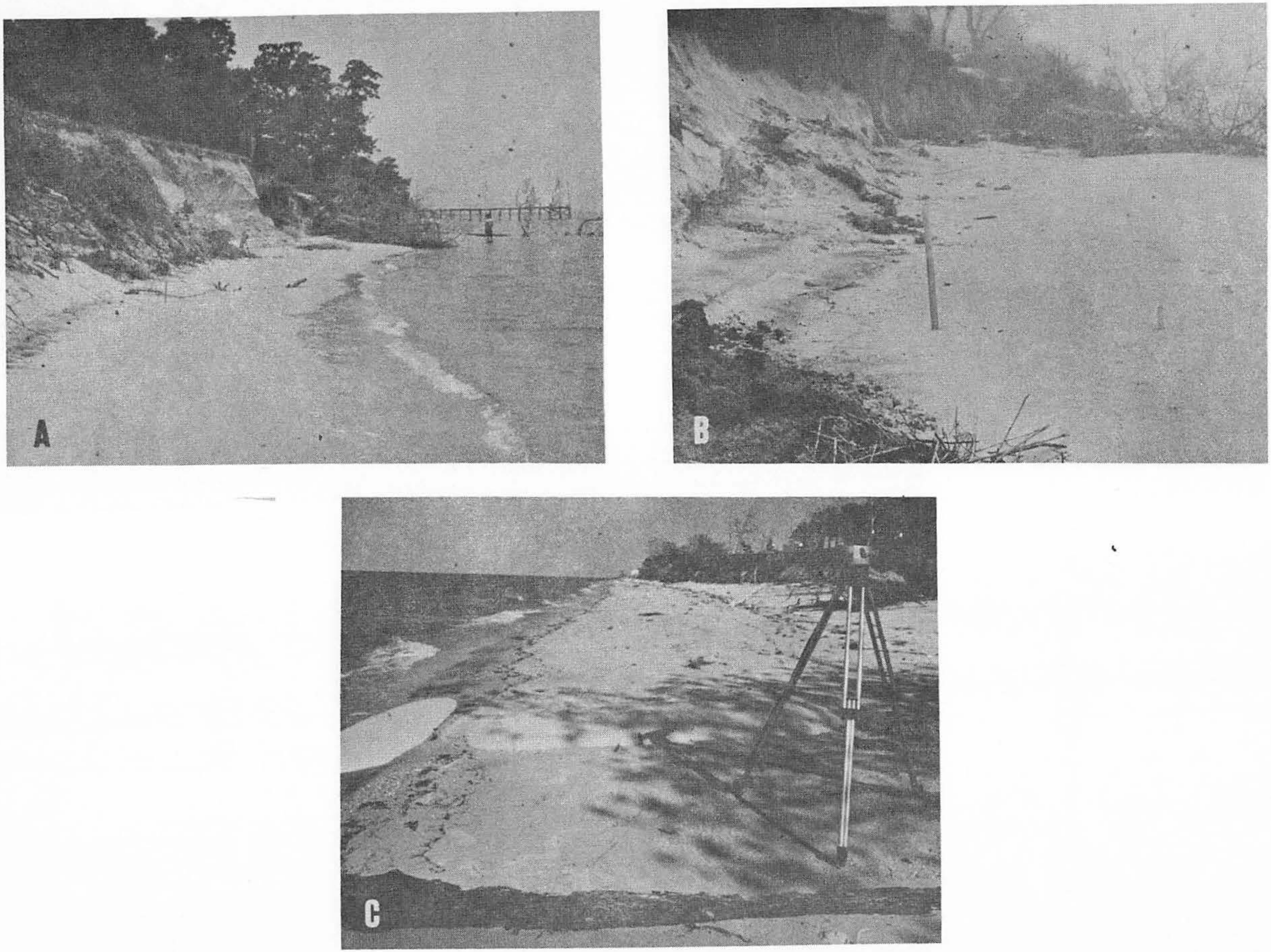

A
B
C

PLATE 22

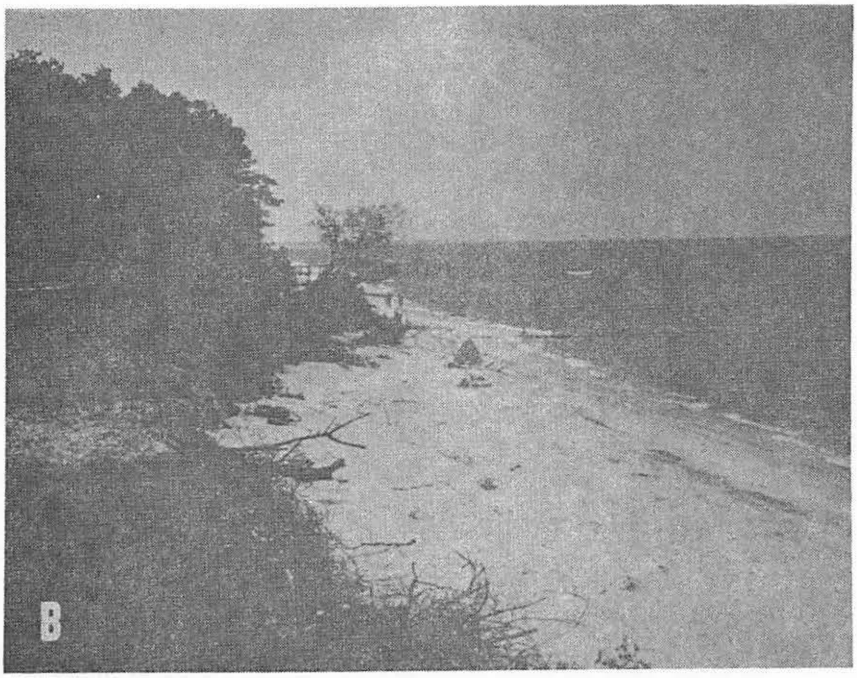
A. DENNIS

The fallen tree and row cliff give evidence to the rapid retreat of the shoreline in this April 18, 1977 photograph.

B. DENNIS

While the bluff had receded considerably the beach has widened dramatically in this June 28, 1978 photo taken from atop the bluff. Note that the water line is approximately at the same relative position to the fallen tree in both A and B, and that the waterline concavity no longer exists in the lower photograph. The profile pipes have been nearly completely buried with but a few inches exposed at pipes 1, 2, and 3. Tops of sandbags can be seen at the waterline in the vicinity of the fallen tree.


A


B

COLONIAL BEACH SITE

Easement:

D. F. Denson, Mayor, attested by B. M. Boyd, Clerk, Town of Colonial Beach, Virginia, 22443.

Site Location:

Off Irving Avenue and Sulgrave Street, Town of Colonial Beach, Colonial Beach, Virginia, on the Potomac River.

Directions to Site:

From Fredericksburg, take route 3 to Oak Grove, then turn left onto route 205. Travel on route 205 for five miles and bear to the right at the fork onto Colonial Avenue (205Y). Use Colonial Avenue for 0.6 mile and turn right onto Washington Avenue. At the 'T' (0.3 mile on Washington) turn left and bear to the right onto Irving Avenue. Go 0.8 mile further and the site is located on the left between Sulgrave Street and Thackary Street. The site is open to view from Irving Avenue.

Shoreline Physiography

The Town of Colonial Beach has about a 4.4 mile shoreline fronting the Potomac River. The northern half is a bluffed headland (Figure 41) while the southern half is a moderately low shore (5 to 10 feet in elevation) which terminates in an active spit at the entrance

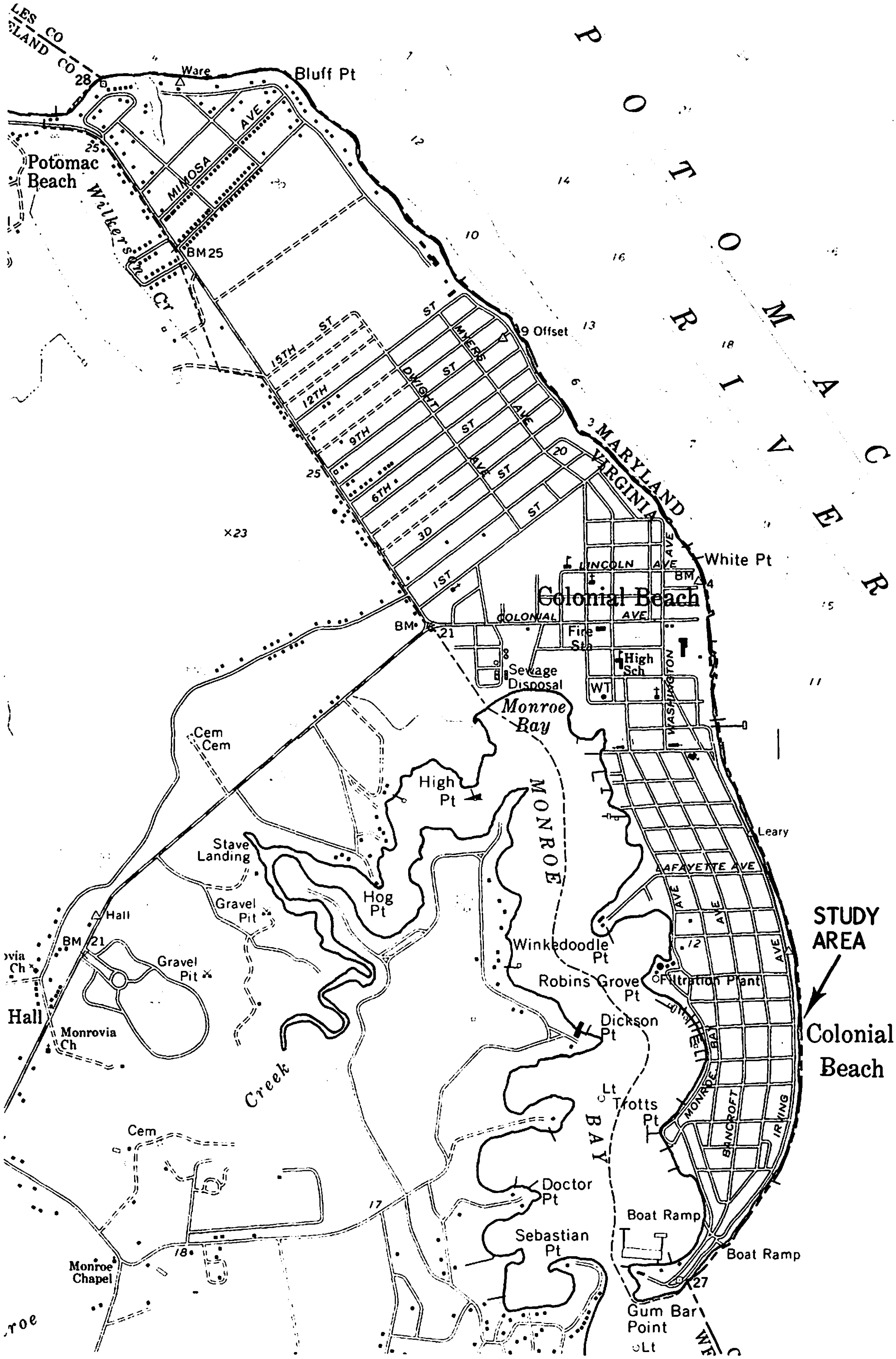


FIGURE 41. Colonial Beach site. From Colonial Beach North and Colonial Beach South Quadrangles.
Scale 1 inch = 2000 feet

to Monroe Bay. Much of the shoreline in the northern portion has been hardened with bulkheading and riprap revetments. Similarly, the shoreline in the southern portion fronting Irving Avenue has been treated in various ways in an attempt to protect the roadway itself. While this has been successful where heavy duty revetments have been used, the roadway along the last mile remains in jeopardy.

The littoral drift supply is limited; the principal local source is the town beach located 4,000 feet to the north of the study site. Although the fetch to the east is not extreme (Figure 42) the site is vulnerable to high waves during easterly storms. In addition, winds from the north and northwest generate waves that do impact the site.

The site under investigation is located near the intersection of Irving Avenue and Sulgrave Street where the backshore elevation is about 5 feet. To the north the roadway embankment is stabilized with a concrete revetment. At the site itself a series of groins had been constructed using stacks of small burlap bags filled with ready-mix concrete. Prior to our experiments the beach had an average width of 12 feet and was composed of medium to coarse sand ranging from 0.33 to 1.78 mm in median diameter. Mean gravel content was 45% by weight.

Structure Design

The goal of our experiment at the Colonial Beach site was to test whether the trapping characteristics of the existing groin field could be improved by the addition of sills at the ends of the groin and to

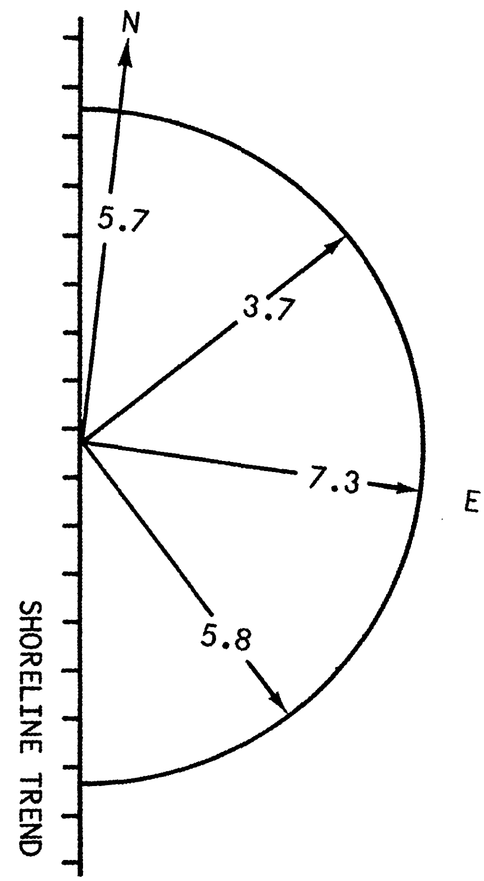


FIGURE 42. Fetch distances (nautical miles) at the Colonial Beach site.

thereby form a closed compartment. Secondly, we wished to test how well such compartments could retain sand if the system was artificially sand nourished. The plan view of the layout is shown in Figure 43. In order to test this question combinations of conditions using sills, with and without additional sand fill, were employed. Relative to Figure 43 the following plan was adopted:

Profile Line	Condition Tested
1	No treatment - a control
2	Sill with fill
3	Sill only
4	Fill only
5	Sill only
6	Sill and fill
7	Fill only
8	Sill only
9	Sill and fill
10	No treatment - a control

The installations were completed 31 May, 1978.

Results and Effects

A few days prior to the 26 April, 1978 storm sandfill was delivered to the site and placed along the backshore. This material, extracted from Gum Bar Point (Figure 41), was to be used as fill material for the sandbags and to fill the appropriate groin cells.

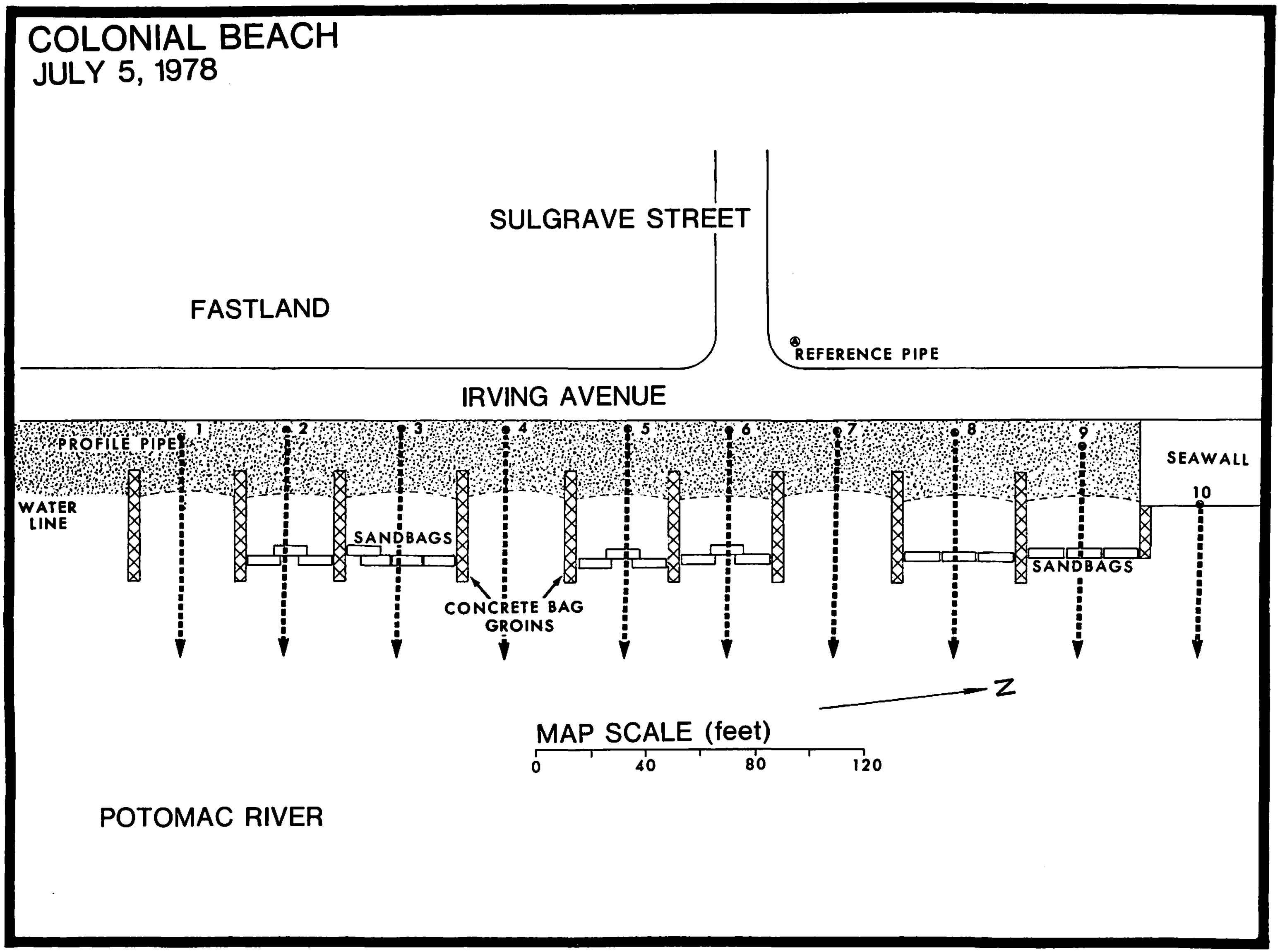


FIGURE 43. Plan view of the structure layout at the Colonial Beach site.

The 26 April northeast storm removed the emplaced sand. Additional fill sand was brought in following the storm.

Typical results illustrating the site response are shown by Plates 23 and 24, and by Profile Lines 5, 6, and 7 (Figures 44, 45, and 46, respectively) which contrast a cell with sill only (Line 5), a cell with sill plus fill (Line 6), and a cell with a fill only (Line 7). While all three cells show slight accretion on the middle and lower foreshore (+1 to -1.5 feet MTL), Line 5, the cell with sill only (no fill) showed the smallest change. Cell 6, sill and fill, shows greater retention relative to Cell 7 which had fill only for the period 5 July to 25 July. However, more time will be required to evaluate the question whether a sill plus fill results in significant benefits over simply sand fill. These early results indicate, however, that fill does offer advantages to emplacement of a sill without fill. The slow response in trapping sand is no doubt related to relatively small sand supply in the littoral drift system.

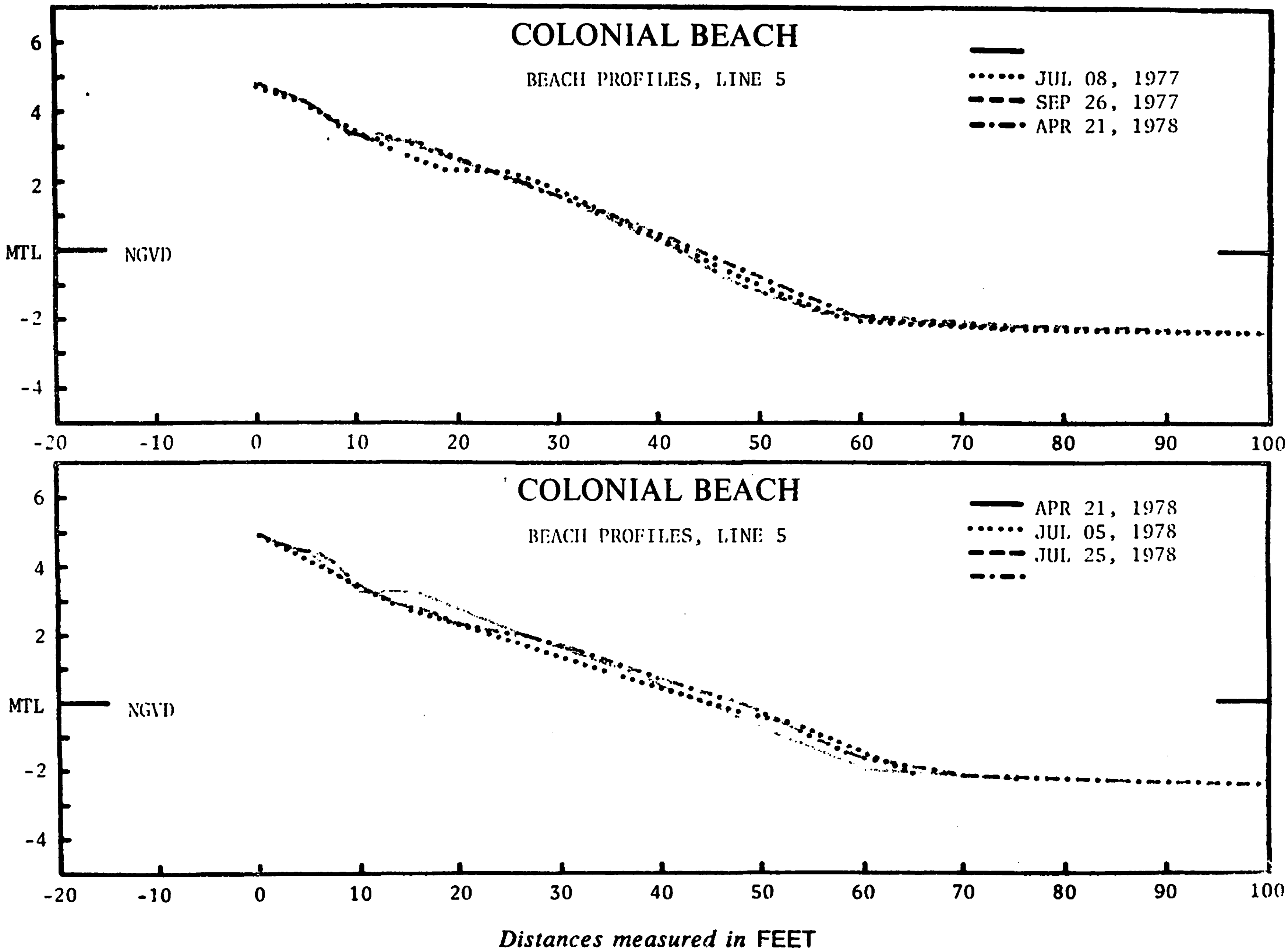


FIGURE 44. Profile Line 5 at the Colonial Beach site.

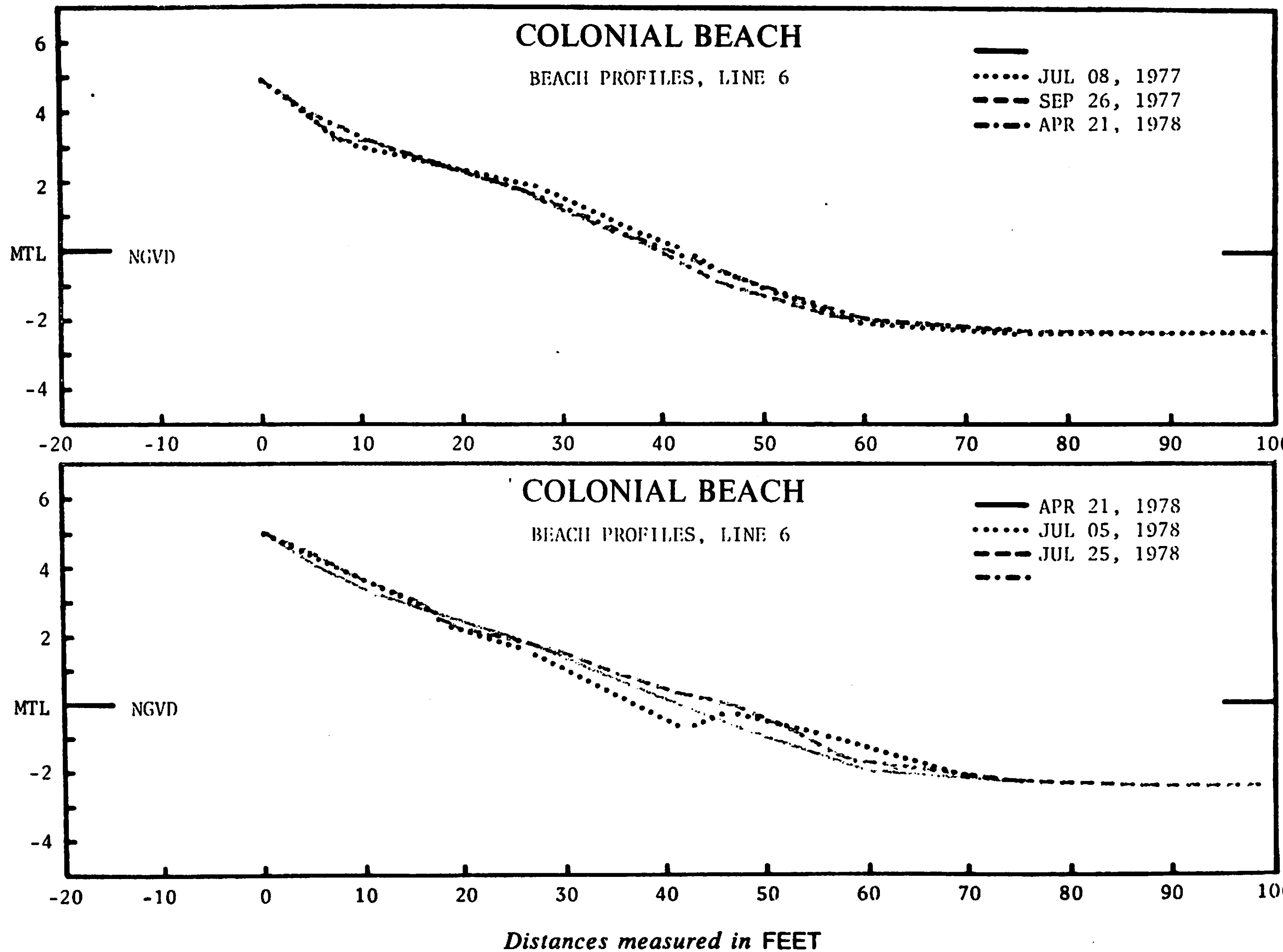


FIGURE 45. Profile Line 6 at the Colonial Beach site.

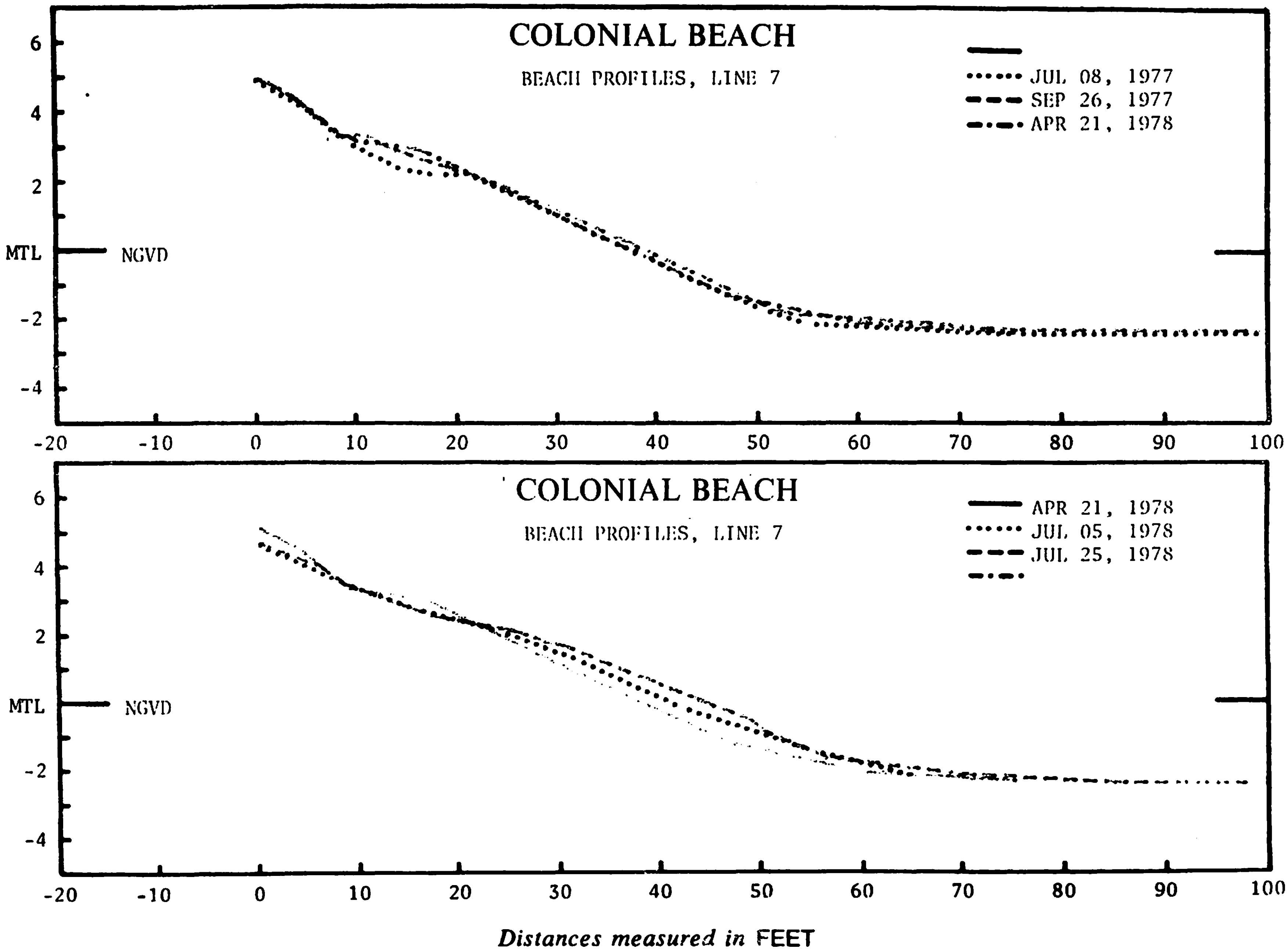


FIGURE 46. Profile Line 7 at the Colonial Beach site.

PLATE 23

A. COLONIAL BEACH

The pre-installation site conditions as of March 16, 1977. Note the close proximity of Irving Avenue to the shoreline.

B. COLONIAL BEACH

The sandbag sills were installed on May 31, 1978. This photo of July 5, 1978 records the situation after installation.

C. COLONIAL BEACH

By July 12, 1978, some response can be noted in several of the groin cells.


A


B


C

PLATE 24

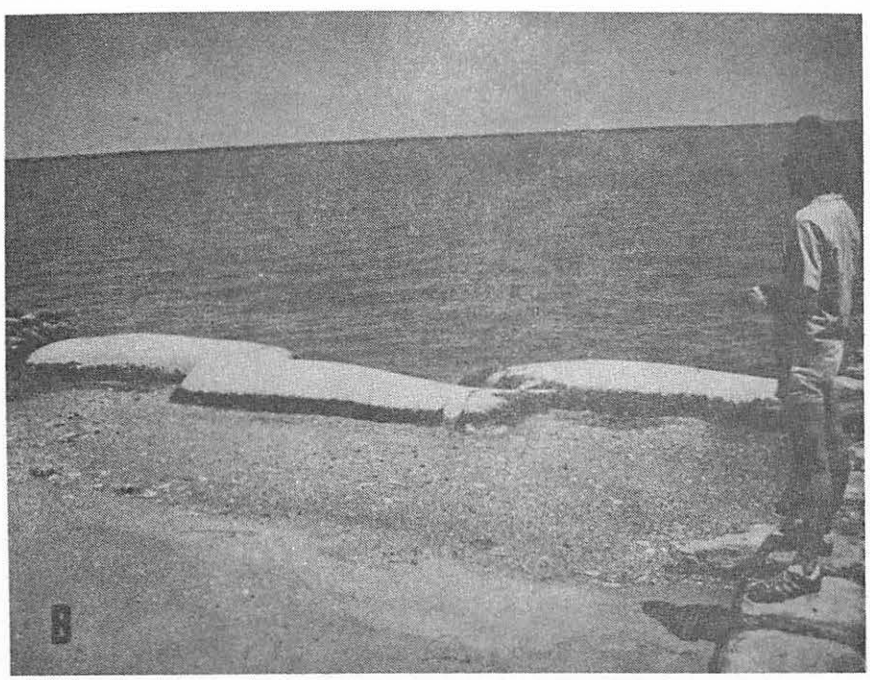
A. COLONIAL BEACH

This photograph of April 21, 1978, illustrates the fill used during construction. The April 26, 1978 storm removed most of this material.

B. COLONIAL BEACH

This groin-sill cell demonstrates a modest entrapment of sand and gravel. Photograph was taken July 12, 1978.


A


B

Summary of Results

Given the short post-installation monitoring period (May to August), it is not possible to arrive at a complete judgement of the effectiveness of the installations. However, the characteristics of the early beach response to the structures are viewed as a reasonable basis for formulating an opinion of what to expect. Those sites exhibiting the weakest initial response were Scroggins/Crew, Gwynn Island Association and Cherry Point, all located on Gwynn Island, and the Colonial Beach site. These four sites represent the joint conditions of a low to moderate littoral drift supply and are under the influence, either directly or indirectly, of groin fields. A partial explanation may be that a component of the weak littoral drift by-passes the installations at the seaward ends of the groins therein by-passing the installations. The D. Smith site has similar environmental circumstances yet it responded very quickly to the installation of a sill. Two factors may contribute to this. First, although flanked on both sides by properties with groins, the length of D. Smith site is evidently sufficient to allow the littoral drift to return to the beach face system. Second, the site represents an indentation in the shoreline so that material may be trapped in the "pocket" by the sill and to remain. In this connection, it is noteworthy that the Silver Beach and Dennis sites are also indented shorelines. These systems also responded quickly with the tendency to fill the indentation.

Those sites which exhibited the most dramatic accretion were those with relatively strong littoral drift; and/or where the installation was designed to trap material moving directly on the shore face. These cases are represented by the Saxis, Silver Beach, Maynard, and Dennis sites.

The formal post-installation monitoring period has not covered the period of the year (October-April) when erosion events are most frequent. Inspection of the sites in late spring 1979 will provide the basis for the next level of evaluation. Finally, a period of two or three years will be required for a final judgement of the effectiveness of the installations. The criterion for effectiveness is whether or not the installations have reduced the local erosion rate or provided a buffer beach to protect bulkheads.

The Gloucester Point site successfully illustrated the use of a spur on a groin to inhibit the formation of an erosion notch where the groin intersects the fastland. In addition, the test indicates that used tire casings may be employed as gabion fill for single layer installations. Further study is warranted on this use of old tires. Particular attention should be given to a comparison of the performance between compressed whole tires and baled split tires. The baled split tires may result in increased unit gabion weight and therefore could be expected to withstand greater wave forces.

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Appendix A - Grain Size Analyses at Demonstration Sites

SAXIS

July 19, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	-	-	-	-	-	-	54.5
2	1.406	-0.492	-	-	-	-	44.4
3	1.593	-0.672	-	-	-	-	46.1
4	0.850	0.234	-	-	-	-	23.7
5	1.080	-0.111	-	-	-	-	32.6
6	-	-	-	-	-	-	50.1
7	0.523	0.934	-	-	-	-	31.2
May 15, 1977							
-	0.538	0.893	-	-	-	-	19.9

SILVER BEACH

July 26, 1978

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	0.161	2.634	2.609	0.429	-0.089	1.179	0.0
2	0.245	2.029	2.017	0.615	-0.031	0.953	0.0
3	0.232	2.109	2.121	0.415	0.043	1.050	0.0
4	0.220	2.184	1.610	1.629	-0.529	0.773	3.1
5	0.217	2.205	2.111	0.750	-0.188	0.964	2.8
6	0.164	2.610	2.569	0.452	-0.137	1.031	0.0

GLOUCESTER POINT

June 22, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	0.736	0.442	0.609	1.061	0.236	-	5.4
2	0.263	1.925	1.894	0.446	-0.105	1.310	0.2
3	0.403	1.312	1.109	1.121	-0.272	-	5.2
4	0.532	0.910	0.701	1.262	-0.248	-	8.0
August 2, 1978							
-	0.546	0.873	0.609	1.323	-0.299	-	13.9

SCROGGINS/CREW

June 28, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	1.198	-0.261	-	-	-	-	31.3
2	0.559	0.840	0.731	0.782	-0.208	0.932	2.7
3	0.411	1.284	1.179	0.590	-0.267	1.211	1.7
4	0.834	0.262	-	-	-	-	20.0
5	0.296	1.755	1.471	0.962	-0.442	-	6.8
6	0.295	1.760	1.680	0.560	-0.216	1.230	0.1
7	0.306	1.710	1.640	0.644	-0.163	1.086	0.1
July 29, 1978							
-	0.237	2.076	2.092	0.400	0.059	1.537	0.0

D. SMITH

June 24, 1977

Profile Line	Median mm.	Median φ	Mean φ	Std. Dev. φ	Skew. φ	Kurtosis φ	% Gravel
1	0.163	2.621	2.626	0.347	0.025	1.028	0.0
2	0.166	2.594	2.601	0.287	0.036	1.381	0.0
3	0.203	2.298	2.192	0.584	-0.271	1.029	0.0
5	0.244	2.036	1.979	0.575	-0.149	0.811	0.0
May 19, 1978							
-	0.541	0.887	0.936	0.514	0.145	1.308	0.1

GWYNN ISLAND ASSOCIATION

June 27, 1977

Profile Line	Median mm.	Median φ	Mean φ	Std. Dev. φ	Skew. φ	Kurtosis φ	% Gravel
1	1.453	-0.539	-	-	-	-	23.0
2	0.629	0.670	0.517	1.123	-0.204	-	8.4
3	0.795	0.331	-	-	-	-	21.5
May 10, 1978							
-	0.361	1.468	1.519	0.649	0.117	0.887	0.3

CHERRY POINT

June 24, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	1.420	-0.506	-	-	-	-	21.2
2	0.502	0.995	0.784	0.946	-0.335	-	6.1
3	0.475	1.074	0.894	0.957	-0.282	1.096	4.4
4	0.626	0.676	0.528	1.205	-0.184	-	9.2
May 10, 1978							
-	0.428	1.226	1.227	0.203	0.005	1.332	0.0

MAYNARD

June 29, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	0.383	1.385	1.439	0.444	0.180	1.140	0.0
2	0.592	0.757	0.737	0.521	-0.059	1.107	0.6
3	0.441	1.181	1.207	0.940	0.037	-	5.9
4	0.360	1.475	1.547	0.639	0.170	1.149	0.0
5	0.706	0.503	0.452	0.675	-0.114	1.223	3.4
6	-	-	-	-	-	-	55.8
May 10, 1978							
3	0.311	1.687	1.717	0.899	0.049	0.965	2.0

DENNIS

July 8, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	0.462	1.113	-	-	-	-	19.2
2	0.541	0.886	-	-	-	-	22.8
3	0.558	0.841	-	-	-	-	30.0
4	0.270	1.888	1.717	0.816	-0.314	-	8.6
5	0.264	1.924	1.977	0.490	0.163	0.931	2.5
May 1, 1978							
-	0.329	1.606	1.657	0.346	0.220	1.447	0.0

COLONIAL BEACH

July 8, 1977

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
1	-	-	-	-	-	-	59.2
2	0.490	1.028	0.948	0.802	-0.150	-	10.0
3	1.754	-0.811	-	-	-	-	45.0
4	1.778	-0.830	-	-	-	-	43.3
5	-	-	-	-	-	-	53.3
6	-	-	-	-	-	-	52.5
7	0.328	1.610	1.522	0.502	-0.264	-	9.9
8	-	-	-	-	-	-	51.5
9	-	-	-	-	-	-	60.1
10	-	-	-	-	-	-	61.0

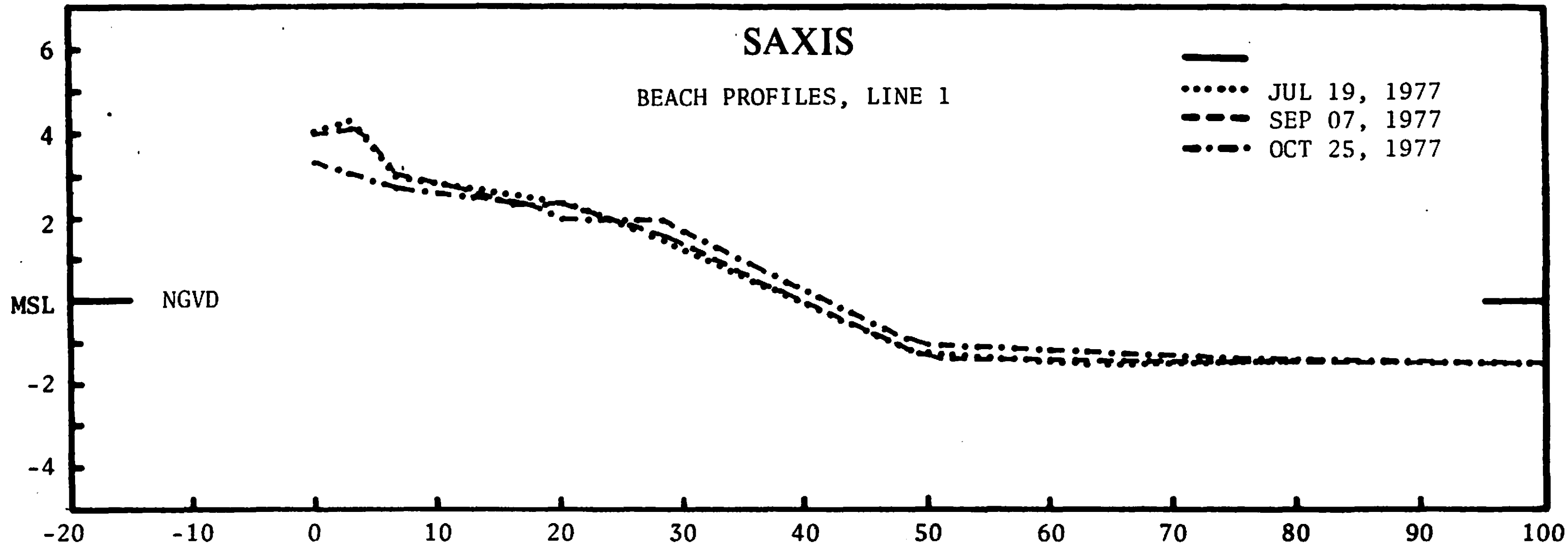
COLONIAL BEACH (continued)

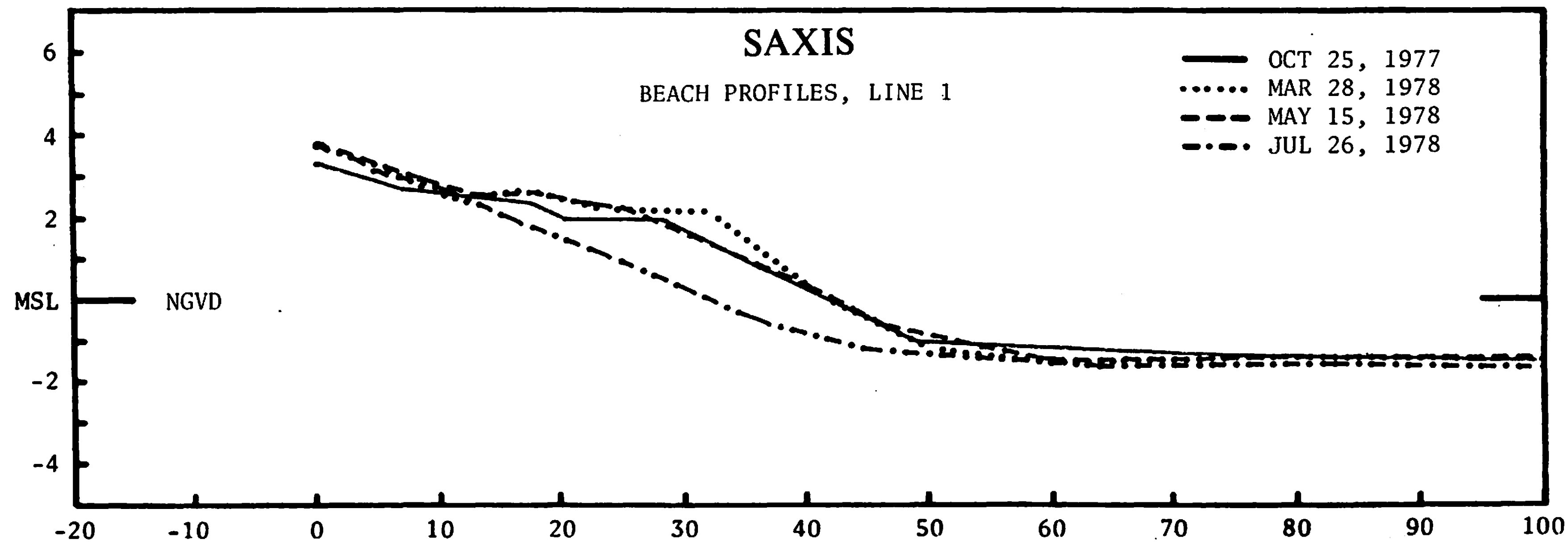
July 25, 1978

Profile Line	Median mm.	Median ϕ	Mean ϕ	Std. Dev. ϕ	Skew. ϕ	Kurtosis ϕ	% Gravel
4*	0.250	2.002	-	-	-	-	16.3
4	0.631	0.665	-	-	-	-	23.5
5*	1.997	-0.998	-	-	-	-	50.0
5	0.442	1.179	0.934	0.798	-0.460	-	11.3

*Backshore

Appendix B - Beach Profiles





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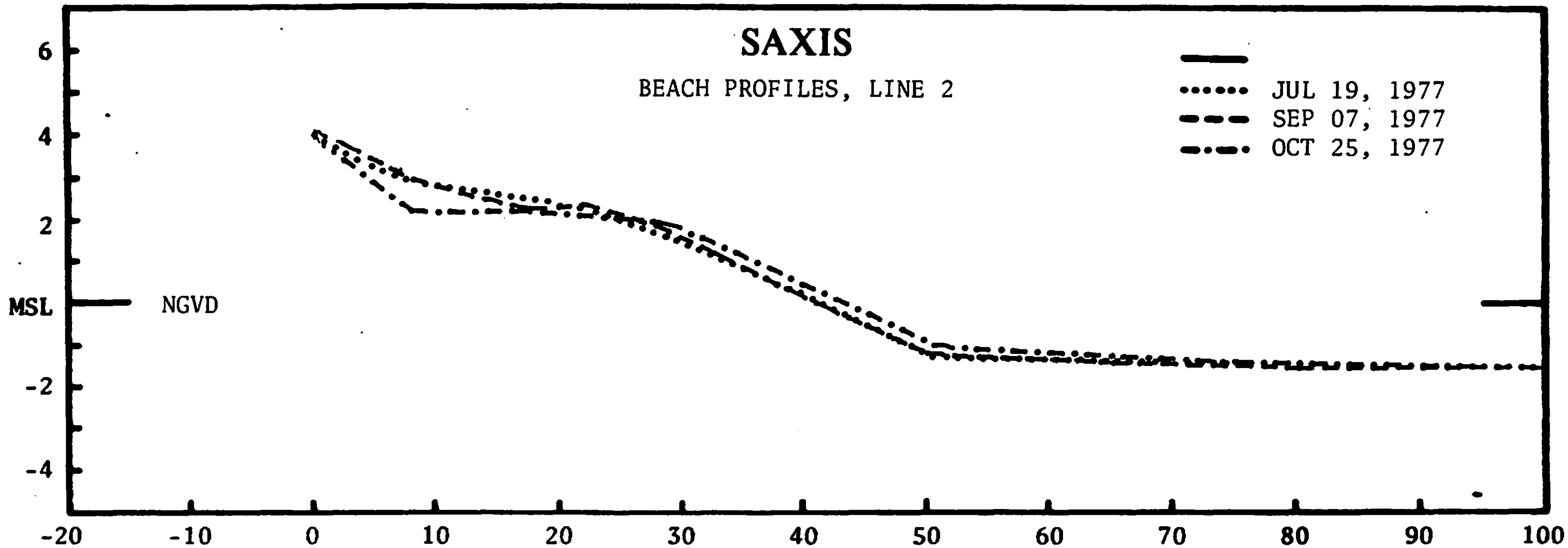

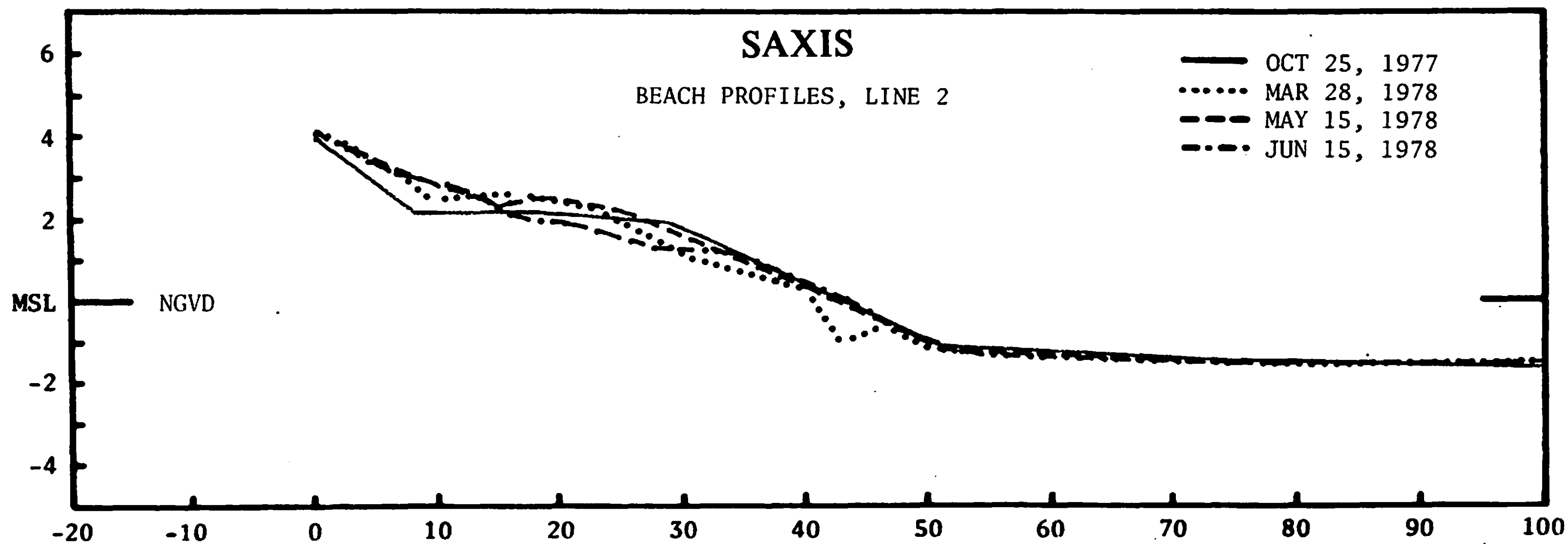

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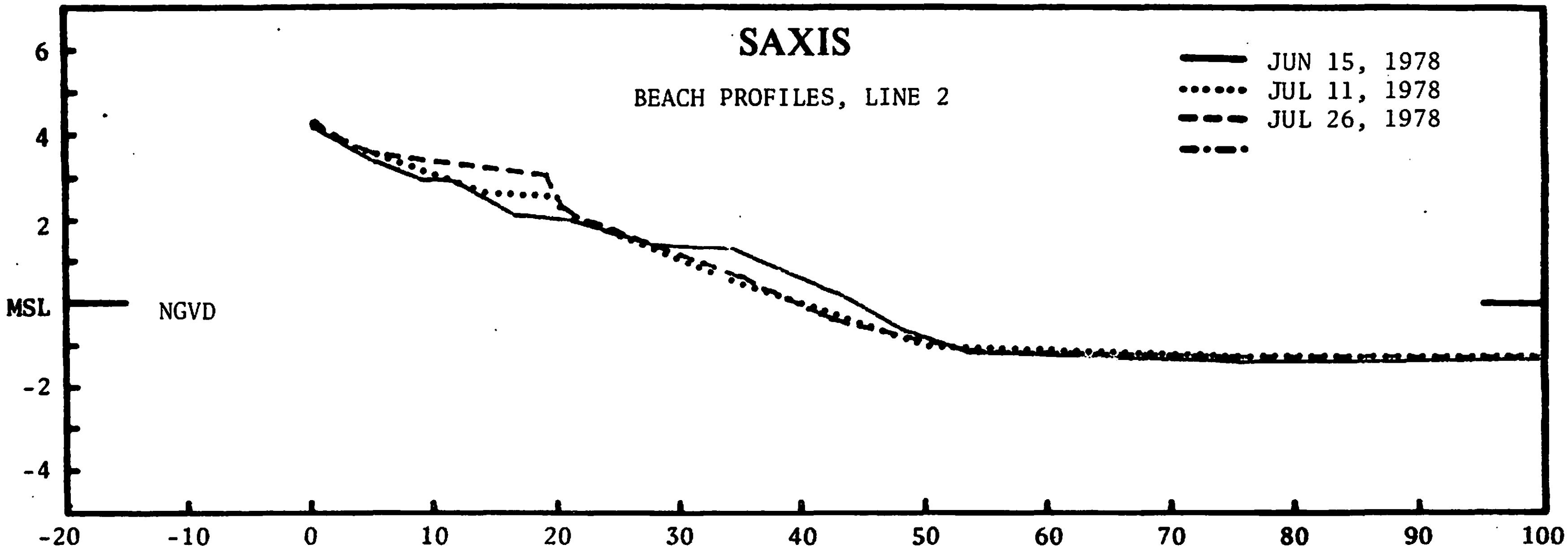

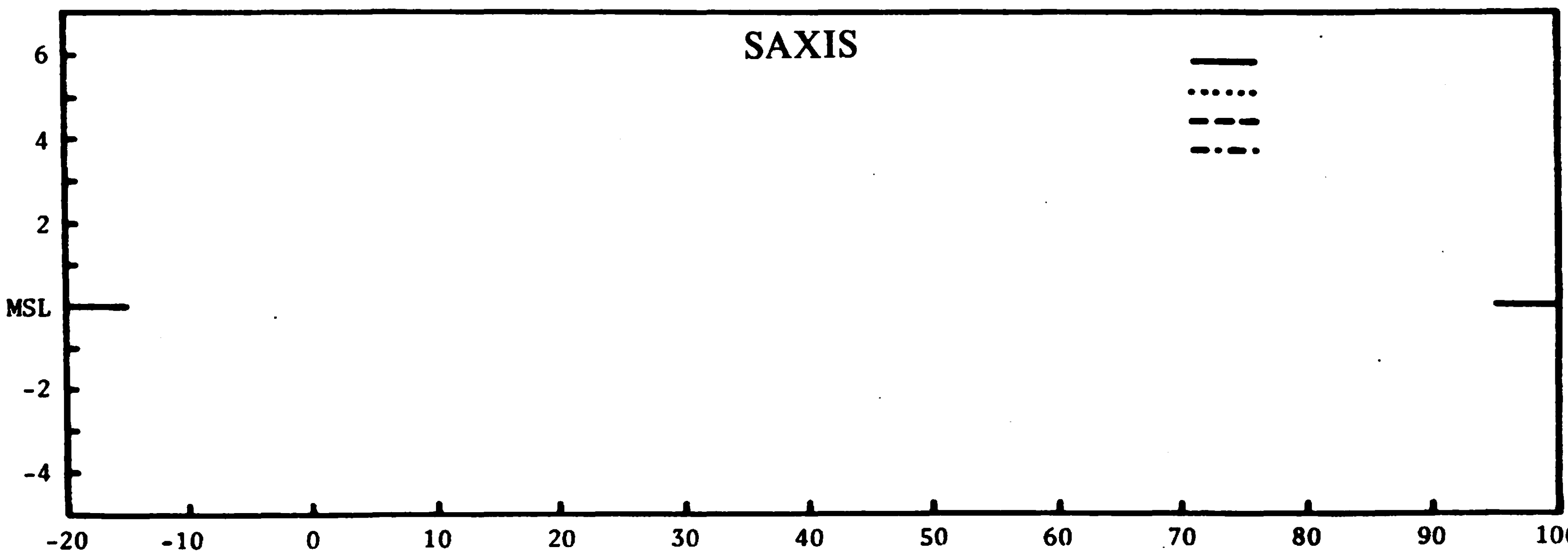

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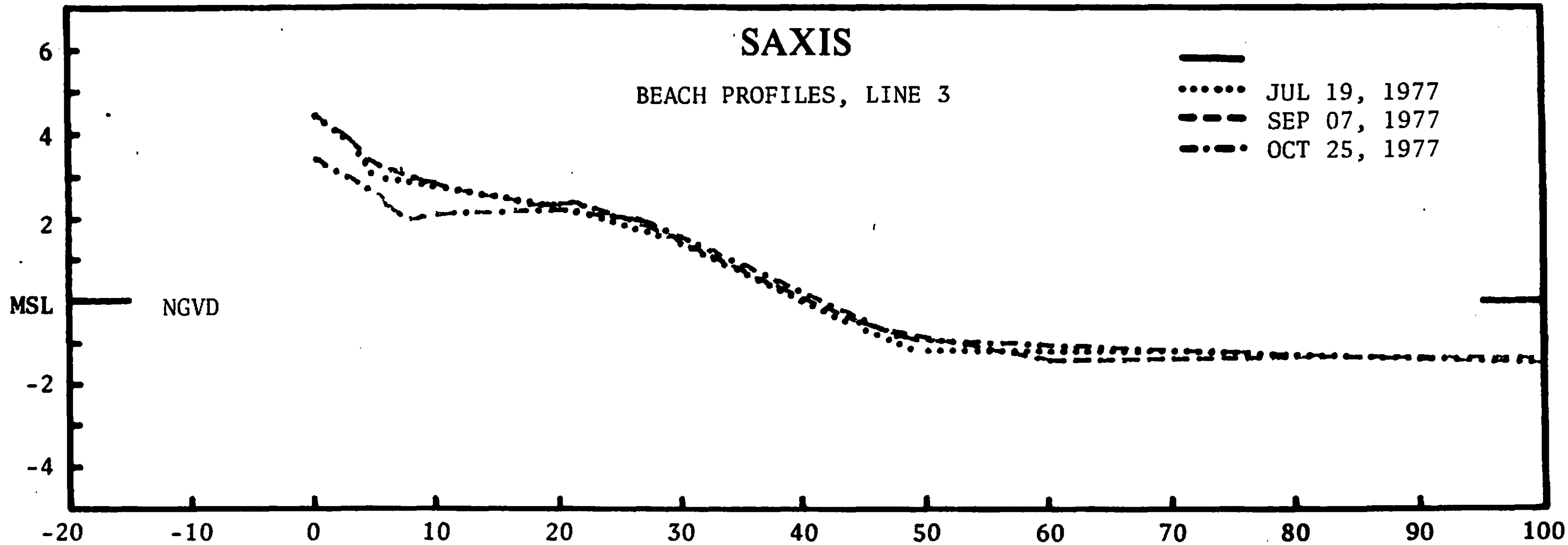
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JUL 19, 1977
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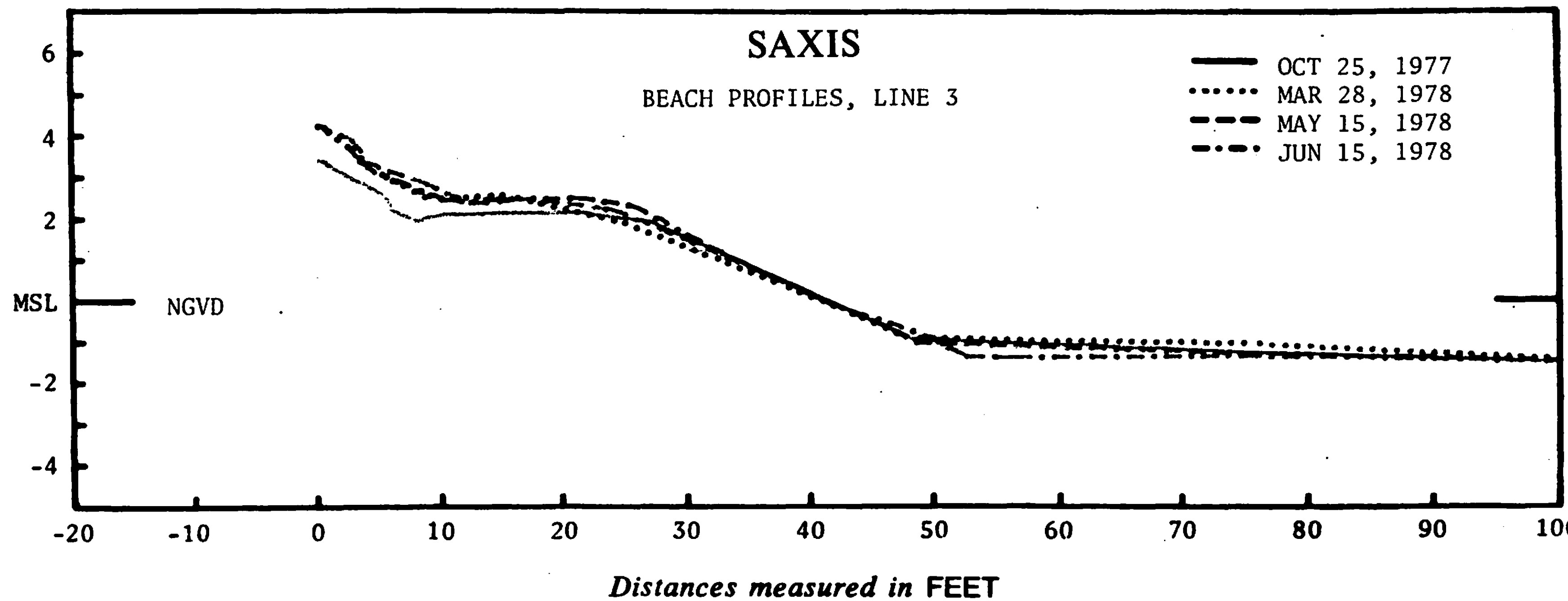
SAXIS
BEACH PROFILES, LINE 3
OCT 25, 1977
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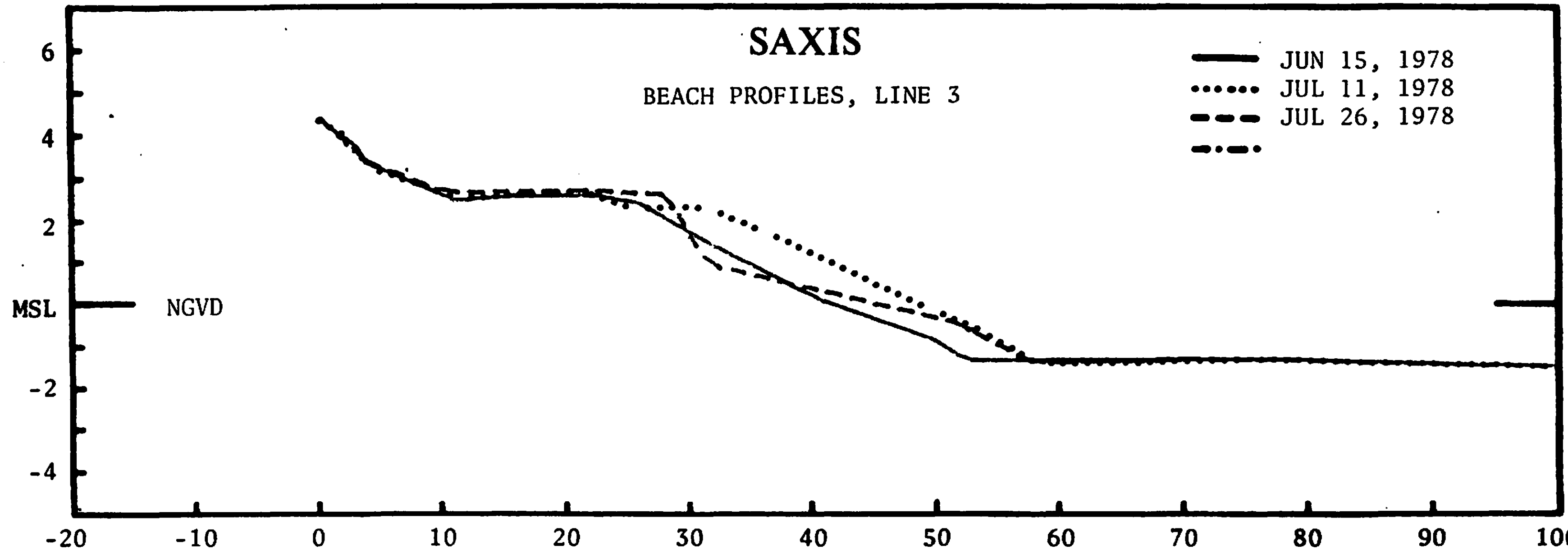

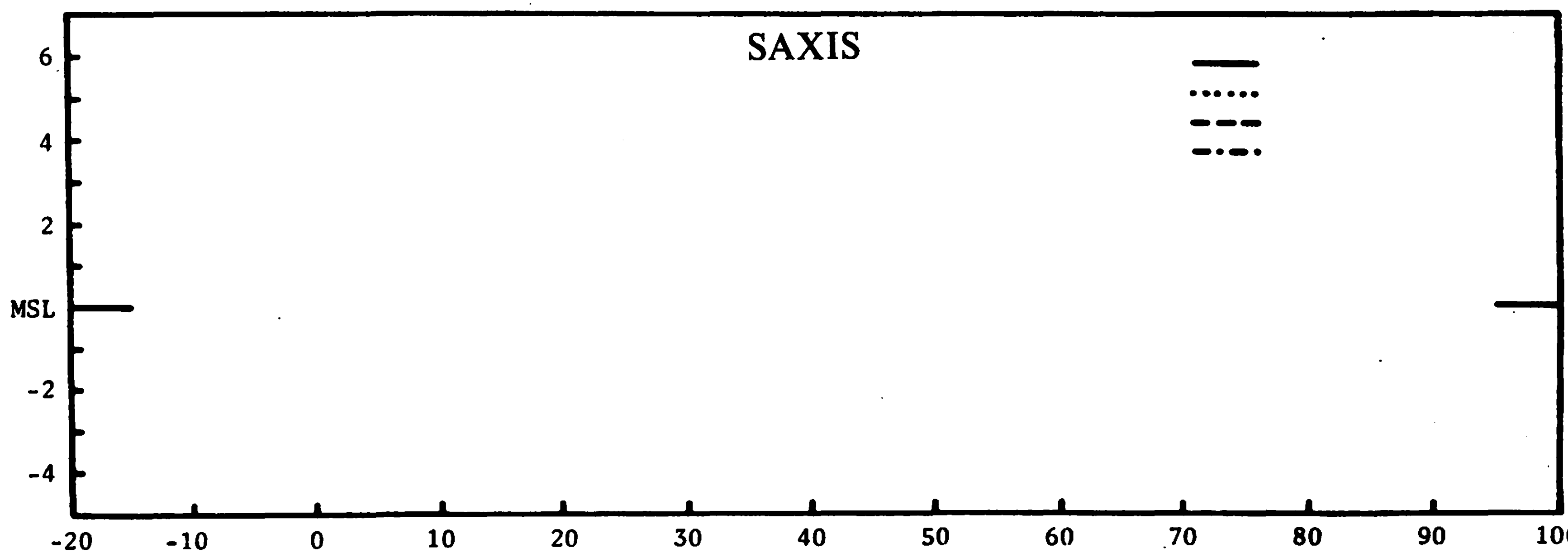

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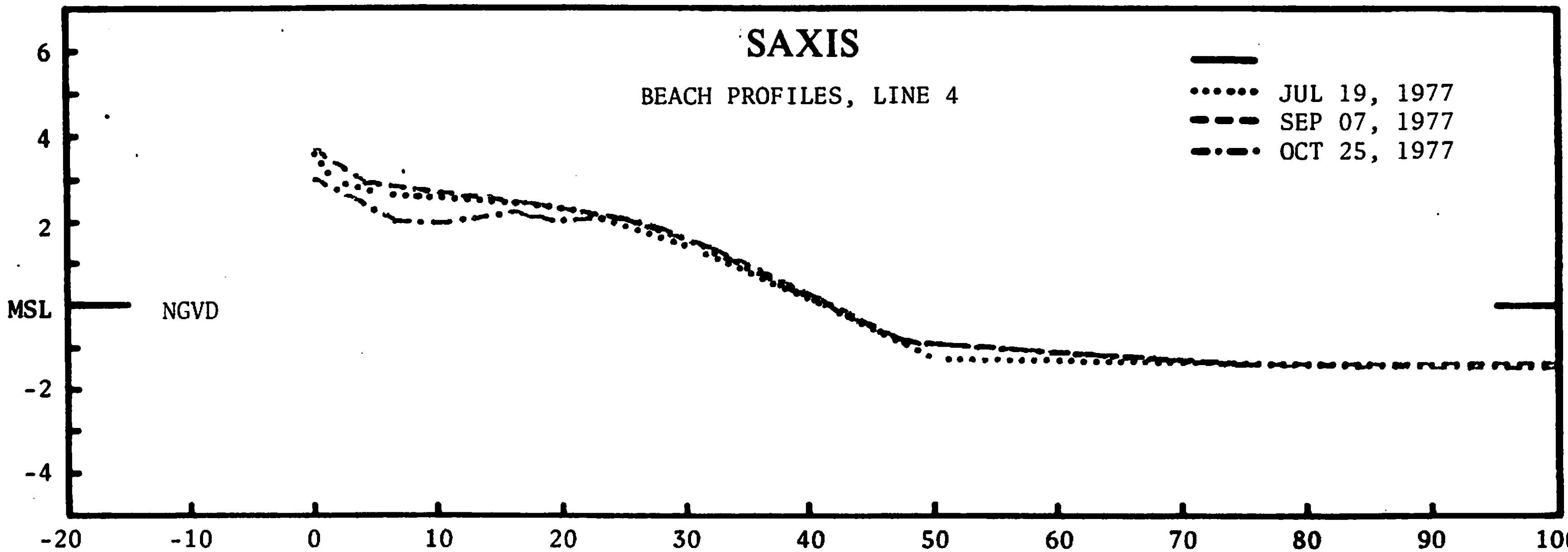

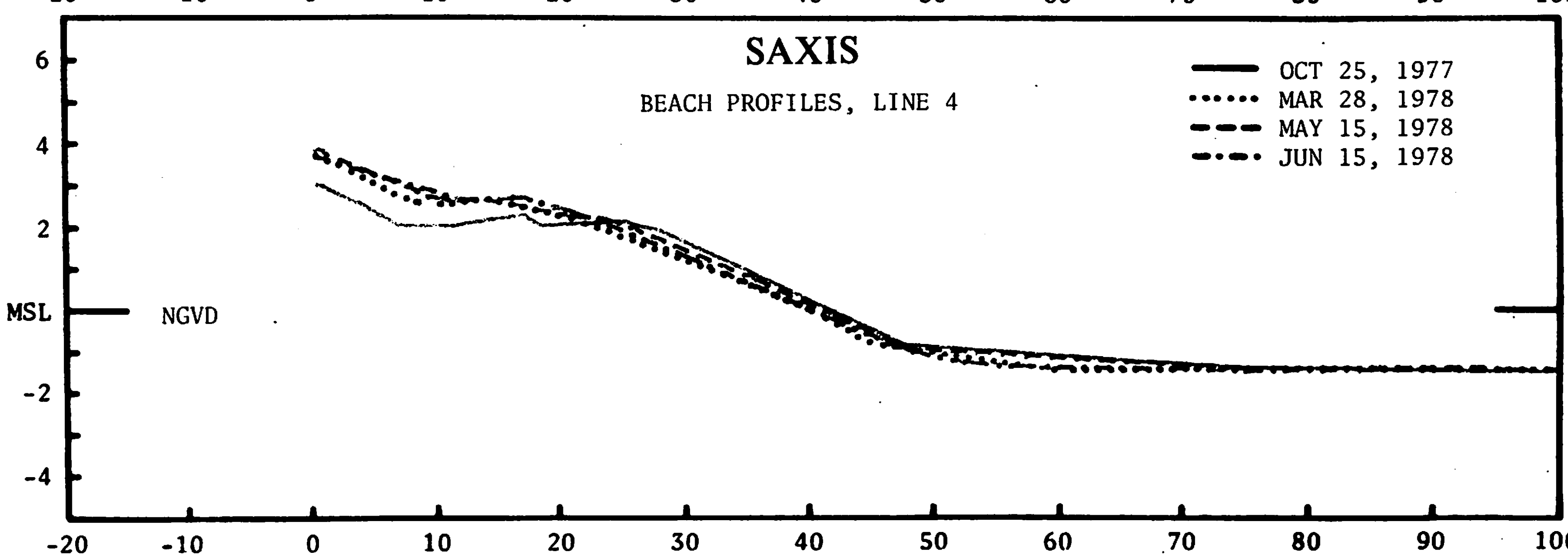

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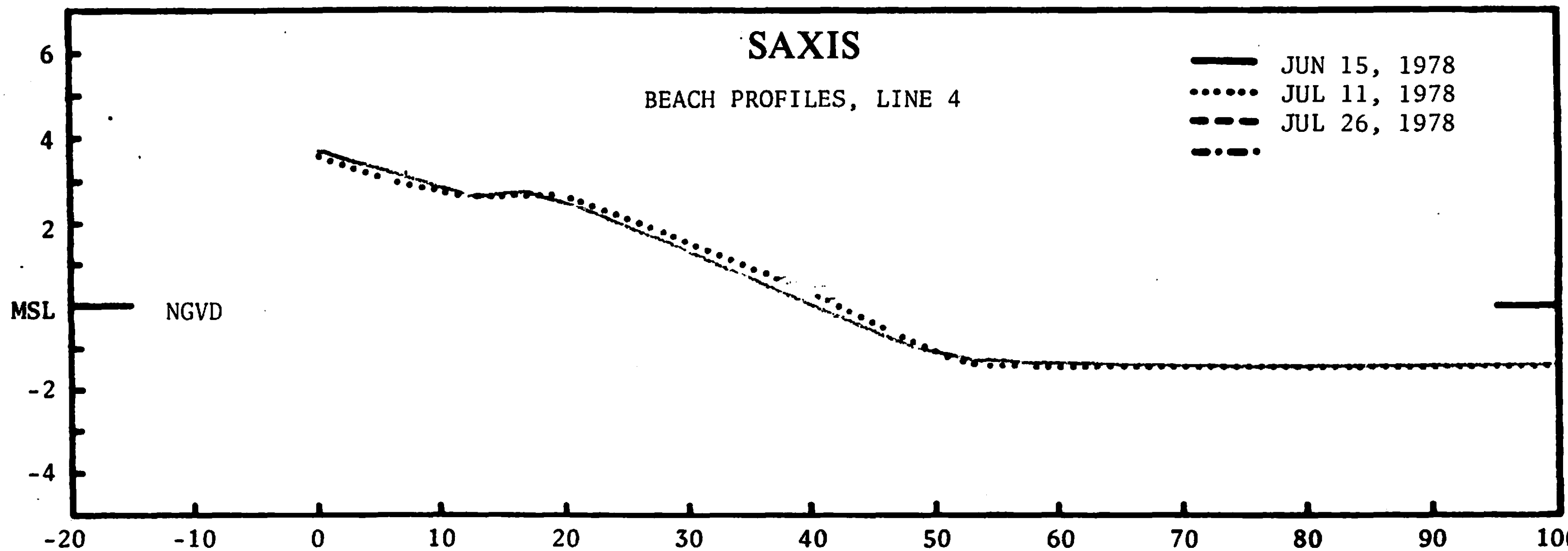

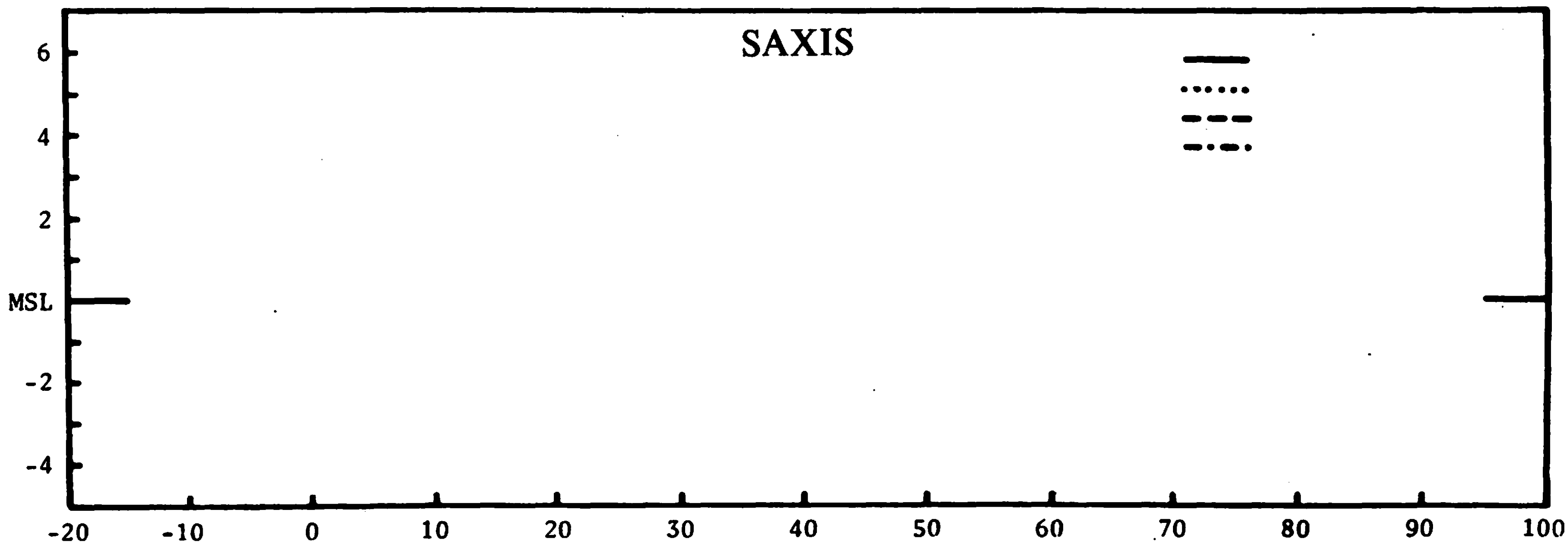

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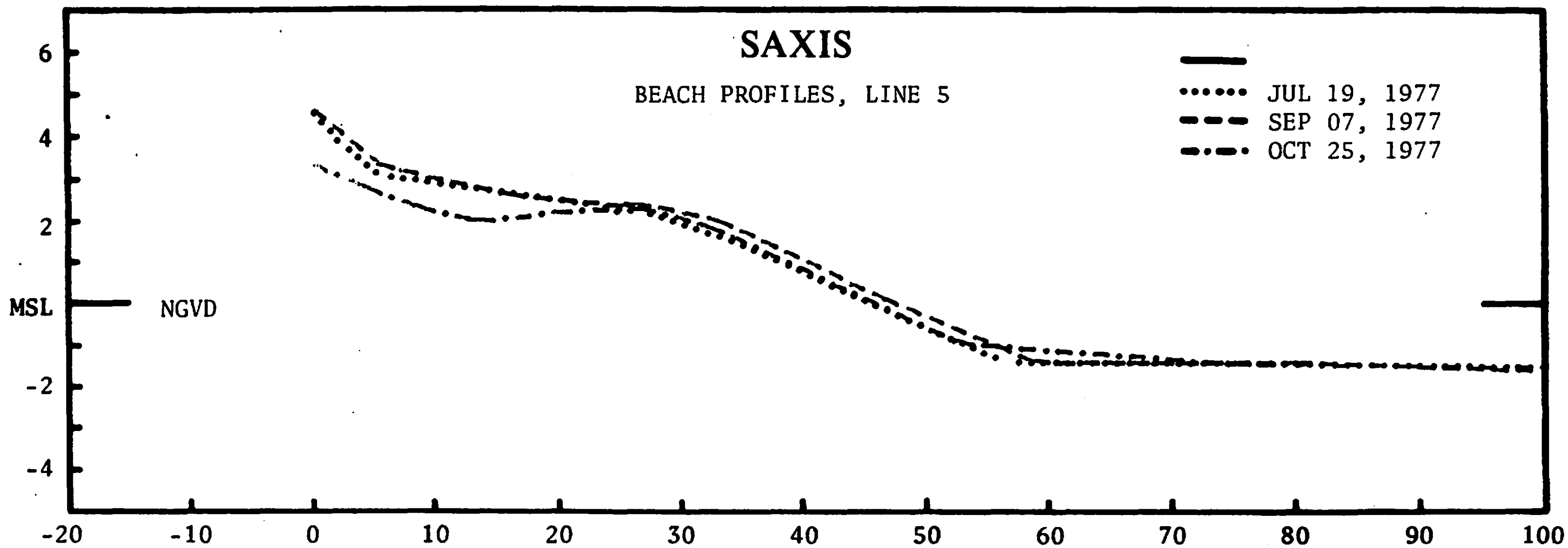
SAXIS
BEACH PROFILES, LINE 5
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SEP 07, 1977
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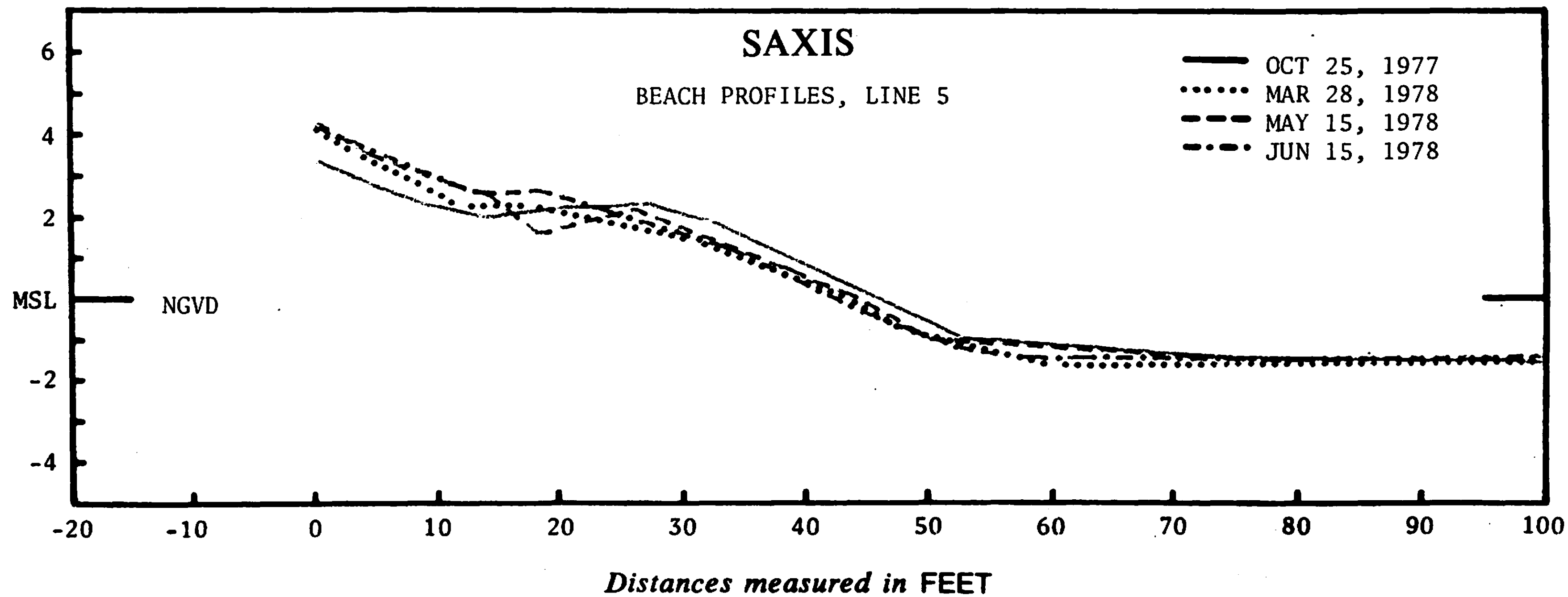
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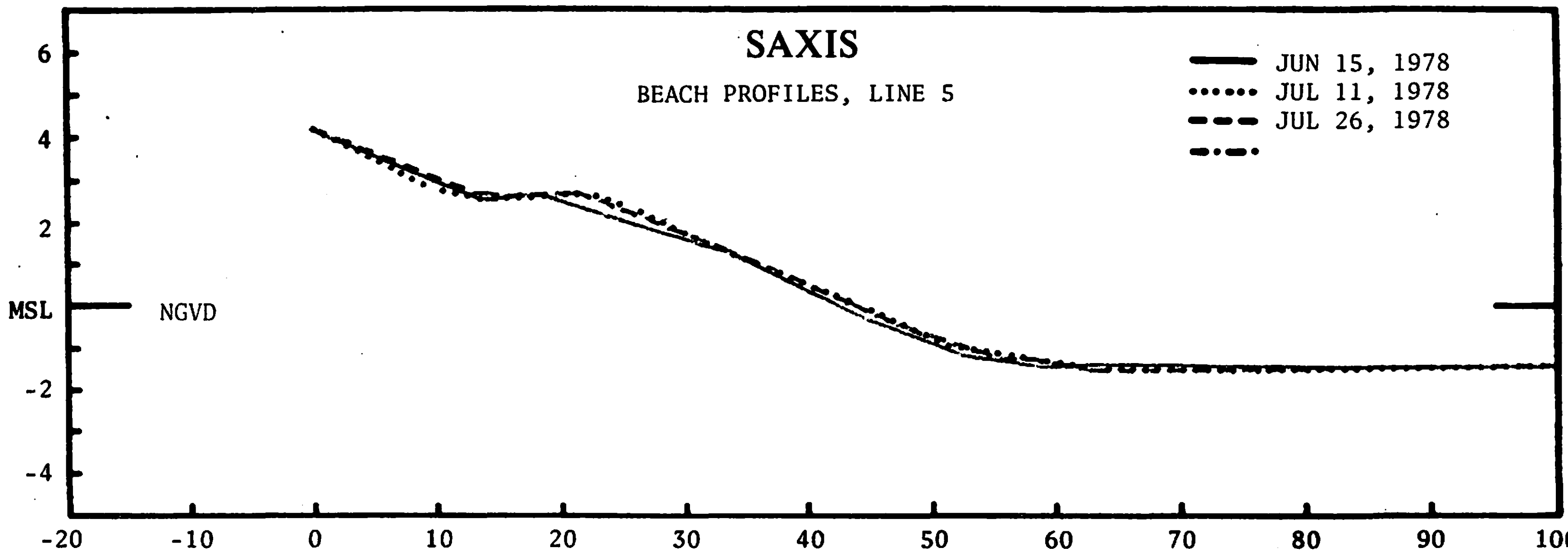

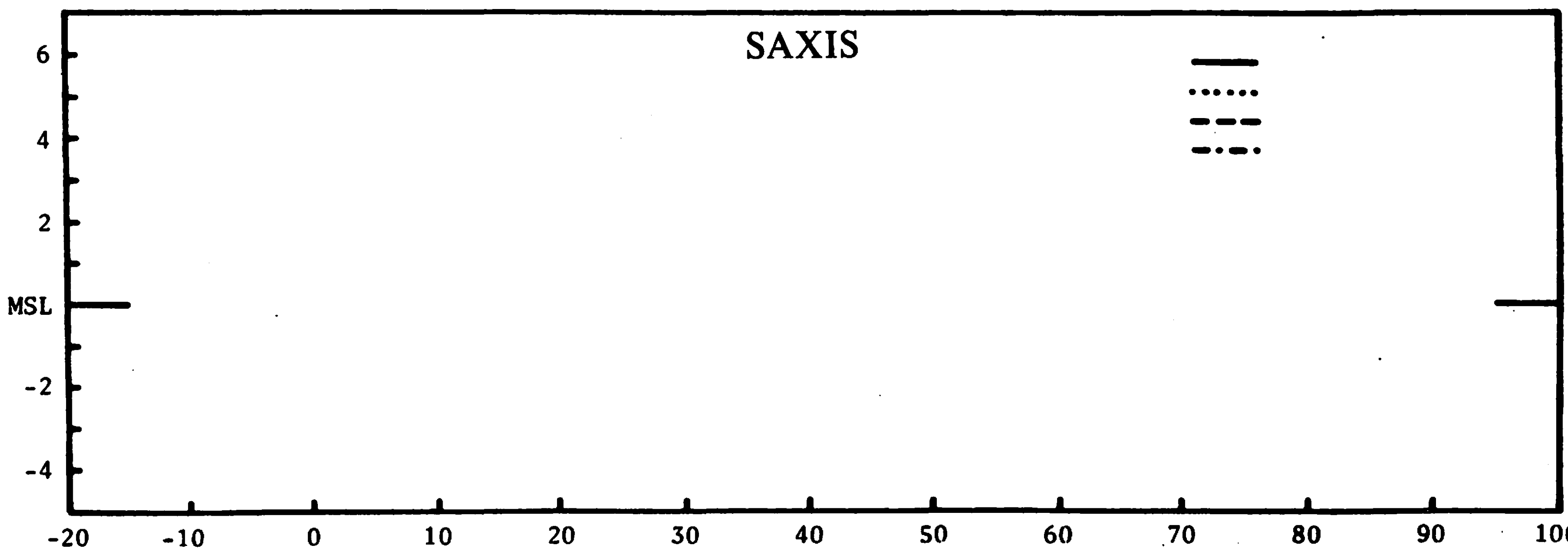

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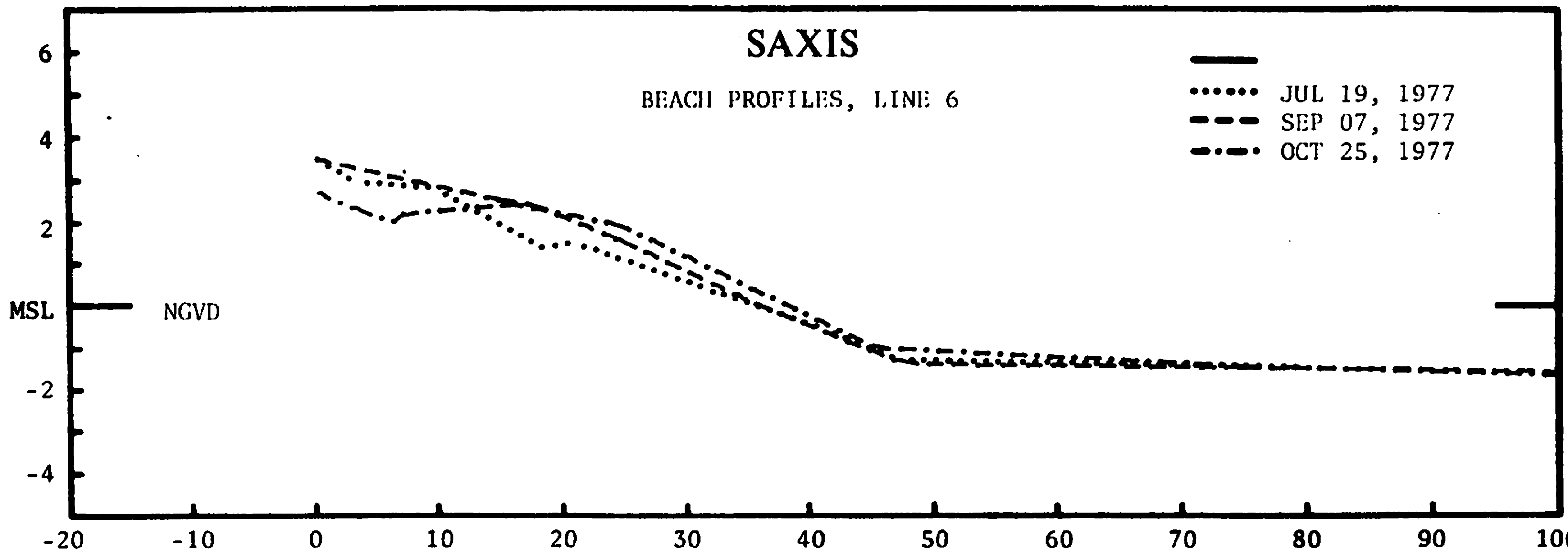

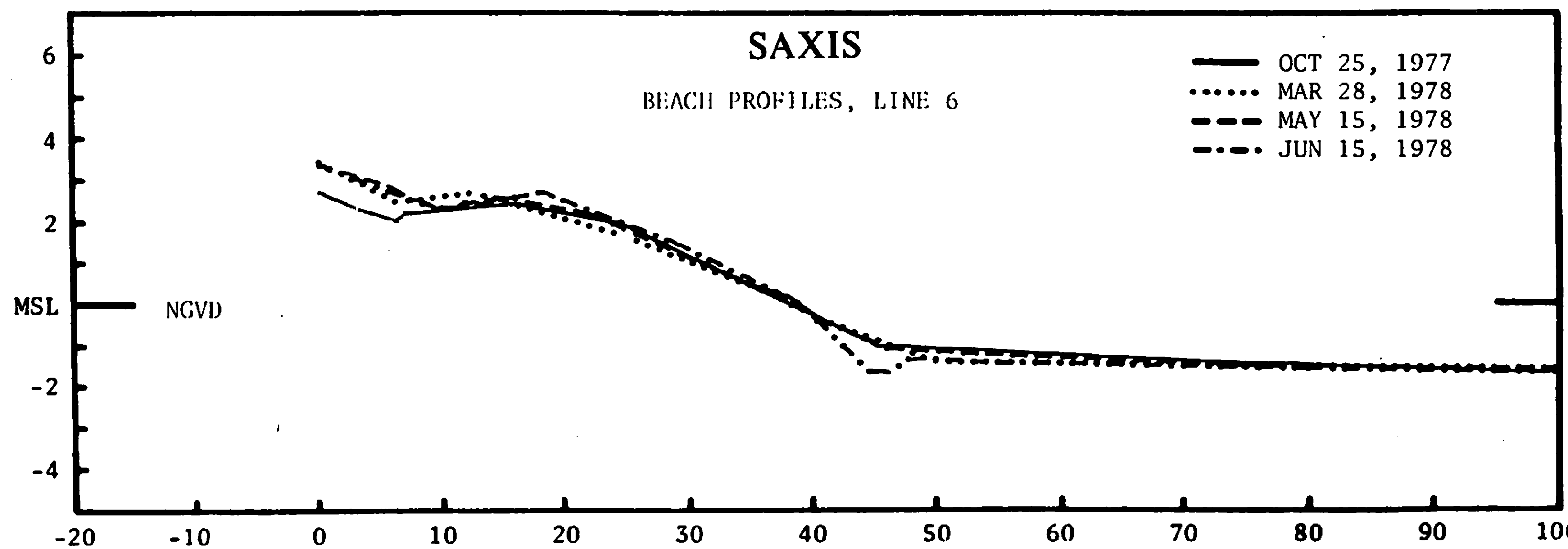

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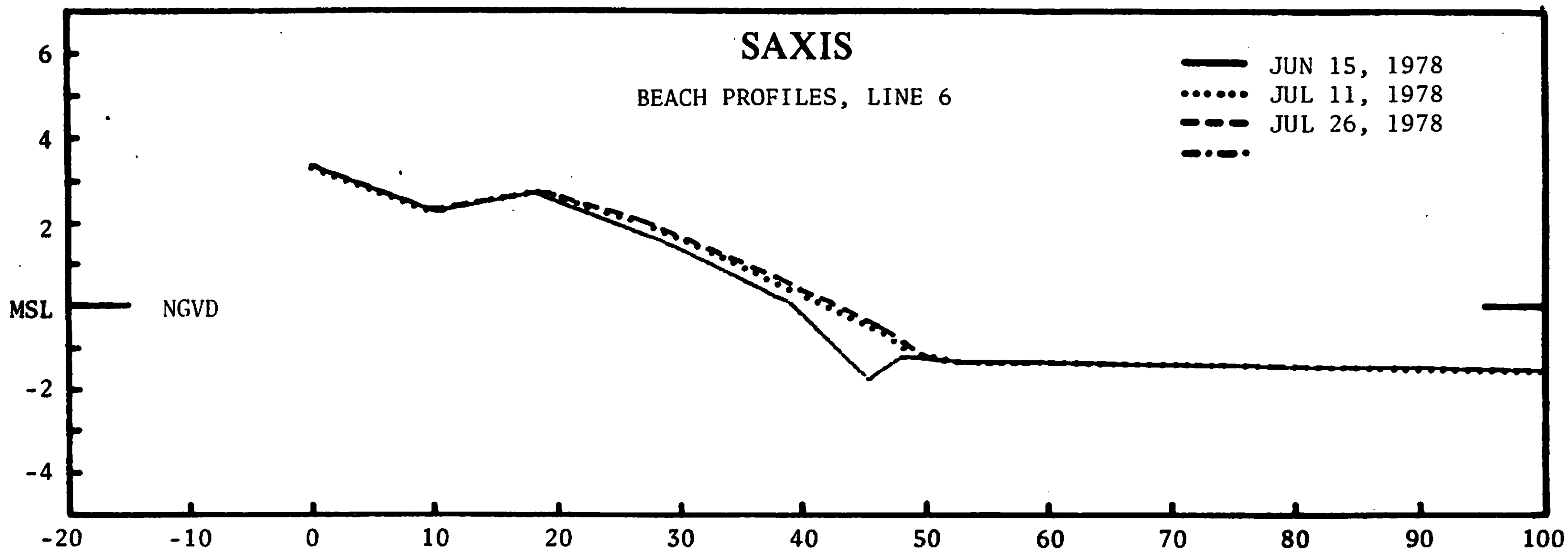

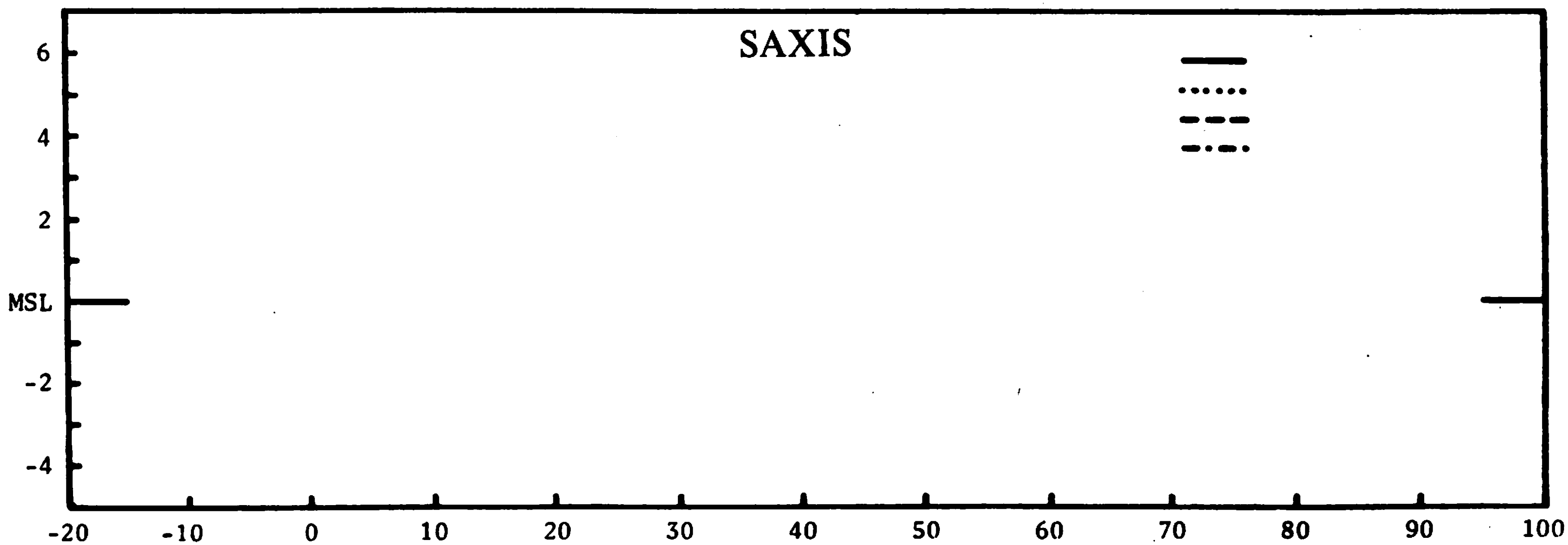

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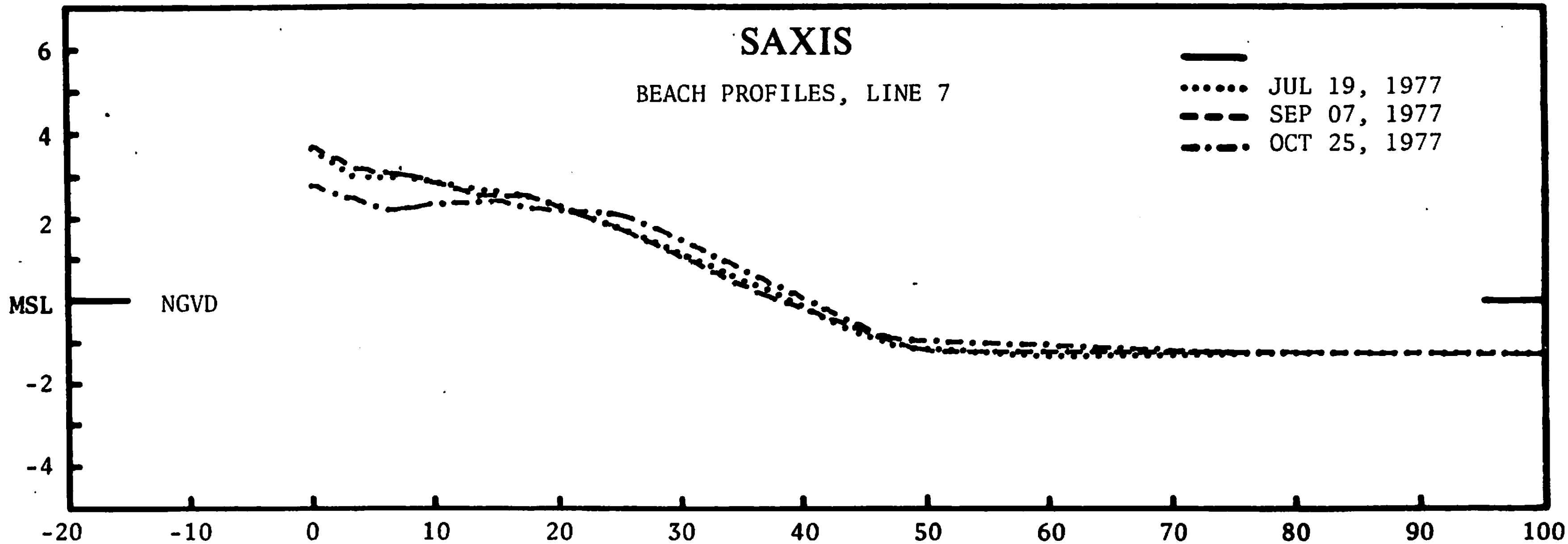

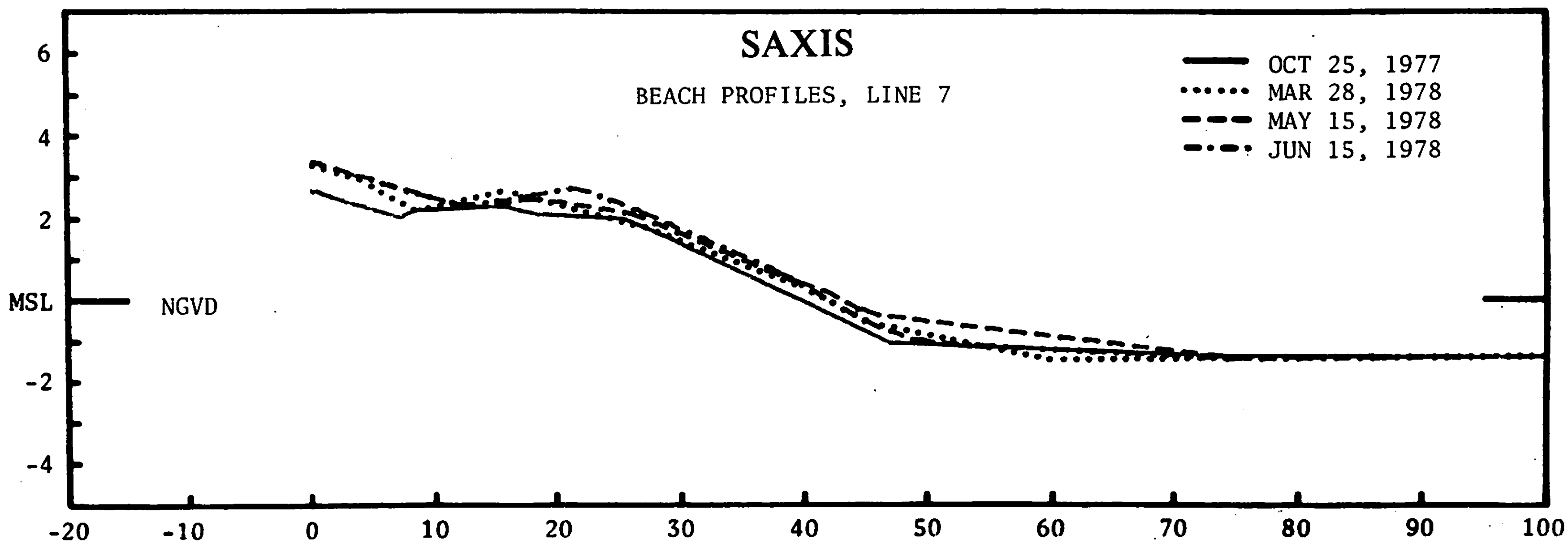

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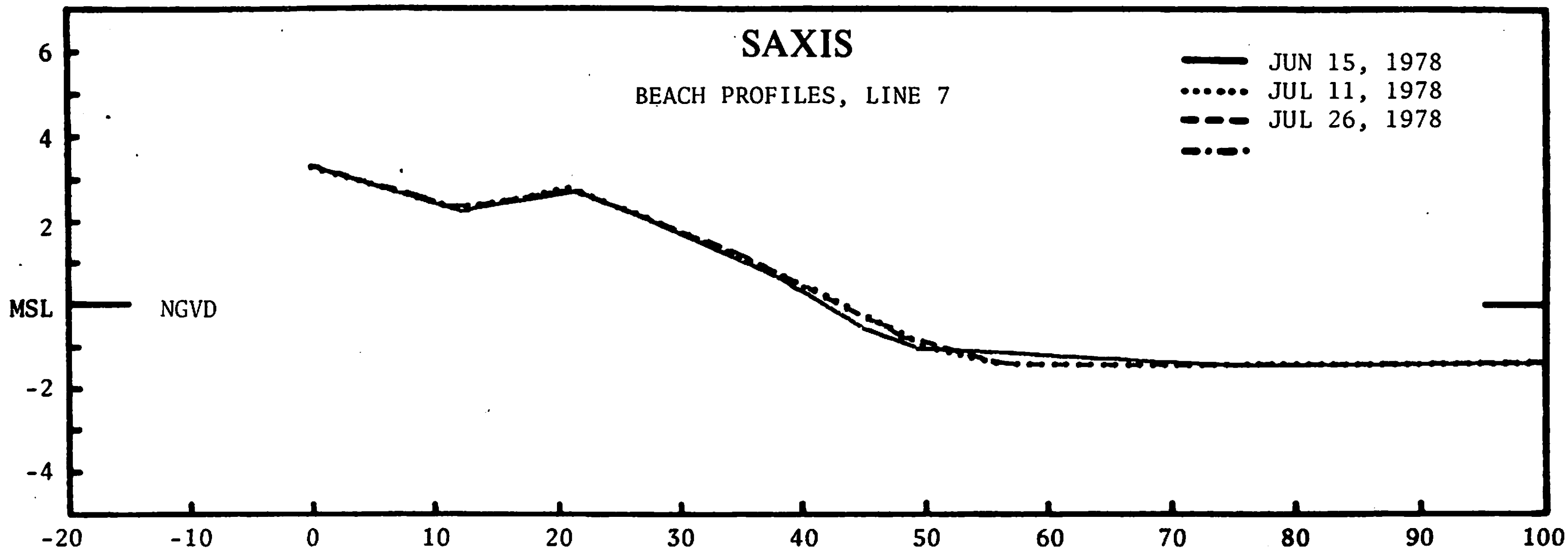

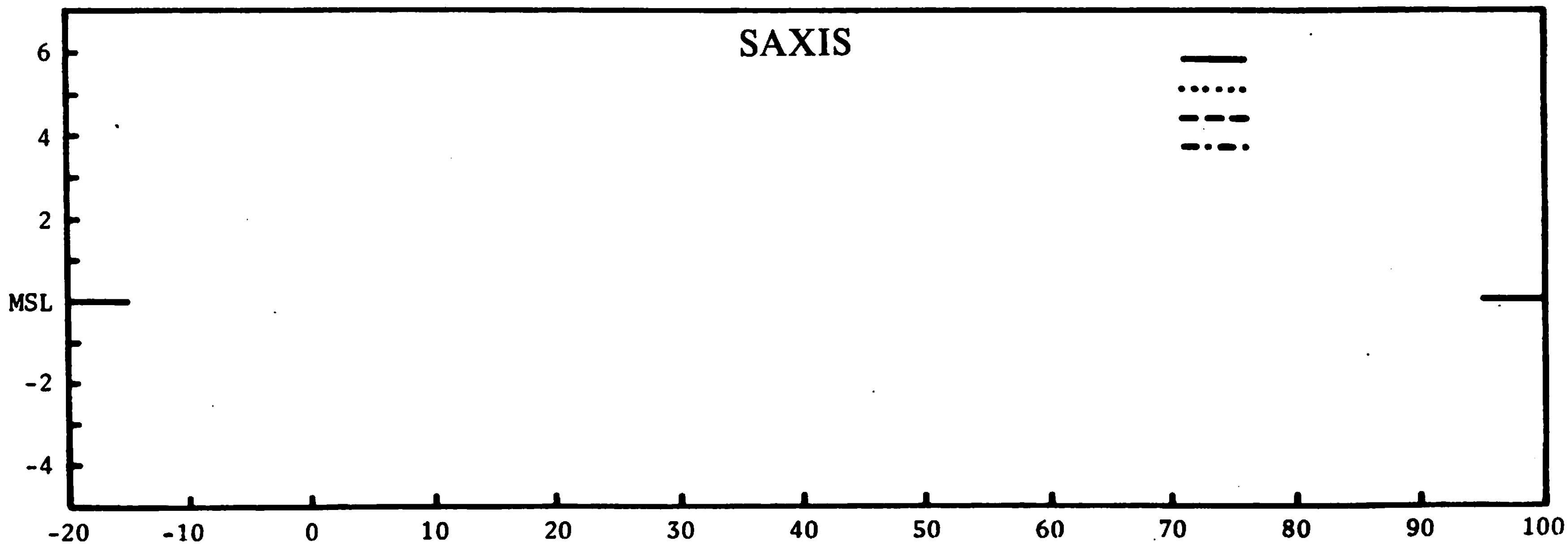

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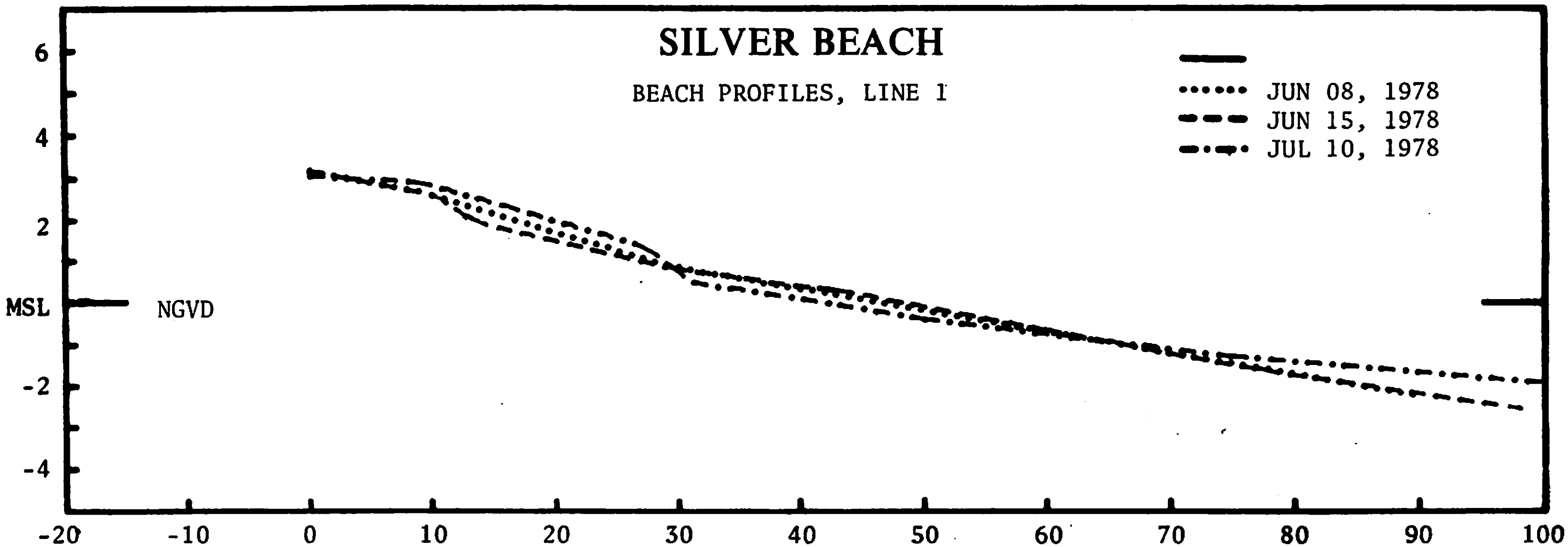

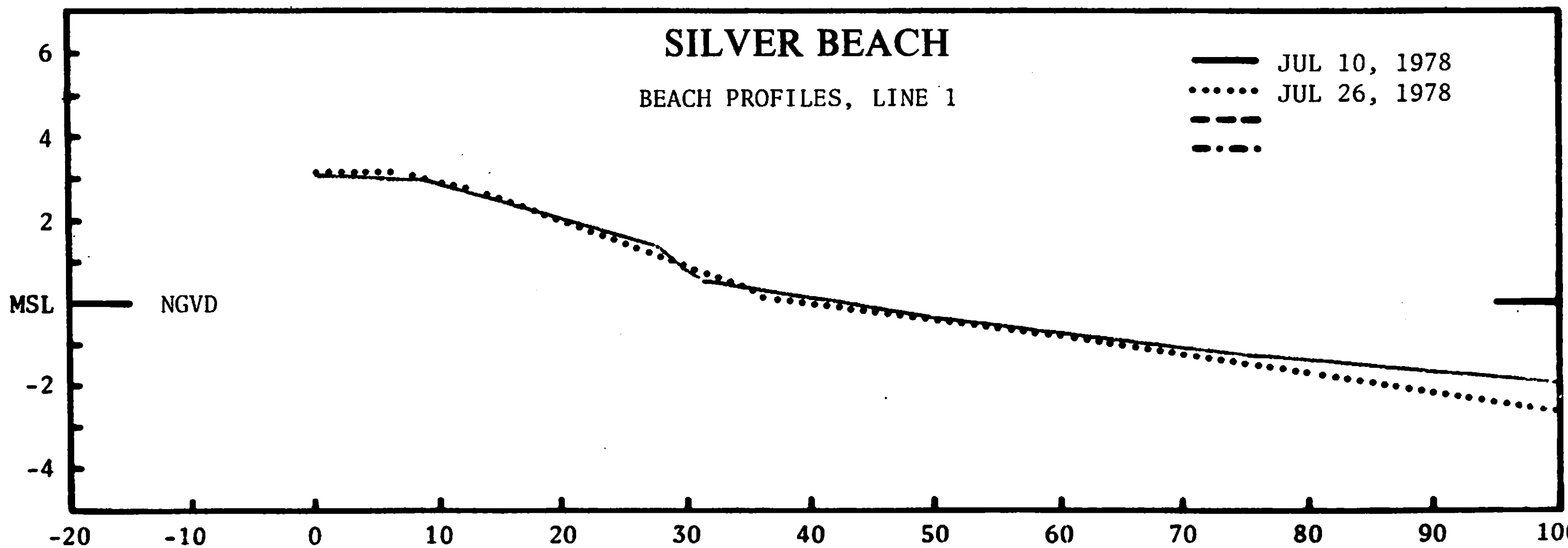

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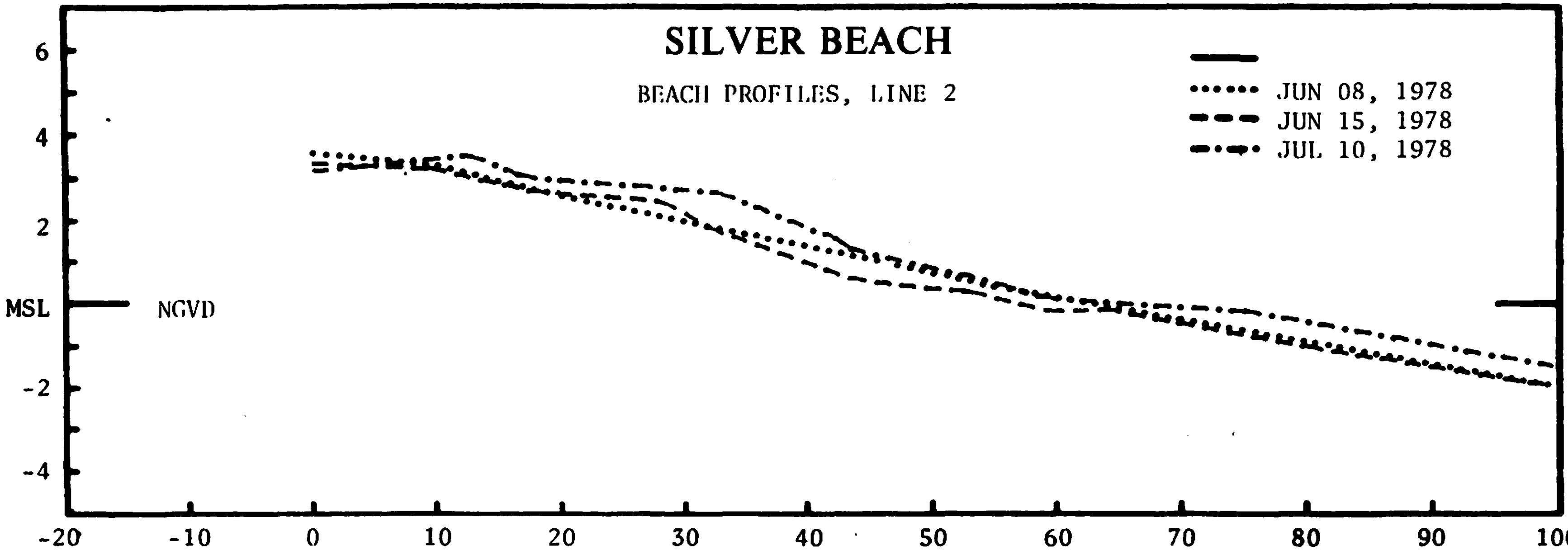

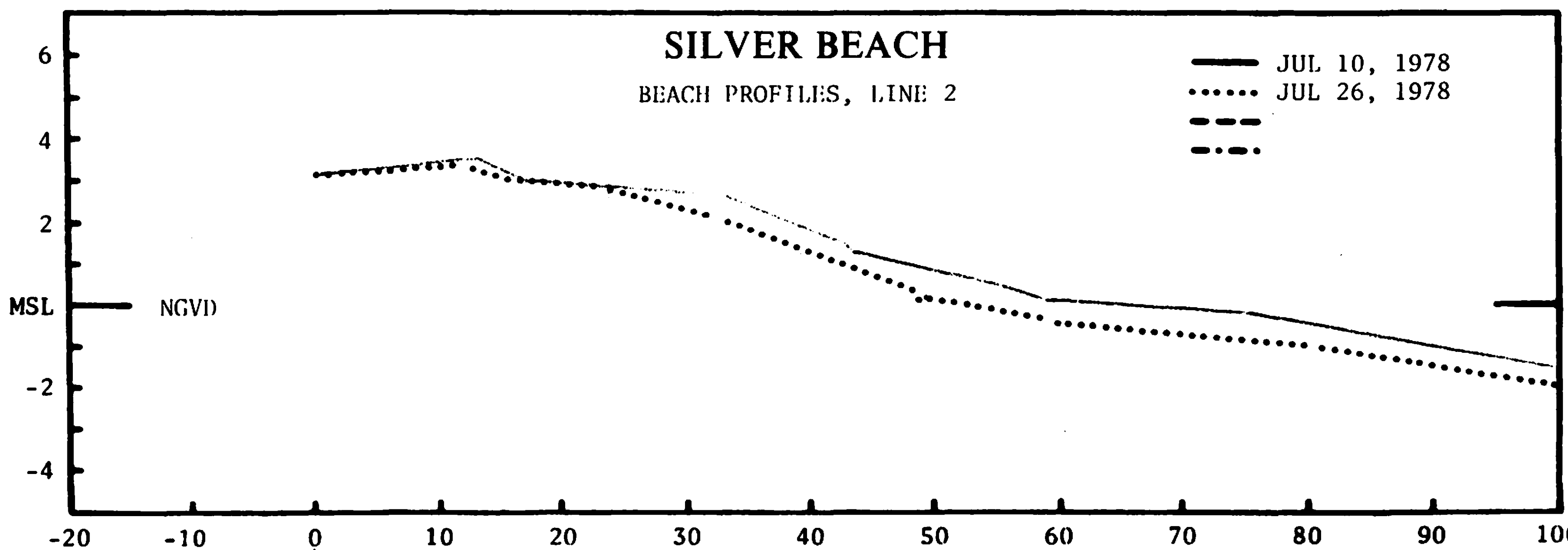

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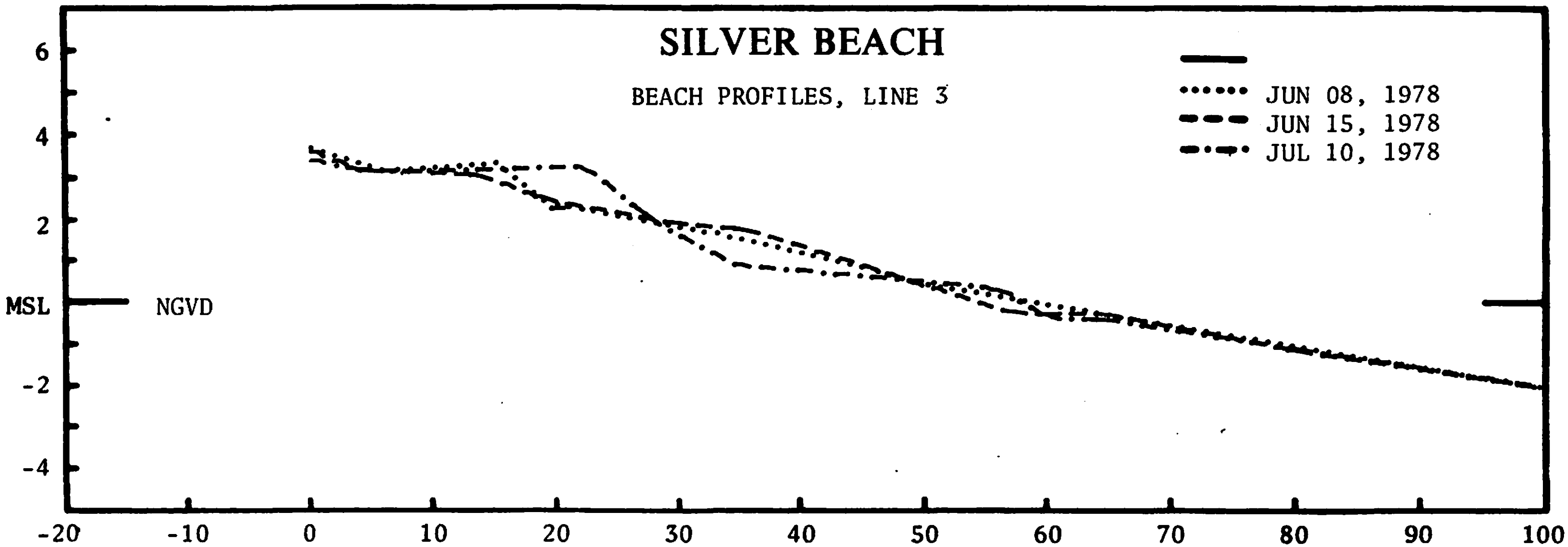

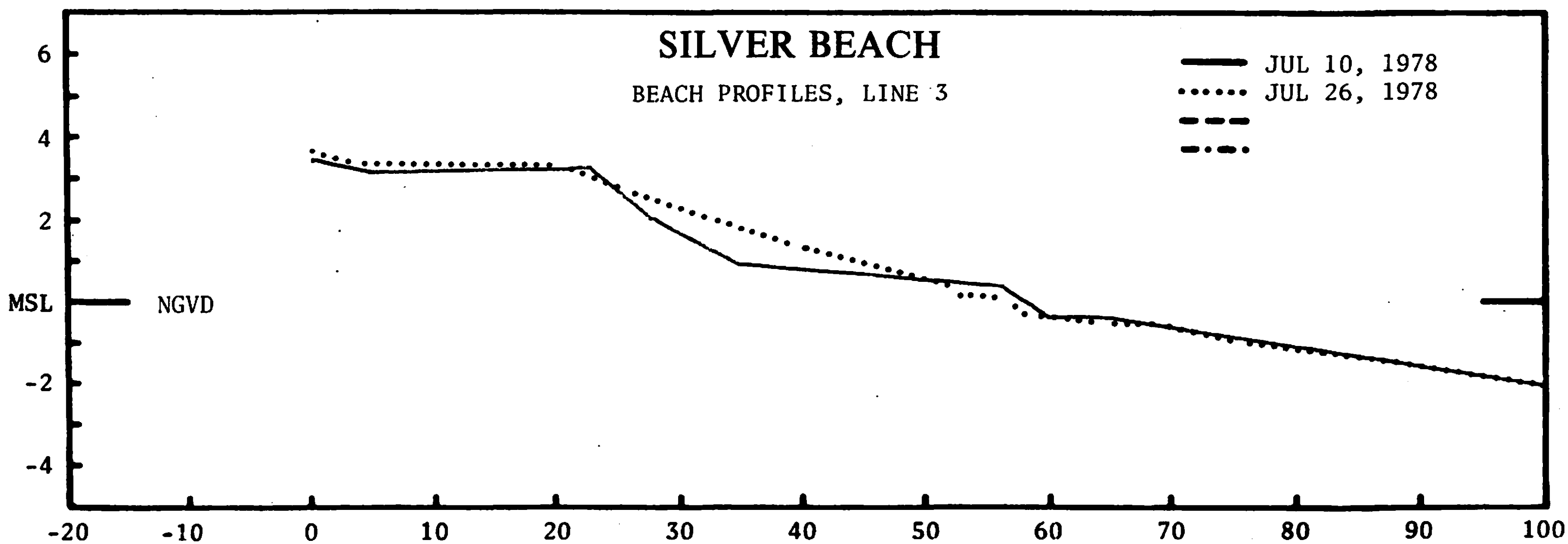

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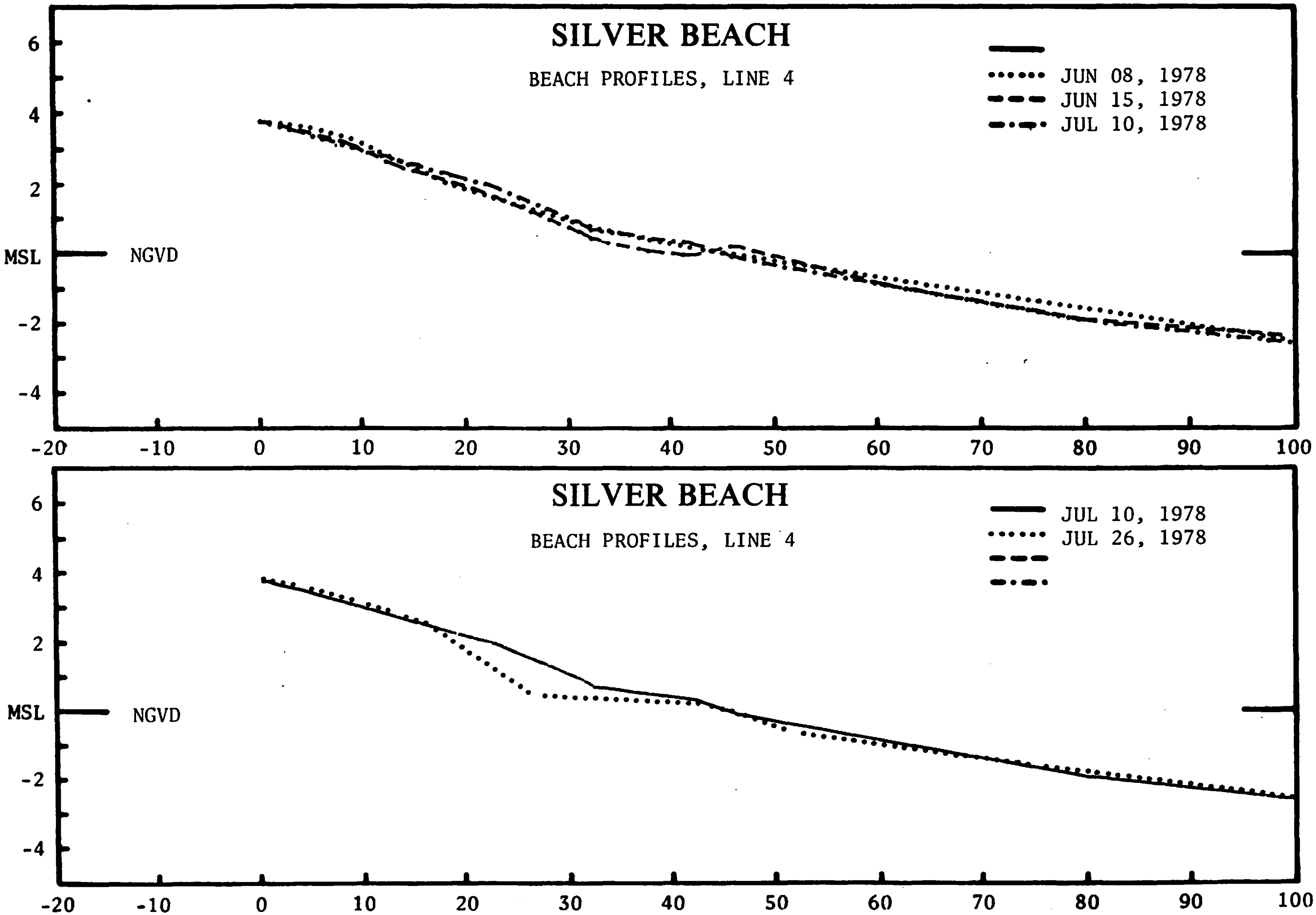

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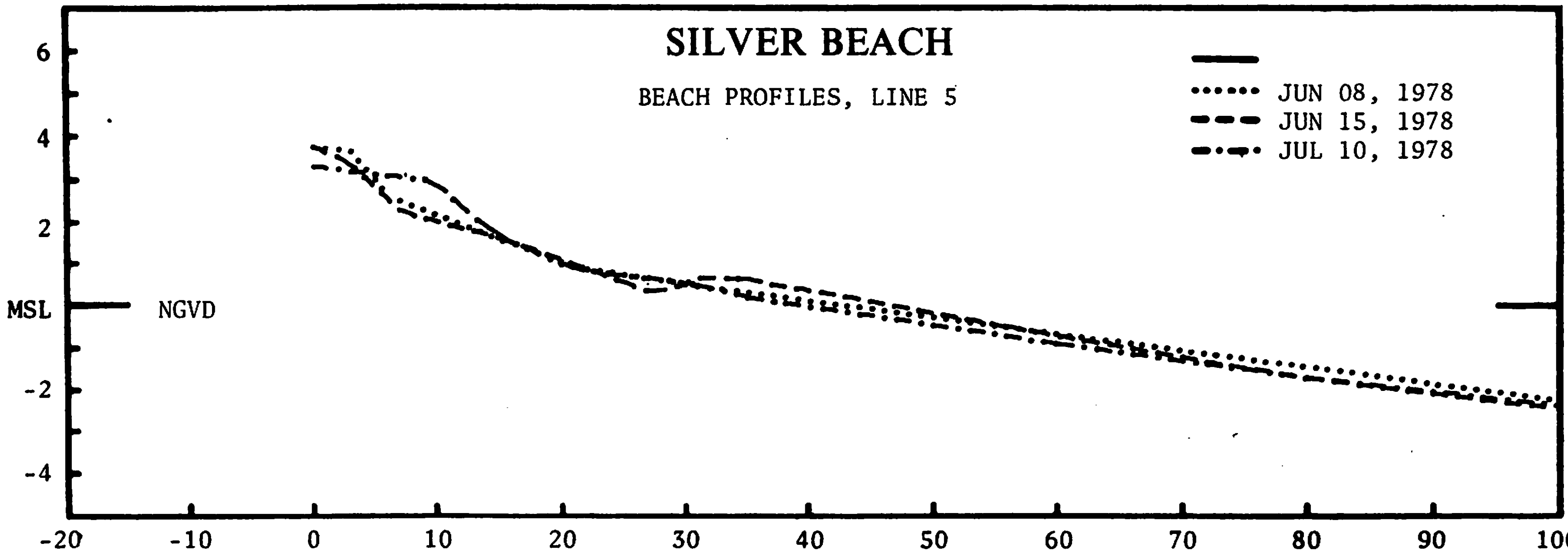

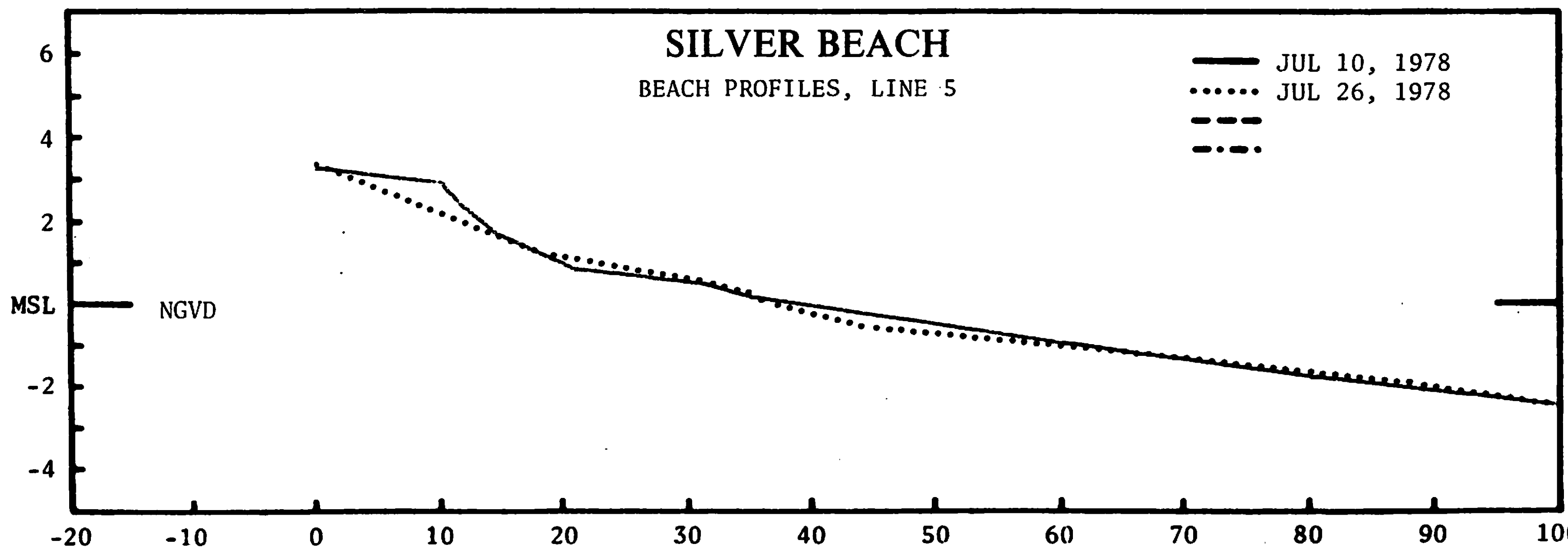

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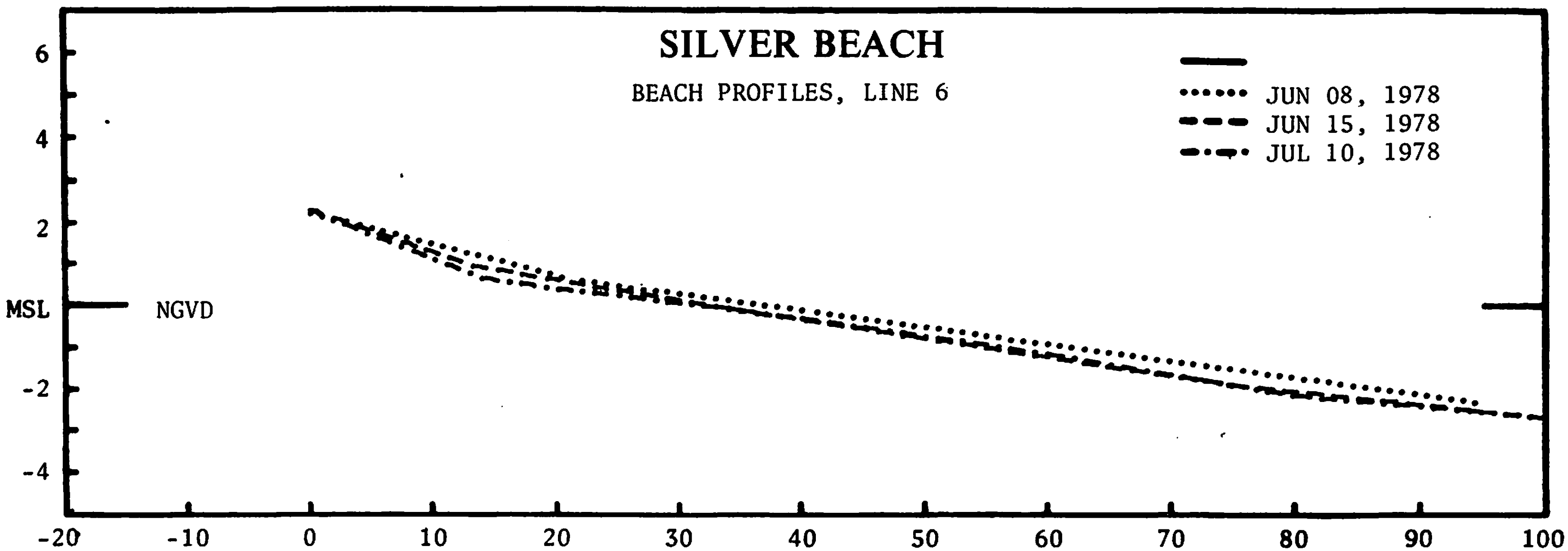
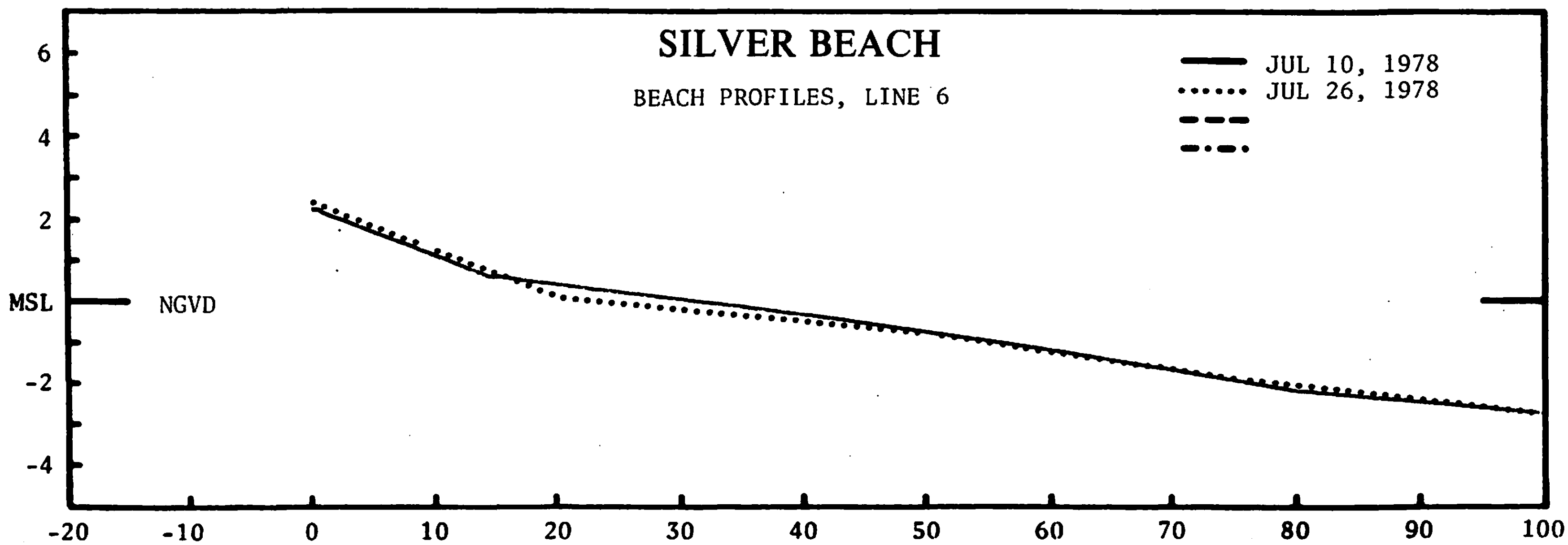
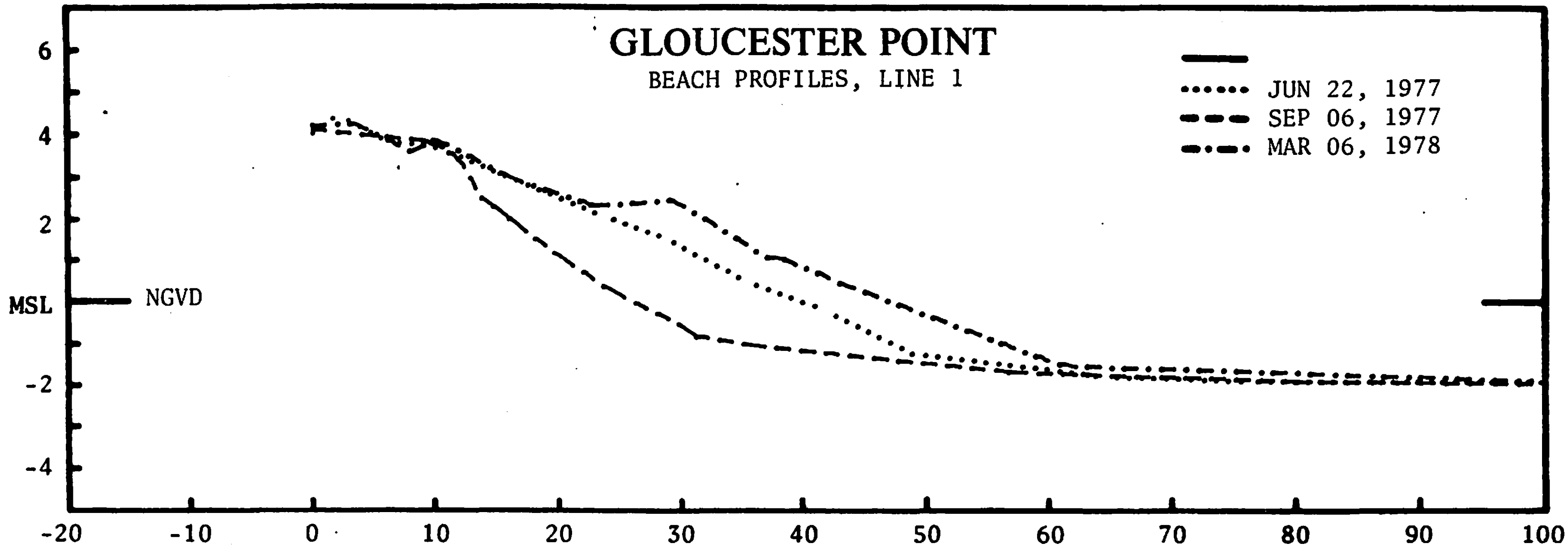
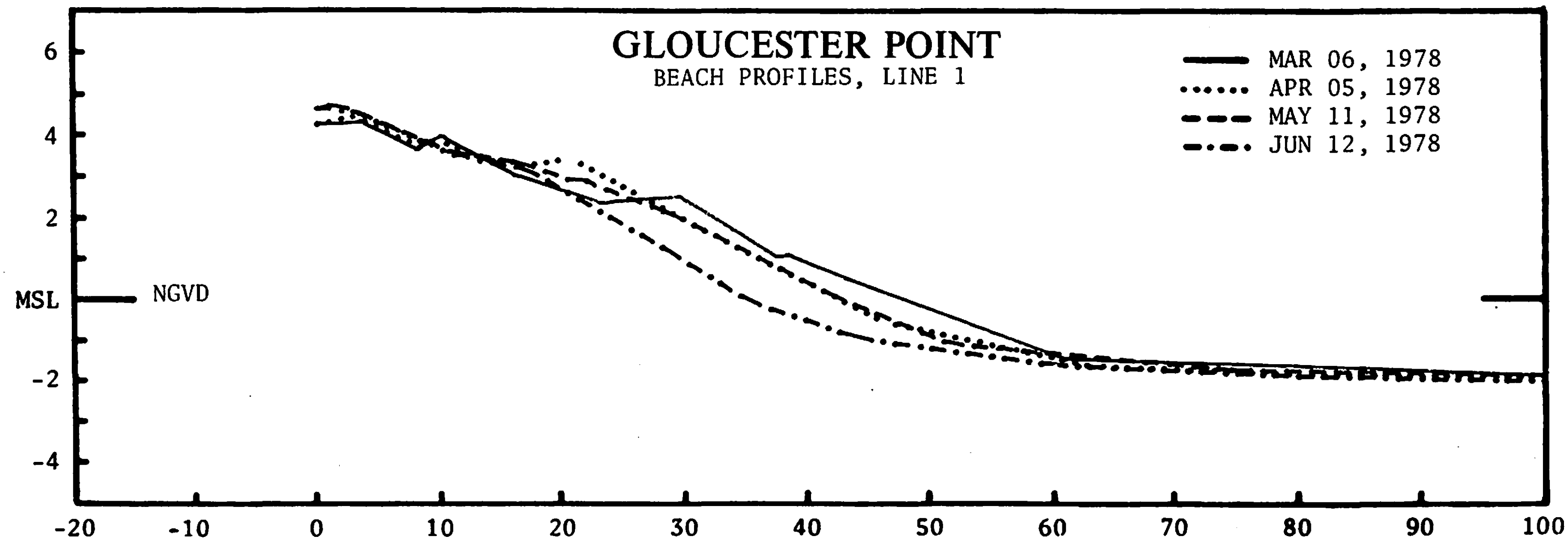




Distances measured in FEET





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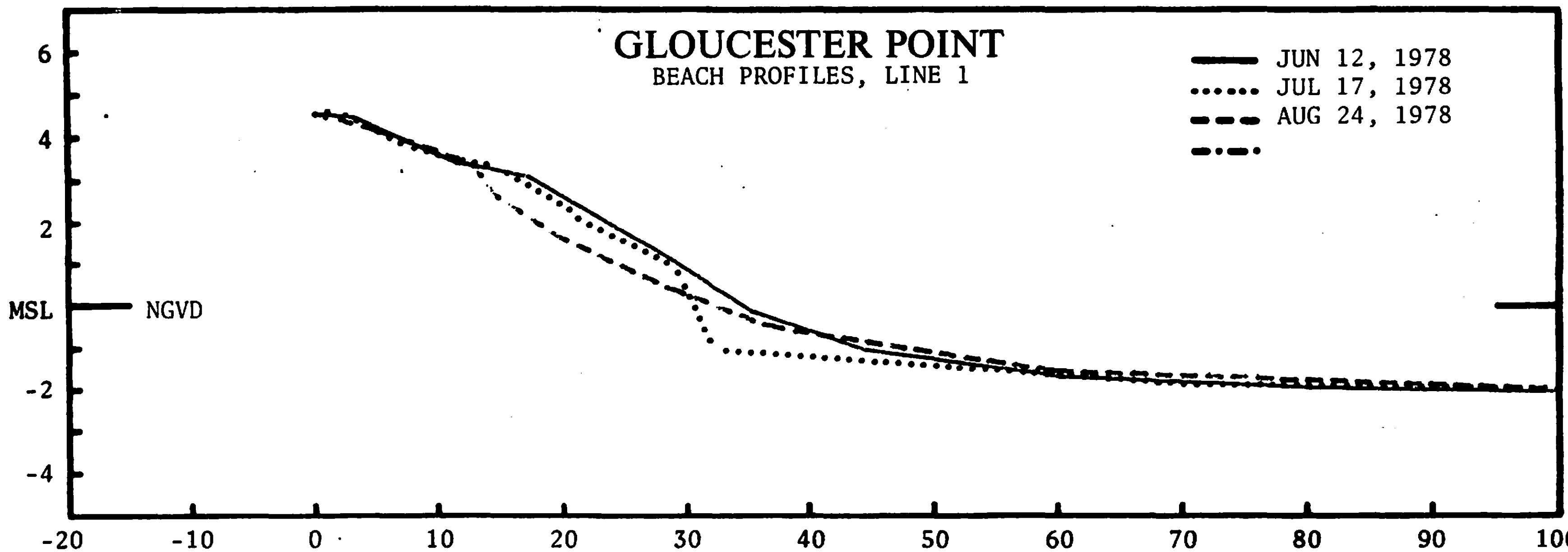

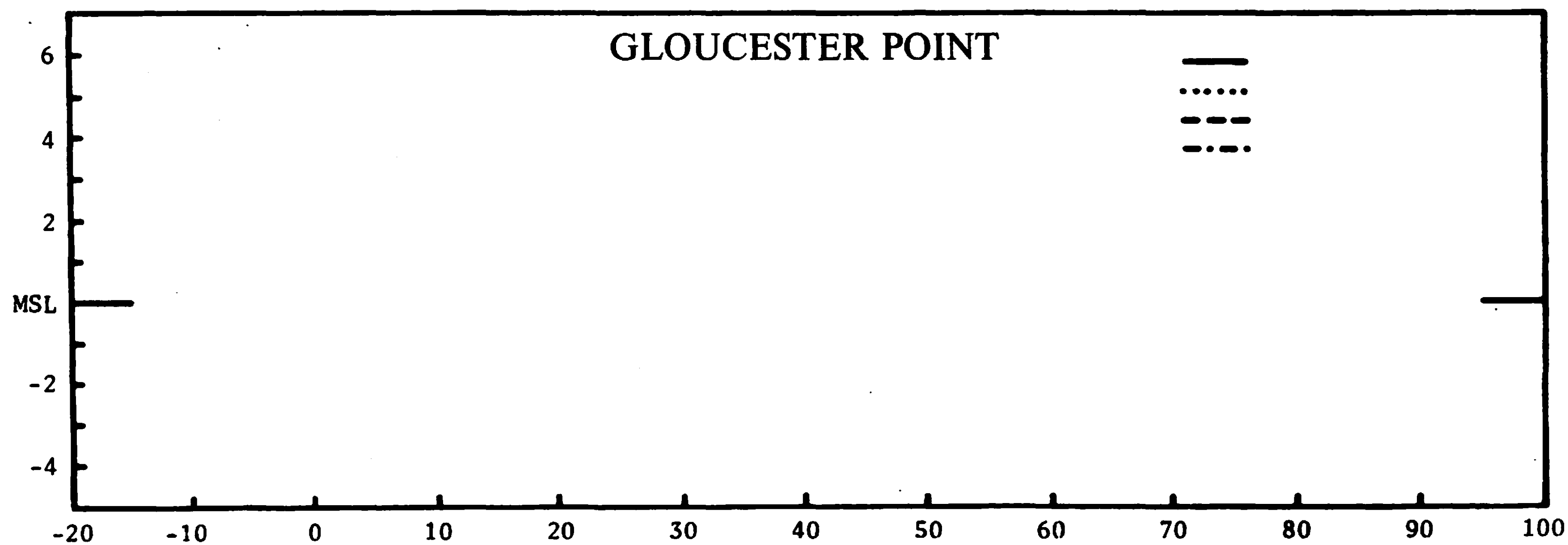

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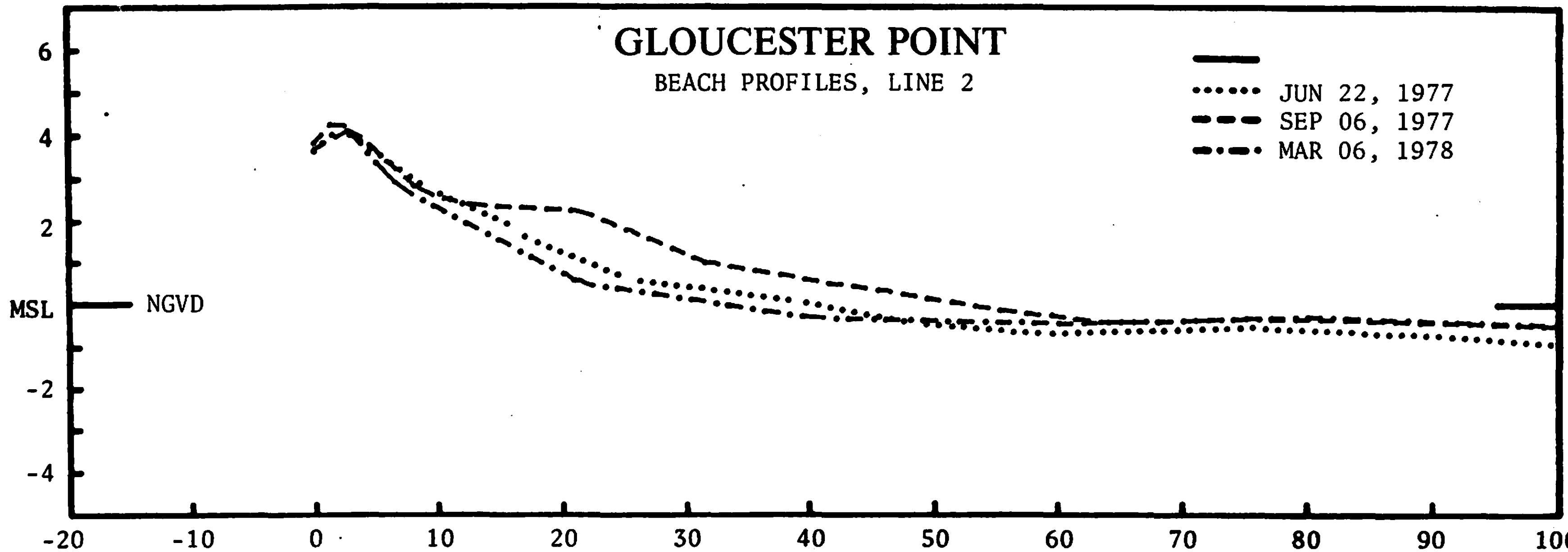

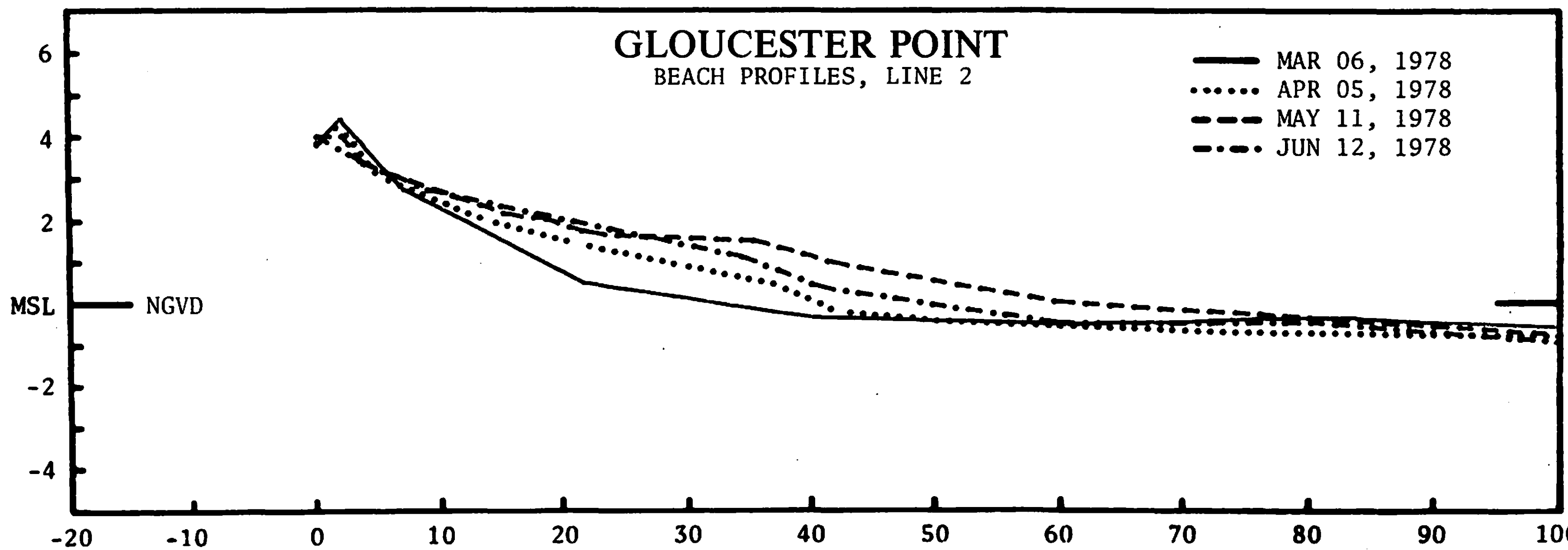

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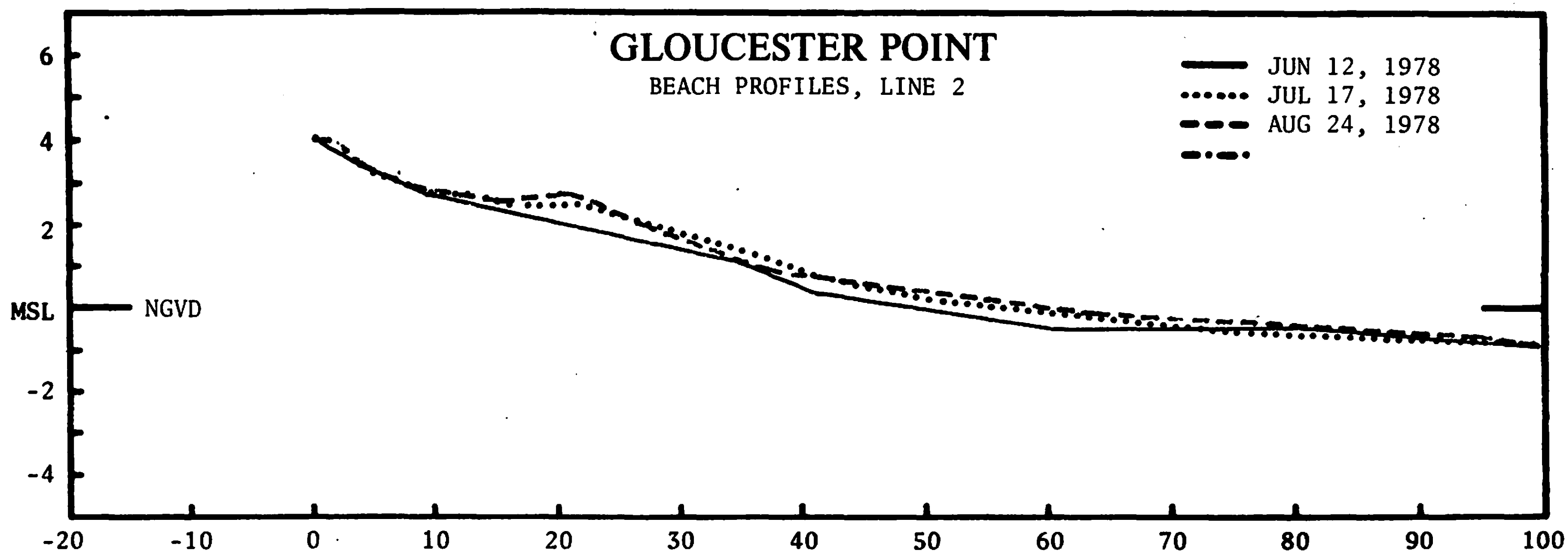

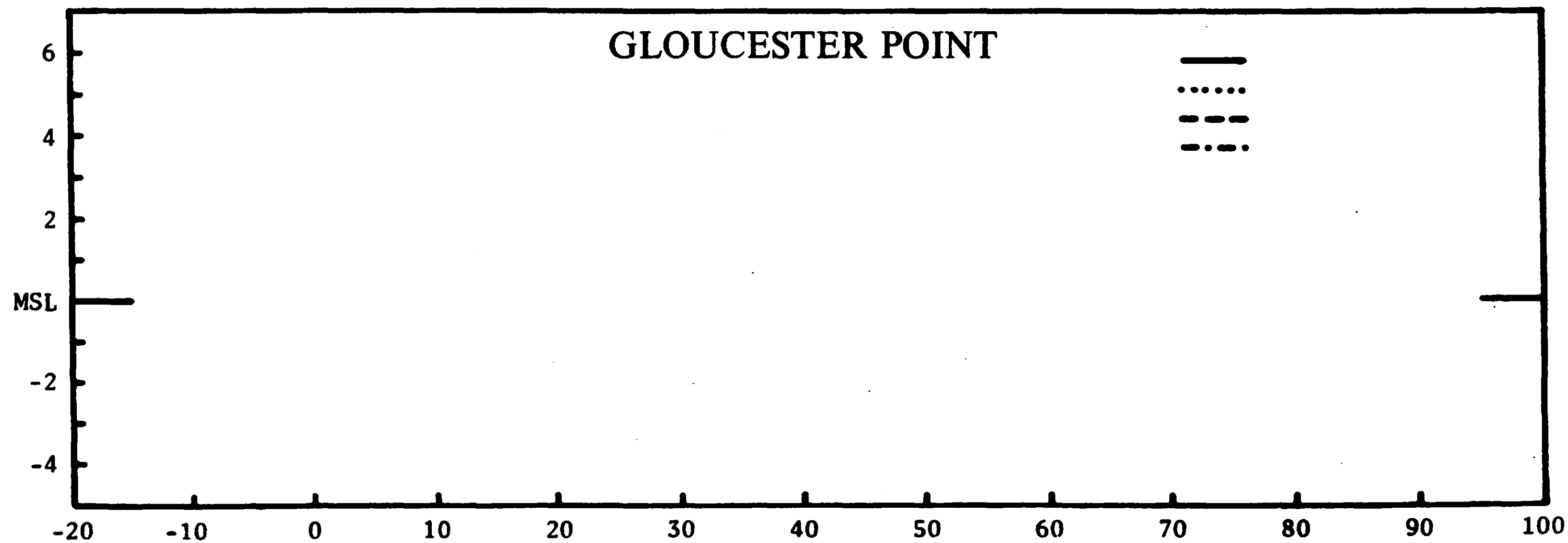

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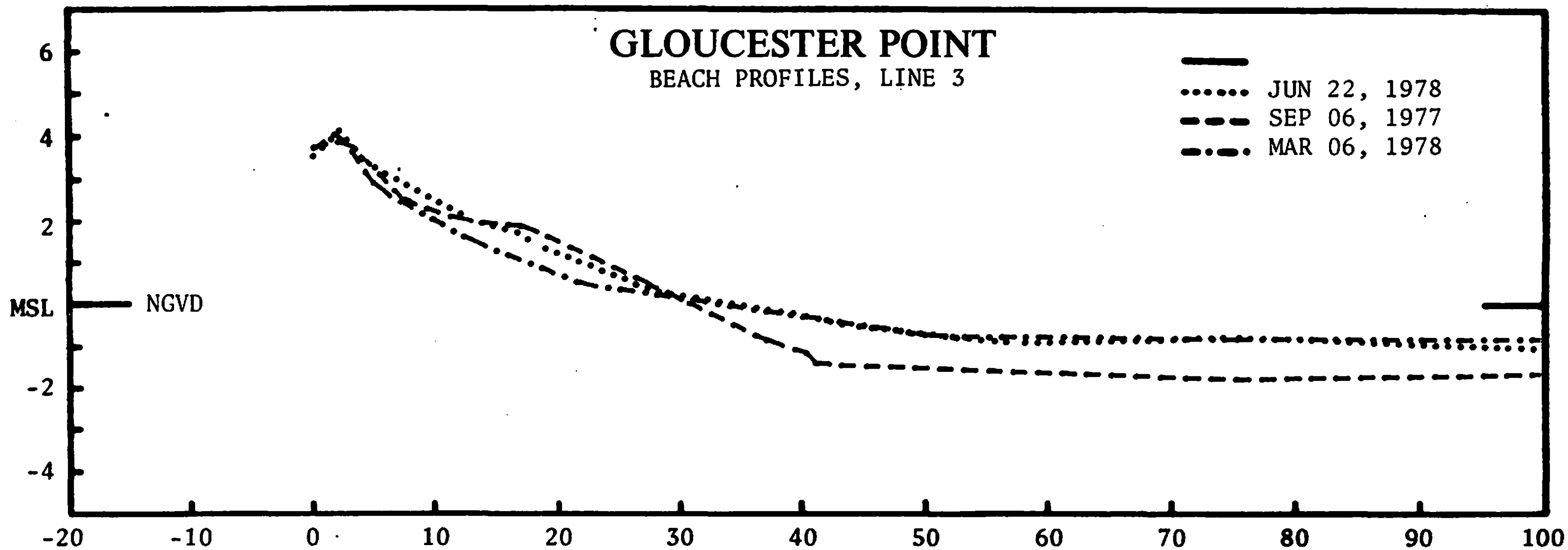

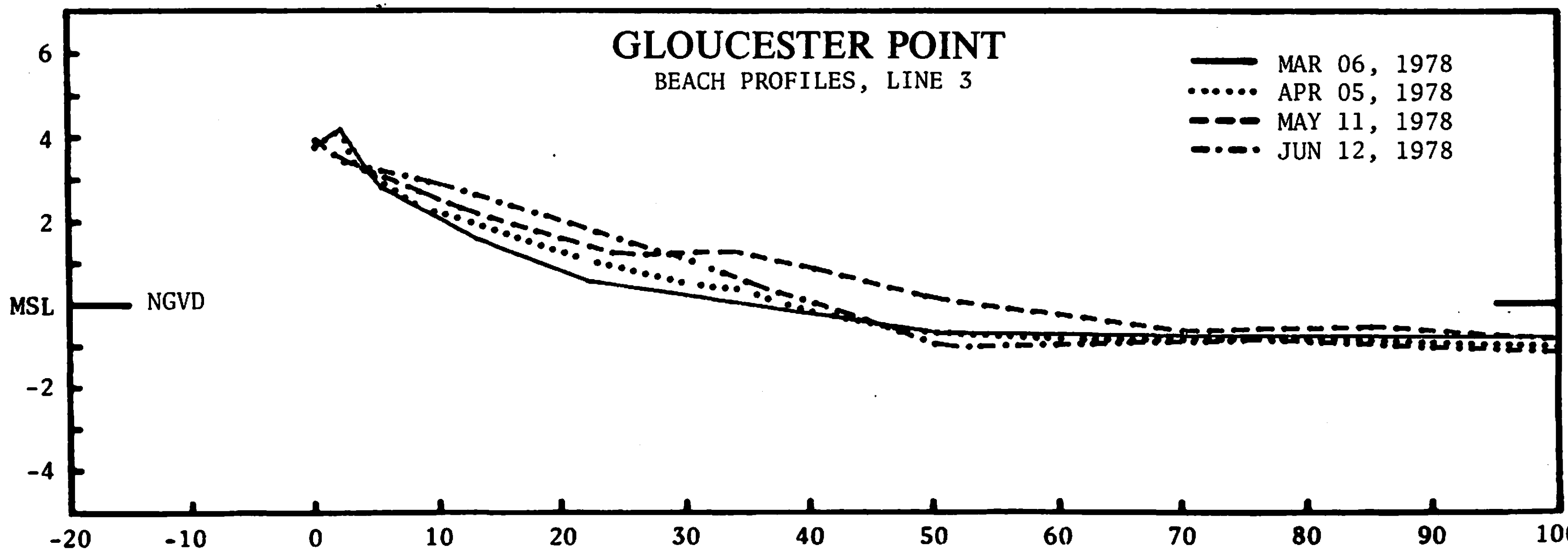

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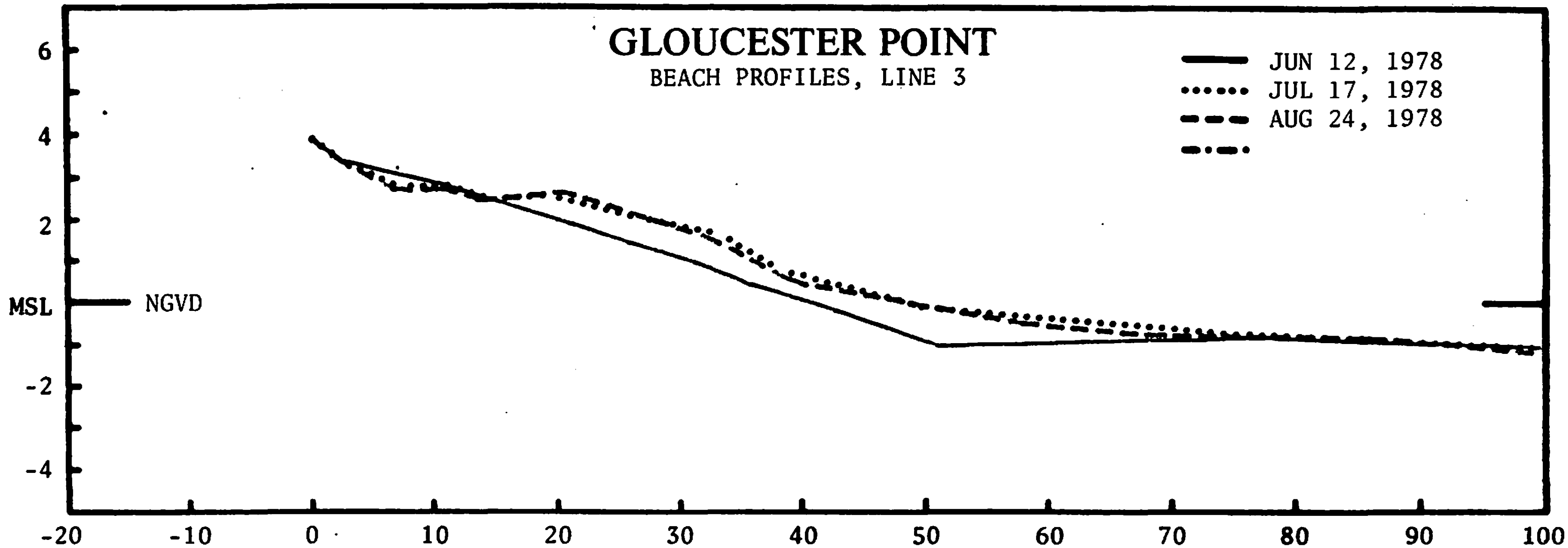

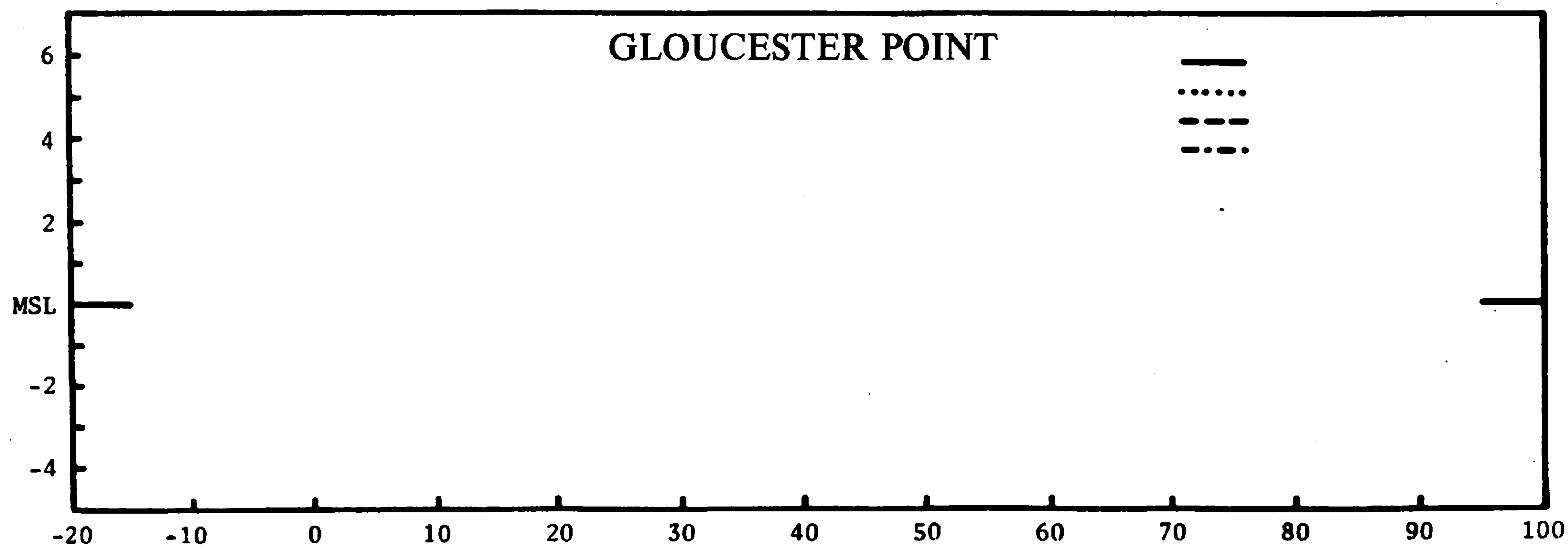

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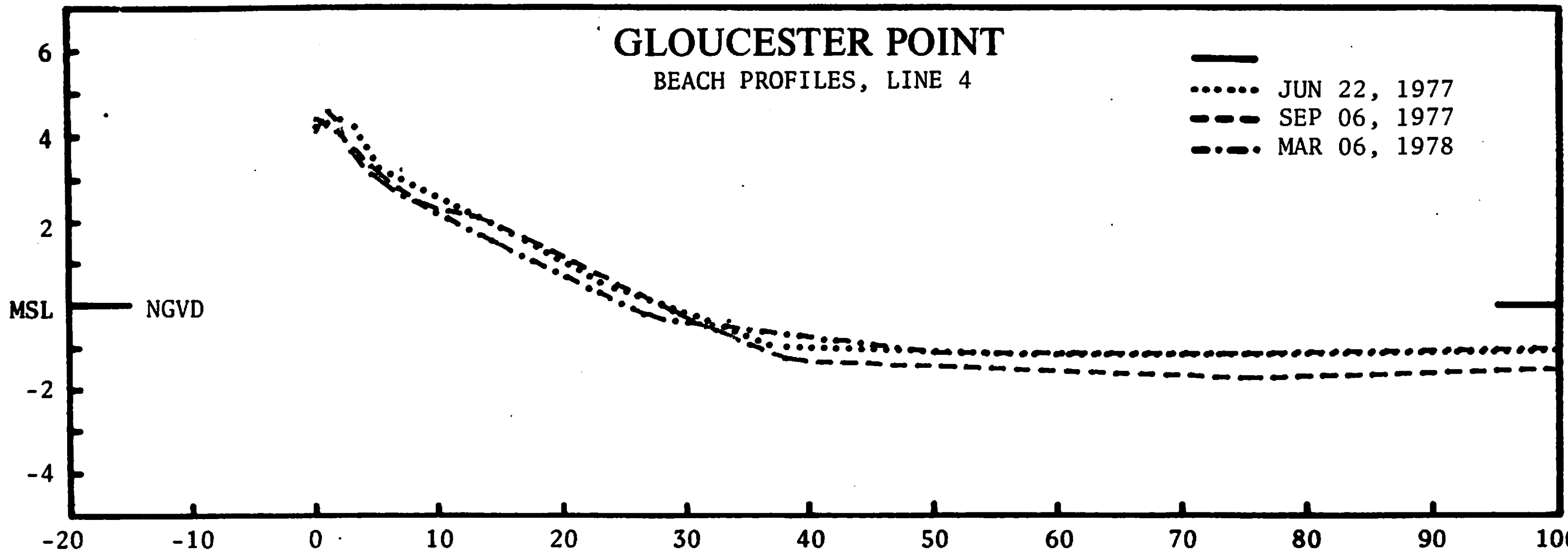

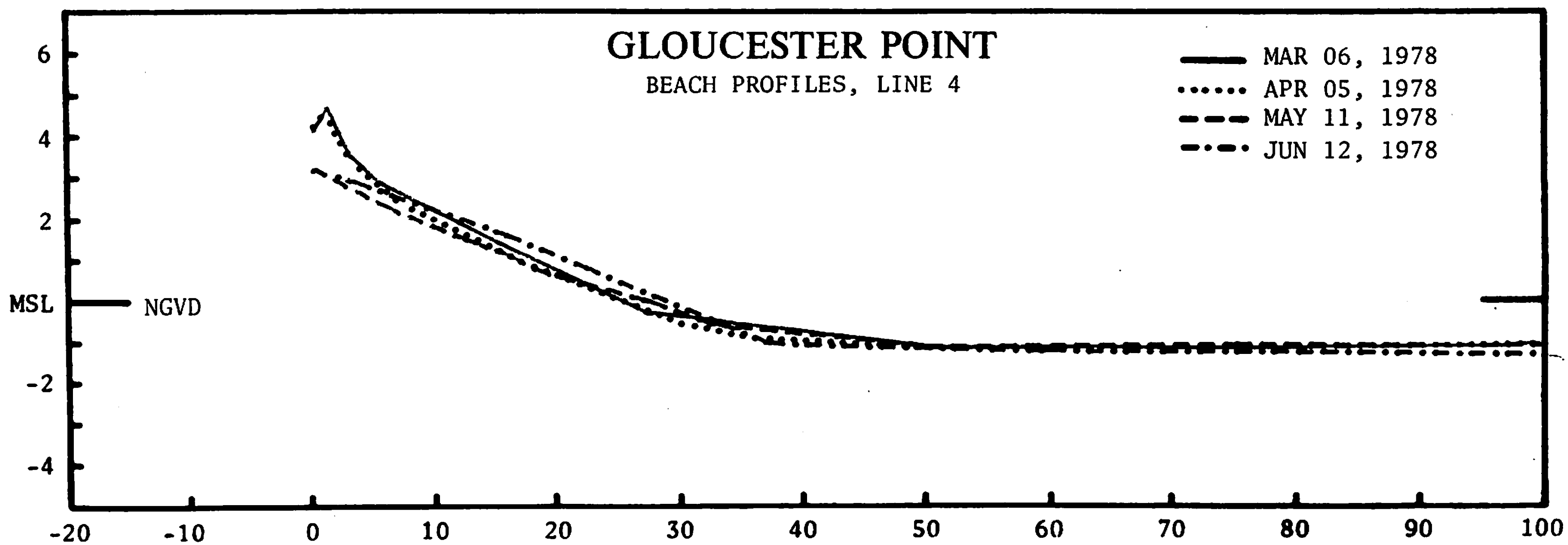

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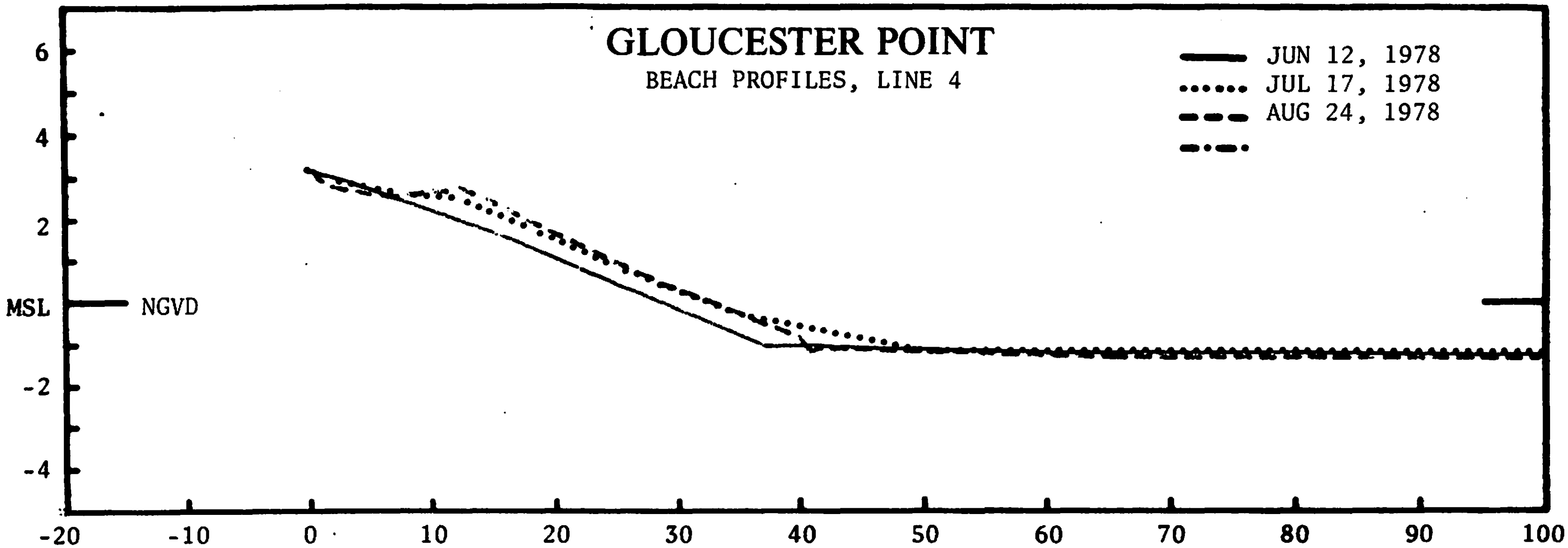
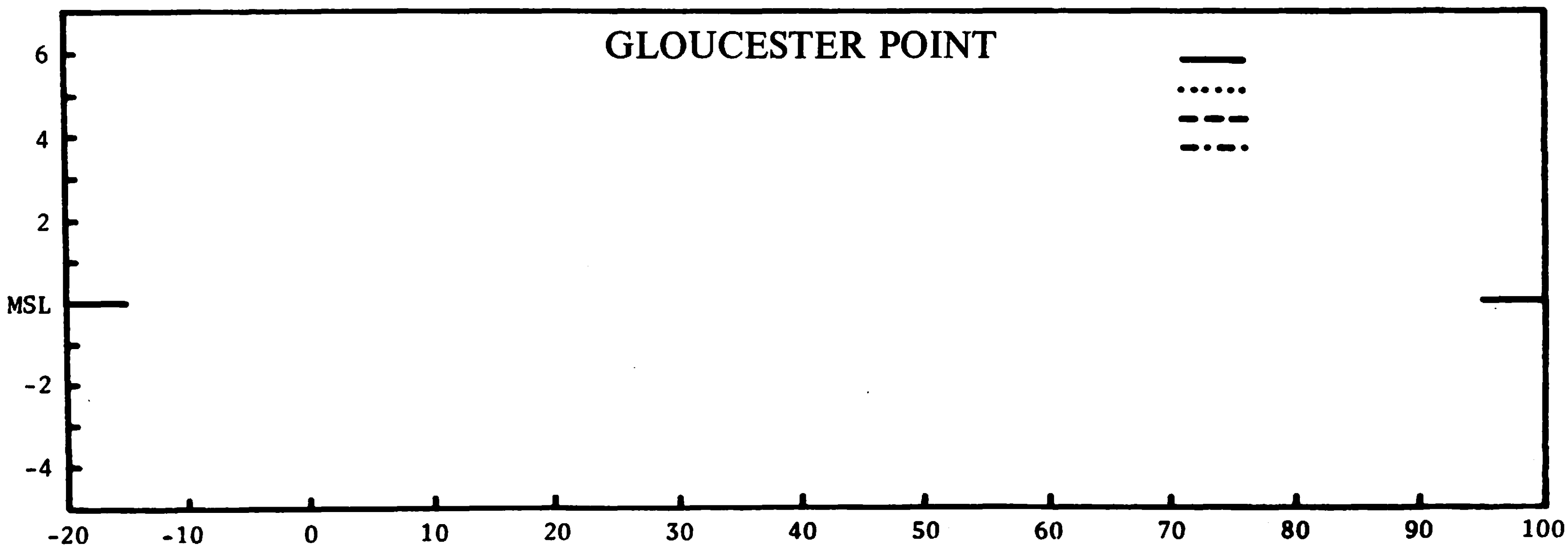
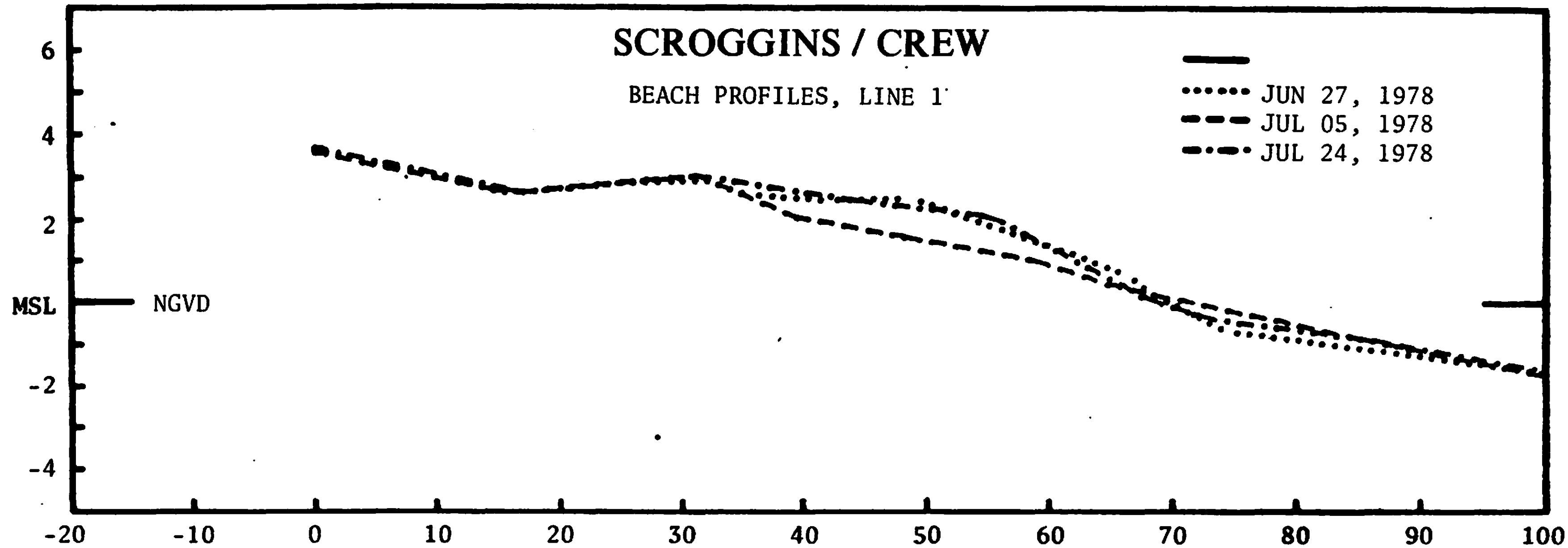
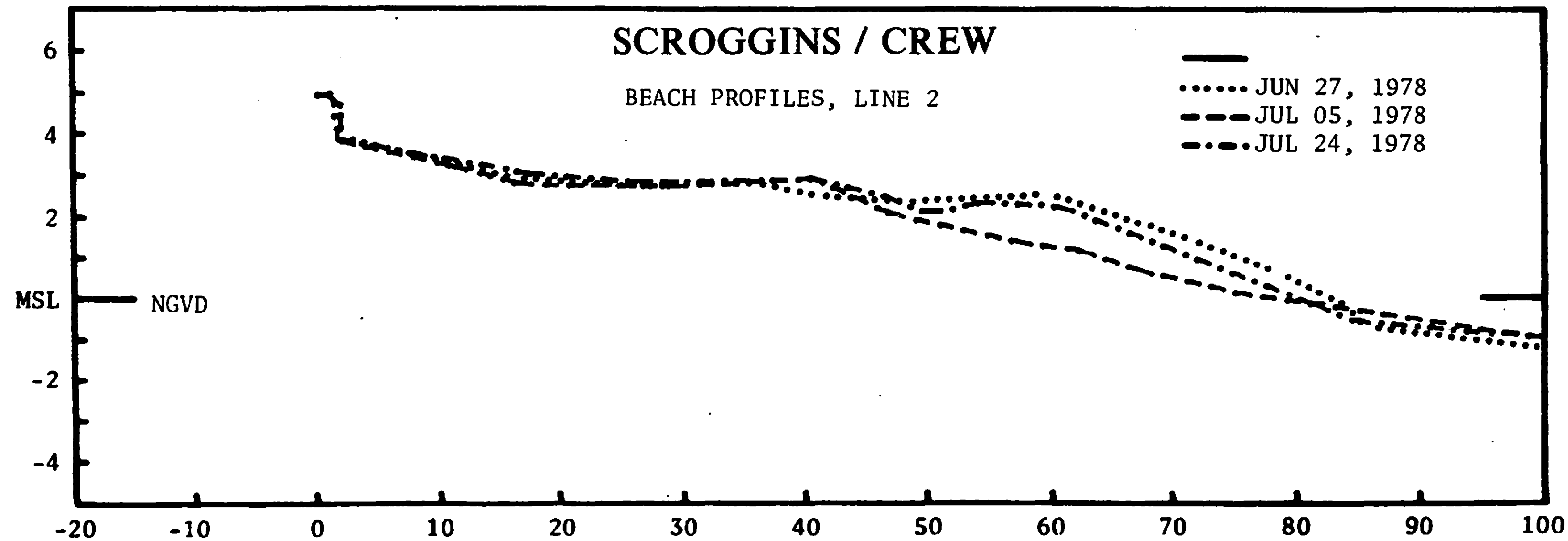


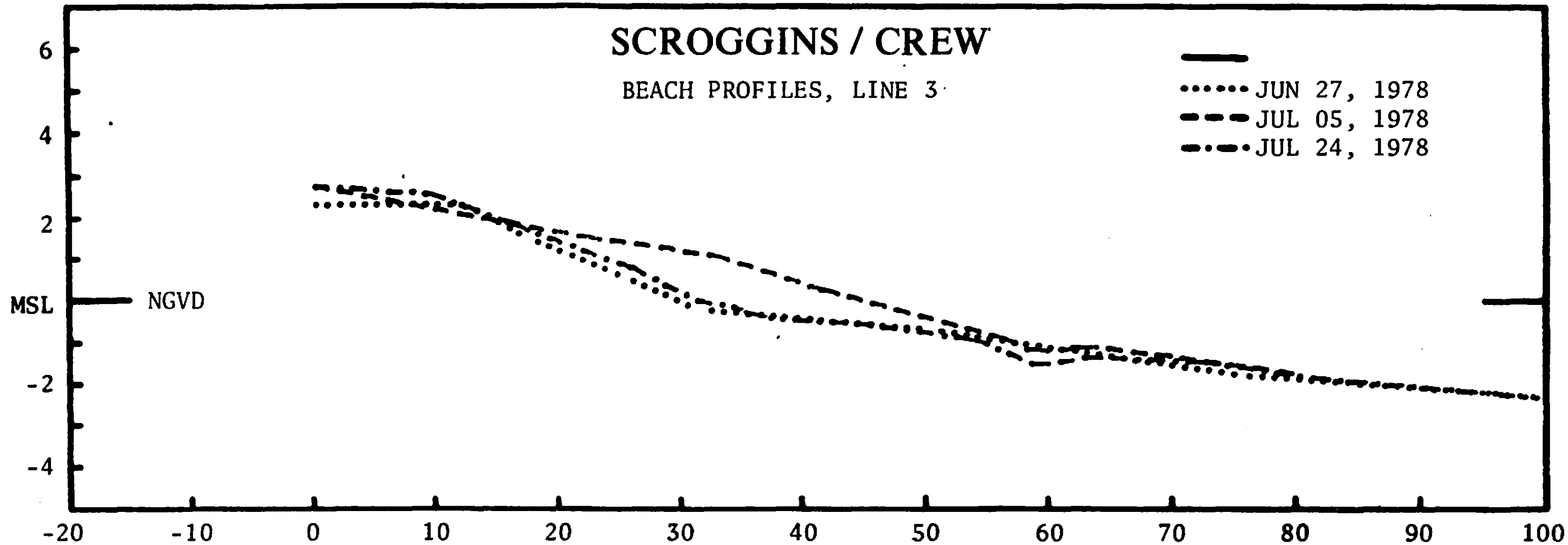


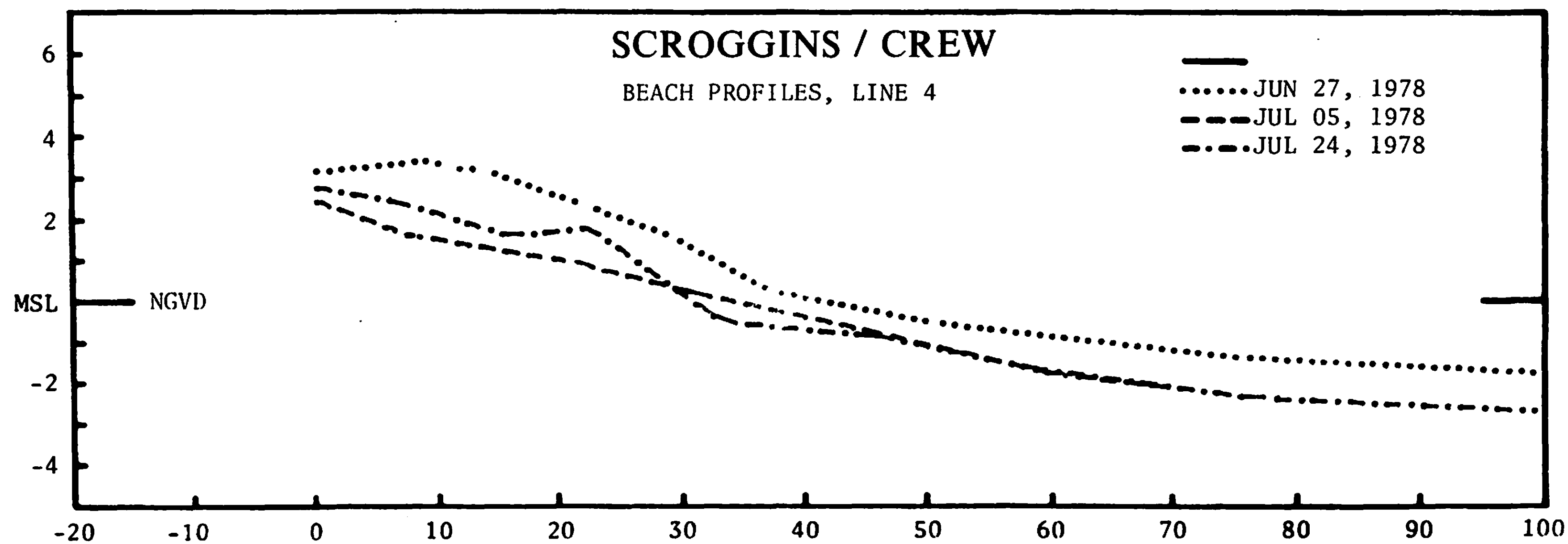
Distances measured in FEET



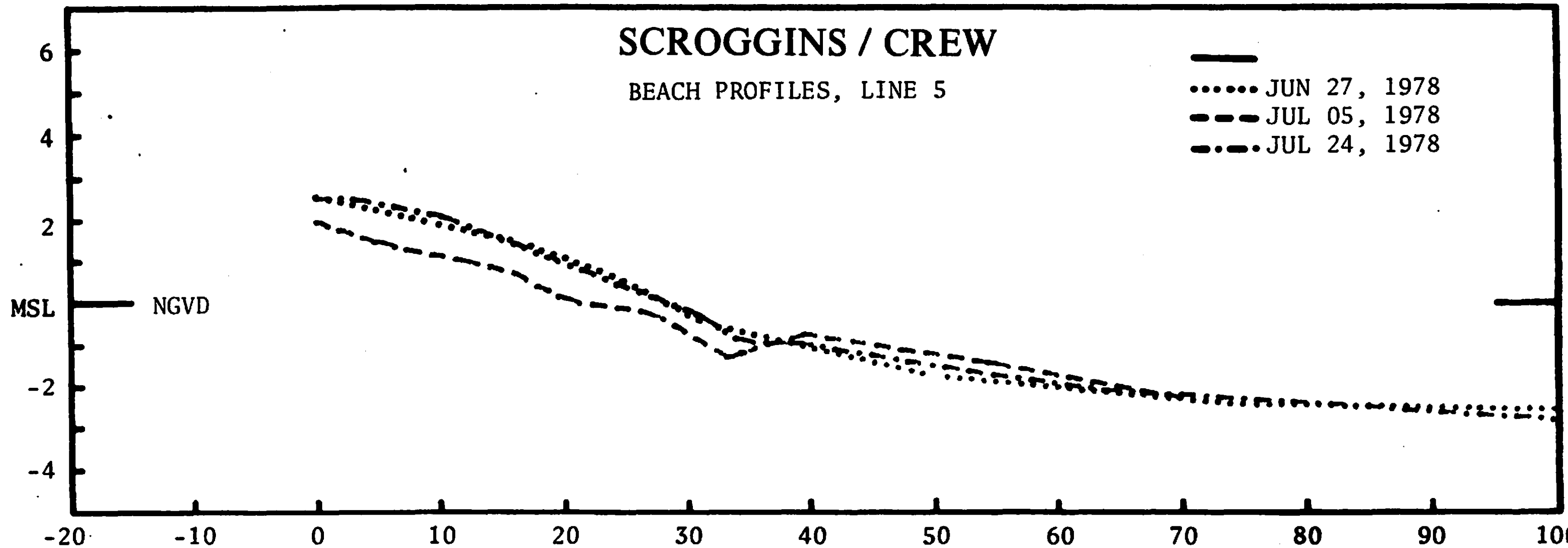


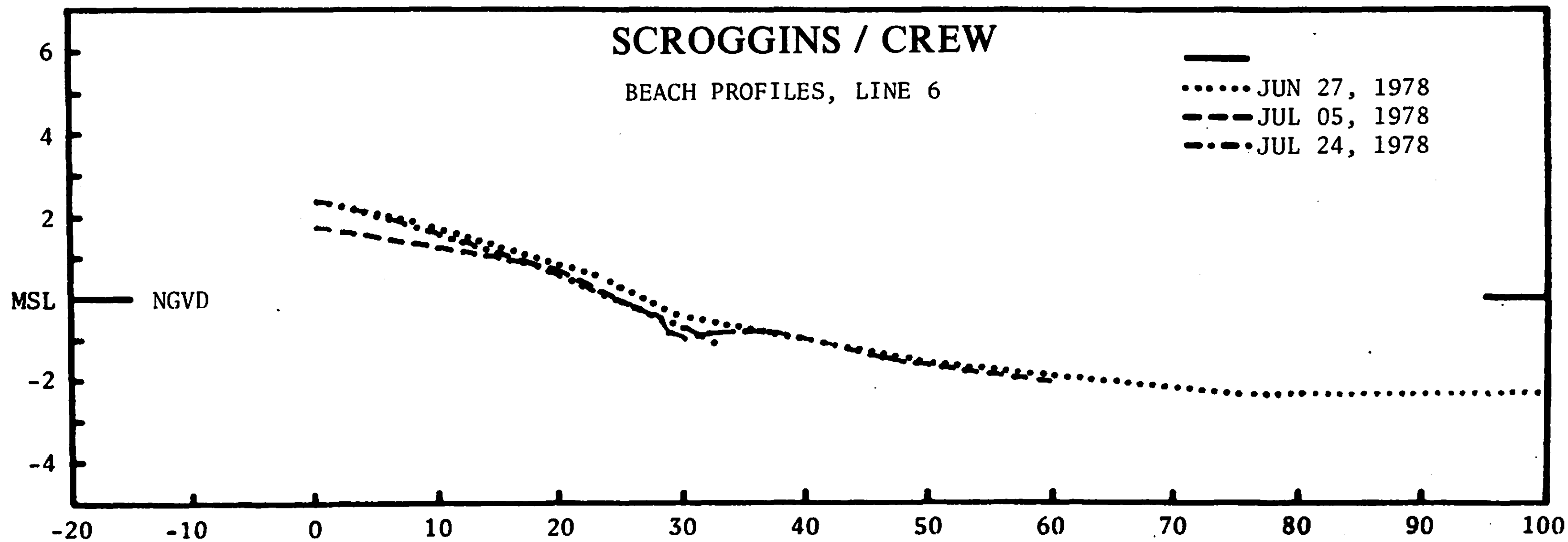
Distances measured in FEET





Distances measured in FEET





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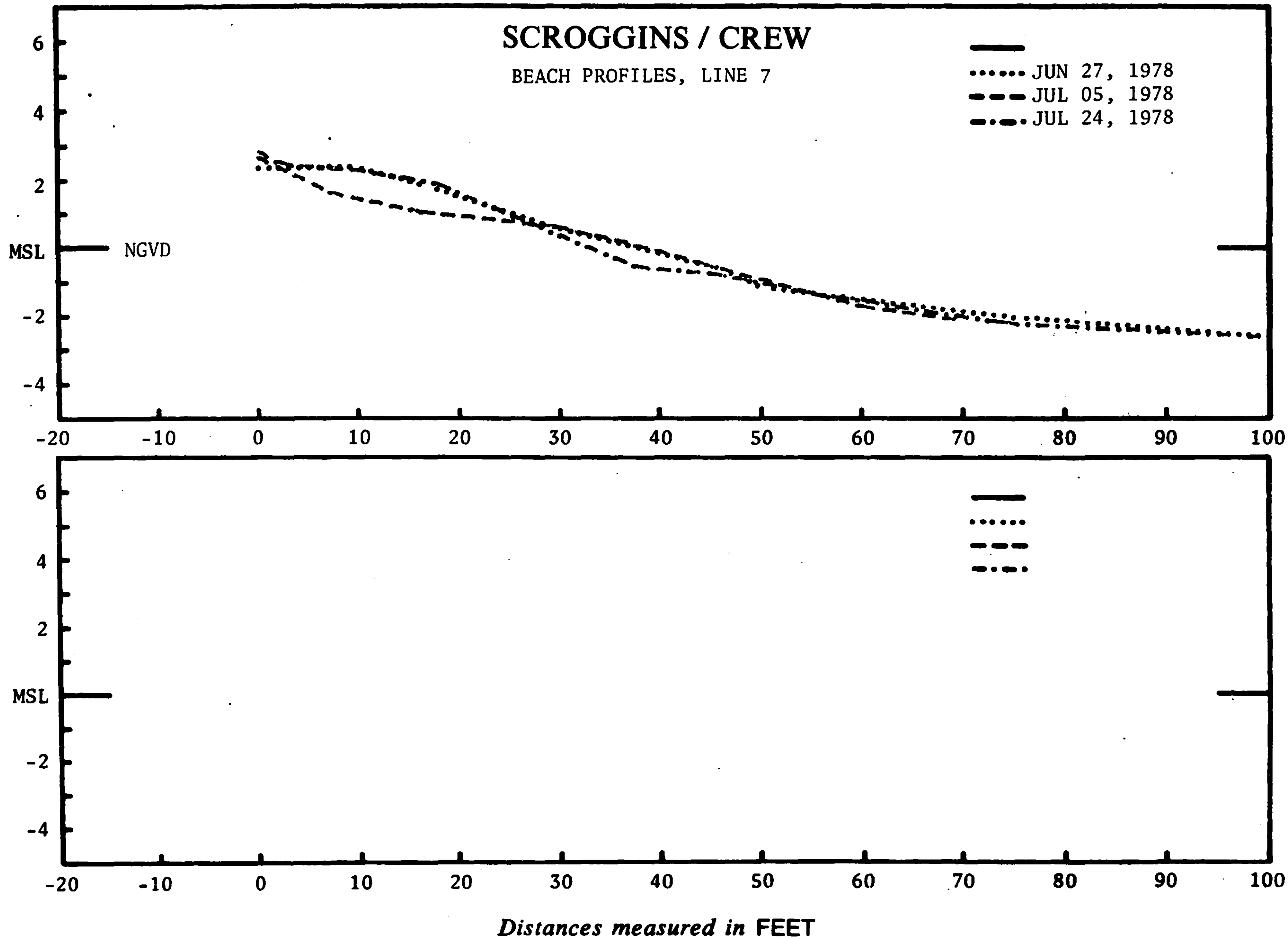
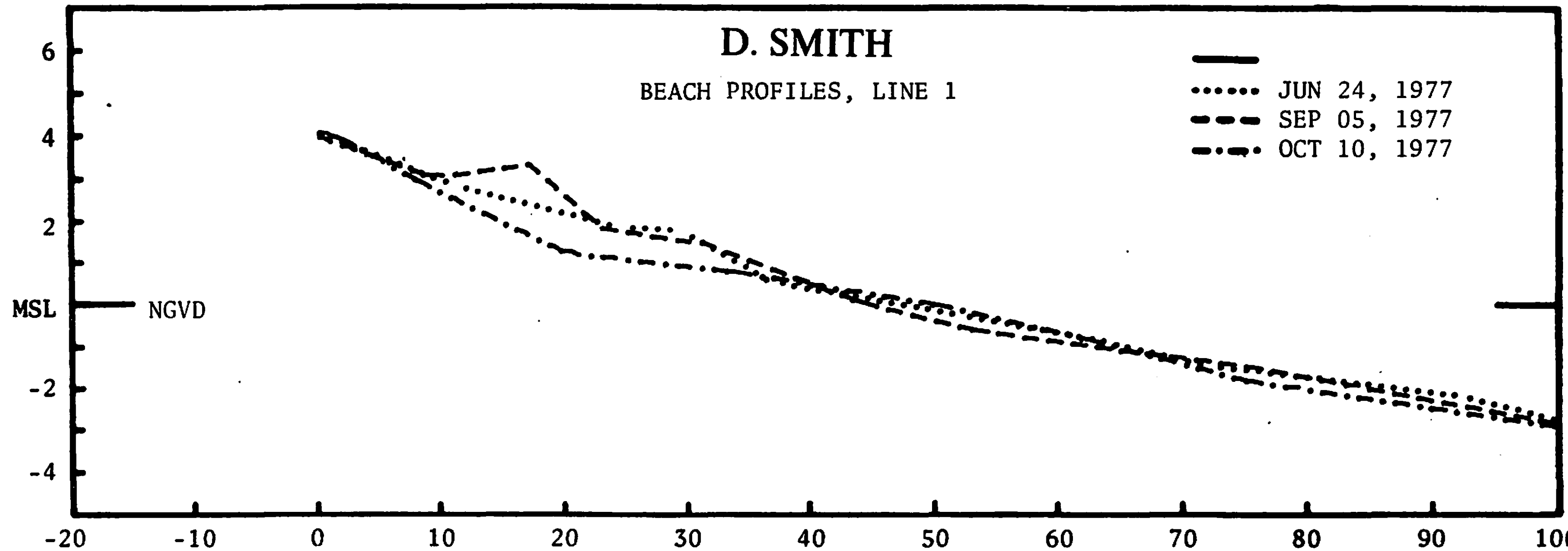
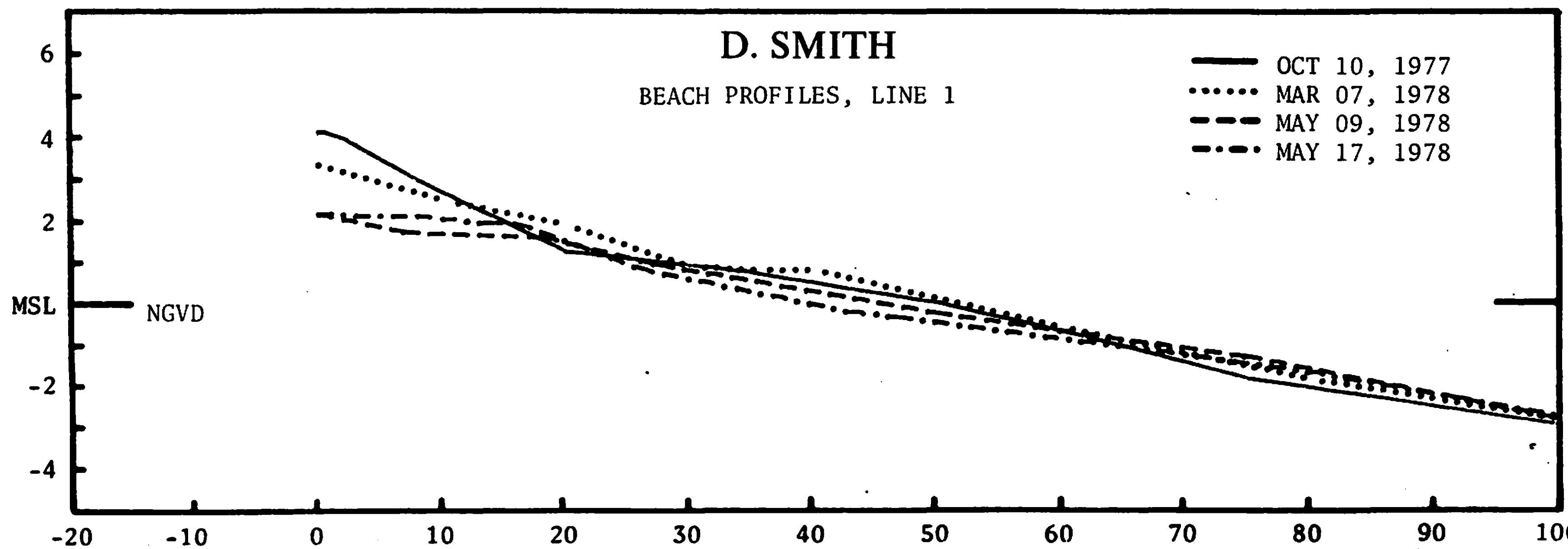
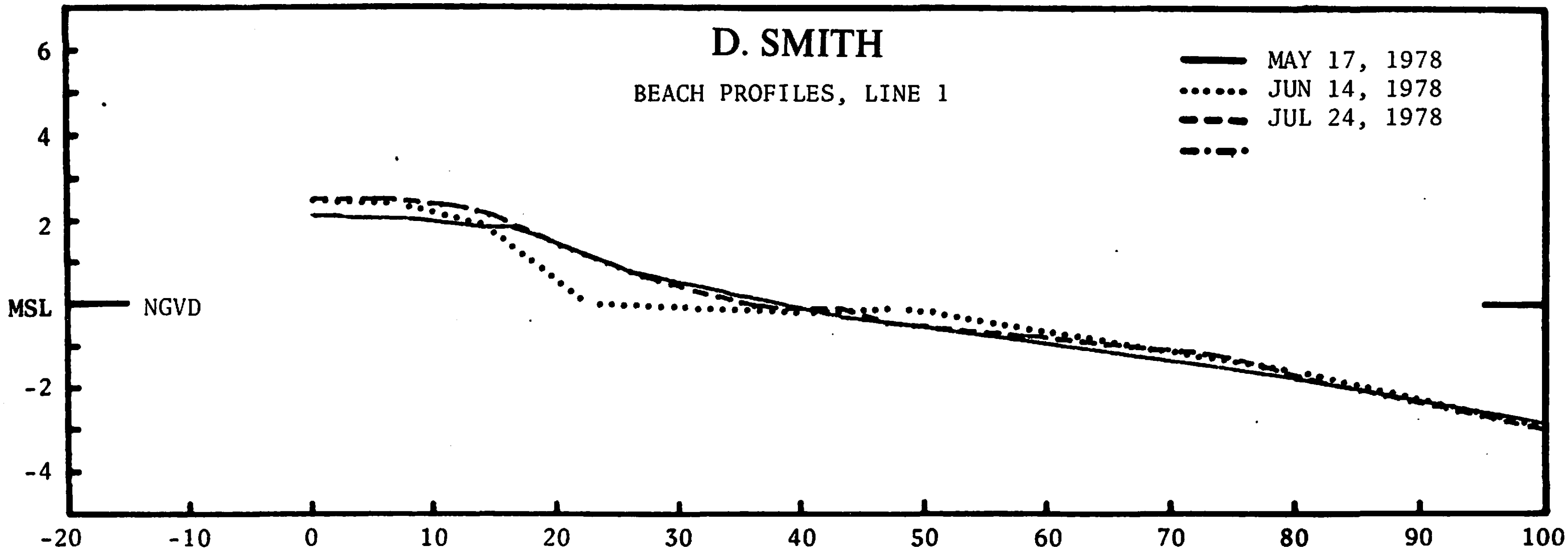


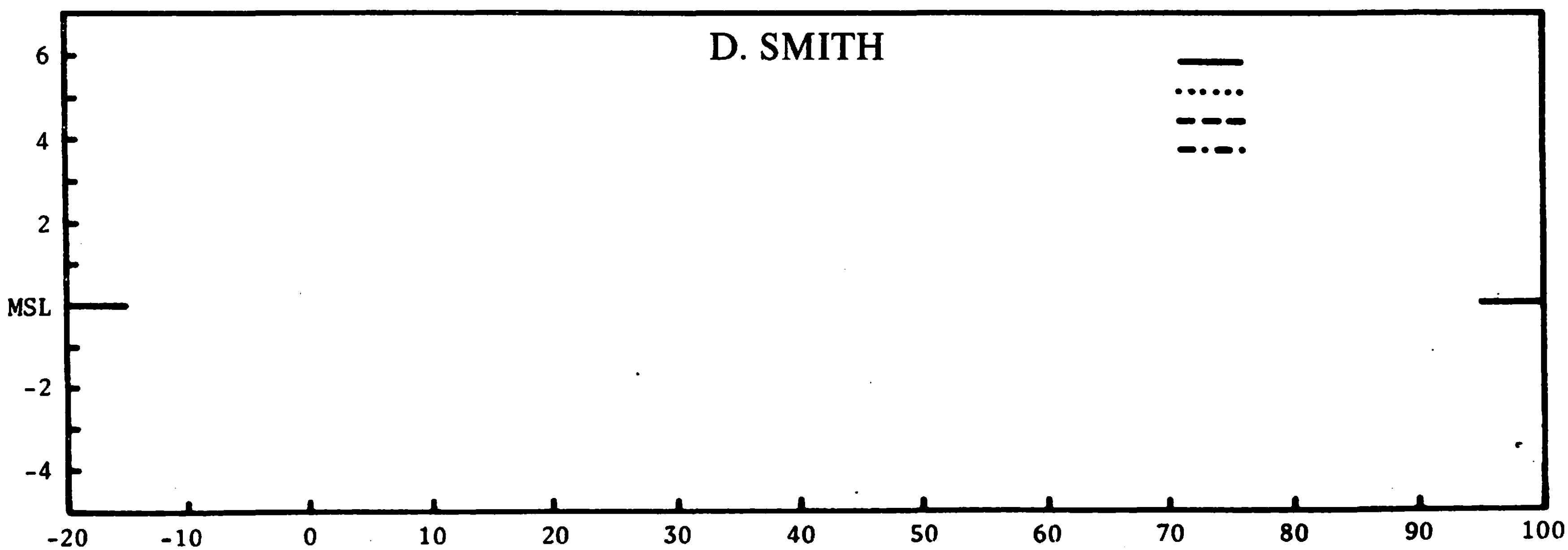
SCROGGINS / CREW
BEACH PROFILES, LINE 7
JUN 27, 1978
JUL 05, 1978
JUL 24, 1978
6
4
2
MSL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
6
4
2
MSL
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET





Distances measured in FEET





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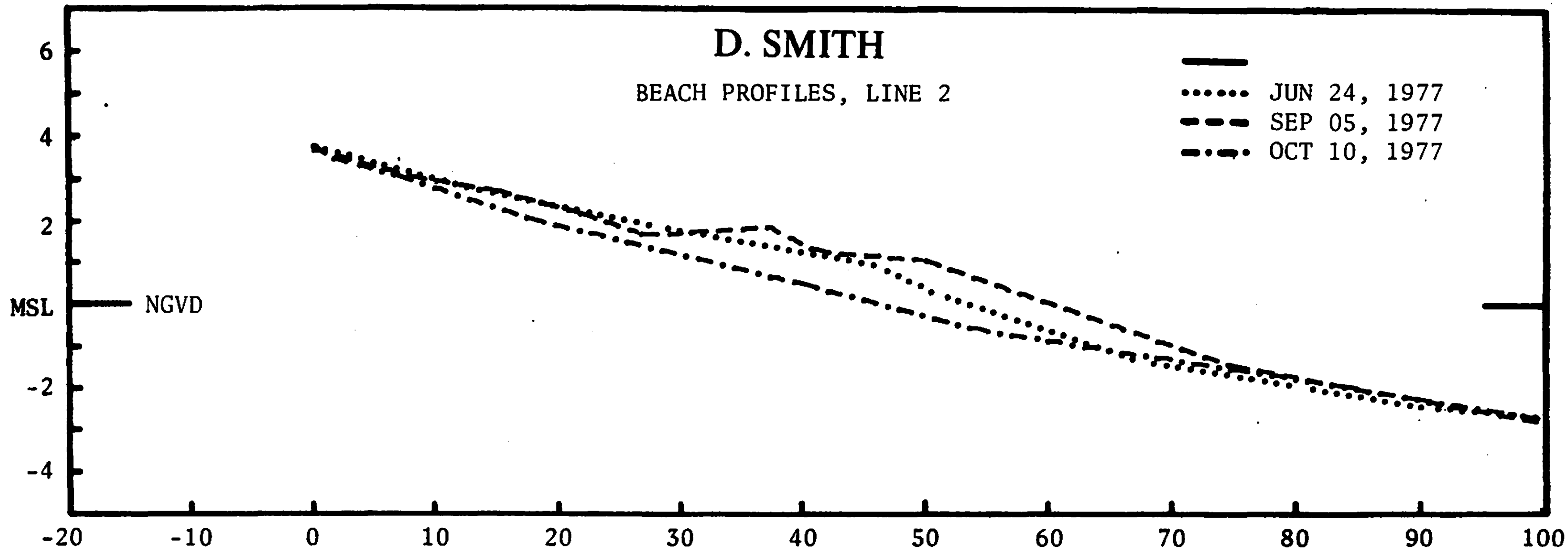

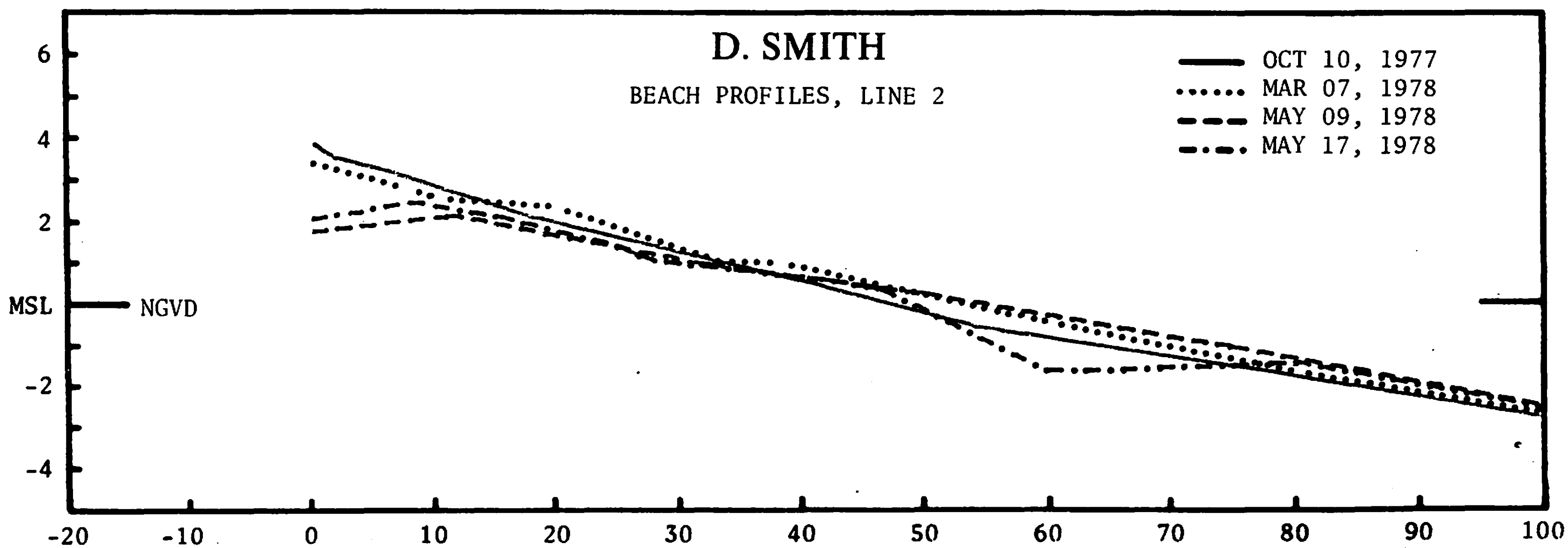

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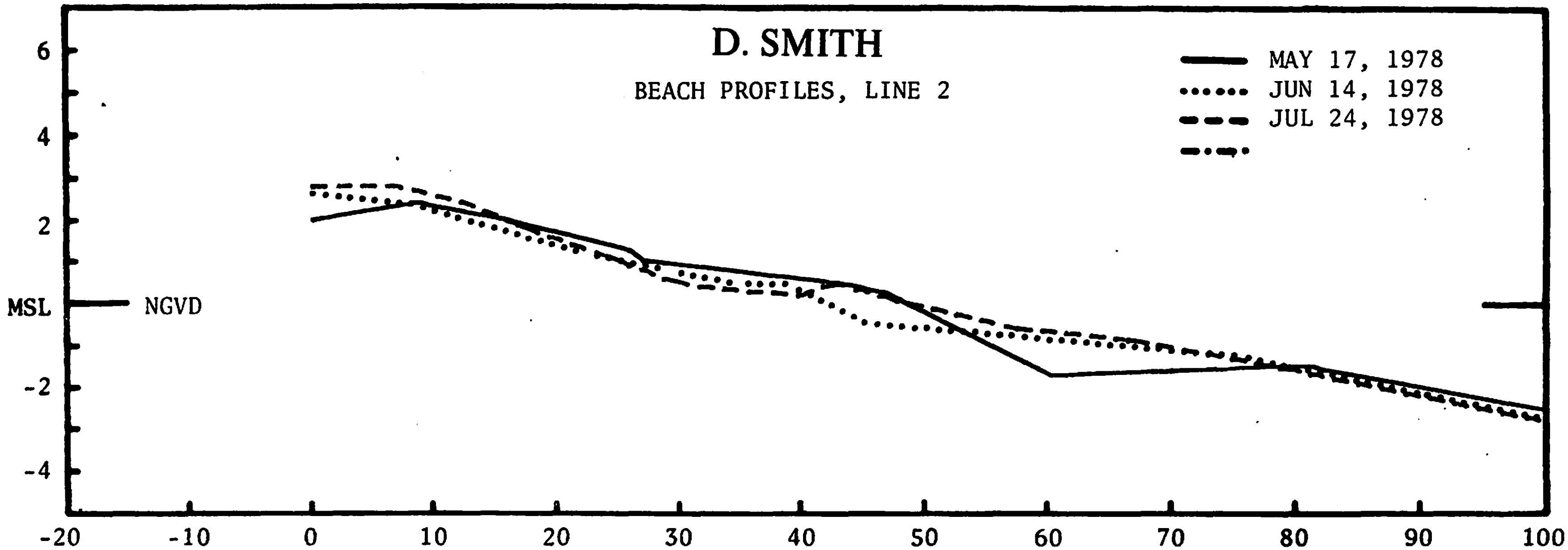

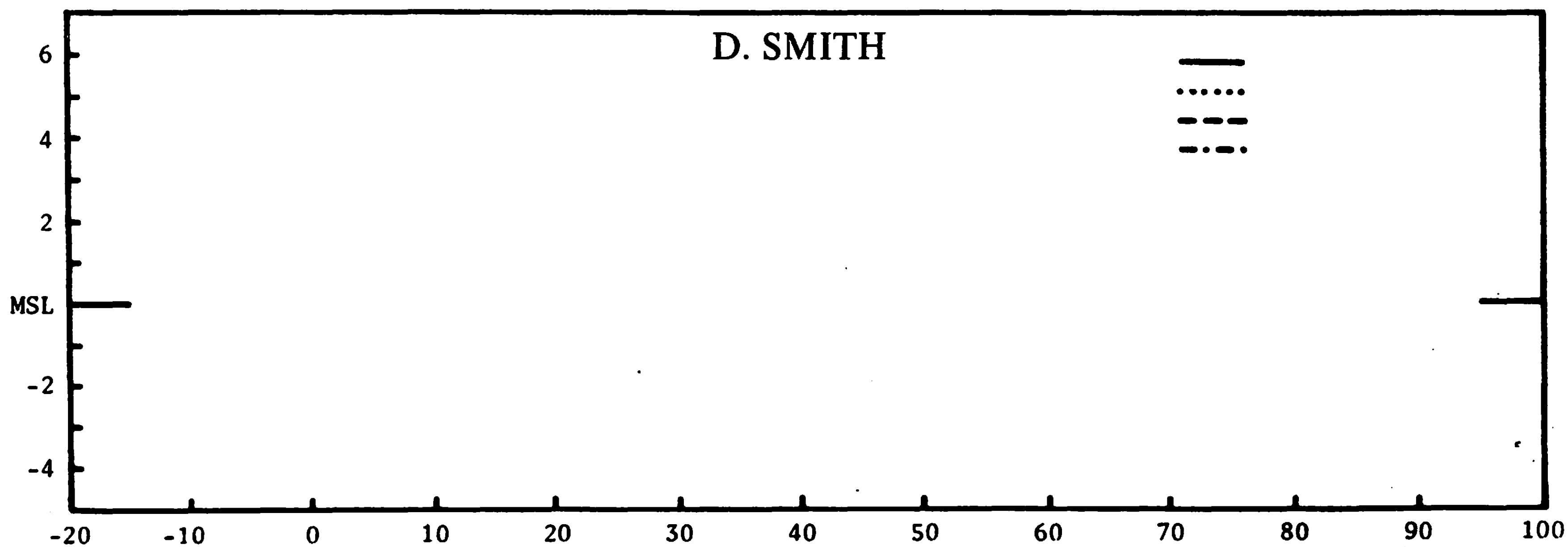

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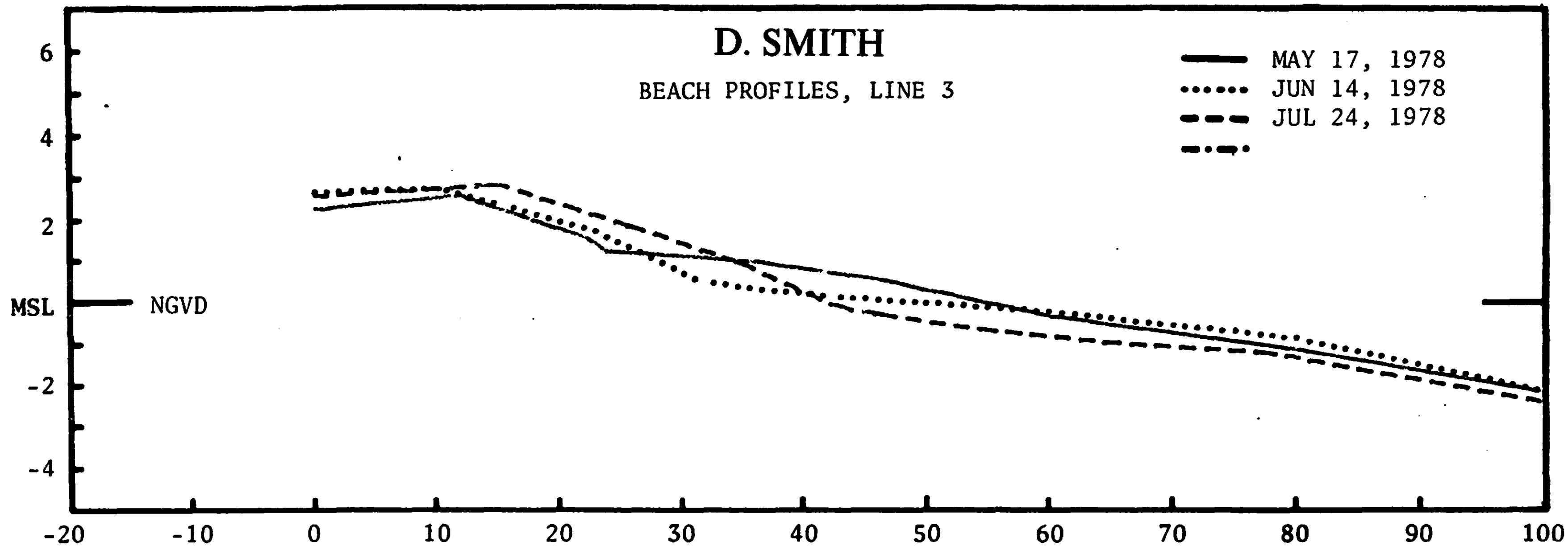

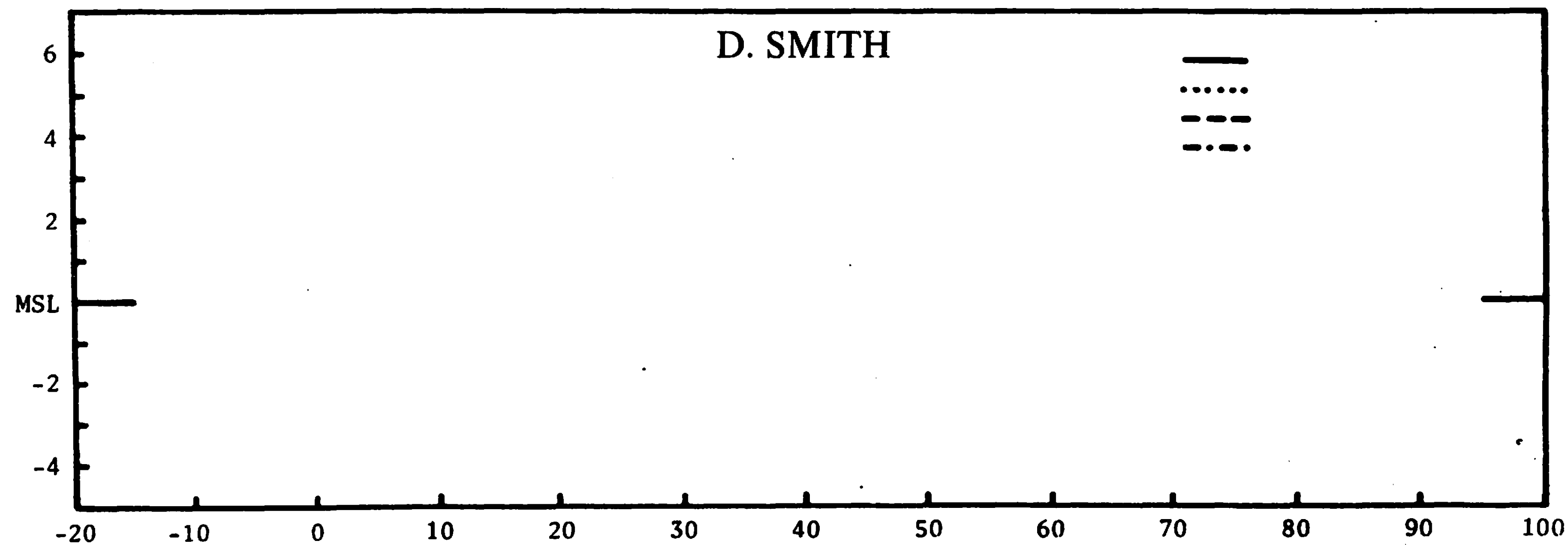

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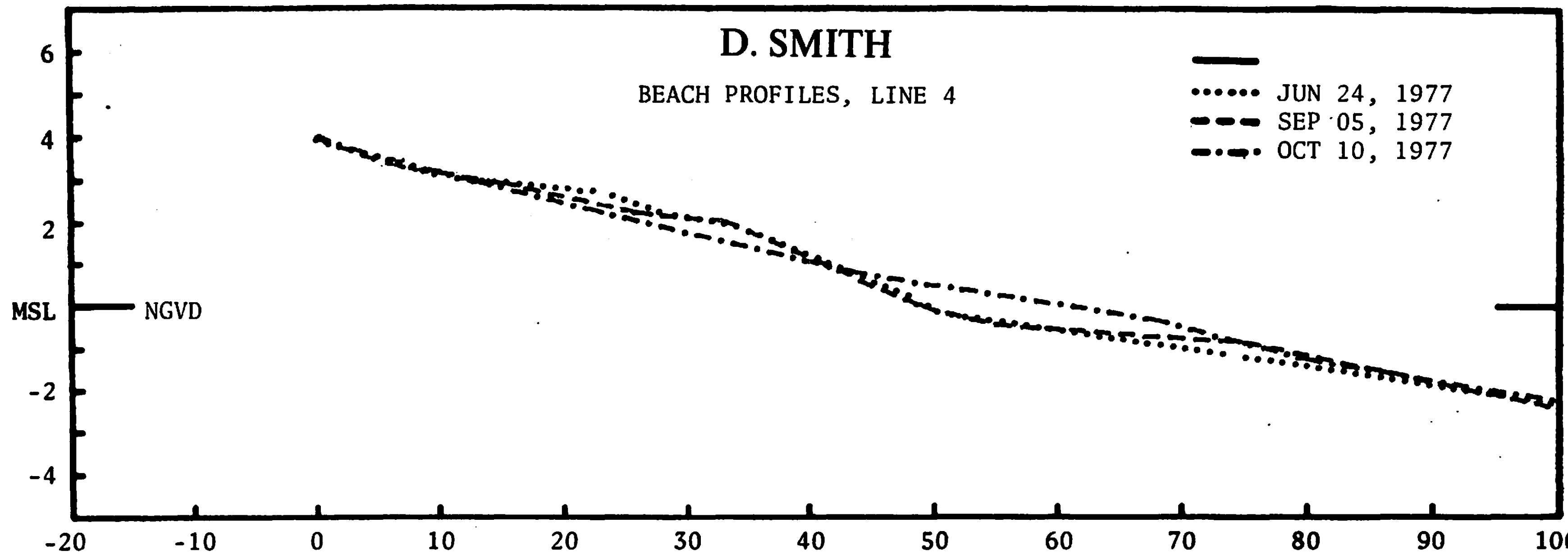

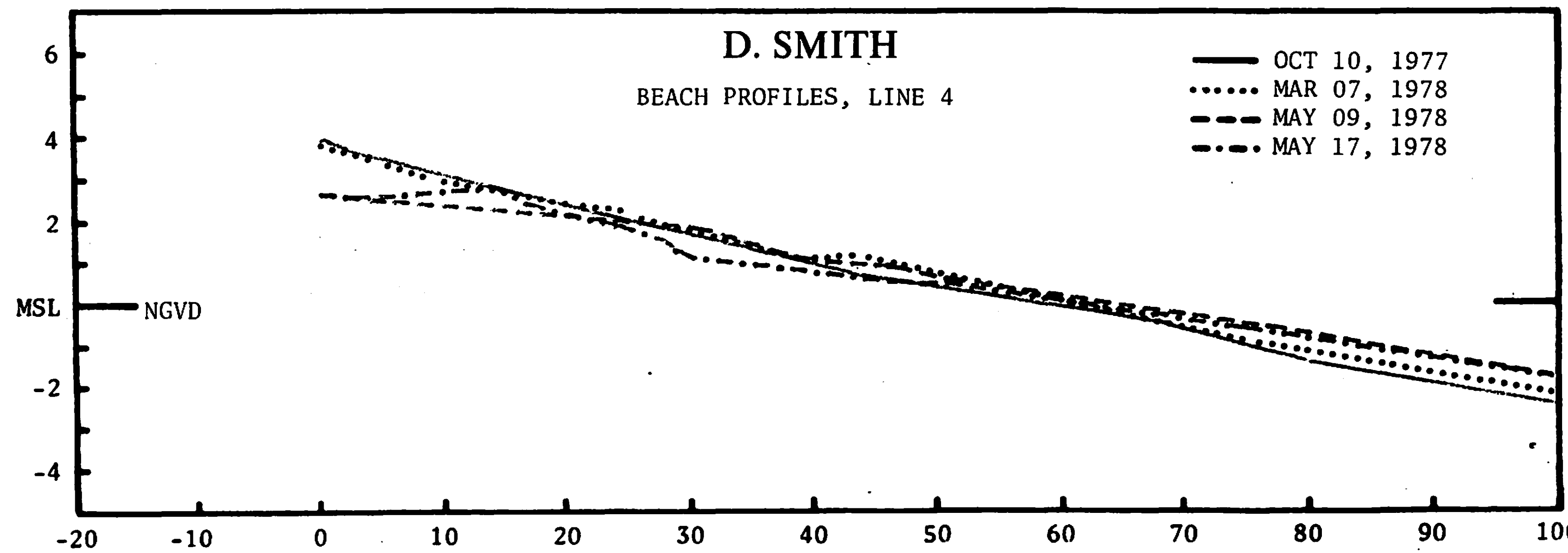

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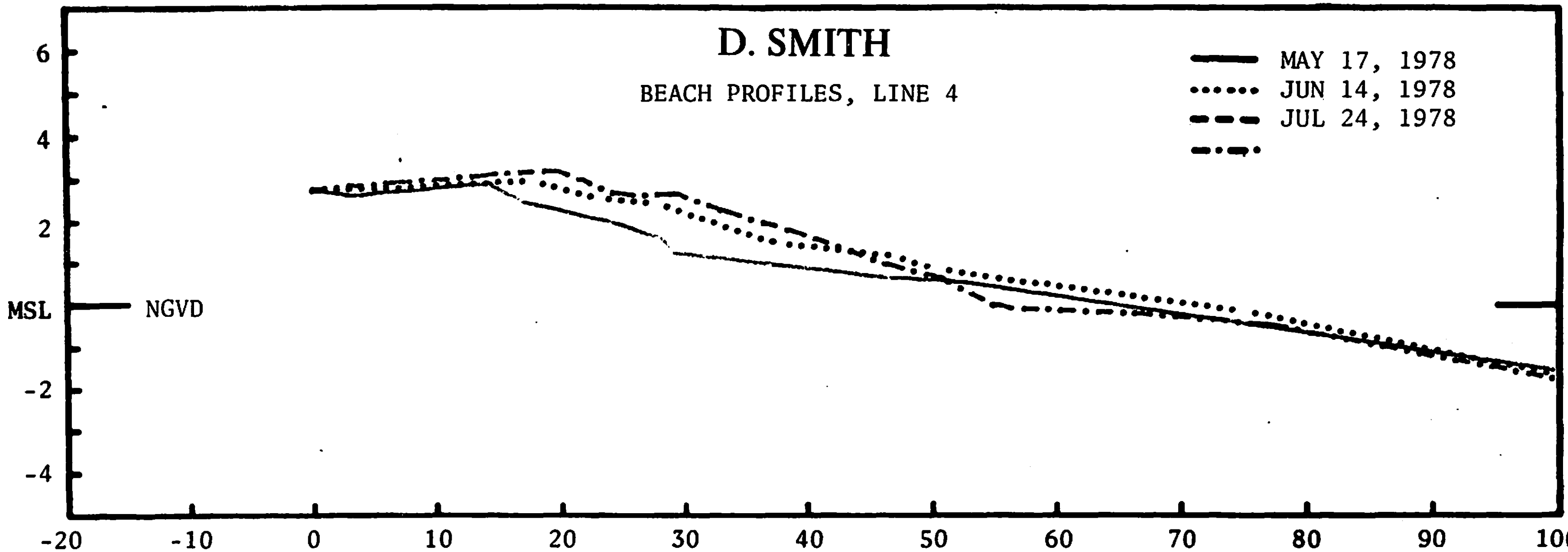
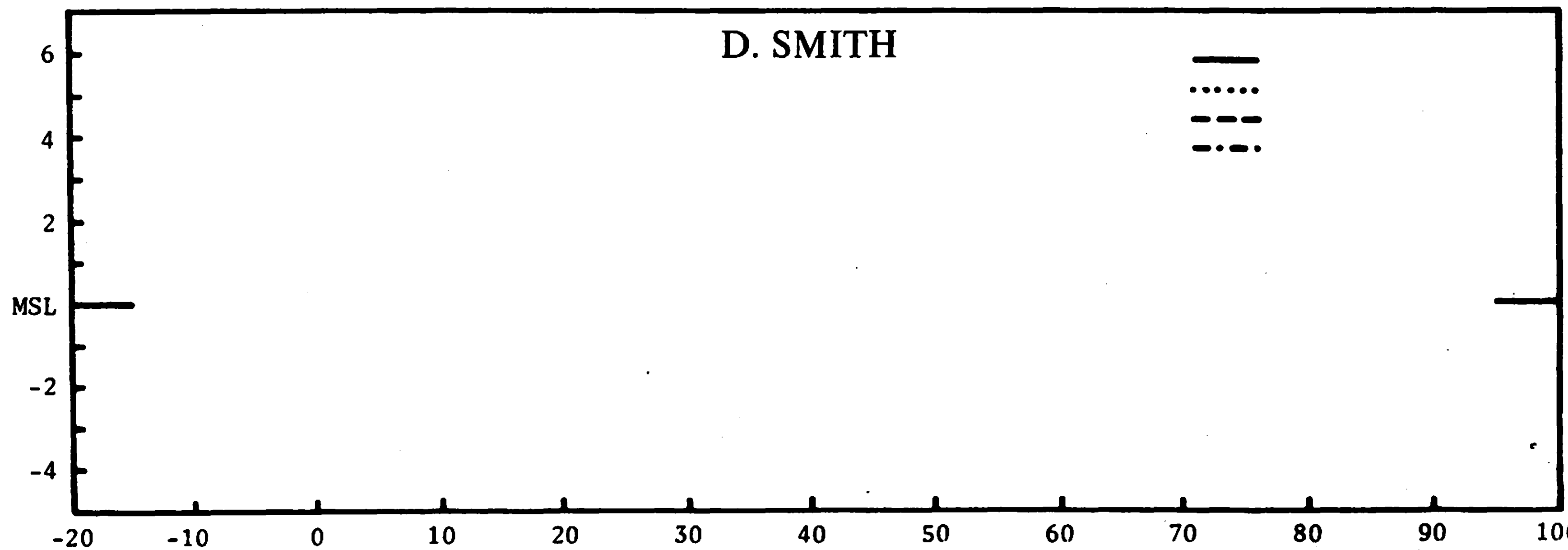
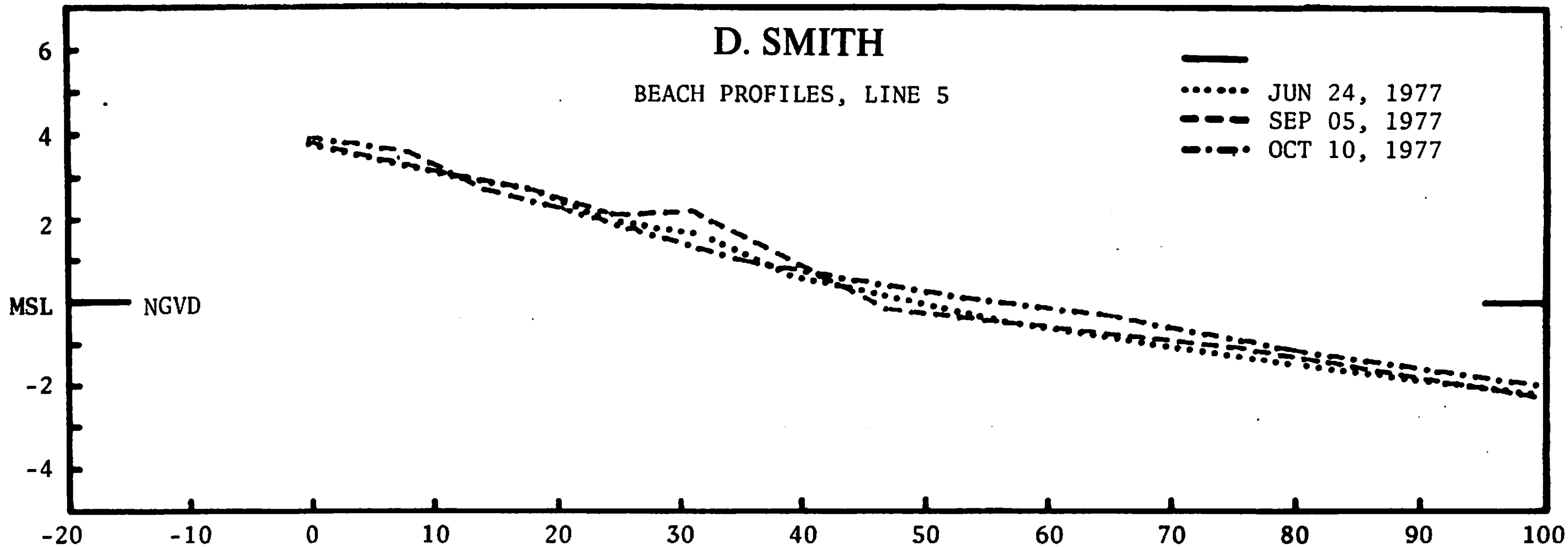




Distances measured in FEET


D. SMITH
BEACH PROFILES, LINE 5
JUN 24, 1977
SEP 05, 1977
OCT 10, 1977
MSL
NGVD
6
4
2
-2
-4
-20
-10
0
10
20
30
40
50
60
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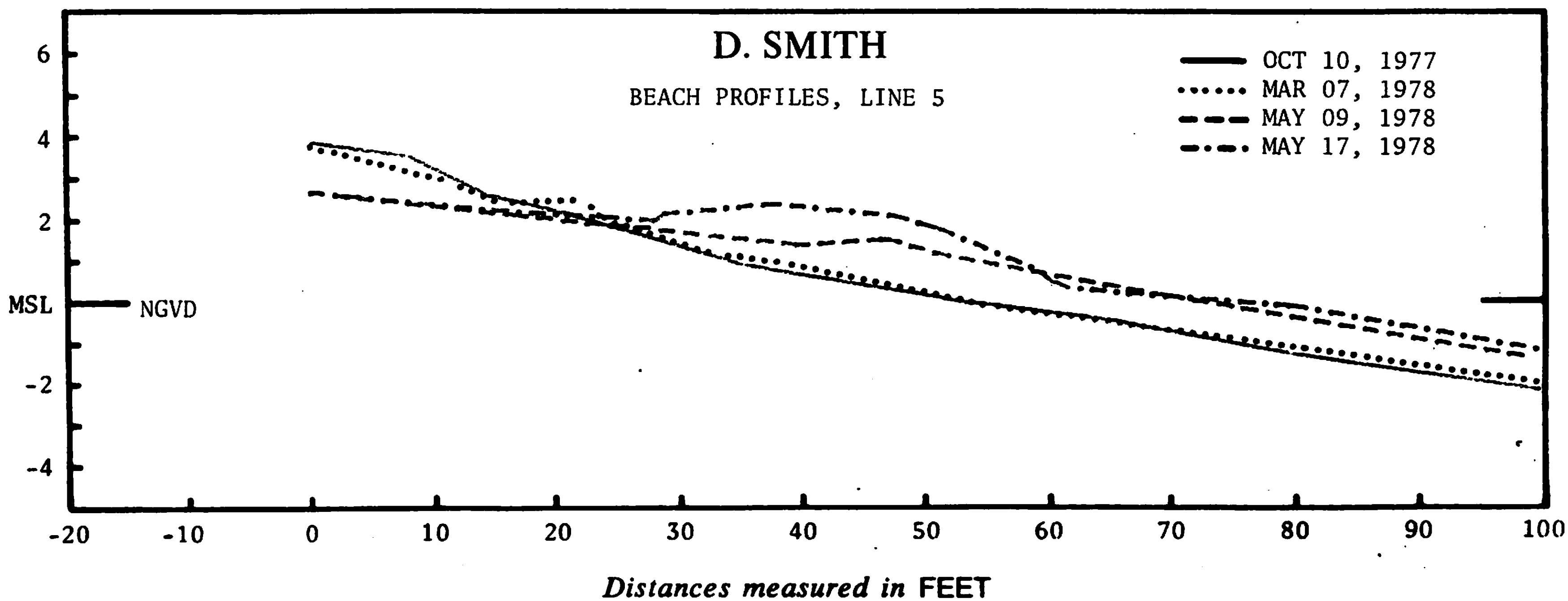
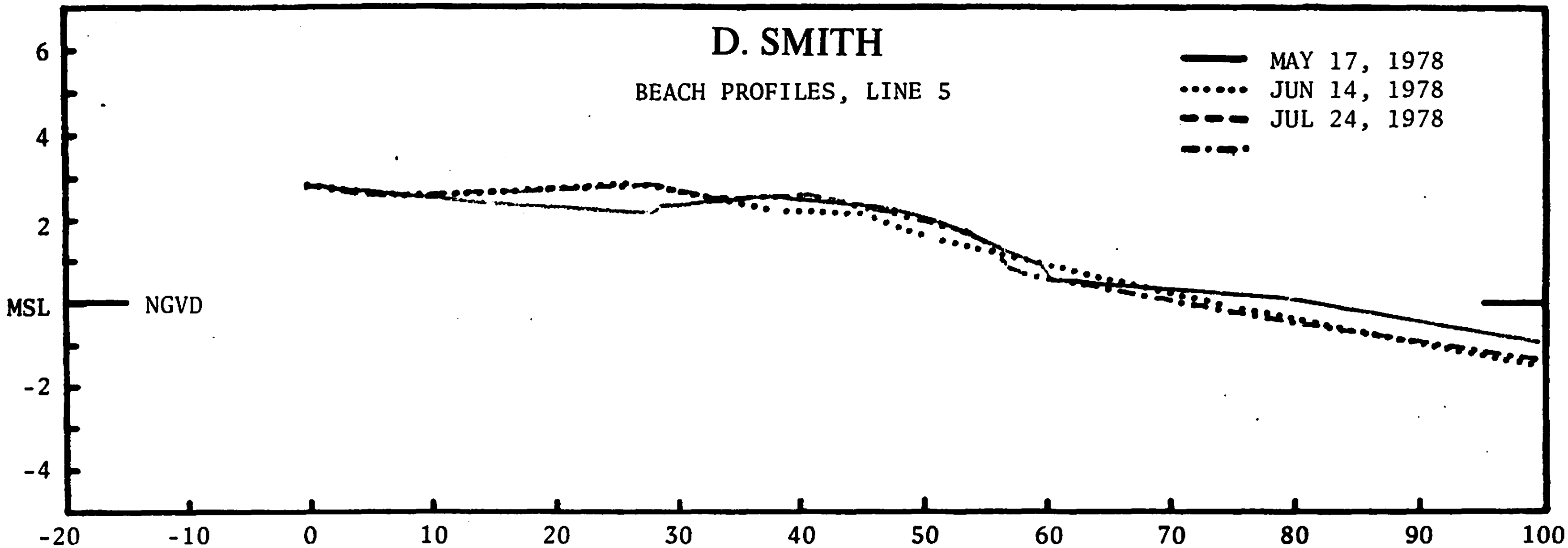
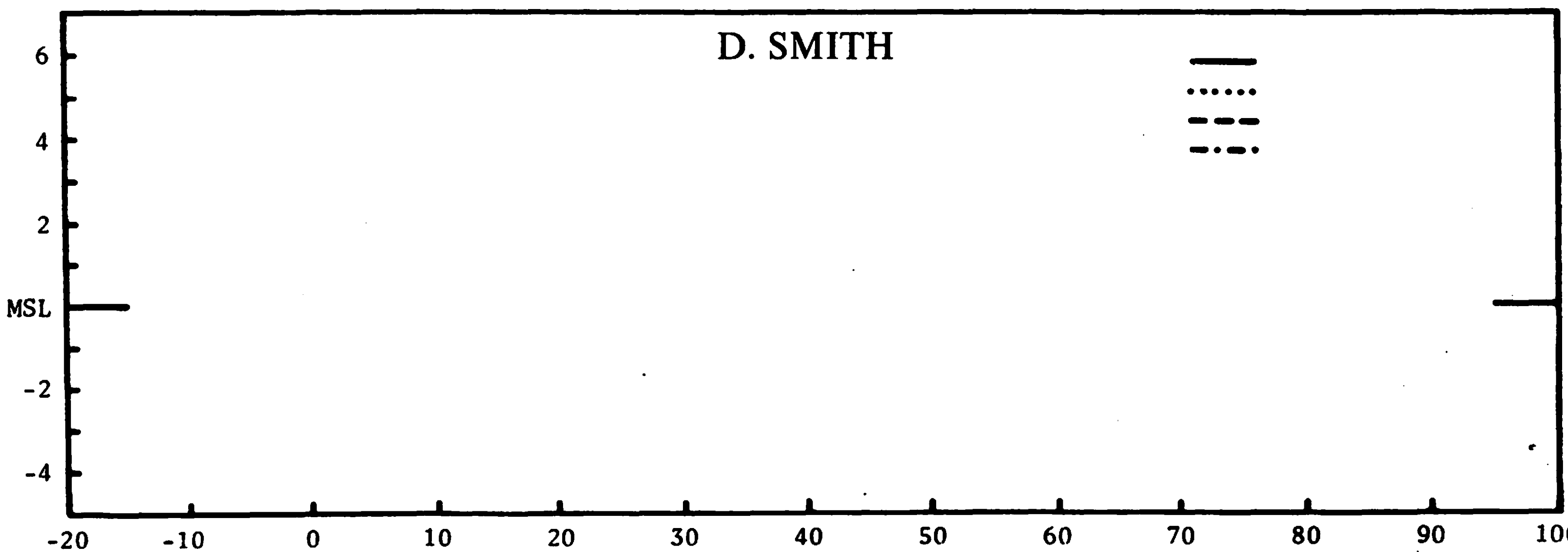
100


D. SMITH
BEACH PROFILES, LINE 5
OCT 10, 1977
MAR 07, 1978
MAY 09, 1978
MAY 17, 1978
MSL
NGVD
6
4
2
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET





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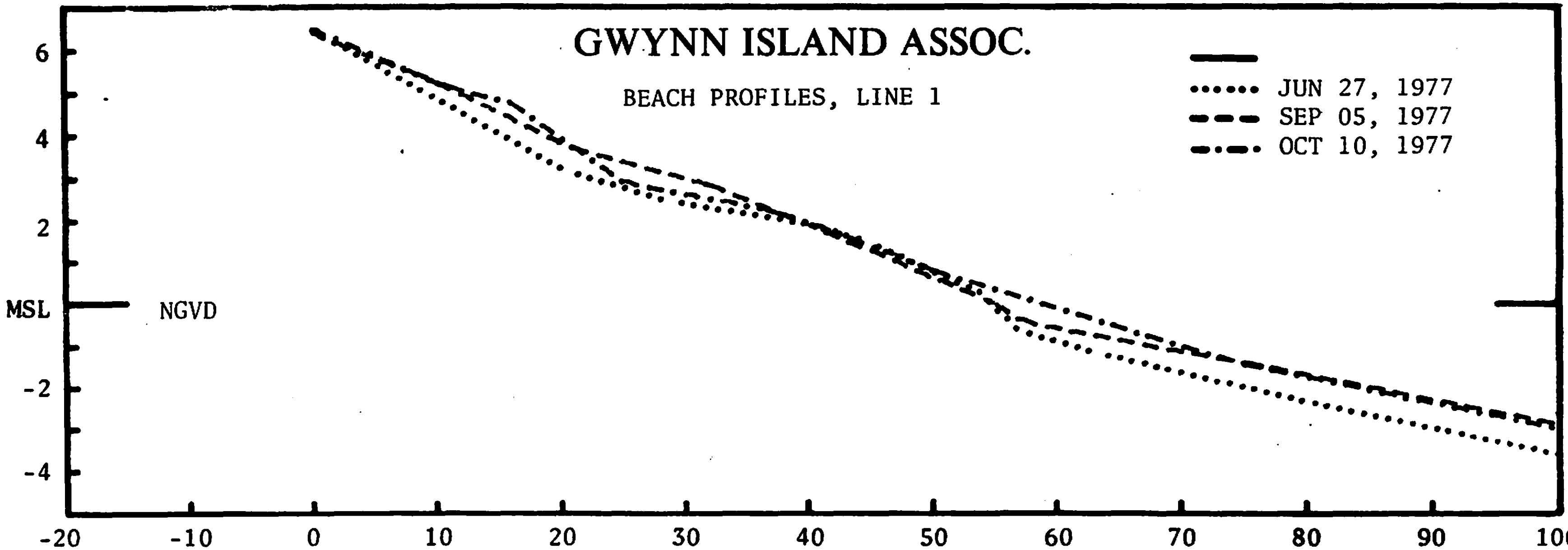
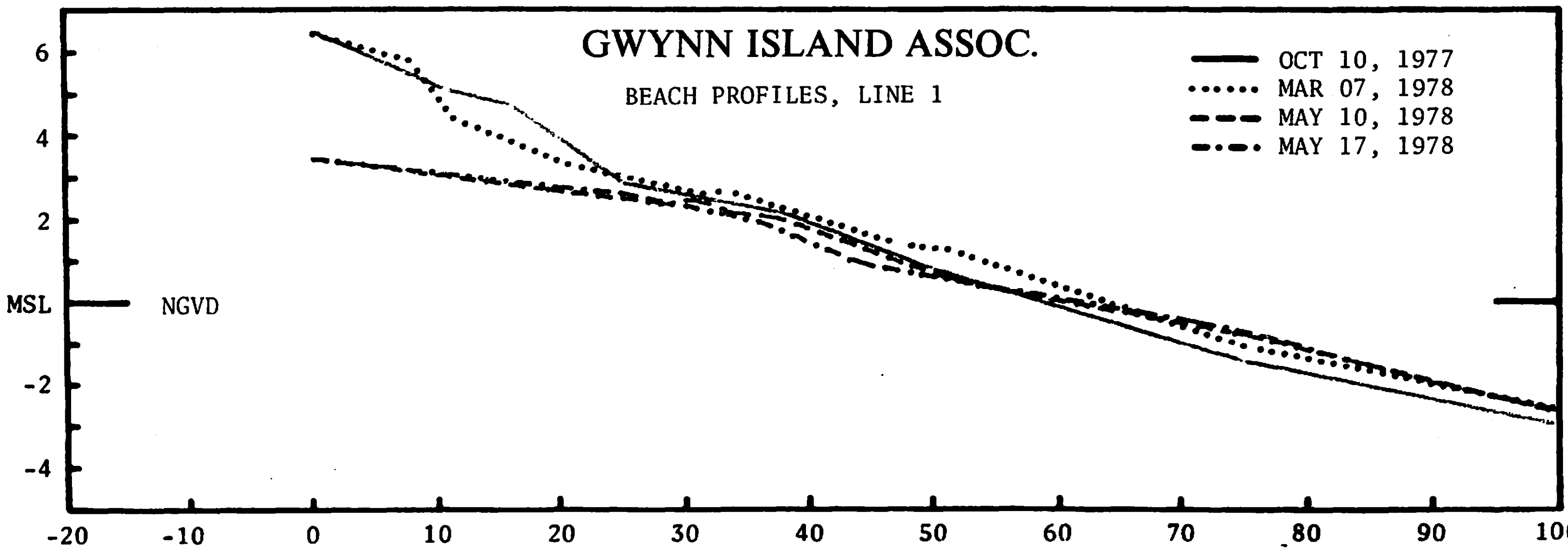
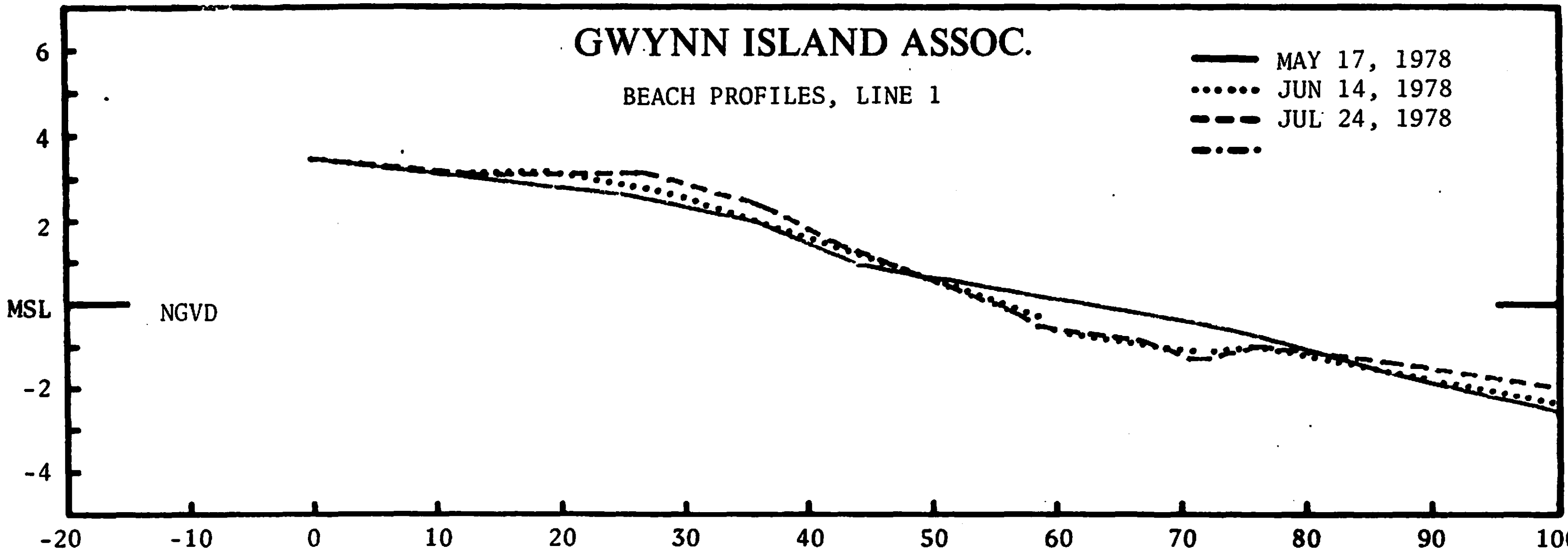
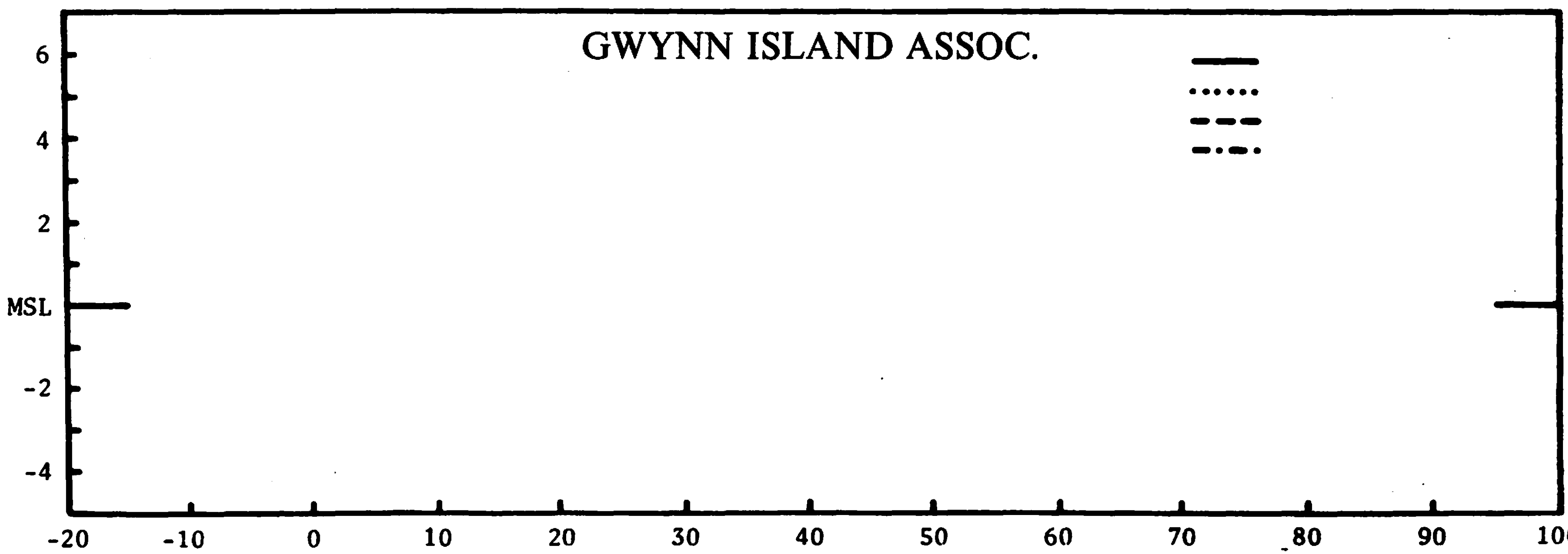




Distances measured in FEET





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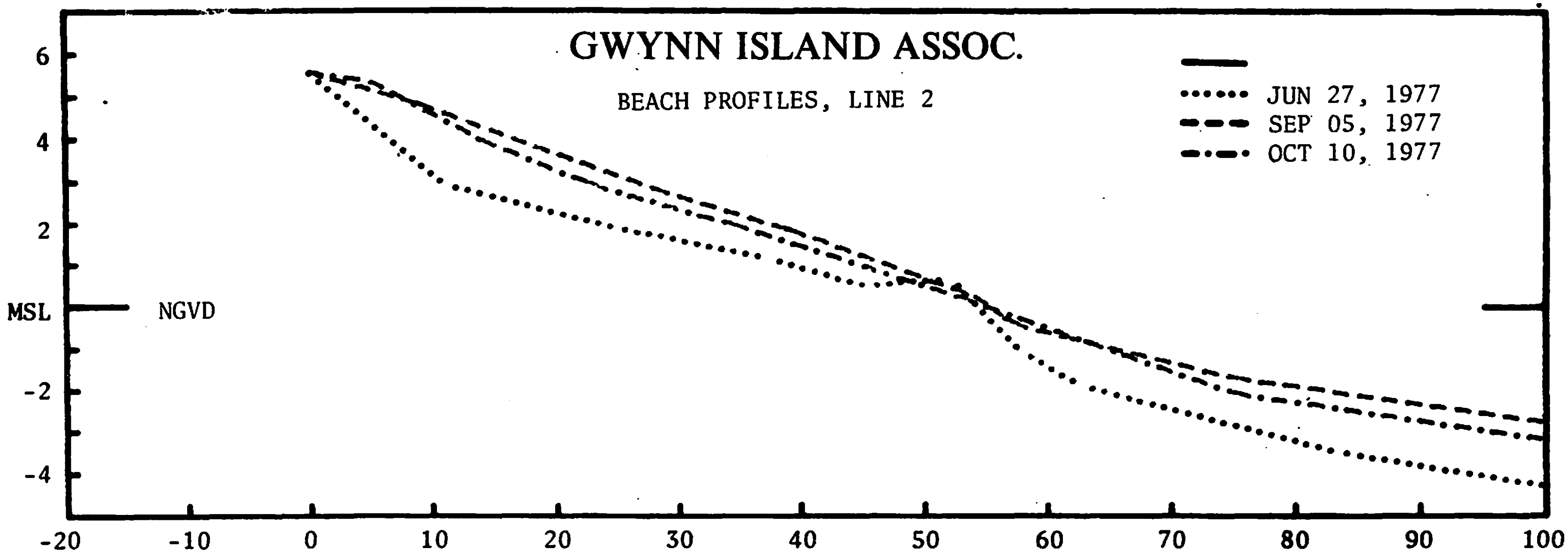

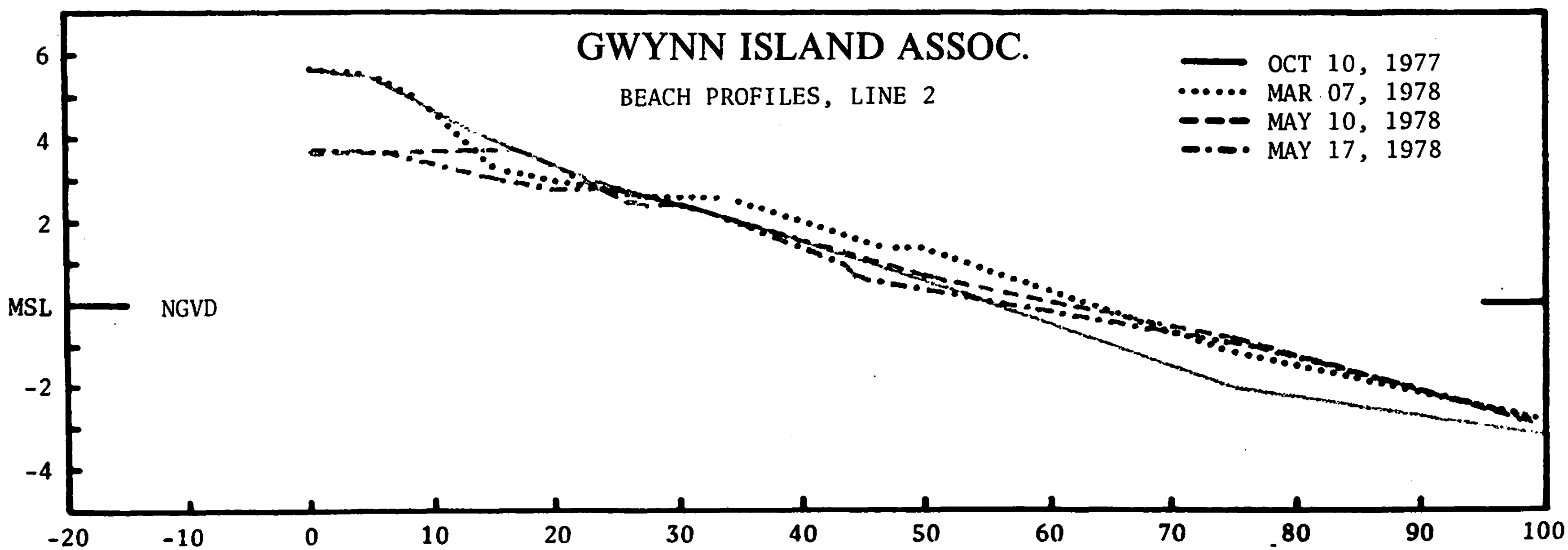

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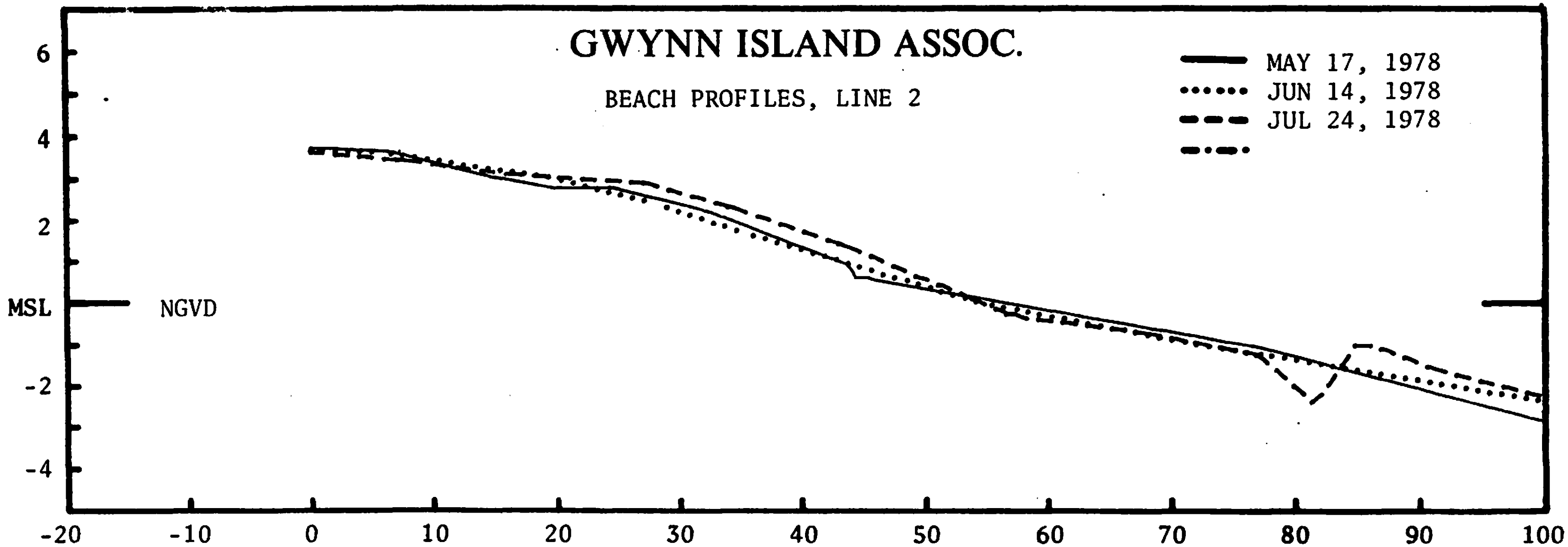

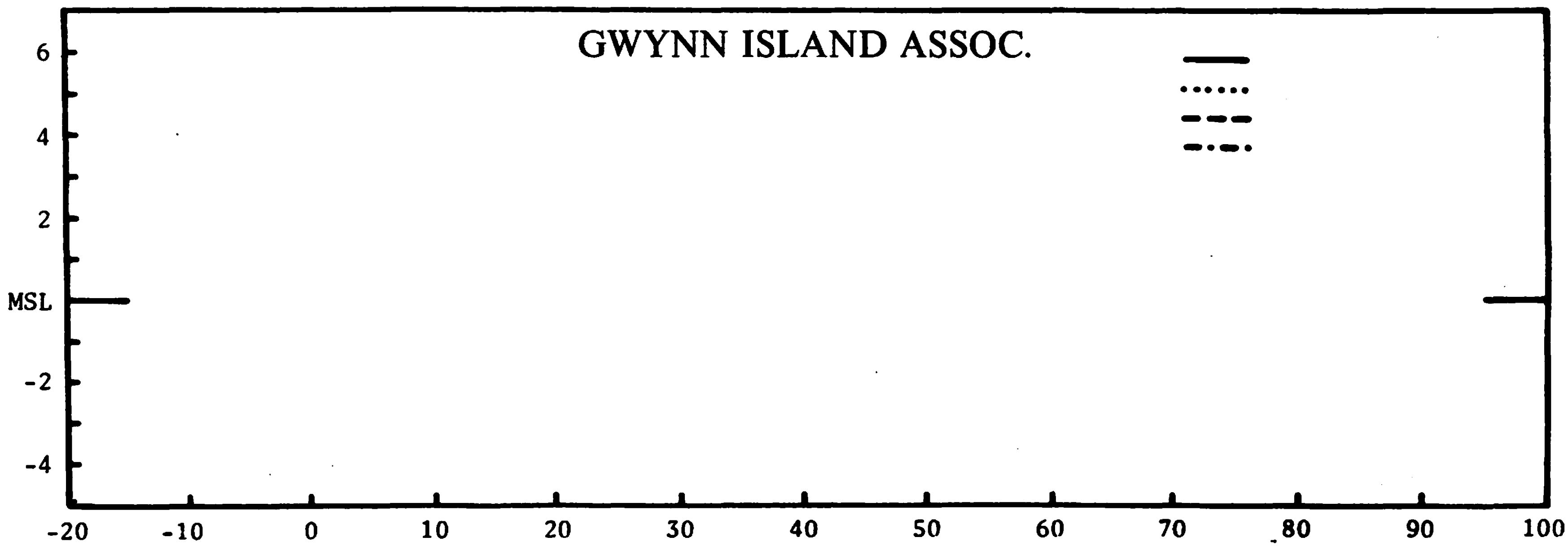

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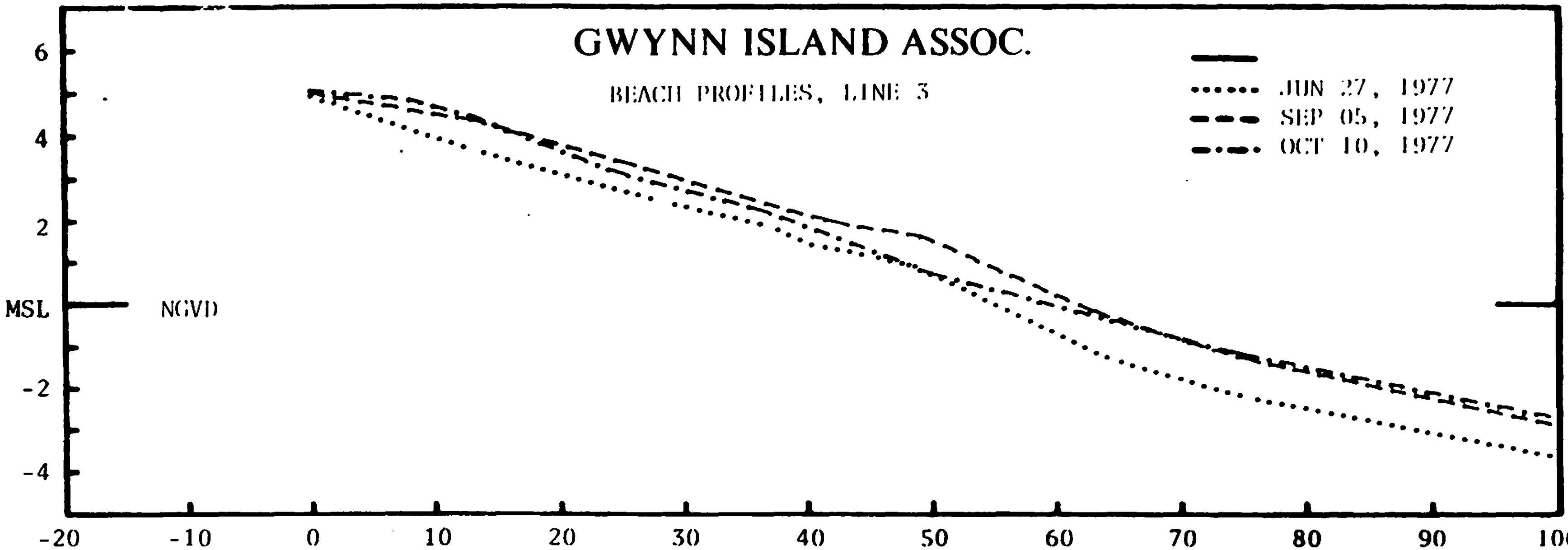

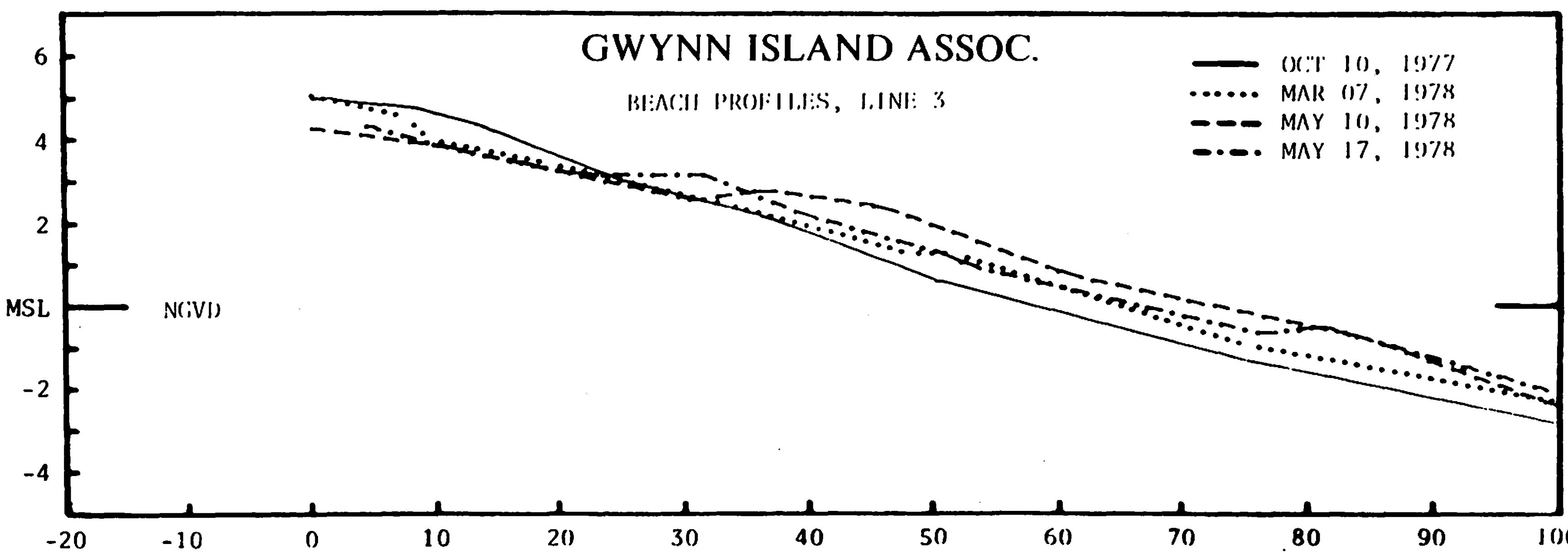

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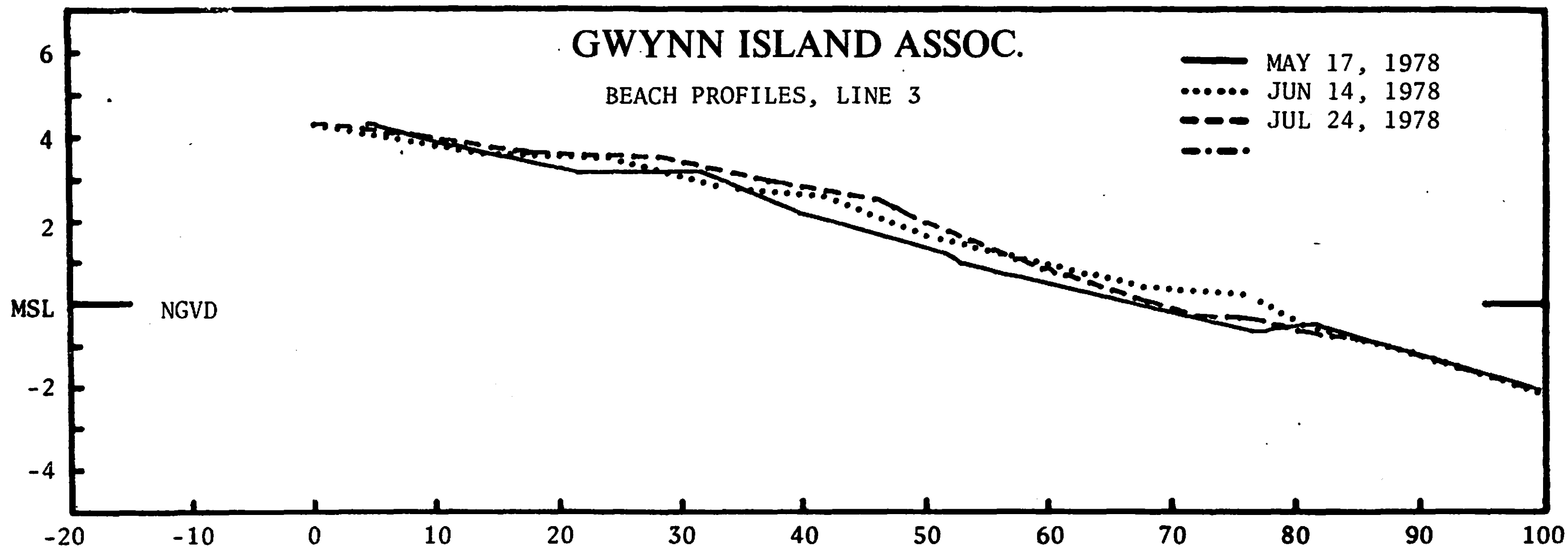

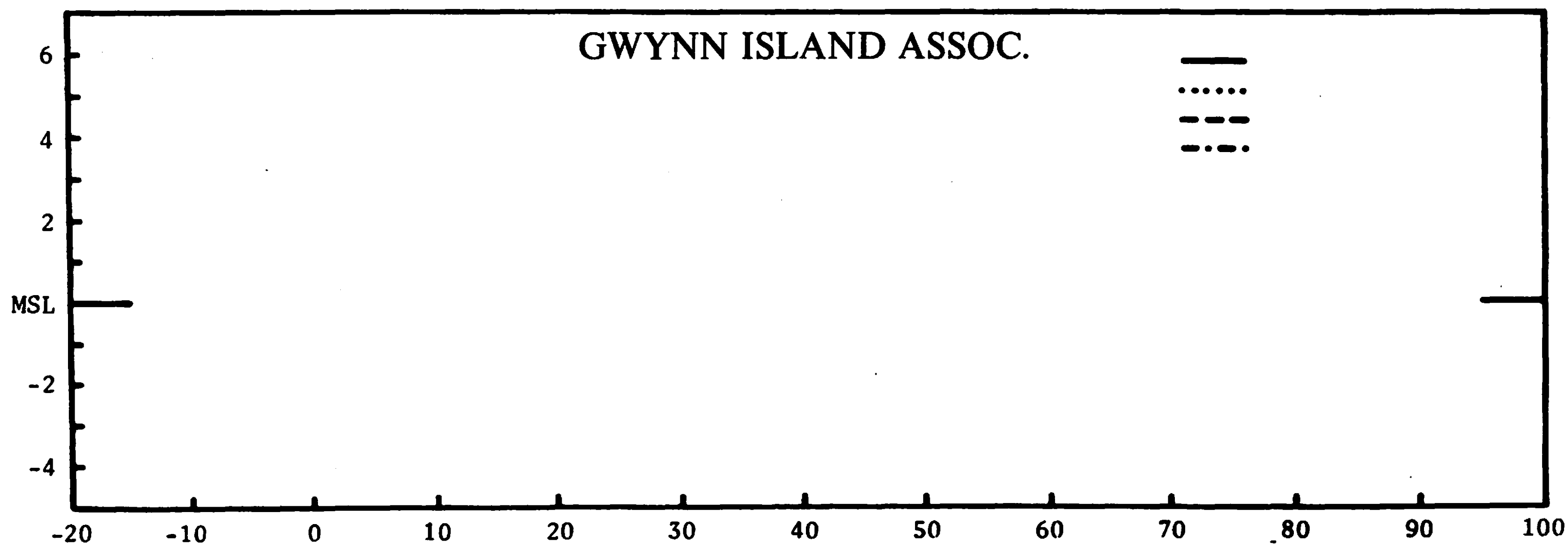

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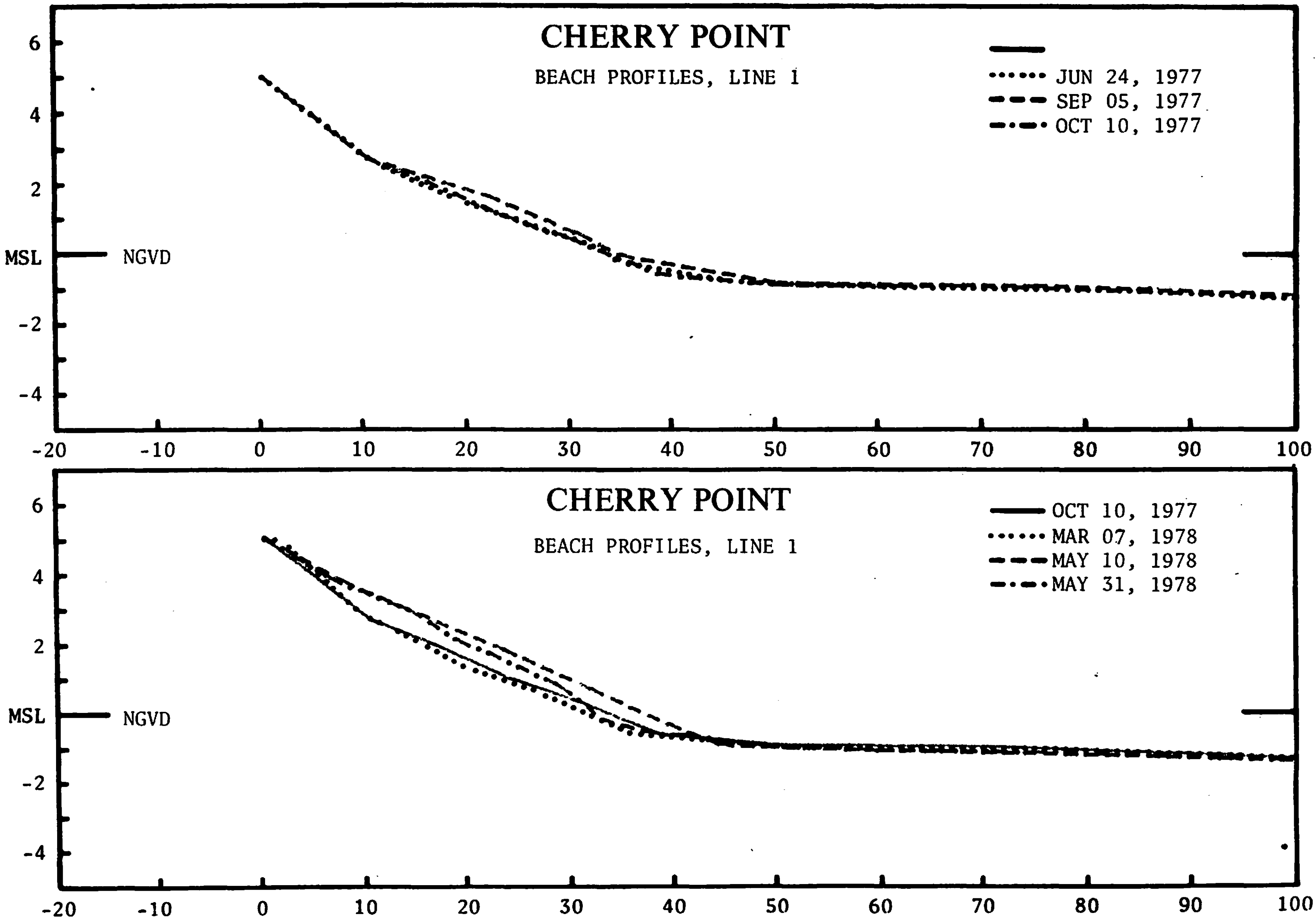
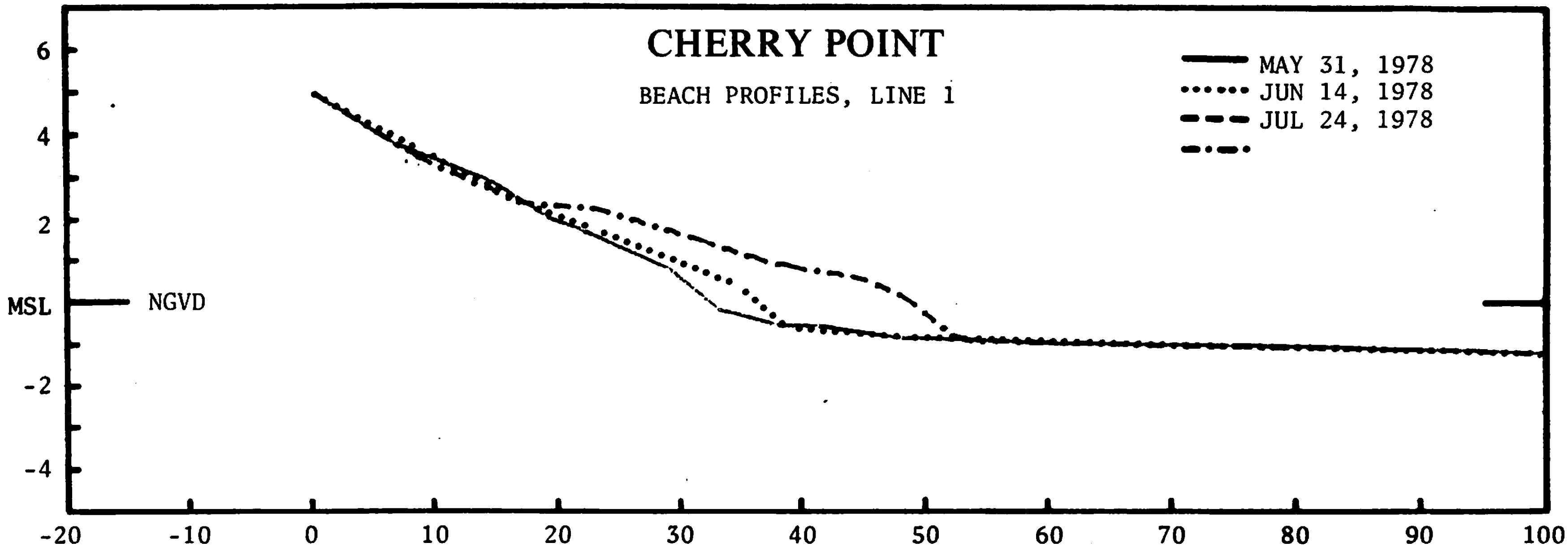
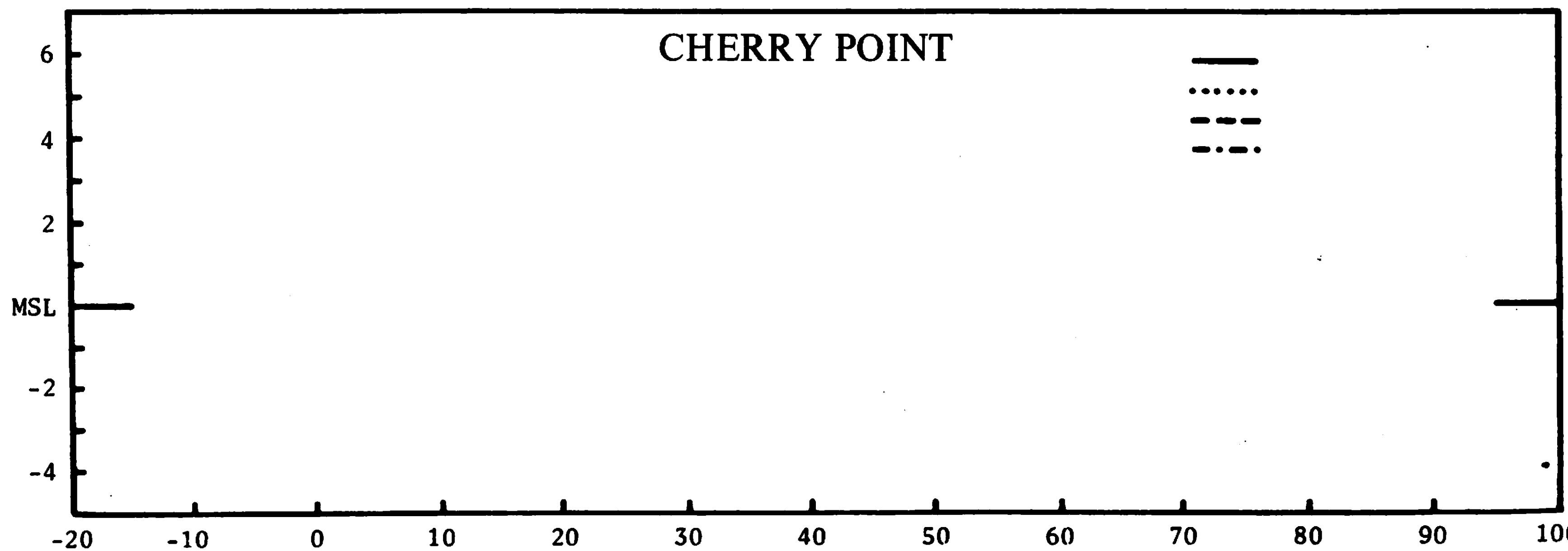
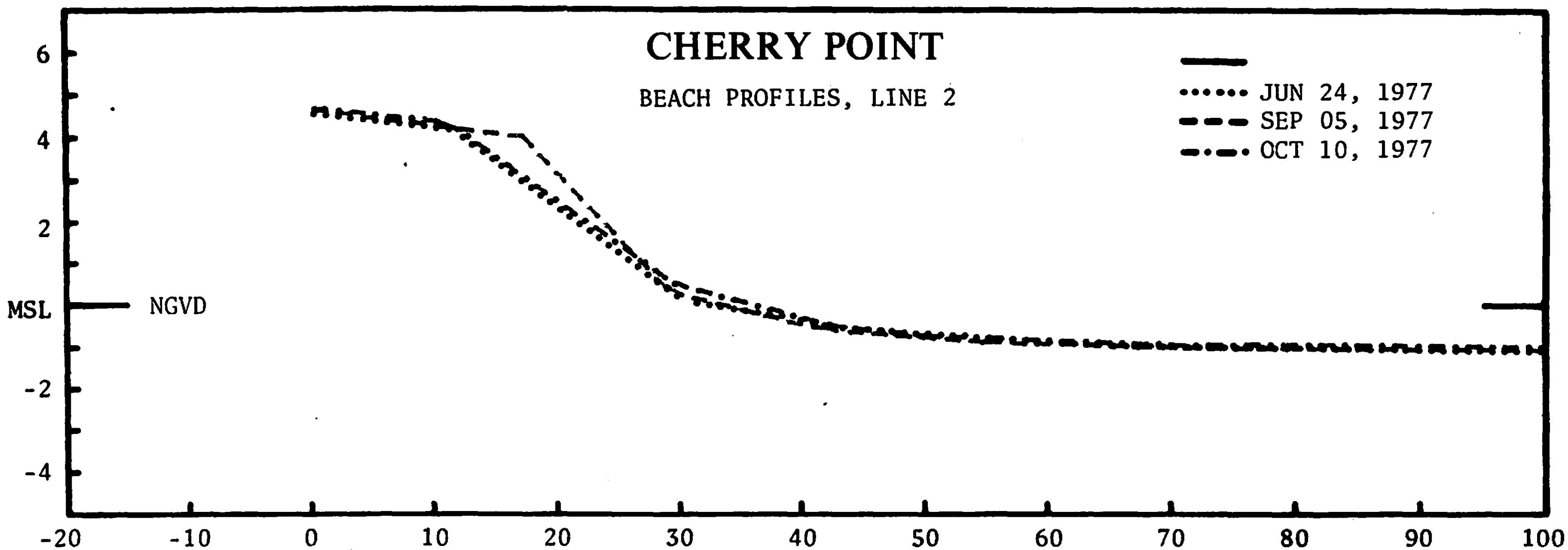


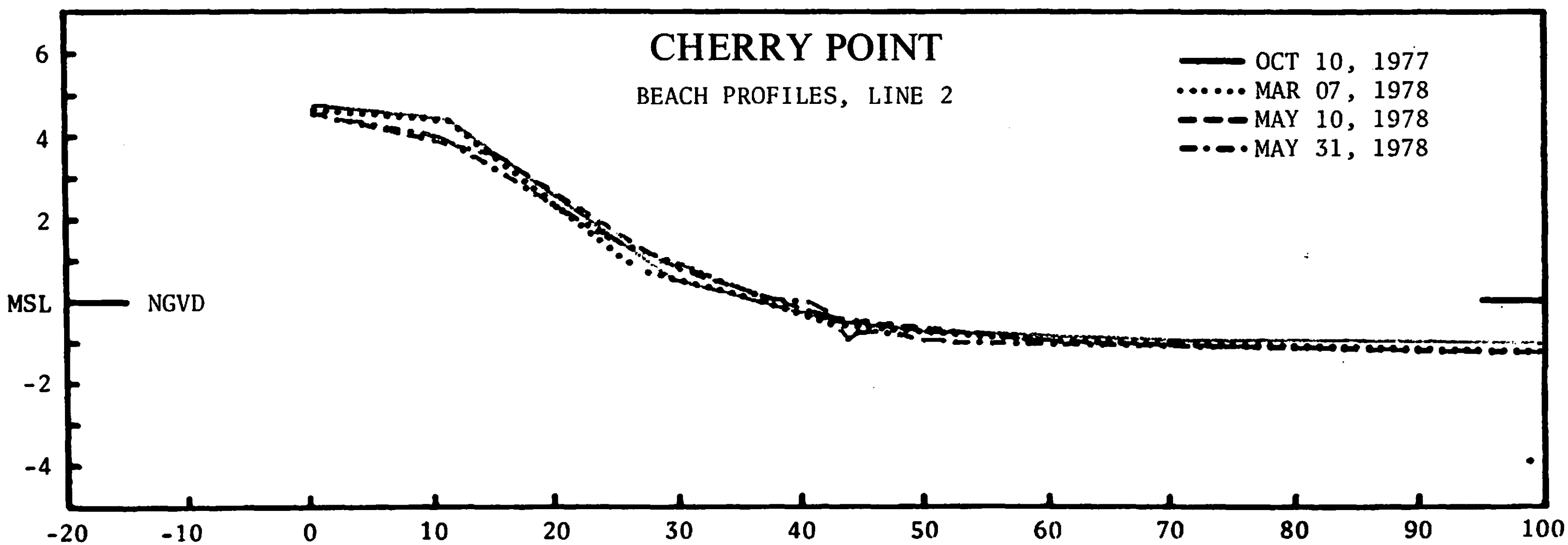
Distances measured in FEET



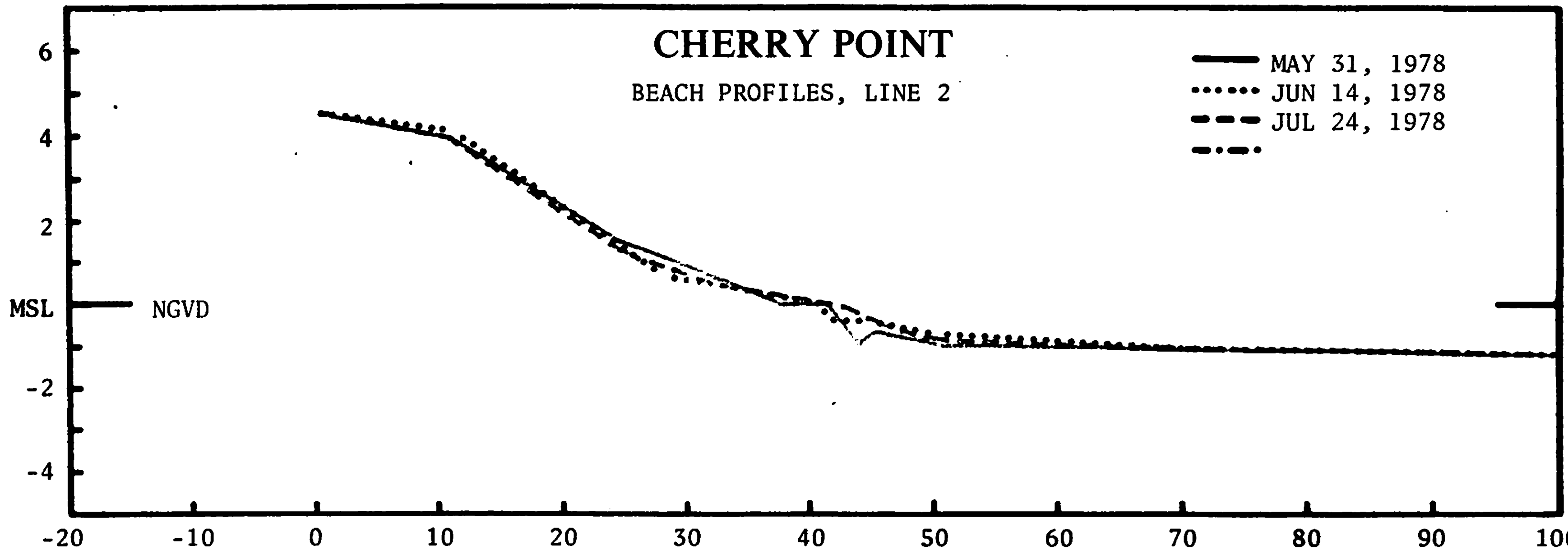


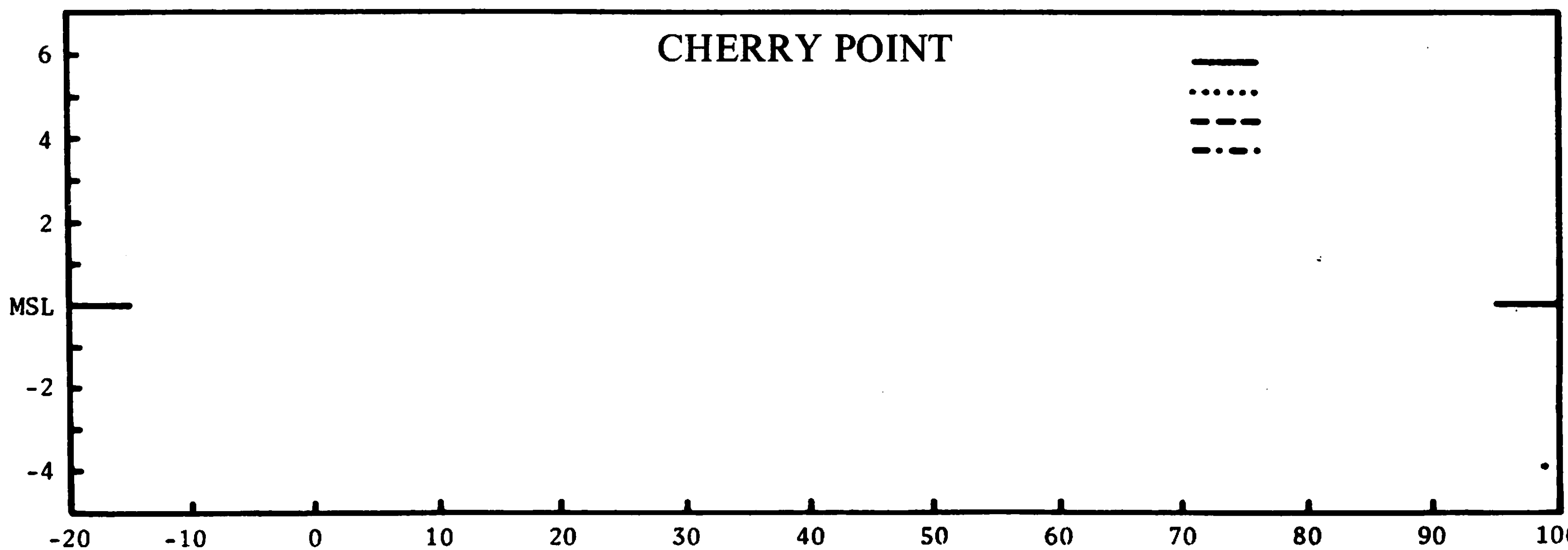
Distances measured in FEET



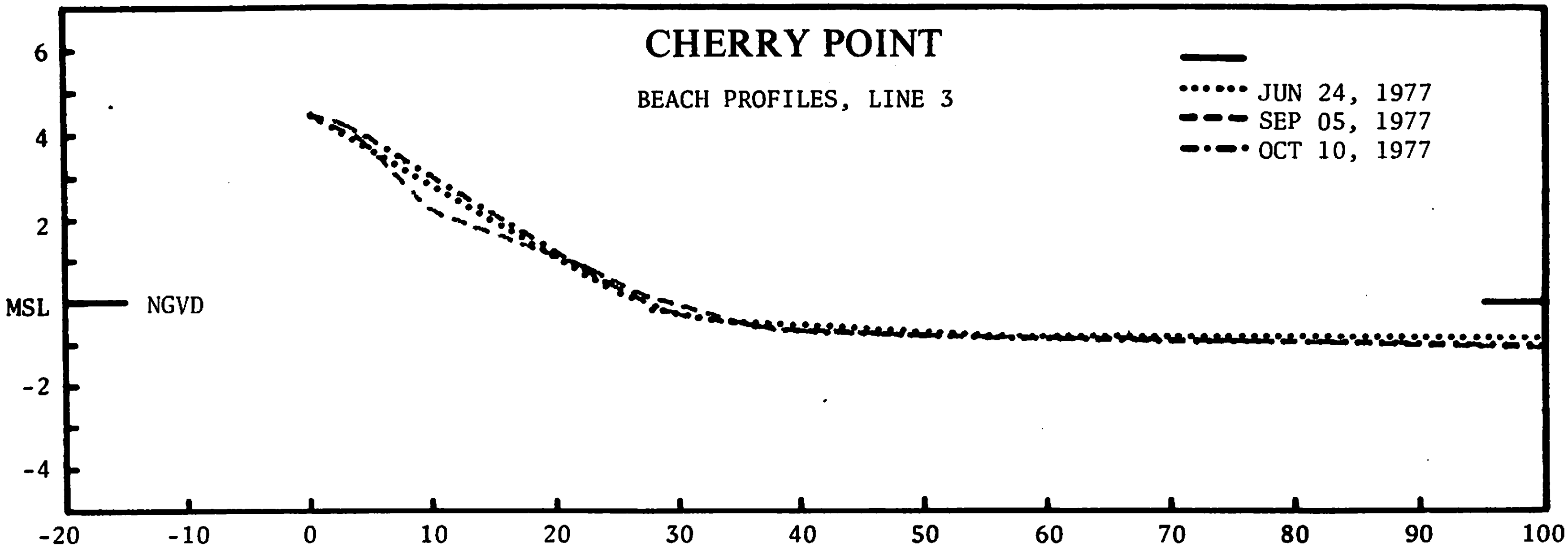


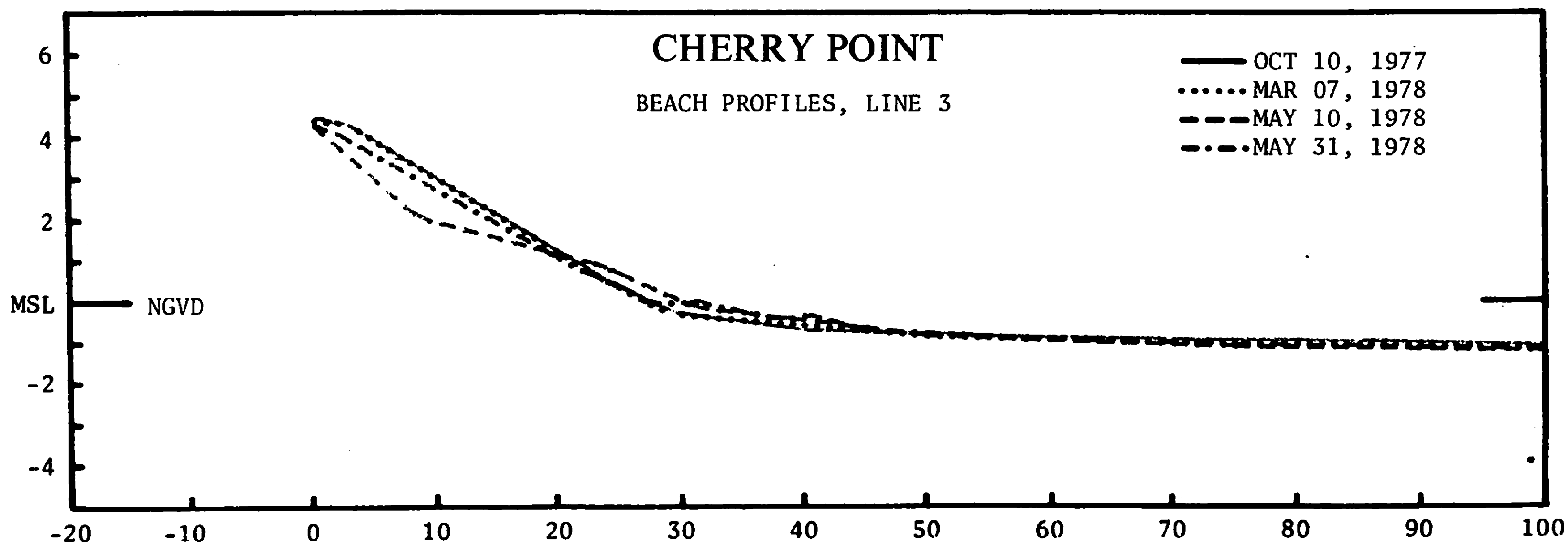
Distances measured in FEET



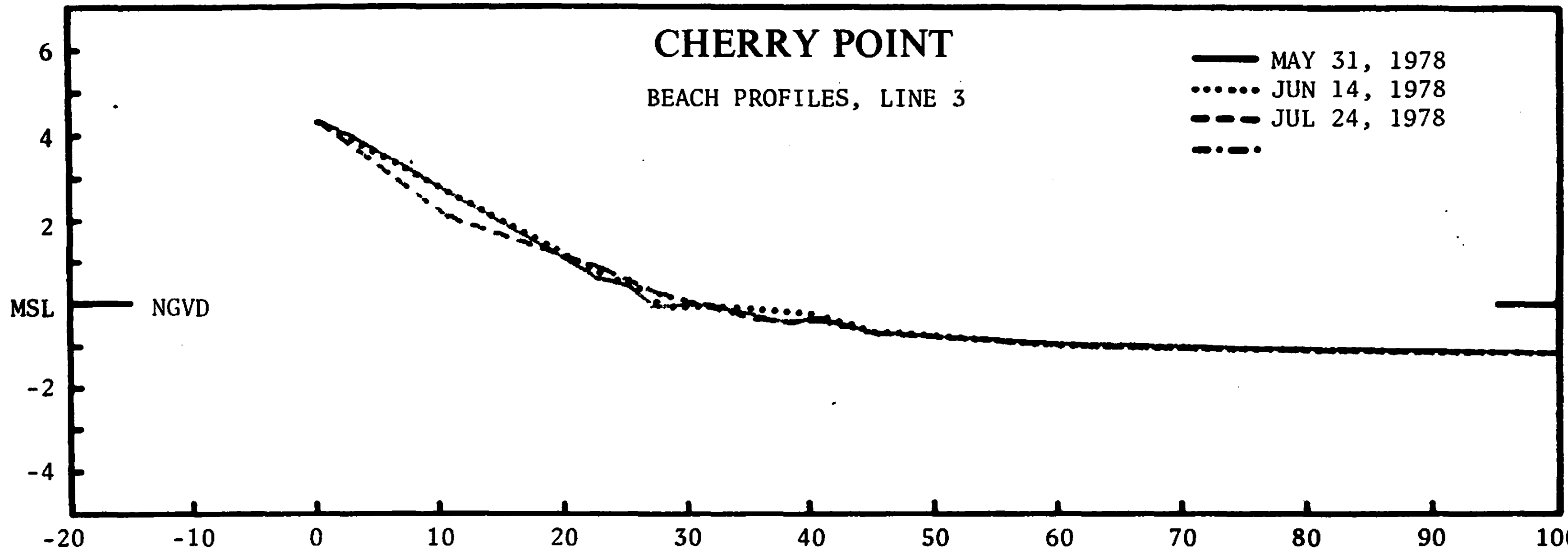


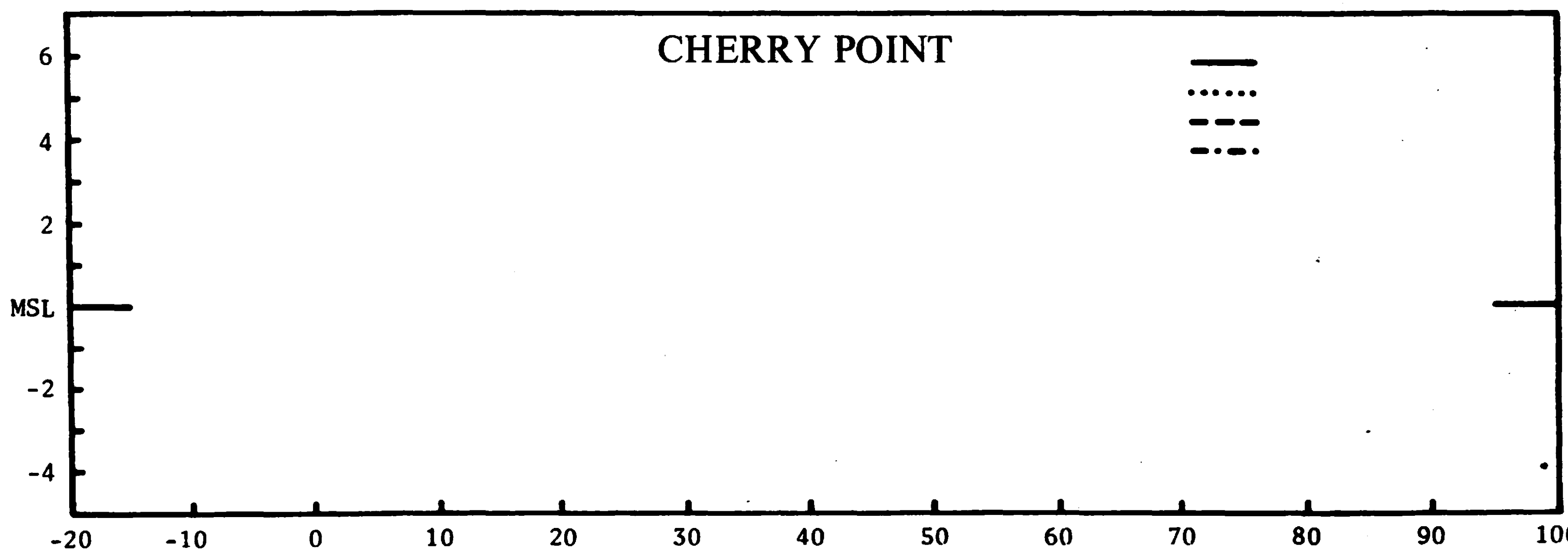
Distances measured in FEET





Distances measured in FEET





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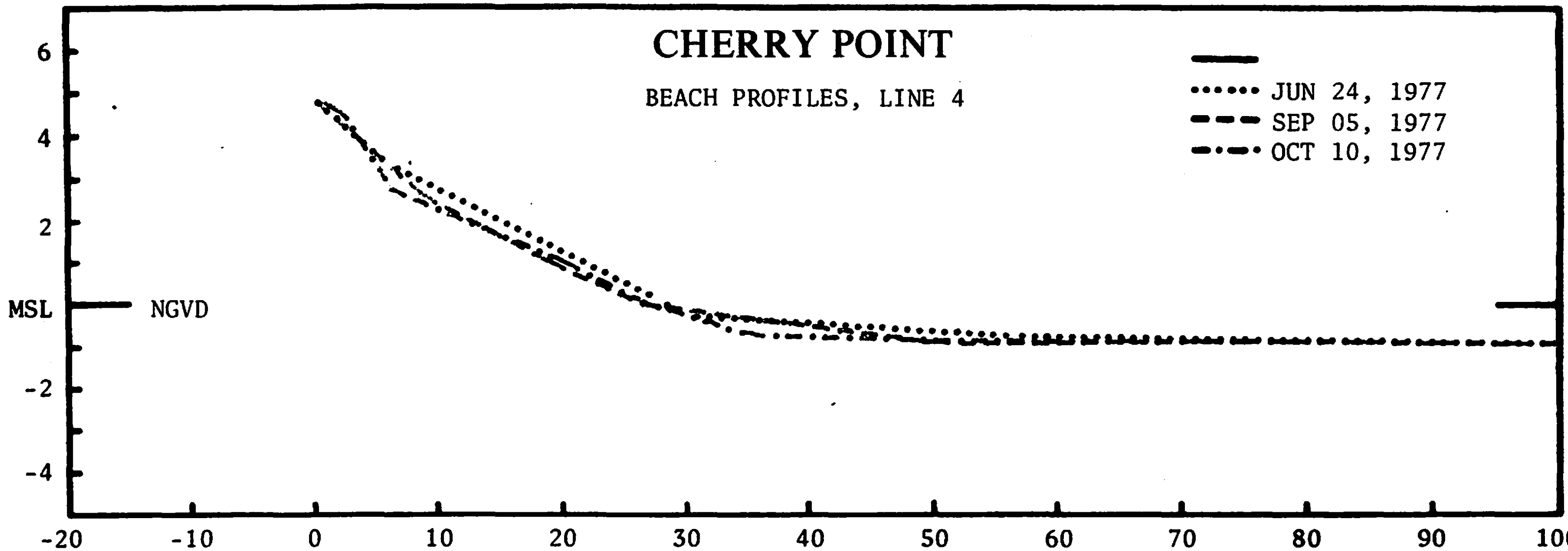

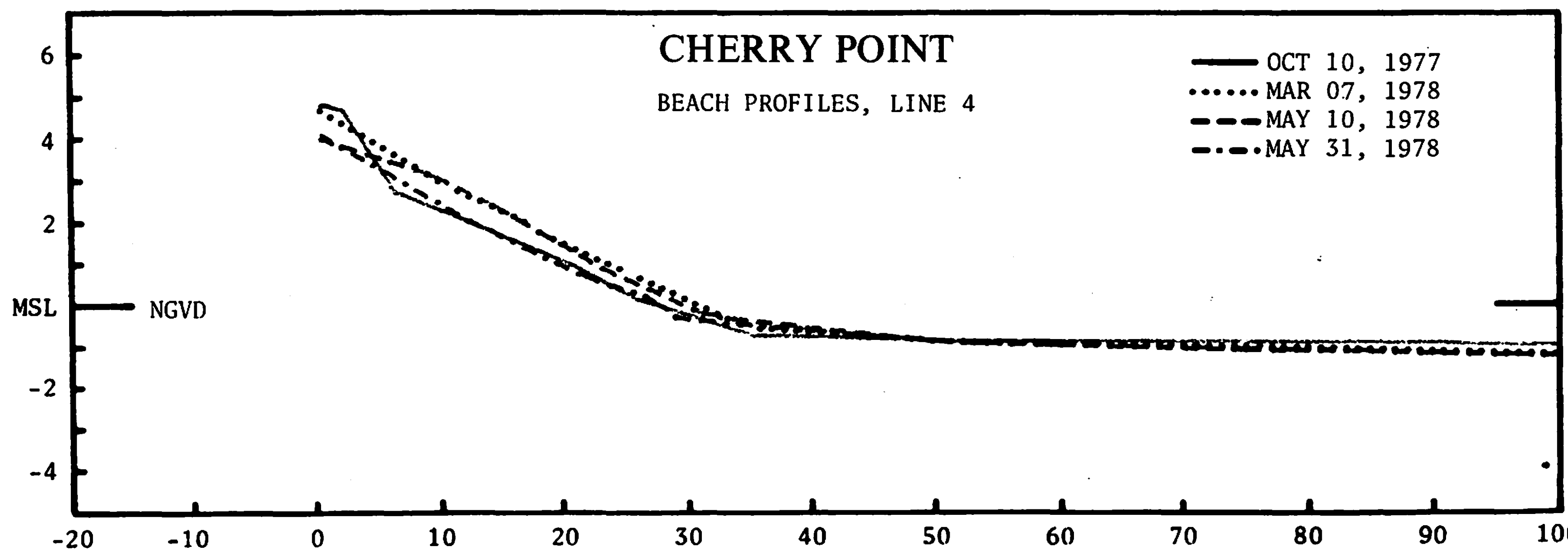

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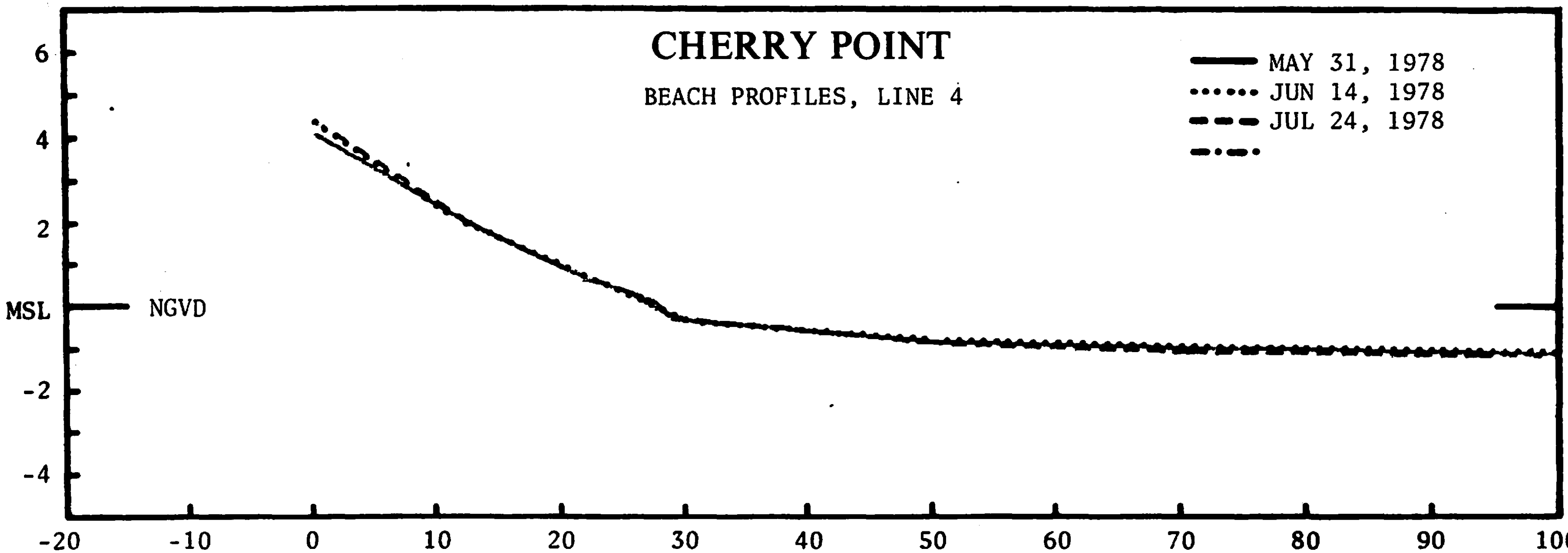

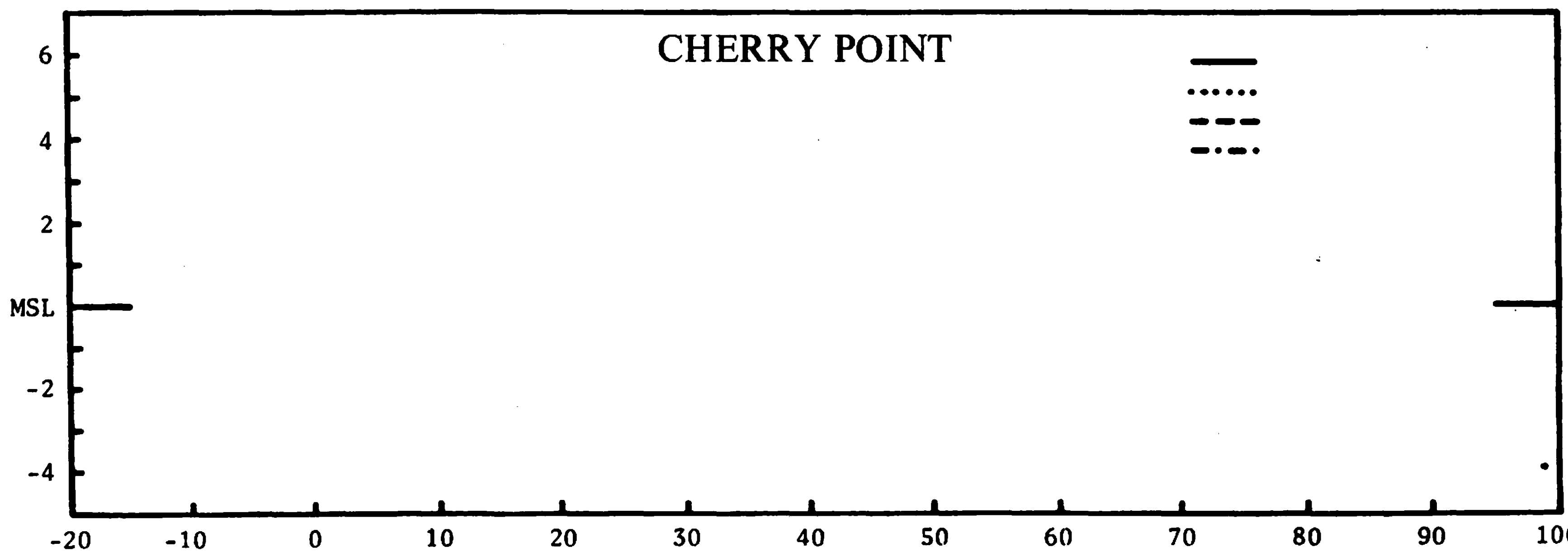

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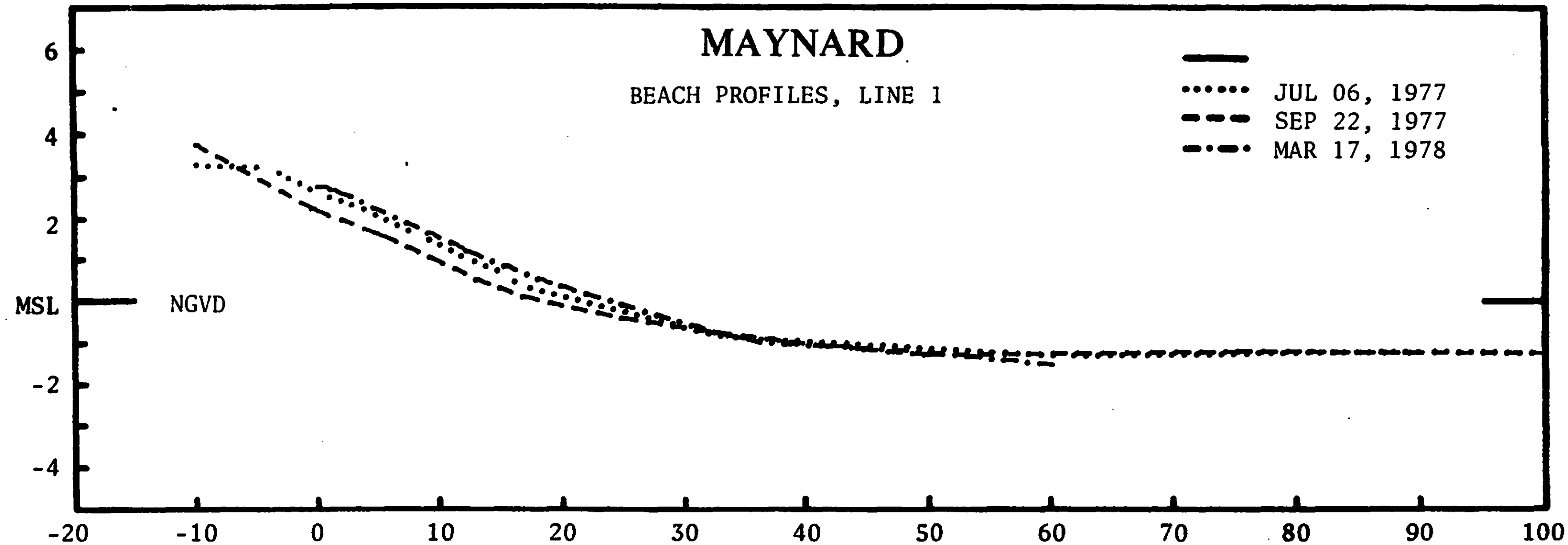
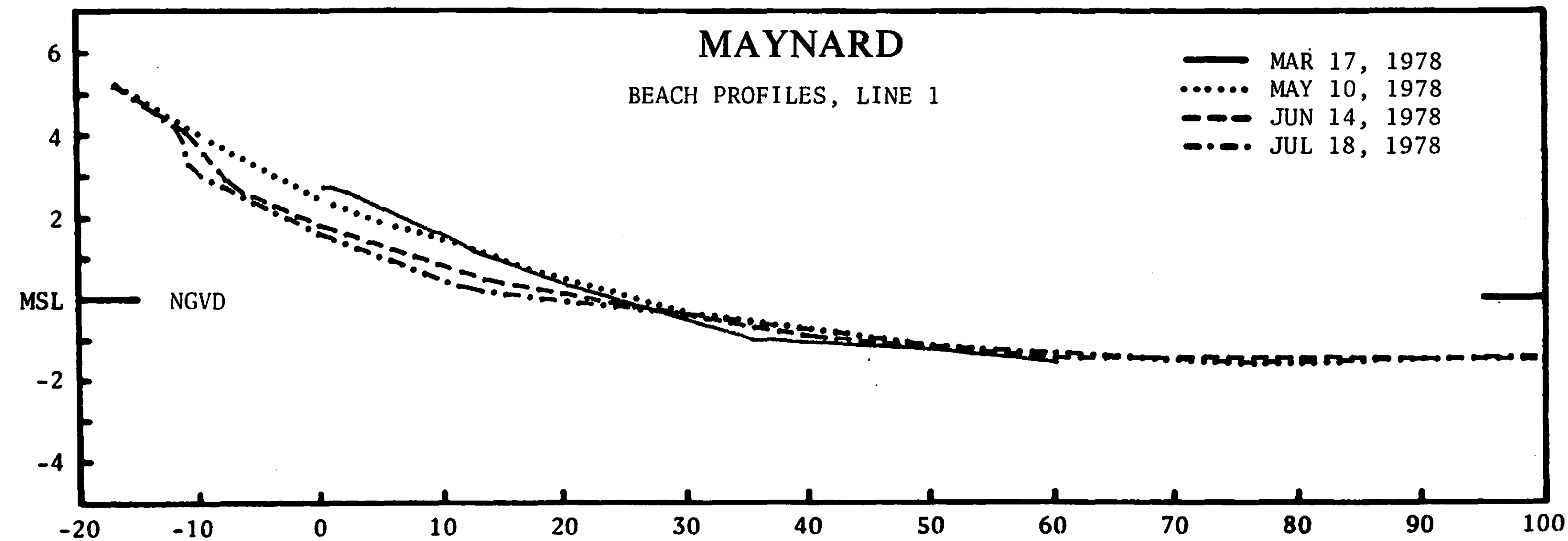
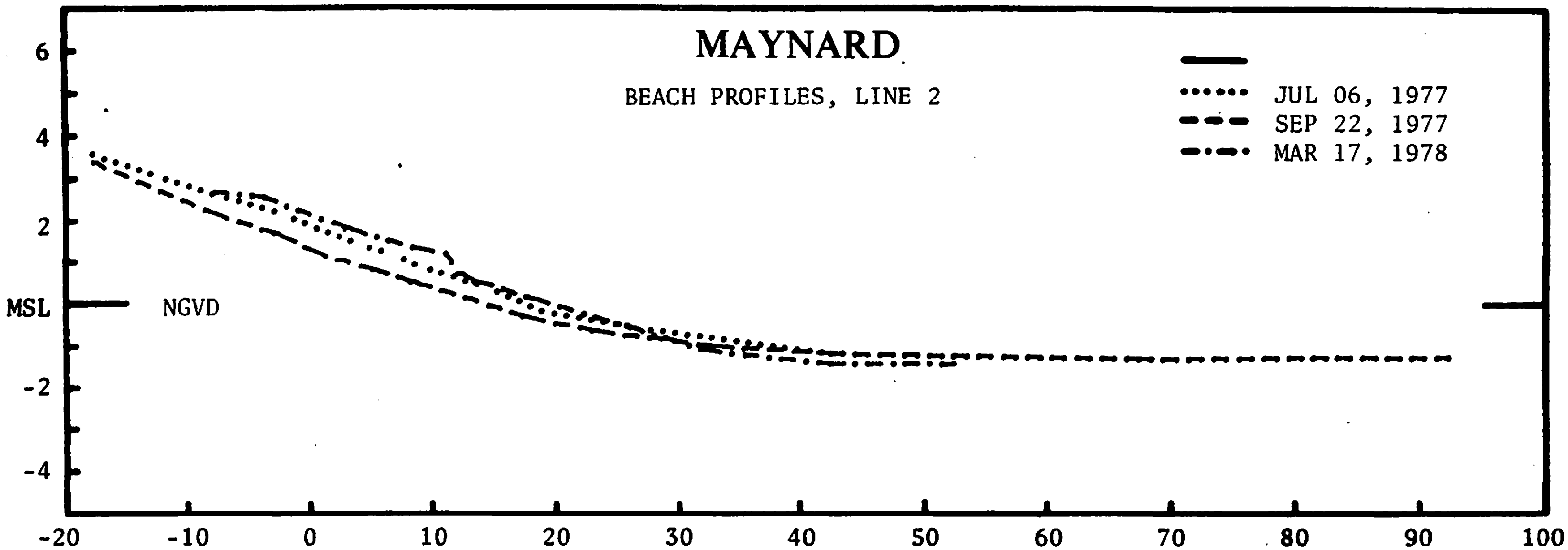
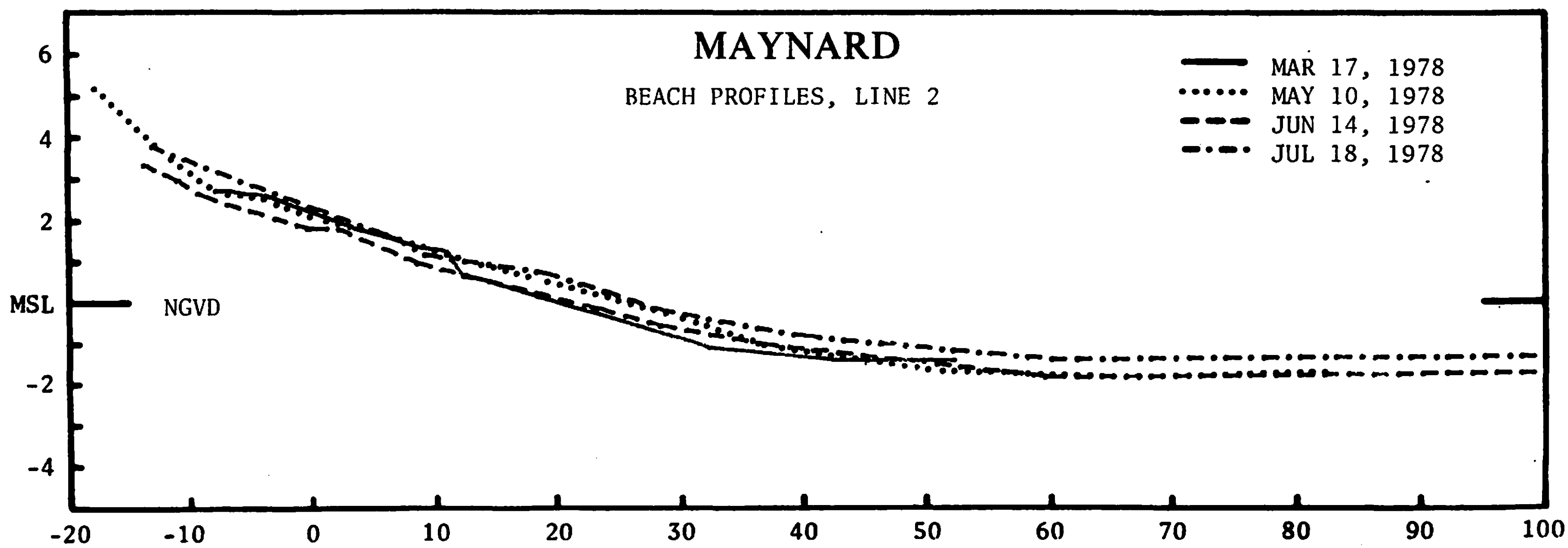


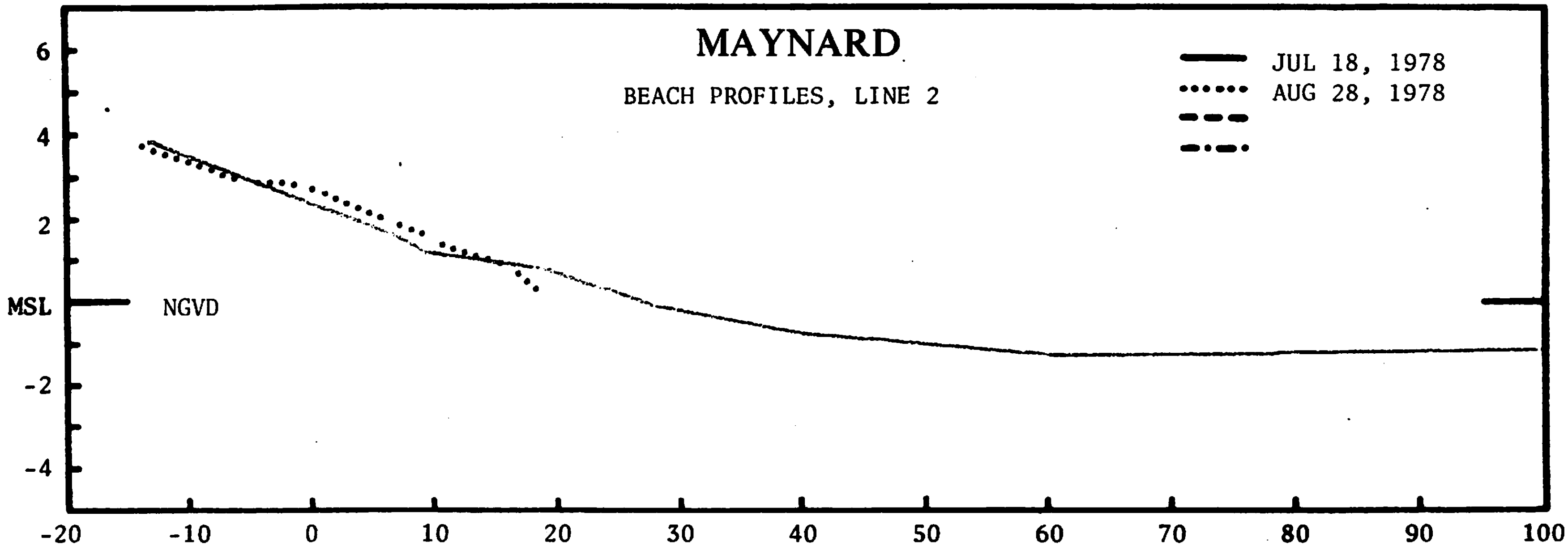


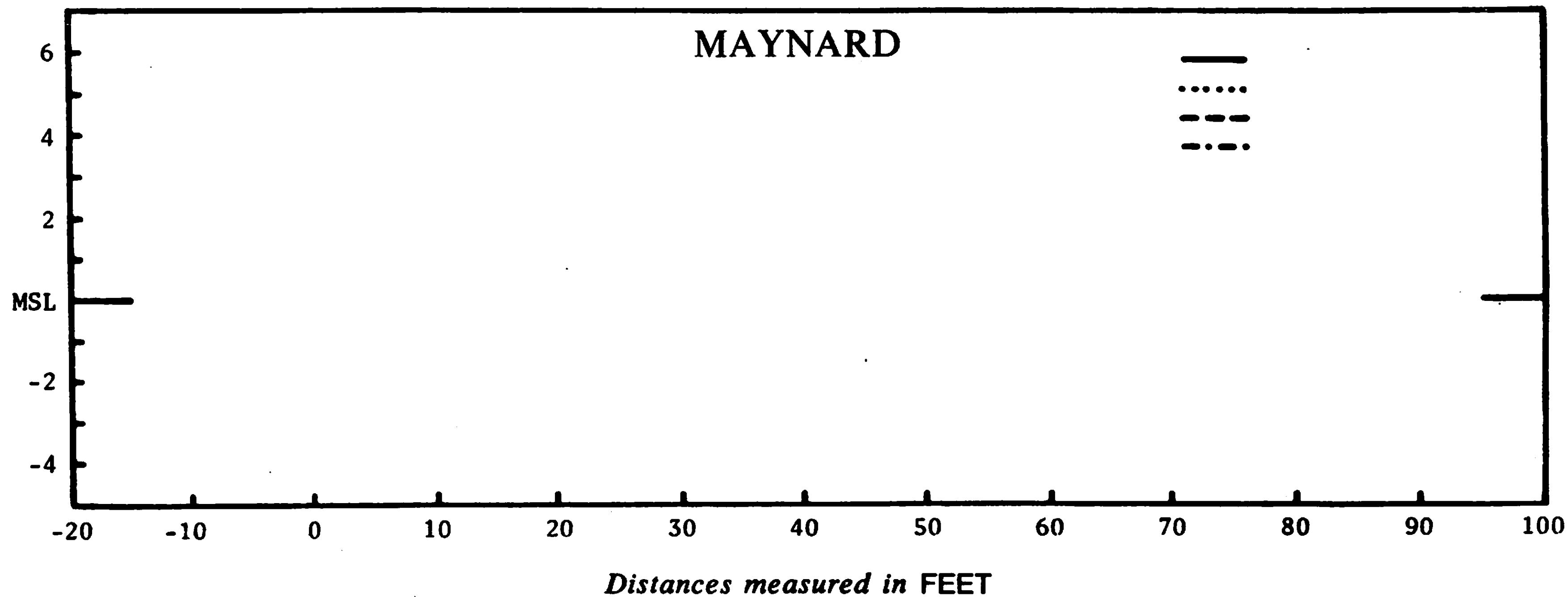
Distances measured in FEET

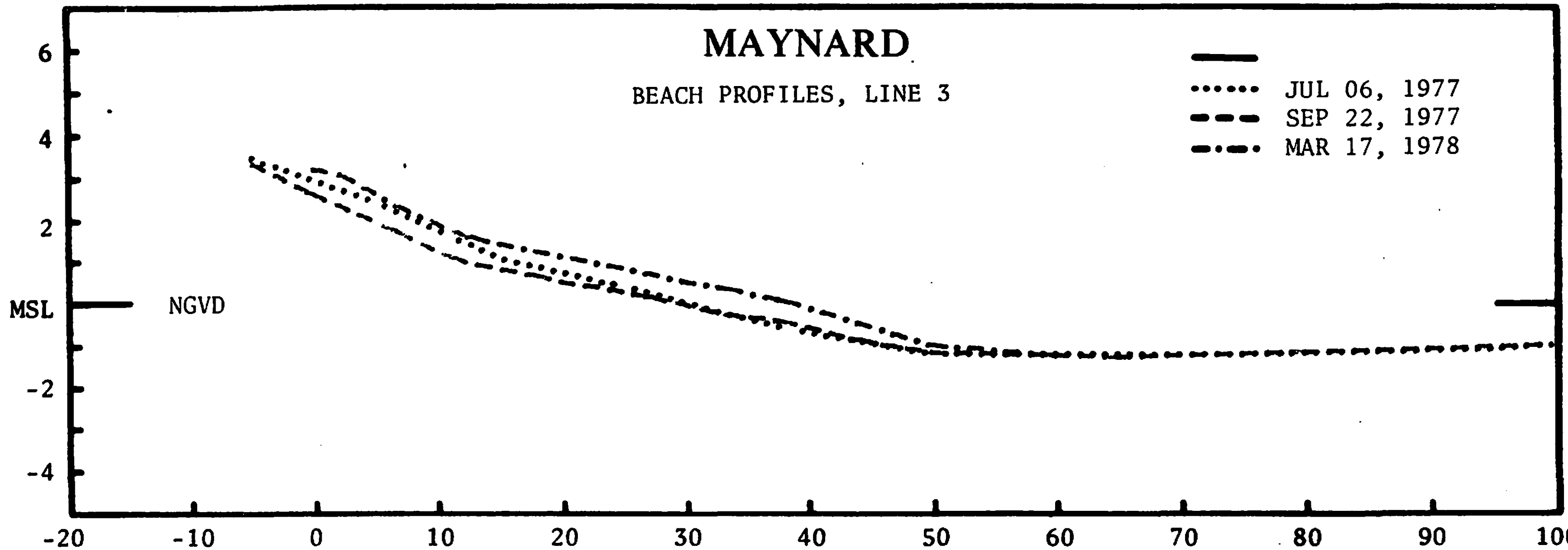


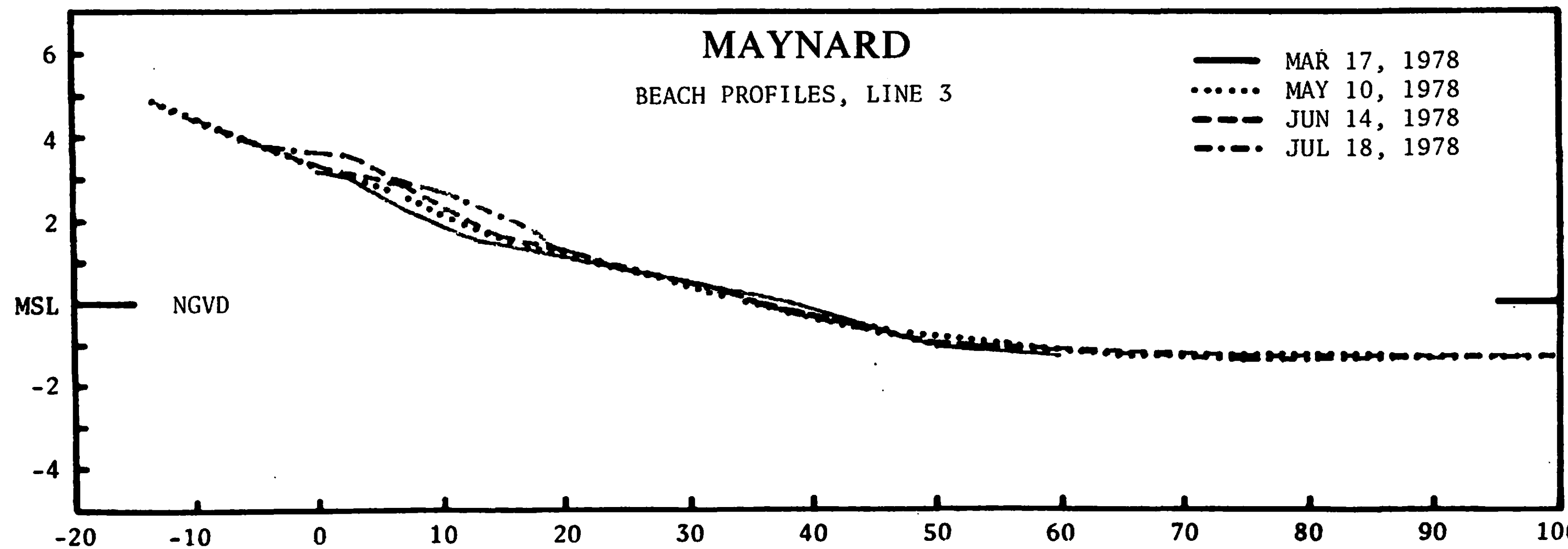


Distances measured in FEET


MAYNARD
BEACH PROFILES, LINE 2
JUL 18, 1978
AUG 28, 1978
6
4
2
MSL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100


MAYNARD
6
4
2
MSL
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET





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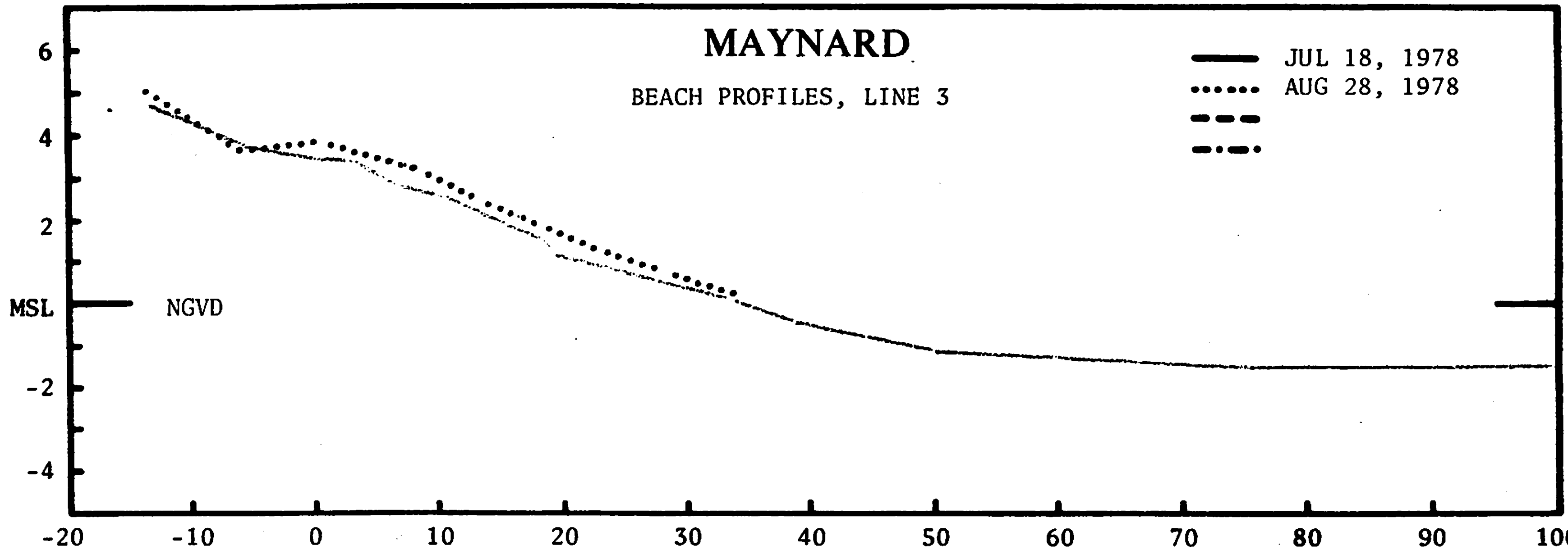

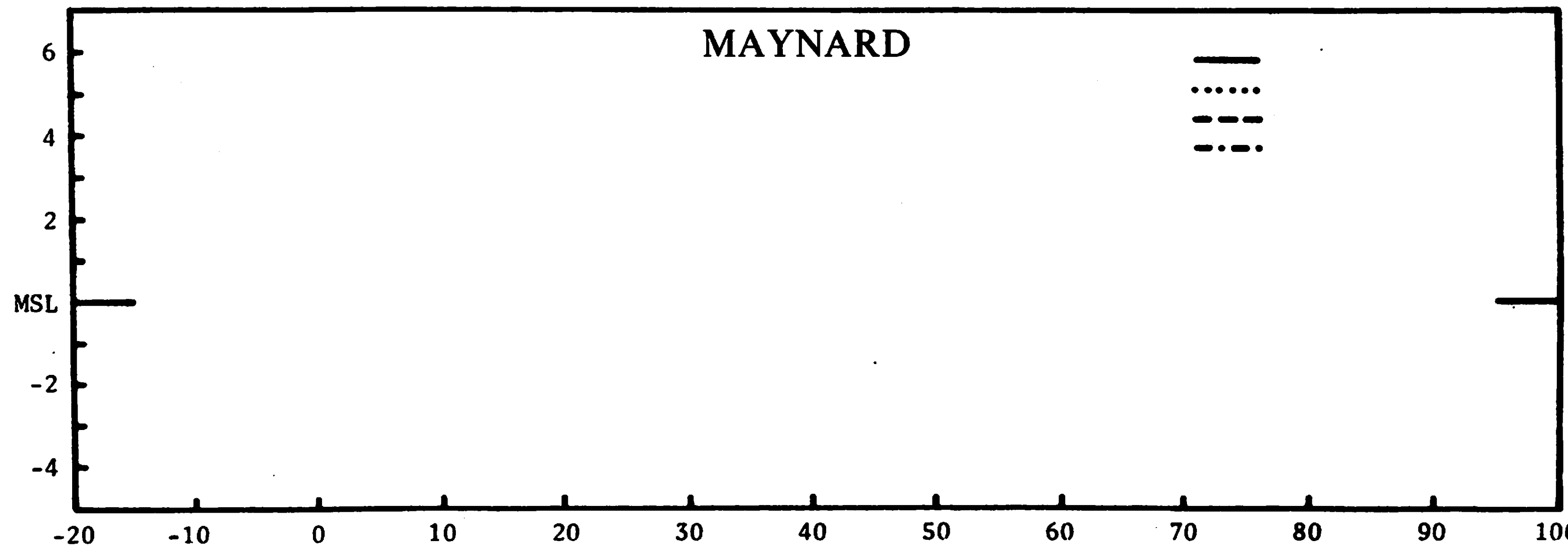

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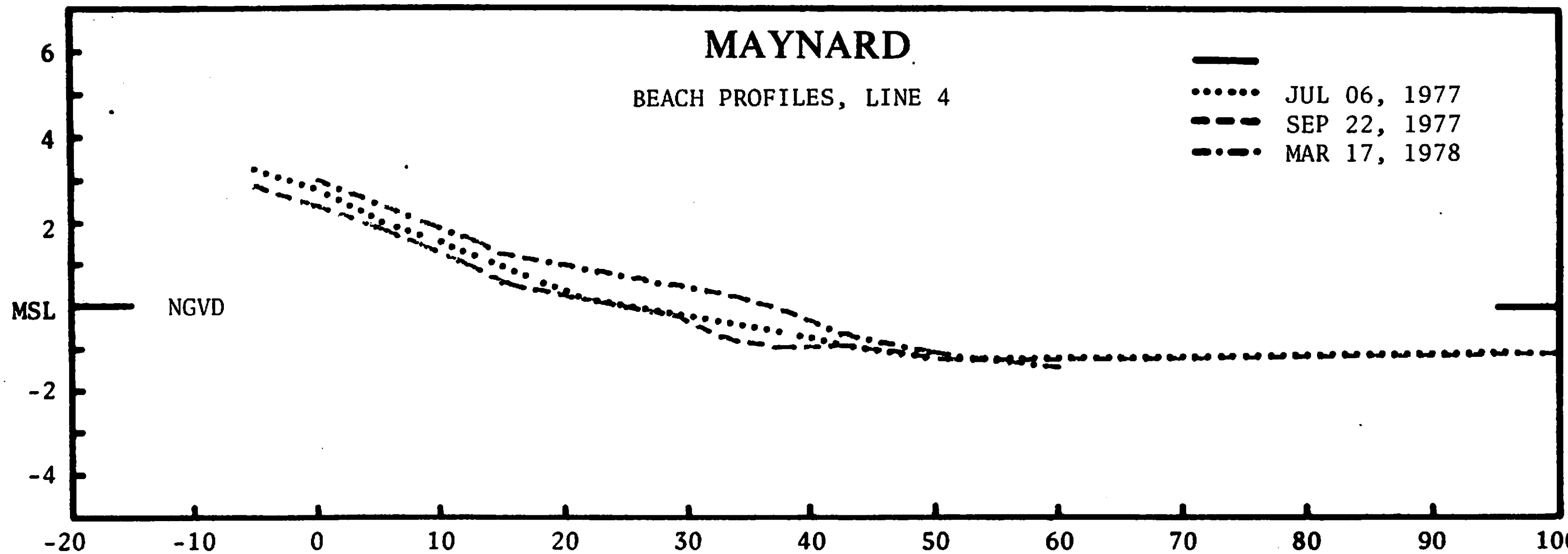
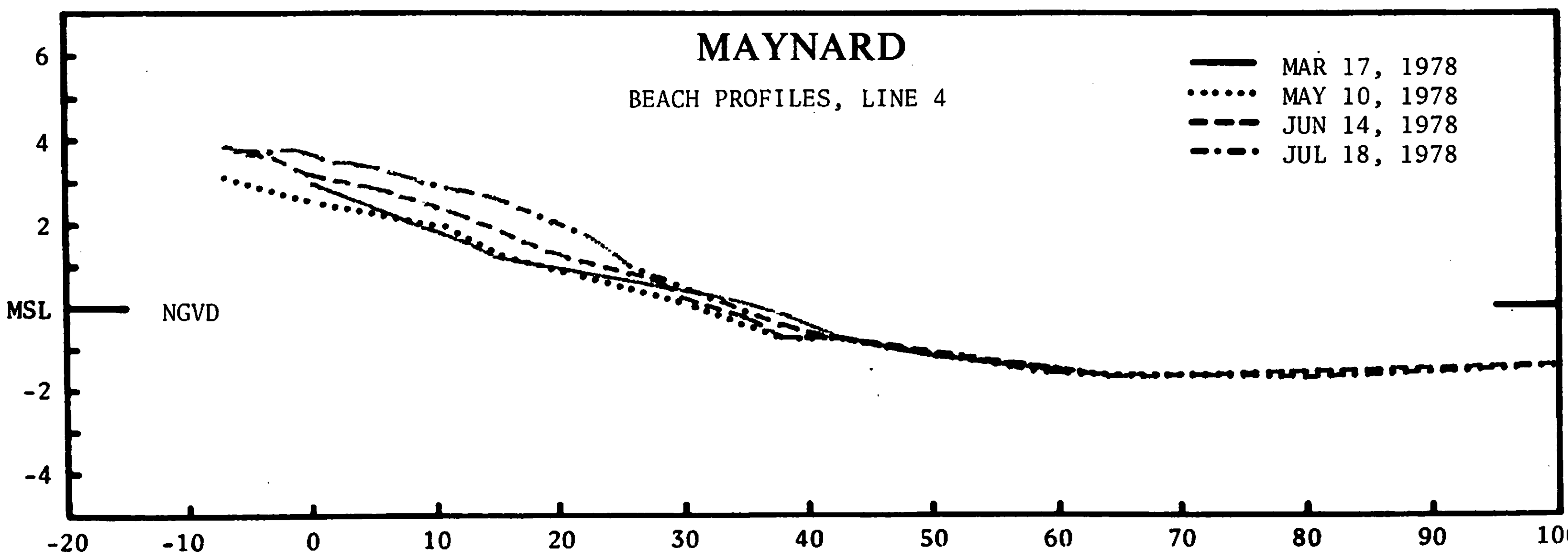
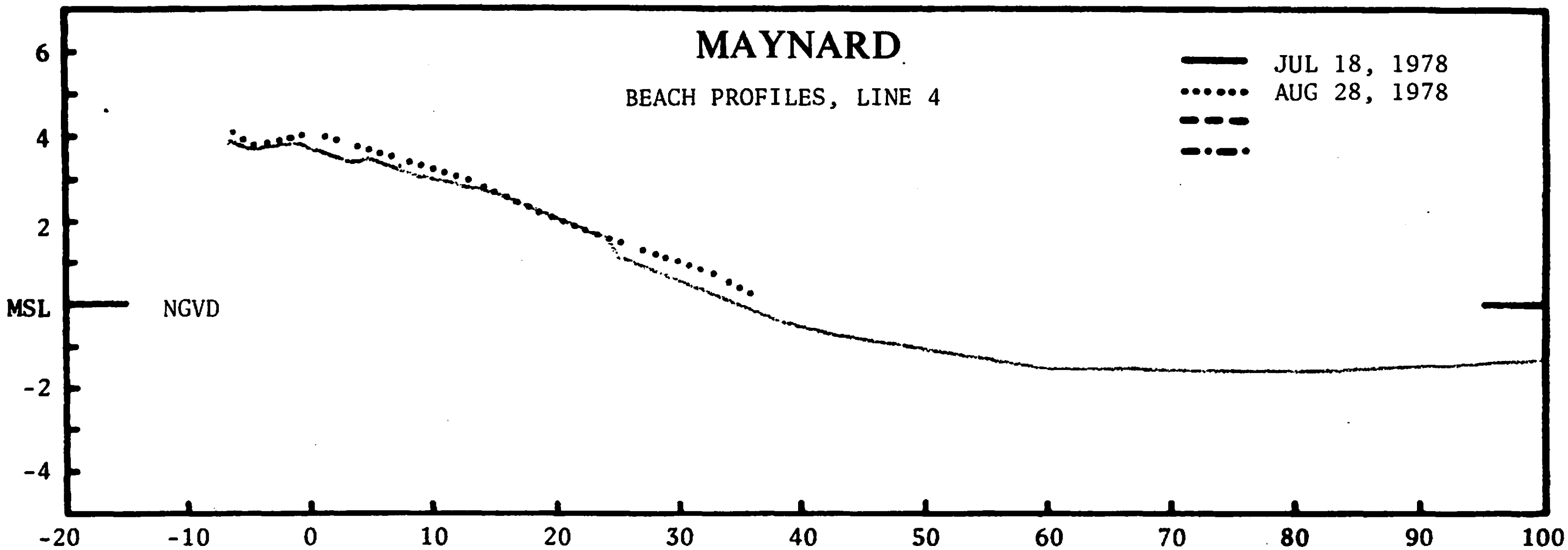
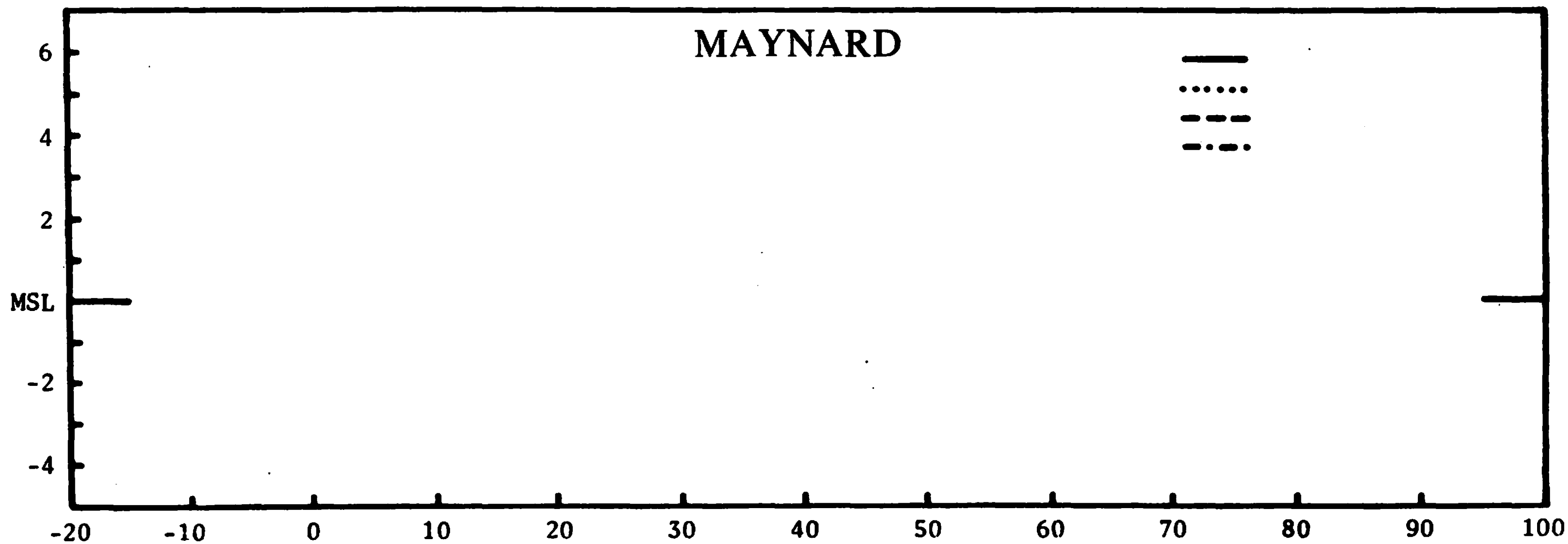




Distances measured in FEET





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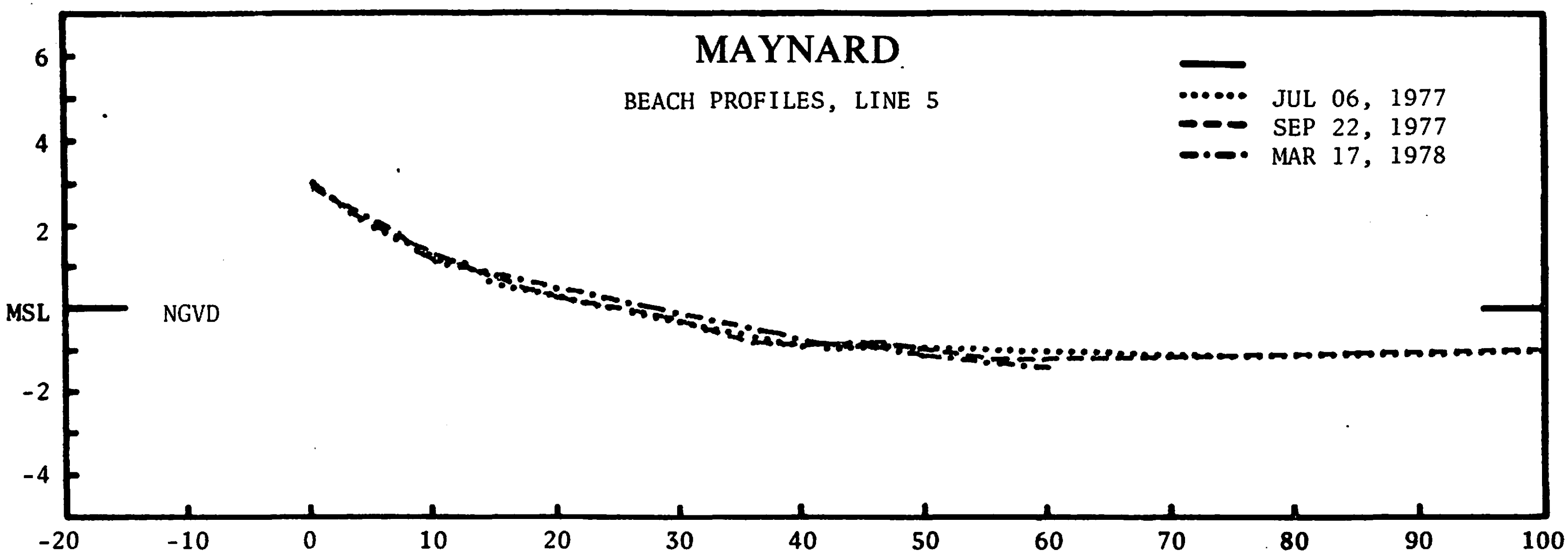
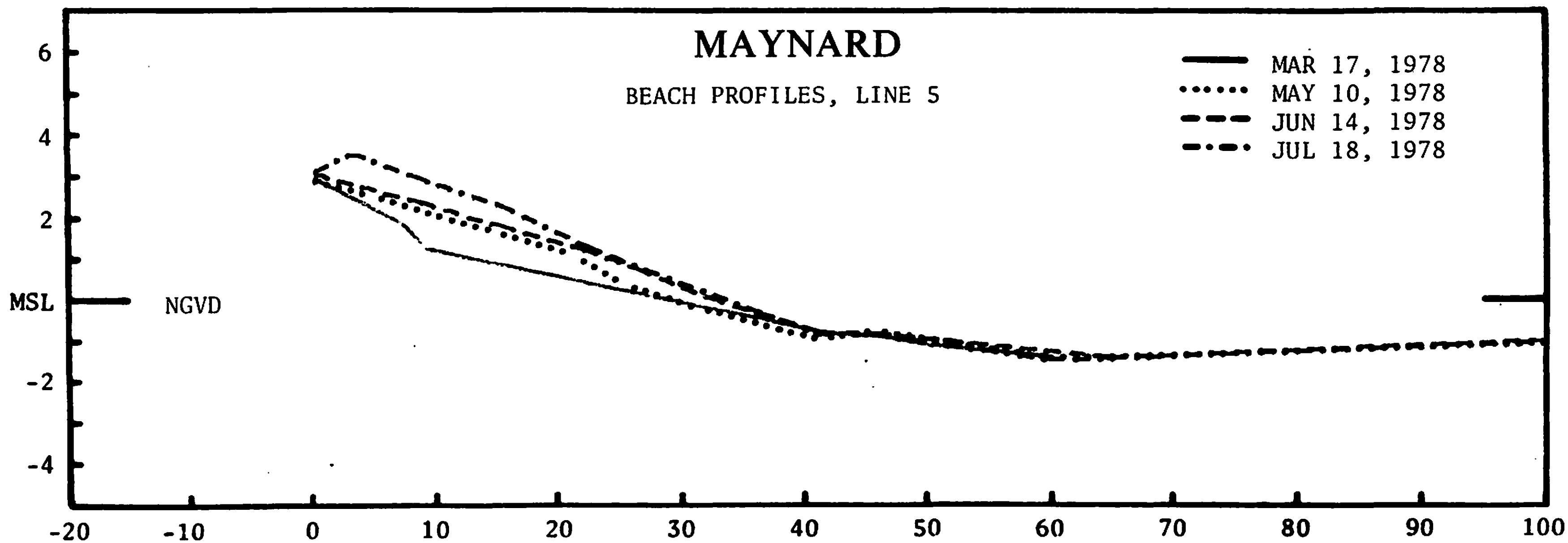
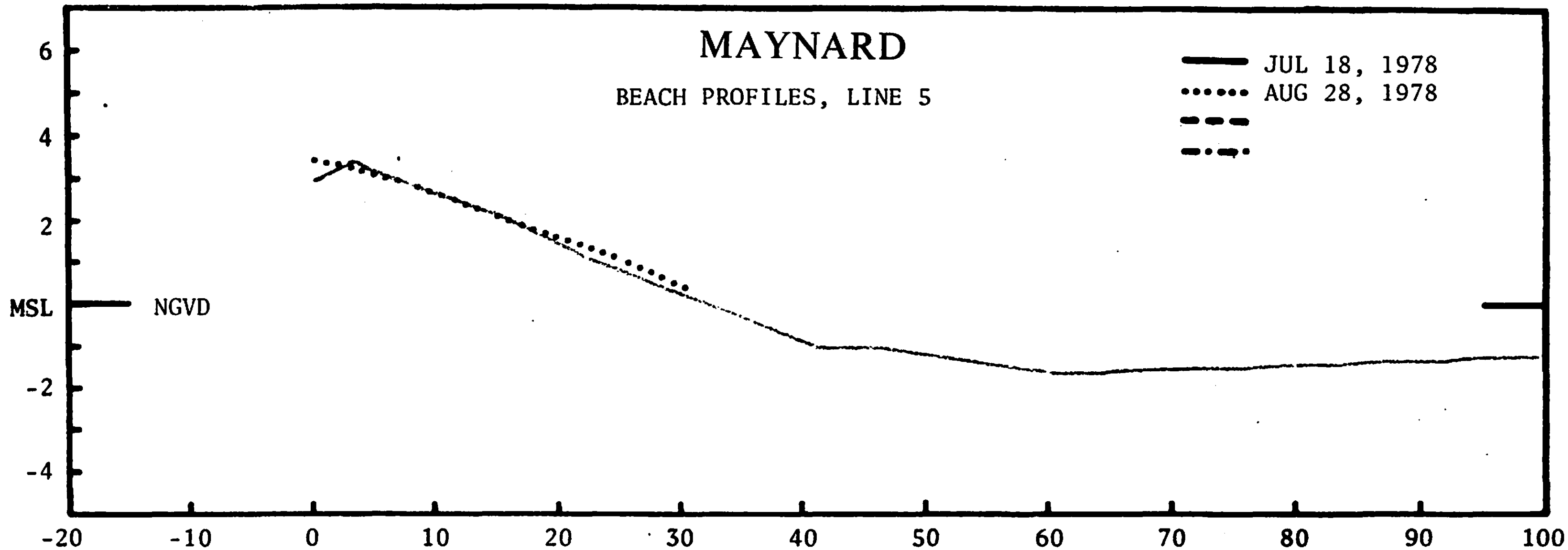
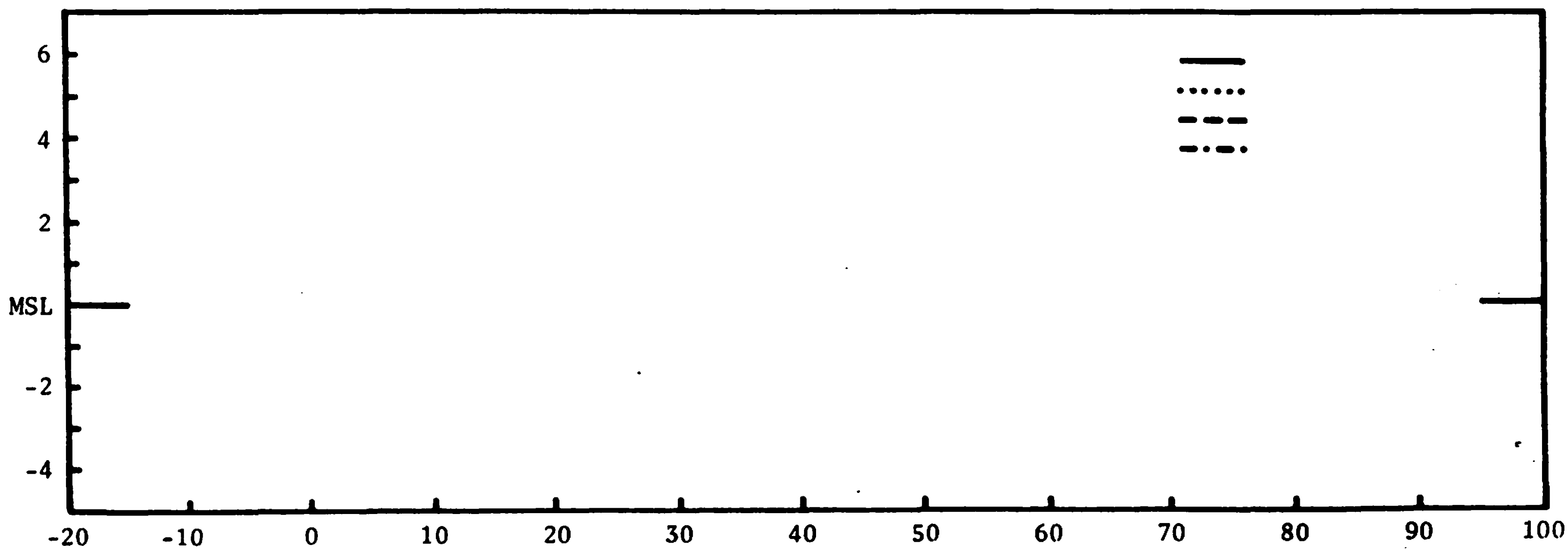


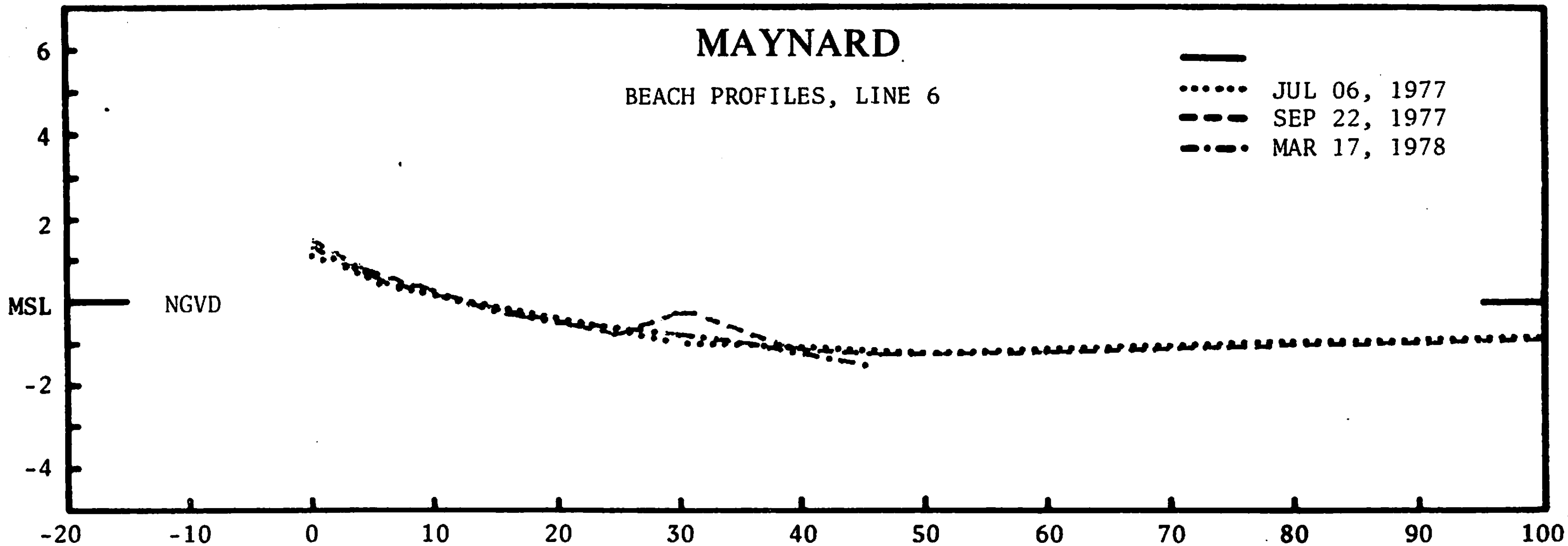


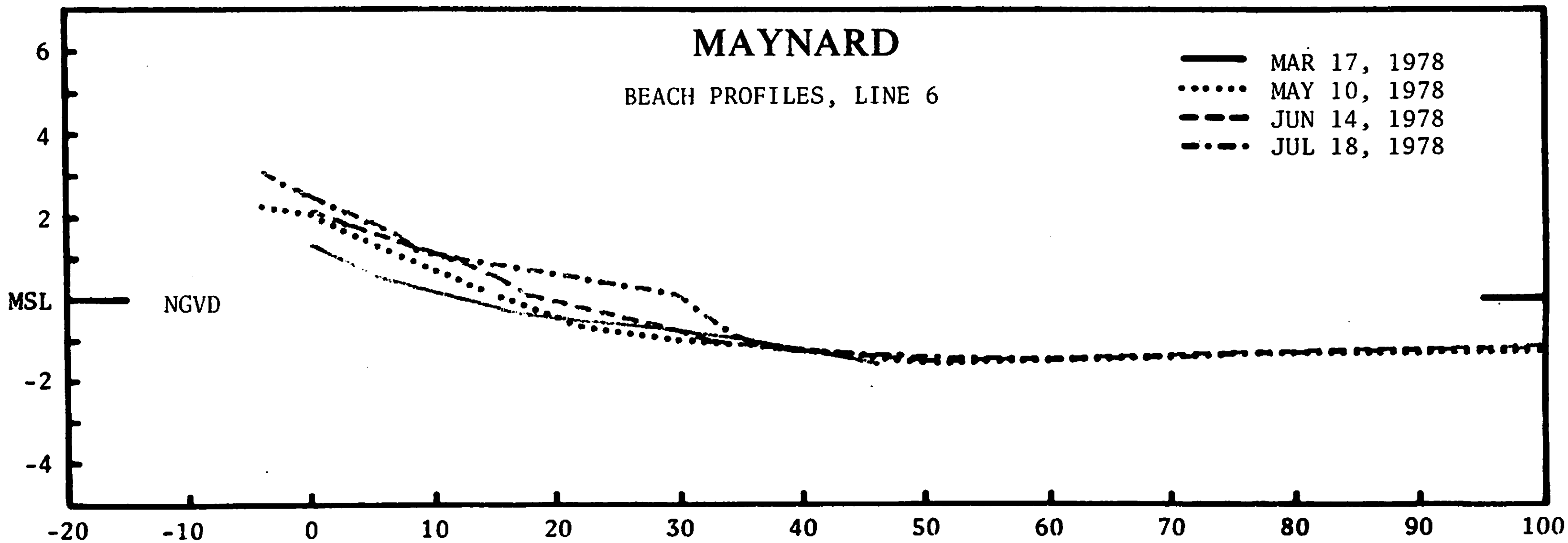
Distances measured in FEET



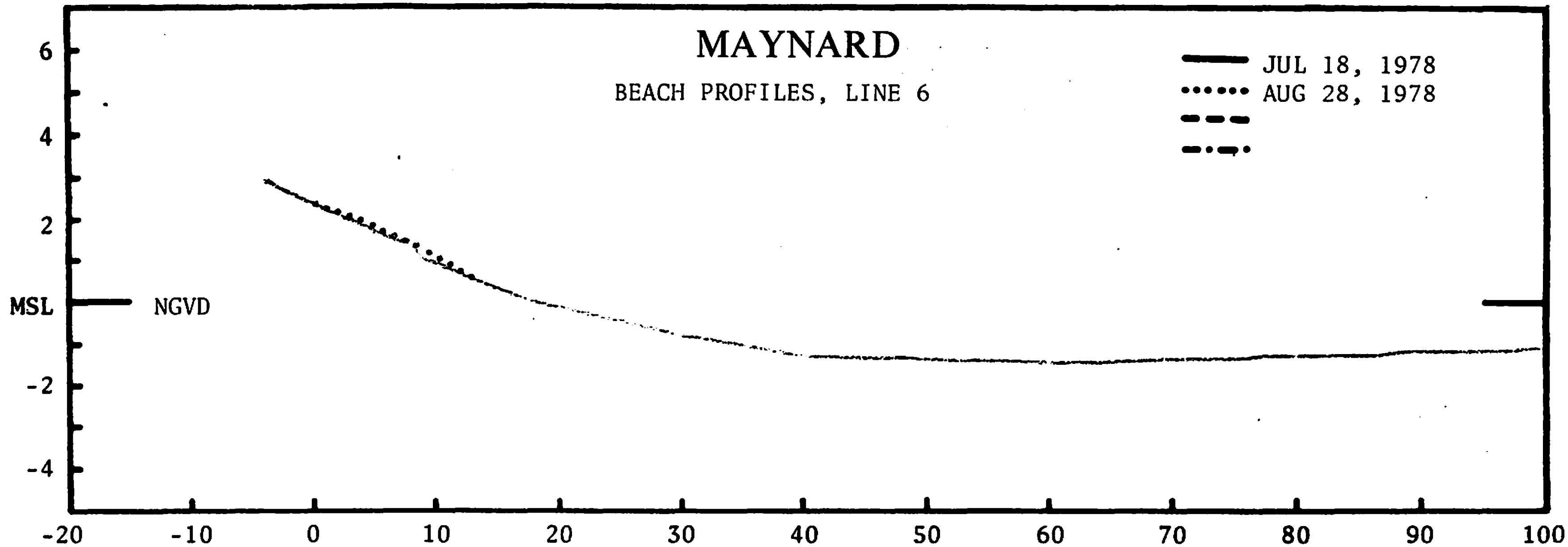


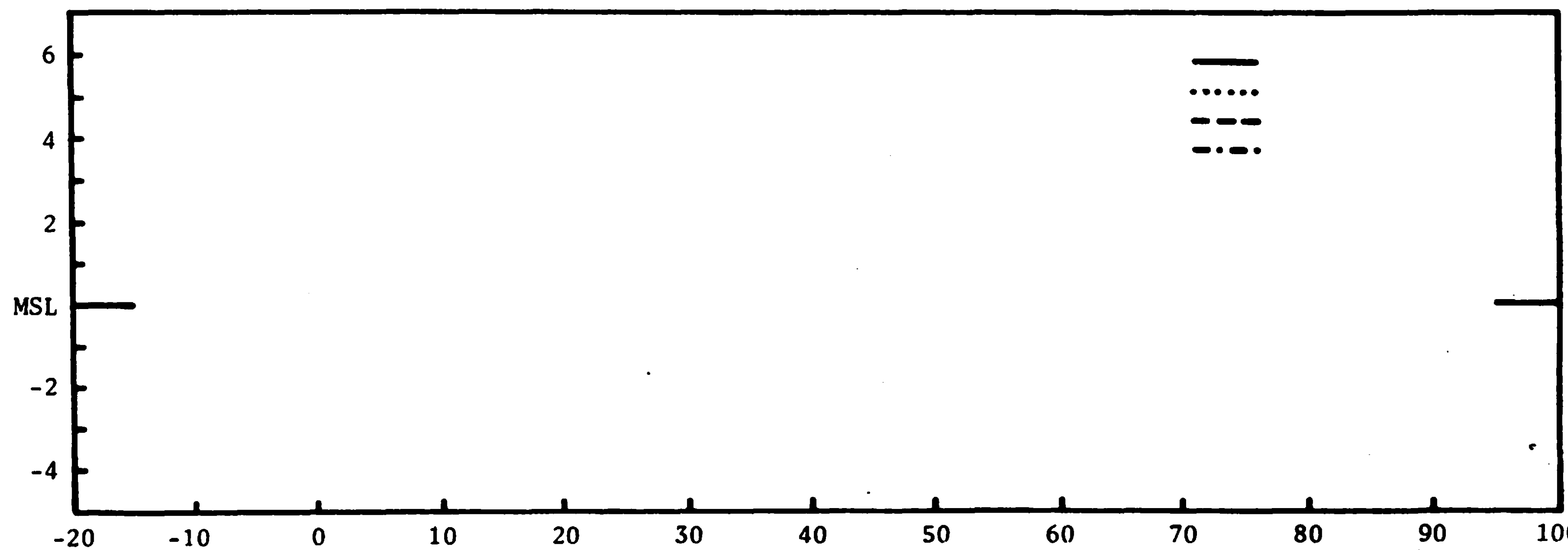
Distances measured in FEET



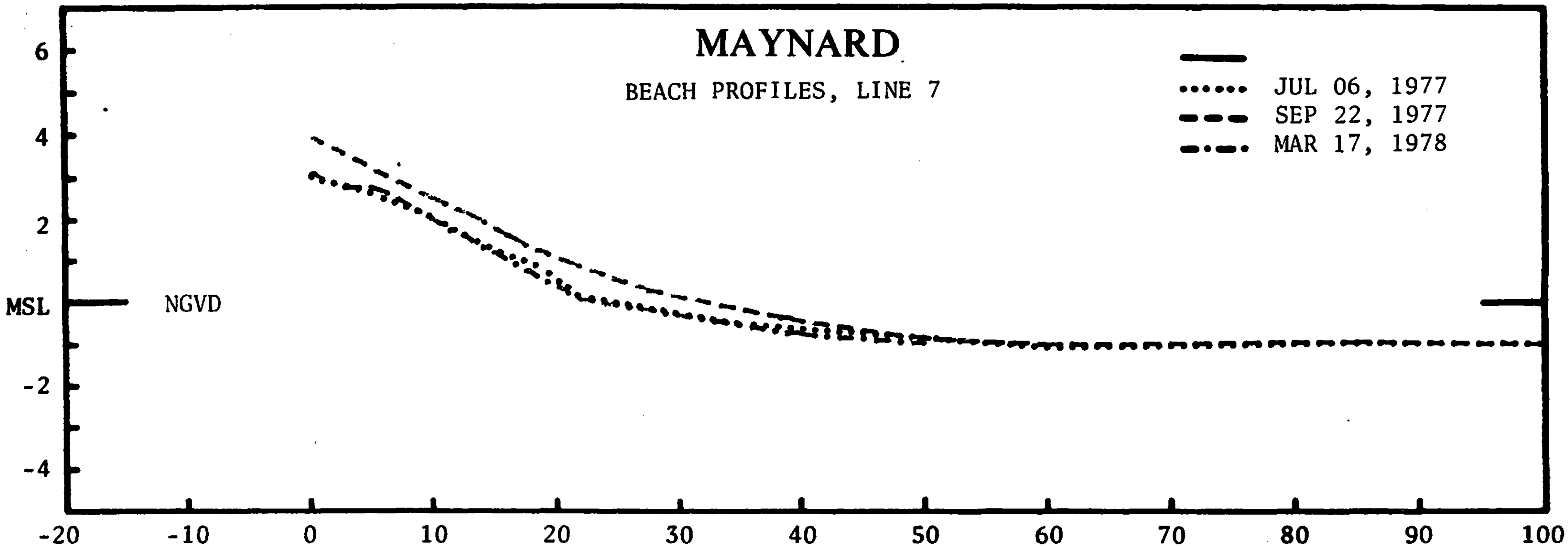


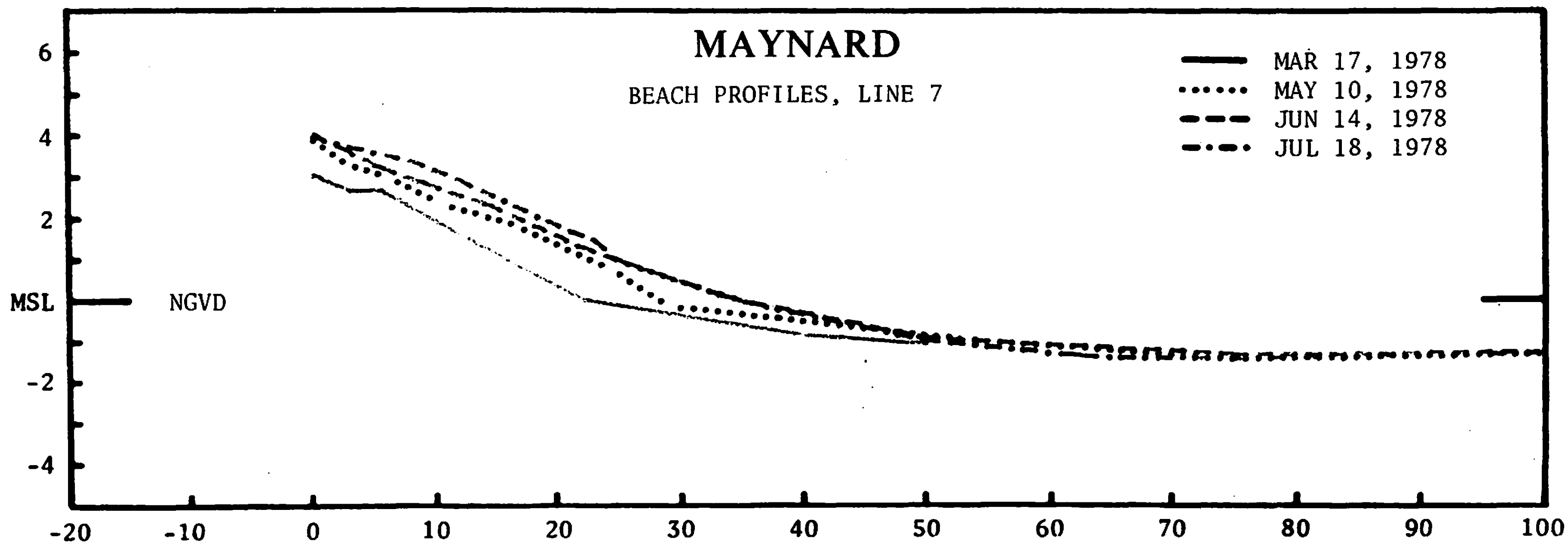
Distances measured in FEET





Distances measured in FEET





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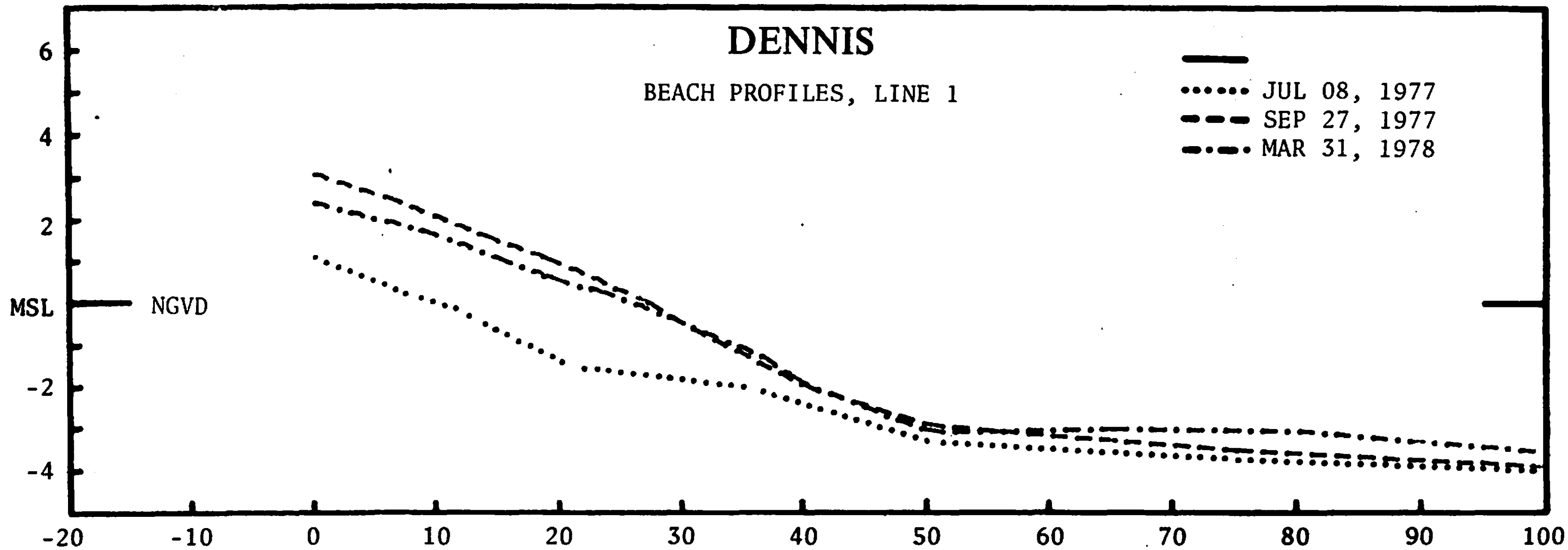
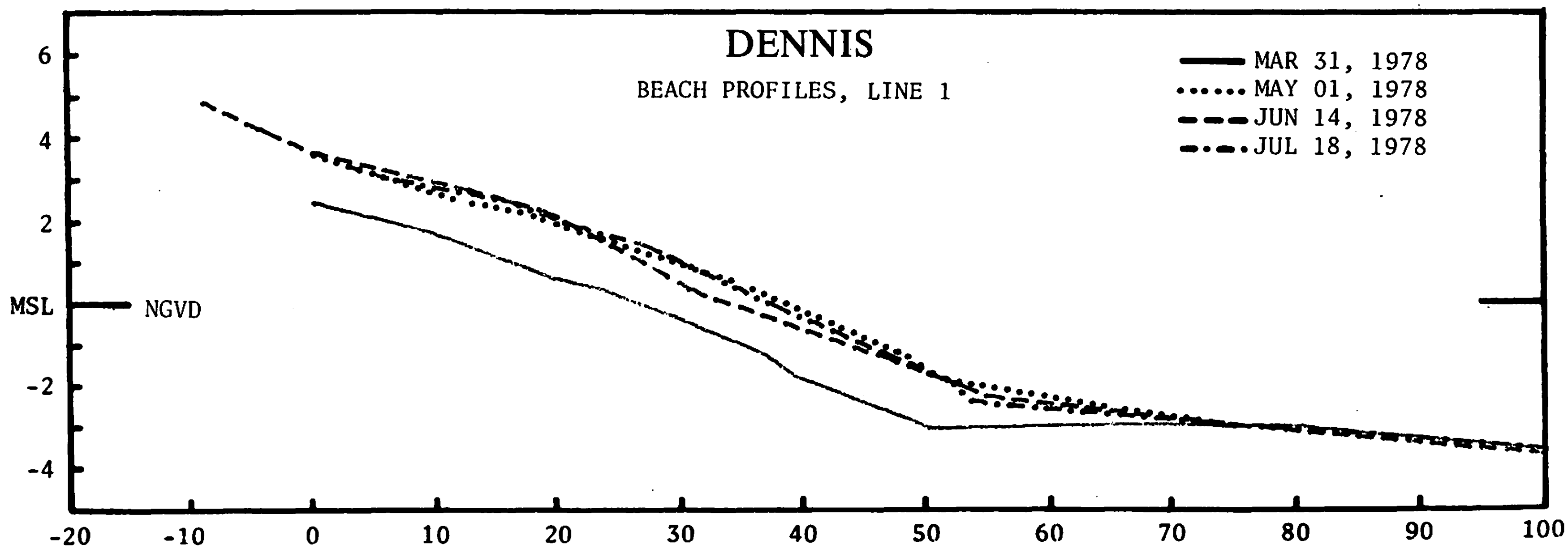
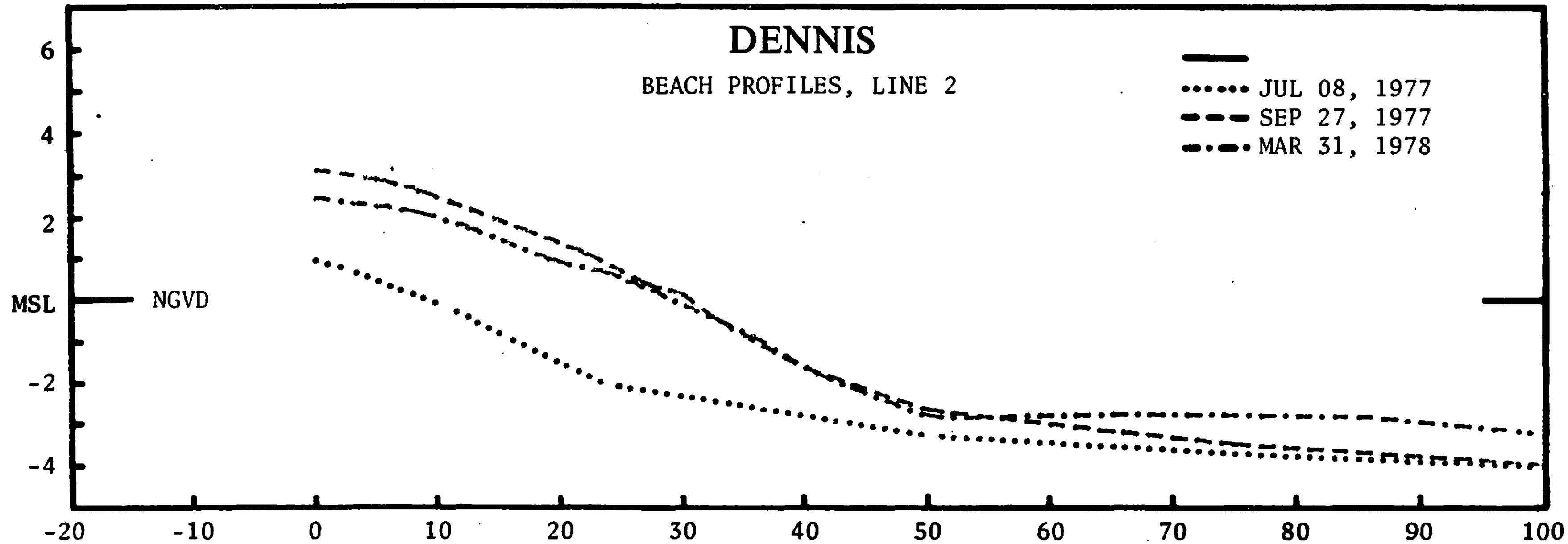
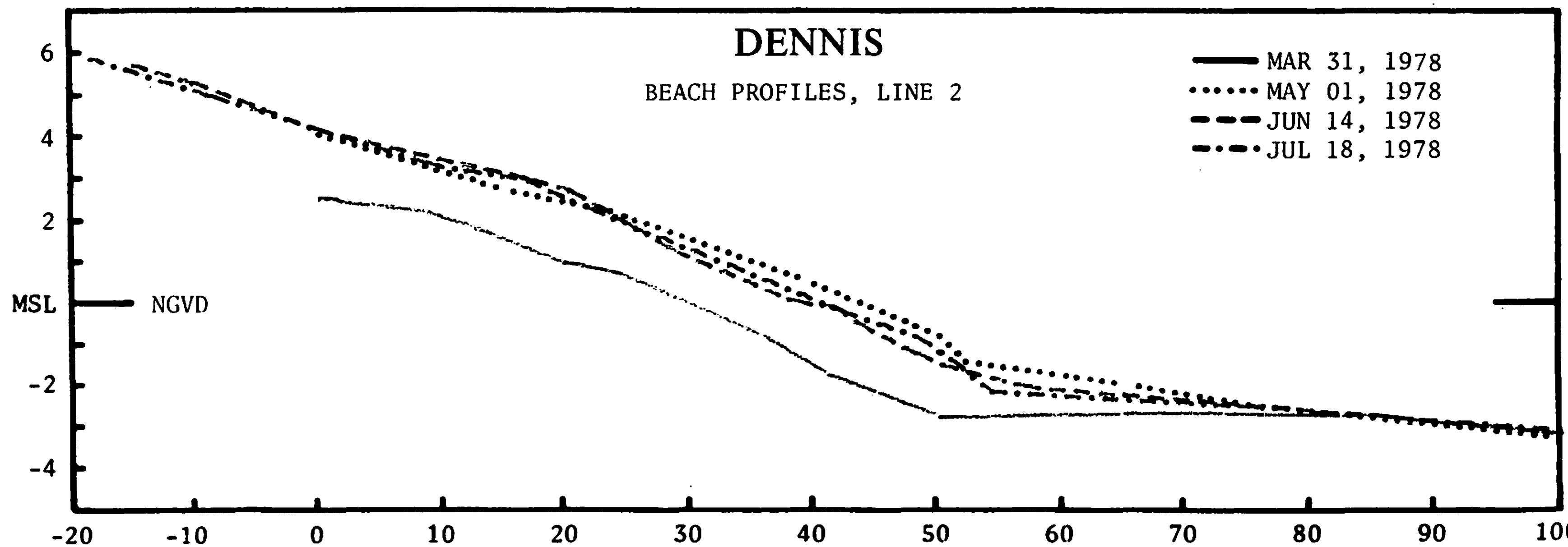


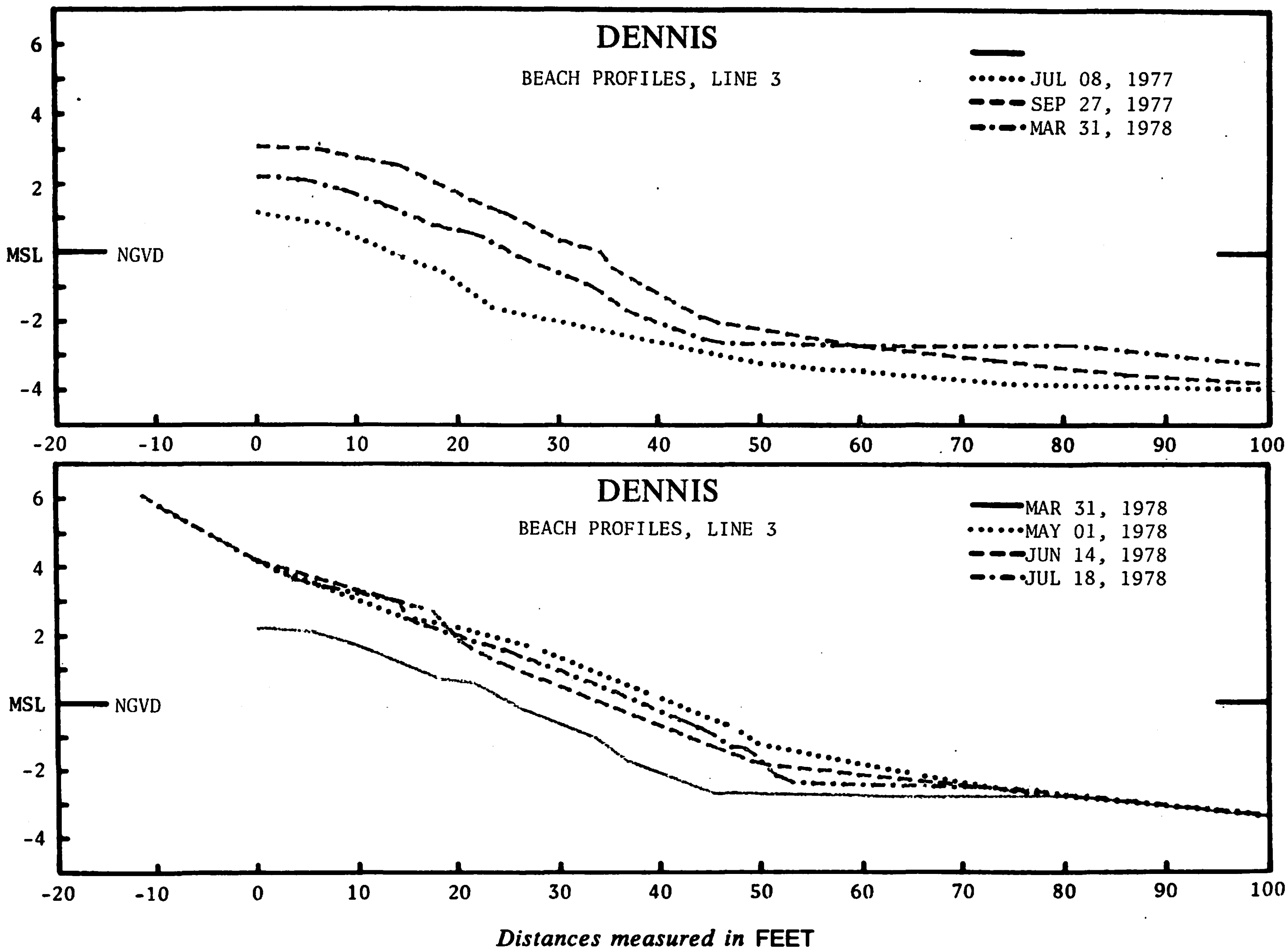


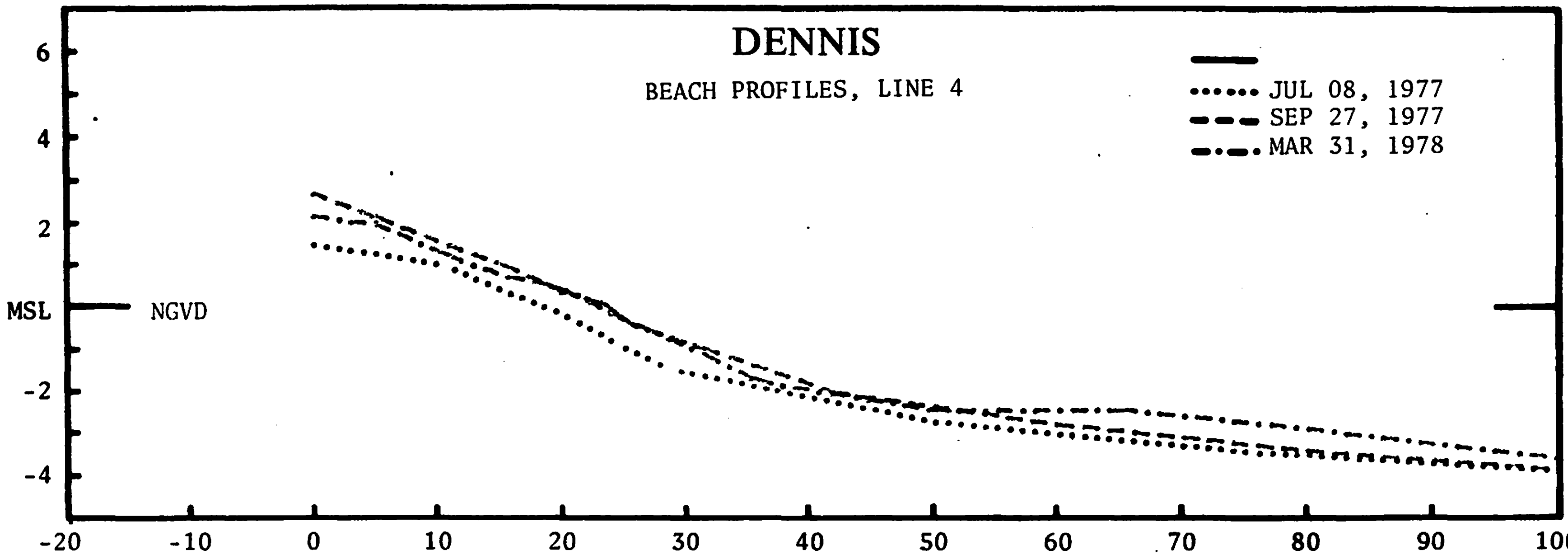
Distances measured in FEET

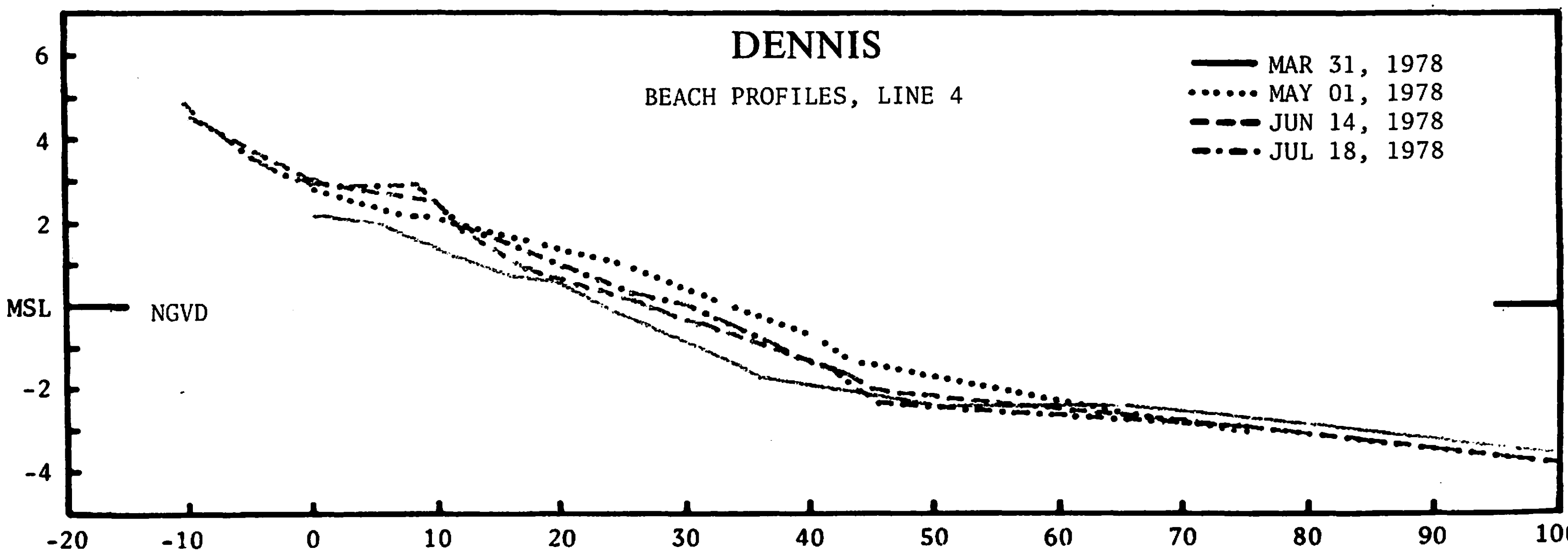




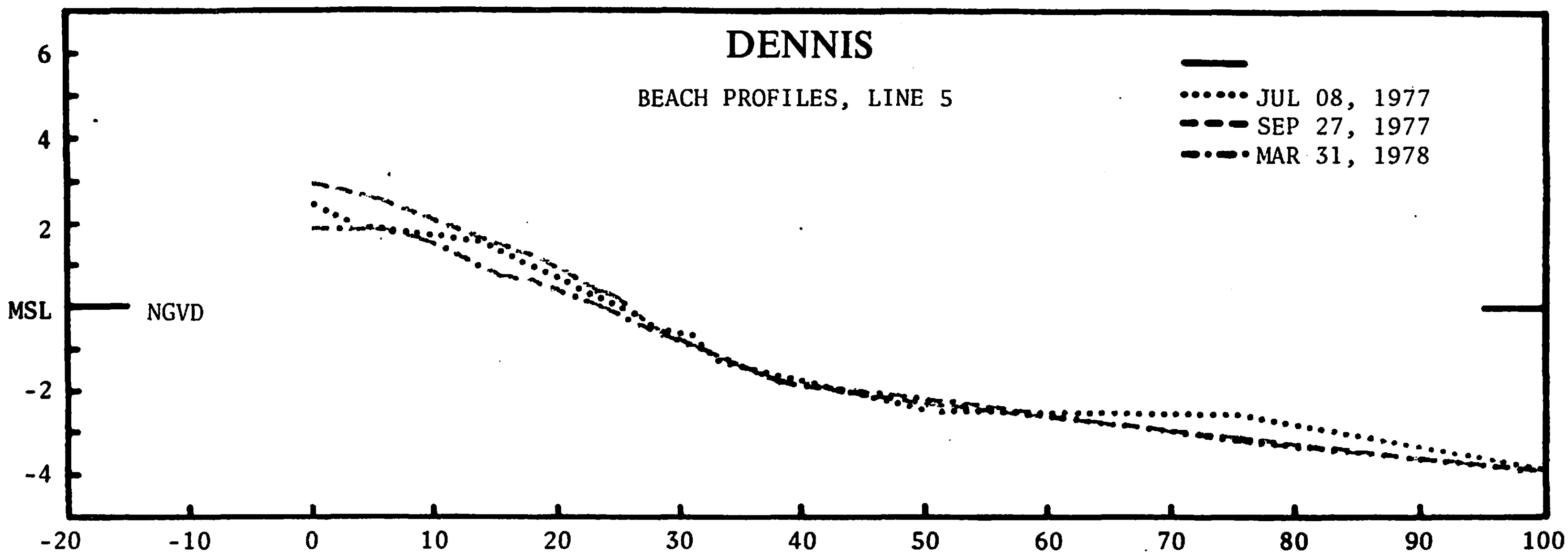
Distances measured in FEET

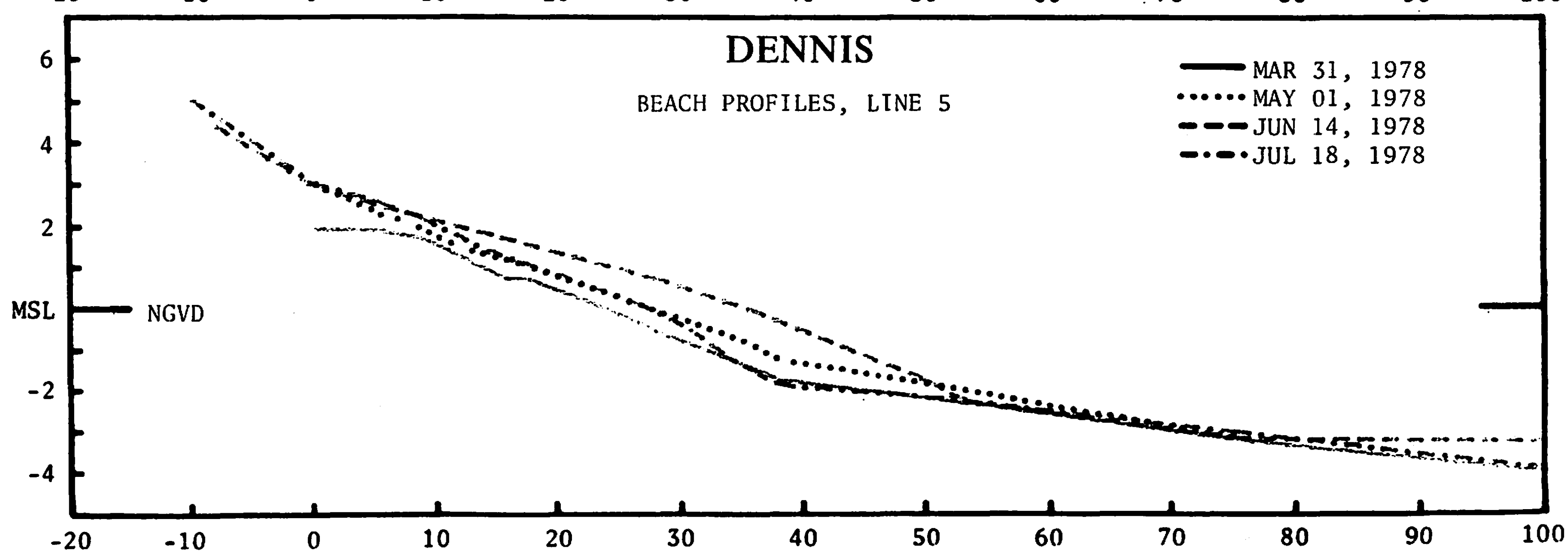

DENNIS
BEACH PROFILES, LINE 3
JUL 08, 1977
SEP 27, 1977
MAR 31, 1978
6
4
2
MSL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
DENNIS
BEACH PROFILES, LINE 3
MAR 31, 1978
MAY 01, 1978
JUN 14, 1978
JUL 18, 1978
6
4
2
MSL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET



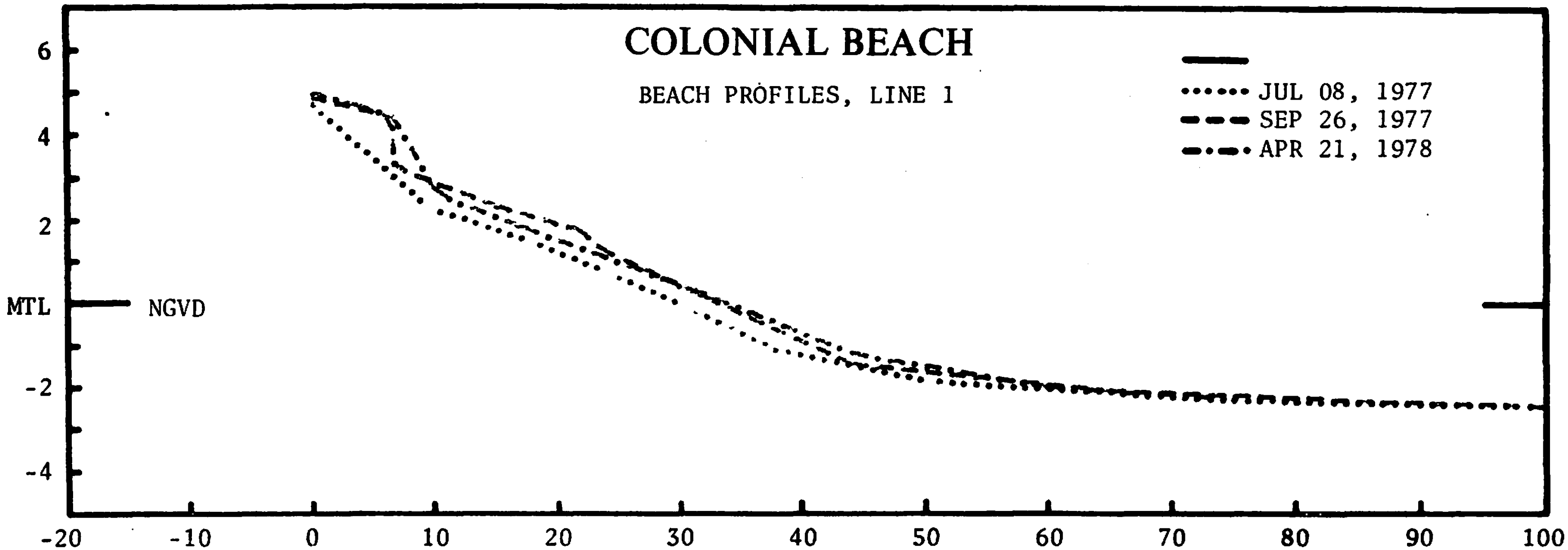


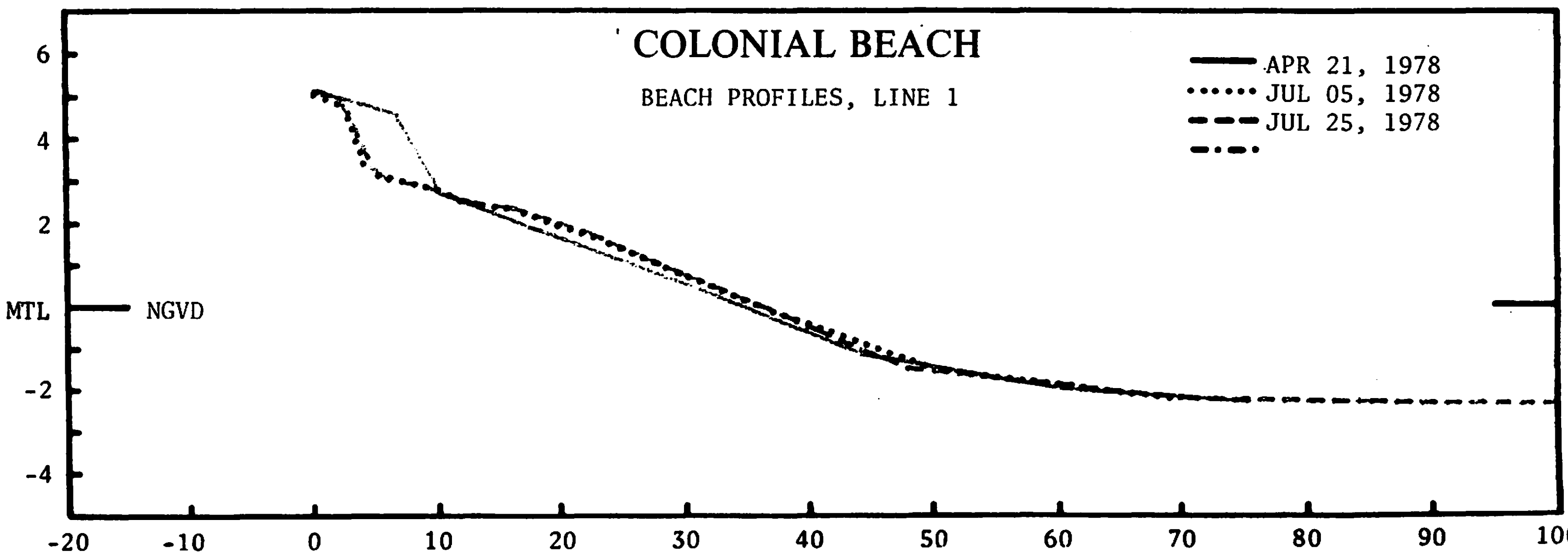
Distances measured in FEET



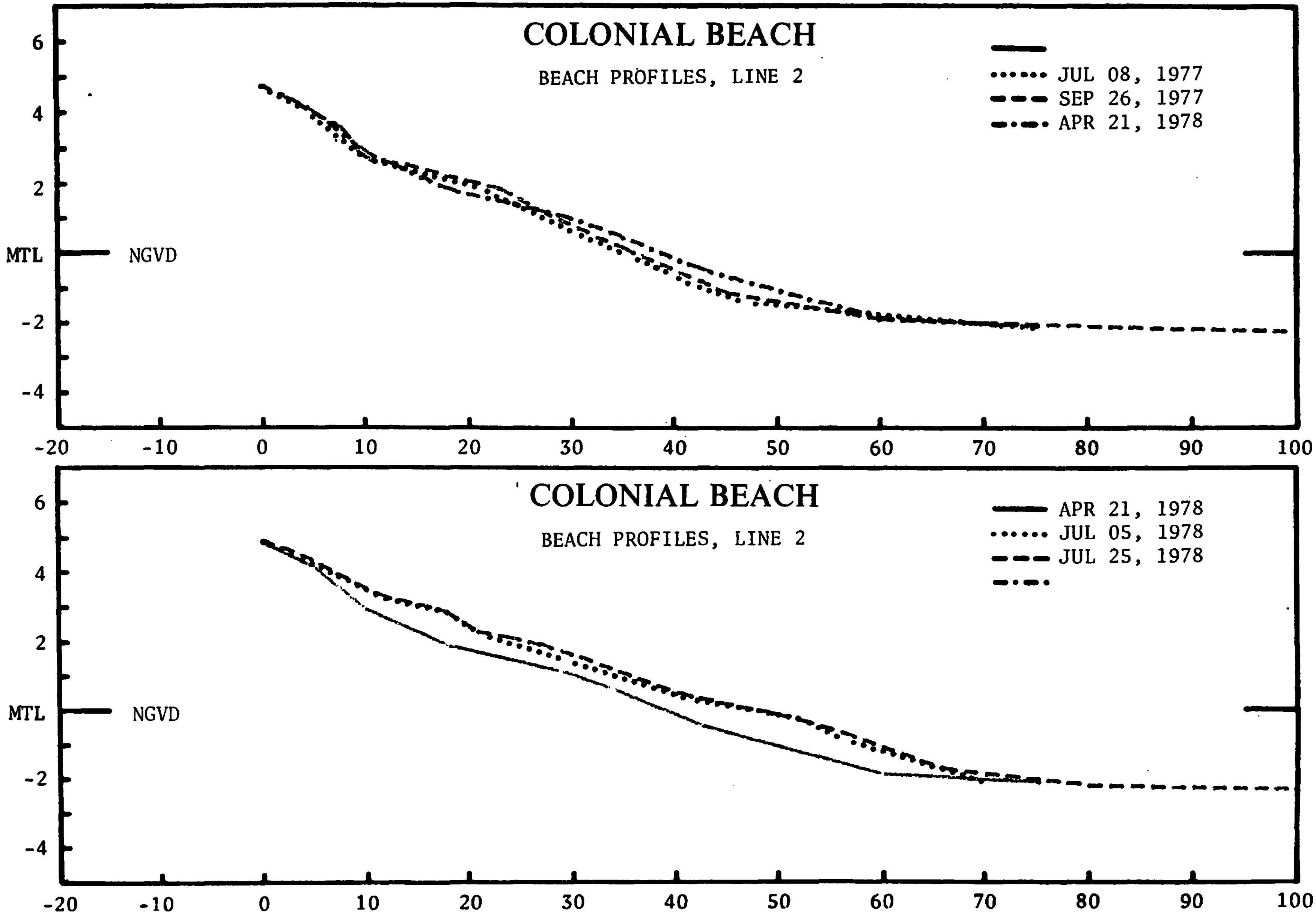


Distances measured in FEET

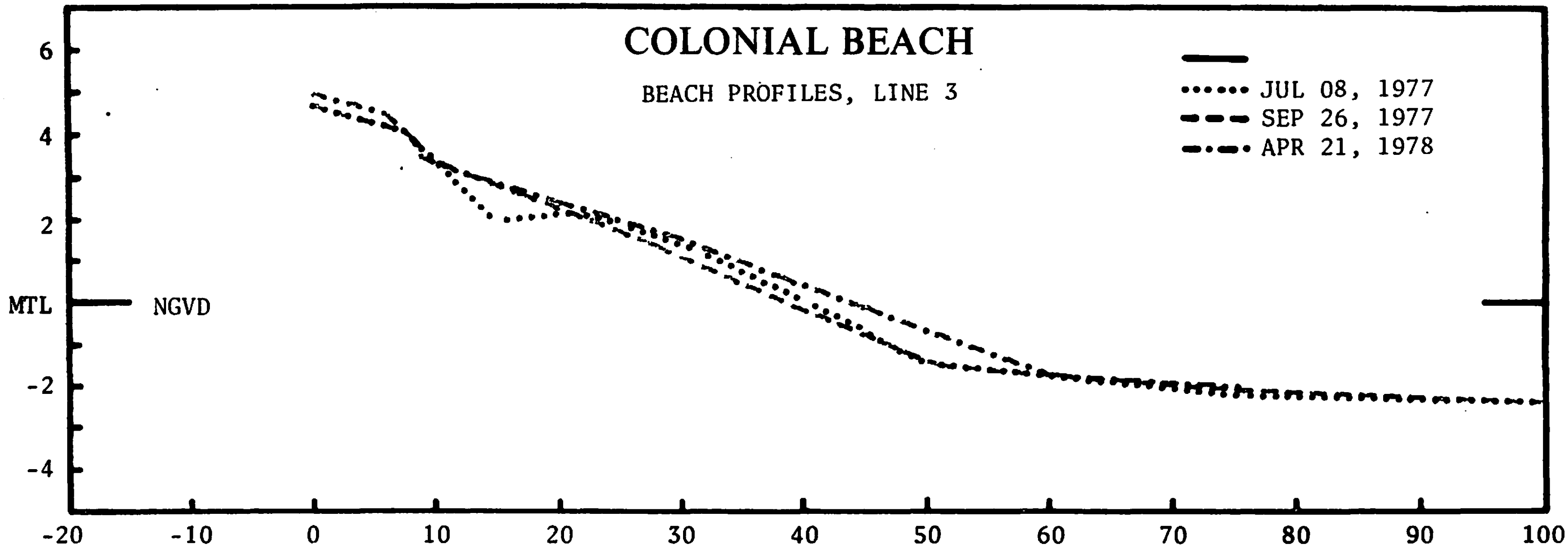


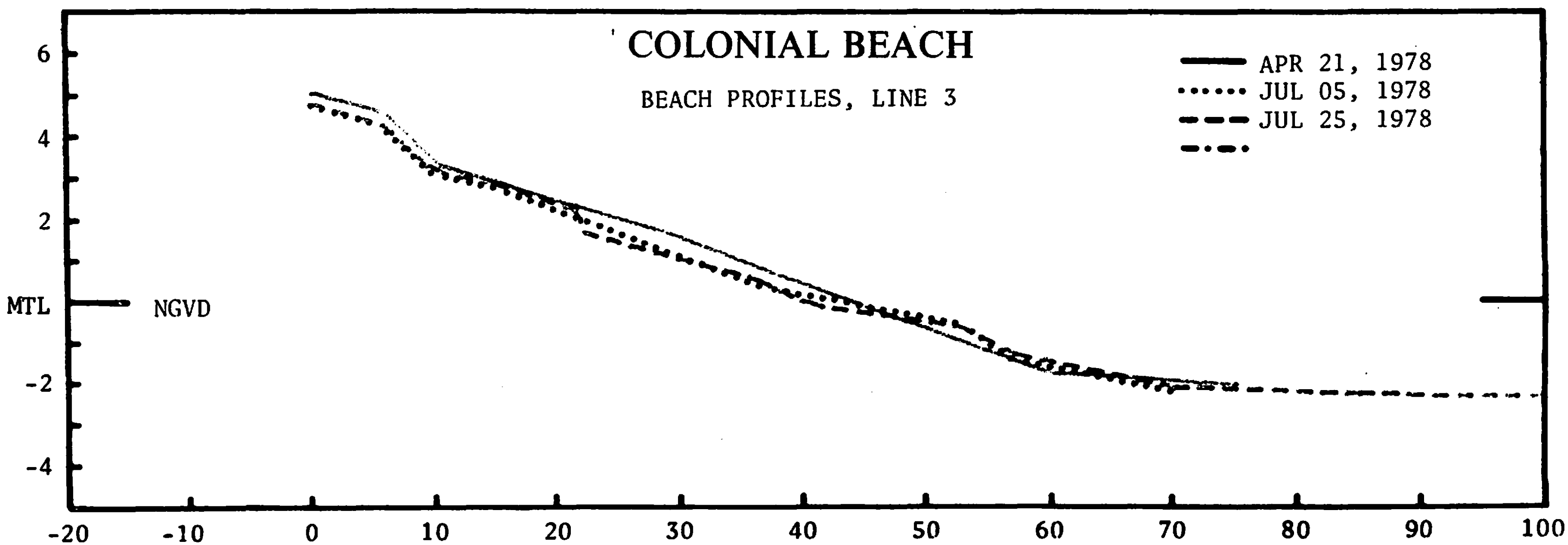


Distances measured in FEET

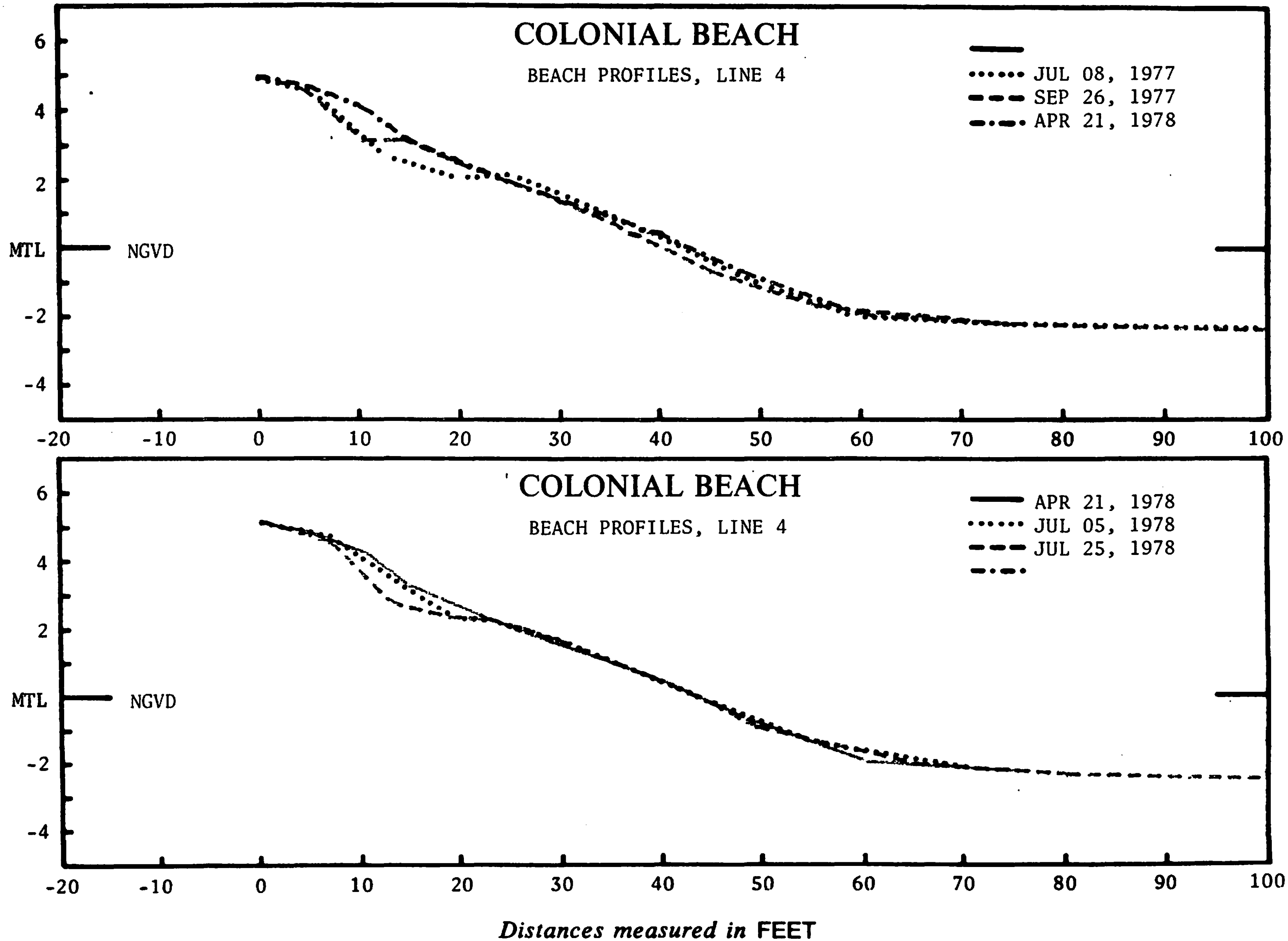


Distances measured in FEET

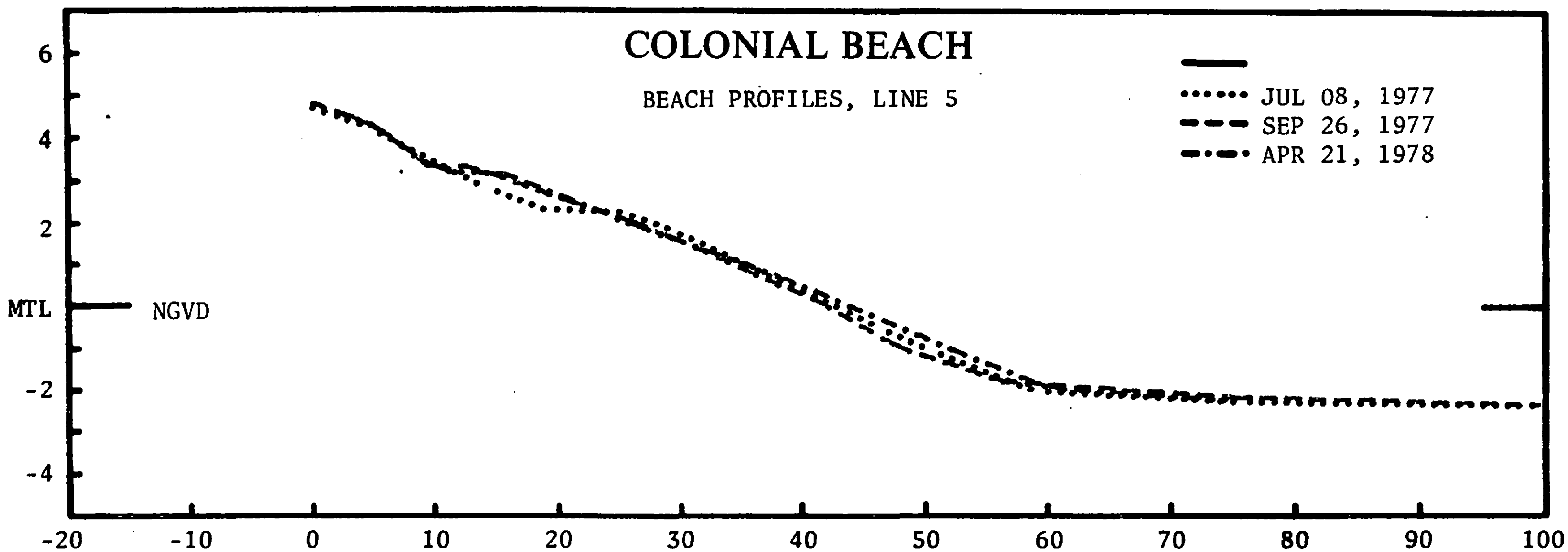


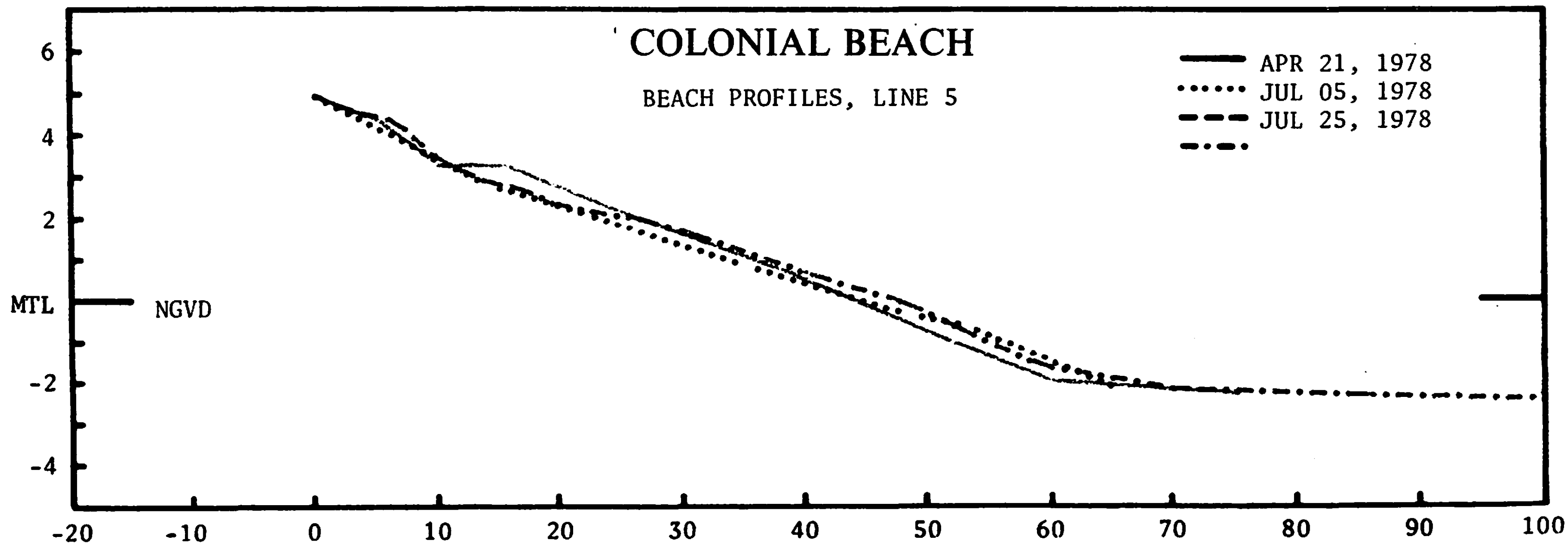


Distances measured in FEET

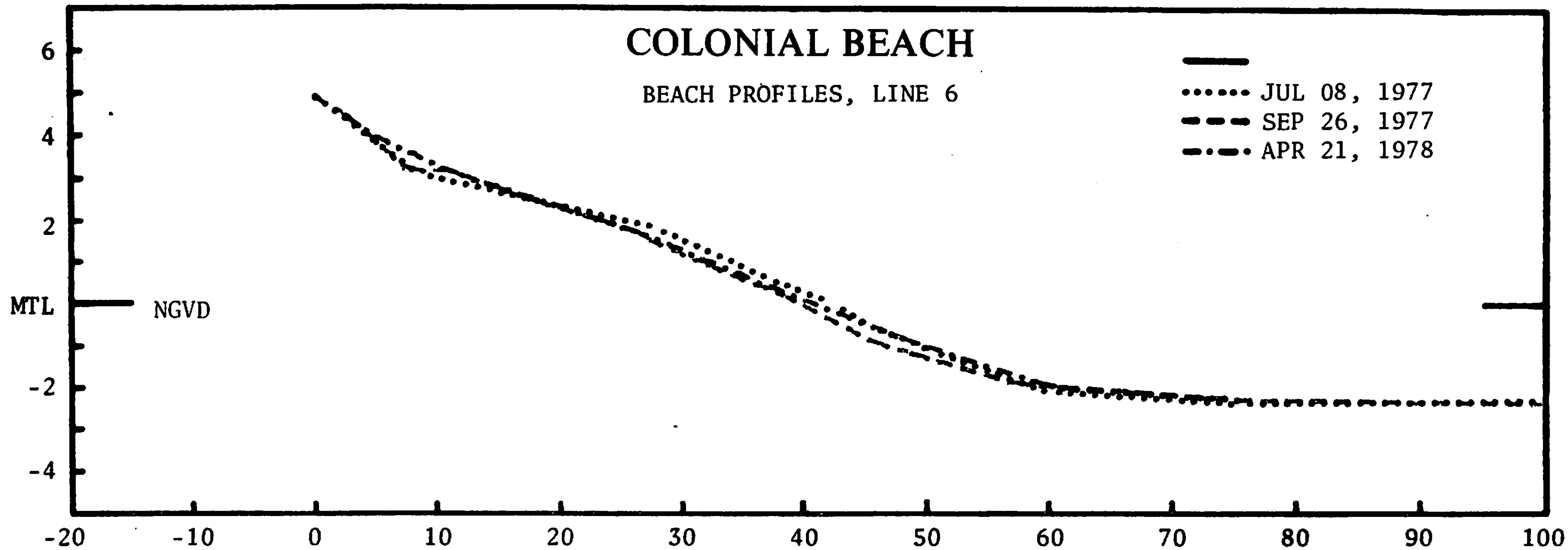


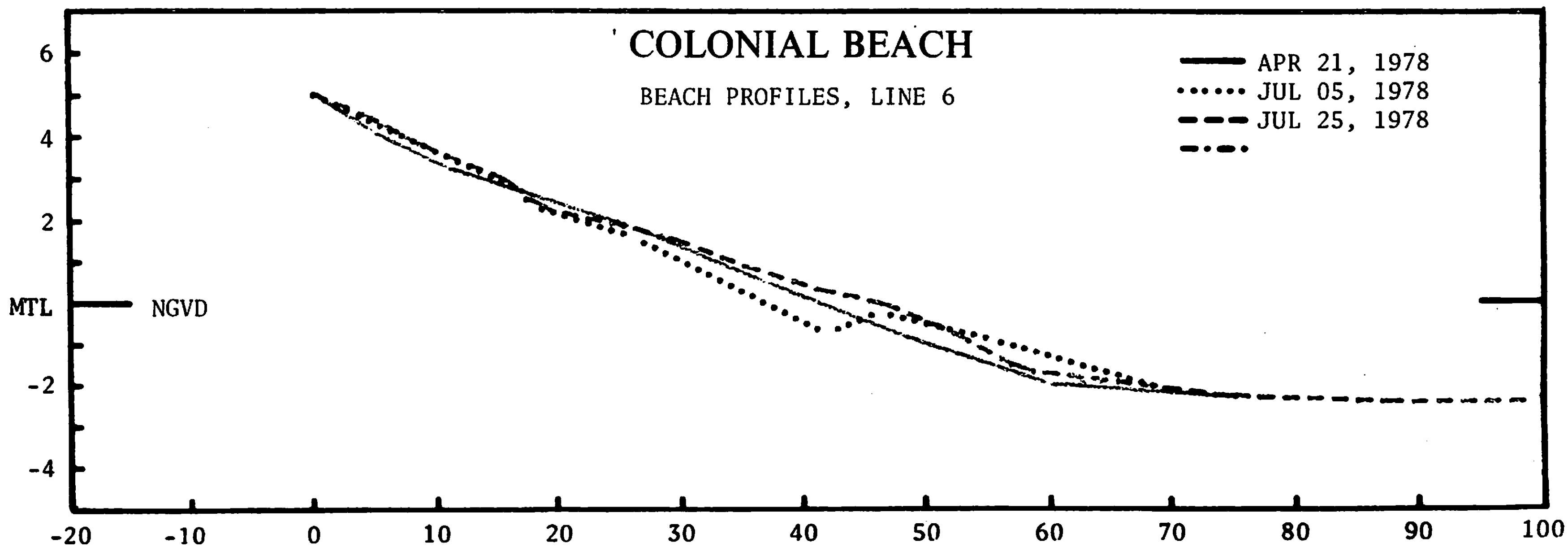
COLONIAL BEACH
BEACH PROFILES, LINE 4
JUL 08, 1977
SEP 26, 1977
APR 21, 1978
6
4
2
MTL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
COLONIAL BEACH
BEACH PROFILES, LINE 4
APR 21, 1978
JUL 05, 1978
JUL 25, 1978
6
4
2
MTL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET



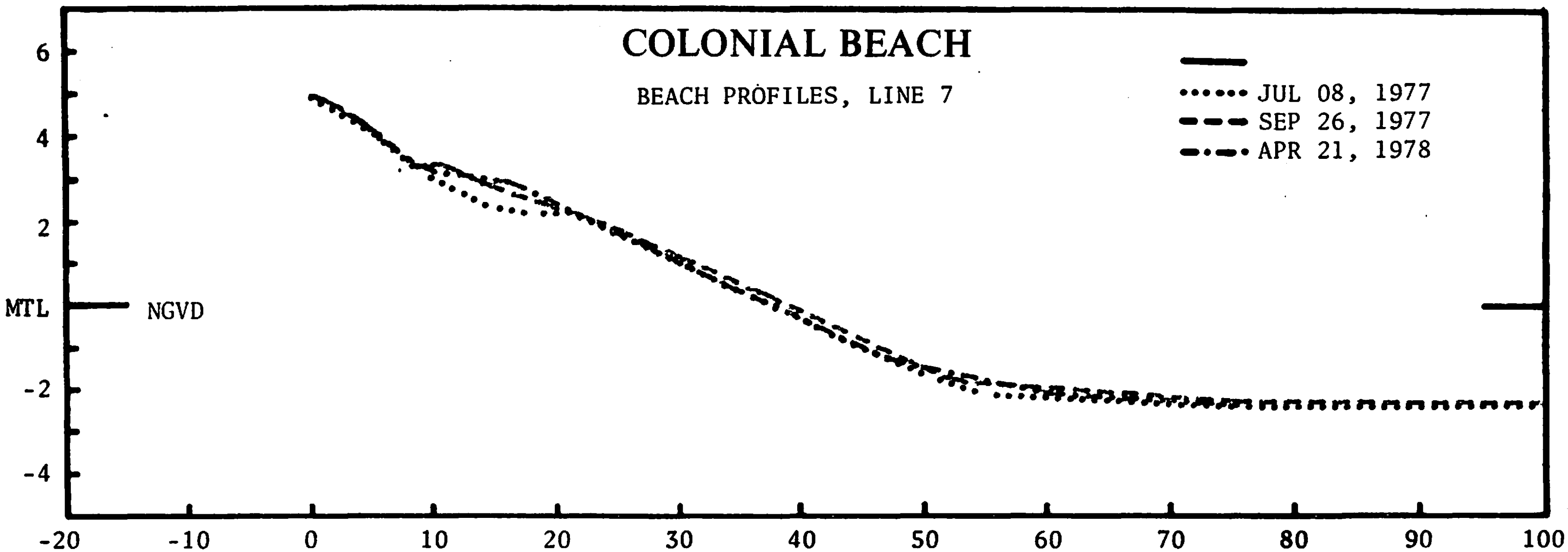


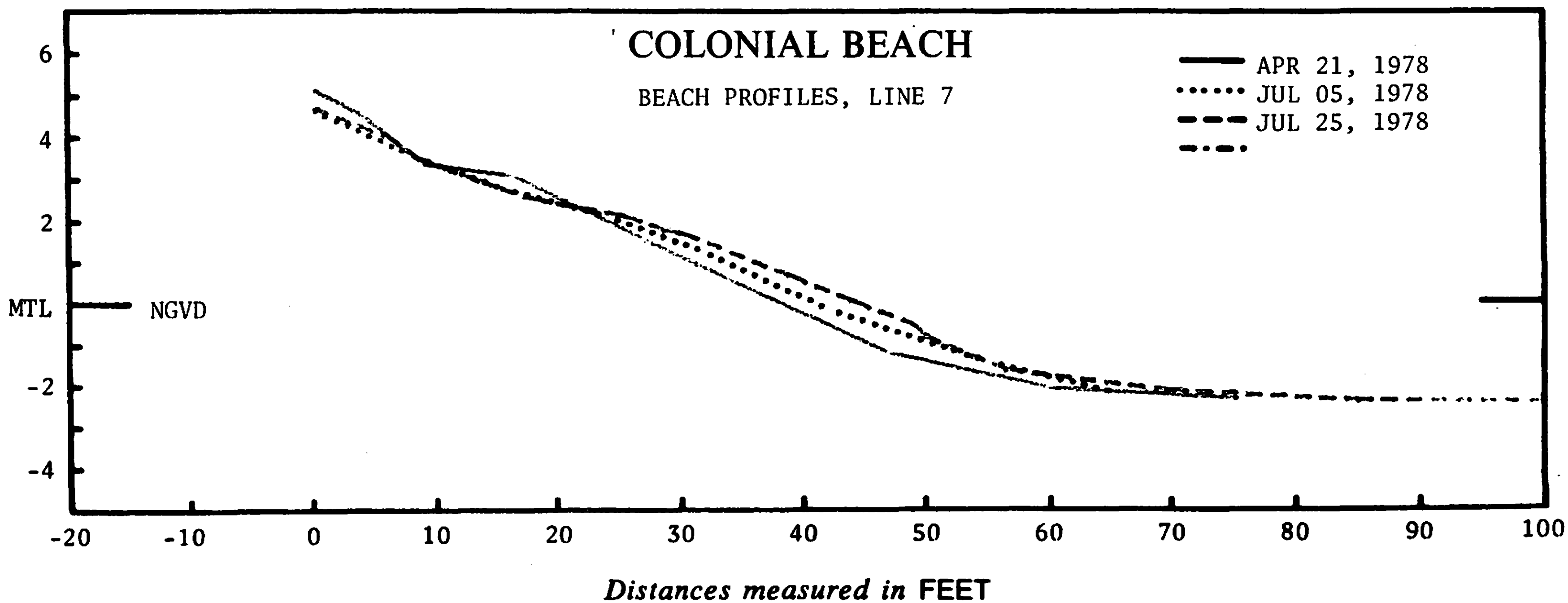
Distances measured in FEET

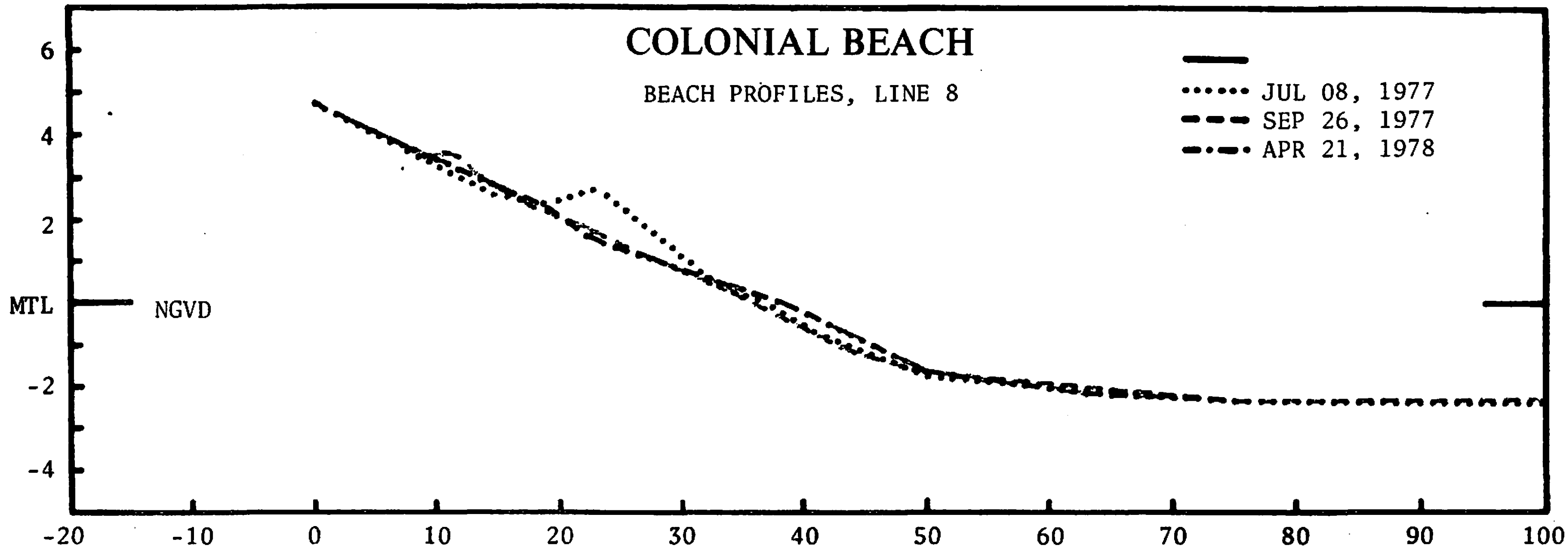


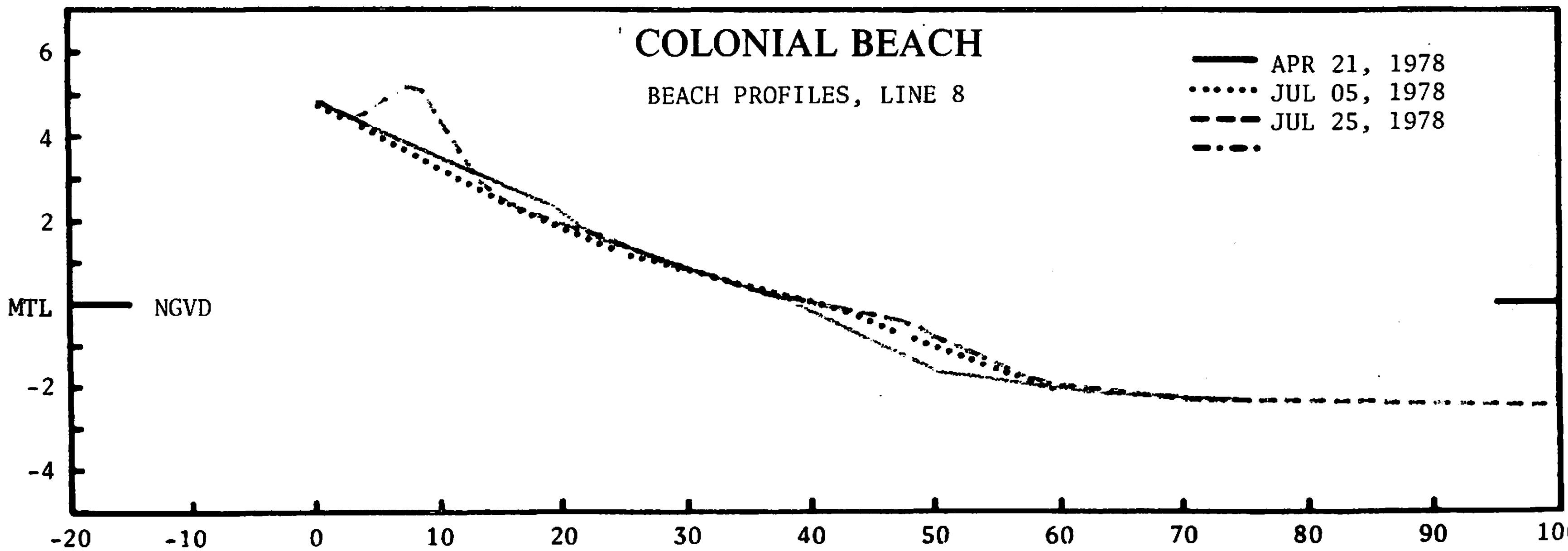


Distances measured in FEET

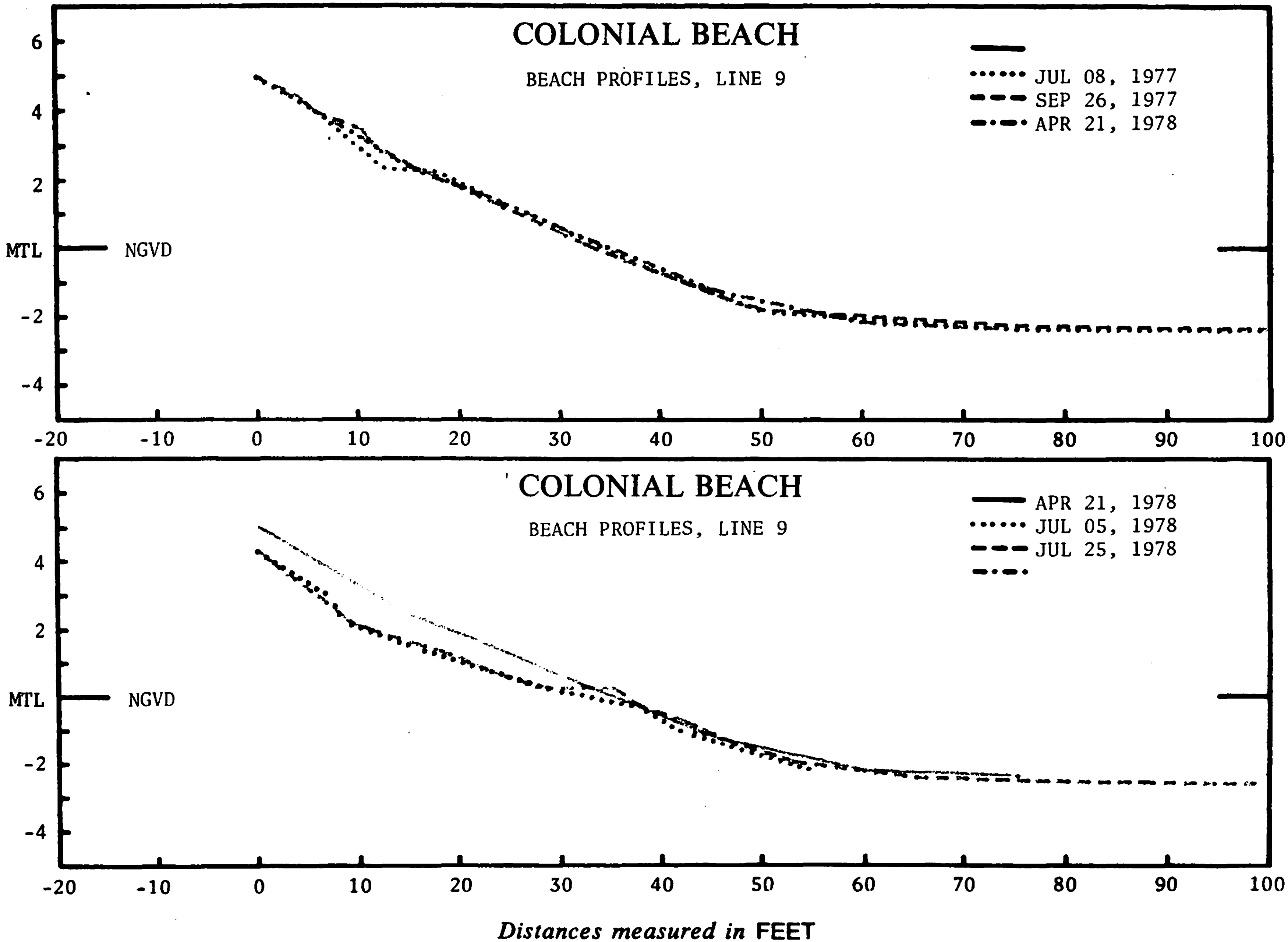

COLONIAL BEACH
BEACH PROFILES, LINE 7
JUL 08, 1977
SEP 26, 1977
APR 21, 1978
MTL
NGVD
6
4
2
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100

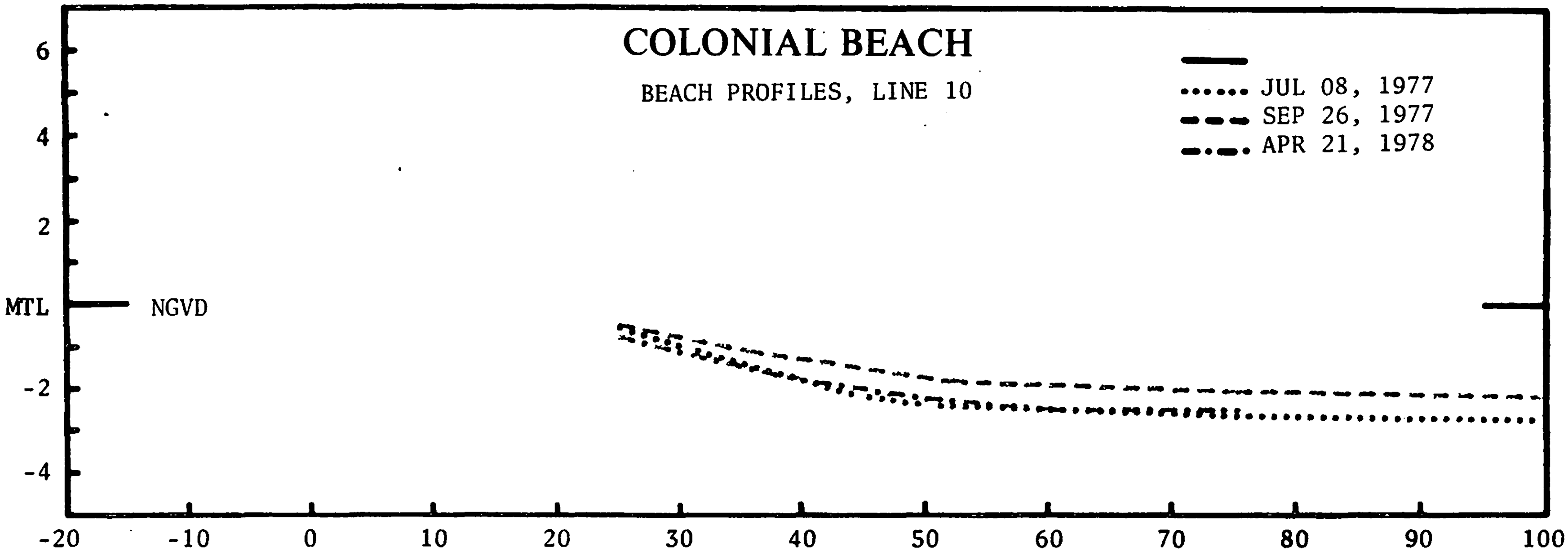

COLONIAL BEACH
BEACH PROFILES, LINE 7
APR 21, 1978
JUL 05, 1978
JUL 25, 1978
MTL
NGVD
6
4
2
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Distances measured in FEET

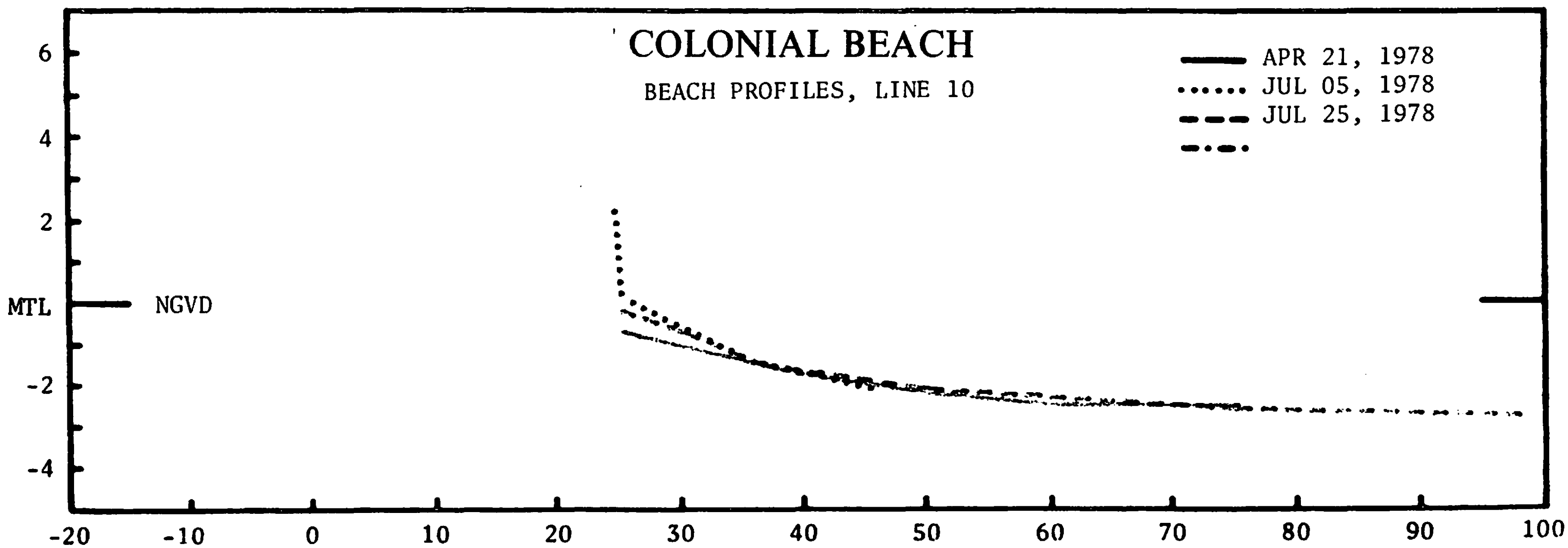




Distances measured in FEET


COLONIAL BEACH
BEACH PROFILES, LINE 9
JUL 08, 1977
SEP 26, 1977
APR 21, 1978
6
4
2
MTL
NGVD
-2
-4
-20
-10
0
10
20
30
40
50
60
70
80
90
100
COLONIAL BEACH
BEACH PROFILES, LINE 9
APR 21, 1978
JUL 05, 1978
JUL 25, 1978
Distances measured in FEET





Distances measured in FEET