AN OVERVIEW AND ASSESSMENT OF THE COASTAL PROCESSES DATA BASE FOR THE SOUTH SHORE OF LONG ISLAND

Proceedings of a Workshop
Held April 20-21, 1989

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AN OVERVIEW AND ASSESSMENT OF THE COASTAL PROCESSES DATA BASE FOR THE SOUTH SHORE OF LONG ISLAND

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INTRODUCTION

Background

In response to erosion and flooding problems encountered along the south shore of Long Island, the New York State Department of State, Division of Coastal Resources and Waterfront Revitalization and the Long Island Regional Planning Board are developing a shoreline development management plan that is cognizant of coastal erosion conditions for this area. The preparation of the plan is to include an examination and analysis of the environmental, economic, land use and regulatory factors affecting development and erosion control decisions along the coast for the purpose of formulating a comprehensive, coordinated response to chronic flooding and erosion conditions on the south shore.

In conjunction with these efforts a series of three workshops was held to bring together experts in coastal processes and engineering to examine erosion problems encountered along Long Island's south shore and possible means available for dealing with these problems from a technical perspective. More specifically, the individual workshops have been designed to focus on 1) identifying the generic physical data and information needed to develop a sound coastal erosion management program, 2) identifying the technical data presently available for the south shore, and 3) if possible, using these data to discriminate among the various available erosion control strategies for regional reaches of the coast in terms of their potential effectiveness and impacts.

The intent of these workshops is to provide technical information that will assist government officials and other interested parties in identifying, assessing, and selecting appropriate erosion management strategies for a particular area. The findings of the second workshop in this series are presented in this report.

Summary of First Workshop

The proceedings of the first meeting were summarized in a separate report (Tanski and Bokuniewicz, 1990). Based on the findings of the first workshop the information needed to develop a management plan for Long Island's ocean shoreline was grouped into eight categories:

1. long-term and short-term trends in shoreline migration
2. magnitude of shoreline changes caused by storms
3. volumetric shoreline changes including longshore transport rates
4. dune morphology and dynamics
5. effects of existing shore protective structures

6. wave climate

7. relative sea level rise

8. storm surges.

The confidence with which this type of information can be applied in the development of management programs depends not only on the quality of the specific data available but also upon the current state of our understanding of coastal processes in general and the processes active on the south shore in particular. As a result, there is a ninth category of information needed for management - knowledge of the coastal or shoreline processes. This includes the processes associated with inlets, longshore sediment transport, cross-shore sediment transport, dune formation, overwash and bluff erosion. Our understanding of all of these processes and their interaction must continue to evolve even as management decisions are being made based on the best data available at the time.

Workshop Objectives

The specific objectives of this meeting were to:

1. Identify the basic coastal processes data that are presently available for the south shore of Long Island based on the information needs identified in the first workshop in this series.

2. Assess the quality and coverage of the available data in terms of their utility for developing management strategies.

3. Identify critical gaps in the coastal processes data base.

Procedure

To achieve these objectives, four coastal scientists who have worked extensively on south shore erosion problems were invited to participate in this workshop (Appendix 1). Prior to the meeting, the participants were provided with the proceedings of the first workshop which defined the generic technical information required to identify, develop and evaluate erosion management strategies for coastal areas. At the meeting, the data requirements identified in the first workshop were reviewed. The participants then discussed the availability, coverage and quality of the coastal information in the categories listed above that has been collected along the south shore of Long Island.

The results of these deliberations are presented in this report.

GEOGRAPHIC SETTING

The area considered is a 106-mile stretch of the south shore of Long Island extending from East Rockaway Inlet to Montauk Point (Figure 1). This area can be divided into two physiographic provinces: a barrier island section extending from East Rockaway Inlet to Southampton (73 miles) and a headlands section between Southampton and Montauk Point (Taney, 1961). The barrier system is composed of four islands (from west to east: Long Beach, Jones Beach Island, Fire Island and Westhampton Beach) bounded by five stabilized inlets (from west to east: East Rockaway Inlet, Jones Inlet, Fire Island Inlet, Moriches Inlet, and Shinnecock Inlet). Extensive marshland is found behind the two westernmost barrier islands while the eastern two islands are separated from the mainland by wide shallow bays (Wolff, 1982). The 33-mile headland section is comprised primarily of beaches cut into glacial outwash deposits and, in certain locations, shallow ponds which are remnants of glacial drainage channels. The beaches along the easternmost 10 miles of this section fringe bluffs of glacial till 40 to 60 feet high.

An analysis of the land use patterns along the south shore was provided in the hurricane mitigation plan developed for each section by the Long Island Regional Planning Board (Long Island Regional Planning Board, 1984). In general, Long Beach is an urban area with high density development along much of its coast. Jones Beach Island is publicly owned and used primarily for recreational purposes. Over 10 million people a year visit its beaches. A 4-lane parkway built on a platform of about 40 million cubic yards of fill dredged from the bay in the 1920's extends along the length of the Island. There are also four small residential communities on lands leased from the local governments. Three of these communities are located on the landward side of the parkway. Fire Island is largely undeveloped but there are 17 low-to-moderate density seasonal residential communities along its length. Vehicle traffic is restricted (there are no paved roads) and access is primarily by ferry. Approximately 26 miles or 80 percent of the total length of the island is part of the Fire Island National Seashore and a portion of the 26 miles is managed by the National Parks Service as a wilderness area. Westhampton Beach is characterized by low density residential development, open space, and recreational beaches. Fifteen groins built as part of federal project between 1964 and 1970 are situated about 3 miles east of Moriches Inlet. The headland coast contains a mixture of low density residential development, recreation areas and open space.

SOUTH SHORE COASTAL DATA BASE

General Nature of Available Data

Most of the data and information on coastal processes available for the south shore of Long Island are largely the result of studies done by or for the U.S. Army Corps of Engineers as part of their hurricane protection, beach erosion, and navigation projects.

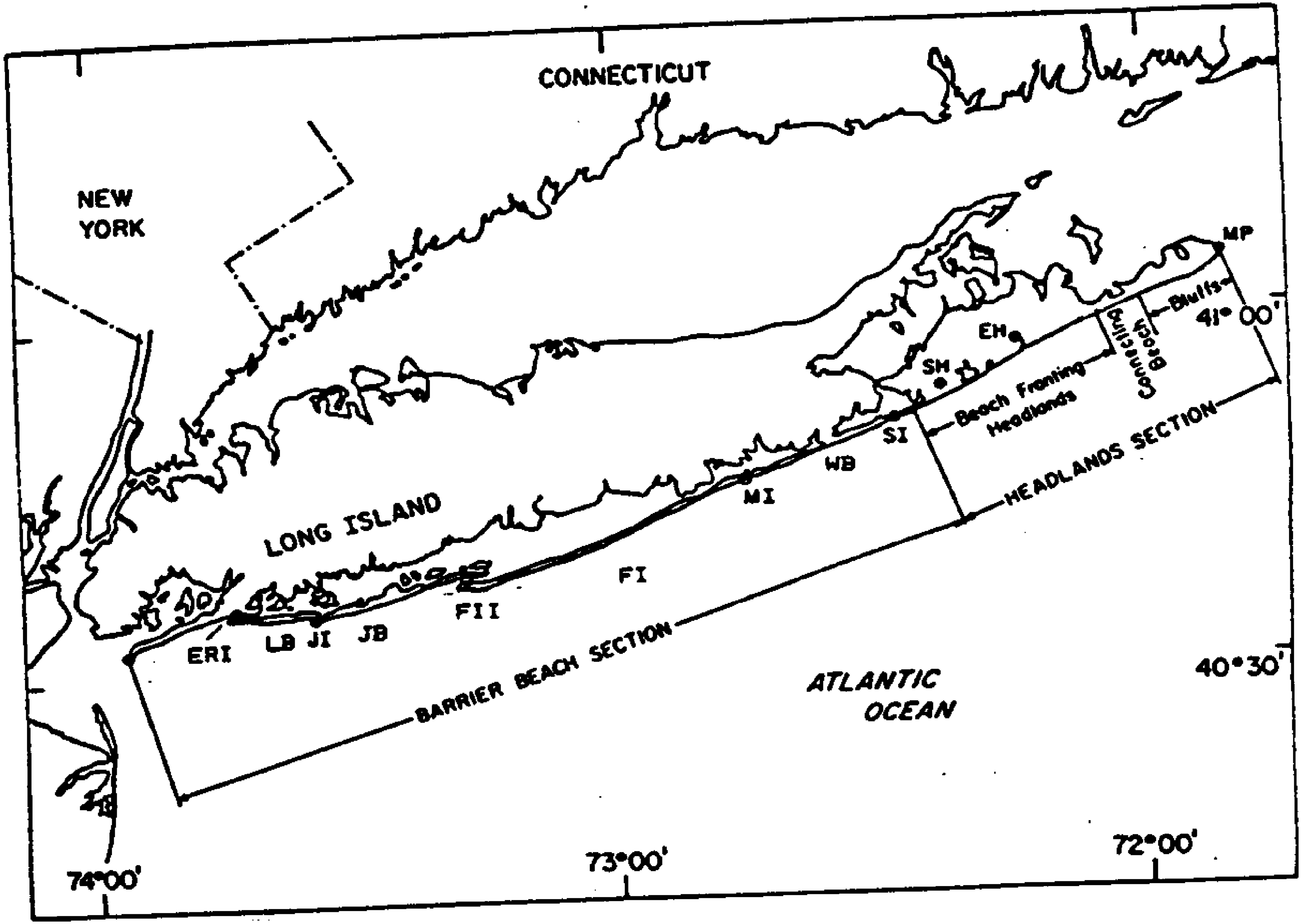

FIGURE 1. Index map. ERI = East Rockaway Inlet; LB = Long Beach; JI = Jones Inlet; JB = Jones Beach Island; FII = Fire Island Inlet; FI = Fire Island; MI = Moriches Inlet; WB = Westhampton Beach; SI = Shinnecock Inlet; SH = Southampton; EH = Easthampton; MP = Montauk Point.

Several regional studies of the geomorphology and sediments of the south shore were performed by the Coastal Engineering Research Center (CERC) (Taney, 1961; Taney, 1961a; Williams, 1976). For the purposes of their projects, the Corps has divided the study area into three separate reaches: Fire Island Inlet to Montauk Point; Fire Island Inlet to Jones Inlet; and Jones Inlet to East Rockaway Inlet.

For the Fire Island Inlet to Montauk Point reach, over 20 reports and general design memoranda have been developed for several federal projects in the area including; the Fire Island Inlet to Montauk Point beach erosion control and hurricane protection project, inlet navigation stabilization projects at Shinnecock, Moriches and Fire Island Inlets, and groin construction at Westhampton and East Hampton. Quantitative data for the littoral zone is skewed to those areas where projects have been undertaken. Although surveys and maps are available for the entire shoreline, 90 percent of the available information covers only about 20 percent of the shoreline. The detailed studies that have been done have been restricted to specific areas and limited time periods. As a result, few data sets are available that can be used to document the behavior of the beach at uniformly distributed locations over long time periods. Two recent studies have been done using the data sets that do meet this criteria. These studies were a regional sediment budget (Research Planning Institute, Inc., 1985) and a geomorphic analysis of shoreline conditions which included a comparison of historic shoreline positions (Leatherman and Allen, 1985). Both studies were done as part of a Corps' reformulation of the erosion control and hurricane protection plan authorized in 1960.

Survey data from 1933, 1940, 1955, a partial set in 1967, and 1979 were analyzed to construct the sediment budget (Research Planning Institute, Inc., 1985). According to the investigators involved in this project the most important data in terms of developing the budget were those obtained from long ranges surveyed by the Corps in 1955 at bench marks spaced approximately every mile along the shore and another set of ranges surveyed by Strock, Inc. in 1979 (Research Planning Institute, Inc., 1985). Although the Strock ranges did not necessarily correspond with the earlier Corps ranges, these two data sets were cited by the Research Planning Institute, Inc. as the most useful because they: 1) provided the most uniformly distributed coverage of the study area (Fire Island Inlet to Montauk Point) over a relatively long time interval; 2) represented survey data with good vertical control extending beyond the surf zone; and 3) covered a time period when most of the existing major coastal construction projects (inlet stabilization, groins, etc.) were in place and, thus, represent current conditions. Comparisons among a total of 135 profiles from the two years were used in developing the sediment budget for the 1955-1979 period.

The geomorphic analysis focused on identifying and quantifying the rates and modes of barrier island behavior over the past 500 years

(Leatherman and Allen, 1985). In addition to reviewing the literature (including the sediment budget done by the Research Planning Institute, Inc., 1985) Leatherman and Allen examined 139 vibracores, 80 miles of seismic reflection records, ground penetrating radar records, historic maps and aerial photographs from 1834 to 1979 (for the development of metric maps of the past shoreline positions), as well as the results of an eolian sediment transport study.

Data on coastal processes west of Fire Island are less comprehensive, not as well documented, and, in many cases, not as recent as that available for the eastern section of the study area. As mentioned previously, most of the available studies relate to the federal dredging project at Fire Island Inlet. A physical model of this inlet was developed by the Waterways Experiment Station (Bobb and Boland, 1969) and the 1971 general design memorandum for the inlet was recently reviewed (Galvin, 1985). Under the authorized Corps' project, material dredged from the inlet is supposed to be placed on a feeder beach on Jones Beach Island (between Fire Island Inlet and Jones Inlet) as part of a combined navigation and shore protection program. The erosion protection plan and data on shore conditions for Jones Beach Island are contained primarily in a 1964 beach erosion study (U.S. Army Corps of Engineers, 1965). Researchers from the Corps' Coastal Engineering Research Center (CERC) have also analyzed data from monthly subaerial beach profiles taken between 1962 and 1974 (Everts, 1973; Morton et al., 1986). Quantitative survey data in this area have also been collected by the Corps in conjunction with a recent inlet dredging and sand bypassing project but an analysis of these data has not been published by the Corps at this time.

The only data available from the Corps for the shoreline between Jones Inlet and East Rockaway Inlet was in the form of draft hurricane and beach erosion protection study dated 1966 (U.S. Army Corps of Engineers, 1966). The Corps is presently updating and analyzing the available data for this area. The results of these efforts, however, were not available at the time of this meeting.

In addition to the Corps-related work there have been a number of studies and reports done on the south shore by other groups and individuals. For the most part, these studies focus on specific parts of the coast during different time periods. Many of the published studies and available reports are cited in the bibliography and references section of this report, but this listing is not necessarily complete.

Trends in Shoreline Migration

Studies of the long-term trends in shoreline position have been conducted by Taney (1961) for most of the south shore and by Leatherman and Allen (1985) for the area east of Fire Island Inlet. Taney compared the position of high-water shorelines for various time periods using several sets of Coast and Geodetic Survey charts and U.S. Army Corps of Engineers maps and ranges dating from 1834 to 1956. Leatherman and Allen developed maps of the shoreline at mean high tide based on Coast and Geodetic Survey charts and aerial photographs and compared the shoreline position for four time periods (1834/1838, 1873/1892, 1933, and 1979) to calculate annual recession/accretion rates. Because of the technique used in the latter study, these are considered the most precise values available on shoreline changes (Leatherman, 1983). The data from Leatherman and Allen (1985) are plotted in Figures 2 and 3; data collected by Taney (1961) are also plotted for those areas that were not investigated by Leatherman and Allen.

Additional information on long-term shoreline changes for some subsections is also available. Zarillo and Zarillo (1989) have compiled information on the 20-mile stretch of shoreline between Southampton and East Hampton. Rich (1975) studied the same area using 10 sets of aerial photographs taken between 1938 and 1972 to measure changes in the vegetation line, the dune base line and the high water line. A graphic summary of the results of Rich's study is provided in Figure 4.

A number of problems in interpreting the data available on the long-term shoreline position changes were noted. These problems include:

1. The old maps and charts used for comparison often represent surveys done over many months and it is not always clear whether or not the shoreline mapped represents the shoreline at mean sea level, the high-water shoreline or some other indicator. As a result, unless the shoreline indicator surveyed is clearly defined, as it is on National Ocean Survey topographic sheets (NOS T-Sheets), maps must be interpreted as qualitative indicators of shoreline position.

2. If aerial photographs are used the position of the color change on the beach representing the demarcation between saturated and unsaturated sand is often interpreted as the high water shoreline. Since the water level is constantly changing, this point is likely to be between mean sea level and high water. However, because of storm surges and other non-tidal water level variations, the wet-sand boundary may actually be below mean sea level or above high water under certain conditions.

3. Because of the differences in the exact indicator used for the shoreline position, comparisons between some maps and aerial photographs may be less reliable than comparisons between two maps or between two aerial photographs.

4. There are unavoidable measurement errors due to the accuracy of maps, their scale, distortion and mismatching overlays of two sequential shorelines. If the process is

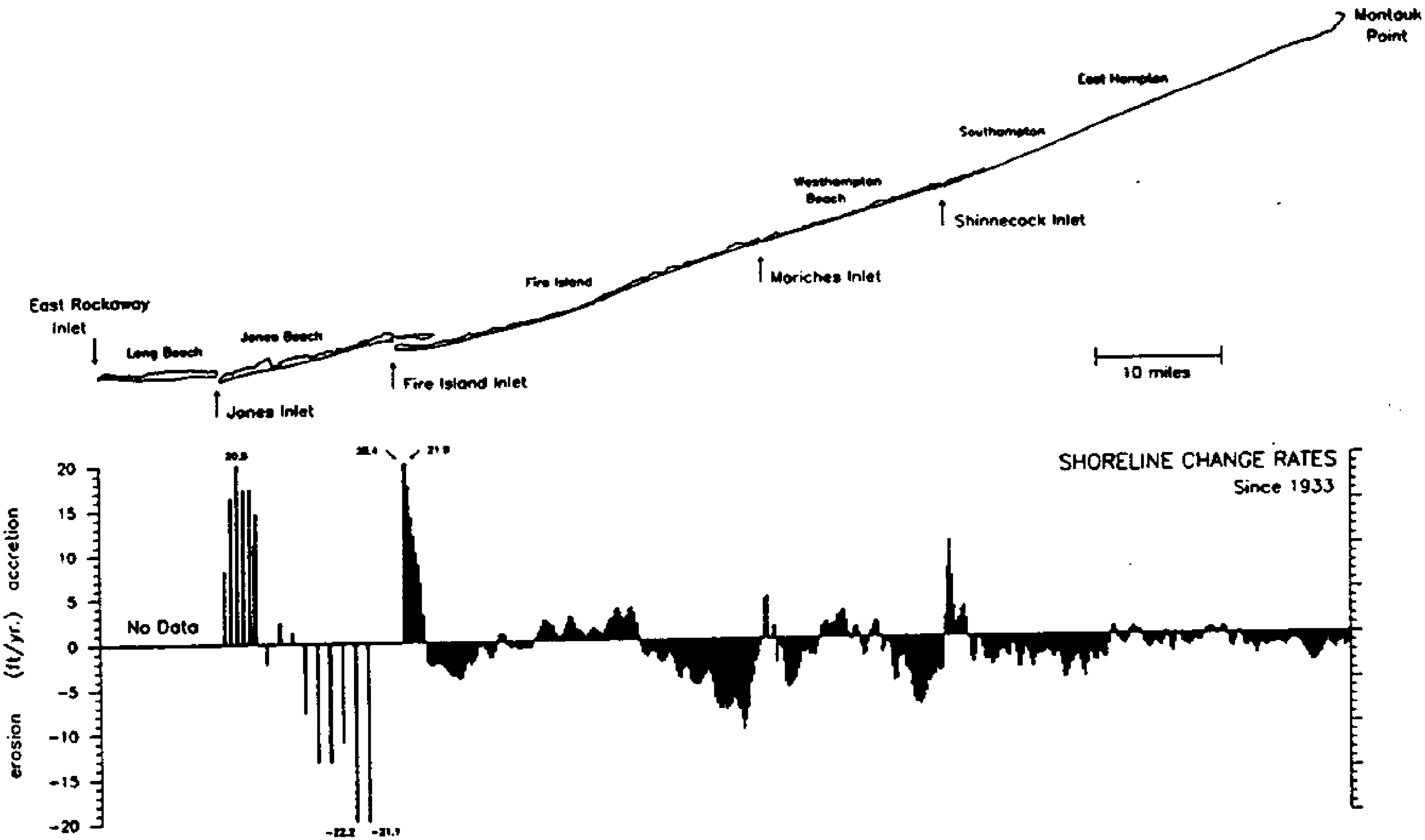

FIGURE 2. Average rate of shoreline change based on comparisons of maps, surveys and aerial photographs dating from 1933. East of Fire Island Inlet the changes are the average between 1933 and 1979 (Leatherman and Allen, 1985); west of Fire Island Inlet the changes are those recorded between 1933 and 1951 or 1955 (Taney, 1961).

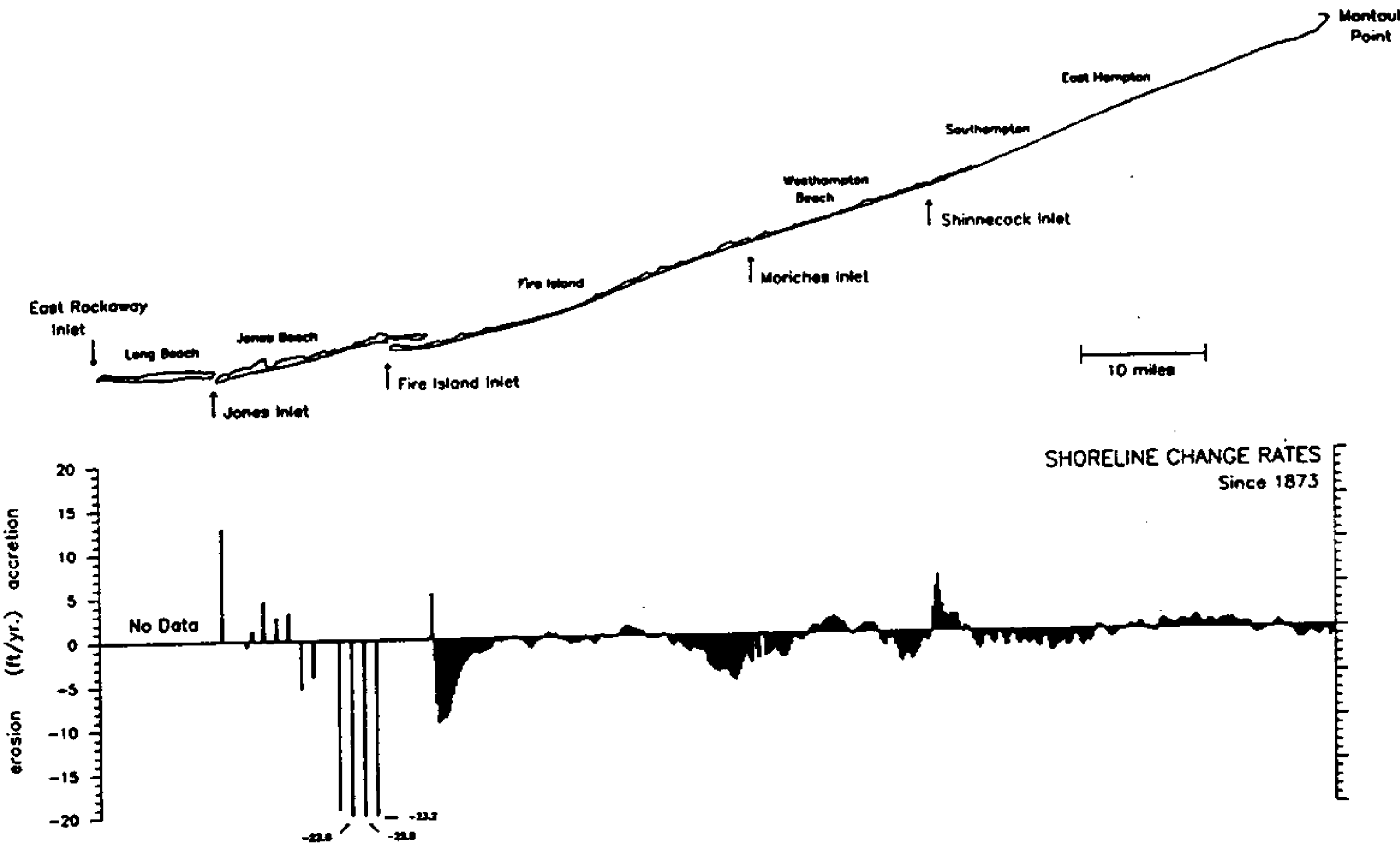

FIGURE 3. Average rate of shoreline change based on comparisons of maps, surveys and aerial photographs dating from 1873. East of Fire Island Inlet the changes are the average between 1873 or 1892 and 1979 (Leatherman and Allen, 1985); west of Fire Island Inlet the changes are those recorded between 1873 or 1892 and 1951 or 1955 (Taney, 1961).

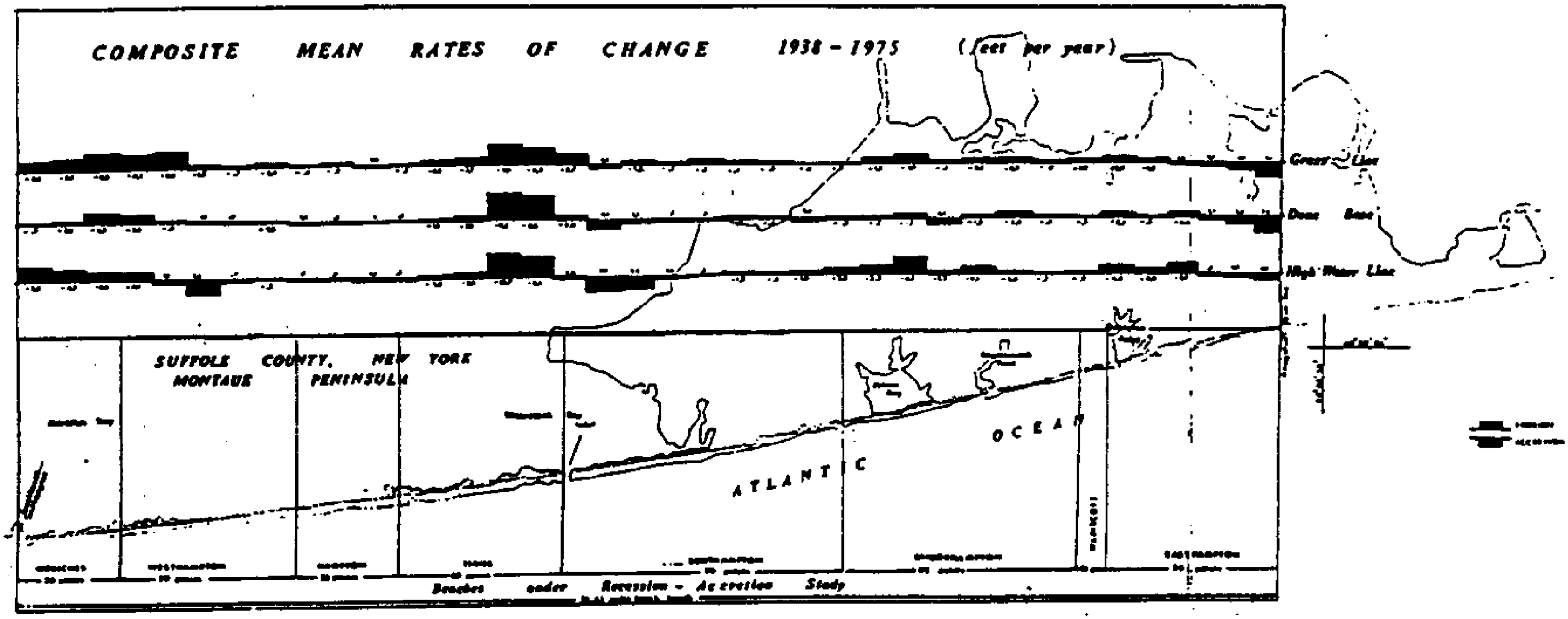

FIGURE 4. Changes in vegetation line, dune base and high water line between 1938 and 1975 in Southampton and East Hampton. From: Rich, 1975.

done carefully, however, these errors can be small.

5. There are large unpredictable interannual variations in the shoreline position due to short-term changes in the beach form caused by storms. In some cases, this short-term variability may result in changes in the location of the waterline that are of the same magnitude as the long-term change in shoreline position. Because of these short-term changes it is very difficult to establish reliable estimates of the long-term trends in shoreline migrations with the available data sets unless the trends are very large (see Appendix 2).

Data on the short-term fluctuations of shoreline positions have been developed for four locations where subaerial beach profiles had been surveyed at least several times per year for periods up to 10 years. The studies were done at Jones Beach Island (Everts, 1973), Ocean Beach (Fire Island) (Tanski, 1983), Fire Island Pines (Bokuniewicz, 1987) and East Hampton (Bokuniewicz et al., 1980). An examination of the available profile data indicated that the maximum annual horizontal variations in the shoreline position for individual profiles ranged from 148 feet to 270 feet (Table 1).

The magnitude of the uncertainty introduced into the calculation of long-term shoreline trends by these short-term variations at the four locations is illustrated in Figures 5 and 6. Both the maximum and average range of the interannual (short-term) variations in shoreline position were determined from the measured profiles and were divided by the number of years in the different time periods for which long-term rates shown in Figures 2 and 3 have been calculated. These periods were 22 and 78 years for the shoreline west of Fire Island Inlet (Taney, 1961) and 46 and 106 years for the shoreline east of Fire Island Inlet (Leatherman and Allen, 1985). The resulting values in feet per year are plotted for the different sites in Figures 5 and 6. As can be seen, for the shorter time intervals (22 and 46 years), the average short-term variations in the beach can account for uncertainties of between ±2 and ±7 feet per year in the calculated recession (or accretion) rate depending upon the location (Figure 5). The uncertainty decreases as the time period increases (Figure 6). With the data presently available, long-term rates of shoreline change can only be accurately established if they exceed the magnitude of the uncertainty caused by these short-term fluctuations. Appendix 2 presents a discussion of how these interannual variations were calculated and the effect they have in interpreting shoreline change.

Several recommendations were made during the workshop for improving the quality of information on long-term shoreline recession and accretion rates:

1. Only aerial photographs and/or NOS T-sheets should be used in the analysis. The photographs should be properly

Table 1. Short-Term (Interannual), Horizontal Variations in Shoreline Position Based on Profile Data.

Location	Maximum Range, Ft.	Average Range, Ft.	Years of Data
Jones Beach	270	169	10
Ocean Beach	188	98	1
Fire Island Pines	147	89	3
East Hampton	280	124	9

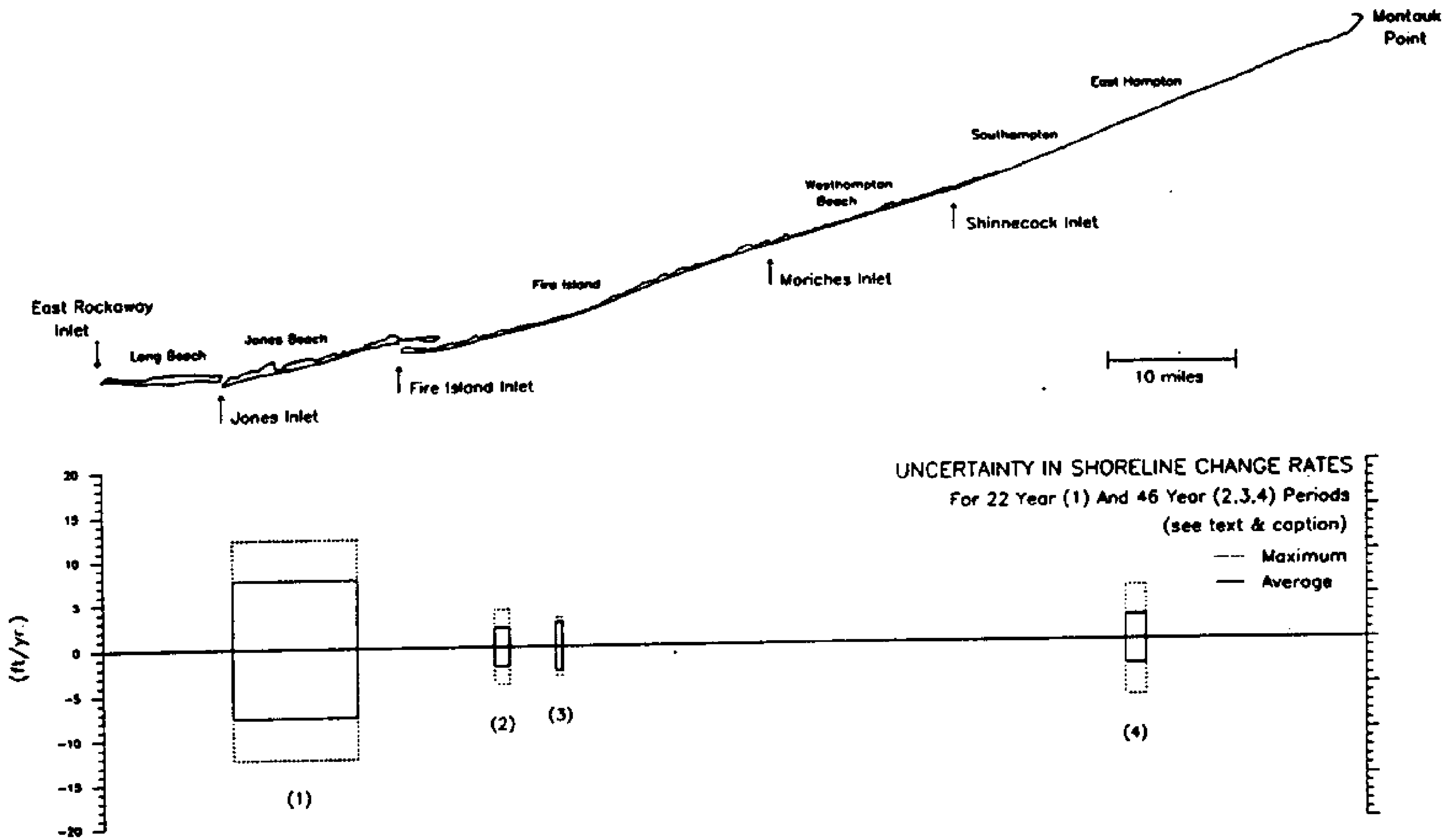

FIGURE 5. Possible uncertainty in shoreline change rates measured over 22-year (west of Fire Island Inlet) and 46-year periods (east of Fire Island Inlet) due to short-term (interannual) fluctuations in shoreline position measured from beach profiles. The solid bars represent the uncertainty, in feet per year, calculated using the average observed interannual variation while the dashed bars are based on the maximum annual variation observed at each location.

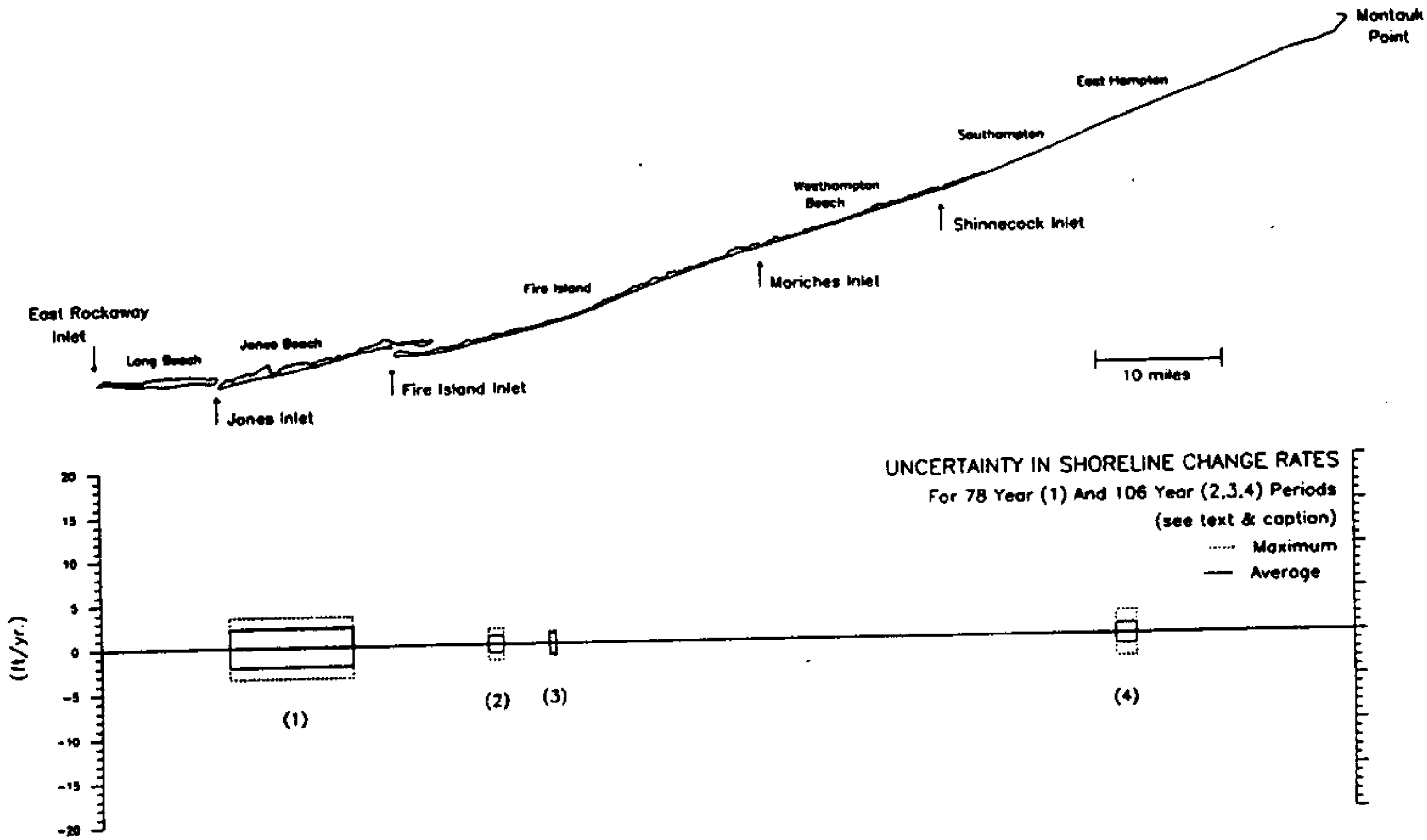

FIGURE 6. Possible uncertainty in shoreline change rates measured over 78-year (west of Fire Island Inlet) and 106-year periods (east of Fire Island Inlet) due to short-term (interannual) fluctuations in shoreline position measured from beach profiles. The solid bars represent the uncertainty, in feet per year, calculated using the average observed interannual variation while the dashed bars are based on the maximum annual variation observed at each location.

rectified and superimposed on a well-surveyed, large scale (1 inch = 200 feet) maps. Such maps are available from the Suffolk County Department of Public Works at Yaphank.

2. The period from 1940 (after the 1938 hurricane) to the present is of most interest, since this period includes most of the major structural alterations that have been implemented along the shore and is, thus, most representative of present conditions.

3. The comparisons could be redone using the position of a particular contour related to some part of the dune instead of the high water shoreline. The dune should respond instantly to severe erosion but should only change slowly during the interval between major storms, reducing the uncertainties associated with the use of the highly variable high water mark as an indicator of shoreline position.

4. The uncertainties in long-term shoreline trends associated with the use of the high water mark as an indicator of shoreline position should not be calculated from the extremes in the observed interannual ranges of the position of the water line. Rather, a probability distribution of widths around the average position should be calculated and used as a measure of the uncertainty of the long-term shoreline erosion and accretion rates.

Shoreline Changes Due to Storms

Although the occurrence of storms on Long Island is well documented (Table 2), quantitative data on the response of the shoreline to storm events are extremely limited due to the lack of measurements during periods of storm activity. Morton and others (1986) analyzed beach volume changes on Jones Beach Island based on comparisons of sequential, subaerial profiles for eight major storms occurring between 1968 and 1971. Surveys were done between 1 and 3 days after the passage of the storms. Although the shoreline response was variable along this stretch of the coast, they found that winter storms consistently reduced the volume of sand on the subaerial beaches with losses of sand ranging from 4 to 21 cubic yards per foot of beach. These volume losses were nearly completely recovered within one month of the storm activity. DeWall (1979) reported similar results for Westhampton Beach indicating that the rapid storm recovery of the subaerial beach is typical of the south shore beaches. This phenomena was primarily attributed to natural onshore transport of sediment and the relatively low frequency of occurrence of storm waves in the area (Morton et al., 1986).

No quantitative information on storm-induced changes of the beach below mean sea level is available due to the lack of sequential surveys extending offshore.

Table 2. Major storms of record. From: Leatherman, 1989.

Date		Type	Date		Type
1635	Aug. 15	Hurricane	1953	Nov. 6-7	Extratropical
1638	Aug. 3	Hurricane	1954	Aug. 31	Hurricane
1656	Dec. 28	Unknown	1954	Sept. 11	Hurricane
1667	Aug. 29	Unknown	1954	Oct. 15	Hurricane
1690-91	Winter	Unknown	1955	Aug. 13	Hurricane
1720	May 22	Unknown	1955	Oct. 14-16	Extratropical
1723	July 29	Unknown	1958	Mar.20-21	Extratropical
1776	Aug. ?	Unknown	1961	Sept. 22	Hurricane
1788	Aug. 19	Hurricane	1962	Mar. 6-8	Extratropical
1811	Dec. 23-24	Unknown	1963	Nov. 7	Extratropical
1815	Sept. 22	Hurricane	1963	Nov. 29-30	Extratropical
1821	Sept. 3	Hurricane	1966	Jan. 23	Extratropical
1851	Aug. 26	Tropical	1967	Jan. 26-28	Extratropical
1869	Sept. 8	Hurricane	1968	Nov. 10-13	Extratropical
1873	Aug. 13	Northeaster	1969	Mar. 2	Extratropical
1879	Aug. 18	Hurricane	1969	Dec. 12	Extratropical
1880	Feb. 3	Unknown	1969	Dec. 25	Extratropical
1888	Mar. 11-14	Extratropical	1970	Nov. 17	Extratropical
1893	Aug. 23-24	Hurricane	1970	Dec. 12	Extratropical
1894	Oct. 10	Hurricane	1972	Feb. 19	Extratropical
1897	Oct. 24-25	Extratropical	1972	Dec. 15	Extratropical
1903	Sept. 16-17	Hurricane	1973	Mar. 21	Extratropical
1904	Sept. 14-15	Hurricane	1973	April 5	Extratropical
1931	Mar. 4	Extratropical	1980	Jan. 22-23	Extratropical
1935	Nov. 17	Hurricane	1984	Mar. 29	Extratropical
1938	Sept. 21	Hurricane			

A number of recommendations for improving information on shoreline changes during storms were suggested. These include:

1. The shift in the shoreline position after the 1962 storms could be calculated. There was a set of aerial photographs taken after this storm and this shoreline was reported by Leatherman and Allen (1985). The comparison should be made between the 1962 storm shoreline and the next closest (in time) shorelines before and after 1962. A particular contour related to the dune could be used instead of the waterline as an indicator of shoreline position change. It was suggested that the six-foot contour might be used as an indicator of the base of the dune in many areas.

2. Available beach surveys should be searched for sets before and after storms and a detailed analysis of these data performed.

3. Models of coastal flooding including dynamic changes in the beach and the dune could be developed. The present V-zone maps prepared by FEMA were not considered to be adequate since they only consider relative elevations and do not take into account beach changes due to erosion or deposition.

Volumetric Shoreline Changes/Sediment Budgets

The most complete long-term information on volumetric shoreline changes is that developed in a sediment budget study by the Research Planning Institute, Inc., (1985) for the area east of Fire Island Inlet. The data on the net longshore transport and the total net annual volume changes occurring along the shore from Montauk Point to Fire Island Inlet are plotted in Figure 7. The net annual volume changes for the portions of the shoreline above mean high water, in the intertidal zone and between mean low water (MLW) and -24 feet MLW for the period 1955-1979 are shown in Figure 8. The results show, for example, that the large increase in the longshore drift at Fire Island Inlet appears to be due to the reworking of the old Fire Island Inlet ebb tidal delta to the east of the inlet. Unfortunately, similar information for comparative time periods has not been accumulated for the shoreline west of Fire Island Inlet.

Although the sediment budget study represents the best available data on long-term volumetric changes, four limitations associated with this data set were noted:

1. Reliable comparative long ranges and bathymetry were available only for limited areas and time periods. One hundred and thirty-five profiles were available for a 85-mile stretch of coast and in many cases sequential profiles (in time) were not done at exactly the same location requiring the juxtaposition of data from

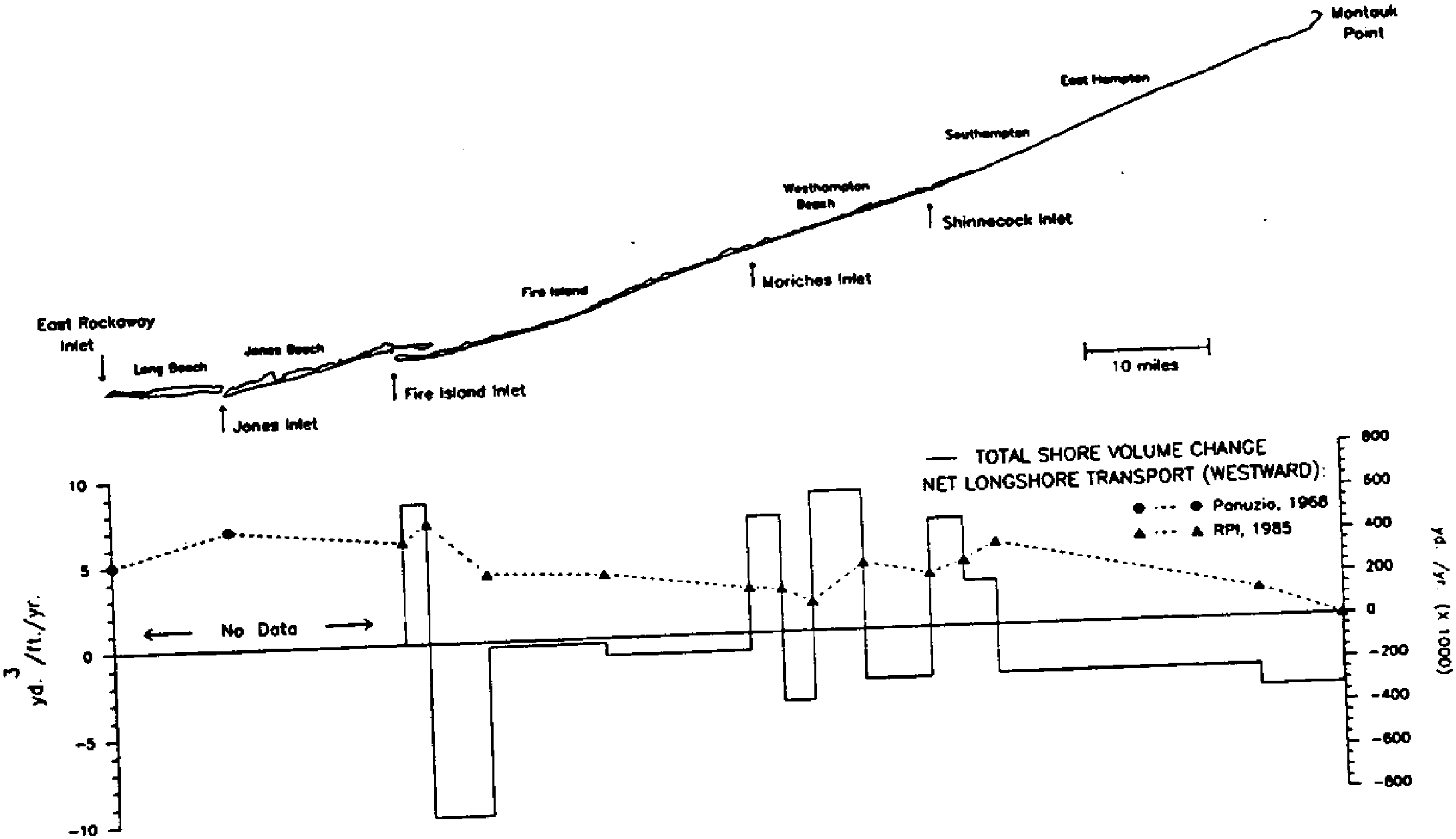

FIGURE 7. Net longshore transport rates and average net shore volume changes above -24 feet MLW between 1955 and 1979. From: Research Planning Institute, Inc., 1985.

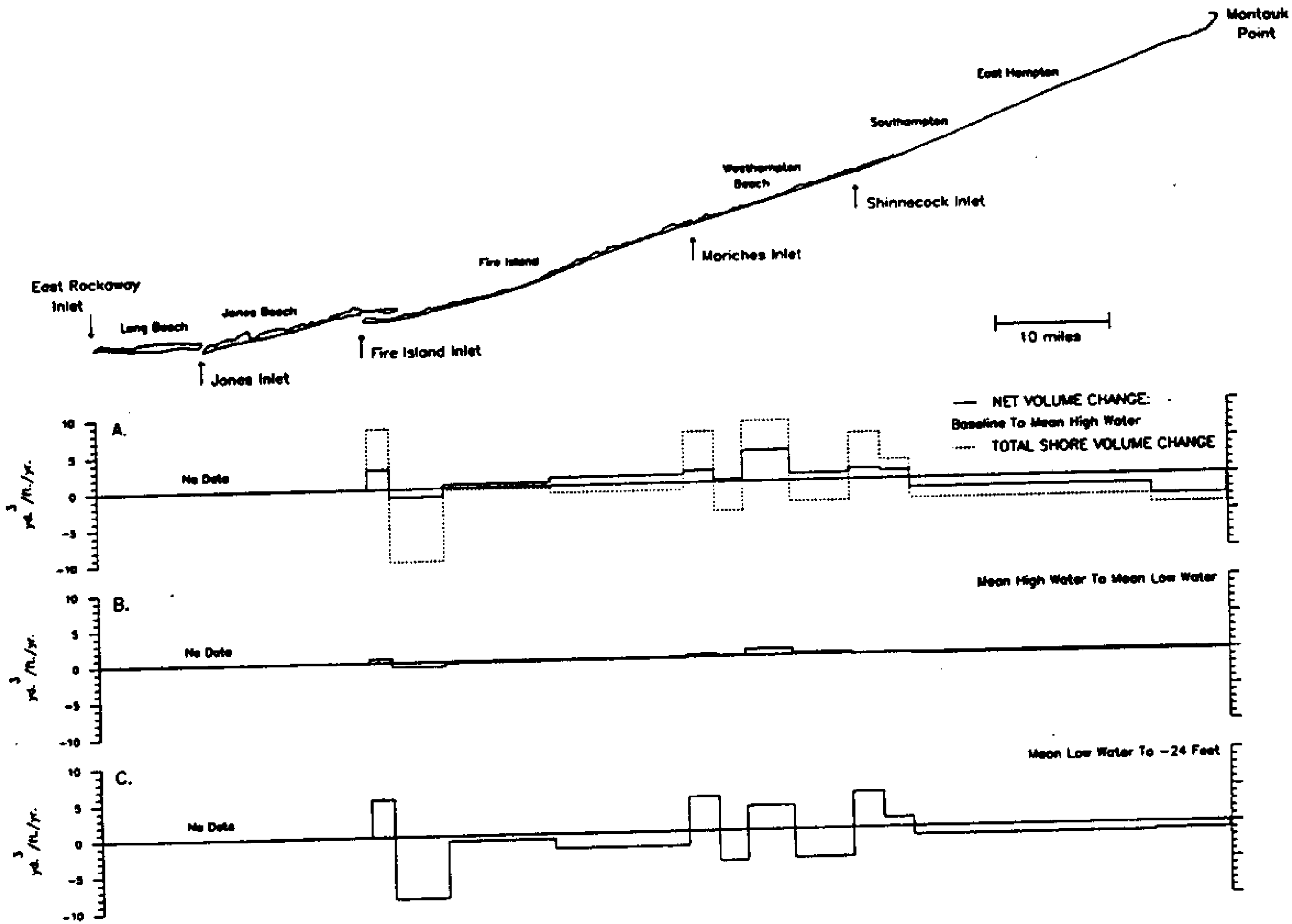

FIGURE 8. Average net shore volume change by lens between 1955 and 1979. Dashed line in A represents total observed volume changes for all three lenses. From: Research Planning Institute, Inc., 1985.

adjacent ranges for comparisons.

2. Some of the available ranges only extended to depths of 24 feet MLW. Although other ranges extended further seaward, the lack of comparative data precluded an analysis of changes below this depth for the entire study area.

3. The relatively stable geomorphic history of the south shore shoreline over the past 50 years increases the margin of error for comparative profile analysis compared to areas that are experiencing rapid erosion or accretion.

4. The study only covered the area east of Fire Island Inlet.

To improve the long-term information at least two steps should be taken:

1. The 1955 Corps profile lines and the 1979 Strock profile lines should be reoccupied and the volume comparisons updated to include the 1979-1989 period.

2. More closely spaced ranges are needed, especially near inlets. Additional profile lines should be established and surveyed. A recommended spacing of 2000 feet along the shoreline was suggested.

Information on seasonal and short-term volumetric changes is limited to those areas where regular beach monitoring programs have been undertaken (Everts, 1973; Morton et al., 1986; Tanski, 1983; Bokuniewicz, 1987; Bokuniewicz et al., 1980). Beach profiles extending to mean sea level or low water have been measured at the four locations described in the previous section on shoreline trends. The New York State Office of Parks and Recreation and the Department of Transportation have also been surveying the position of the driftline along a 15,000-foot section of Jones Beach Island since 1987 in response to an emergency situation where erosion threatened the parkway (Buttner, 1989). This particular section of coast is within the area analyzed by Everts (1973) and Morton et al. (1986). These studies only involved measurements of the subaerial beach; they do not provide information on changes occurring below mean sea level where substantial sediment movement takes place.

The short-term volumetric changes associated with the subaerial beach are fairly constant along the shoreline (Bokuniewicz and Schubel, 1987). Profiles taken at approximately monthly intervals do not reveal a strong seasonal cycle but appear to be influenced by storm events. As an example, Figure 8 illustrates the subaerial beach volume changes measured at a station in East Hampton over a multi-year period. Average changes between successive surveys in the areas where profiles were measured were 13 cubic yards per foot of shoreline. Although the maximum change caused by a storm at any

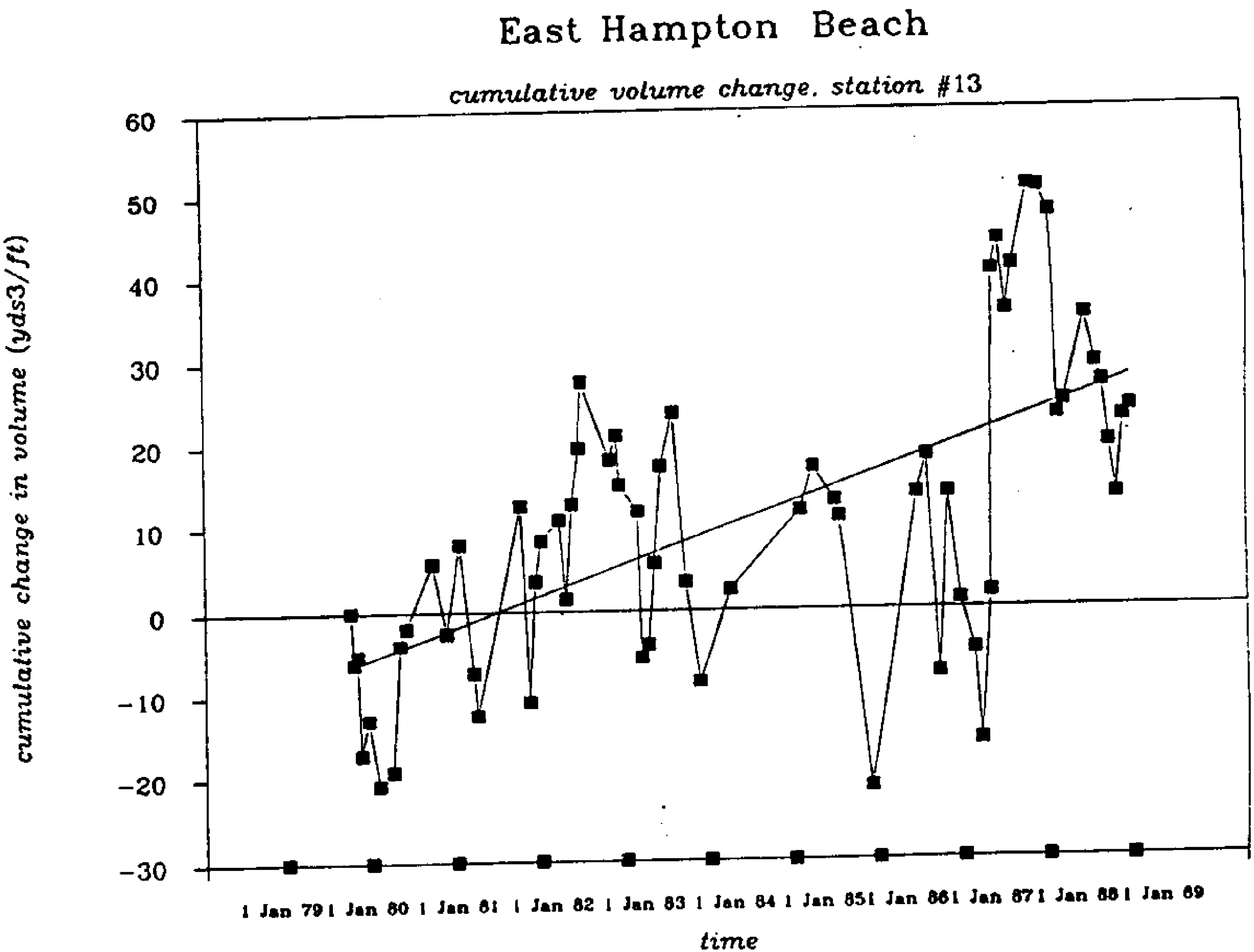

FIGURE 9. Beach volume changes at East Hampton based on successive subaerial profiles at a typical station.

particular station may be 5 to 10 times the average change, the average volumetric changes due to storms were not exceptionally larger than 13 cubic yards per foot of shoreline (Bokuniewicz and Schubel, 1987).

Dune Morphology and Dynamics

No systematic studies of dune morphology have been done for the area even though the data needed to develop this information might be obtained from available topographic maps. Changes in dune morphology could also be obtained by digitizing contours on large-scale topographic maps surveyed in 1955 and 1979 but the workshop participants thought that the changes were likely to be very small and extremely uncertain.

A study of the eolian sediment budget for shores east of Fire Island Inlet was done by investigators from Rutgers University for the National Park Service (McCluskey et al., 1983). They calculated the volume of sediment transported by eolian processes for the entire area to be approximately 250,000 cubic yards per year with over 90 percent of this transport occurring seaward of the dune crest and in an easterly direction. Based on sand trap data, they also estimated the amount of sand transported across the crest of the dune from the seaward direction to be 0.08 cubic yards per foot of dune per year. This volume comprised less than 1 percent of the bulk of the dune (the investigators defined a "prototype" dune as having a volume of 37 cubic yards per foot). Using the findings of the eolian sediment budget study, McCluskey et al. (1983) formulated a generalized model of the potential effects of different conditions of development which is shown in Figure 10.

Effects of Structures

The distribution of groins and jetties in the study area are plotted in Figure 11. There are 69 major groins and jetties in the study area. The highest concentration of groins is on Long Beach which has 48. The most persistent questions relating to the impacts of structures concern the amount of sand trapped by the structures, the amount of sand currently bypassing and the degree of downdrift erosion caused by the structures. Although groins are far more prevalent in the urbanized Long Beach section to the west, the only detailed study of the effects of groins in the study area was that done by DeWall (1979), who used subaerial beach profiles measured between 1964 and 1973 to examine the impact of the Westhampton groin field (15 groins constructed between 1965 and 1970). His findings in terms of the net volume changes of the adjacent beach are summarized in Figure 12 which clearly shows substantial accretion within and updrift of the groin field and substantial losses downdrift. The effects of the groin field are also evident in the data on long-term changes in shoreline position (Figures 2 and 3) and the net volume changes (Figure 8).

The sediment budget data indicate the coastal compartment

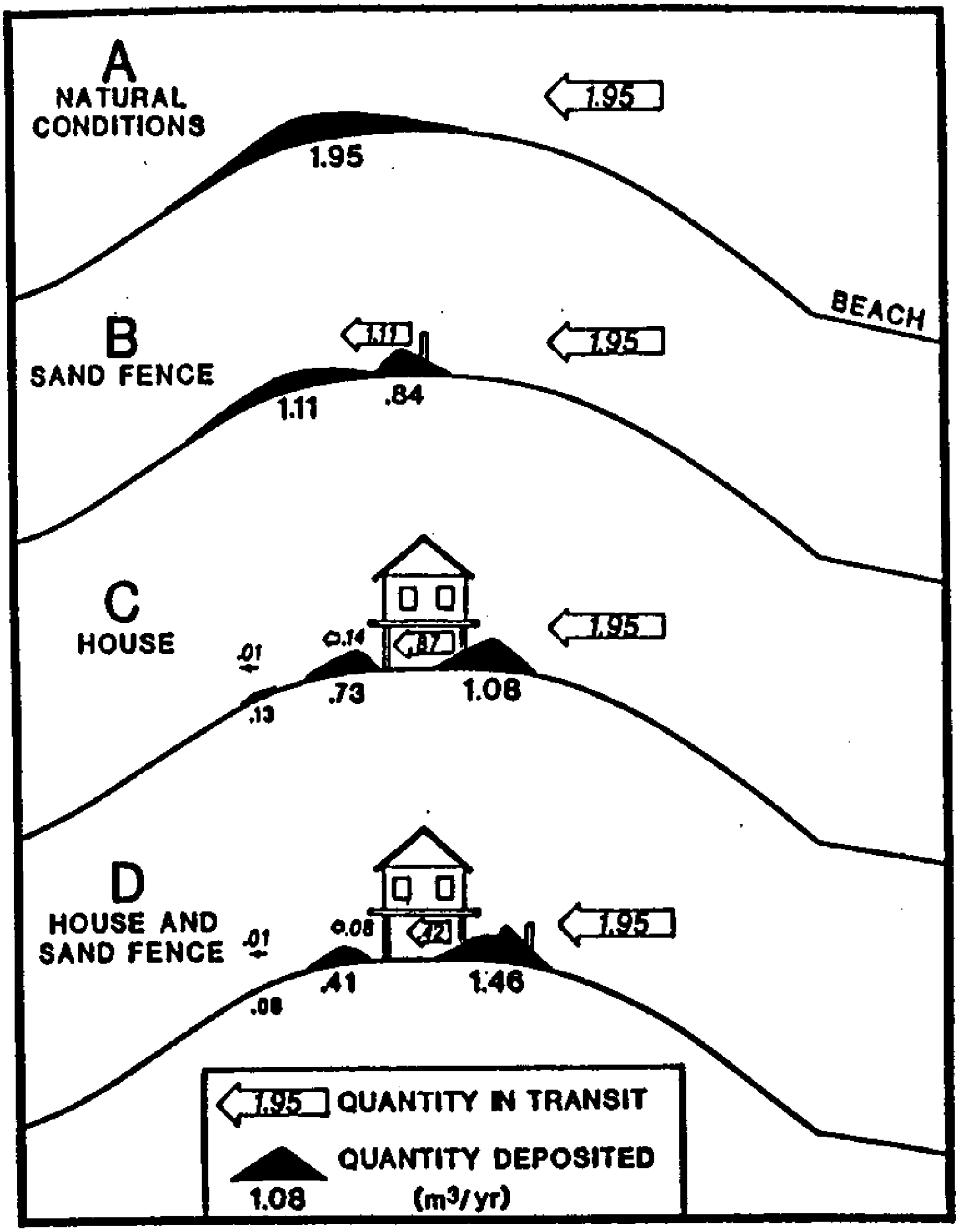

FIGURE 10. Eolian sediment budget for sand crossing 10-meter length of dune crest over the period of a year at Fire Island showing the effect of different conditions of development. From McCloskey et al., 1983.

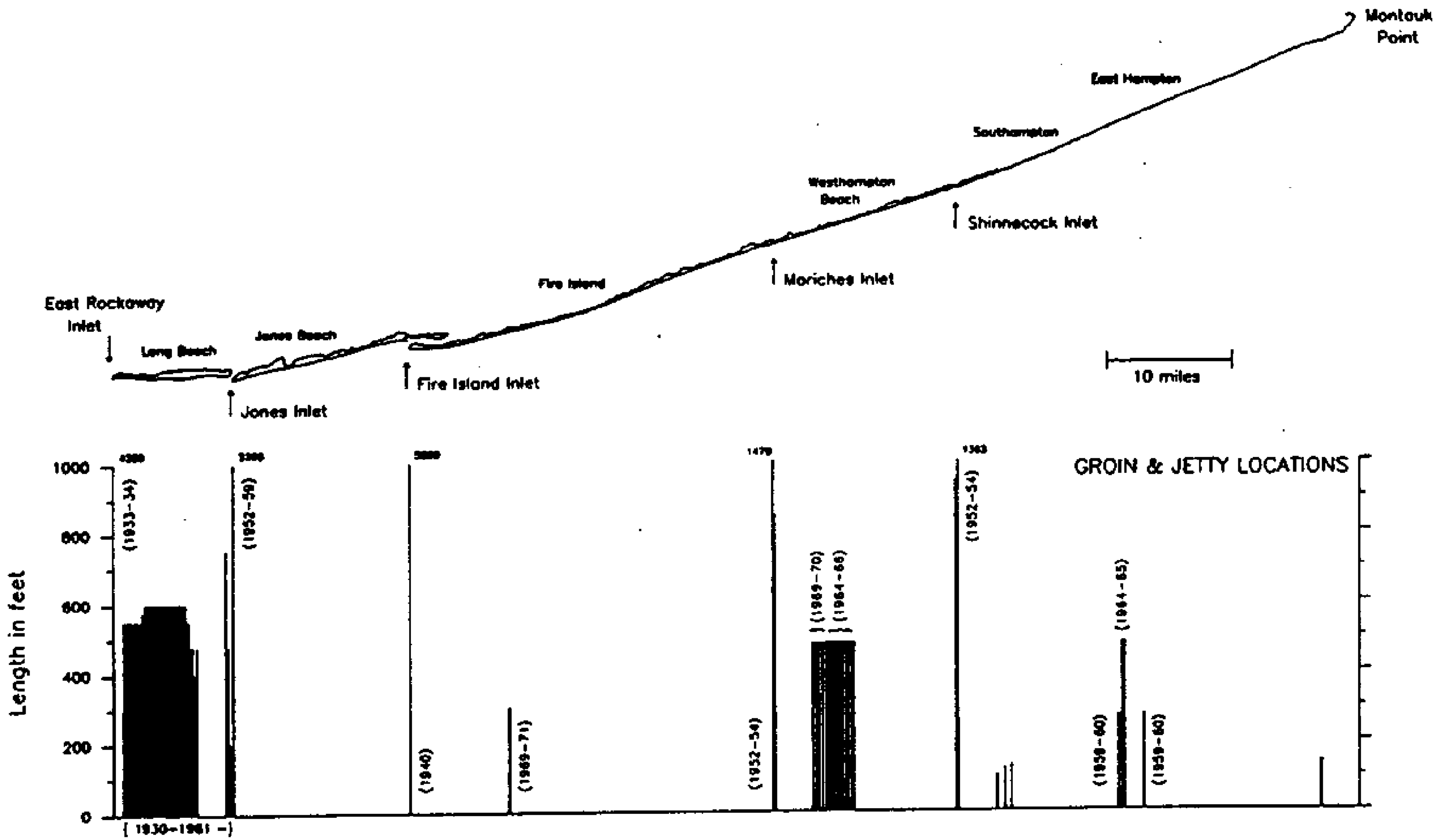

FIGURE 11. Locations, lengths and construction dates of groins and jetties along the south shore. The height of the vertical lines represents the actual length of the structures. For structures greater than 1000 feet long the numbers at the top of the line indicate the length in feet. Dates of construction, where known, are given in parenthesis.

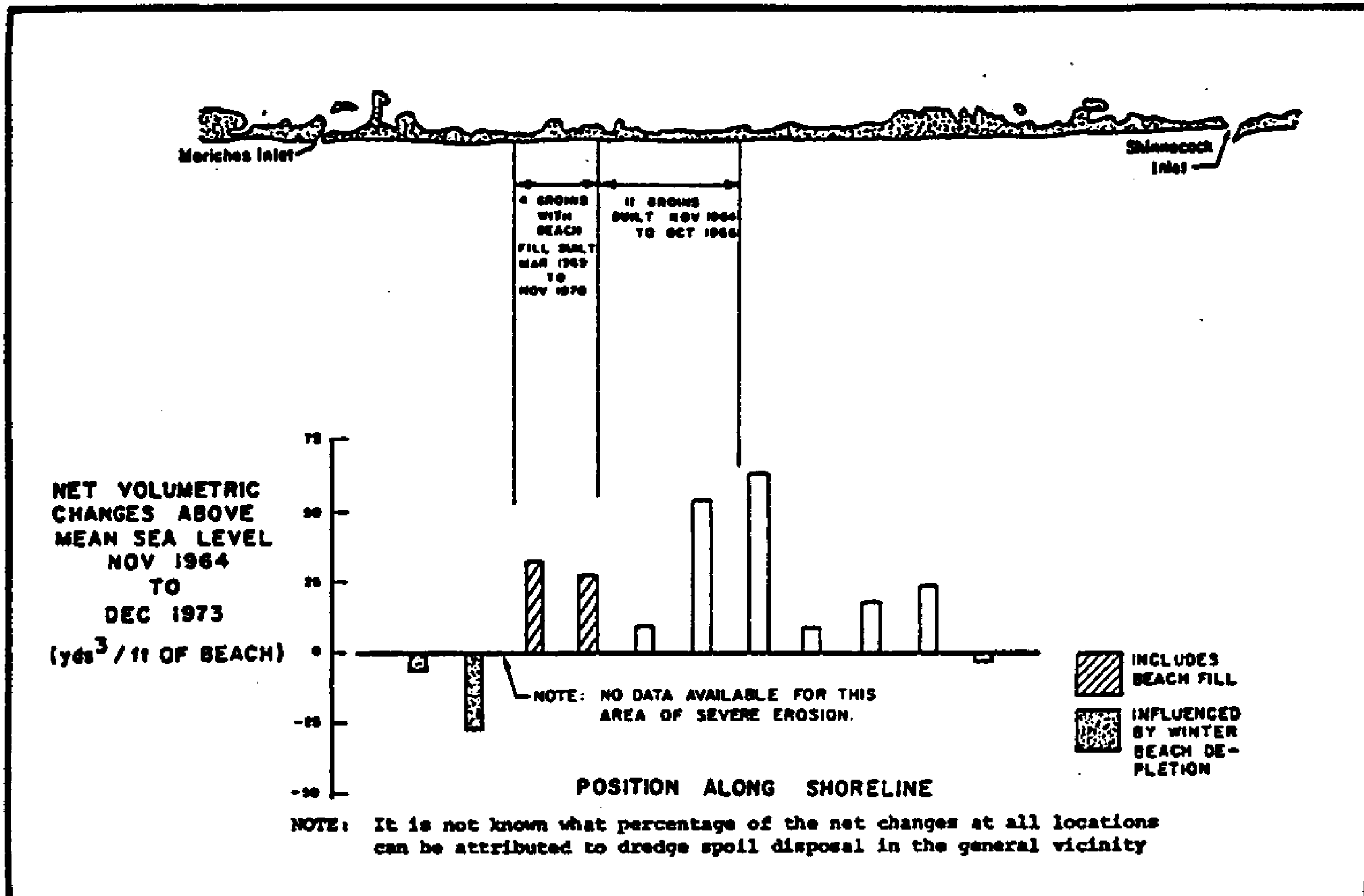

FIGURE 12. Net effect of Westhampton groin field on subaerial beach.
From: U.S. Army Corps of Engineers, 1977.

containing the groins gained an average of 190,000 cubic yards per year (8 cubic yards/foot of shoreline/year) between 1955 and 1979 with a considerable portion of this increase (about 78,000 cubic yards per year) occurring below MLW. Downdrift of these structures there was an average loss of 4 cubic yards/foot of shoreline/year during the same period. The amount of sand bypassing these structures is not known. Estimates could probably be derived from a more detailed analysis of the data used in the sediment budget and from the Corps' records and surveys. However, such calculations may not reflect the current conditions since the efficiency of sand trapping and the rate of bypassing would be expected to change as sand accumulates updrift of the structures, thus altering sediment transport patterns and rates in the vicinity of the groins.

Jetties have been constructed at each of the five major inlets in the study area in an effort to stabilize them for navigational purposes. Pairs of jetties were constructed between 1952 and 1954 at Shinnecock and Moriches inlets. Fire Island, Jones and East Rockaway inlets each have single jetties on the east (updrift) side of the respective inlets. These jetties were constructed in 1939-1944 at Fire Island; 1953-1959 at Jones Inlet; and 1933-1934 at East Rockaway Inlet (Panuzio, 1968). Evidence of the impacts of these inlet stabilization efforts on the downdrift shoreline in the form of increased erosion in the areas immediately west of each of the inlets can also be seen in Figures 2, 7, and 8. The effects of the inlets are discussed in more detail in the section "Shoreline Processes".

Few data on the impacts of shore parallel structures (e.g. revetments or bulkheads) are available for the study area. In fact, the location and extent of these structures along the shoreline has not been documented. However, the effects of structures on the overall sediment budget is probably small in the reach east of Jones Inlet because they have been estimated to cover an aggregate of only 3 to 5 miles or less than 5 percent of the entire shoreline.

In the East Hampton area revetments are usually almost entirely buried with sand and do not influence the short-term beach changes. They are exposed during severe storms and have been effective in preventing inland erosion (Bokuniewicz et al., 1980). Here and in other places on the eastern part of the coast, old bulkheads have occasionally been exposed during severe storms. These structures were apparently built several or more decades ago (presumably in response to local erosion), subsequently buried with sand and forgotten until uncovered by recent storm events.

As part of the sediment budget study, the Research Planning Institute, Inc. (1985) examined federal, state and local records in an effort to identify dredge and fill projects undertaken along the shoreline east of Fire Island Inlet between 1955 and 1979. Although 12 million cubic yards of fill were added to the beach over the 24-year period, much of the material was dredged from the back barrier bays in conjunction with construction projects. In many cases, the primary objective of these activities was probably dredged material disposal rather than beach renourishment and the dredged fill was not always compatible with the native beach sand in terms of grain size. As a result, these fill activities are not necessarily comparable or equivalent to engineered beach renourishment projects. Precise information on the boundaries of the disposal areas was often lacking. Figure 13 indicates the volume added to the different compartments by these projects in terms of cubic yards per foot of a beach per year for the period 1955 to 1979.

In conjunction with a combined inlet navigation and beach erosion control project, approximately 7 million cubic yards of sand dredged from Fire Island Inlet was placed on feeder beaches located approximately 1 mile west of the inlet on Jones Beach in 5 separate projects between 1959 and 1977 (Galvin, 1985). However, dredging activities were suspended until the potential effects of this activity on erosion on the north side of the inlet could be studied. During this hiatus the downdrift beaches experienced severe erosion. Two emergency dredging projects in 1985 and 1987 resulted in a total of about 1.2 million cubic yards of sand being placed offshore Jones Beach in waters 16 feet deep. In 1988/89 approximately 1 million cubic yards of sand was dredged from the vicinity of the inlet and placed on downdrift beaches. The data for this area plotted in Figure 13 represent approximate volumes and locations of the fill projects.

The Corps' records (U.S. Army Corps of Engineers, 1966) show that approximately 550,000 cubic yards of material dredged from the bay was placed on Long Beach between 1959 and 1962. However, recent information on the history of fill projects along this segment has not been compiled or summarized. These data may be contained in a Corps' report being prepared for this area that has not yet been released.

Detailed monitoring information on dredge and fill operations in the study area is not available. Although permit and dredging project records may contain information on various projects that have been undertaken, a substantial effort would be required to determine the quality and completeness of the data. It is often not known for example, if a particular permitted project was ever actually completed. Additional effort would be needed to synthesize, if possible, a meaningful analysis of the performance of the various fill projects.

Wave Climate

Direct measurements of the wave climate are extremely sparse. In-situ wave gauge data are either short in duration, unreported or non-existent (Morton et al., 1986). One non-directional gauge operated intermittently between 1950 and 1954 at several locations in the area of Jones Beach indicated waves higher than 6 to 10 feet occurred less than 1 percent of the time and a maximum wave height of 13.4 feet (Panuzio, 1968). Another non-directional wave gauge

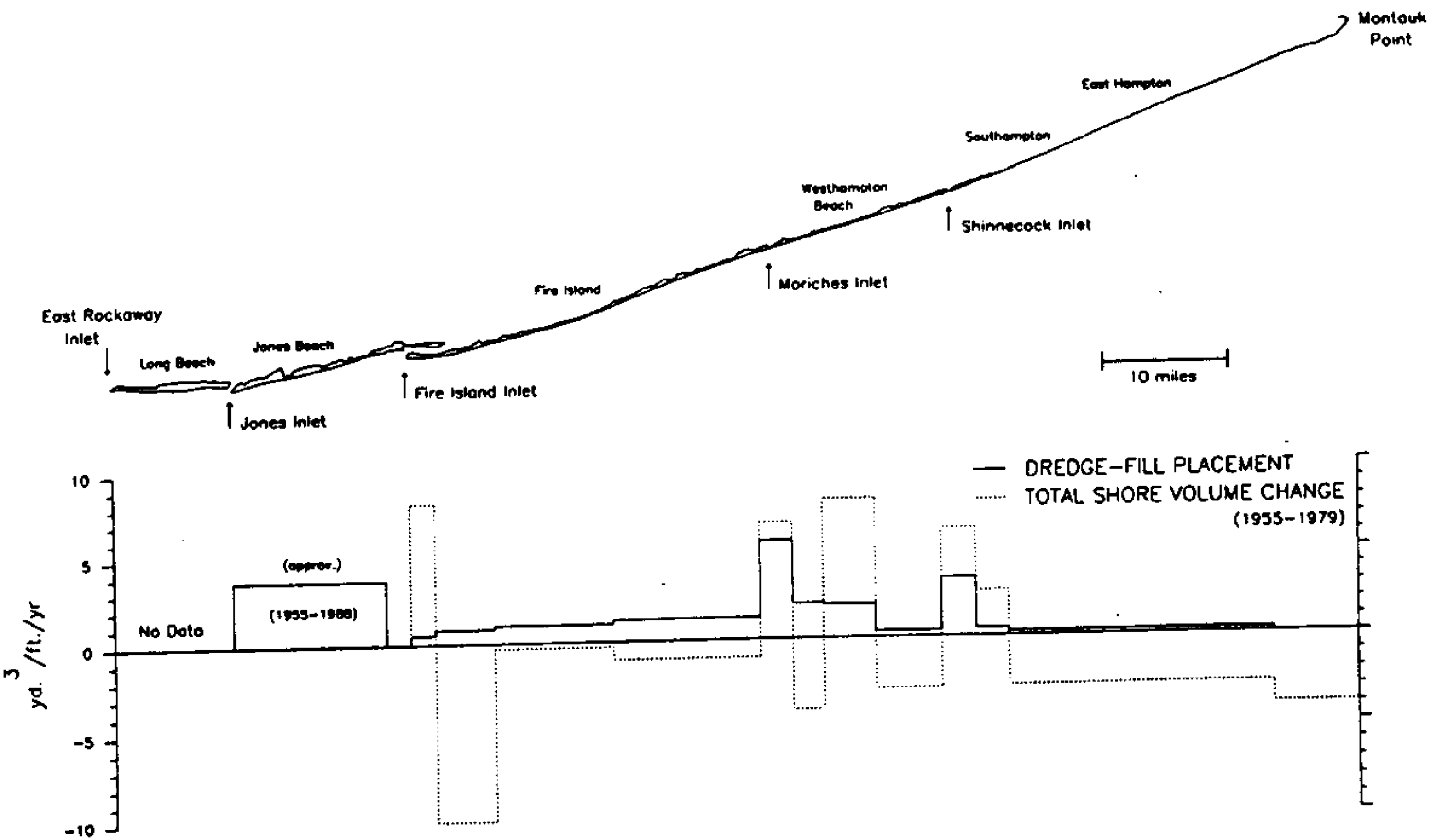

FIGURE 13. Average volume of dredged fill added to beach between 1955 and 1979. Dashed line indicates observed net volume change above -24 MLW for the same period based on surveys. Data east of Fire Island Inlet is from Research Planning Institute, Inc., 1985.

located in 30 feet of water offshore of Southampton operated between 1975 and 1976 as part of a CERC program. A data report was never issued however.

The only directional, long-term nearshore wave measurements available for the study area are visual observations collected at several points along the shore including; Jones Beach, Fire Island, Westhampton, and Southampton. Some of these observations were made as part of CERC's Littoral Environmental Observation (LEO) Program in the 1970's. Unfortunately, a summary of these data has not been done for the entire study area. A summary of surf observations taken at a station near Jones Inlet is given in Table 3 (Morton et al., 1986). The probability distribution curves for breaker height derived from LEO measurements for stations in Southampton and Fire Island are given in Figure 14. Monthly mean heights and periods for Southampton and Westhampton observations are shown in Figure 15. Since these are visual observations, the data reported are subject to large uncertainties (Morton et al., 1986).

Twenty-year hindcasts of the shallow water wave climate done as part of CERC's Wave Information Study are also available for 10 mile segments along the entire south shore (Jensen, 1983). The average and largest significant wave heights from this data set are plotted in Figure 16. It should be noted that the hindcast data do not take into account waves associated with tropical storms. In addition, values of the net longshore transport computed from wave energy flux based on the hindcast data gave results incompatible with rates based on estimates of the accretion of sand updrift of inlet jetties (Figure 17). These inconsistencies indicate that the hindcasts may be adequate for some design needs or 2-dimensional shore models, but their use in other applications may be limited. The only way to improve this information would be to install at least 2 arrays of directional wave sensors in the study area; one in the east, near Montauk Point, and one in the west, perhaps near Fire Island Inlet.

The Corps of Engineers uses deepwater wave statistics from a number of sources for project design. These data include: Summary of Synoptic Meteorological Observations (SSMO) offshore visual wave data, swell height and direction observations from a station 260 miles south east of Fire Island Inlet, and 2 sets of deepwater hindcast data calculated for a station offshore of the entrance of New York Harbor for the periods 1947 to 1949 (Nuemann and James, 1957) and 1948 to 1950 (Saville, 1954). Graphic summaries of these data are provided in Appendix 3. Based on these data, a design wave for hurricane conditions with a deep water wave height of 17 feet (20 foot breaking wave) and period of 13 seconds which has an exceedance probability of 1 percent (SSMO data) was selected for Westhampton Beach (U.S. Army Corps of Engineers, 1980).

Sea Level Rise

Long-term tide gauge records in both New York Harbor and New London, Connecticut, indicate an average rise in sea level on the

Table 3. Summary of Surf Height and Wave Direction from Visual Observations at Jones Beach, October 1954 to December 1957. From: Morton et al., 1986.

Month	Surf Height in Feet (%)[a]				Wave Direction (%)[b]			
	0-1.9	2-3.9	4-5.9	6-9.9	E	SE	S	SW
January	37	51	12	0	6	48	4	42
February	29	66	5	0	1	32	10	57
March	39	48	12	1	2	49	6	43
April	38	53	8	1	6	44	6	44
May	43	53	4	0	3	34	26	37
June	54	45	1	0	0	42	18	40
July	44	54	2	0	0	30	22	48
August	55	40	5	0	0	44	16	40
September	37	59	4	0	0	56	11	33
October	43	45	10	2	1	46	28	25
November	35	53	11	1	5	37	26	32
December	42	48	9	1	2	33	25	40
Total Period	41	51	7	1	2	41	17	40

(a) All observed surf heights were less than 10 feet.

(b) No waves were observed approaching from any of the other directions which are not listed.

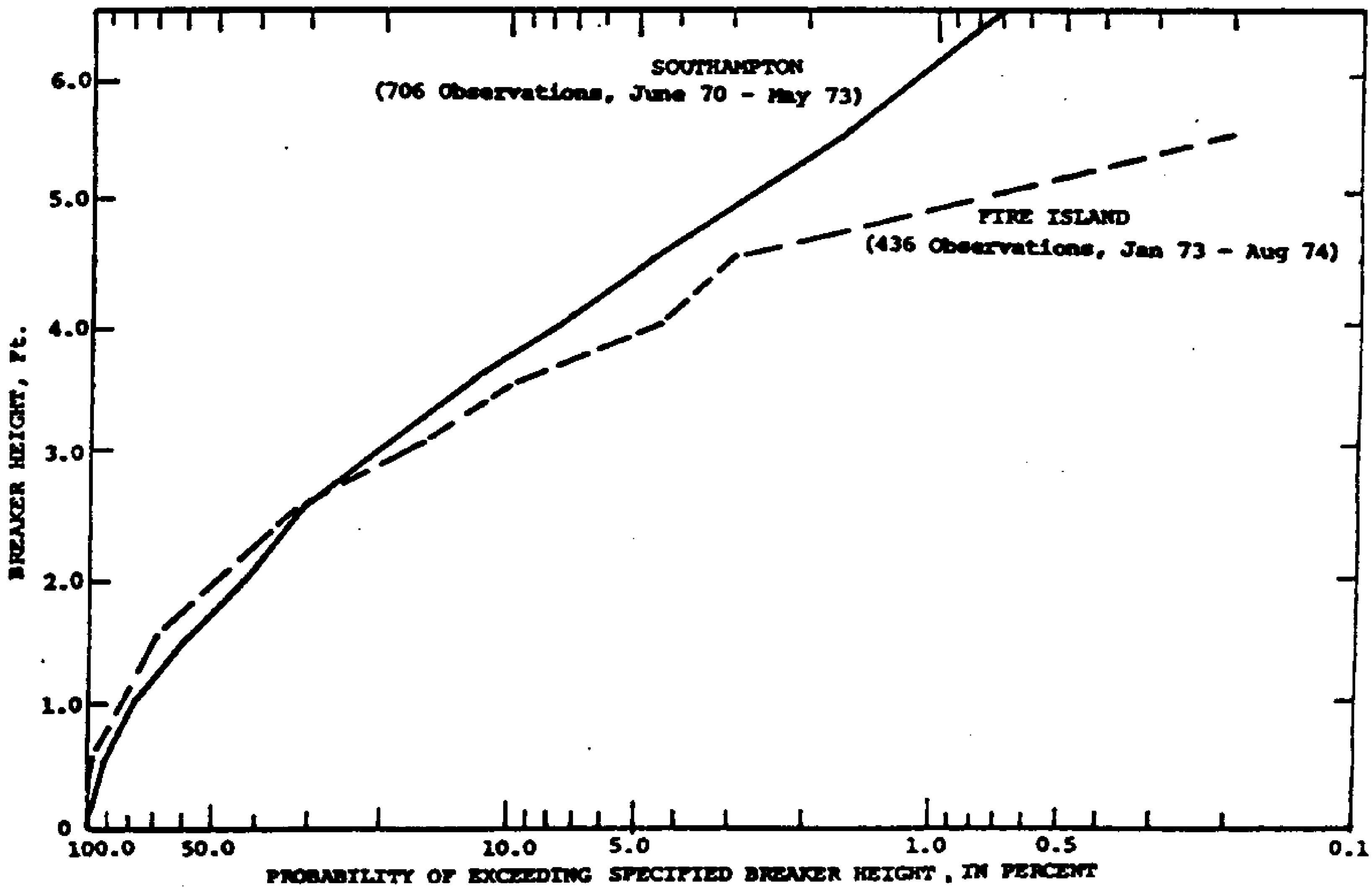

FIGURE 14. Probability distribution curves for breaker height from visual wave observations at Southampton and Fire Island. From: U.S. Army Corps of Engineers, 1977.

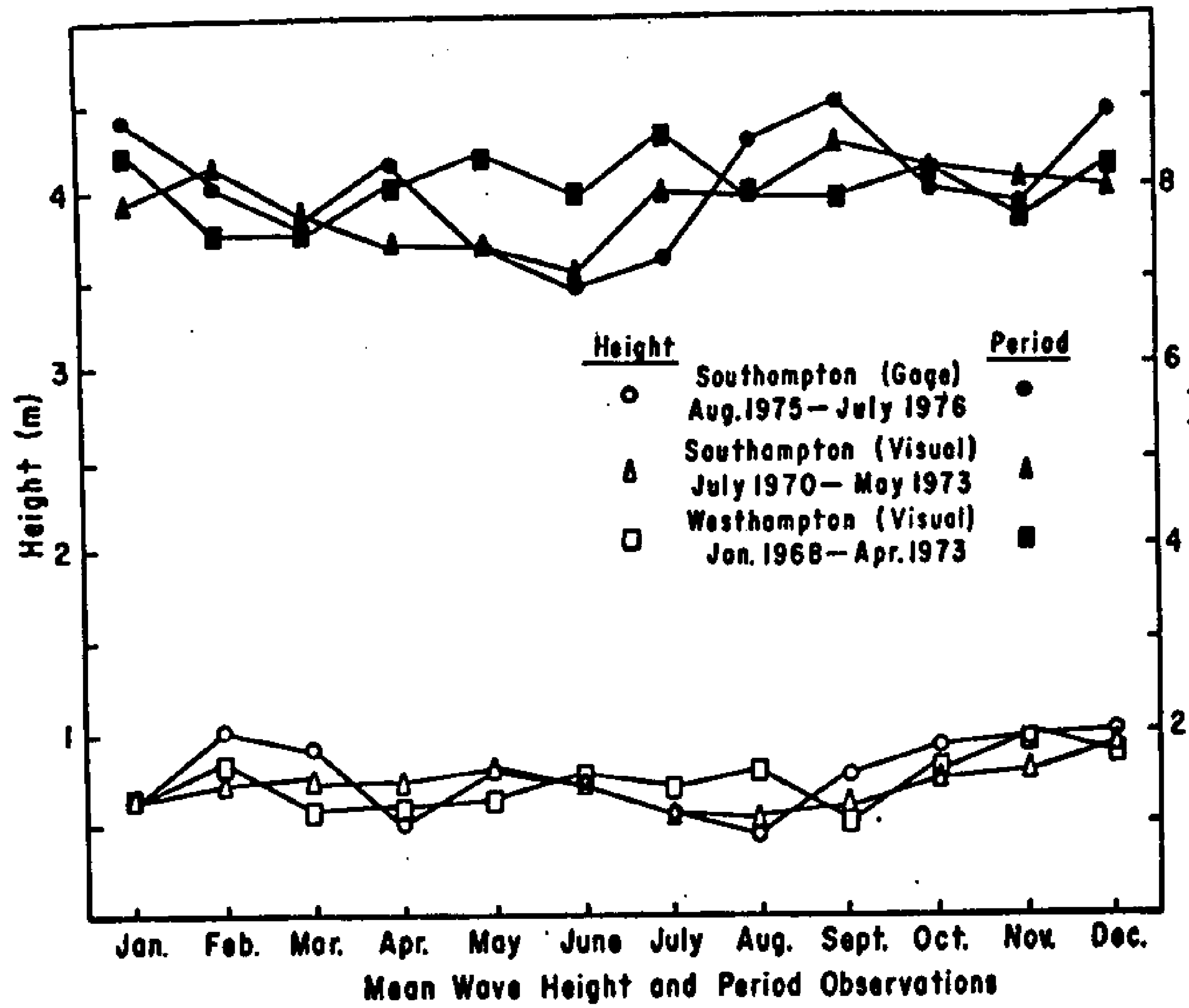

FIGURE 15. Monthly mean wave height and period observations. From: DeWall, 1979.

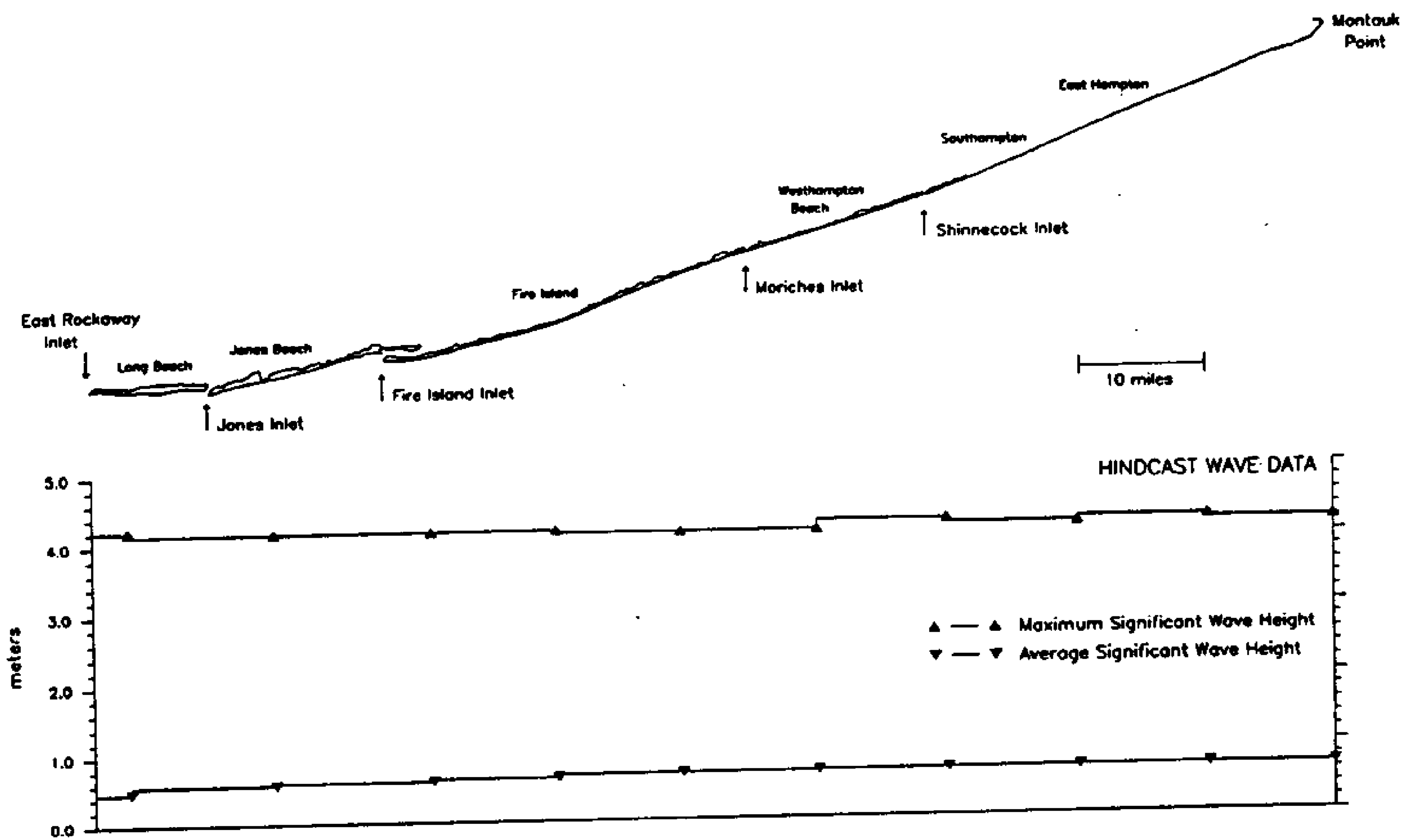

FIGURE 16. Significant wave heights based on 20-year shallow-water wave hindcast data (Jensen, 1983).

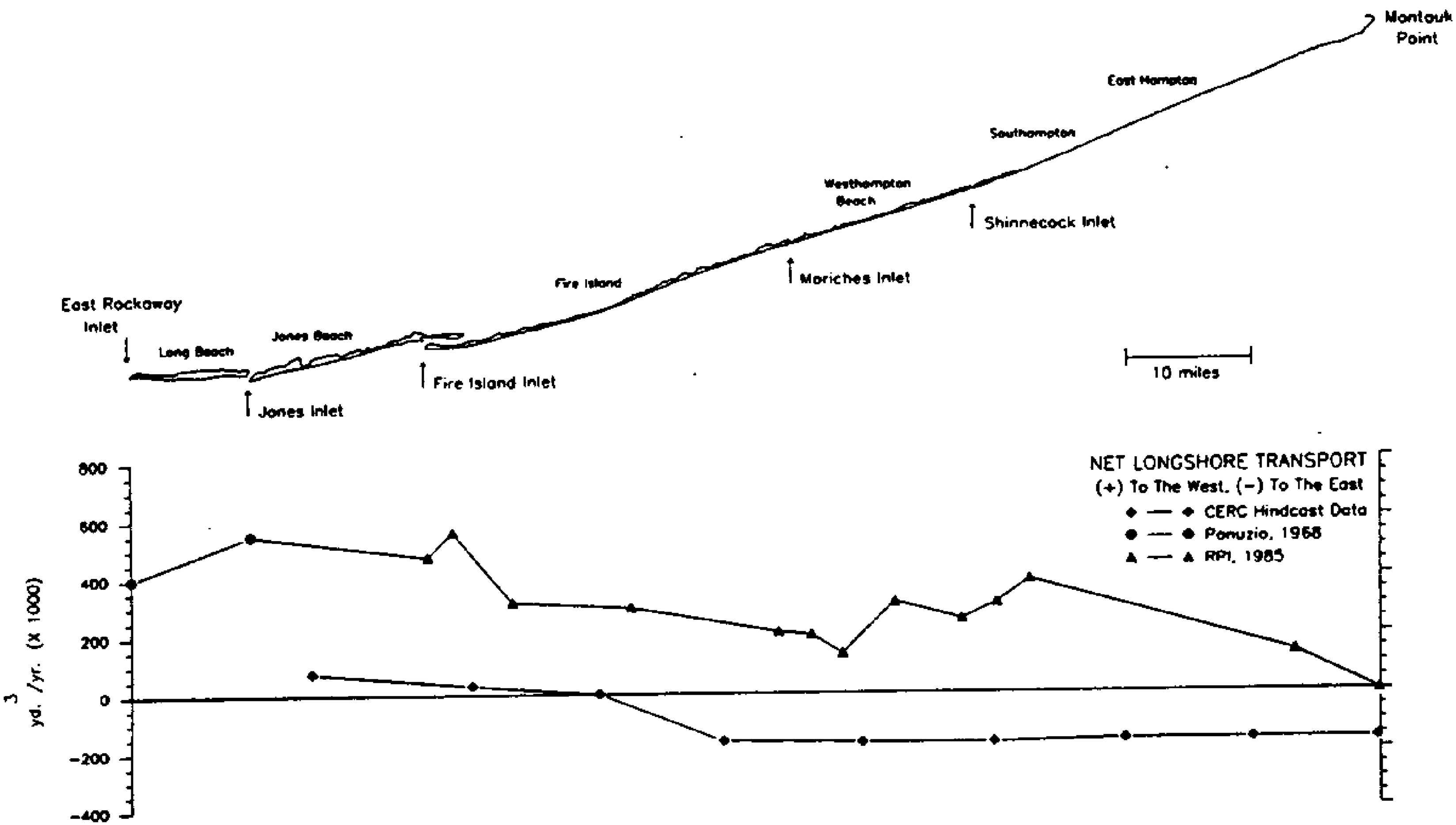

FIGURE 17. Comparison of longshore transport rates predicted from hindcasted wave data (diamonds) with estimates based on surveys and field observations of sand impoundment at structures (triangles and circles).

order of 0.01 feet per year with a good deal of temporal variability (Figure 18). Since these gauges are on bedrock, it is likely that the relative rise on Long Island may be somewhat higher due to compaction and subsidence. However, the tide gauge at Montauk has not been operating long enough to resolve long-term trends in sea level. As a result, there have been no accurate measurements of relative sea level rise made in the study area.

According to McCormick (1973), sea level rise does not appear to play a significant role in controlling erosion on the south shore. As part of the sediment budget study (Research Planning Institute, Inc., 1985), the Hands (1981) model was applied to estimate the possible sediment loss resulting from profile readjustment in response to a sea level rise of 0.01 feet per year. The results of this analysis in terms of annualized volume losses per foot of shoreline for the portion of the profile above and below MLW are plotted in Figure 19. The changes related to the rise in sea level are much smaller than the total measured net volume changes reported in the study. In addition, there is evidence that offshore sources contribute sand to the nearshore sediment budget (McCormick and Toscano, 1980; Research Planning Institute, Inc., 1985; Niedoroda et al., 1985; and Williams and Meisburger, 1987) indicating that the Bruun Rule (upon which the Hands model is based) may not be applicable in this area (Wolff, 1982). If this is the case, even the relatively small volume losses caused by sea level rise shown in Figure 19 may be overestimates. In the absence of profile readjustment, Morton et al. (1986) estimated that in the Jones Beach area the present observed rate of sea level rise over a period of ten years would result in a landward displacement of the waterline of approximately one foot or 0.1 feet per year. A rise in sea level will increase the vulnerability of the shoreline to storm erosion, but the available data indicate that the percentage of the total erosion occurring along the south shore attributable to sea level rise is of secondary importance in comparison to other processes operating in the area, especially when considered in the context of the planning time frame of 30 to 50 years.

A number of studies indicate that global warming caused by the "greenhouse effect" could result in an accelerated rate of sea level rise in the future, although the timing and magnitude of future sea level rise are uncertain (National Research Council, 1987 and Schnieder, 1989). A study of the engineering implications of sea level rise done by a committee of the National Research Council (NRC, 1987) examined three possible scenarios of sea level rise to the year 2100; rises of 0.5 m, 1.0 m and 1.5 m. According to most projections, the increase in the rate of sea level rise, if it occurs, will not occur in a linear fashion. Rather, the change will start slowly and increase more rapidly in the distant future. Based on the projections used by the NRC panel, accelerated sea level rise could increase present water level elevations along the south shore 4 to 5 cm (0.13 to 0.17 feet) by the year 2000 compared to an increase of 2.5 cm (0.08 feet) if the present rate of sea level rise continues. By the year 2025 the increase due to atmospheric warming could be 13 to 24 cm (0.42 to 0.75 feet) while

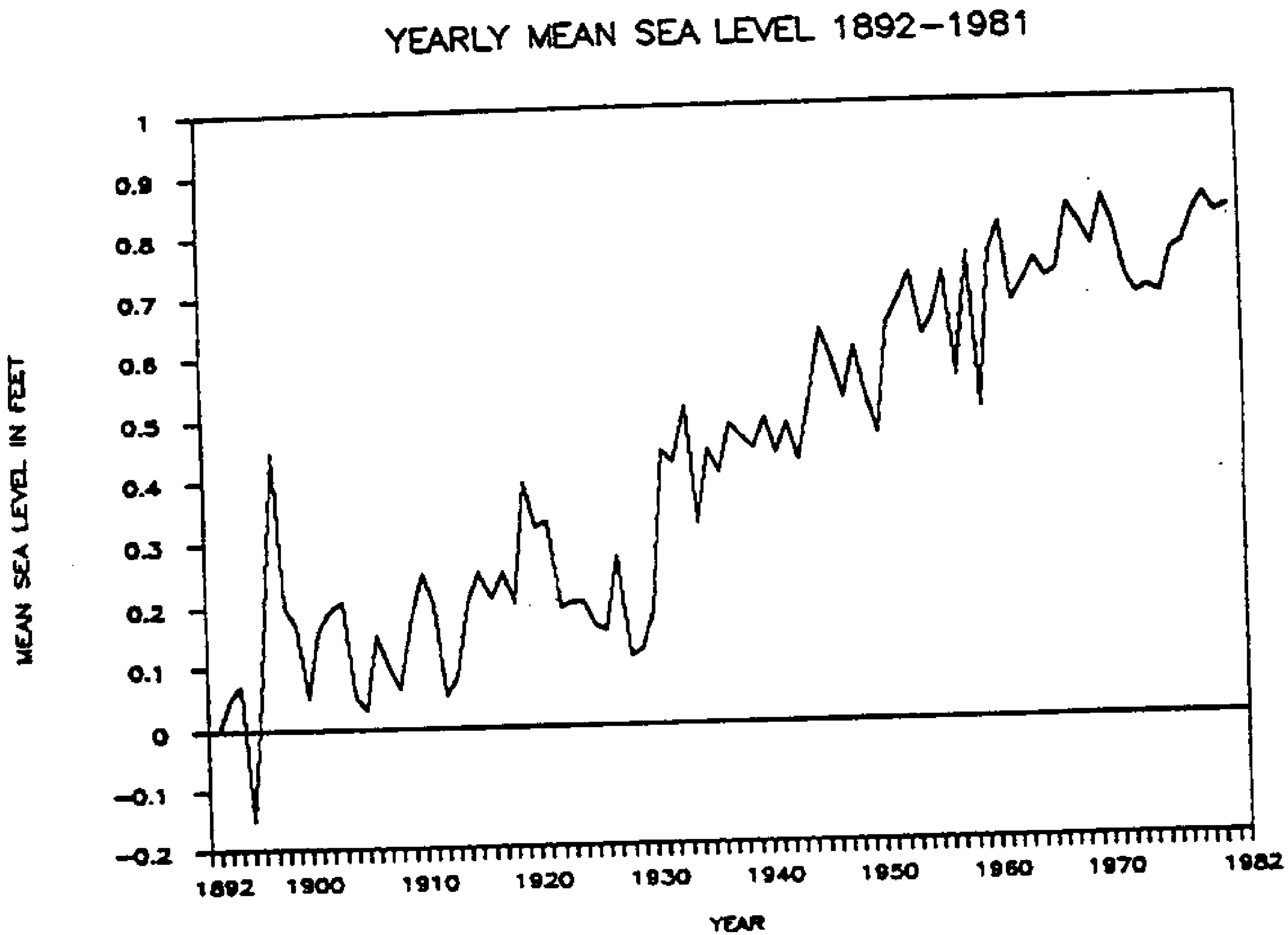

FIGURE 18. Sea level rise in the New York area between 1892 and 1982 based on water-level records at Fort Hamilton, Brooklyn, New York. From: Zarillo and Zarillo, 1989.

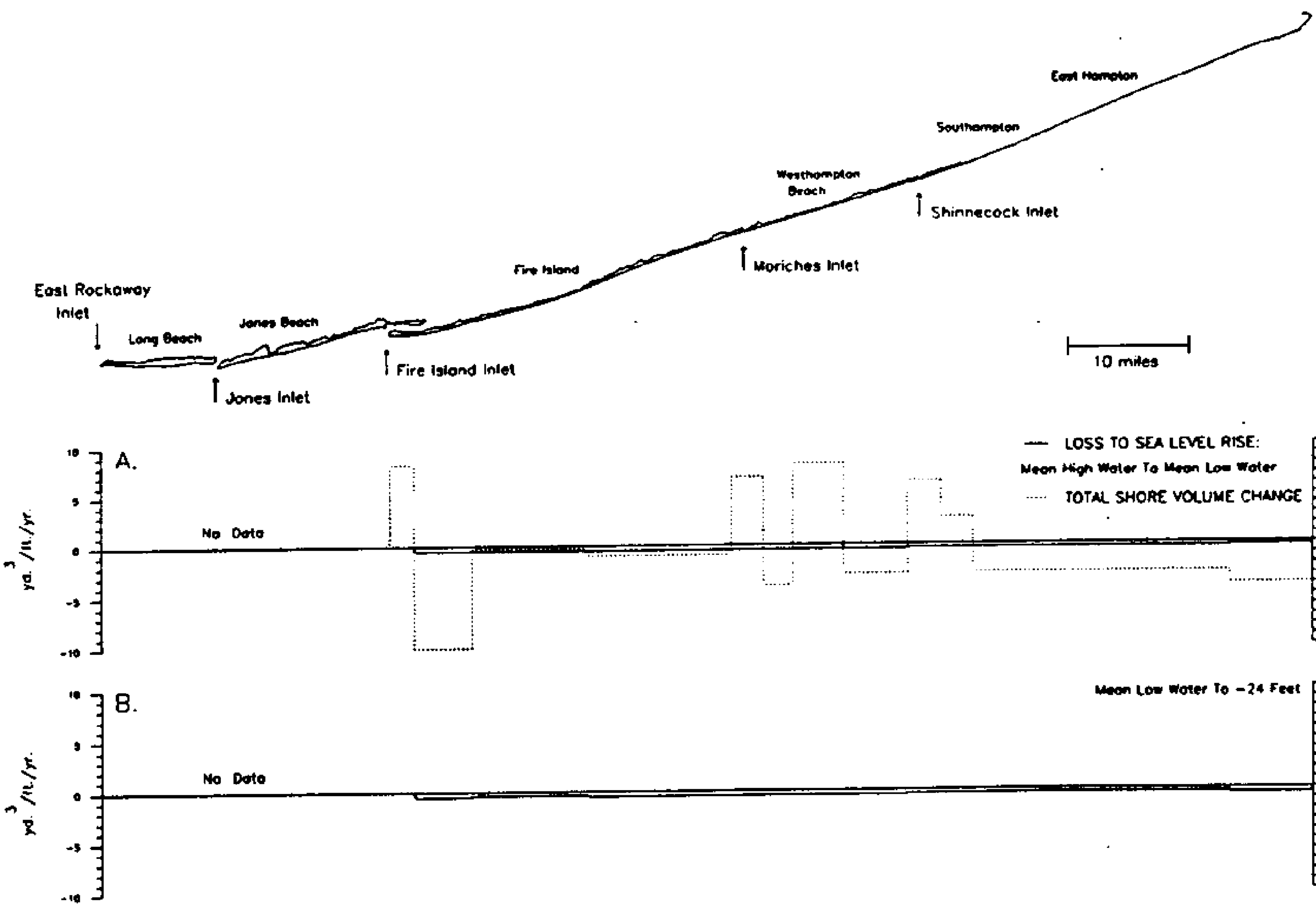

FIGURE 19. Estimated net sediment volume loss due to sea level rise between 1955 and 1979. The solid lines indicate the net loss of material due to sea level rise between high and low water (A) and between low water and -24 feet (B). The dashed line in A indicates the actual observed net volume changes above -24 feet MLW for the same period based on surveys. From: Research Planning Institute, Inc., 1985.

the expected increase if present conditions persist would be about 8 cm (0.25 feet). For 2050, an accelerated sea level rise could result in water elevations 41 to 50 cm (1.3 to 1.8 feet) higher than present compared to an increase of 26 cm (0.5 feet) under current conditions. While the rate of sea level rise may increase more rapidly beyond 2050, the projections, already subject to a great deal of uncertainty, become less reliable as they are extended further into the future. Because of these uncertainties, a rigorous assessment of the management implications of future sea level rise is difficult.

To account for potential increases in the rate of sea level rise over the next 35 to 40 years, it was suggested during the workshop that the present rate could be doubled or tripled for erosion management purposes. This rate is similar to the estimates used by others (NRC, 1987) and is slightly higher than the rates calculated by Hoffman et al. (1986) which were a revision of the Environmental Protection Agency's mid-range estimates (Hoffman et al., 1983) based on updated information. However, even this increase would probably have a relatively small impact on the observed rate of erosion compared to the magnitude of shoreline changes caused by storms and disruptions in the nearshore sediment transport systems resulting from man's activities. From a planning perspective, the submergence of low lying areas around the south shore bays due to possible increases in sea level rise is probably a more critical problem than the potential for increased ocean front erosion.

Storm Surges and Tides

Mean tide ranges and still water storm surge elevations for the 10, 50, and 100 year storms are plotted in Figure 20. For planning purposes, models which incorporate wave run up, beach dynamics and dune dynamics, where appropriate, in determining storm surge penetration may be of more value than the still-water storm-surge elevations. While these types of models are available, they have not been applied to the south shore.

Shoreline Processes

Discussion and analysis of the informational needs related to all the individual topics identified in the general category of "Shoreline Processes" was beyond the scope of this workshop. However, the major issues and pertinent information associated with these topical areas were discussed. The major points and suggestions concerning future investigations related to the individual topics are briefly summarized in the following sections.

Longshore Sediment Transport: Estimates of the net rate of longshore sediment transport are reported in the sediment budget study (Research Planning Institute, Inc., 1985) and were discussed previously. Reliable estimates of the gross longshore transport and relative volumes moving east and west are also extremely important. Local deviations can be large in areas around inlets or the direction of net drift can reverse due to changes in wave

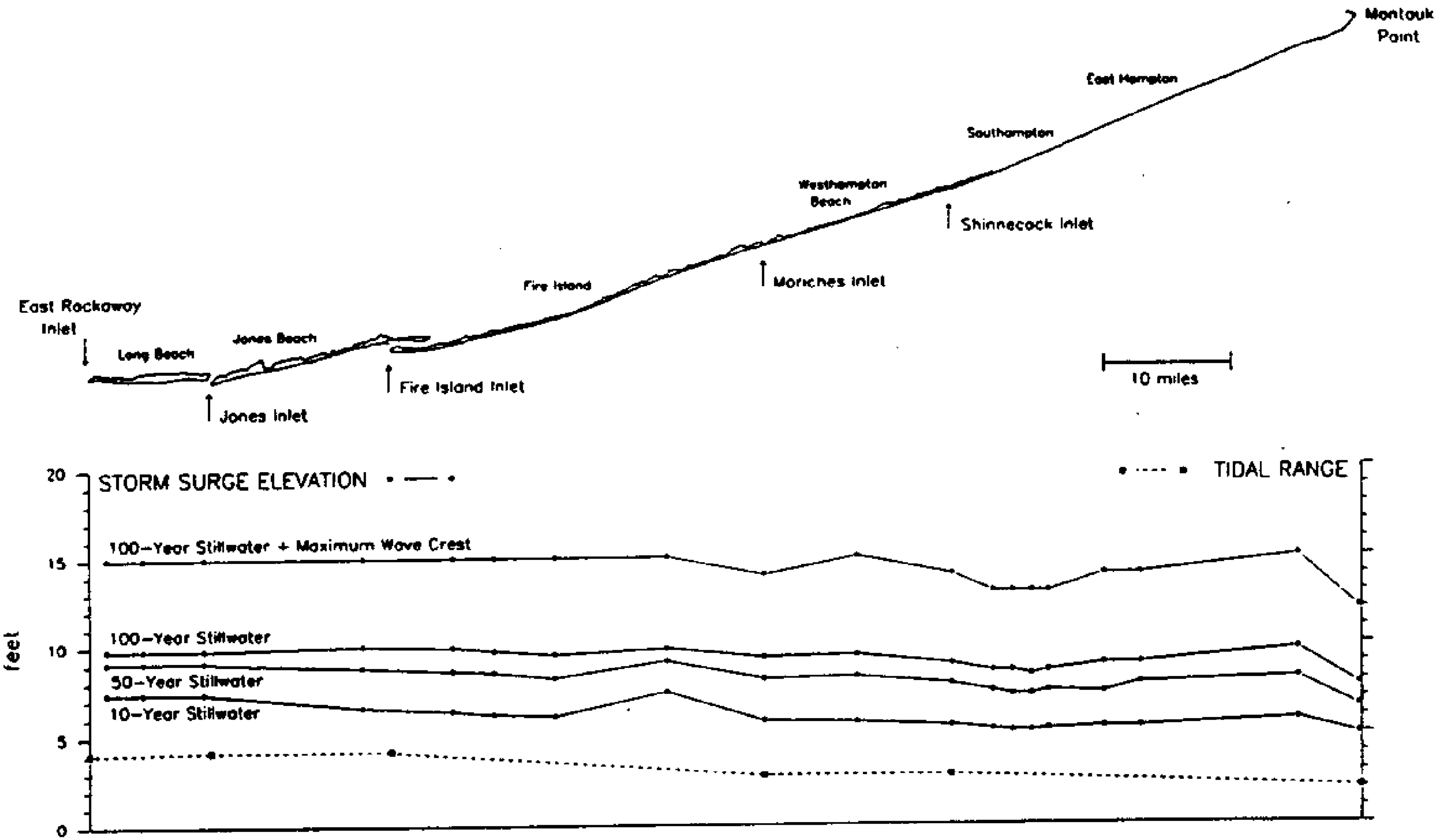

FIGURE 20. Mean tidal range and storm surge water levels.

conditions. Although attempts to calculate these values based on available wave statistics have been made, the results have not agreed with the estimates obtained by using measurements of sand impoundment at structures and/or inlet migrations. Czerniak (1976) used offshore wave statistics (Nuemann and James, 1957) to calculate longshore transport rates at Moriches Inlet. Based on these calculations (Table 4), he estimated a net transport rate of approximately 72,000 cubic yards per year to the west. This is considerably less than the annual net transport rate of 300,000 cubic yards per year to the west reported in the sediment budget. As mentioned previously, net transport rates calculated from the twenty-year CERC hindcast data resulted in transport directions opposite of those evidenced by impoundment at structures (Figure 17). Reliable, systematic estimates of the gross and relative transport rates and directions along the shore would be extremely useful in developing and evaluating proposed coastal projects. However, development of such estimates would require better wave information than is presently available.

Cross-shore Transport: Although previous studies (Vincent et al., 1983; Niedoroda et al., 1985; and Williams and Meisburger, 1987) indicate sediment exchange between the shore face and inner continental shelf does occur, the data available on this process are not sufficient to quantify the transport.

Cross-shore sediment grain size data are plotted in Figure 21. A single offshore bar located about 500-1500 feet offshore with a crest 10 to 15 feet below mean sea level is present along much of the coast between Fire Island Inlet and Montauk Point (Leatherman and Allen, 1985). Except for two short-term, site-specific studies at East Hampton (Shipp, 1980) and Fire Island (Allen and Psuty, 1987), the scale and variation in bar morphology and the effects of bar geometry on the shoreline have not been documented.

Pre- and post-storm profiles along the coast may be especially useful in defining the behavior of the offshore bar and sediment transport patterns. After Hurricane Gloria in 1985, for example, the bar, usually a stable feature, was absent temporarily along much of the shoreline but the length of time this condition persisted is uncertain (G. Zarillo, personal communication).

Inlet Processes: The five inlets in the study area exert a dominant influence on the coastal changes occurring along the shore. The largest long-term shoreline recession/accretion rates (Figures 2 and 3) and some of the greatest volume changes (Figures 7 and 8) are associated with inlets. With the exception of the Westhampton groin field, the most severe erosion problems occur immediately downdrift (west) of the five inlets and are the result of the interruption of sand transport patterns and inadequate sand management practices at the inlets. As an example, the effect of the opening and subsequent stabilization of Shinnecock Inlet on the downdrift shoreline is shown in Figure 22.

Table 5 developed by Panuzio (1968) provides historical information related to the south shore inlets. (It should be noted that some

Table 4. Longshore Sediment Transport Statistics at Moriches Inlet Calculated by Czerniak (1976) Based on Hindcast Wave Statistics from Nuemann and James (1955). (Units are cubic yards)

Period	Westward Transport	Eastward Transport	Ratio (E/W)	Net Transport	Gross Transport
January	-94,506	58,170	.616	-36,336	152,676
February	-34,062	43,476	1.276	9,414	77,537
March	-26,299	108,620	4.130	82,320	134,919
April	-28,985	74,981	2.587	45,996	103,966
May	-24,658	31,292	1.269	6,634	55,950
June	-47,552	22,248	.468	-25,305	69,800
July	-11,856	18,544	1.564	6,688	30,400
August	-10,342	13,922	1.346	3,580	24,265
September	-25,840	28,193	1.091	2,353	54,033
October	-40,846	13,514	.331	-27,331	54,360
November	-97,564	11,924	.122	-85,640	109,488
December	-90,316	35,502	.393	-54,814	125,817
Annual	-532,827	460,386	.864	-72,441	993,212

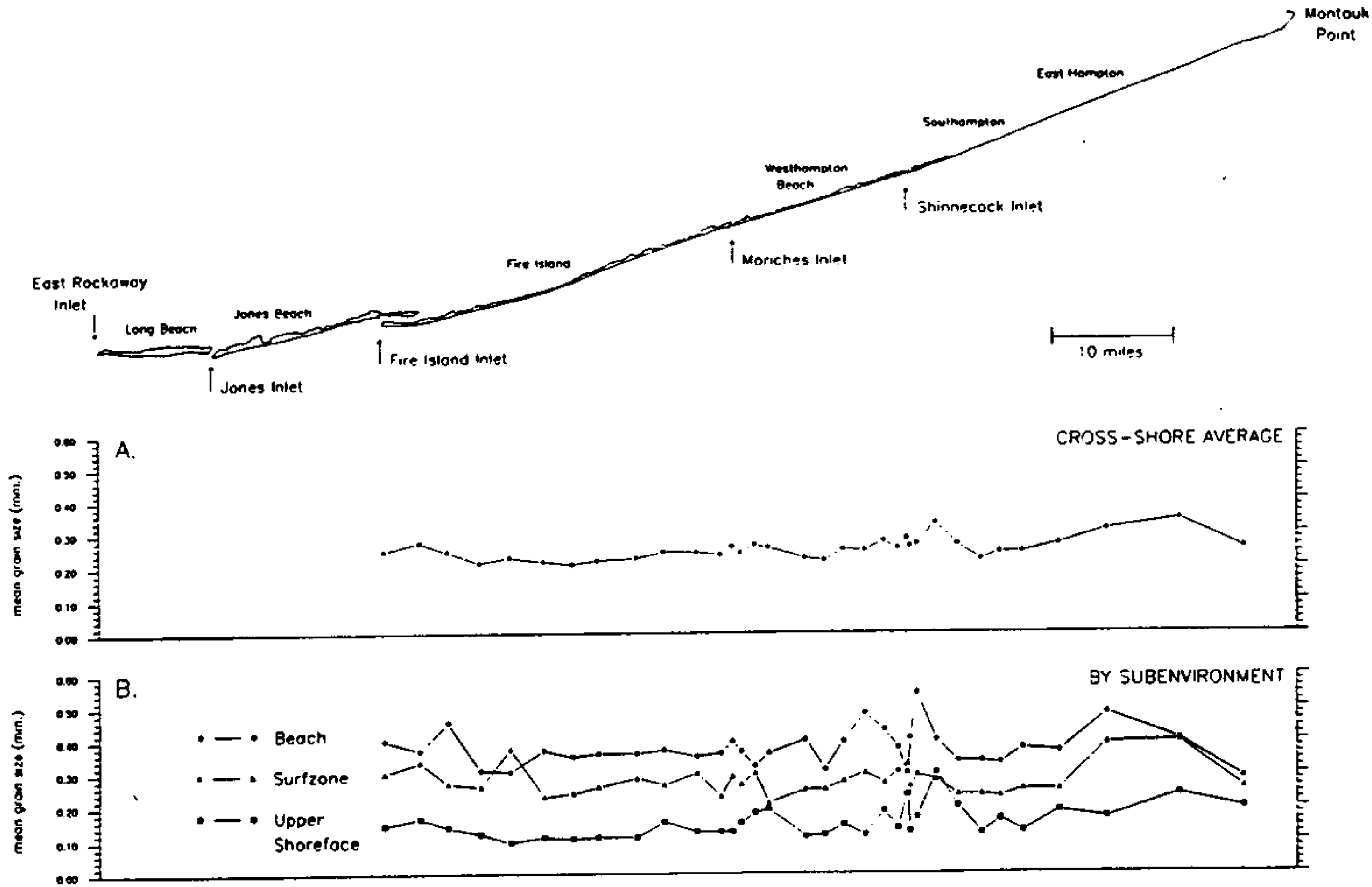

FIGURE 21. Mean sediment grain size. From: Tsien, 1986.

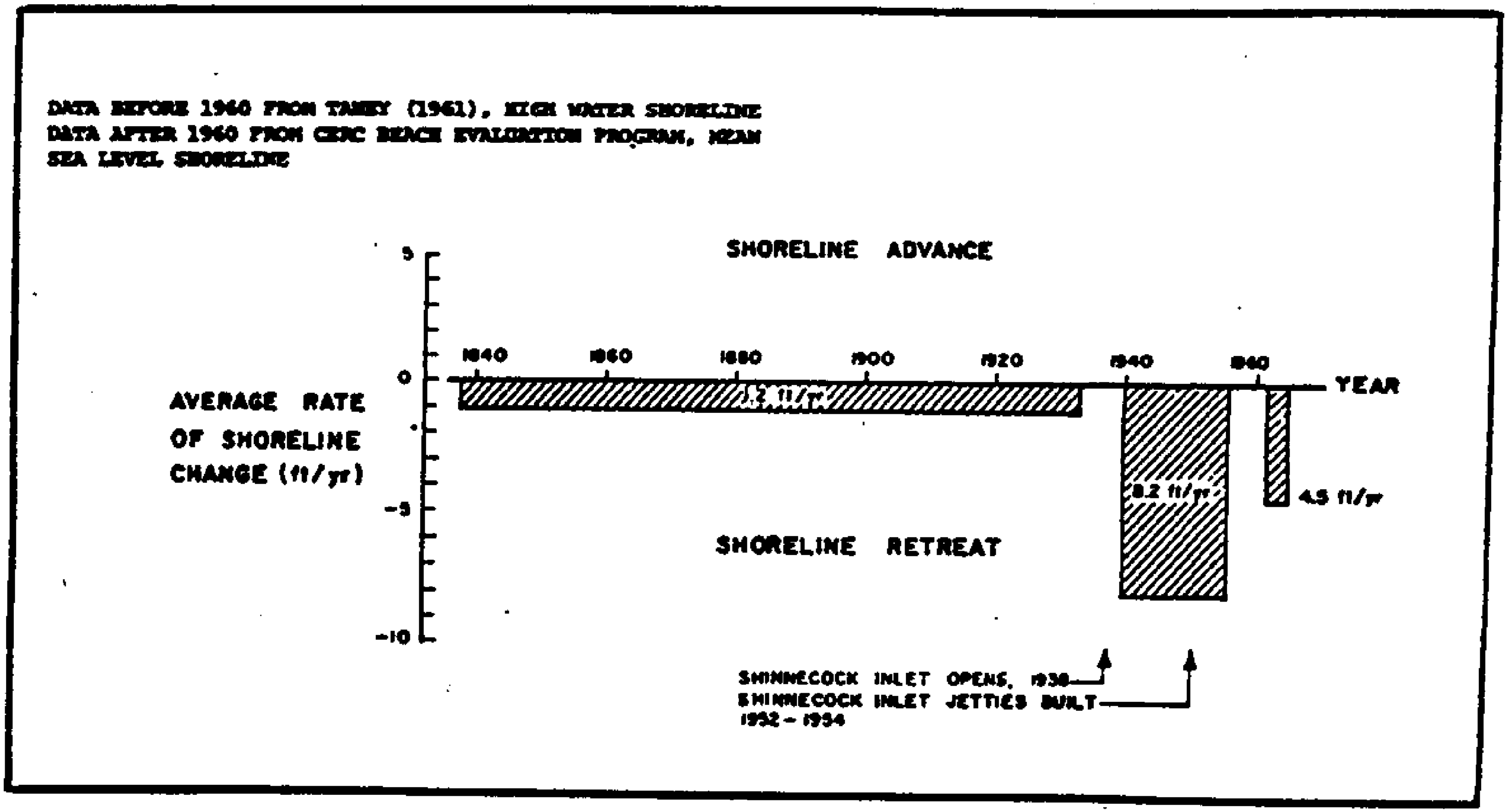

FIGURE 22. Average rates of shoreline change between Shinnecock and Moriches Inlet from 1838 to 1965. From: U.S. Army Corps of Engineers, 1977.

Shinnecock Inlet	1829-1839 Inlet Open	1839-1858 Inlet Closed	1858-1890 Inlet Open	1890-1938 Inlet Closed	1938-1951(a) 60 feet	1951-1955 -130 feet	1955-1968 -
	Total Migration West feet years feet/yr. 60 13 4.6		Littoral Drift cubic yards/yr. 300,000			Jetties Built 1952-1954	
Moriches Inlet	1829-1839 Inlet Open	1839-1931 Inlet Closed	1931-1933(b) 220 feet	1933-1949 3880 feet	1949-1955 150 feet	1955-1968	
	Total Migration West feet years feet/yr. 4290 24 177		Littoral Drift cubic yards/yr. 150,000		Jetties Built 1952-1954		
Fire Island Inlet	1825-1834 3050 feet	1834-1873 9625 feet	1873-1909 5175 feet	1909-1924 6775 feet	1924-1934 2030 feet	1934-1940 1670 feet	1940-1968 -
	Total Migration West feet years feet/yr. 24325 115 212		Littoral Drift cubic yards/yr. 600,000			Jetty Built 1939-1941	
Jones Inlet	1855-1879 -2880 feet	1879-1909 3390 feet	1909-1926 2900 feet	1926-1934 1540 feet	1934-1953 2500 feet	1953-1968 -	
	Total Migration West feet years feet/yr. 10720 74 135		Littoral Drift cubic yards/yr. 550,000			Jetty Built 1953-1959	
East Rockaway Inlet	1835-1879 7920 feet	1879-1909 5130 feet	1909-1926 3620 feet	1926-1934 400 feet	1934-1968 -		
	Total Migration West feet years feet/yr. 17070 99 172		Littoral Drift cubic yards/yr. 400,000	Jetty Built 1933-1934			
Rockaway Inlet	1835-1877 10030 feet	1877-1902 5190 feet	1902-1928 2740 feet	1928-1934 2450 feet	1934-1968 -		
	Total Migration West feet years feet/yr. 20410 99 206		Littoral Drift cubic yards/yr. 400,000	Jetty Built 1931-1933			

(a) Break through barrier peninsula during storm of 12 September 1938.
(b) Break through barrier peninsula during storm of 31 March 1931.
Minus indicates easterly migration.

Table 5. Westerly Migration of the Eastern Sides of Long Island Inlets.
From: Panuzio, 1968.

of the data (i.e., net longshore transport rates) have been updated since 1968, see Figure 7).

The amount of sand bypassing occurring at the inlets is of critical importance in determining the effects of these features on shoreline erosion. While estimates of the bypassing taking place at the various inlets have been made (Table 6), the accuracy of the resultant figures is questionable due to the paucity of data available for making these estimates. Although the sediment budget study provides the best available information on volumetric changes and has been used as a basis for some of the estimates given in Table 6, the resolution of the data used in this study was deemed inadequate for accurately quantifying sediment transport and bypassing at inlets.

Inlet dredging projects in the study area are most often done in response to navigation needs rather than for erosion control purposes. There is no program of regular artificial sand bypassing and dredging is usually sporadic. At Shinnecock and Moriches Inlets most of the dredging work has focused on maintaining channels through the flood tidal deltas bayward of the inlet channels and much of the resultant dredged material has been placed on the emergent portion of the flood delta (Kassner and Black, 1982). The only dredging in the channel or seaward of the channel at Shinnecock Inlet since it was stabilized was the emergency removal of 162,000 cubic yards of material in 1984 (U.S. Army Corps of Engineers, 1987) and 83,000 cubic yards in 1988. This sand was placed offshore at a depth of 10 feet below MLW downdrift of the inlet. No dredging in the channel or seaward of the channel has been done at Moriches Inlet since it was stabilized in the 1950's. As noted in the Coast Guard's "Notice to Mariners" and on the National Ocean Survey's nautical charts, the inlet has been legally closed to navigation for years due to severe shoaling conditions.

The recent dredging history of Fire Island Inlet was previously described in the section on the effects of structures. Some 8 million cubic yards of material have been dredged from the inlet and placed on the downdrift beaches in 6 separate projects undertaken between 1954 and 1989. Recent quantitative summaries of the federal dredging projects at Jones and East Rockaway Inlets apparently are not available at this time although this information could probably be obtained from an analysis of Corps' dredging records and surveys.

The inlets serve as large sinks of sand in the nearshore system. The ebb and flood tidal deltas associated with Moriches have trapped some 1 to 2 million cubic yards of sand with most of this material stored in the ebb tidal delta (Research Planning Institute, Inc., 1985). Similar large ebb-tidal deltas are also associated with the other inlets in the area (Leatherman and Allen, 1985).

The impacts and processes associated with the inlets are variable with time. Because of their complexity and importance in the

Table 6. Estimates of Natural Sand Bypassing at Inlets

Inlet	Net Longshore Transport, (yd^3/yr)	Amount Bypassing yd^3/yr
E. Rockaway	400,000(a)	150,000(b)
Jones	550,000(a)	100,000(b)
Fire Island	600,000(c)	? (d)
Moriches	304,500(c)	250,000(c)
Shinnecock	300,000(e)	247,000(e)

Sources:

a: (Panuzio, 1968)
b: (U.S. Army Corps of Engineers, 1966)
c: (Research Planning Institute, Inc., 1985)
d: (Galvin, 1985)
e: (U.S. Army Corps of Engineers, 1987)

coastal sediment system, detailed sand budgets should be developed for each of the inlets (e.g. Massa, 1981). The amount of sand naturally bypassing the inlets and the volume of the flood and ebb deltas and their rates of change should be documented. The data available from dredging records, surveys and studies should be reviewed and, to the extent possible, the results should be reported in terms that facilitate comparisons among the inlets. This information should be used to construct models of local inlet behavior. For management purposes, "inlet impact zones" should be established where information gained from models of local situations could be incorporated into planning considerations.

The development of management policies regarding the potential formation of new inlets is also needed. The locations of historical inlets along the eastern section as determined by Leatherman and Allen (1985) are shown in Figure 23. According to their geomorphic analysis, sediment transport associated with inlet creation is an important process in the migration of the eastern section of the barrier system (between Southampton and a point about 10 miles west of Moriches Inlet). The inlet formation and sediment transport processes that drive barrier migration in this section operate intermittently at 50 to 75-year intervals. The central and western sections of Fire Island have been axially stable for hundreds of years (Leatherman and Allen, 1985). From a management standpoint, the relative stability of the barrier island over long time periods indicates that concerns regarding disruption of barrier island migration by inlet processes may be of secondary importance compared to the other more immediate impacts associated with the formation of inlets. New inlets could cause substantial, rapid changes in the coastal environment and have more immediate management implications especially in terms of the 30 to 50 year planning horizon considered here.

Site-specific information on the potential impacts of new inlets along the south shore is largely limited to one modeling study (Pritchard and DiLorenzo, 1985) which was done in response to a breach that occurred in 1980 just west of Moriches Inlet. This breach reached a width of 2900 feet before it was artificially closed one year after it opened (Schmeltz et al., 1982). The results of the modeling suggested that a large breach would increase normal tidal ranges in Moriches Bay by about 60 percent and short-period (hurricane) storm-water level elevations by 35 to 40 percent. The modeling study also indicated that the tidal exchange between Moriches Bay and the ocean is not great enough to maintain two inlets indefinitely. The shoaling problems presently occurring at Moriches and Shinnecock Inlet tend to support this finding. Although reliable estimates of the potential lifetimes and possible closure rates of new inlets are not available at present, the formation of new inlets could adversely affect shoaling rates at the existing inlets due to changes in the tidal flow.

No known studies have focused on the possible effects of major new inlets on shoreline erosion in the study area. However, based on

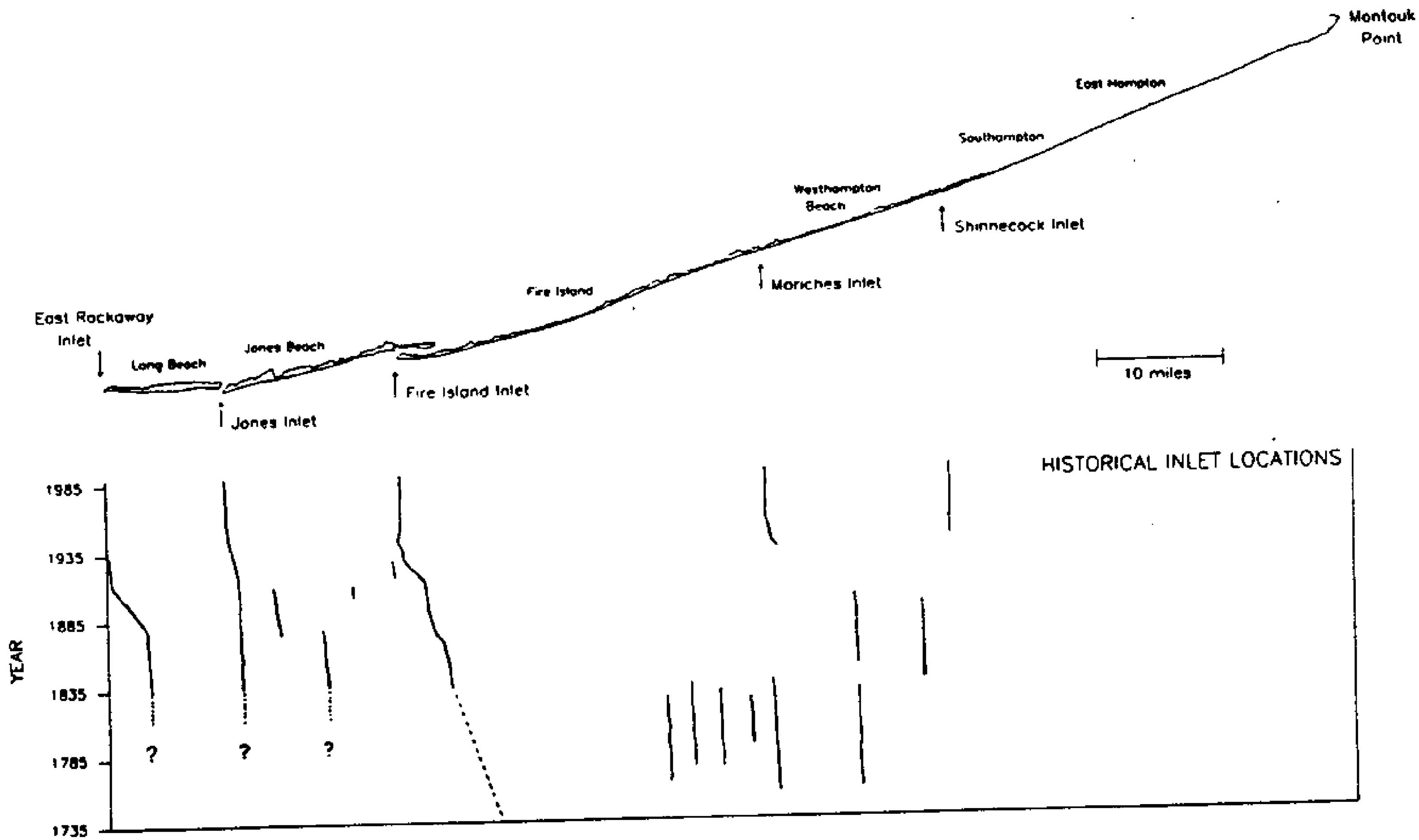

FIGURE 23. Locations of historical inlets based on data from Leatherman and Allen (1985) for the area east of Fire Island Inlet and from Taney (1961) for the area west of Fire Island.

the information available for the existing inlets (i.e., Figure 22, for example), it is reasonable to infer that these features could have significant impacts in terms of accelerated downdrift erosion. During the 11 months the Moriches breach was open some 750,000 cubic yards of material from the longshore sediment system was trapped on its flood tidal delta (Research Planning Institute, Inc., 1985). Obviously the loss of such large volumes of material from the nearshore sediment budget could result in significant downdrift shoreline changes.

There is a body of knowledge concerning the stability of inlets in general, the number that could be supported under different conditions, the processes associated with these features, and possible rates of closure based on hydrodynamics and historical trends, but this information must be reviewed and specifically applied to the conditions on Long Island in order to develop effective strategies for the management of breaches and new inlets. As an initial step, a search for locations where new inlets may form could be undertaken. Important parameters may include: 1) sites of historical inlets, 2) present dune elevation if dunes exist, 3) barrier island width, and 4) bay and shoreface bathymetry. Once potential locations are identified, more intensive studies could be applied to determine possible site-specific impacts of inlet formation.

Overwash Processes: Based on the sediment budget study (Research Planning Institute, Inc., 1985), only about 35,000 cubic yards of sediment per year are moved by overwash processes in the area east of Fire Island Inlet indicating this mechanism is a minor agent in terms of overall sediment transport. Annual overwash volumes in terms of cubic yards per foot of shoreline for different sections of the coast are shown in Figure 24 for the period between 1955 and 1979. The importance of overwash in maintaining a barrier system depends on the migration rate of the barrier island. Since Long Island's barriers are relatively stable, overwash processes are probably not that important especially in terms of management time scales of 30 to 50 years. A management plan might consider dune building and overwash mitigation strategies to help maintain the longshore transport system and enhance shore stability with minimum adverse impacts.

Bluff Erosion: The volume of material contributed to the longshore sediment system by bluff erosion in the eastern headlands sections is relatively low. Based on historic shoreline recession rates, bluff elevations and subtidal volume changes; the sediment budget study indicated that 133,000 cubic yards sediment per year is derived from erosion along the bluffed section of the coast (Research Planning Institute, Inc., 1985). However, not all of this material is moved to the west in the longshore transport system. Because of the varied composition of the bluffs only a portion of the material released by the erosion of these features is of a suitable grain size to be transported by longshore littoral processes. The larger fraction of the material would remain in

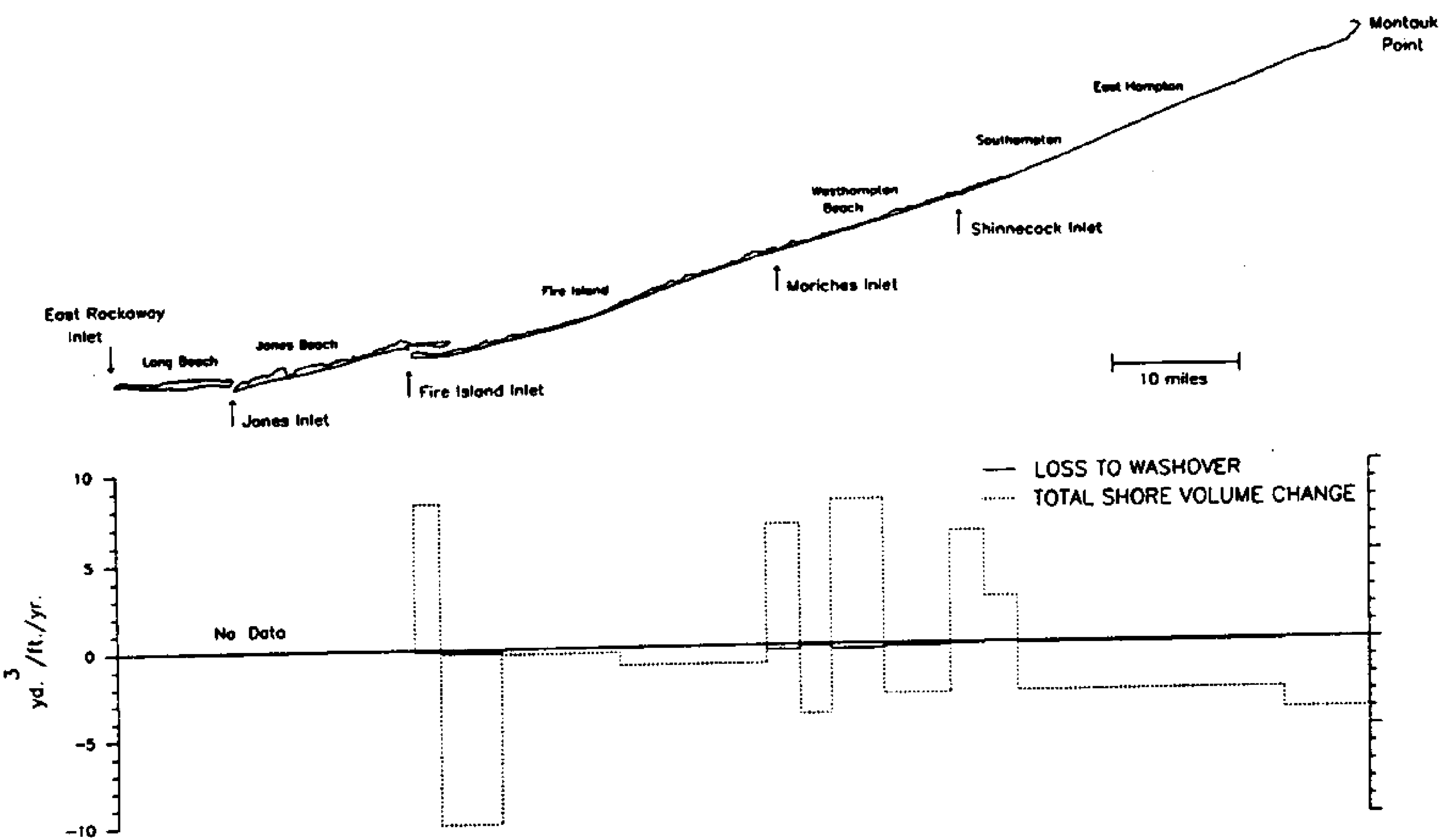

FIGURE 24. Volume losses due to washovers (solid lines) between 1955 and 1979 compared to observed net volume changes (dashed line) based on survey data. From: Research Planning Institute, Inc., 1985.

place while the finer sediments would be dispersed offshore. In addition, the differences in the composition of the bluff along the coast also result in an irregular shoreline further complicating estimates of longshore transport. The geomorphic configuration of the headland and orientation of pocket beaches in this area indicate that longshore transport of material to the west is probably significantly less than the volume derived from erosion processes (Research Planning Institute, Inc., 1985). Although more information on bluff composition and bluff recession rates (rather than shoreline recession rates) are needed to provide accurate estimates, the participants felt based on the available data that the actual total contribution of the bluffed section of coast to the longshore transport system is on the order of 20,000 to 40,000 cubic yards per year, or less than 10 percent of the transport estimated for Fire Island Inlet.

CRITICAL MANAGEMENT DATA NEEDS

To help managers prioritize data collection, the group was also asked to identify and briefly discuss the physical process and coastal information needs that are most critical to developing effective erosion management programs for Long Island's south shore. The following is a brief summary of the suggestions made for improving the information required for management and planning purposes:

1. The 1955 and 1979 profile lines should be reoccupied and surveyed and additional lines, especially in the vicinity of structures and inlets, should be established. Offshore the surveys should extend to the depth of closure (deeper than 30 feet). This information could be used to update and refine the sediment budget and in conjunction with a review of available Corps' data and surveys develop better inlet sediment budgets. It would also provide the bathymetry needed for shoreline response models.

2. Measurements of the interannual variability of shoreline positions should be used to calculate the confidence limits on long-term recession or accretion rates obtained from comparisons of the high waterline on maps and aerial photographs.

3. The presence or absence of dunes and elevation of the dune crest and base should be mapped.

4. Average recession rates over periods of decades determined by changes in dune position (based on contour movements) should be calculated and the results compared with shoreline migration rates based on changes in the position of the high waterline.

5. Directional wave gauge arrays should be established at two locations along the shore.

6. An erosion "vulnerability index" could be devised for the south shore. This index should include:

   a. dune crest and base elevations, where dunes exist,

   b. beach volumes seaward of a particular elevation contour or, where appropriate, the toe of the structure to be protected,

   c. elevations of the storm surges with recurrence intervals appropriate planning needs,

   d. landward limits of storm wave penetration,

   e. long-term recession rates.

Dr. Zarillo developed a preliminary vulnerability index based on two parameters to illustrate this approach. He chose dune height and the volume of sand on the beach per unit length of shore to assign relative values of vulnerability along the shoreline. The empirical index (I) was defined as:

$$I = \frac{100,000 - (VxH)}{10,000},$$

where: V = Volume of sand on the beach in cubic meters
H = Height of dune in meters

in order to obtain values between 1 and 10. This index was calculated for over 70 locations on the south shore where profile data was available. The value ranged from about 4 (low vulnerability) to over 9 (high vulnerability) as shown in Figure 25. While such an approach needs much more work in terms of identifying the most important variables and refining the index, the development of such an index may provide a promising mechanism for reducing the wide array of diverse data into a form that could be more readily used for management and planning.

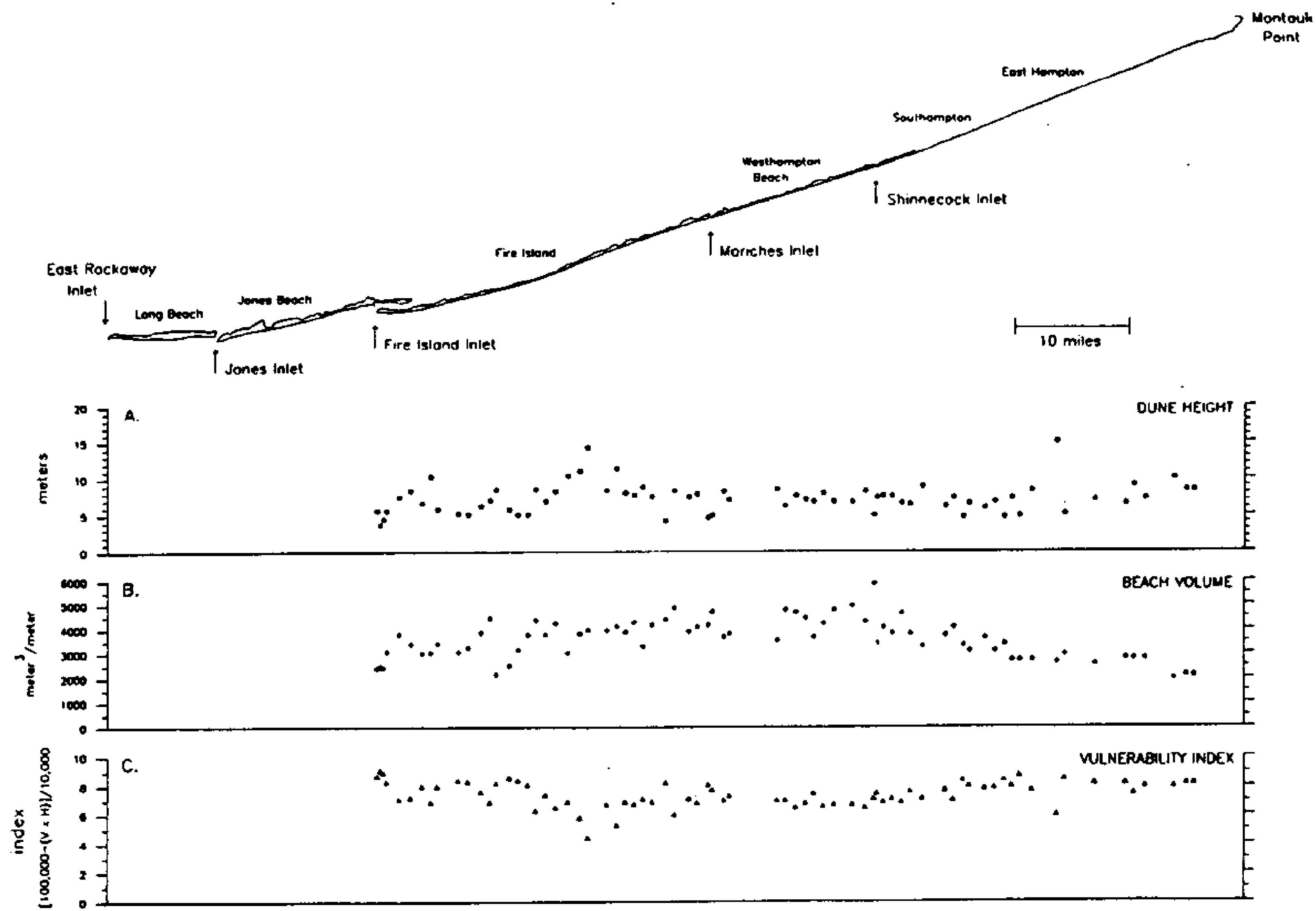

FIGURE 25. Preliminary vulnerability index for south shore based on dune height (A) and beach volume (B). The actual value of the index for seventy discrete points along the shore is shown in C. V = beach volume and H = dune height.

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APPENDIX 1

Attendees

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APPENDIX 2

Interannual Beach Changes

The range of beach changes in terms of horizontal variations in the mean sea-level intercept were calculated at several locations along the shoreline where profiling studies have been done. At each location profiles were available at between 5 and 20 stations surveyed at least several times per year for up to 11 years. At each location, the range of changes in observed shoreline position over every year were determined for each station and both the average value of all the stations for the year and the maximum value observed at any station for that year were found. Both the average and the maximum for each year were then averaged over the number of years of available record to obtain the mean interannual range, R, and the maximum interannual range.

To calculate the average long-term recession rate in an interval of duration, P, the annual average shoreline position at the beginning of the period, S1, is subtracted from the average annual shoreline position at the end of the period, S2, and the difference divided by P:

$$\text{Recession rate} = (S2- S1)/P$$

The observed shoreline on any particular map or aerial photograph is unlikely to be at the annual average position but rather to depart from it by some distance, E, so,

$$S1 = S1 + E1$$

and

$$S2 = S2 + E2$$

On the average the maximum departure would be $\pm$ R/2 and the maximum difference between the unmeasured, mean shoreline over the period would be:

$$[(S2 + R/2) - (S1 - R/2)]/P$$

$$\text{or } [(S2 - S1) + R]/P.$$

Likewise, the minimum difference would be when each shoreline is at the opposite end of the interannual range:

$$[(S2 - R/2) - (S1 + R/2)]/P$$

$$\text{or } [(S2 - S1) - R]/P.$$

So the maximum uncertainty in the recession rate calculated from observed shorelines (rather than from the annual mean shoreline) is

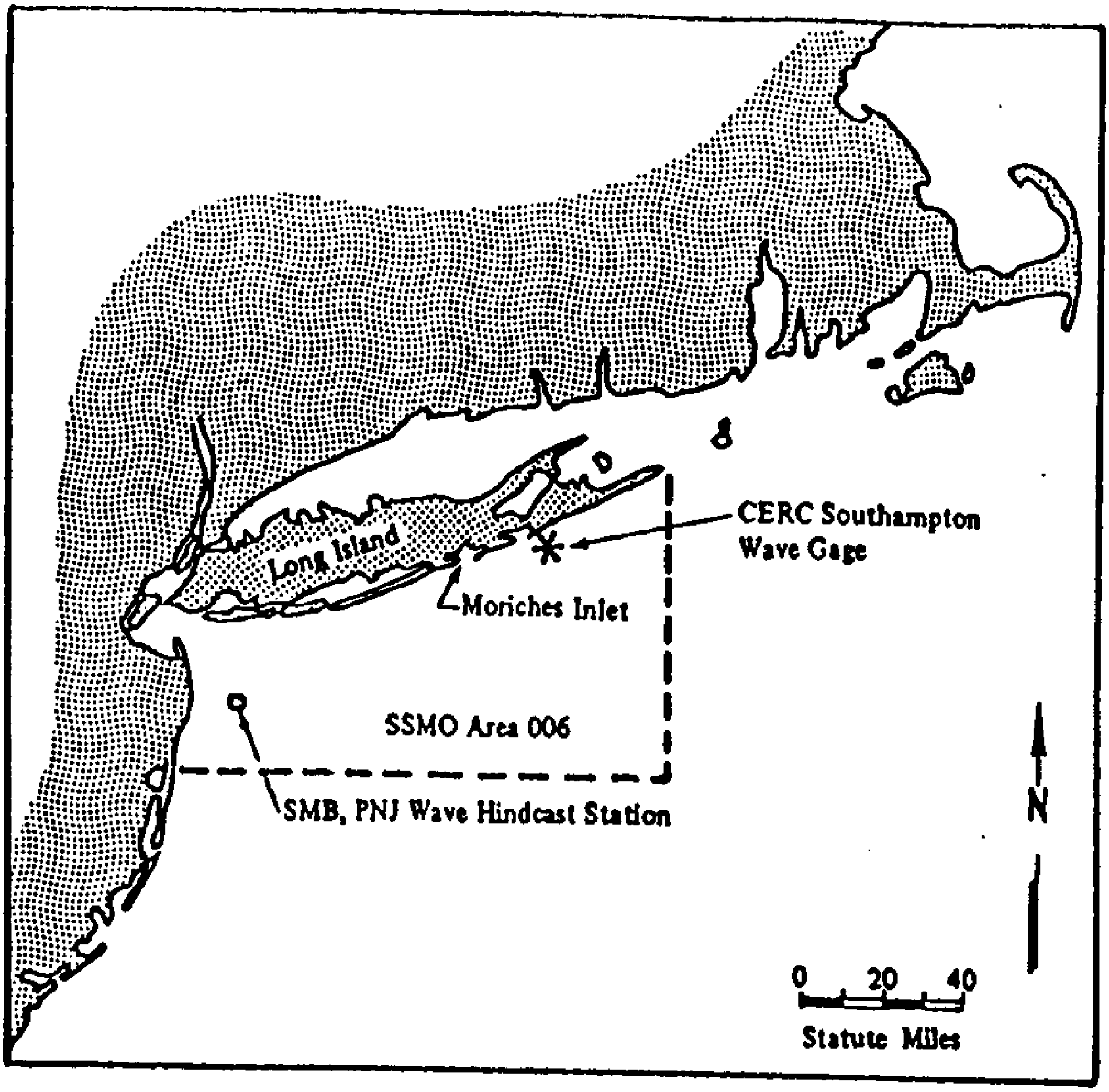
$$\pm R/P$$

For the available data sets this corresponds to a rate of about ± 2 feet/year to ± 3.5 feet/year for the period between 1933 and 1979. The uncertainty is larger if we use the average maximum range rather than the average range.

It must be noted, however, that the chances of the error being as large as $\pm R/P$ is very small; it may be smaller perhaps 99 percent of the time. As a result, a better estimate of the uncertainty would be to recalculate E values at some reasonable level of probability of occurrence, perhaps the E that is realized more than 80 percent of the time.

APPENDIX 3

Offshore Wave Data



Available Wave Climate Statistics

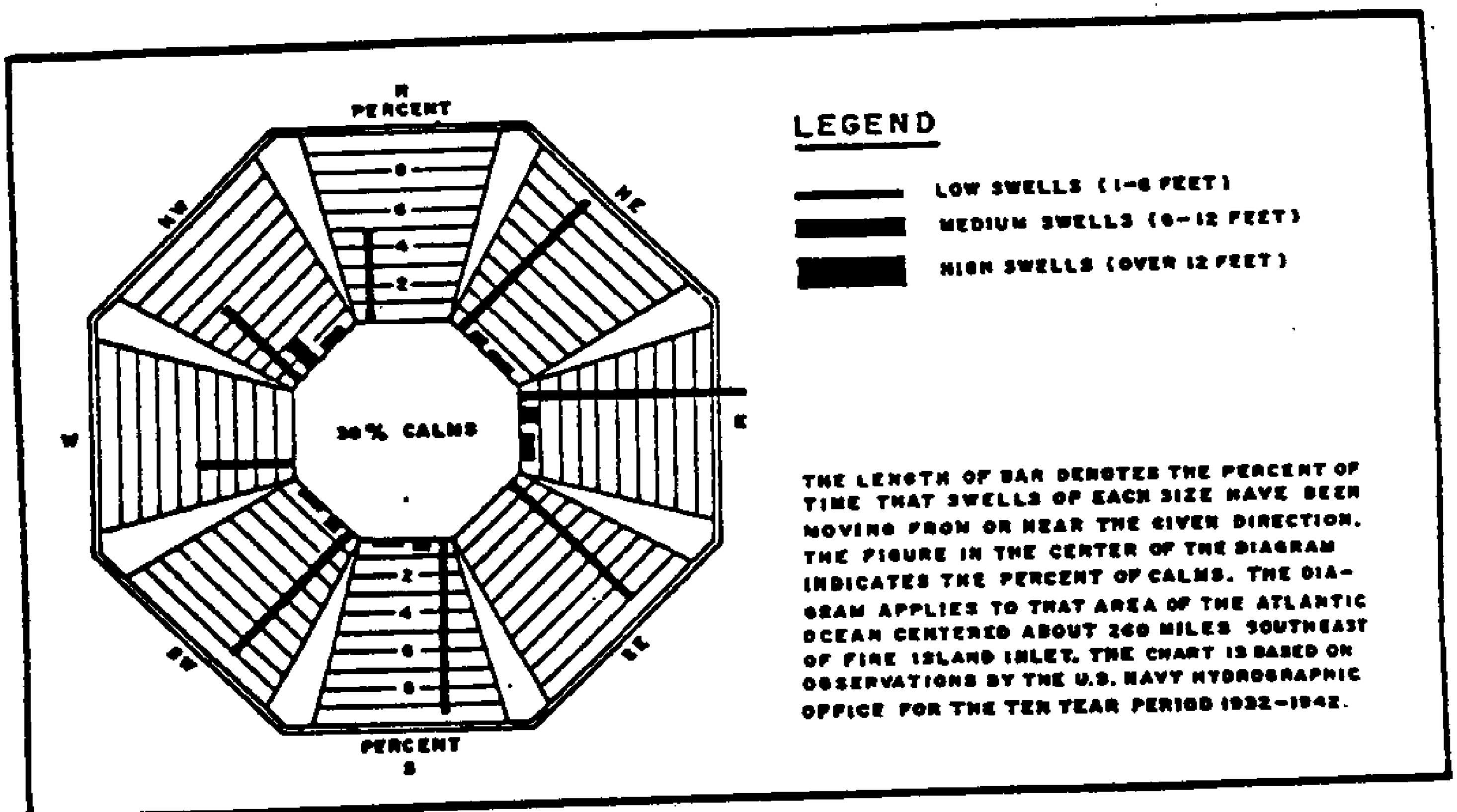
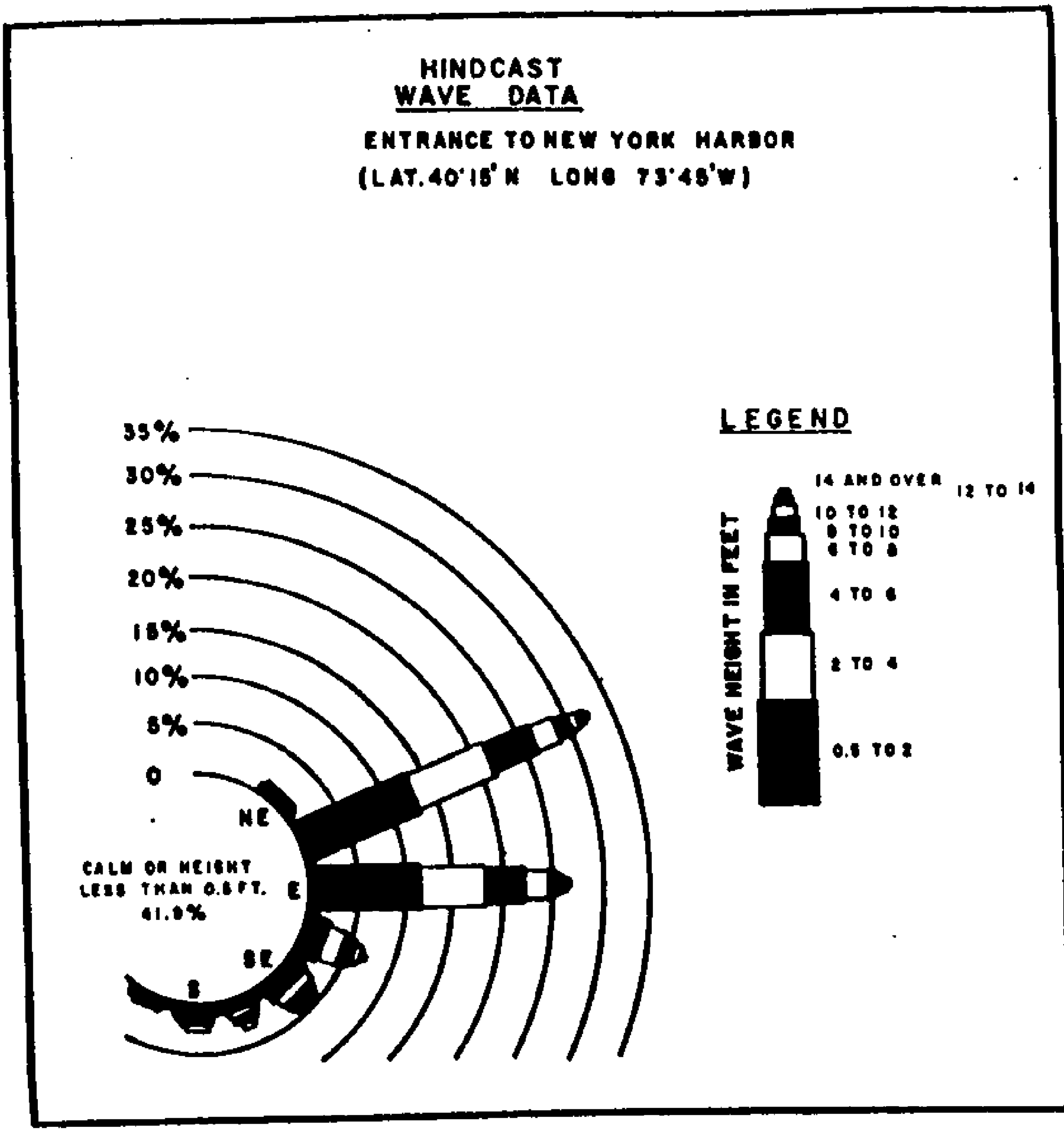
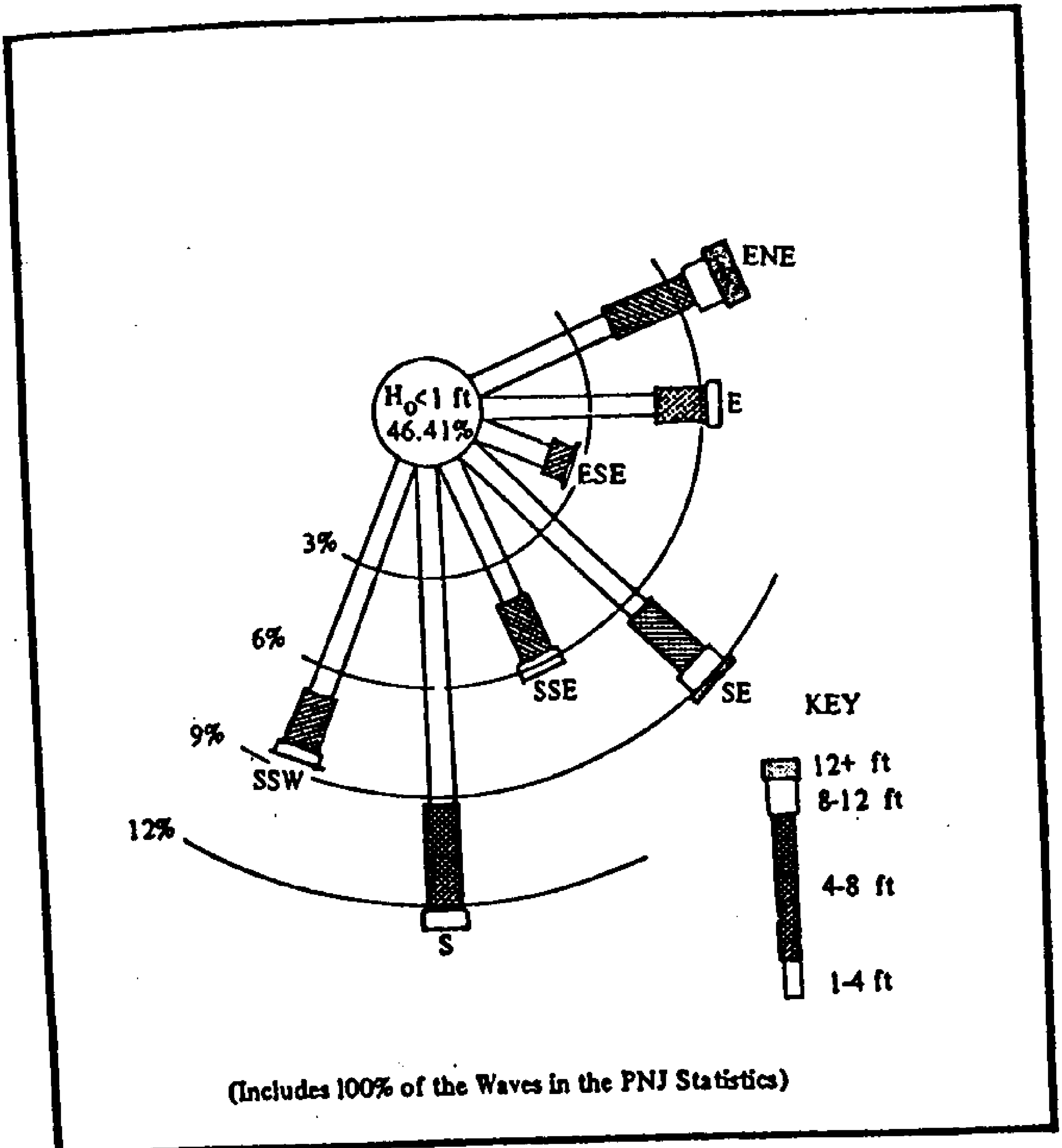


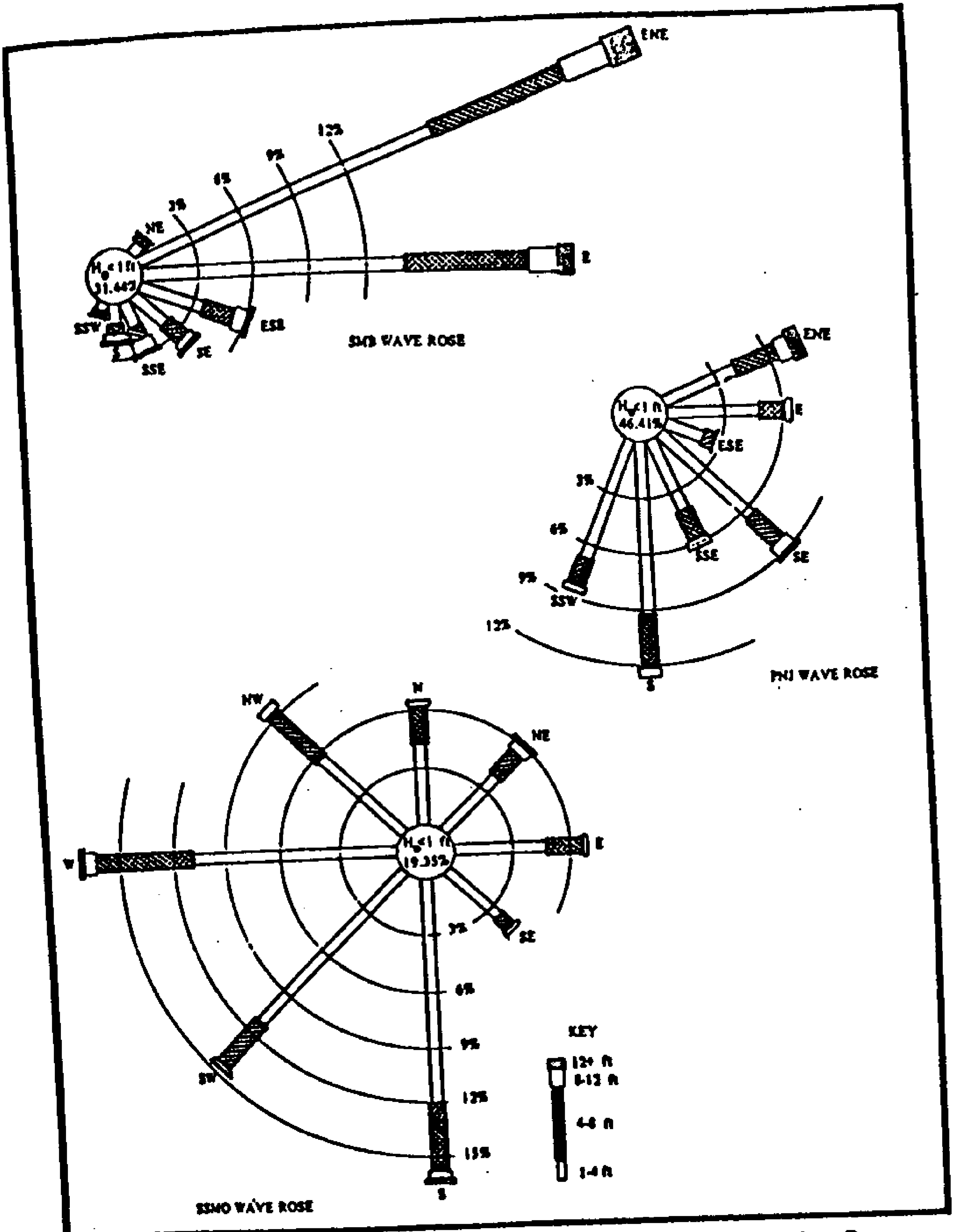
DIAGRAM OF OBSERVED SWELL HEIGHT AND DIRECTION FROM WHICH OBSERVED, 1932-1942, 260 MILES SOUTHEAST OF FIRE ISLAND INLET



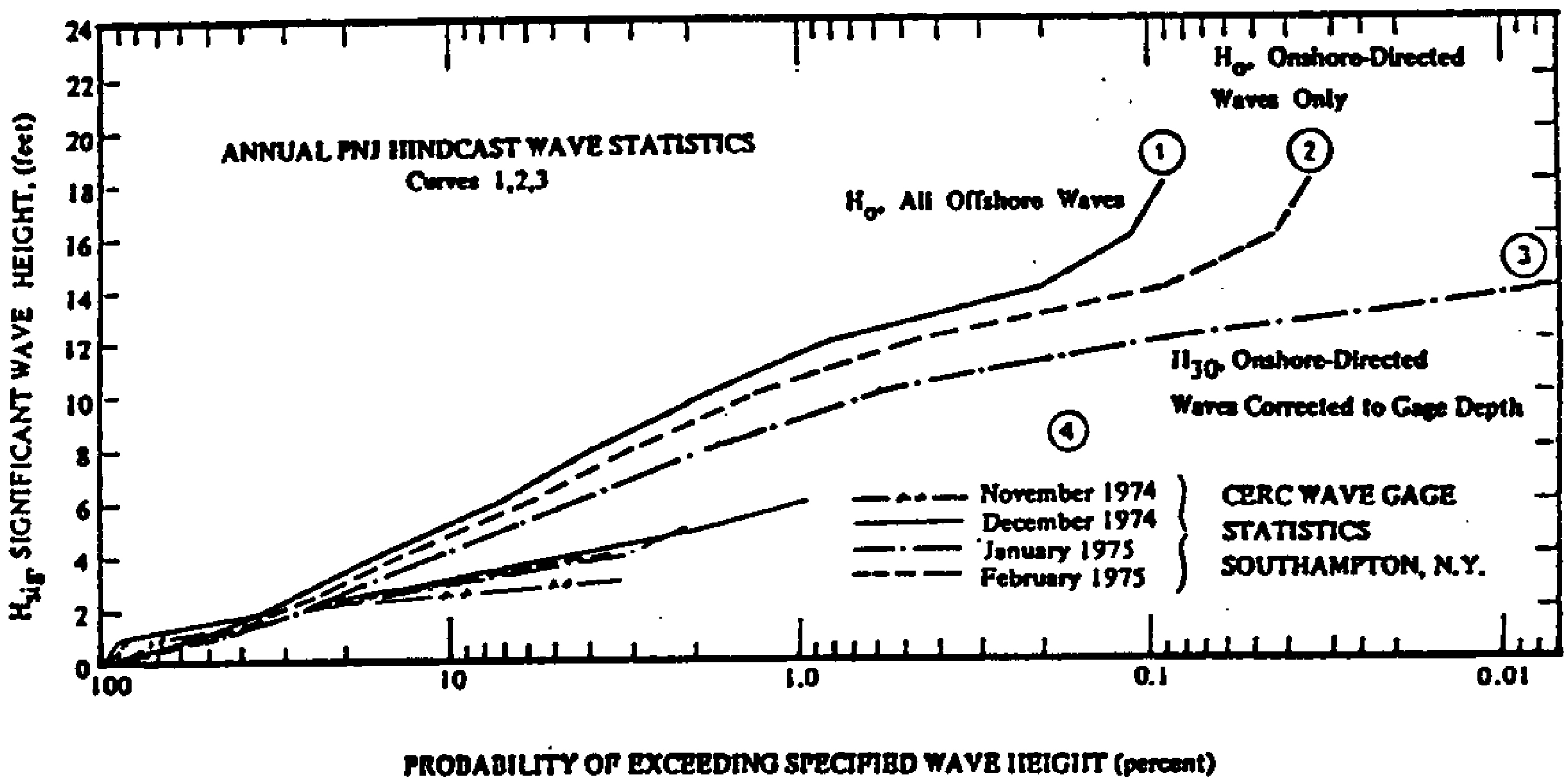
HINDCAST WAVE ROSE FOR DEEPWATER OFFSHORE OF NEW YORK HARBOR (Saville, Jr., 1954)



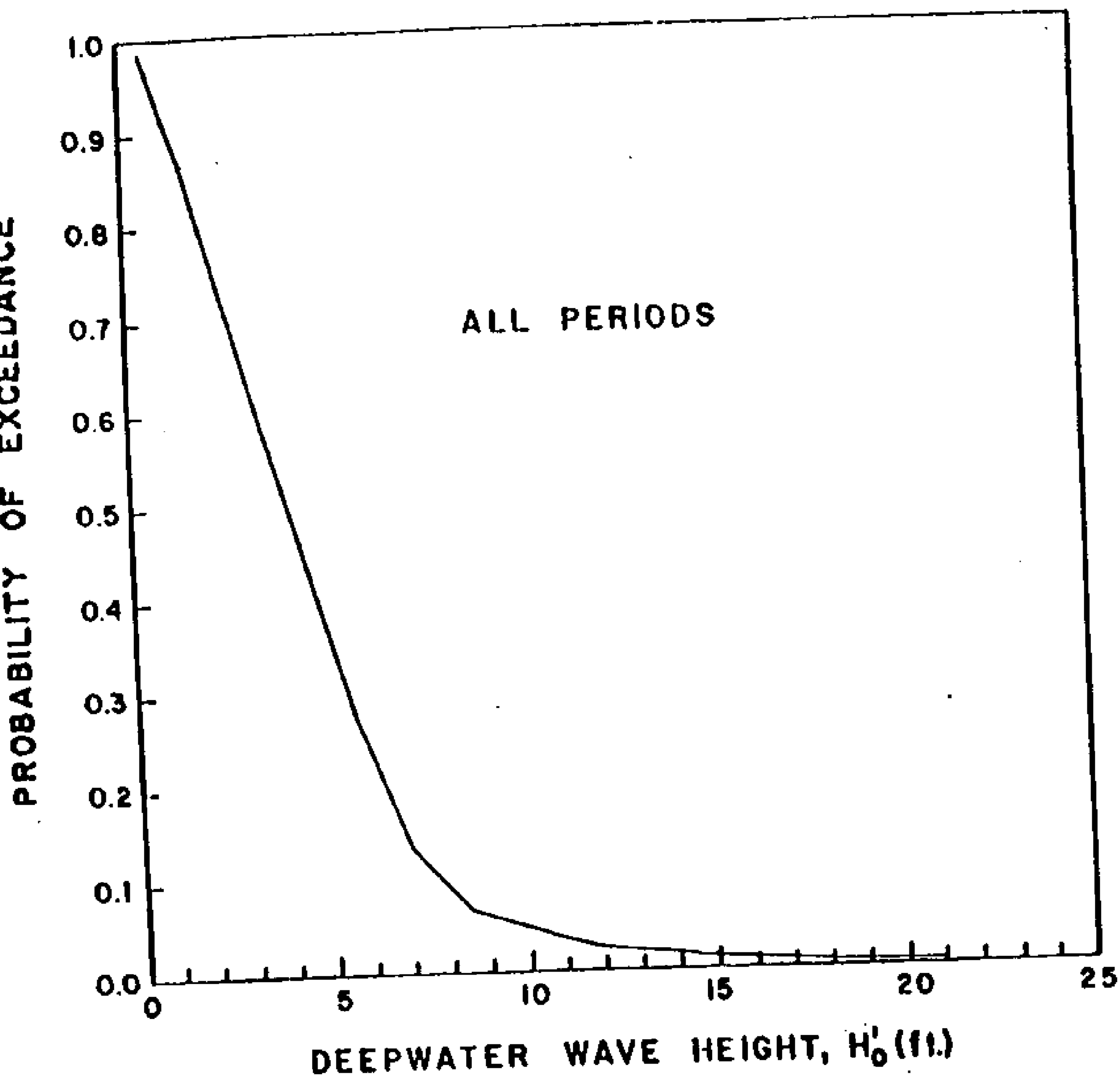
Annual DeepWater Wave Height-Direction Rose Given by the PNJ Hindcasting Procedure (Data from Neumann and James, 1955).



Comparison of Annual Deep Water Wave Height – Direction Roses, SMB, PNJ and SSMO Wave Statistics



Comparison of Cumulative Wave Height Statistics, PNJ Hindcast and CERC Southampton Wave Gage.



EXCEEDANCE PROBABILITY OF WAVE HEIGHTS FOR ALL PERIODS. (SSMO)

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