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 in the process of 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.

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In conjunction with this effort, a series of three workshops is being 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 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. This report summarizes the findings of the second workshop in this series.

Summary of First Workshop

Based on the findings of the first workshop (the proceeding of the first meeting are summarized in a separate report), 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 including the processes associated with inlets, longshore sediment transport, the cross-shore 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 is 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 its utility for developing management strategies.

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

Procedure

To achieve these objectives, coastal scientists who have worked extensively on south shore erosion problems were invited to participate in this workshop (See 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 presented and discussed by the entire group in terms of the availability, coverage and quality of the coastal information in the various categories listed above that has been collected along the south shore of Long Island.

The results of the groups efforts are reported in the following sections.

GEOGRAPHIC SETTING

The study area 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 (Taney, 1961); a barrier island section extending from East Rockaway Inlet to Southampton (73 miles) and a headlands section between Southampton and Montauk Point. The barrier system is composed of four separate 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). The 33-mile headland section is comprised primarily of beaches backed by glacial outwash deposits and in certain locations shallow ponds which are remnants of glacial drainage channels. Glacial till bluffs 40 to 60 feet high back the beach along the easternmost 10-miles of this section.

A detailed analysis of the land use patterns along the south shore is provided in the hurricane mitigation plan developed for the area 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 the beaches here. A 4-lane parkway built on 40 million cubic yards of fill dredged from the back bay in the 1920's runs along the length of the island. There are also 4 small residential communities on lands leased from the local governments. Three of these communities are located landward of the parkway. Fire Island is largely undeveloped with 20 low-to-moderate density seasonal residential communities. Vehicle traffic is severely restricted (there are no paved roads) and access is primarily by ferry. Much of the island is owned by federal government as part of the Fire Island National Seashore and and a portion is managed by the National Parks Service as a wilderness area. Westhampton Beach is characterized primarily 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.

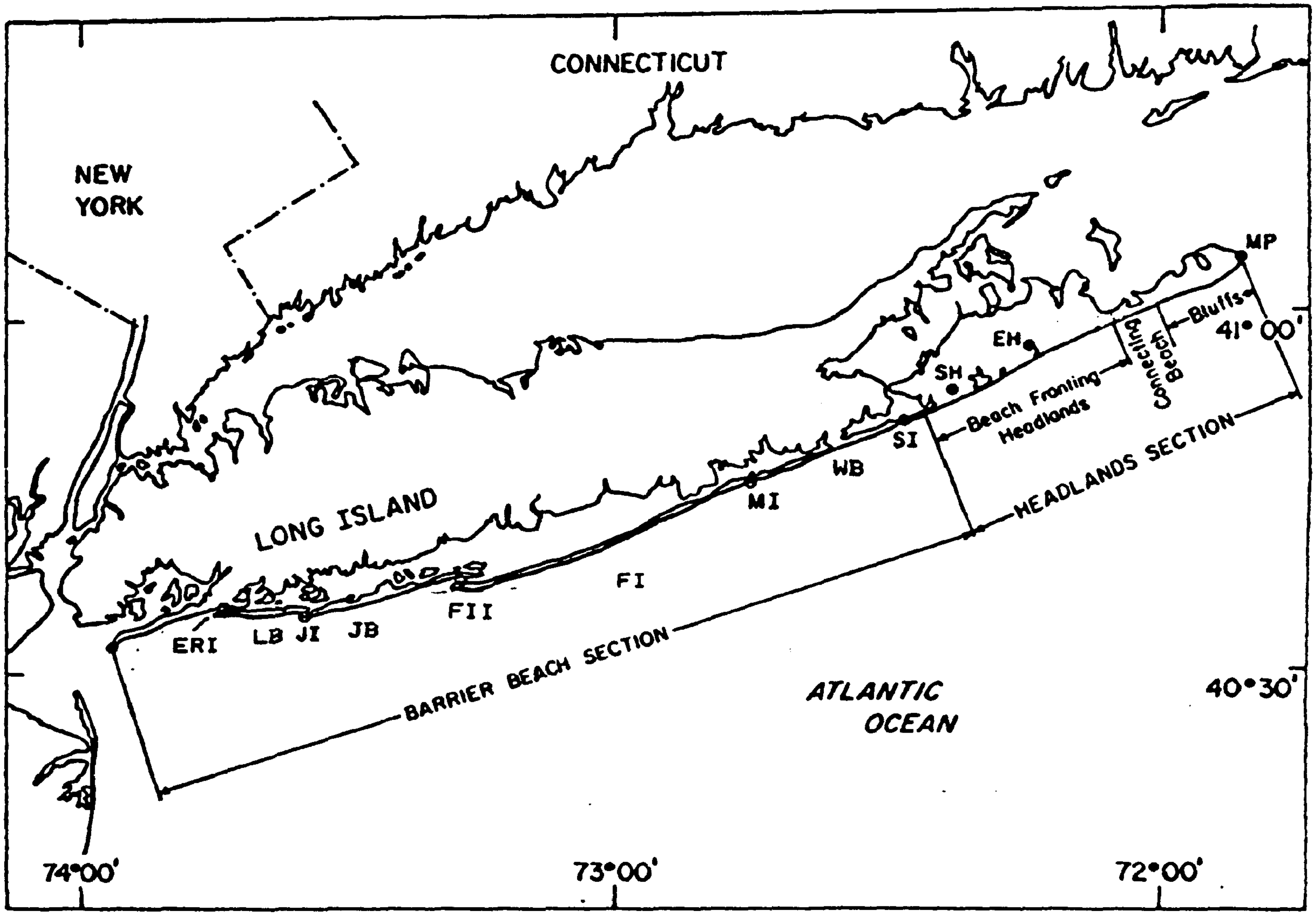


FIGURE 1. Index map. ERI = East Rockaway Inlet; LB = Long Beach; JI = Jones Inlet; JB = Jones Beach Island; FII = Fire Island Inlet; FI = Fire Island; MI = Moriches Inlet; WB = Westhampton Beach; SI = Shinnecock Inlet; SH = Southampton; EH = Easthampton; MP = Montauk Point.

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, several federal projects have resulted in a number of general design memoranda including; the Fire Island to Montauk Point Hurricane and Beach Erosion Protection Project (U.S. Army Corps of Engineers, 1977), 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. Ninety percent of the available survey and map data covers only about 20 percent of the shoreline along this section. The detailed studies that have been done have been restricted to specific areas and limited time periods. As a result, there is little comparative data available for the entire shoreline over an extended time period.

Two of the more comprehensive studies in terms of coverage in time and space for this stretch of coast were a regional sediment budget study (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 1977 hurricane protection plan study.

For the sediment budget, survey data from 1933, 1940, 1955, a partial set in 1967, and 1979 were reviewed and analyzed. The most important data in terms of the preparation of the budget were 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. Although the Strock ranges did not correspond with the earlier Corps bench marks, these two data sets were cited as the most useful because they: 1) provided the most comprehensive coverage of the entire study area over a relatively long time interval; 2) represented controlled survey data 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, most accurately represent current conditions. Comparative analysis of a total of 135 profiles from the two years were used in developing the sediment budget for the 1955-1979 period.

The geomorphic analysis study focused on identifying and quantifying the rates and modes of barrier island behavior over the past 500 years using data derived from several sources, including: a review of the literature, 139 vibracores and 80 miles of seismic reflection and ground penetrating radar records, historic maps and aerial photographs from the past 150 years (for the development of metric maps of the past shoreline positions), an aeolian sediment transport study, and the above-mentioned sediment budget study. Data on coastal processes west of Fire Island are less comprehensive, not as well documented, and, in many cases, somewhat dated in comparison to 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 Jones Beach Island (between Fire Island Inlet and Jones Inlet) as part of a combined navigation and hurricane 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 CERC have also synthesized data from monthly subaerial beach profiles taken between 1962 and 1974 (Everts, 1973; Morton et al., 1986). Quantitative survey data in this area has also been collected in conjunction with a recent inlet dredging and sand bypassing project but this data has not been compiled or analyzed in a comprehensive fashion 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). Although the Corps is apparently updating and analyzing the available data for this area, the results of these efforts, to be issued as a CERC report, were not available at the time of this meeting.

In addition to the Corps-related work there have been a number of other studies and reports done on the south shore by various groups and individuals. For the most part, these studies focus on specific, relatively small sections of the coast shore during different time periods. Many of the available studies and 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 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 1955. Leatherman and Allen developed maps of the mean high tide shoreline 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 long-term annual recession/accretion rates. Because of the technique used in the latter study, these are considered the best data available on shoreline changes. The data from these two studies are plotted together in Figure 2.

Additional information on long-term shoreline changes for some subsections is also available. Zarillo and Zarillo (1989) have compiled information on the area 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 3.

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

a. 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, these maps must be interpreted as qualitative indicators of shoreline position.

b. When aerial photographs are used the position of the color change on the beach representing the demarcation between saturated and unsaturated sand is usually 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.

c. Because of the differences in the exact indicator used for the shoreline position, comparisons between maps and aerial photographs may be unreliable.

d. 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 done carefully, however, these errors can be small.

e. There are large unpredictable interannual variations in the shoreline position due to short-term changes in the beach from caused by storms.

Data on the short-term fluctuations of shoreline positions have been developed for a limited number of locations where subaerial beach profiles had been surveyed at least several times per year for periods up to 11 years (Jones Beach Island, Ocean Beach (Fire Island), Fire Island Pines, and East Hampton). An examination of the available profile data indicated that the maximum annual

Figure 2. Annualized long-term rates of shoreline recession (-) and accretion (+). (A) = data from Taney, 1961; (B) = data from Leatherman and Allen, 1985. Boxes indicate average and maximum annual variations in the mean sea level intercept based on surveys at selected locations.

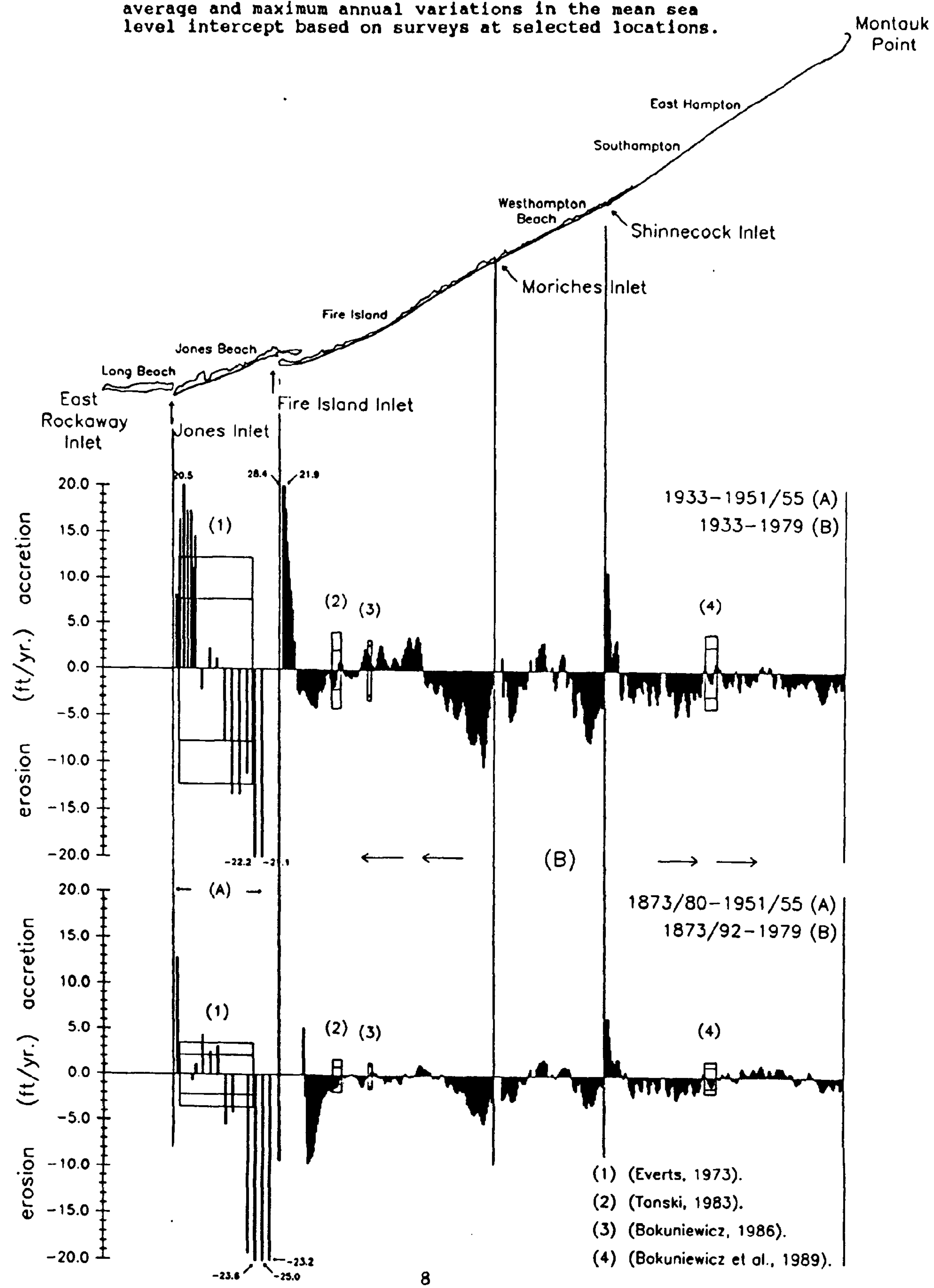
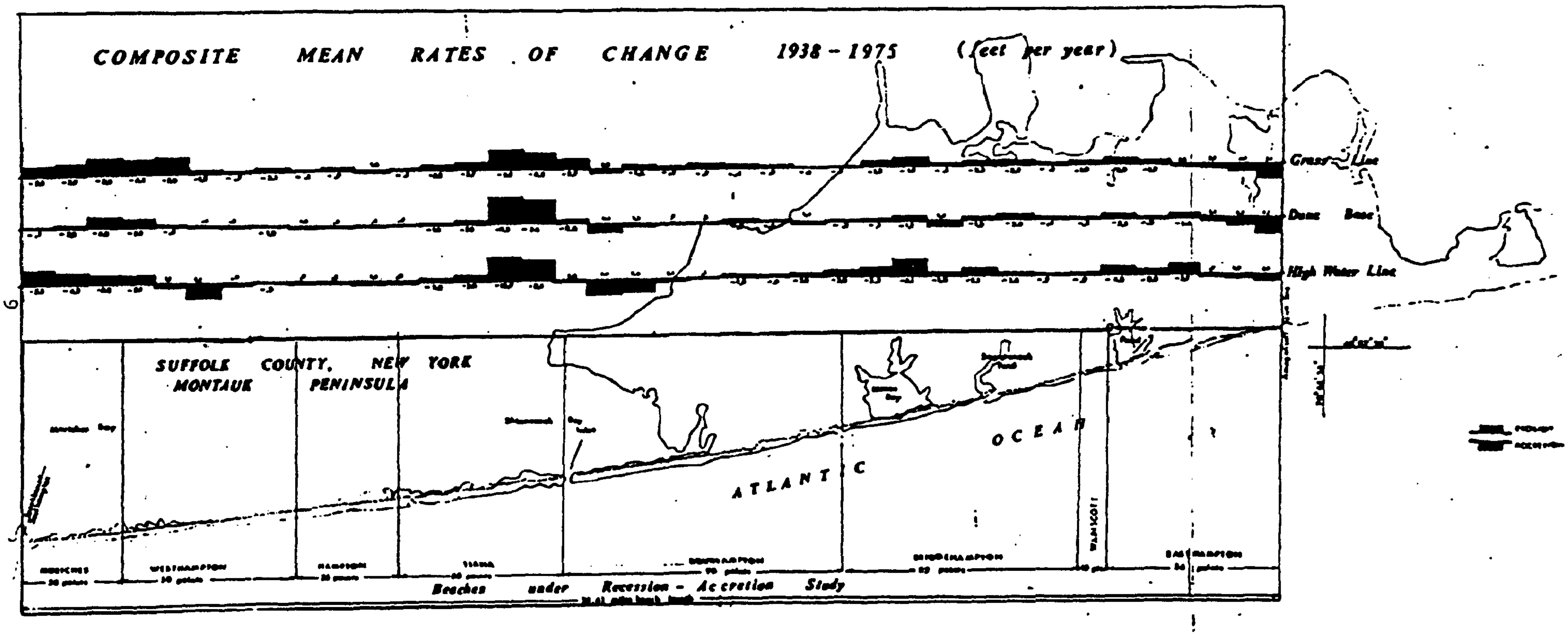


Figure 3. Changes in vegetation line, dune base and high water line between 1938 and 1975 for a section of the study area from Rich (1975).



horizontal variations in the mean sea level intercept for individual profiles ranged from 148 feet to 270 feet (with an average value over a decade of 183 feet) and the mean annual range varied from 100 feet to 169 feet (with an average value over a decade of 122 feet) at the different locations.

The uncertainty associated with the calculated long term annual recession/accretion rates due to the interannual variations in shoreline position derived from the profile data is also shown in Figure 2. The maximum and average range of annual shoreline position (as indicated by horizontal changes in the mean sea level intercept) divided by the number of years in the associated period of record are indicated by the boxes at the four locations. (See Appendix 2 for a discussion of the procedure used).

Several recommendations were made for improving the quality of information on long-term shoreline recession/accretion rates.

1. Only aerial photographs should be used in the analysis. These should be properly rectified and superimposed on a well-surveyed, large scale (1 inch = 200 feet) map. 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 should be redone using the position of the vegetation line or a particular contour related to some part of the dune instead of the high water shoreline. The vegetation line and 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 shoreline trends associated with the use of the high water mark as an indicator 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

Quantitative data on the response of the shoreline to storm events are extremely limited due to the paucity of actual measurements on the south shore during periods of storm activity. Morton and others (1986) in a study on Jones Beach Island analyzed beach volume changes based on comparisons of sequential, subaerial profiles for eight storms occurring between 1968 and 1971. 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 cubic yards per foot of beach to 21 cubic yards per foot. However, they also reported that 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 are available due to the lack of sequential surveys extending offshore.

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. The comparison should be made between the 1962 storm shoreline and the next closest (in time) shorelines before and after 1962). Again, the vegetation line or a particular contour related to the dune (the six-foot contour is probably indicative of the base of the dune in most areas) should be used instead of the waterline as an indicator of shoreline position change).

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 maps are not 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 best existing long-term information on volumetric shoreline changes is that developed in sediment budget study by Research Planning Institute for the area east of Fire Island Inlet. The data on the net longshore transport, the total net annual volume changes; and the net annual volume changes for the portions of the shoreline above mean high water, in the intertidal zone and between mean low water and -24 feet MLW for the period 1955-1979 are plotted in Figures 4 and 5. The results show, for example, that

Figure 4. Annualized net longshore transport rates and net shoreline volume changes for period 1955-1979 from sediment budget study (Research Planning Institute, Inc., 1985).

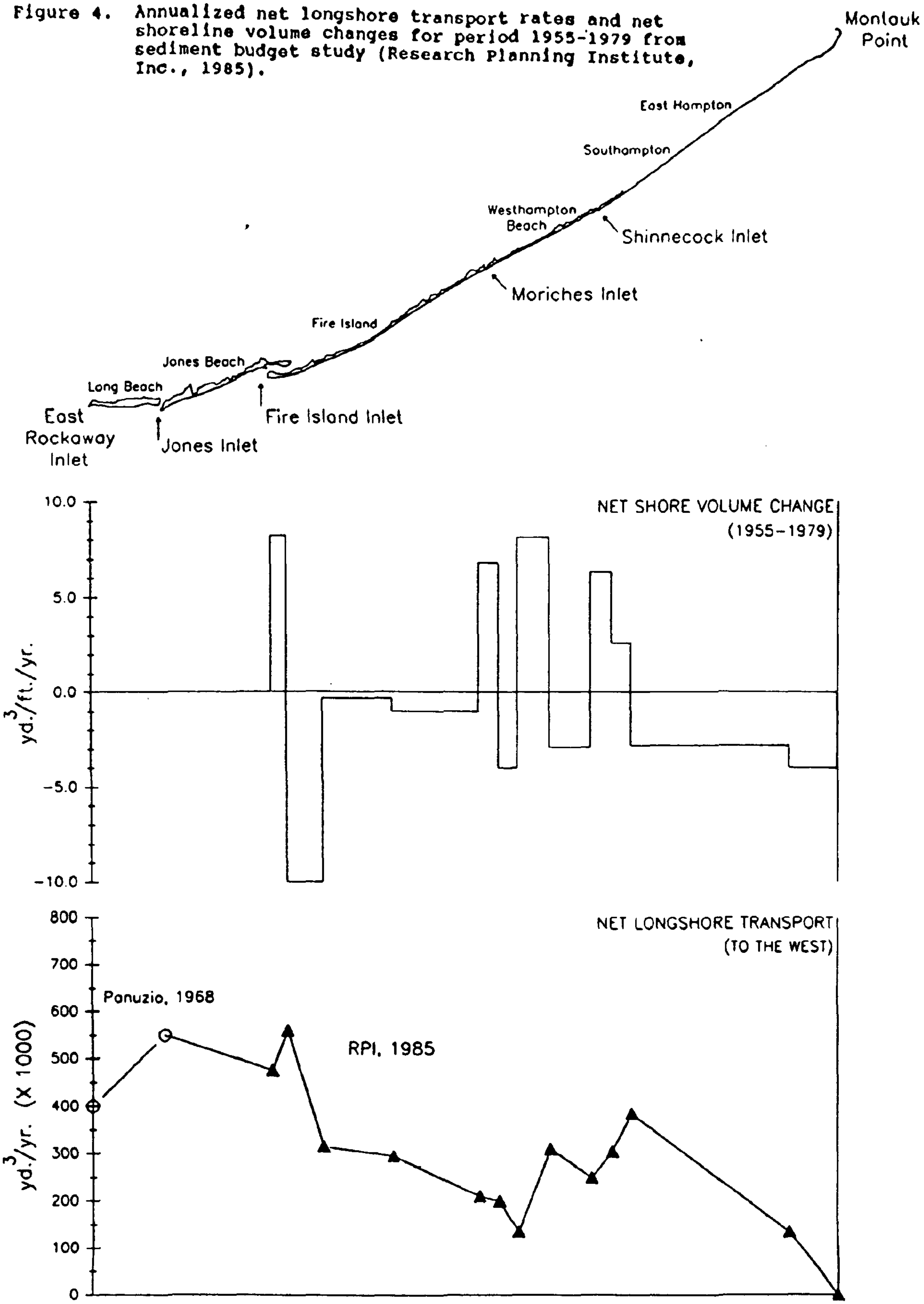
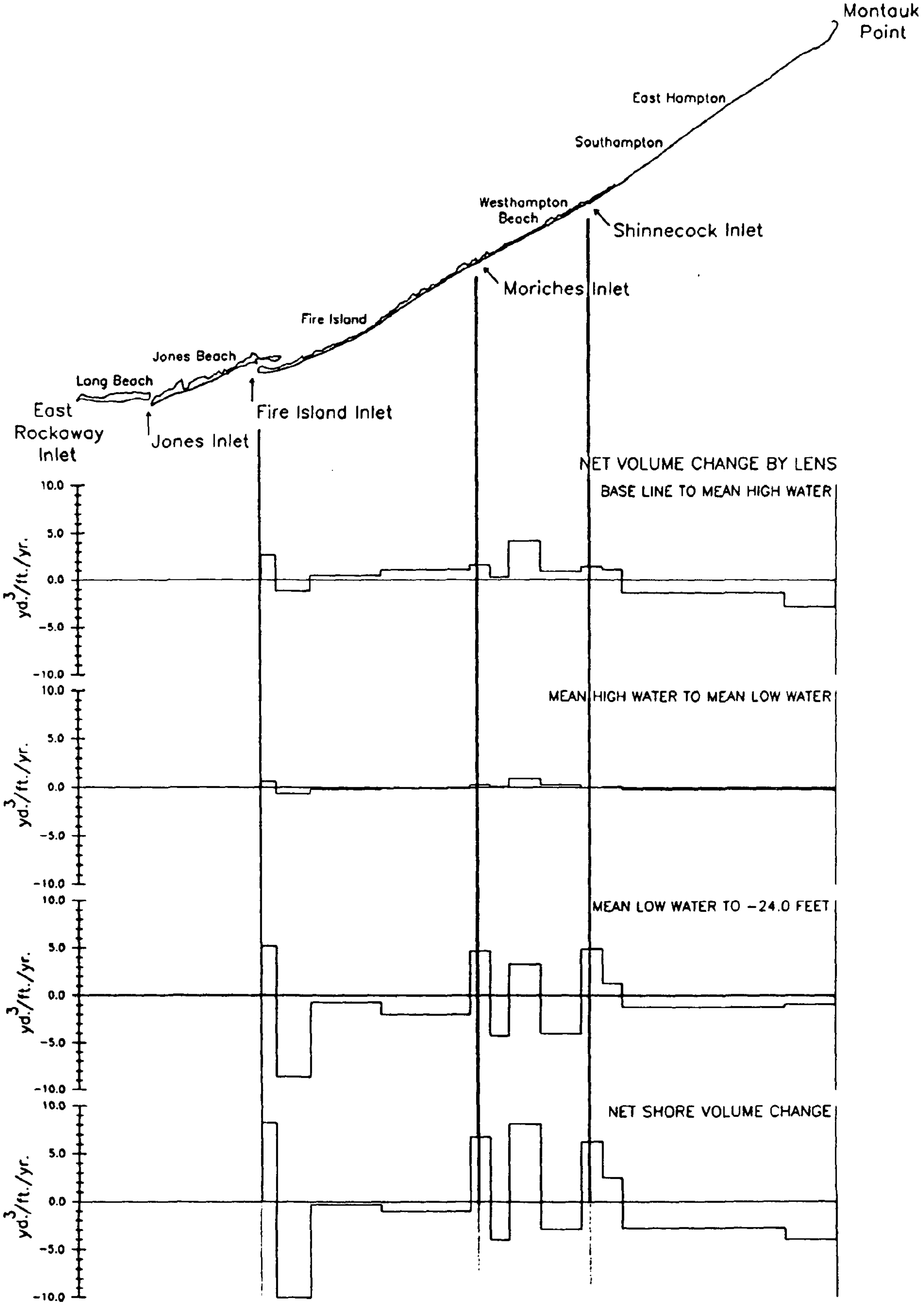


Figure 5. Annualized net shoreline volume changes by lens and total net change (RPI,1985).



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 developed for the shoreline west of Fire Island Inlet.

Although the sediment budget study represents the best available data on long term volumetric changes a number of limitations associated with this data set were noted.

1. Reliable comparative long ranges and bathymetry were generally only available for limited areas and time periods. As a result, only a limited number of usable profiles (a total of 135) were available for a relatively long 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 adjacent ranges for comparisons.

2. The ranges used only extended to 24 feet MLW. There is no information on changes below this depth.

3. The relatively stable geomorphic history of the 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. Better resolution, especially around inlets, is needed. 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 generally limited to those few areas described in the previous section on trends of shoreline migration where regular beach profile monitoring programs have been undertaken for various time periods. It is important to note that these studies only involved measurements of the subaerial beach. As a result, they do not provide information on changes occurring below mean sea level, which are of far greater magnitude than the changes taking place on the subaerial beach.

In general, 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 strongly influenced by storm events. As an example, Figure 6 illustrates the subaerial beach volume changes measured at a typical 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. Although the maximum change caused by a storm at any particular station may be 5 to 10 times the typical change, the average volumetric changes due to storms were not exceptionally larger than the average changes measured between survey dates (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 could, for the most part, 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 changes are likely to be very small and extremely uncertain.

A study of the aeolian 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). The volume of sediment transported by aeolian processes for the entire area was calculated to be on the order of 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, the amount of sand transported across the crest of the dune from the seaward direction was estimated to be approximately 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 identified a "prototype" dune having a volume of 37 cubic yards per foot). Based on the findings of the aeolian sediment budget, a generalized model of the potential effects of different conditions of development was formulated (Figure 7).

Effects of Structures

The locations of groins and jetties in the study area are plotted in Figure 8. There are some 69 groins and jetties in the study area. The highest concentration of groins is on Long Beach which has a total of 48 of these structures. In general, the most important 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 down drift 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

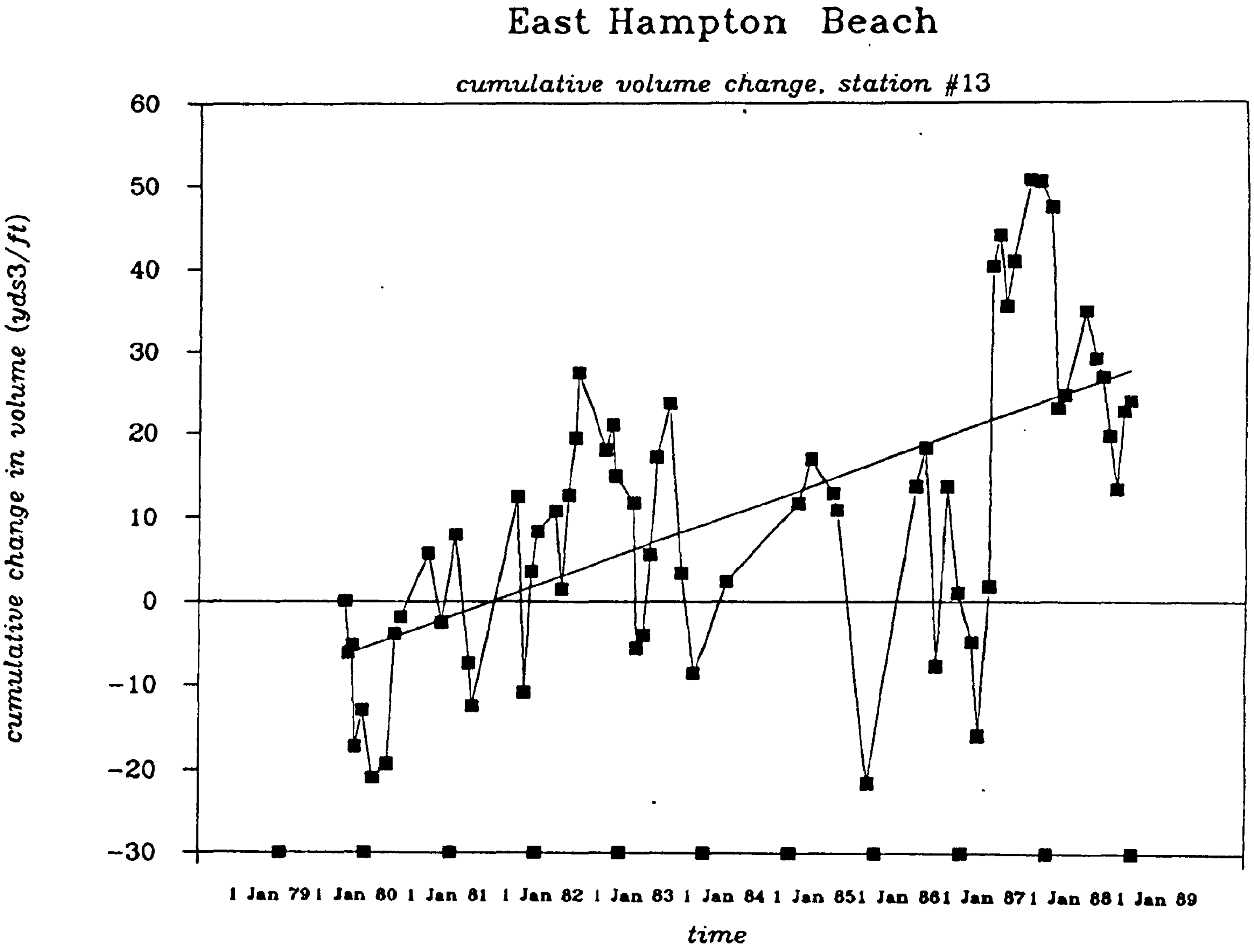


Figure 6. Beach volume changes based on successive subaerial profiles at a typical station in East Hampton.

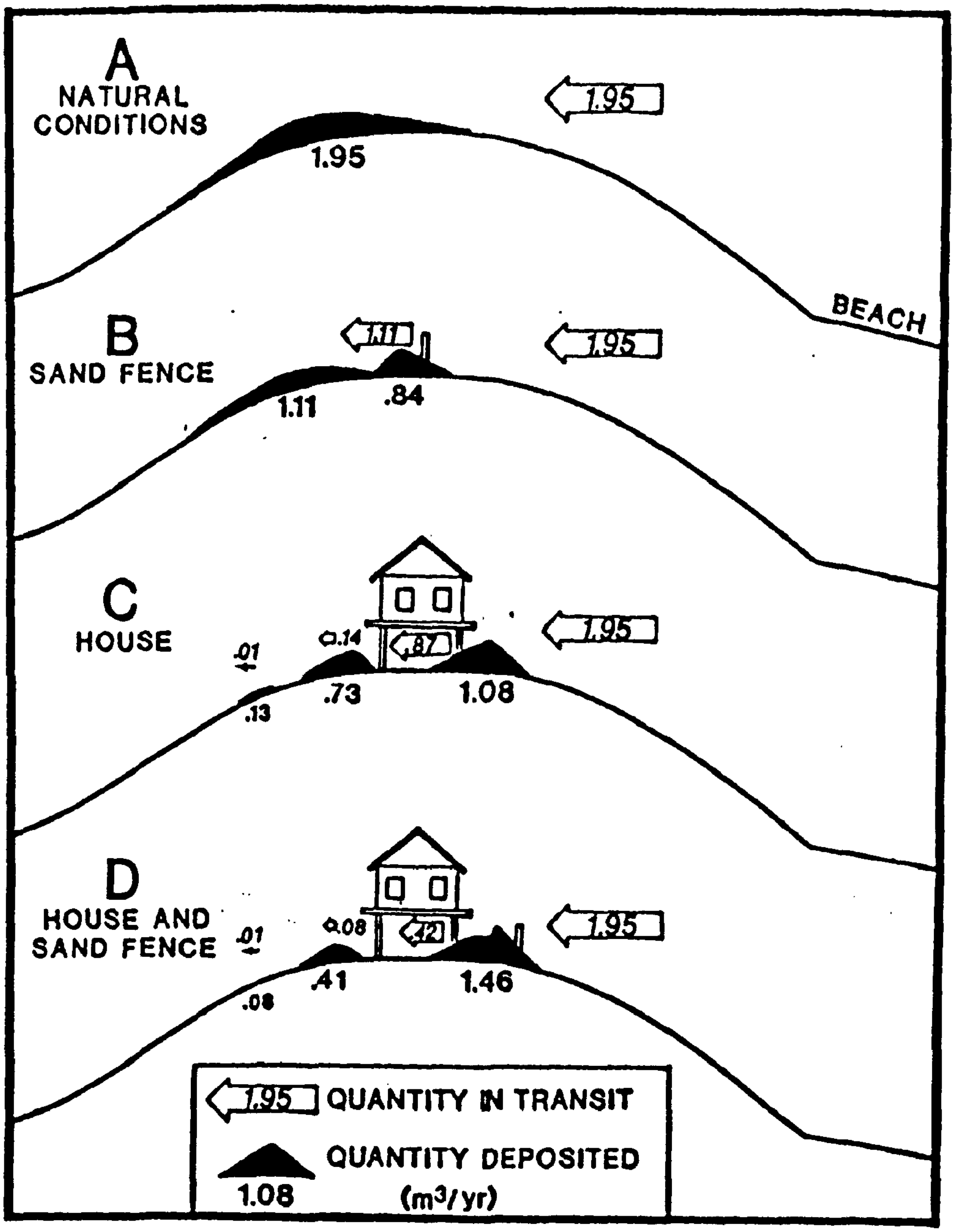


Figure 7. Calculated annual net eolian sediment budget for sand crossing a 10 meter length of dune crest at Fire Island under different conditions of development. From: McCluskey et al., 1983.

Figure 8. Locations, dates of construction and approximate lengths of groins and jetties in the study area.

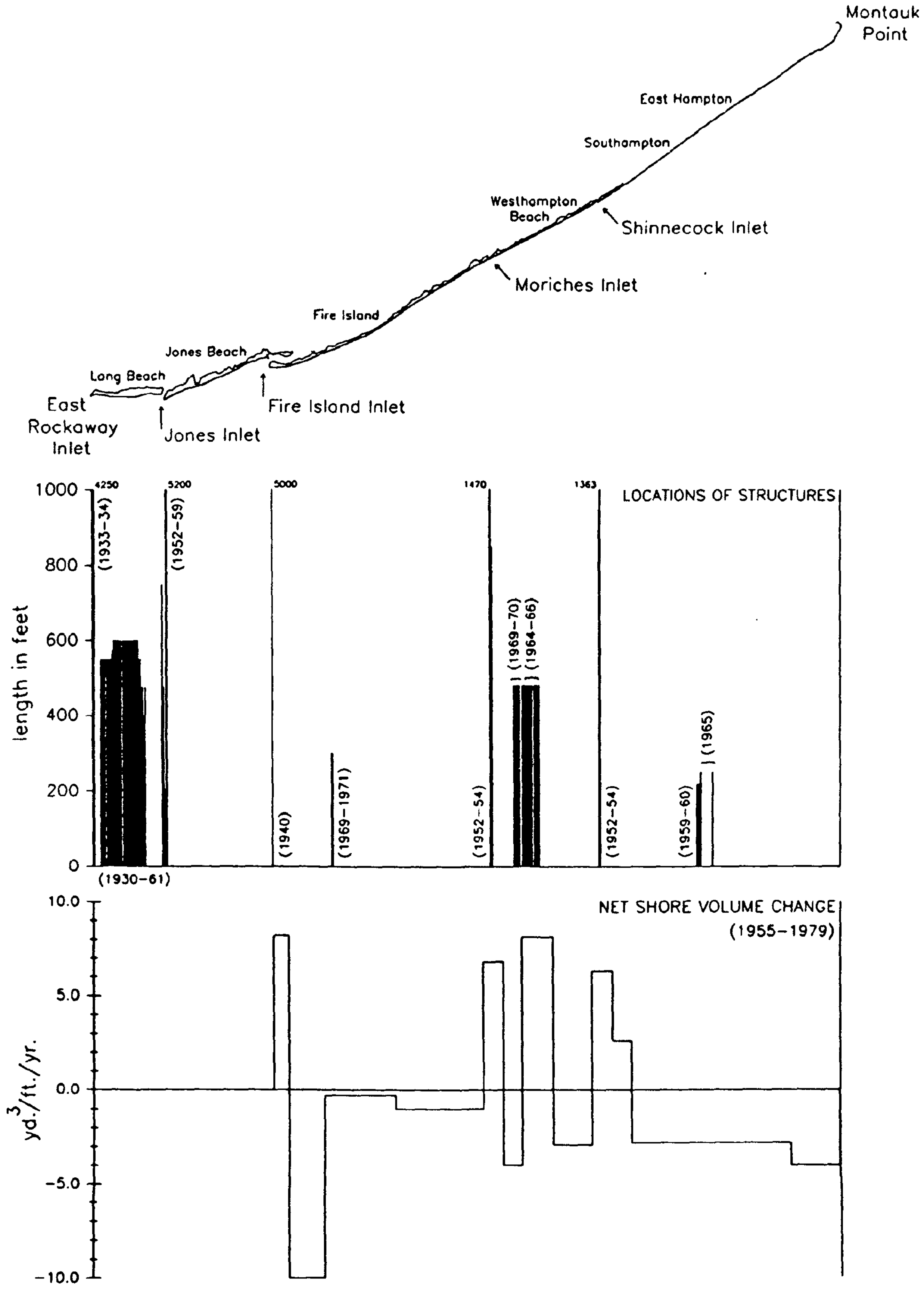


Figure 9. The effect of the groin field are also evident in the data on long-term shoreline changes (Figure 2) and the net volume changes (Figures 4 and 5). The sediment budget data indicate the coastal compartment containing the groins gained an average of 190,000 cubic yards per year (8 cubic yards/foot/year) 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 55,000 cubic yards per year (4 cubic yards/foot/year) with most of the loss occurring below MLW. The amount of sand actually bypassing these structures is not known. Although estimates could probably be derived from a more detailed analysis of the data used in the sediment budget and from Corps records and surveys, 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 the structures age.

All of the inlets in the study area have been stabilized with jetties. Shinnecock and Moriches Inlets are both stabilized with pairs of jetties that were constructed between 1952 and 1954. Fire Island, Jones and East Rockaway Inlet are each stabilized with 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 the stabilization of the inlets on the down drift shoreline can also be seen in Figure 2, 4, and 5. The possible effects of the inlets are discussed in more detail in the section on Shoreline Processes.

Little data on the impacts of shore parallel structures is available. 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 given they only cover a relatively small stretch of the total coast (estimated to be 3 to 5 miles).

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 and have been effective in preventing inland erosion during severe storms. Here and in other places on the eastern part of the coast, old bulkheads have occasionally been exposed by unusually severe erosion. 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, Research Planning Institute 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 substantial amounts of fill were added to the beach (an estimated 12 million cubic yards over the 24 year period), it appears most of the material was dredged from the back barrier bays and placed on the beach. In many cases, the primary objective of these activities

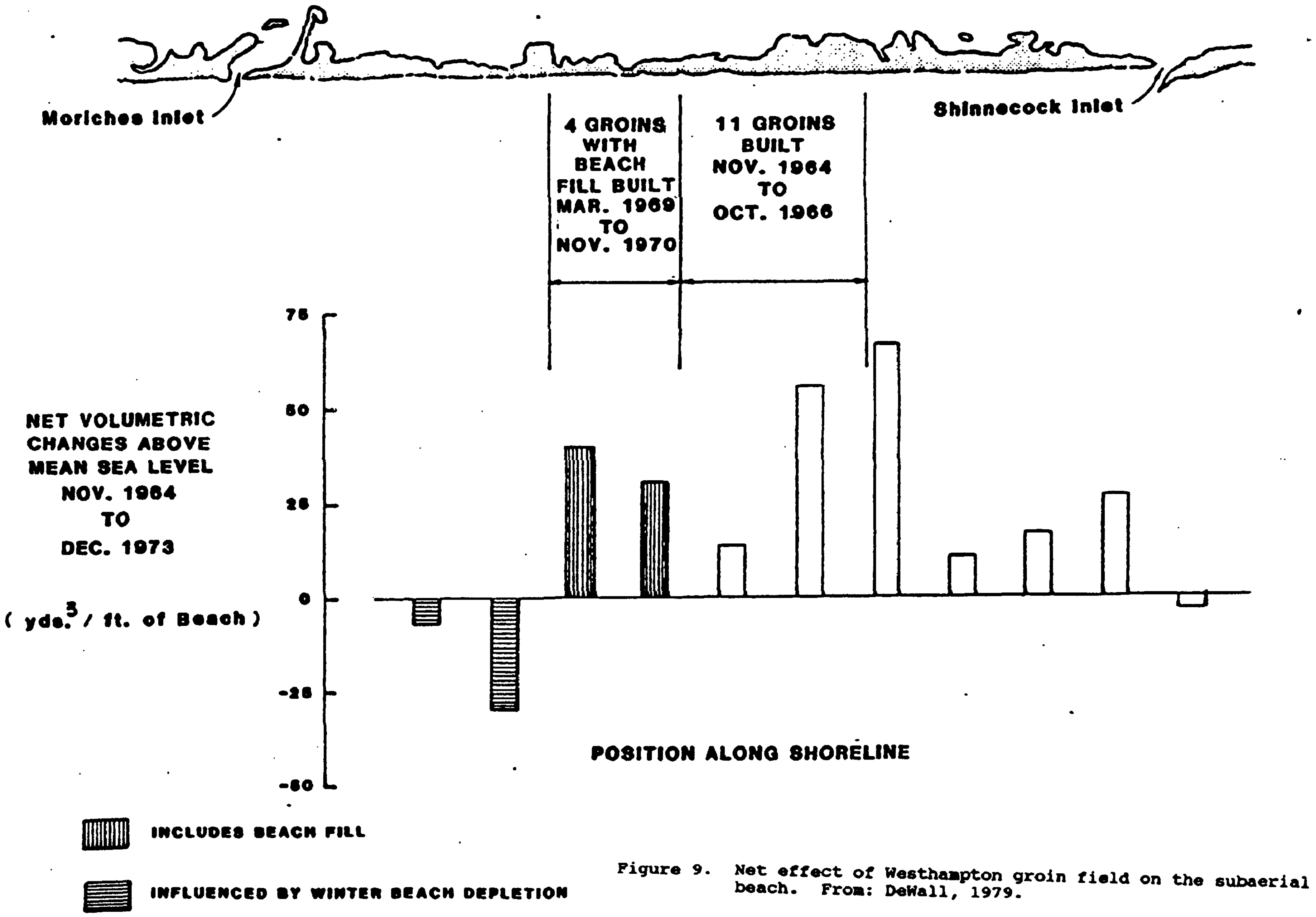


Figure 9. Net effect of Westhampton groin field on the subaerial beach. From: DeWall, 1979.

was probably dredged material disposal rather than beach renourishment. Precise information on the boundaries of the disposal areas was often lacking. Figure 10 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.

As part of a combined inlet navigation and beach erosion control project, approximately 7 million cubic yards of sand dredged from Fire Island Inlet was placed on a feeder beach located approximately 1 mile west of the inlet on Jones Beach in 5 separat 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 of 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 10 represent approximate volumes and locations of the fill projects.

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. This data may be contained in a Corps' report being prepared for this area which is scheduled for release in the near future.

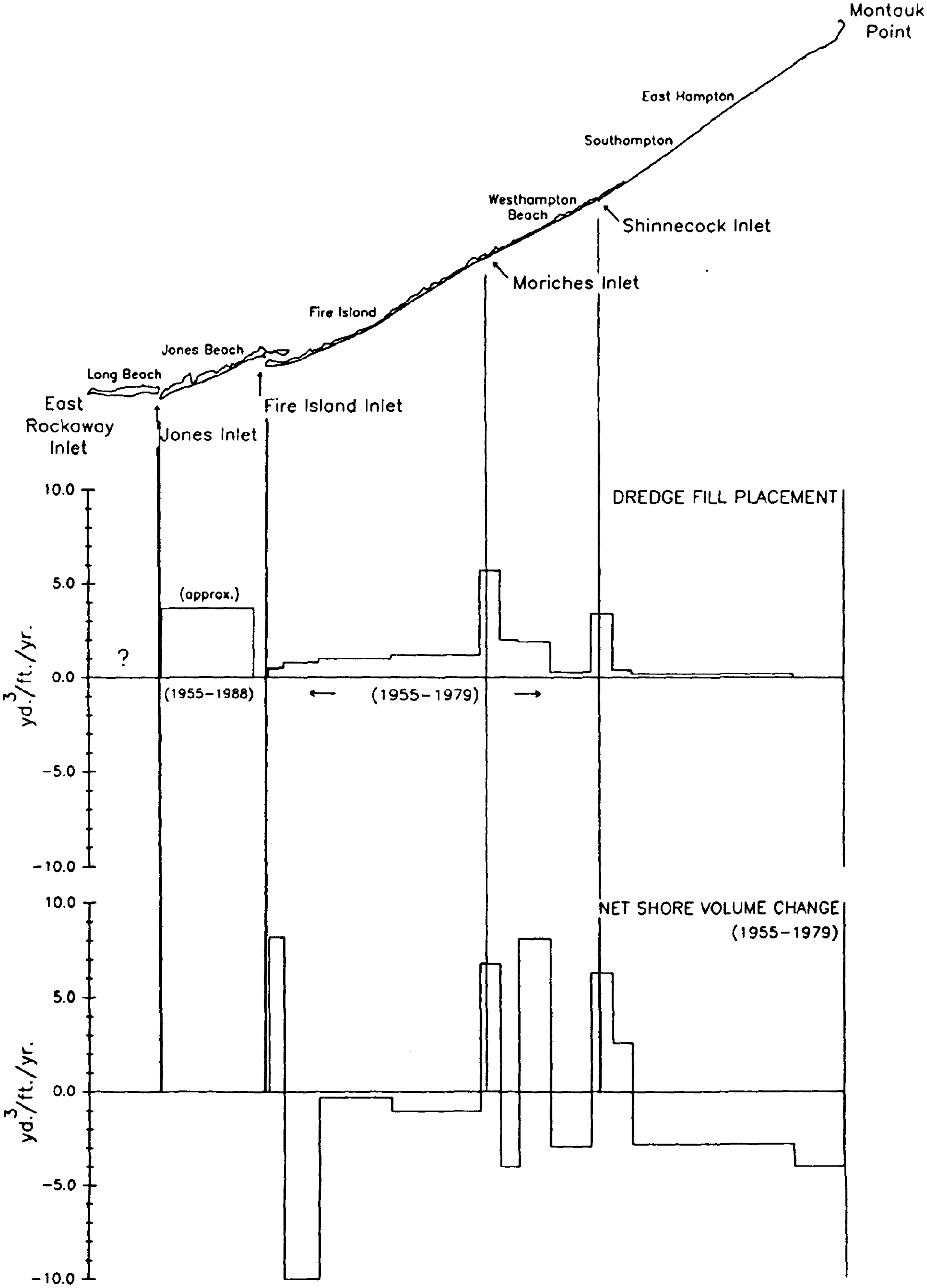
Detailed monitoring information on dredge and fill operations in the study area is not readily available. Although permit and dredging project records may contain information on various projects that have been undertaken, a substantial effort would be required to determine the quality and completeness of the data. I 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. Insitu 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 fee occurred less than 1% of the time and a maximum wave height of 13. feet (Panuzio, 1968). Another non-directional wave gauge located in 30 feet of water offshore of Southampton operated between 1975 and 1976 as part of a CERC program.

The only directional, long-term near shore wave measurements

Figure 10. Annualized fill placement and net volume change (1955-1979). Data east of Fire Island Inlet from RPI, 1985.



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 Beach Evaluation Program in the 1970's. Unfortunately, a systematic synthesis and 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 1 (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 11. Monthly mean heights and periods for Southampton and Westhampton observations are shown in Figure 12. Since these are visual observations, the data reported are subject to large uncertainties.

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 13. 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 computed for the sediment budget study which were based on estimates of an accretion updrift of structures (Figure 14). 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 and one in the west.

For project design, the Corps of Engineers uses deepwater wave statistics from a number of sources. These data include: SSMO offshore wave observations, swell height and direction observations from a station 260 miles south east of Fire Island Inlet, and 2 sets 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 statistics, 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 order of 0.01 feet per year with a good deal of temporal variability (Figure 15). 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

Table 1. 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.

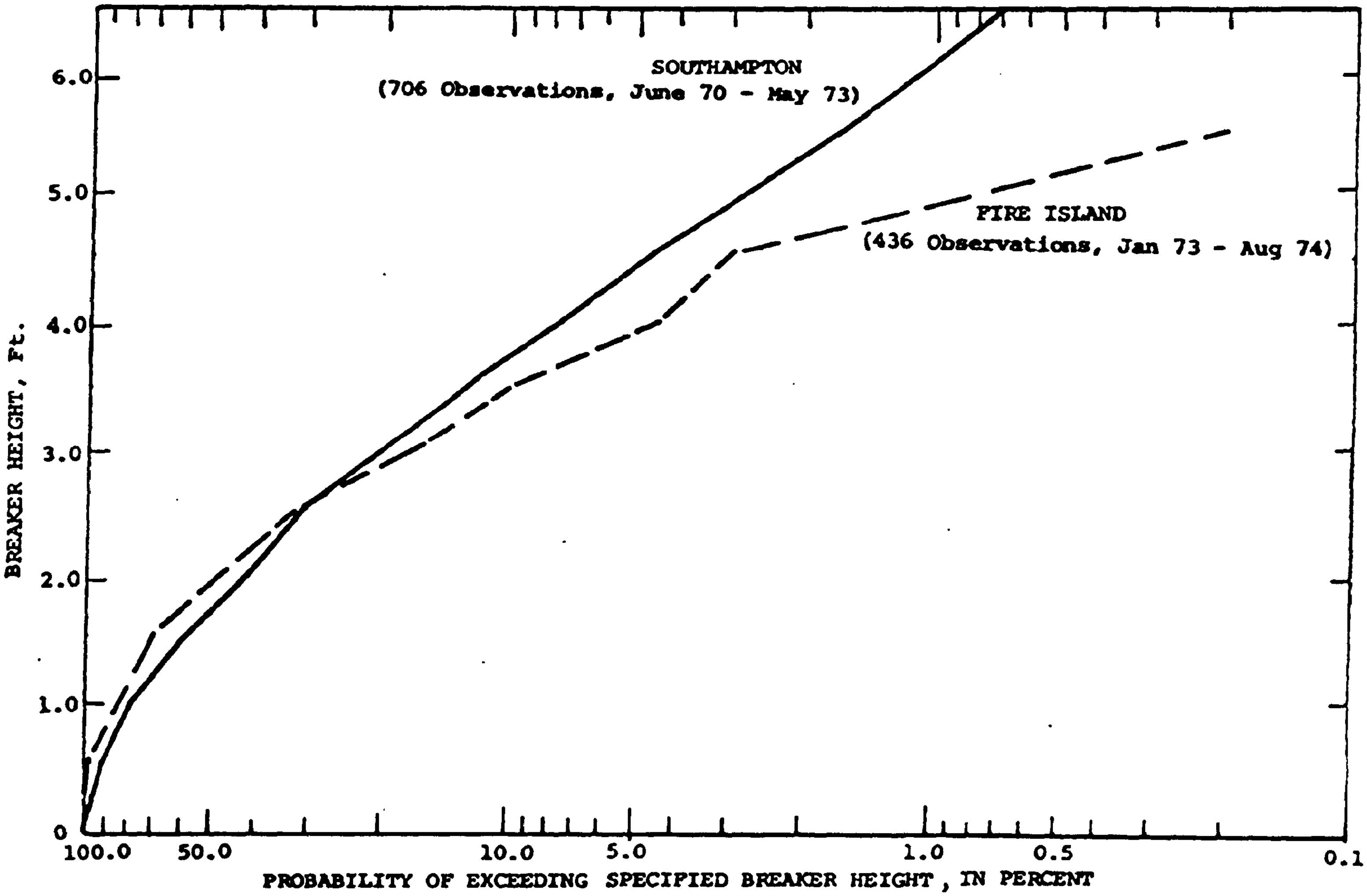


Figure 11. Probability distribution curves for breaker height from visual wave observations at Southampton and Fire Island. (Data from CERC Beach Evaluation Program.)

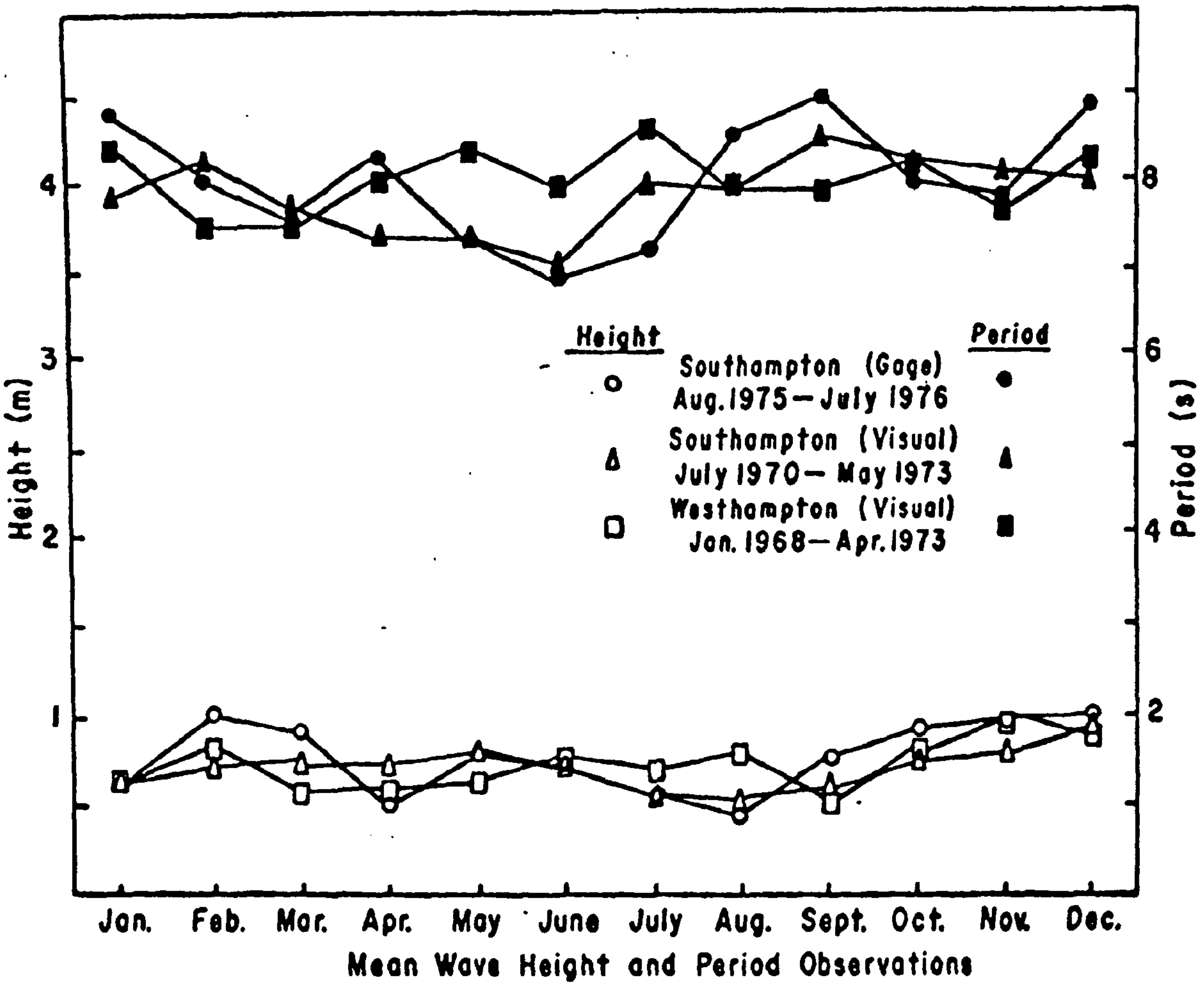


Figure 12. Monthly mean wave height and period observations from DeWall (1979).

Figure 13. Significant wave heights based on Wave Information Study 20-year shallow-water wave hindcast data (Jensen, 1983).

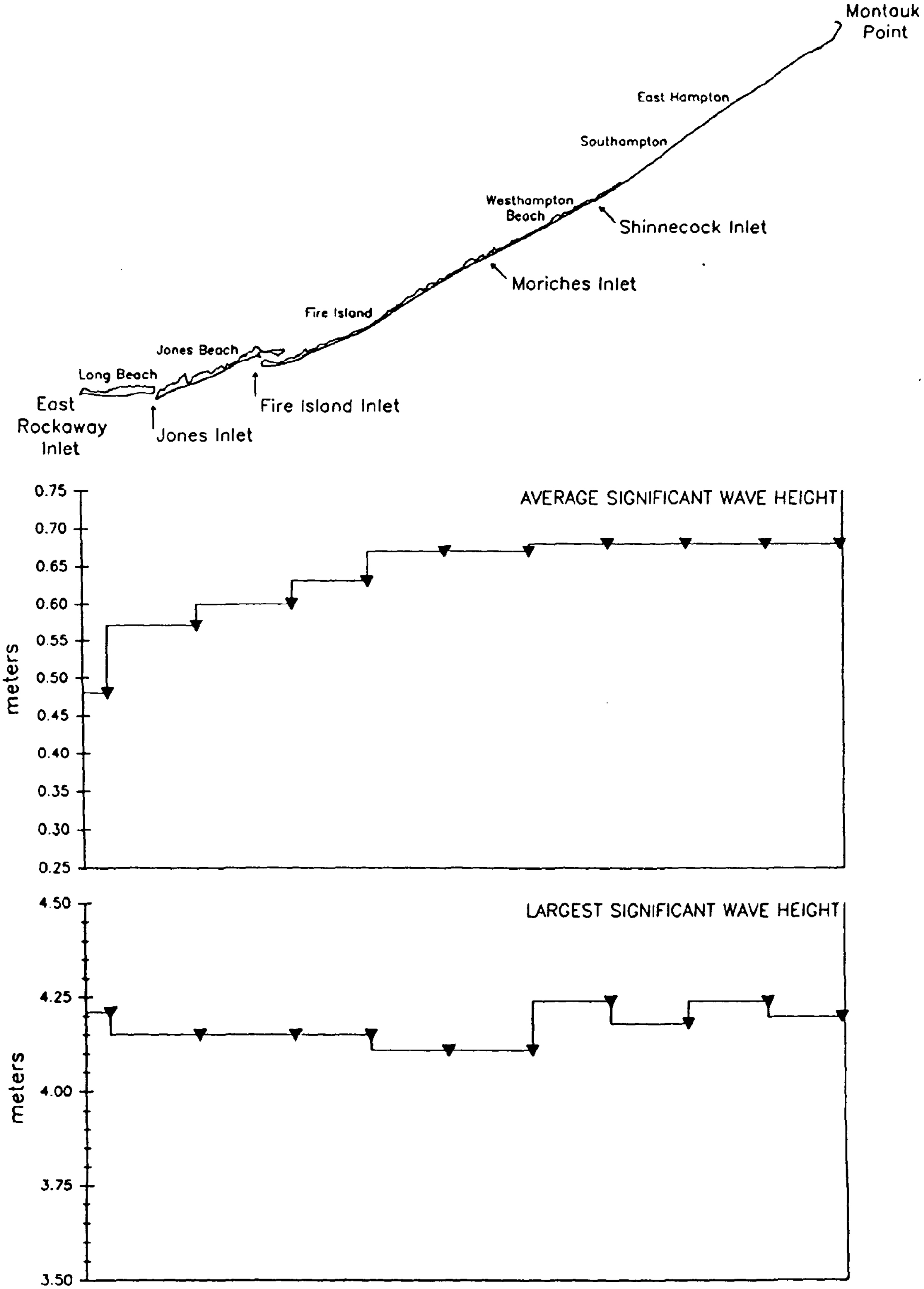
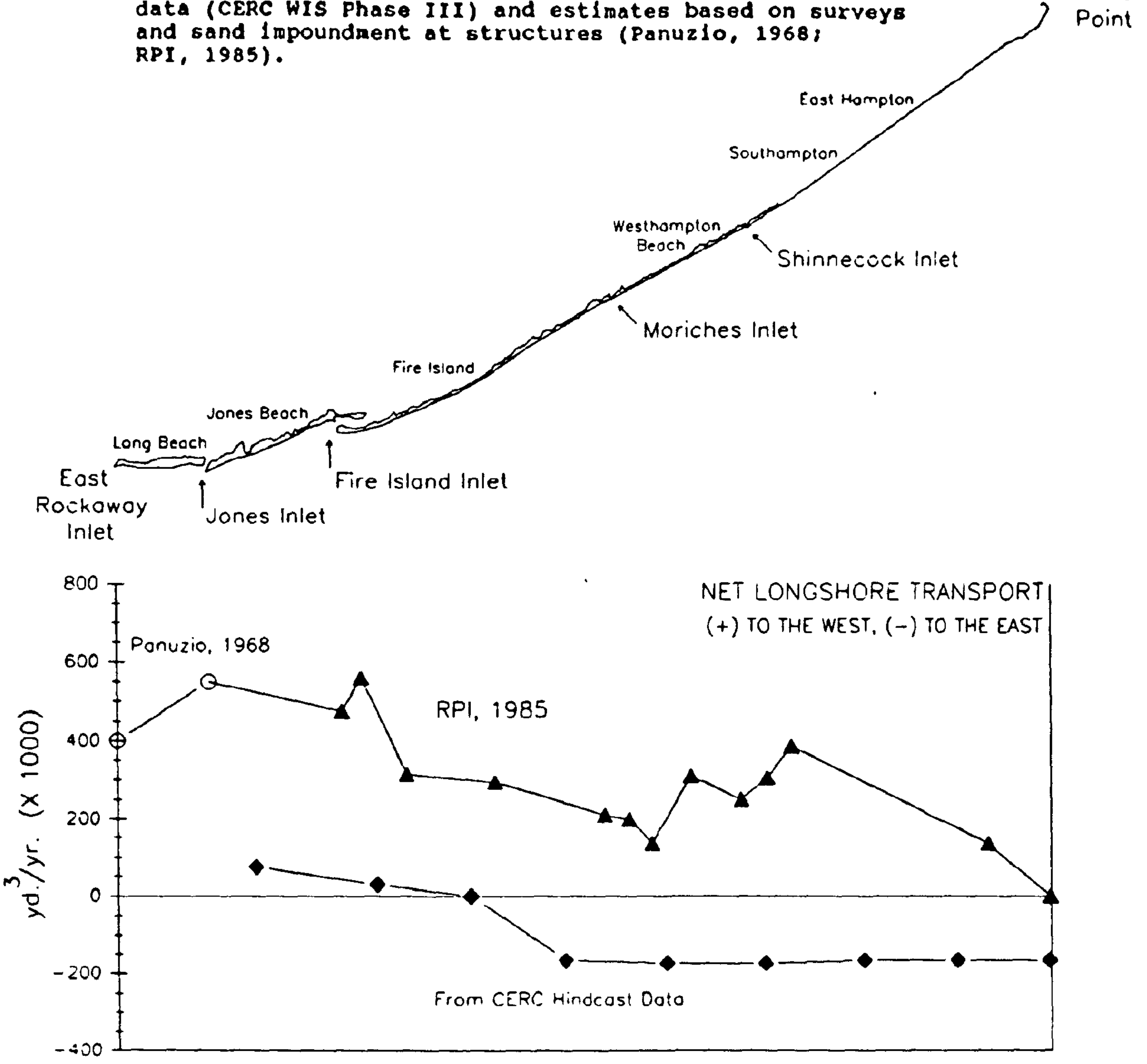


Figure 14. Comparison of net longshore sediment transport rate estimates calculated from shallow-water wave hindcast data (CERC WIS Phase III) and estimates based on surveys and sand impoundment at structures (Panuzio, 1968; RPI, 1985).



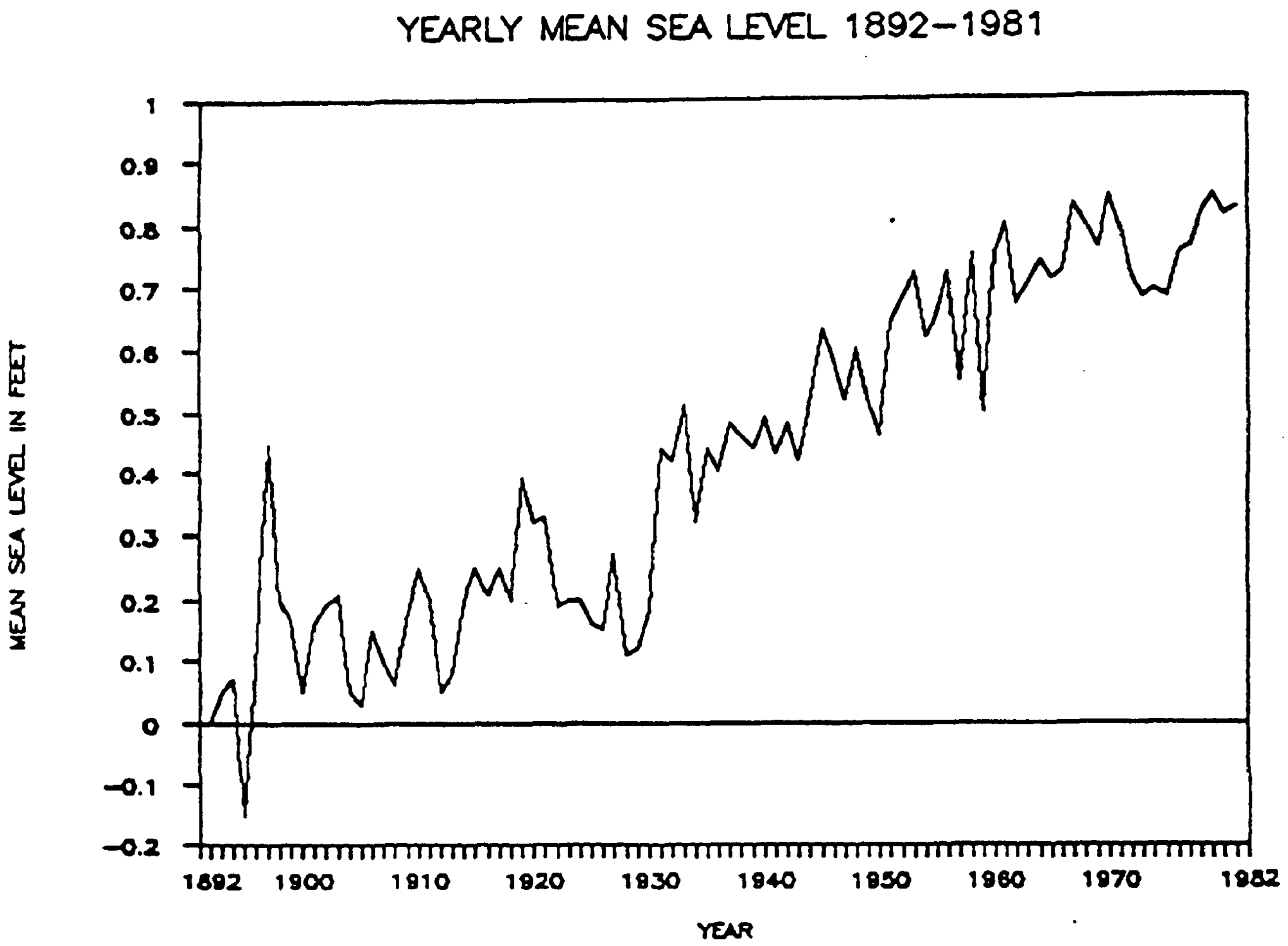


Figure 15. Sea-level rise in the New York area between 1892 and 1982 based on water-level records at Fort Hamilton, Brooklyn, New York. From: Zarillo and Zarillo, 1989.

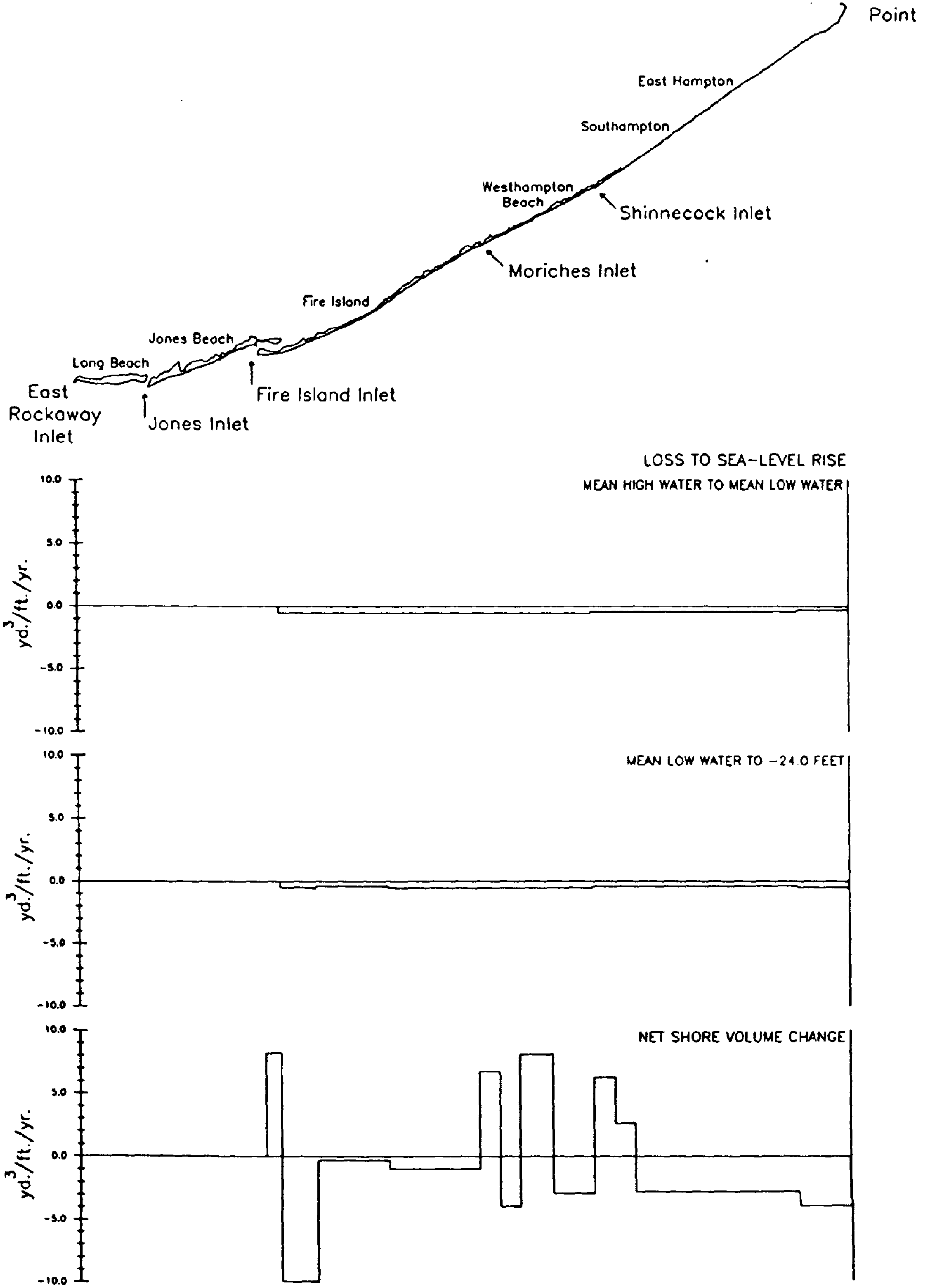
trends in sea level. As a result there are no accurate estimates of relative sea level rise available for the area.

It does not appear that sea level rise plays a significant role in controlling erosion on the south shore (McCormick, 1973). As part of the sediment budget study (Research Planning Institute, Inc., 1985), the Hands (1982) 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 16. These changes are for the most part significantly less than total net volume changes reported in the study. In addition, there is evidence that offshore sources contribute sand to the near shore sediment budget (McCormick and Toscano, 1980; RPI, 1985; Niedoroda et al., 1985; 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 16 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 (0.1 feet per year). 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. However, the timing and magnitude of future sea level rise is highly uncertain.

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 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, these projections, already subject to a great

Figure 16. Estimates of annualized net sediment loss by lens due to sea level rise and total observed net volume changes for the period 1955-1979 based on data from RPI, 1985.



deal of uncertainty, become even less reliable with time. 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, it was suggested the present rate could be doubled or tripled for erosion management purposes. 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~~ and/or natural processes. 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 17. For planning purposes, models which incorporate wave run up and beach and dune dynamics in determining storm surge penetration, such as the SLOSH or Tetra Tech models, may be of more value than the still-water storm-surge elevations. However, it is not known whether these models have been applied to the south shore at this time.

Shoreline Processes

An extensive 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.

<u>Longshore Sediment Transport</u>: The most reliable available estimates of the net rate of longshore sediment transport are those reported in the sediment budget study which were discussed previously. Estimates of the gross longshore transport and relative volumes moving east and west are also extremely important, especially in areas around inlets where local deviations can be large or the direction of net drift can reverse due to changes in wave 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, 1955) to calculate longshore transport rates at Moriches Inlet. Based on these calculations (Table 2), 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.

Figure 17. Mean tidal ranges and storm surge water level elevations for 10, 50, and 100-year storms (based on FEMA flood insurance studies).

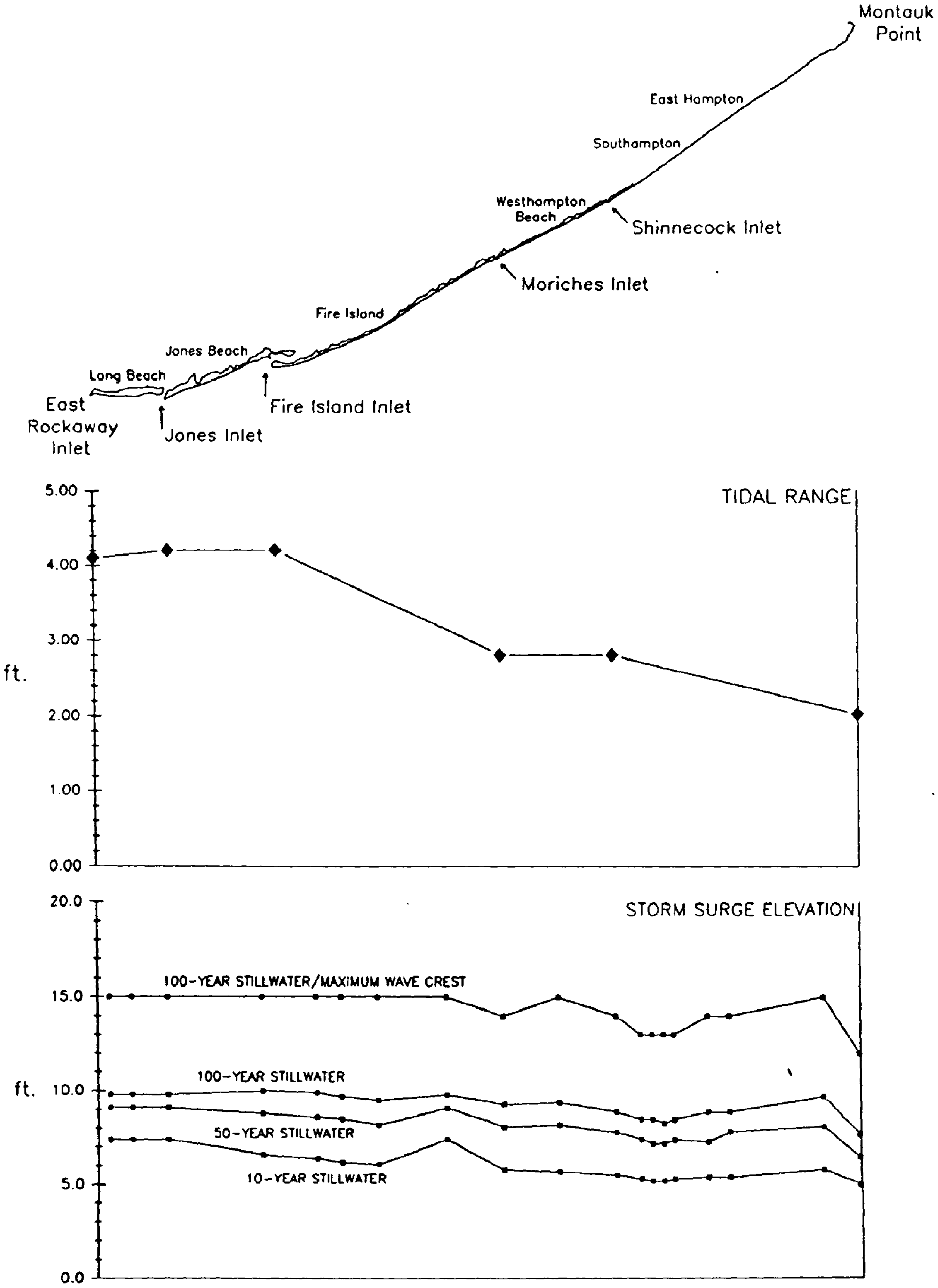


Table 2. Longshore sediment transport statistics at Moriches Inlet calculated by Czerniak (1976) based on hindcast wave statistics from Nuemann and James (1955).

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

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 14).

Although 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, such measurements would require better wave information.

Cross-shore Transport: The sediment budget requires an onshore transport of sand to balance. 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 18. A single offshore bar located about 500-1500 feet offshore with a crest 10 to 15 feet below NGVD is present along much of the coast between Fire Island Inlet and Montauk Point. Although two short-term, site-specific studies of this feature have been undertaken at East Hampton (Shipp, 1980) and at Fire Island (Allen and Psuty, 1987), the scale and variation in bar morphology and the effects of bar geometry on the shoreline as a whole have not been documented.

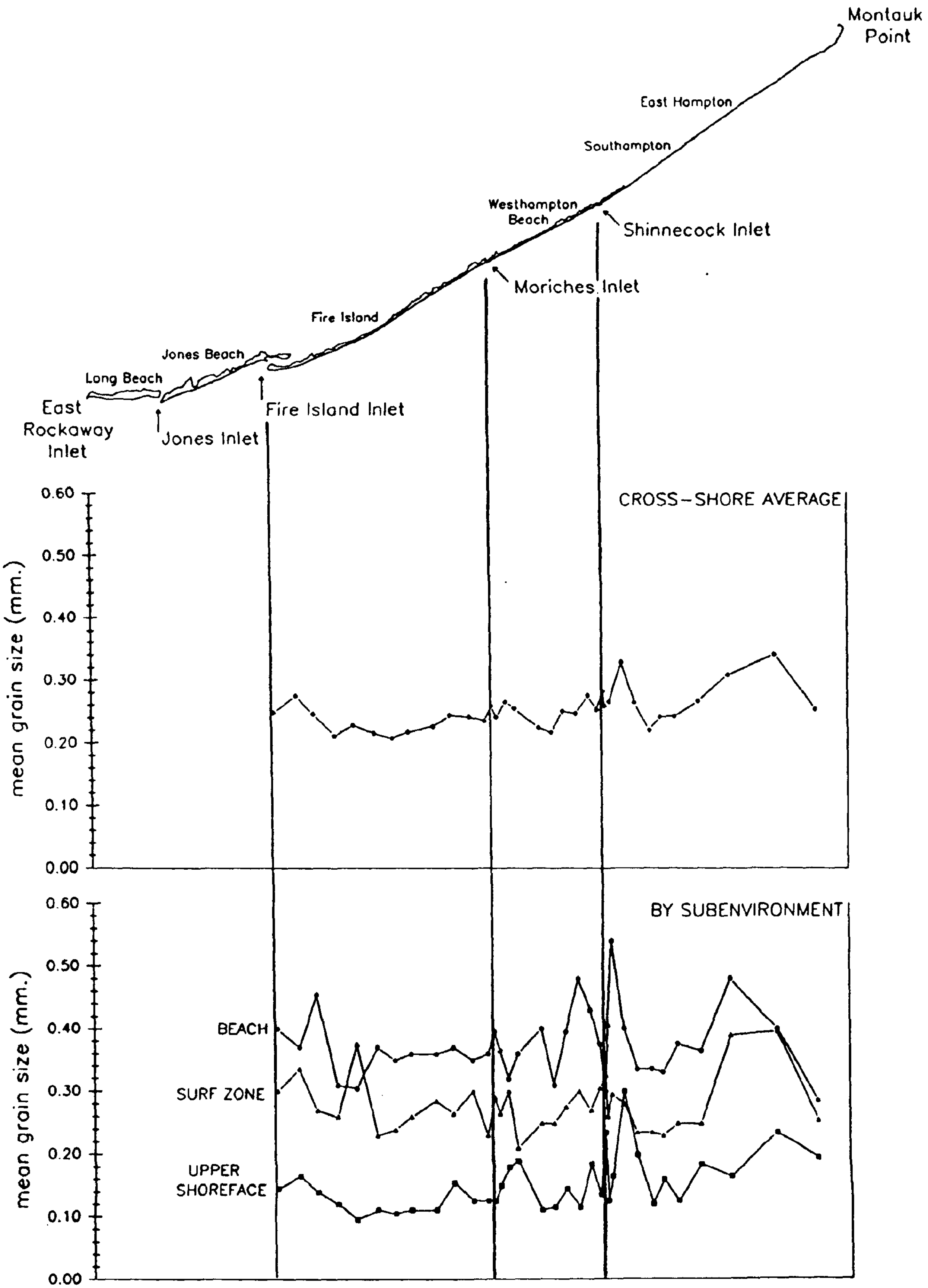
Pre-and post storm profiles along the coast may be especially useful in defining the behavior of the offshore bar and sediment transport patterns. (It seems that after Hurricane Gloria in 1985, for example, the bar, usually a relatively stable feature, was absent along much of the shoreline but the length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

Inlet Processes: The five inlets in the study area exert a dominant influence on the coastal changes occurring along the shore. As can be seen in the plots of long term shoreline recession/accretion rates (Figure 2) and, to a lesser extent, the plots of volume changes (Figures 4 and 5) the most dramatic variations are associated with inlets. With the exception of the Westhampton groin field, the most severe erosion problems are the result of the interruption of sand transport patterns and inadequate sand management practices at inlets. As an example, the effects of the opening and subsequent stabilization of Shinnecock Inlet on the downdrift shoreline are shown in Figure 19.

Table 3 developed by Panuzio (1968) provides historical information related to the south shore inlets. (It should be noted that some of the data (i.e., net longshore transport rates) have been updated since 1968, see Figure 4).

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 4), the accuracy of the

Figure 18. Mean sediment grain size from Tsien (1986).



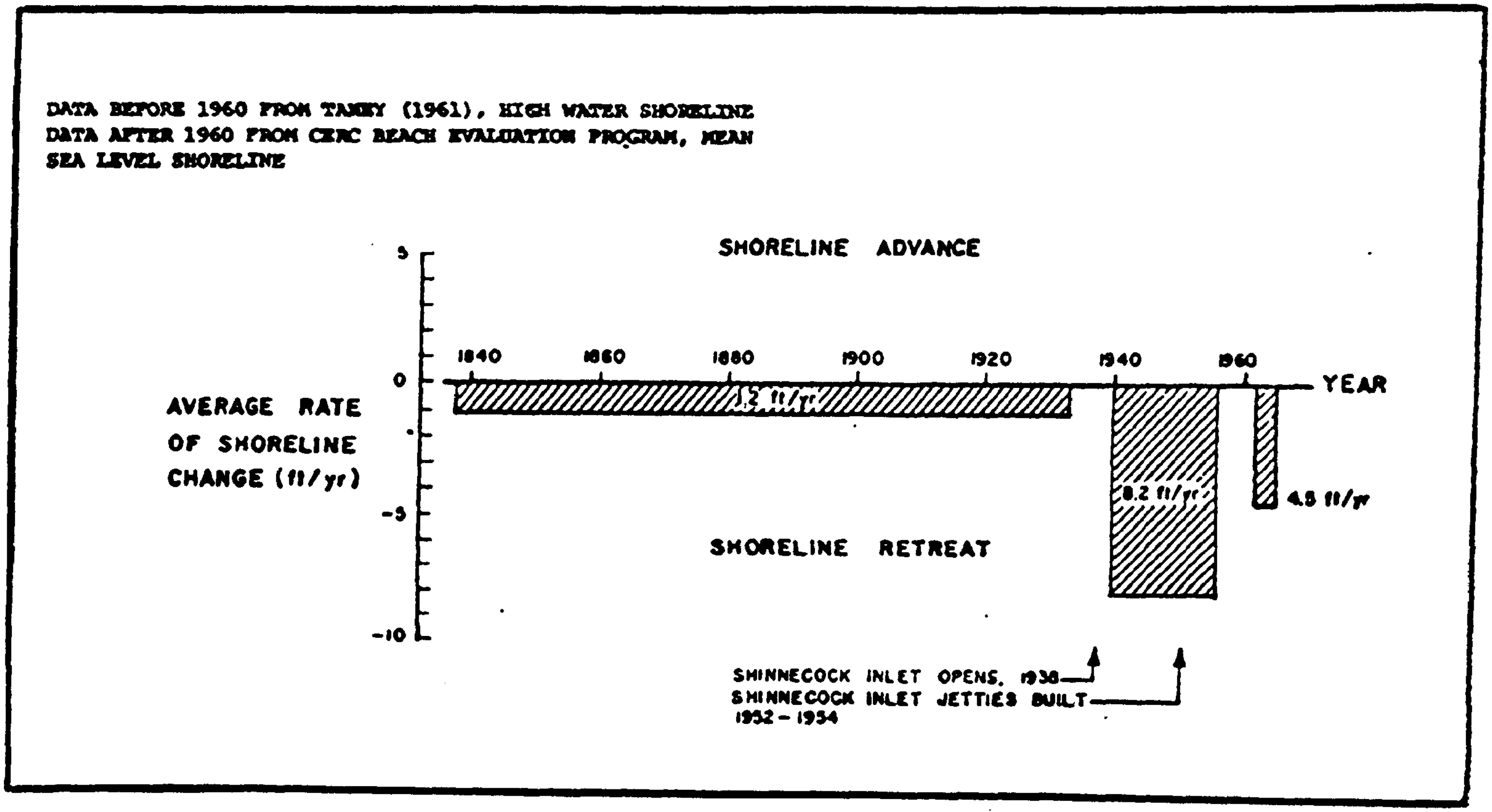


Figure 19. Average rates of shoreline change between Shinnecock and Moriches Inlets between 1838 and 1965 (USACE, 1977).

Table 3. Westerly migration of the eastern sides of Long Island inlets. From: Panuzio, 1968.

Shinnecock Inlet	1829-1839 Inlet Open	1839-1850 Inlet Closed	1850-1890 Inlet Open	1890-1938 Inlet Closed	1938-1951(a) 60 feet	1951-1955 -130 feet	1955-1968 -
	Total Migration West feet years feet/yr. 50 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. -250 24 177		Littoral Drift cubic yards/yr. 350,000		Jetties Built 1952-1954		
Fire Island Inlet	1825-1834 3050 feet	1834-1873 5625 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 1939-1944	
Jones Inlet	1835-1879 -2850 feet	1879-1909 1390 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 4

Estimates of Inlet Bypassing

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)

resultant figures are questionable due to the data and methods used. Although the sediment budget study provides the best available information on volumetric changes and has been used as basis for some of the estimates given in Table 4, the resolution the data used in this study was deemed inadequate for accurately quantifying sediment transport and bypassing at inlets.

For the most part, inlet dredging projects in the area are done i response to navigation needs rather than for erosion control purposes. There is no program of regular artificial sand bypassi 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 plac on the emergent portion of the flood delta (Kassner and Black, 1982). The only dredging in the channel or seaward of the channe at Shinnecock Inlet since it was stabilized was the emergency removal of 162,000 cubic yards of material in 1984 (U.S. Army Cor of Engineers, 1987) and 83,000 cubic yards in 1988. This sand wa 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 The inlet has been legally closed to navigation for a number of 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 the federal dredging projects at Jones and East Rockaway Inlets apparently are not available at this time although this informati could probably be obtained from an analysis of Corps' dredging records and surveys.

The available evidence indicates the inlets serve as large sinks sand in the near shore system. The ebb and flood tidal deltas associated with Moriches appear to have trapped some 1 to 2 milli cubic yards of sand with most of this material stored in the ebb tidal delta (Research Planning Institute, Inc., 1985). Although not quantified, similarly large ebb tidal deltas are also associated with the other inlets in the area (Leatherman and Alle 1985).

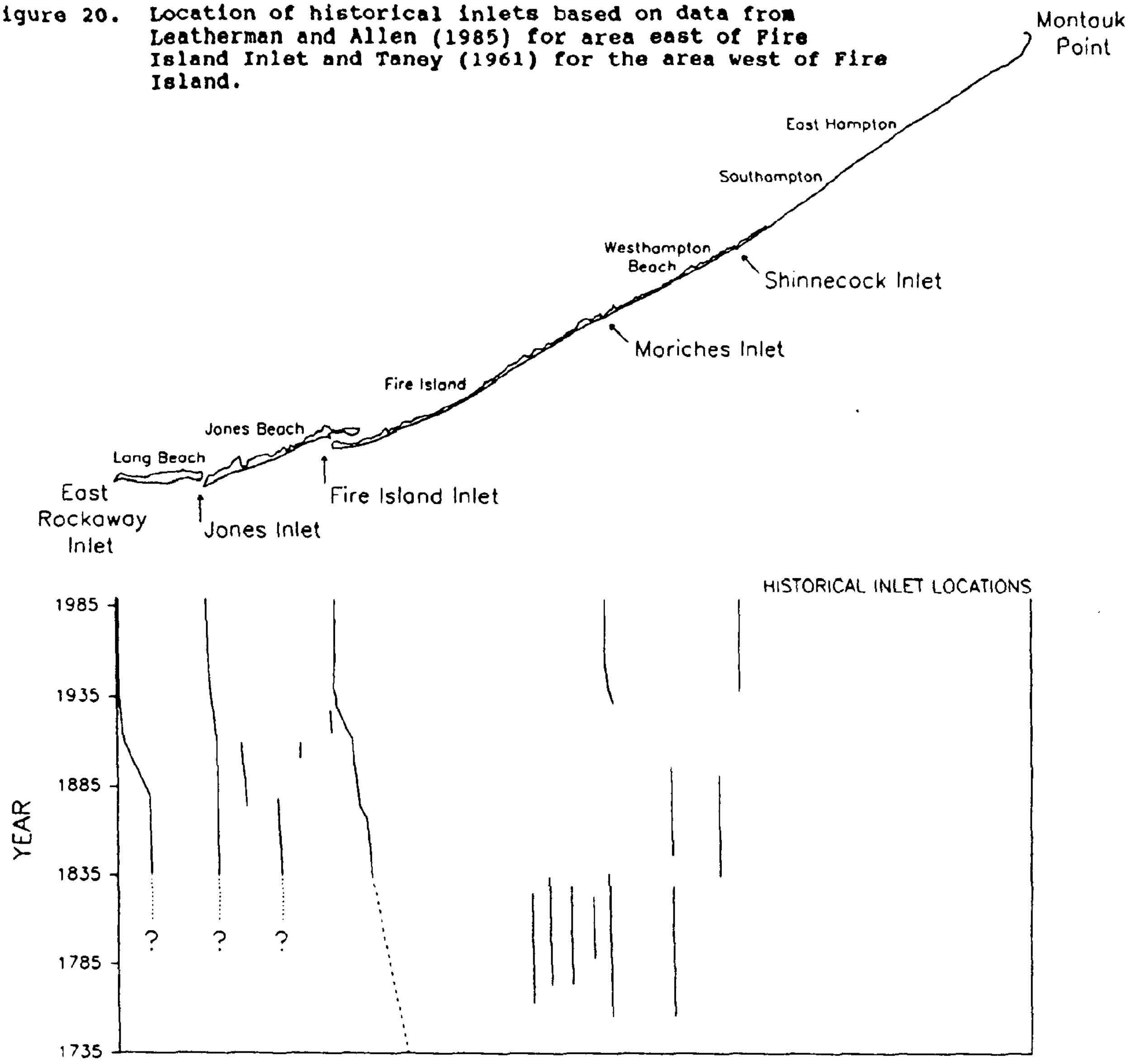
As illustrated in Figure 19, the impacts and processes associated with the inlets are variable with time. Because of their complexity and importance in the coastal sediment system, detaile budgets are needed at each of the inlets. The amount of sand naturally bypassing the inlets and the volume of the flood and eb 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 standardized. This information should be used to construct models of local inlet behavior. For management purposes, "inlet impact zones" should b 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 an area of critical concern. Th locations of historical inlets along the eastern section as determined by Leatherman and Allen (1985) are shown in Figure 20 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) inlet formation and sediment transport processes that drive barr migration in this section operate intermittently at 50-75 year intervals. The central and western sections of the 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 b 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 implicati 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 t 40 percent. The modeling study also indicated that the tidal exchange between Moriches Bay and the ocean is not great enough t maintain two inlets indefinitely. The shoaling problems presentl 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 limited tidal flow.

No studies have focused on the possible effects of new inlets on shoreline erosion. However, based on the information available f the existing inlets (i.e., Figure 19, for example), it is reasonable to assume that these features could have significant impacts in terms of accelerated downdrift erosion. During the 11 months it was open, some 750,000 cubic yards of material from the longshore sediment system was trapped on the flood tidal delta of the Moriches breach (Research Planning Institute, Inc., 1985). Obviously the loss of such large volumes of material from the nea shore sediment budget could result in significant downdrift shoreline changes.

Figure 20. Location of historical inlets based on data from Leatherman and Allen (1985) for area east of Fire Island Inlet and Taney (1961) for the area west of Fire Island.

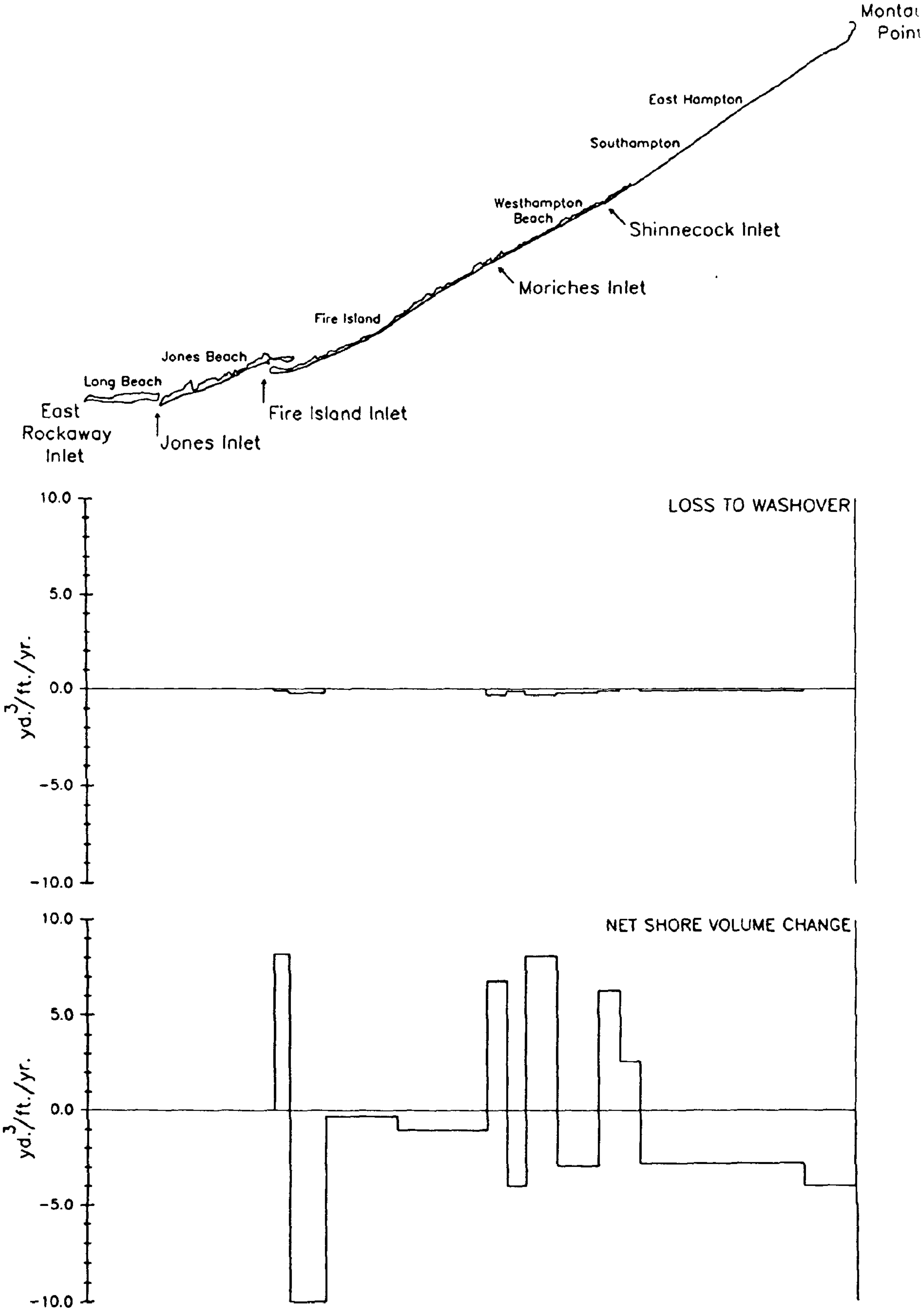


There is a body of knowledge concerning the stability of inlets in general, the number that could be supported under different conditions, the processes associated with these features, and possible rates of closure based on hydrodynamics and historical trends, but this information must be reviewed and 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, 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 Process: Based on the sediment budget study, only about 35,000 cubic yards of sediment per year are moved by overwash processes along the shore 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 for different sections of the coast are shown in Figure 21 for the period 1955-1979. The importance of overwash 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. Based on the available data, a prudent management plan could employ dune building and overwash mitigation strategies as an inexpensive means of helping to maintain the longshore transport system and enhancing 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, a number of factors indicate that all of this material is not 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 suitable for transport by longshore littoral transport processes. The larger fraction of the material most likely remains in place while the finer sediments would be dispersed offshore. In addition, the inhomogeneities in the composition of the bluff also result in an irregular shoreline further complicating estimates of longshore transport. The geomorphic configuration of the headland and orientation of numerous 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. Although more information on bluff composition and actual bluff recession rates (rather than shoreline recession rates) are needed to provide accurate estimates, it is thought that actual total contribution of the bluffed section of coast is to the longshore transport system

Figure 21. Annualized volume losses due washovers for the period 1955-1979 from RPI, 1985.



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.) The probability distribution of short-term shoreline positions around the average annual positions should be calculated in order to evaluate the confidence limits of the available measured rates of historical shoreline changes taken from comparisons of maps and photos.

3) The elevation of the dune crest and base along the shore should be mapped.

4) Long-term recession rates based on changes in the vegetation line and/or dune position (based on contour movements) should be calculated.

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

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

   c) elevations of the appropriate storm surge

   d) landward limits of storm wave penetration

e) long-term recession rates.

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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

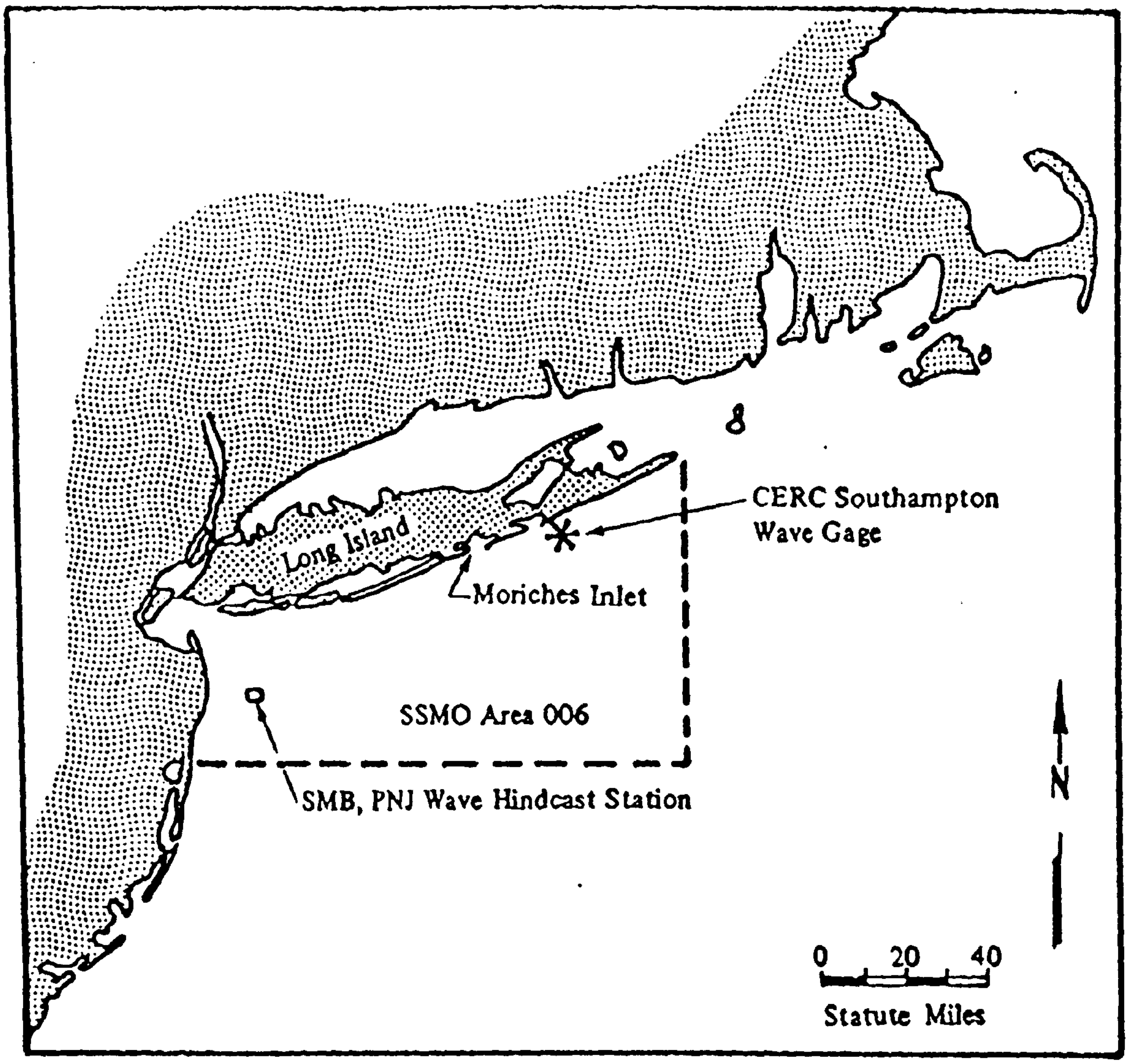
$$\pm R/P$$

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.

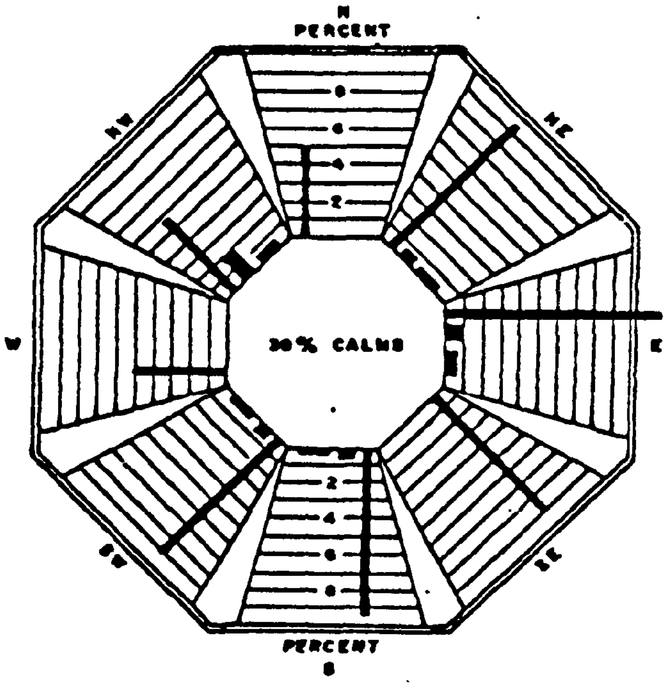
It must be noted, however, that the chances of the error being as large as $\pm R/P$ is very small; it may be smaller perhaps 99 percent of the time. As a result, a better estimate of the uncertainty would be to recalculate E values at some reasonable level of probability of occurrence, perhaps the E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

APPENDIX 3

Miscellaneous Offshore Wave Data



Available Wave Climate Statistics

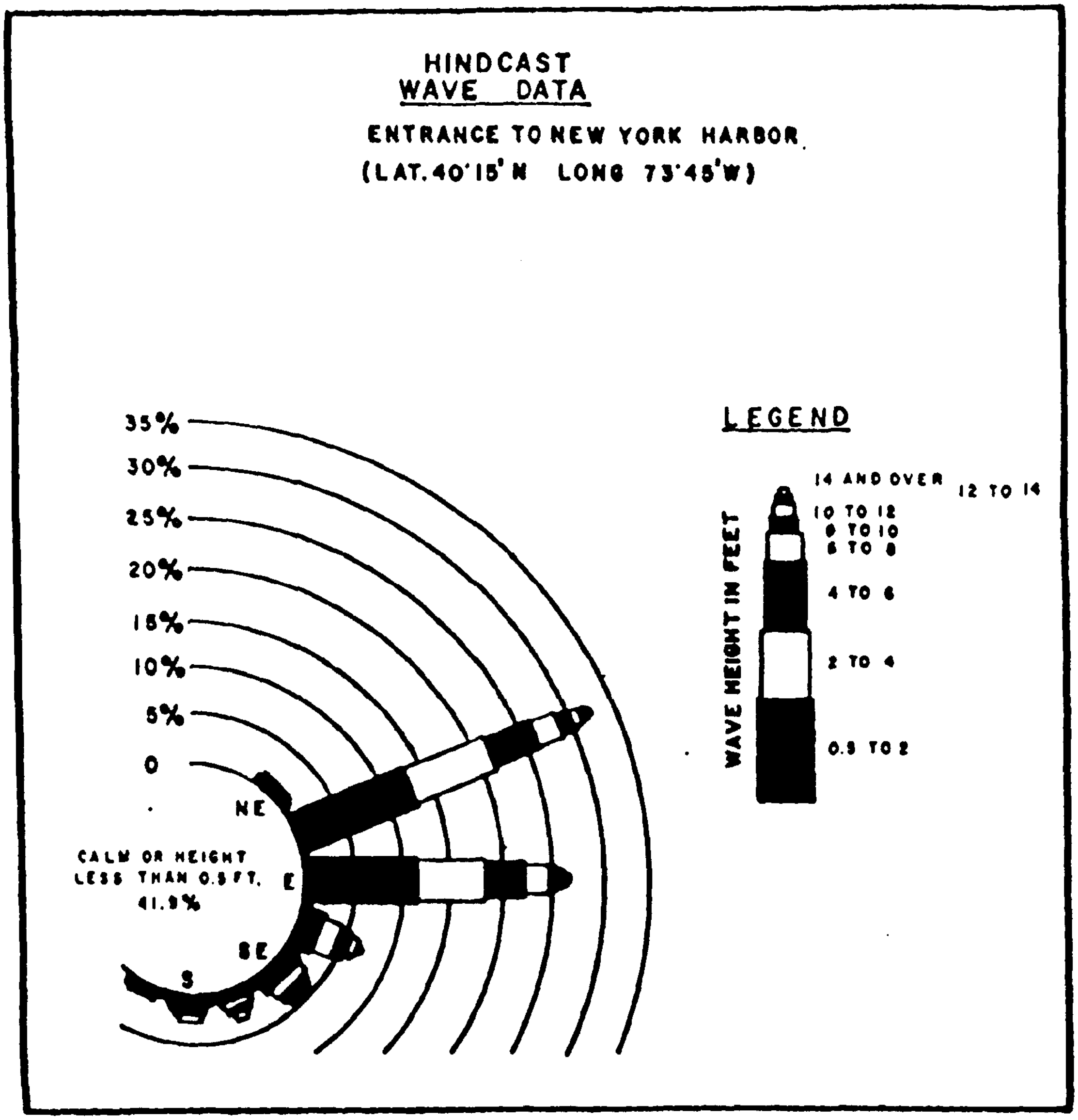


LEGEND

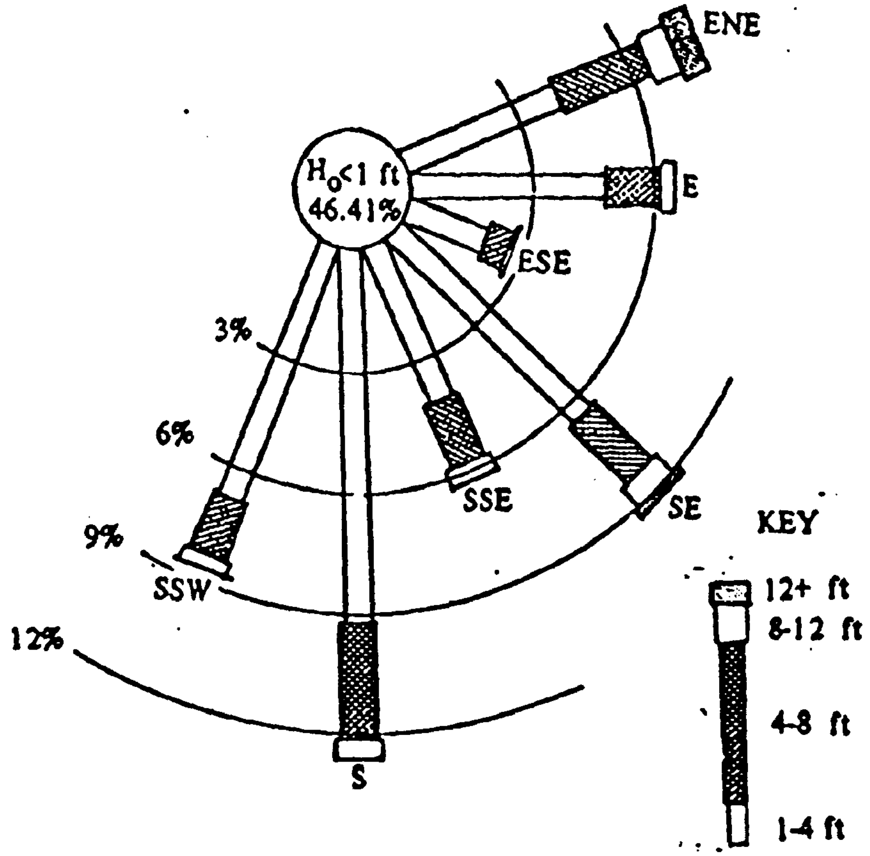
- ▬ LOW SWELLS (1-6 FEET)
- ▬ MEDIUM SWELLS (6-12 FEET)
- ■ HIGH SWELLS (OVER 12 FEET)

THE LENGTH OF BAR DENOTES THE PERCENT OF TIME THAT SWELLS OF EACH SIZE HAVE BEEN MOVING FROM OR NEAR THE GIVEN DIRECTION. THE FIGURE IN THE CENTER OF THE DIAGRAM INDICATES THE PERCENT OF CALMS. THE DIAGRAM APPLIES TO THAT AREA OF THE ATLANTIC OCEAN CENTERED ABOUT 260 MILES SOUTHEAST OF FIRE ISLAND INLET. THE CHART IS BASED ON OBSERVATIONS BY THE U.S. NAVY HYDROGRAPHIC OFFICE FOR THE TEN YEAR PERIOD 1932-1942.

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

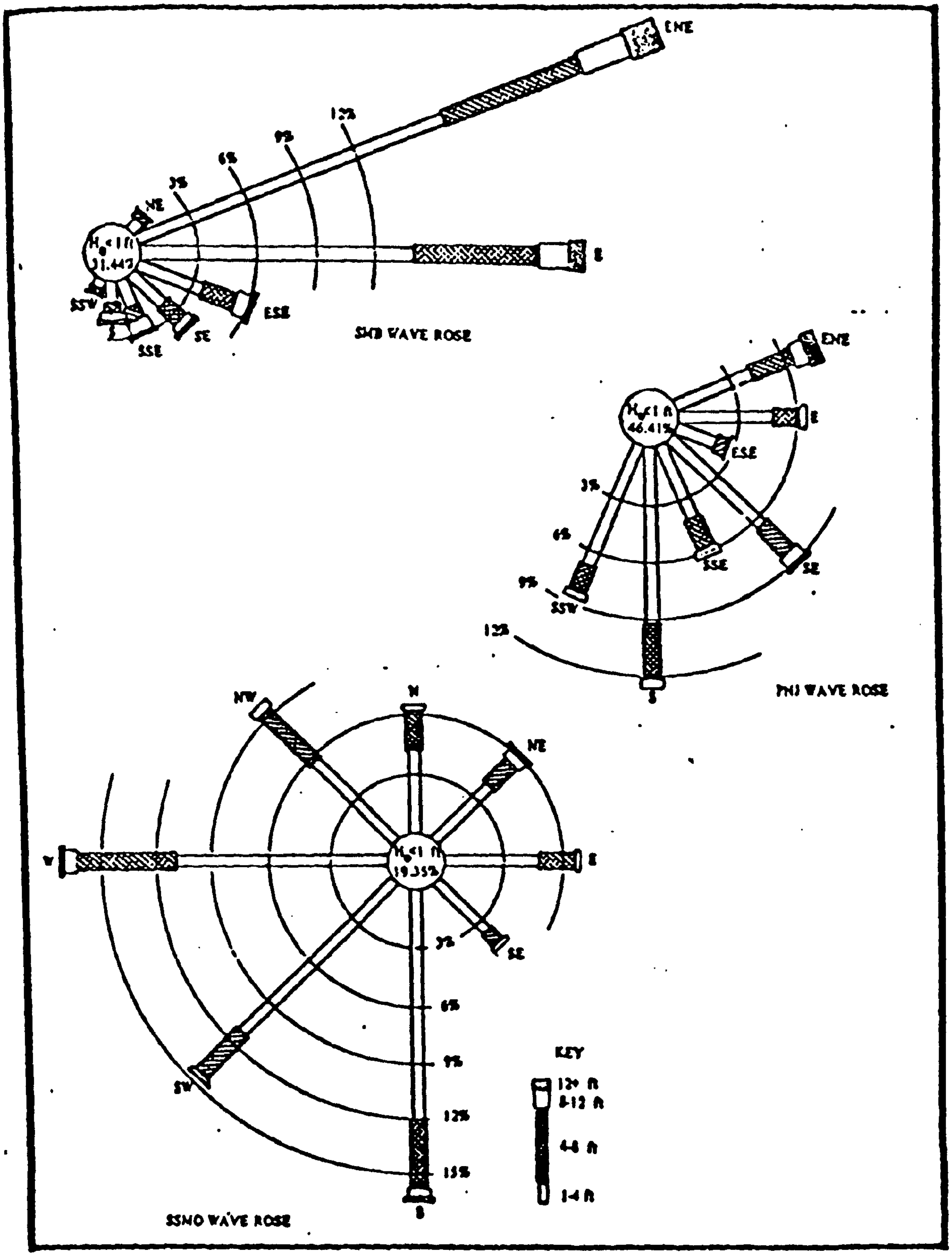


HINDCAST WAVE ROSE FOR DEEPWATER OFFSHORE OF NEW YORK HARBOR (Saville, Jr., 1954)

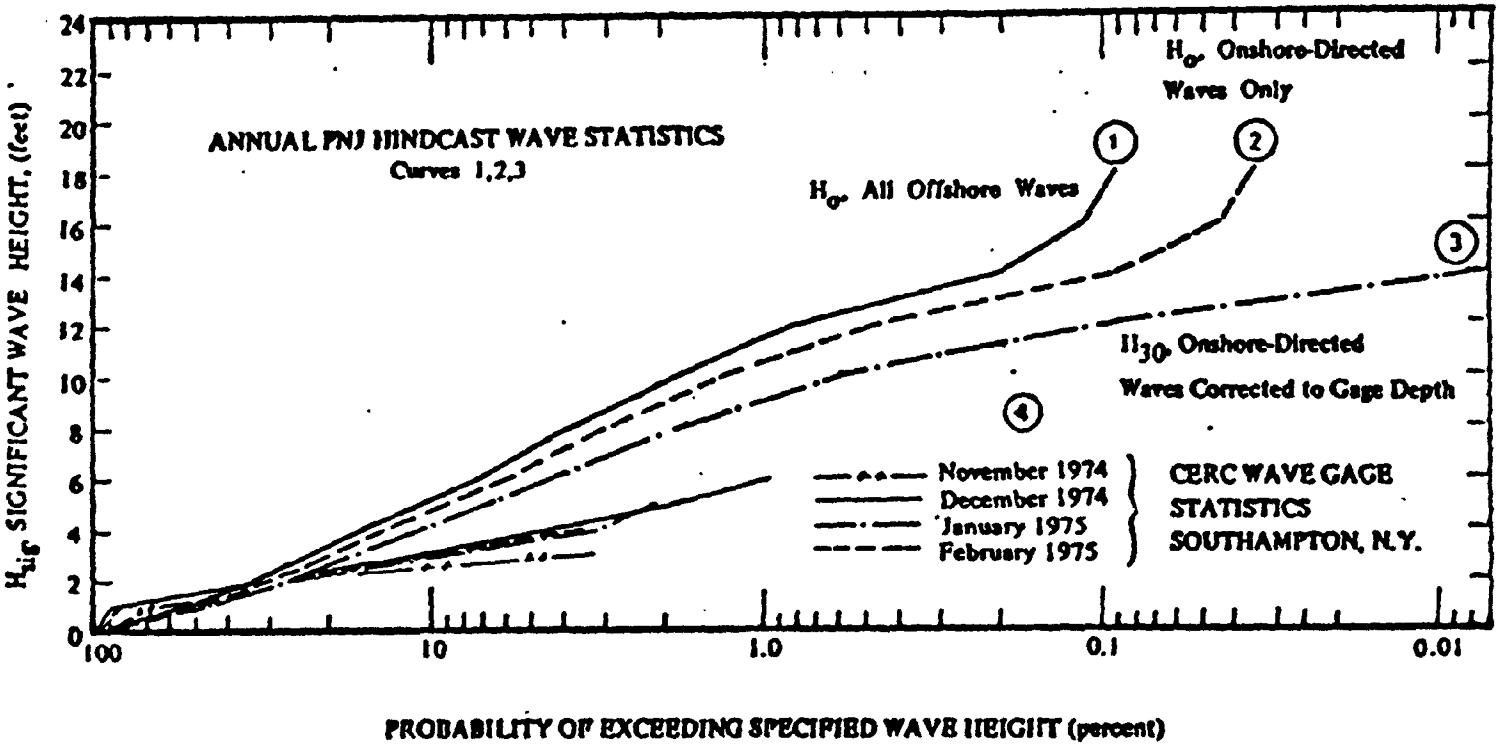


(Includes 100% of the Waves in the PNJ Statistics)

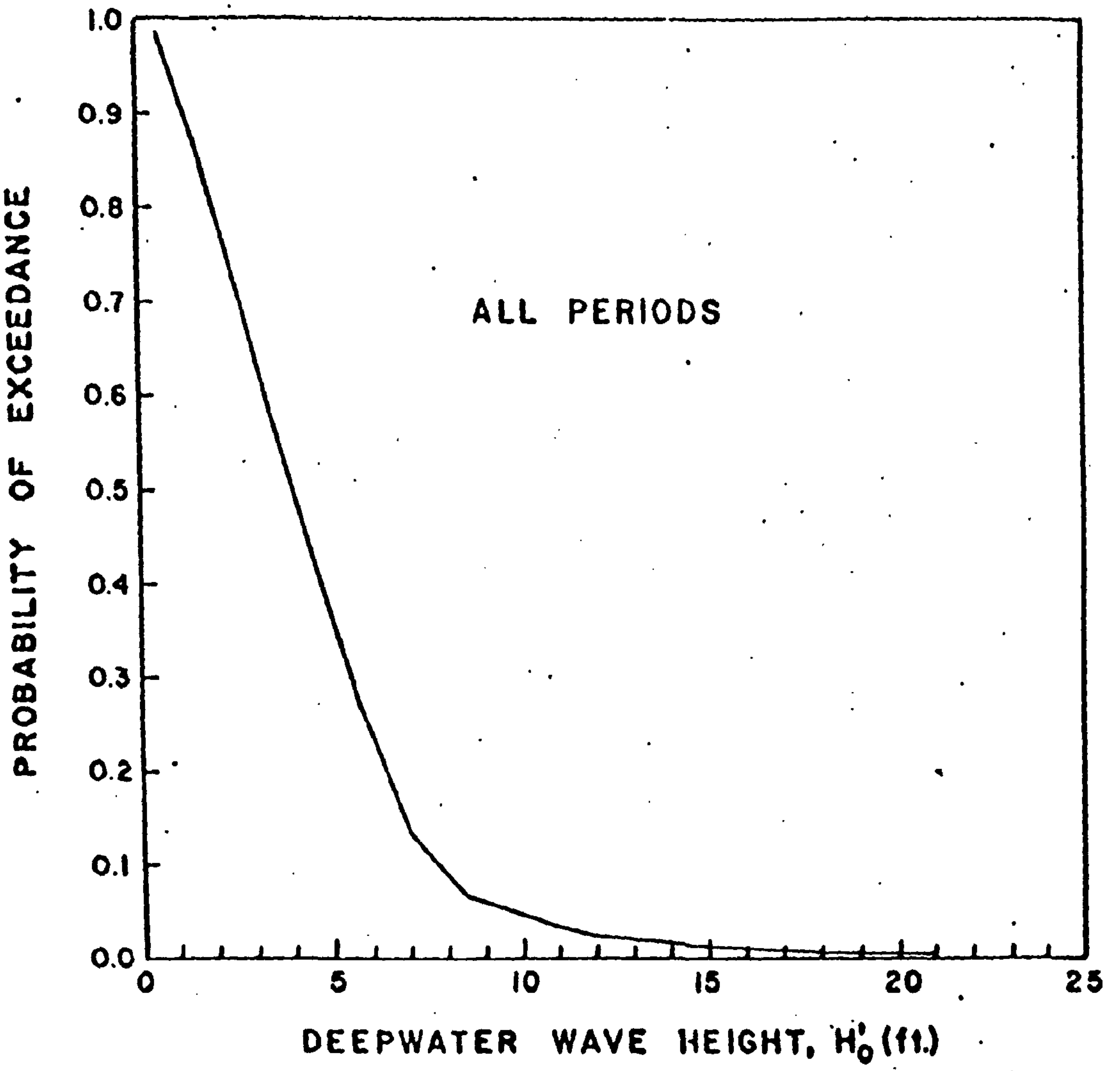
Annual DeepWater Wave Height-Direction Rose Given by the PNJ Hindcasting Procedure (Data from Neumann and James, 1955).



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)