LONG-TERM BEACH RESPONSE AT OCEAN BEACH, FIRE ISLAND, NEW YORK OCTOBER 1981 THROUGH JANUARY 1986

by

M.S. Zimmerman and H.J. Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY OF NEW YORK

LONG-TERM BEACH RESPONSE AT
OCEAN BEACH, FIRE ISLAND, NEW YORK
OCTOBER 1981 THROUGH JANUARY 1986

by

M.S. Zimmerman and H.J. Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

Special Report No. 76

Reference No. 86-14

Approved for Distribution

D.W. Pritchard, Acting Dean
and Director

LONG-TERM BEACH RESPONSE AT OCEAN BEACH, FIRE ISLAND, NEW YORK, OCTOBER 1981 THROUGH JANAURY 1986

by
M. S. Zimmerman and H. J. Bokuniewicz
Marine Sciences Research Center
State University of New York
Stony Brook, New York 11794-5000

INTRODUCTION

The Ocean Beach beach observation program was instituted in October of 1981 to measure and characterize the magnitude of seasonal beach response, wave dynamics and longshore transport along a section of the barrier island at Ocean Beach, Fire Island, New York. This study represents one of the few sets of long-term beach data available for the south shore of Long Island, and the only one for the coast at Ocean Beach. Data and results from previous years of study can be found in earlier reports (Tanski 1982, 1983; Bokuniewicz, Zimmerman and Henrichs 1984; and Zimmerman, Bokuniewicz, et al. 1985). This report will describe long-term changes between October 1981 and January 1986.

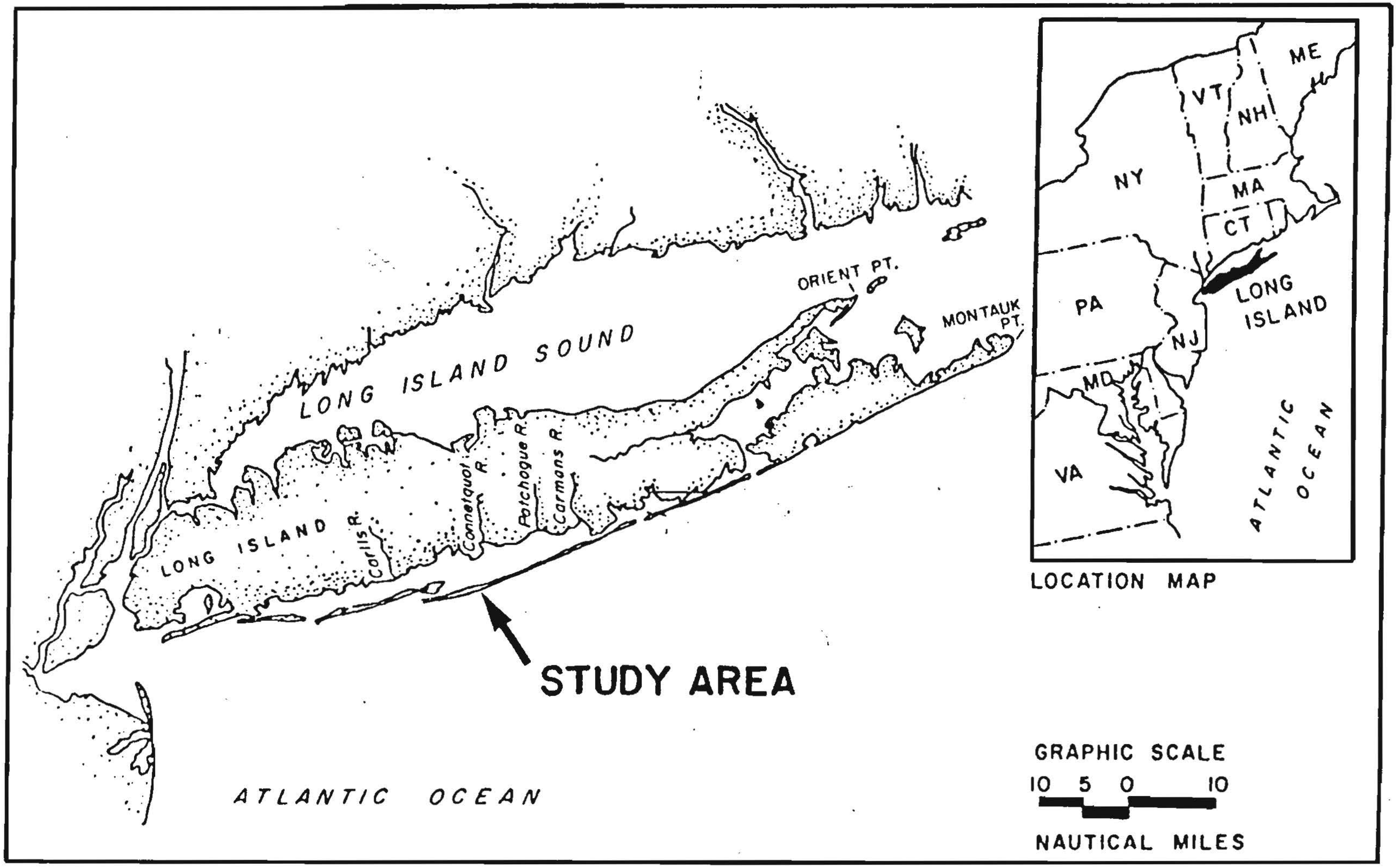
The beach observation program has had two objectives. The first was to monitor the beach in order to detect departures from typical beach conditions that may have indicated environmental changes or unusual events. The occurence of Hurricane Gloria on 27 September 1985 is one such event whose impact can now be measured against the observed, typical conditions. The second objective was to search for evidence of long-term trends in the behavior of the beach that may be detectable over the term of the study. The beach is a dynamic and extremely variable environment, and chronic changes, if they exist, may be relatively small. To try to detect these small chronic changes when day-to-day and month-to-month variations are large, requires a long period of observation.

Measurements were designed to be made monthly at as many as 20 stations along the Ocean Beach, Fire Island shoreline. The stations were set between the toe of the dune and its crest. At each station, a profile of the beach was made about once each month. These cross-sectional profiles documented the elevation of the beach, its slope, width, and volume. By comparing changes in these profiles, changes in the condition of the beach were monitored.

STUDY AREA

The study area is located in the village of Ocean Beach, on western Fire Island, New York (figure 1). Fire Island is a 32-mile long barrier island trending *ENE* along the south shore of Long Island, and is the longest of the barrier islands that lie between Shinnecock and Rockaway Inlets. The study site is a 6400-foot stretch of beach composed primarily of well rounded quartz sands with smaller amounts of heavy minerals (Taney 1961a). The material is believed to be derived from the erosion of the headlands to the east, and from offshore sources (Panuzio 1968; Williams 1976; McCormick 1976). Westward transport of this material by wave generated longshore drift is estimated to be on the order of 450,000 cubic yards of sand per year (Taney 1961a). Results of observations made by volunteer wave observers at Ocean Beach during earlier

Figure 1. Location and study area.



LONG ISLAND SOUND
ORIENT PT.
MONTAUK PT.
LONG ISLAND
Carlls R.
Connetquot R.
Patchogue R.
Carmans R.
STUDY AREA
ATLANTIC OCEAN
ME
VT
NH
NY
MA
CT
PA
LONG ISLAND
NJ
MD
VA
ATLANTIC OCEAN
LOCATION MAP
GRAPHIC SCALE
10 5 0 10
NAUTICAL MILES

segments of this study are comparable to this estimate (Zimmerman, Bokuniewicz, et al. 1985). During the 1981-82 study period, the net longshore transport of sand calculated from observations made over a 175-day period was 135,145 cubic yards to the west. Extrapolated over a full year, this value indictates a net transport rate on the order of 311,900 cubic yards per year to the west with a gross transport through the section of 1,650,900 cubic yards. Eastward transport was observed 36% of the time, and westward transport 53% of the time (Tanski 1983). In the following year, the total transport of sand through the section was about 1,685,450 cubic yards, with a net movement of 893,650 cubic yards to the west (Bokuniewicz, Zimmerman and Henrichs 1984). Westward transport of sand was recorded 63% of the time, and was 3.3 times greater in magnitude than the average eastward transport. Eastward transport was noted to occur 32% of the time. Between January and October 1984, the gross transport of sand across the Ocean Beach study site was on the order of 1,442,000 cubic yards, with a net transport of 440,000 cubic yards of sand to the west (Zimmerman, Bokuniewicz, et al. 1985). Total westward transport equalled about 941,000 cubic yards, and was about twice the calculated value of 501,000 cubic yards of sand transported to the east. Sand was reported to be moving to the west about 65% of the time, while eastward transport occurred 34% of the time.

The stations cover a 1.2 mile stretch of the shoreline. The eastern and western sections of the study area are backed by continuous dunes; in the eastern section the dunes have been disturbed by development on their landward edge. Included in this section are two groins constructed as public works about 20 years ago. To the west, the dune field remains relatively unprotected by groins, revetments or bulkheads. The central section of the study area is backed in part by bulkheads, which lie in front of a constructed dune. Some of the benchmarks used in this study are near groins. Others are in sections of the beach backed by bulkheads and others are in front of dunes unprotected by shore-parallel or shore-perpendicular structures (figure 2). The placement of the stations in sections of the beach with and without protective structures allows us to make comparisons between these sites, and to monitor their response to the same wind and wave conditions.

BACKGROUND

The south shore of Long Island is divided into two physiographic provinces (Taney 1961), the headlands section, extending west from Montauk Point to Southampton, and the barrier island section extending from Southampton west to Rockaway Inlet. The headlands have undergone erosional retreat since the last glaciation (Panuzio 1968; Taney 1961). The barrier island section in contrast is a constructional feature, having derived much of its material from the eroding headlands.

Long-term geologic recession has been demonstrated for much of Long Island's south shore, most notably on the barrier island system on west-central Long Island. Sanders and Kumar (1975) documented barrier island retreat for Fire Island, concluding that the present day barrier has migrated a total of 7 km landward over the past 8,500 years. Historical trends of shoreline stability along Long

Figure 2. Map of Ocean Beach, Fire Island. Small arrows represent station locations for this study. Large arrows correspond to Taney's (1961) reference stations. The letter G denotes the position of shore perpendicular groins. Shore parallel structures are located between stations 12 and 13.

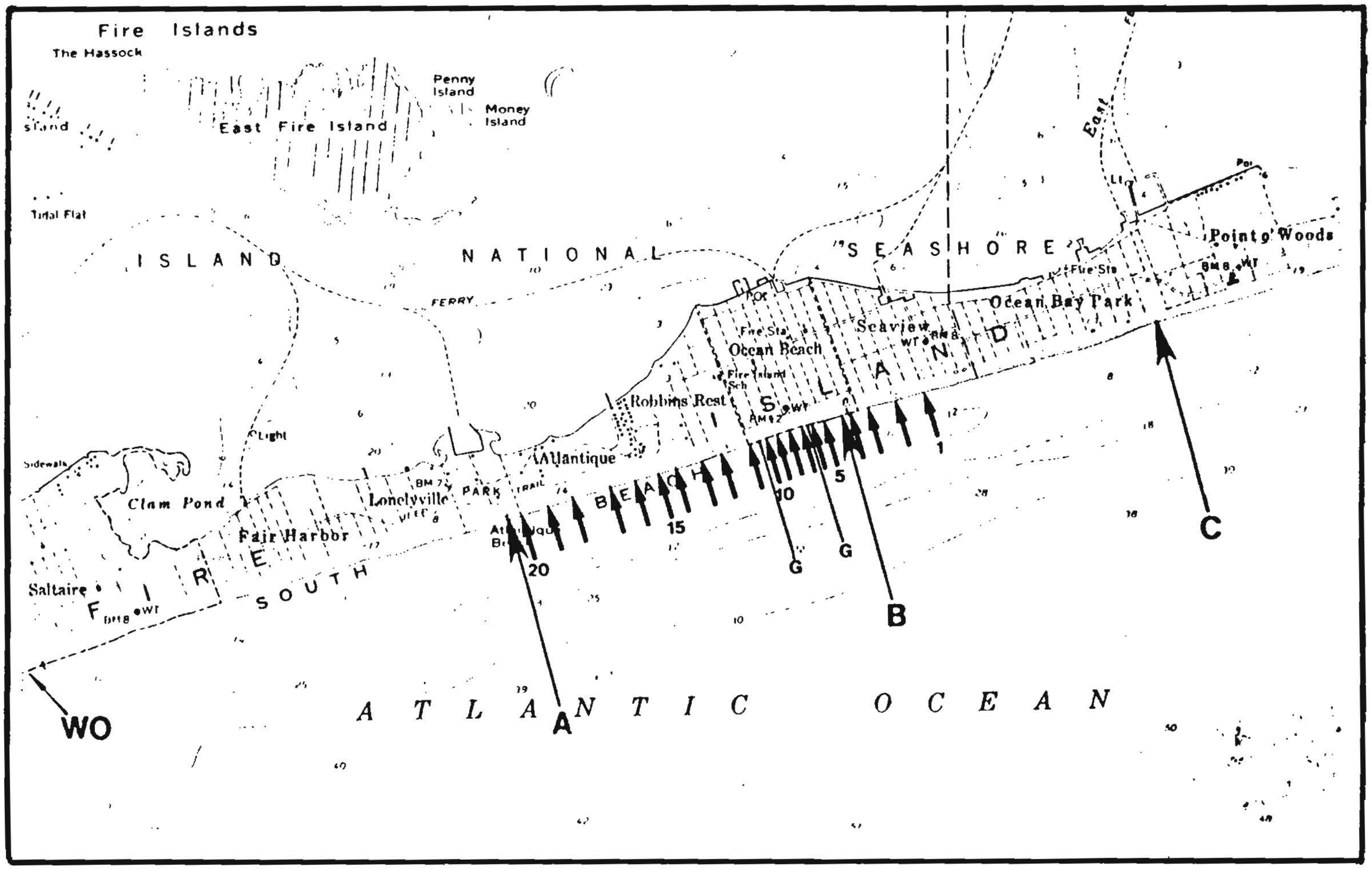

Fire Islands
The Hassock
Penny Island
Money Island
East Fire Island
Tidal Flat
ISLAND NATIONAL SEASHORE
FERRY
Light
Clam Pond
Fair Harbor
Lonelyville
PARK
Atlantique
Robbins Rest
Ocean Beach
Seaview
Ocean Bay Park
Point o' Woods
Saltaire
FIRE ISLAND
SOUTH BEACH
ATLANTIC OCEAN
20
15
10
5
1
G
G
A
B
C
WO

FIG. 2.

Island's south shore suggest a pattern of general recession. Taney (1961) documented shoreline changes for the south shore for the period 1838 through 1956. Three of the reference stations used in his study are within or near the Ocean Beach study site. Over the 118 year study period, the beach had been shown to be receding at an average rate of 2.5 to 3.6 feet per year, or at a total loss of about 340 feet of shoreline. Taney's data indicate that erosion in the eastern section of the study area is somewhat greater than that to the west. Ruzyla (1973), in a study on eastern Fire Island, found erosion rates on the order of three to five feet per year for the period of 1959 through 1969.

Superimposed on these pattterns are seasonal fluctuations in the beach which complicate measurements of the longer-term trends. Data for the segment of Westhampton Beach exclusive of the federal groin field indicate a winter-summer fluctuation in the position of the shoreline (DeWall 1979). During the fall and winter months, steeper waves removed sand from the beach, whereas the lower, less steep summer waves acted to rebuild the beaches (DeWall 1979). Short-term changes in beach width were generally in excess of 60 m.

The study at Ocean Beach is one of two sets of recent long-term beach data currently available for Long Island's south shore. The second study being undertaken is for a segment of the coast in the headlands section of the south shore, in the Village of East Hampton, New York (Zimmerman and Bokuniewicz 1986). Observations over the past 6.2 years have revealed that the beach at East Hampton is dominated by storm events. Strong seasonal patterns of erosion or accretion should not be presumed. From month to month the beach width will typically change by about 25 feet and the beach volume by about 13 cubic yards per foot of beach front. In the face of these variations long-term patterns are difficult to detect, however, in general, the beach at East Hampton shows indications of long-term accretion on the order of six cubic yards per foot of shoreline per year. This does not necessarily reflect a gradual, chronic change. In some instances, for example, the long-term pattern is punctuated by short periods of rapid accretion. In the presence of these large natural variations long-term records are needed to detect chronic trends in the condition of the beach.

METHODS

The elevation of the benchmarks used in this study relative to mean sea level, and the position of the benchmarks within the New York State grid were provided by the Town of Islip (Tanski 1983). Occasionally, benchmarks were lost or covered by debris or sand. Wherever possible, the station markers were replaced and surveyed with respect to the adjacent benchmarks.

The surveys begun in the calendar year 1981 were conducted by students from Bay Shore High School, under the supervision of Mr. James Romansky and the direction of scientists from the Marine Sciences Research Center. Personnel of the Center took over the measurements in August 1985. Measurements were conducted approximately once a month. Between October 1981 and July 1985, surveys were conducted at the 20 original stations set at Ocean Beach. After August 1985, surveys were conducted at 4 of the 20 stations; stations 3, 5, 13 and 19. These are the stations for which the most consistent long-term records are available.

The profiling method employed between October 1981 and July 1985 was essentially the technique developed by Emery (1961) with modifications (Bokuniewicz 1981). At each station a compass was used to take a bearing perpendicular to the trend of the shoreline. A line was laid between the benchmark and the waterline following this compass heading. The height of the benchmark above the sand level was then recorded. Measurements of the surface topography of the beach were made with two five-foot wooden staffs. The vertical staffs were connected by a five foot line. One end of the line was connected to the landward staff. The other end was attached to a ring which was free to slide up and down the seaward staff, graduated in foot and tenth-of-foot increments. A line level was secured to the string. The measurements were made by holding the staffs upright and sliding the free end of the string up and down until the line level indicated the string was level. The elevational displacement between the staffs was recorded to the nearest 0.05 foot. The student observers started the measurements at the survey marker, and following the compass line, continued down the beach to the water's edge. These measurements were repeated every five feet across the width of the beach to the waterline. A second student group made a duplicate profile at each station. All surveys were done within one hour of low tide. The uncertainty in the measured volumes was about 2%.

At the time personnel of the Marine Sciences Research Center took over the field work, the method changed slightly. Instead of 5-foot staffs joined by a 5-foot line, the profiling instrument consisted of an upright pipe joined at right angles to a 10-foot long horizontal piece (Schwartz 1967; Bokuniewicz and Tanski 1982). A level was secured to the horizontal pipe, one end of which was free to slide up and down a graduated vertical rod. The instrument was positioned perpendicular to the shoreline, and the horizontal pipe levelled. The elevational displacement between the two vertical members was then recorded. Utilizing this technique, the personnel in the field made half the number of measurements than would have been necessary if using the previous method. Operational errors associated with the use of the staffs were also reduced due to the rigid construction of the device. The results obtained by this method were compared to those measured by the staffs and were found to be more precise (Bokuniewicz and Tanski 1982).

The measurements were then used to determine the beach volume and width. The beach volume was calculated as the number of cubic yards of sand contained in the cross-section of the beach between the position of the benchmark at the base of the dune and the position of the shoreline at mean sea level for each foot of beach length. The beach width was calculated as the distance between the benchmark and the position of the shoreline at mean sea level. Although the surveys were done within one hour of low tide, in some instances the profile line ended at an elevation greater than mean sea level because of wave action or storm surges. If the profile ended at an elevation not greater than 6 feet above mean sea level, the profile line was extrapolated, and the volume and width calculated. However, our criteria required that the extrapolation not exceed 30% of the length of the profile. Changes in the condition of the beach were monitored by comparing the volume and width of the beach at the same location on different survey dates.

Since the benchmarks were set arbitrarily at the dune line in order to facilitate access, the absolute beach volume and width between stations cannot be compared directly. However, these data are useful when examining temporal and spatial extremes in the condition of the beach at individual stations.

RESULTS

Long-term changes. Over 800 surveys were conducted between 26 October 1981 and 7 January 1986. Data representing the absolute volume in cubic yards per foot of beach length for each of the 20 stations at Ocean Beach over the course of the study are listed in table 1. The greatest sand volume attained by any of the stations during the study period occurred at station 2 on 25 September 1984, when the beach contained 119.4 cubic yards of sand per foot of beach length. Station 12 was observed to exhibit the smallest volume, when on 10 December 1981 it contained 2.7 cubic yards of sand per foot of beach length. This is not significantly different from the situation noted on 24 November 1981, when station 12 contained 2.8 cubic yards of sand. The greatest mean volume of sand noted to occur between October 1981 and January 1986 was measured for station 1, which contained an average of 73.2 cubic yards of sand. Station 13 exhibited the smallest mean volume, containing an average of 20.4 cubic yards of sand per foot of beach length over the 4.3 years of study. The greatest range between maximum and minimum volume was observed to occur at station 2, which fluctuated 45.6 feet about its mean of 60.0 cubic yards. Station 10 was noted to fluctuate the

Table 1. Long-term beach volume data, Ocean Beach, Fire Island.
26 October 1981 through 7 January 1986
(in cubic yards per foot)

		Station Number									
	Date	1	2	3	4	5	6	7	8	9	10
1981	26 Oct	75.7	52.2	29.2	29.7	32.1	61.4	40.9	31.0	42.7	33.0
	24 Nov	47.4	43.7	29.7	27.4	31.4	41.1	48.4	35.4	30.7	32.4
	10 Dec	44.4	39.0	37.3	25.6	36.0	41.4	46.5	39.9	35.4	32.2
1982	08 Jan	48.3	44.1	31.3	25.2	34.1	47.6	37.1	34.9	29.8	35.7
	08 Feb	52.0	43.2	31.1	30.4	27.8	45.0	41.8	37.2	27.9	41.3
	23 Mar	66.8	54.3	45.3	39.6	52.2	53.9	38.1	38.6	43.2	40.4
	21 Apr	69.4	49.4	41.3	29.7	36.4	43.2	33.6	34.1	28.1	32.1
	04 May	64.7	65.5	44.9	35.0	38.5	50.9	36.9	41.5	37.7	31.5
	02 Jun	65.8	57.2	43.2	45.7	47.2	59.9	43.5	35.6	40.8	39.9
	14 Jul	74.2	55.3	43.2	43.2	36.1	70.0		58.4	45.4	46.6
	29 Jul	64.6	49.0	36.7	41.1	46.5	50.3	84.8	63.4		52.8
	29 Sep	64.8	47.6	39.3	45.4	41.1	58.6	55.4	49.7	53.4	42.6
	14 Oct	67.4	43.6	39.3	38.3	35.8	45.9	43.3	41.5	39.6	38.9
	17 Nov	60.8	56.7	32.2	32.6	39.3	44.8	52.3	43.2	39.7	36.8
	14 Dec	76.4	54.3	34.3	35.5	37.0	43.9	45.1	37.6	40.9	40.9
1983	11 Jan			33.2		34.9	47.0	40.7		32.7	40.0
	24 Feb		65.4	47.8	48.7	50.5	59.7	56.6	47.1	46.8	46.8
	25 Mar	96.4	83.5	67.7	65.3	50.6		70.0			
	12 Apr	76.5	69.7	76.2	52.5		82.2	65.3	80.6		62.7
	10 May	93.4	85.5	57.2	53.8	54.8		71.4	62.2	64.2	45.5
	07 Jun		95.4	66.1	42.7	48.8	71.5	86.8	85.4		
	05 Jul			77.5		49.4	105.7	98.9			
	19 Jul				91.1	76.2			69.9		
	20 Sep	108.3	83.3	68.7	69.5	66.6	68.1	73.0			49.4
	18 Oct		74.7	65.5	58.4	60.4		76.2		59.0	
	17 Nov	73.3	84.0	67.7	65.8	56.0	63.1	69.9	65.5	46.3	49.1
	15 Dec	100.4	56.0	52.9	50.9	45.3	28.7	50.0	55.5	45.4	37.9
1984	17 Jan	90.5	85.1	63.9		58.0	78.3	70.2	58.3	59.3	50.3
	15 Feb			60.4		51.1					
	14 Mar	71.1	68.5	56.6	58.0	50.0	67.8	54.3	53.5	43.2	
	12 Apr	80.7	66.0	57.6	37.4	50.0	72.7	65.6		71.2	53.4
	10 May	90.6	86.3	55.8	57.9	67.9	64.1	59.2	69.9	70.8	49.5
	07 Jun	87.6				60.4	77.5				
	05 Jul		67.6	51.4		53.6	37.4	67.8	72.8	62.7	63.6
	08 Aug			56.3							
	25 Sept		119.4	55.3	49.0	65.0	52.9	64.0	86.1	69.4	
	24 Oct	61.7	28.2	62.8		58.6	67.6	68.1	55.4	55.6	43.0
	21 Nov	83.1	32.0	61.3	50.5	52.7	80.8	64.2	60.9	69.1	43.4
	05 Dec	77.0	47.7	50.2	40.8	58.3	73.4	74.0	50.1	82.4	43.6
1985	04 Jan	74.8	54.2	44.9	40.7	48.9	74.4	67.1	50.8	58.3	37.9
	15 Feb	55.6	43.1	34.6	35.1	44.1	76.3			54.7	
	19 Mar	57.8	38.8	36.0	33.9	36.1	67.2		33.0	54.2	
	18 Apr	73.2	47.9	42.0	40.7	54.6	67.5		29.7	61.4	47.5
	17 May		42.7	37.8	33.5		55.5	70.6	27.0	51.1	37.4
	31 May	101.3	60.2	52.1		58.6	88.4	94.2	38.6		
	27 Jun	72.0	63.1	43.0		47.0	38.1	84.3		60.8	
	29 Jul	67.0	55.2	35.5	43.3	48.4	67.7	80.4		89.2	60.5
	13 Aug			44.7		51.8					
	09 Oct			45.1		64.8					
	10 Dec					47.7					
1986	07 Jan					40.3					
	Mean	73.2	60.0	48.6	44.4	48.6	60.8	61.3	50.7	51.2	43.6
	Max	108.3	119.4	77.5	91.1	76.2	105.7	98.9	86.1	89.2	63.6
	Min	44.4	28.2	29.2	25.2	27.8	28.7	33.6	27.0	27.9	31.5
	Range	63.9	91.2	48.3	65.9	48.4	77.0	65.3	59.1	61.3	32.1

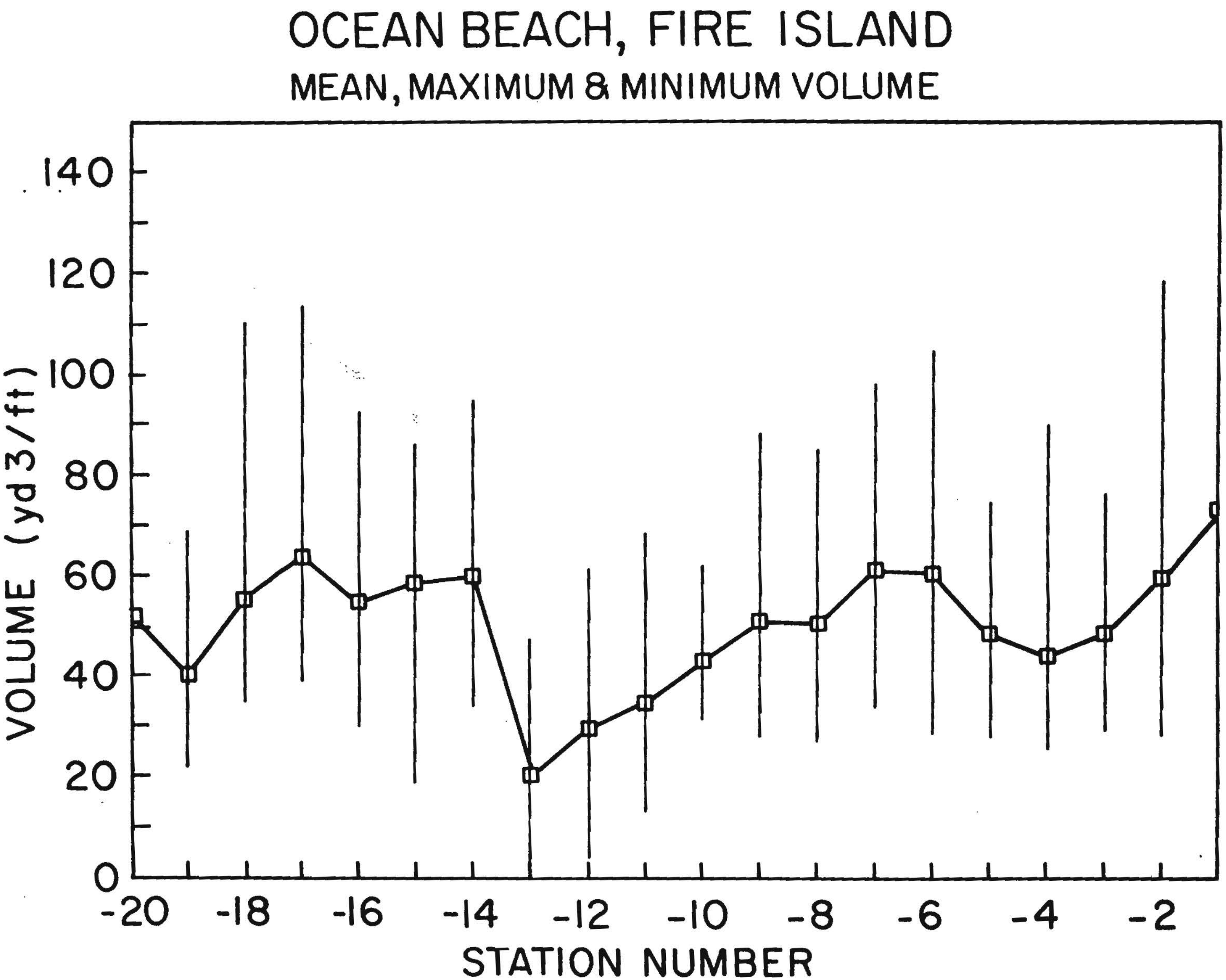
Table 1. Long-term beach volume data, Ocean Beach, Fire Island. (continued)

	Date	11	12	13	14	15	16	17	18	19	20
					Station Number						
1981	26 Oct	24.0	6.3	7.0	56.1	51.4	61.8	55.0	37.8	30.0	34.3
	24 Nov	14.5	2.8	5.7	52.3	47.5	48.8	56.3	44.6	35.9	29.2
	10 Dec	13.3	2.7	5.6	52.9	60.9	50.8	47.6	41.7	34.1	30.5
1982	08 Jan	22.2	15.4	9.2	51.8	56.3	36.7	49.3	43.8	31.9	33.0
	08 Feb	19.2	20.1	6.9	57.4	57.4	42.4	44.3	37.1	31.3	37.6
	23 Mar	20.1	12.2	9.6	57.3	44.1	44.1	52.2	37.4	38.2	39.8
	21 Apr	17.1	14.7	12.2	54.9	42.1	47.8	45.2	48.5	38.8	39.4
	04 May	21.0	16.0	7.9	41.3	50.1	37.4	46.4	40.4	43.2	42.4
	02 Jun	12.8	12.7	9.9			55.6	52.6	49.7	38.0	39.2
	14 Jul	22.4	13.9	11.3	53.1		50.7	47.8	44.2	40.0	39.1
	29 Jul			15.3	58.1		50.4	73.4	55.3	55.0	52.7
	29 Sep	24.5	23.2		53.0		42.1	63.4	43.2	39.5	54.1
	14 Oct			3.9	46.5		46.7	53.6	41.7	35.4	40.0
	17 Nov	24.8	13.9	5.1	37.8		46.8	53.6	51.3	43.6	32.6
	14 Dec	23.8	14.4	9.2	36.9		42.3	59.5	45.4	32.4	25.6
1983	11 Jan	15.2			41.6		31.0		39.8		26.5
	24 Feb		8.2		34.2		40.0	51.1	35.2	24.0	24.8
	25 Mar									22.1	23.4
	12 Apr	52.6	38.6				88.5		47.3	42.6	36.5
	10 May	37.0	45.8				74.9	114.4	110.5	53.2	49.3
	07 Jun	61.7	48.0	39.6			82.9			58.0	65.4
	05 Jul	57.9	59.2						84.6	61.7	88.1
	19 Jul			38.7							
	20 Sep	56.3	50.6	48.3				98.9			76.2
	18 Oct	36.4	28.1	31.5			93.5		72.7	69.2	82.2
	17 Nov	19.3						68.1	74.4		70.8
	15 Dec	20.5	9.9		46.2	18.6	44.1	39.4	54.1	54.4	64.3
1984	17 Jan	22.9	26.7	28.0			61.8	76.0	76.6	67.1	73.9
	15 Feb	19.8	25.0	22.4		59.7	62.9	73.2	66.8		
	14 Mar	22.0	18.1	13.4	60.6	53.5	52.4	63.4	68.3	52.9	61.2
	12 Apr	37.3		20.1		58.8	30.0	54.3	64.8		59.9
	10 May	39.4		19.5	72.2	66.1	49.7	64.9	58.7	35.4	75.9
	07 Jun	34.4		26.0		55.9			55.4	38.6	64.3
	05 Jul	43.2		31.0		58.6	41.6	62.0	57.6	43.6	61.6
	08 Aug									54.3	
	25 Sept	35.3	49.9	30.9				68.1	60.9	49.0	64.1
	24 Oct	48.8	27.7	22.4	59.0		51.9	68.6	55.2	31.9	62.4
	21 Nov		43.2	31.4	86.9	76.8	70.0	67.4	59.2	36.2	64.3
	05 Dec	52.3	52.6	25.6	92.7	86.7	74.1	76.4	65.5	46.4	71.4
1985	04 Jan	50.2	38.0	36.8	95.9	78.7	74.9	77.8	60.2	40.7	63.8
	15 Feb	42.1	27.2	13.2	70.2	56.1	56.5	62.2	55.4	30.4	57.5
	19 Mar	49.2	39.6	27.6	89.6	63.8	50.7	71.5		35.6	56.8
	18 Apr	45.7	49.5	23.7		79.6	69	73.8	62.1	27.1	56.2
	17 May	55.1	39.6	15.9	63.1	64.8	55.3	69.2	54.7	37.9	55.2
	31 May	53.7	42.5	25.5		60.2		79.8	55.4	34.5	51.1
	27 Jun	69.6	62.6	32.3	80.3	62.3	53.9	82.4	67.0	34.5	59.7
	29 Jul	69.4	58.0	33.5	84.9	67.7	74.6		64.9	41.0	
	13 Aug		48.0	31.3						41.6	
	09 Oct			20.7						33.5	
	10 Dec			6.5						23.8	
1986	07 Jan										
	Mean	35.2	29.9	20.4	60.2	59.1	55.0	63.9	55.8	40.6	52.0
	Max	69.6	62.6	48.3	95.9	86.7	93.5	114.4	110.5	69.2	88.1
	Min	12.8	2.7	3.9	34.2	18.6	30.0	39.4	35.2	22.1	23.4
	Range	56.8	59.9	44.4	61.7	68.1	63.5	75.0	75.3	47.1	64.7

least, varying only 32.1 cubic yards between its minimum volume of 31.5 cubic yards and its maximum of 63.6 cubic yards of sand per foot of beach length. Figure 3 illustrates the mean, maximum, and minimum volumes for all stations within the study area between October 1981 and January 1986. There is no pattern of variation visible from east to west (from station 1 to station 20) across the study area. The only strong departures occurred at stations 12 and 13, where the mean volume of sand contained on the beach was less than that at other stations. These stations both lie in front of a wooden bulkhead, and the benchmark may be set relatively nearer to the shore than at the other stations. However, although the mean volume of sand contained at stations 12 and 13 was less than that for the other stations at Ocean Beach, the magnitude of the change between successive surveys was comparable.

In general, the beach at Ocean Beach, Fire Island exhibited minimum or near minimum volumes early in the study period. Ten of the 20 stations (stations 1, 3, 4, 5, 7, 9, 10, 11, 12, and 13) were near or at their minimum recorded volumes within the first year of observation. These stations have all consistently increased in volume since that time. Five stations (stations 14, 16, 18, 19, and 20) exhibited minimum volumes within a three month period between December 1982 and February 1983. The remainder of the stations reached minimum volumes at various times over the course of the study. Maximum recorded volumes were attained by 14 of the 20 stations (stations 1, 3, 4, 5, 6, 7, 8, 10, 13, 16, 17, 18, 19, and 20) within a 7 month period between April and October 1983. The remainder of the stations peaked in volume at various times late in the study.

Figure 3. Mean, maximum and minimum volume for all stations within the study area.


OCEAN BEACH, FIRE ISLAND
MEAN, MAXIMUM & MINIMUM VOLUME
VOLUME (yd 3/ft)
140
120
100
80
60
40
20
0
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
STATION NUMBER

The average change in volume between successive successful surveys for all the stations at Ocean Beach, Fire Island bewteen October 1981 and January 1986 was 9.18 cubic yards of sand per foot of beach length (table 2). Station 6 exhibited the greatest magnitude of change, eroding or accreting an average of 14.85 cubic yards per foot for each survey interval. Station 2 varied the least, fluctuating on the order of 6.21 cubic yards per foot of beach length between successive measurements. The response at station 3 was similar, exhibiting an average change between successive surveys of 6.25 cubic yards of sand per foot of beach length. As a result of these variations, the minimum detectable linear trend in volume across the study area would be on the order of two cubic yards of sand per foot of beach length per year.

For the 4-year, 3-month period of 26 October 1981 through 7 January 1986, the beach at Ocean Beach exhibited a net gain of sand (table 2). Net accretion over the study period ranged from a high of 46.5 cubic yards of sand per foot of beach at station 9, to a low of 6.3 cubic yards at station 6. Stations 13 and 19 were the only stations noted to have lost sand during the study, losing about 0.5, and 6.2 cubic yards of sand per foot of beach length respectively. The largest gross accumulation of sand was observed at station 6, which gained 300.1 cubic yards. This gain, however, was offset by a loss of 293.8 cubic yards of sand, yielding a net accretionary change of 6.3 cubic yards of sand per foot of beach. The erosional loss at station 6 represents the largest total loss of sand for any of the stations at Ocean Beach. Additionally, station 6 exhibited the greatest gross change in volume, accreting or eroding a total of 593.9 cubic yards of sand per foot of beach length. In contrast,

Table 2. Gross volume changes, Ocean Beach, Fire Island. October 1981 through January 1986 (in cubic yards per foot)

Station #	Gross Erosion	Gross Accretion	Gross Change	Net Change	Magnitude of Change	Note
1	-227.04	218.29	495.33	8.75	12.72	1
2	-98.77	124.79	223.56	26.02	6.21	1
3	-135.85	151.76	287.61	15.91	6.25	2
4	-156.49	170.04	326.53	13.55	9.07	1
5	-180.71	188.86	369.57	8.15	7.86	3
6	-293.78	300.12	593.90	6.34	14.85	1
7	-180.28	219.73	400.01	39.45	10.53	1
8	-161.24	168.84	330.08	7.60	9.71	4
9	-152.09	198.55	350.64	46.46	10.02	1
10	-96.50	124.00	220.50	27.50	6.89	1
11	-123.72	169.13	292.85	45.41	7.51	1
12	-160.39	202.09	362.48	41.70	10.07	1
13	-132.51	132.05	264.56	-0.46	6.78	5
14	-115.00	143.80	258.80	28.80	9.59	1
15	-121.64	137.98	259.62	16.34	10.82	1
16	-210.10	222.85	432.95	12.75	11.70	1
17	-174.54	201.93	376.47	27.39	10.46	6
18	-149.45	176.53	325.98	27.08	8.03	1
19	-165.55	159.32	324.87	-6.23	7.56	5
20	-120.48	145.89	266.37	25.41	6.34	6

1 Data available through 29 July 1985
2 Data available through 9 October 1985
3 Data available through 7 Janauary 1986
4 Data available through 17 May 1985
5 Data available through 10 December 1985
6 Data available through 27 June 1985

station 10 was observed to fluctuate the least, having shown a gross volume change of 220.5 cubic yards of sand between October 1981 and January 1986. This was closely followed by station 2 which exhibited an overall change in volume of 223.6 cubic yards. In fact, stations 2 and 10 behaved similarly throughout the study period. Station 2 was observed to lose a total of about 98.8 cubic yards of sand, while stataion 10 lost 96.5 cubic yards. Both stations gained sand on the order of 124 cubic yards per foot of beach length between October 1981 and January 1986, and exhibited net gains in volume of 26.0 cubic yards at station 2 and 27.5 cubic yards of sand at station 10.

Long-term trends. The stations markers were set between the toe of the dune and its crest, and over the course of the study, several stations were lost due to extreme erosion events. These stations were reset at or near their original locations and their replacements have remained in place.

Continuous long-term records are available through August 1985 for all 20 of the original stations set at Ocean Beach, Fire Island. Data are available for four of these stations (stations 3, 5, 13, and 19) between September 1985 and January 1986.

Over the period of October 1981 through January 1986, the beach at Ocean Beach showed evidence of long-term accumulation of sand at an average rate of 5.98 cubic yards of sand per foot of beach length per year (table 3). The linear accretionary trend was weak, however, for several stations; station 3 at a rate of 2.16 cubic yards per foot per year (correlation coefficient = 0.20), station 4

Table 3. Long-term data statistics, Ocean Beach, Fire Island. October 1981 through January 1986

Station #	Corr Coef(R)	N	Slope	Y-Int	Rate (yd3/ft/yr)	Note
1	0.38	35	0.01	-11.44	4.94	1
2	0.66	36	0.02	1.73	6.49	1
3	0.20	46	0.01	15.62	2.16	2
4	0.22	36	0.01	10.52	2.74	1
5	0.47	47	0.01	8.65	4.08	3
6	0.41	40	0.02	-11.29	5.69	1
7	0.65	38	0.03	3.68	9.90	1
8	0.18	34	0.01	15.99	2.53	4
9	0.78	35	0.03	-9.49	9.87	1
10	0.45	32	0.01	5.50	3.40	1
11	0.72	39	0.03	-8.46	10.44	1
12	0.72	36	0.03	4.72	10.16	1
13	0.52	39	0.01	3.84	4.71	5
14	0.75	27	0.03	-13.22	10.40	1
15	0.57	24	0.02	-4.74	5.95	1
16	0.38	37	0.01	-15.93	5.00	1
17	0.51	36	0.02	-2.99	6.57	6
18	0.47	40	0.02	7.55	5.93	1
19	-0.06	43	0.00	12.03	-0.57	5
20	0.61	42	0.03	1.42	9.23	6

1 Data available through 29 July 1985
2 Data available through 9 October 1985
3 Data available through 7 January 1986
4 Data available through 17 May 1985
5 Data available through 10 December 1985
6 Data available through 27 June 1985

at 2.74 cubic yards per foot per year (correlation coefficient = 0.22), and station 8 at a rate of 2.53 cubic yards per year (correlation coefficient = 0.18). Station 19 was noted to be the only site at Ocean Beach consistently losing sand over the course of the study, eroding at a rate of -0.57 cubic yards of sand per foot of beach length per year. This relationship, however, was very weak (correlation coefficient = -0.06), due in large part to low values since April 1984. The strongest trends were observed at stations 9, 11, 12, and 14 which exhibited gains in sand volume at rates of 9.87, 10.44, 10.16, and 10.40 cubic yards per foot of beach length per year respectively. The correlation coefficients were 0.78 for station 9, 0.72 for station 11, 0.72 for station 12, and 0.75 for station 14.

The accretionary trends, however, are only linear at a few stations. At station 5 for example, the volume has increased gradually since the earliest available surveys (figure 4). This type of behavior was observed to occur at stations 1, 2, 3, 4, and 10 as well. The other stations did not show gradual increases; the trends at these stations seem to be indicative of three different types of behavior. Stations 6, 7, 9, 11, 12 and 17 represent one type where the long-term trend has been towards an increase in volume since the beginning of the study in October 1981. Figure 5 represents the three-point running mean of the long-term cumulative change in volume at station 6. This presentation reduces the amount of variability in the plot, thus allowing us to more clearly identify any trends which may exist within the data set. The increase in volume at this station is marked by several abrupt events. The most notable of these is the pronounced increase in

Figure 4. Long-term cumulative change in volume at station 5, Ocean Beach, Fire Island. See text for explanation.

OCEAN BEACH, FIRE ISLAND

STATION NO. 5

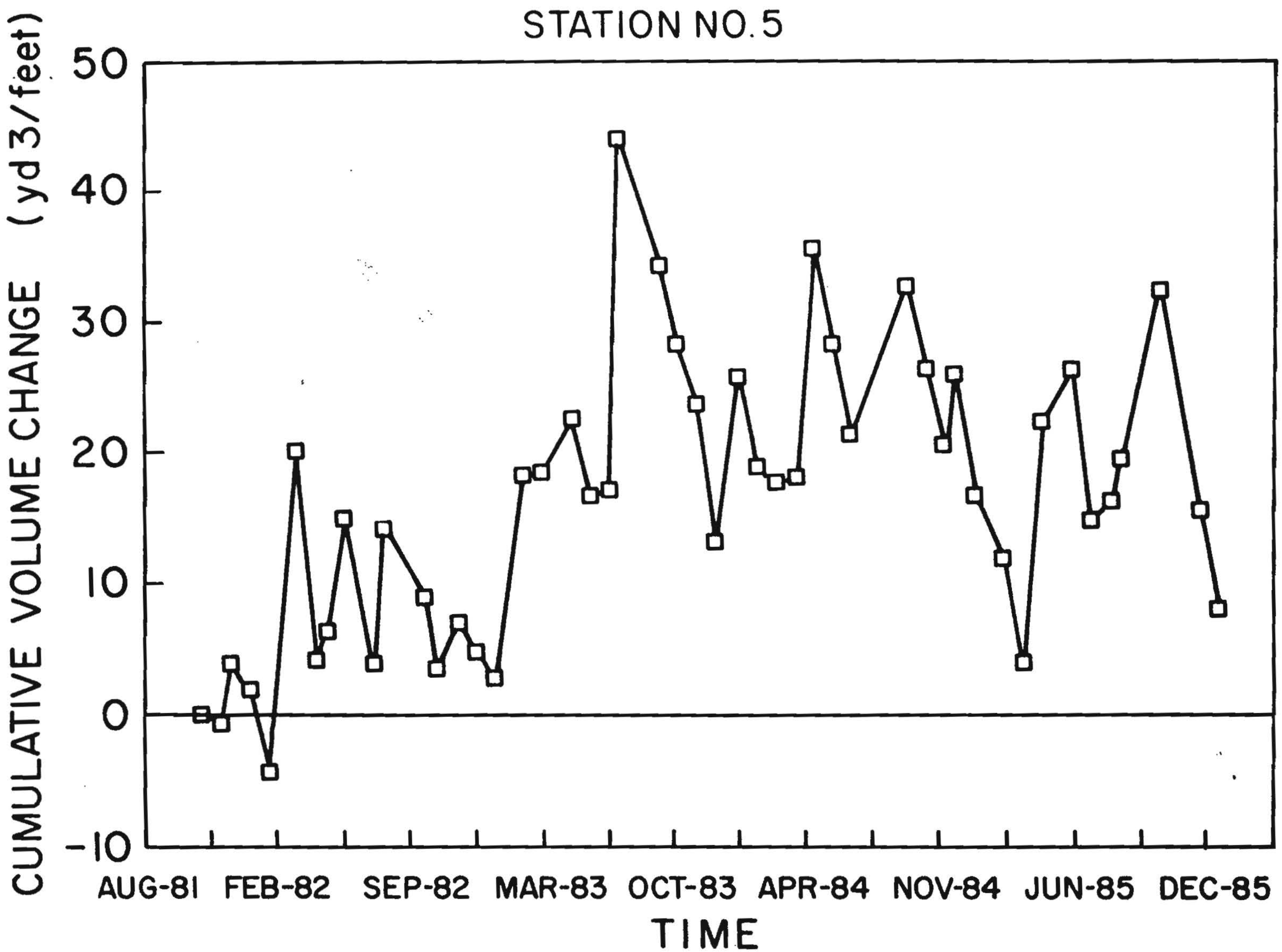
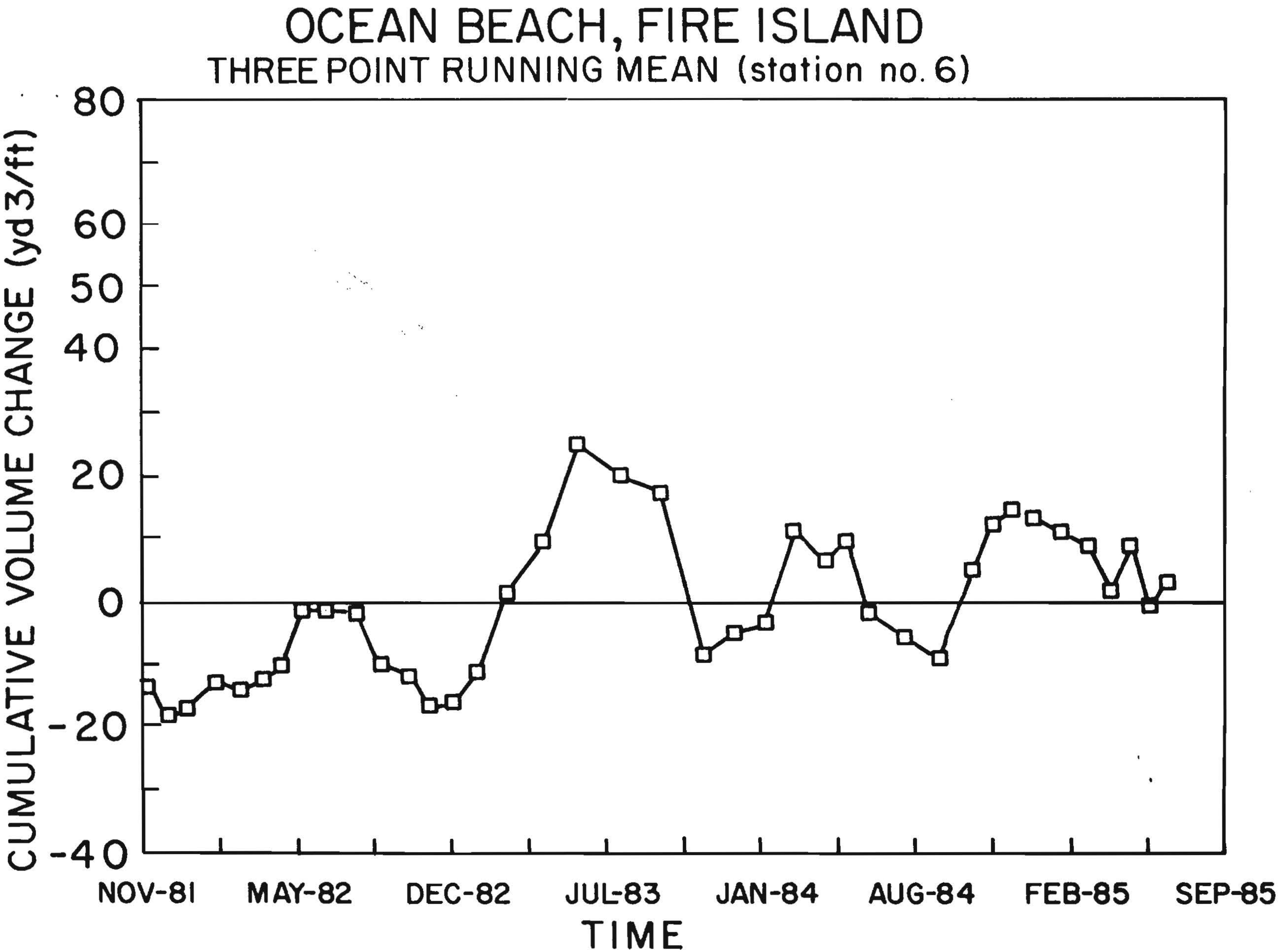


Figure 5. Three-point running mean of cumulative volume change since October 1981 at station 6. See text for explanation.


OCEAN BEACH, FIRE ISLAND
THREE POINT RUNNING MEAN (station no. 6)
CUMULATIVE VOLUME CHANGE (yd3/ft)
80
60
50
40
20
0
-20
-40
NOV-81
MAY-82
DEC-82
JUL-83
JAN-84
AUG-84
FEB-85
SEP-85
TIME

volume late in 1982, extending well into 1983. Stations 13, 18 and 20 represent the second type of long-term behavior observed. In this instance (figure 6), after an abrupt volume increase in late 1982, the station maintained a persistently higher volume than had been observed early in the study period. The third response was noted to occur at stations 8 and 19, where, following several pronounced accretionary events, sand had been lost, returning the volume to levels near or below that originally measured (figure 7). The decrease in volume at these stations is not supported by comparable changes in other parts of the study area. Station 19, for example, would be expected to have increased in volume as a result of the trends observed at stations 18 and 20, which both show persistently higher volumes than measured originally. It is possible that there was a break in the bar offshore of this station, however, if this were true, we would expect to see comparable changes at other stations in this section.

Extreme events:Hurricane Gloria. The Hurricane Gloria passed rapidly over Long Island about midday on Friday, 27 September 1985. This was a time of spring low tides, and, as a result, the impact of the storm on the coast was somewhat mitigated. Nevertheless, the effects of the storm can now be put in perspective.

There were no unusual departures from typical beach conditions at Ocean Beach, Fire Island that could be attributed to the occurrence of Hurricane Gloria. Two of the stations surveyed following the storm exhibited an accumulation of sand (stations 3 and 5) while two stations eroded (stations 13 and 19). Station 3

Figure 6. Three-point running mean of cumulative volume change since October 1981 at station 18. See text for explanation.

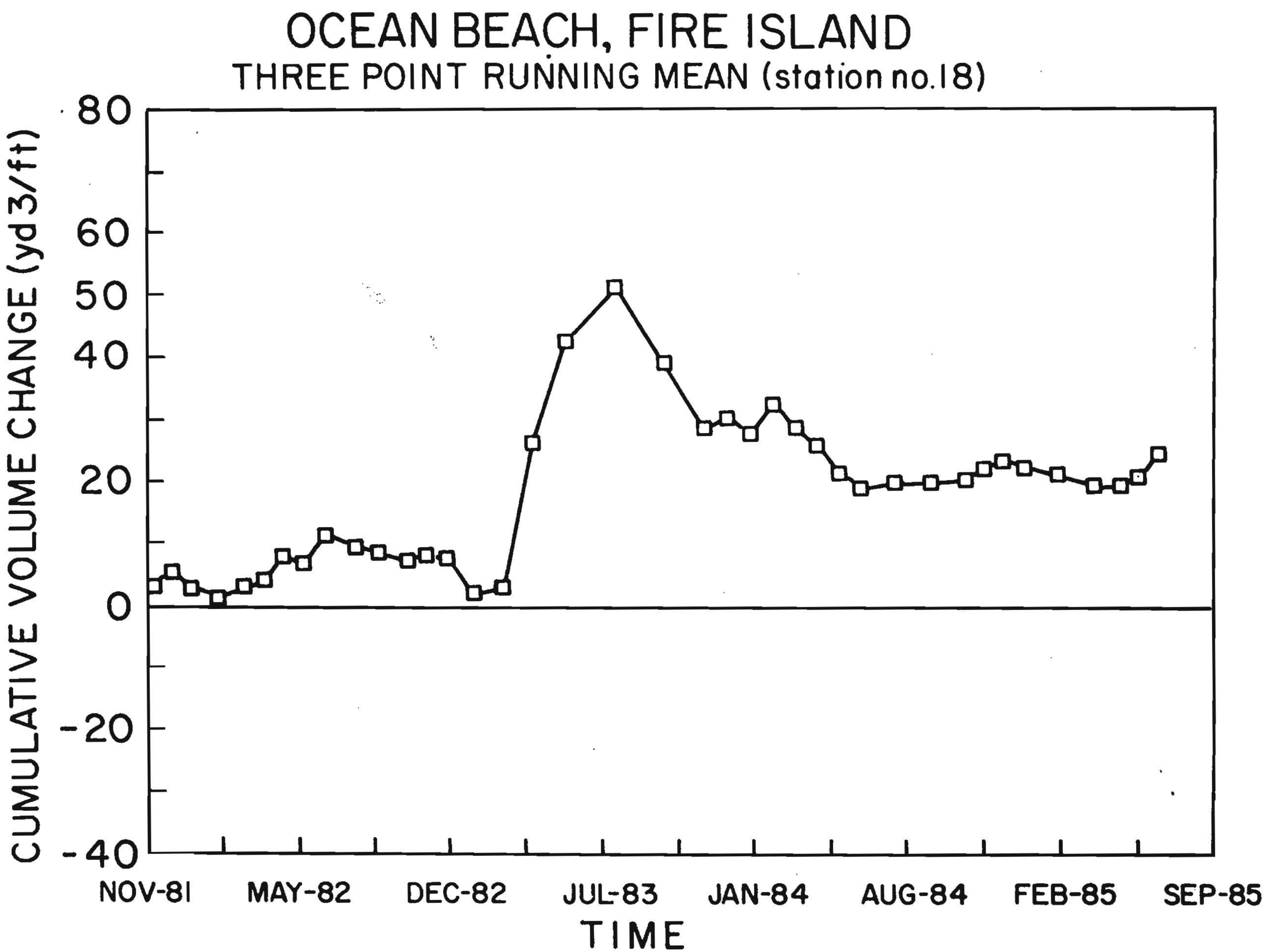
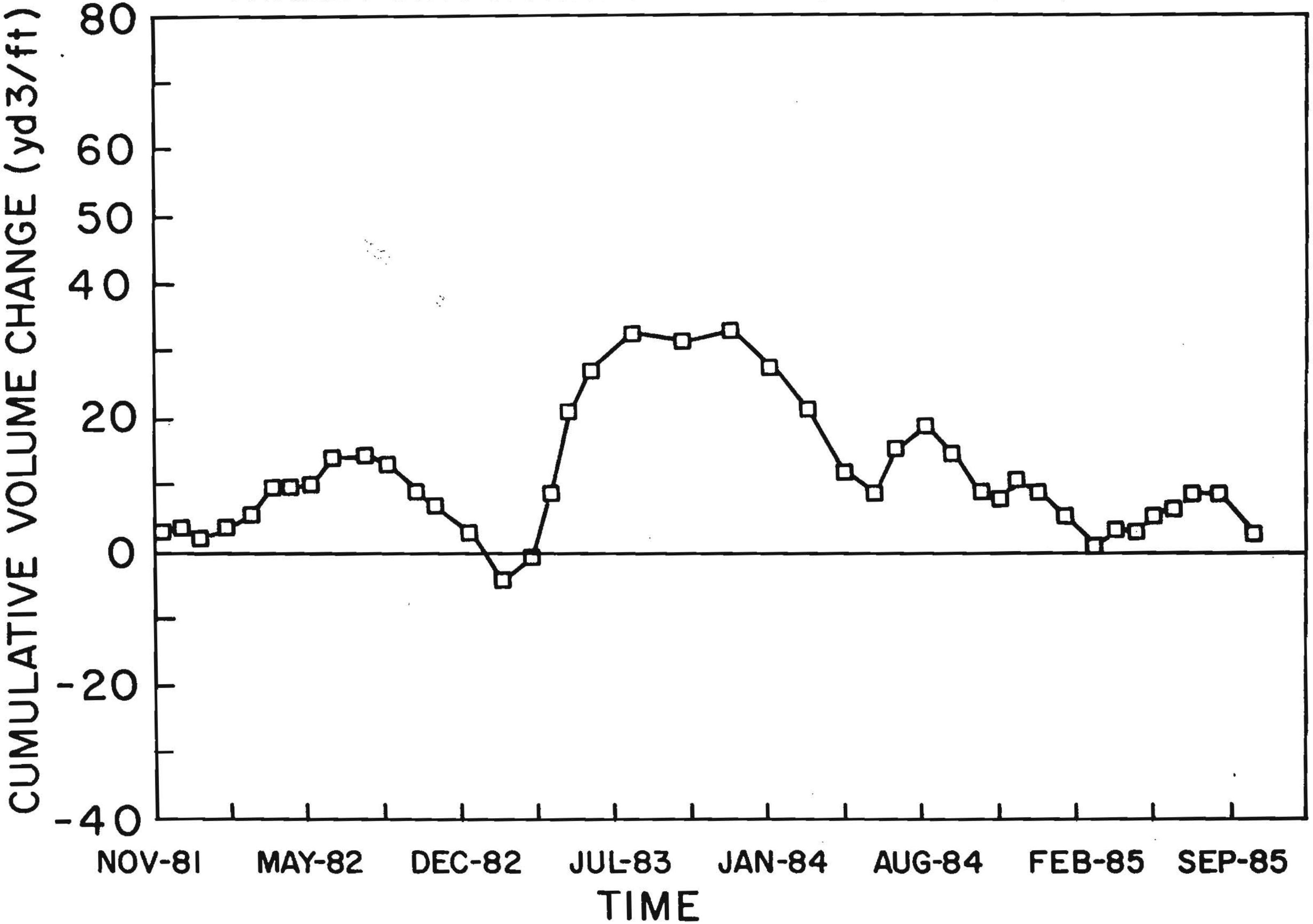

OCEAN BEACH, FIRE ISLAND
THREE POINT RUNNING MEAN (station no.18)
CUMULATIVE VOLUME CHANGE (yd 3/ft)
80
60
50
40
20
0
-20
-40
NOV-81
MAY-82
DEC-82
JUL-83
JAN-84
AUG-84
FEB-85
SEP-85
TIME

Figure 7. Three-point running mean of cumulative volume change since October 1981 at station 19. See text for explanation.

OCEAN BEACH, FIRE ISLAND
THREE POINT RUNNING MEAN (station no.19)



accreted sand on the order of 0.4 cubic yards per foot of beach front, while station 5 gained 12.98 cubic yards of sand per foot of beach. Stations 13 and 19 lost sand on the order of 10.6 and 8.2 cubic yards per foot respectively. There were, however, some common responses of the beach profile produced by the hurricane (figures 8 and 9). These figures represent the cross-sectional profile of the beach at representative stations (stations 5 and 19) on the survey dates both prior to, and following the storm. The response of the profile at both stations 3 and 5 was a gain of sand on the backshore and a gain of sand on the shoreface (figure 8). The response of the profile at stations 13 and 19 (figure 9) was a general decrease in the elevation of the berm. Station 19, however, also accreted sand on the backshore; station 13 did not exhibit a pronounced increase in elevation here.

DISCUSSION

The beach monitoring program at Ocean Beach, Fire Island has been underway since October 1981. Over the 4-year, 3-month study period, the beach here has been shown to respond to natural variations in sand supply rather than to the presence or absence of erosion control structures on the beach (Tanski 1982; Bokuniewicz, Zimmerman and Henrichs 1984). The presence of groins and bulkheads had no discernible effect on the volumetric changes measured across the study area. Although the average volume of sand contained at the two stations which fronted the bulkhead was less than that for other stations at Ocean Beach, the magnitude and pattern of erosion

Figure 8. Cross-sectional profile at station 5, Ocean Beach, Fire Island, pre and post Hurricane Gloria. See text for explanation.

OCEAN BEACH, FIRE ISLAND

STATION NO. 5

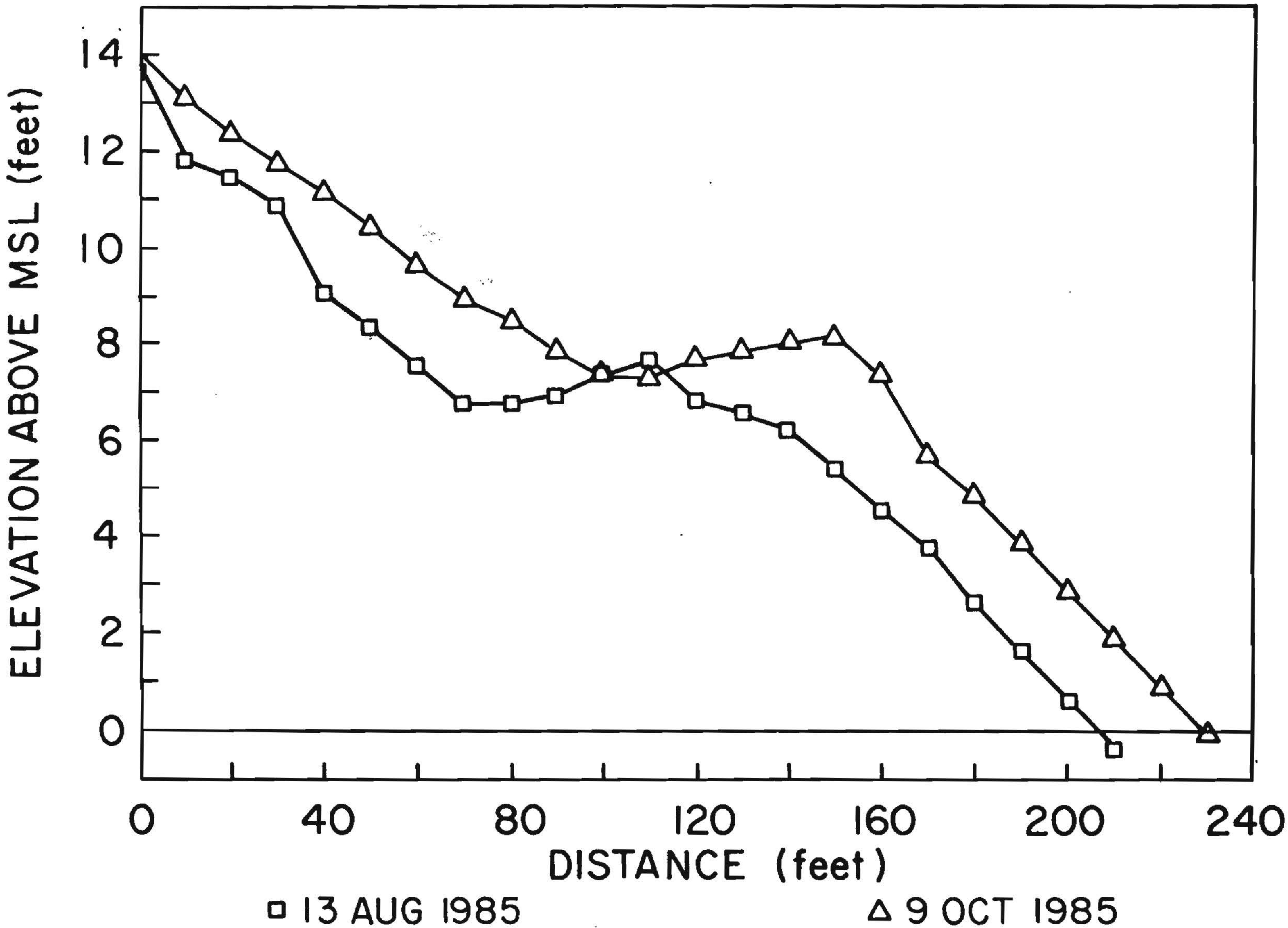
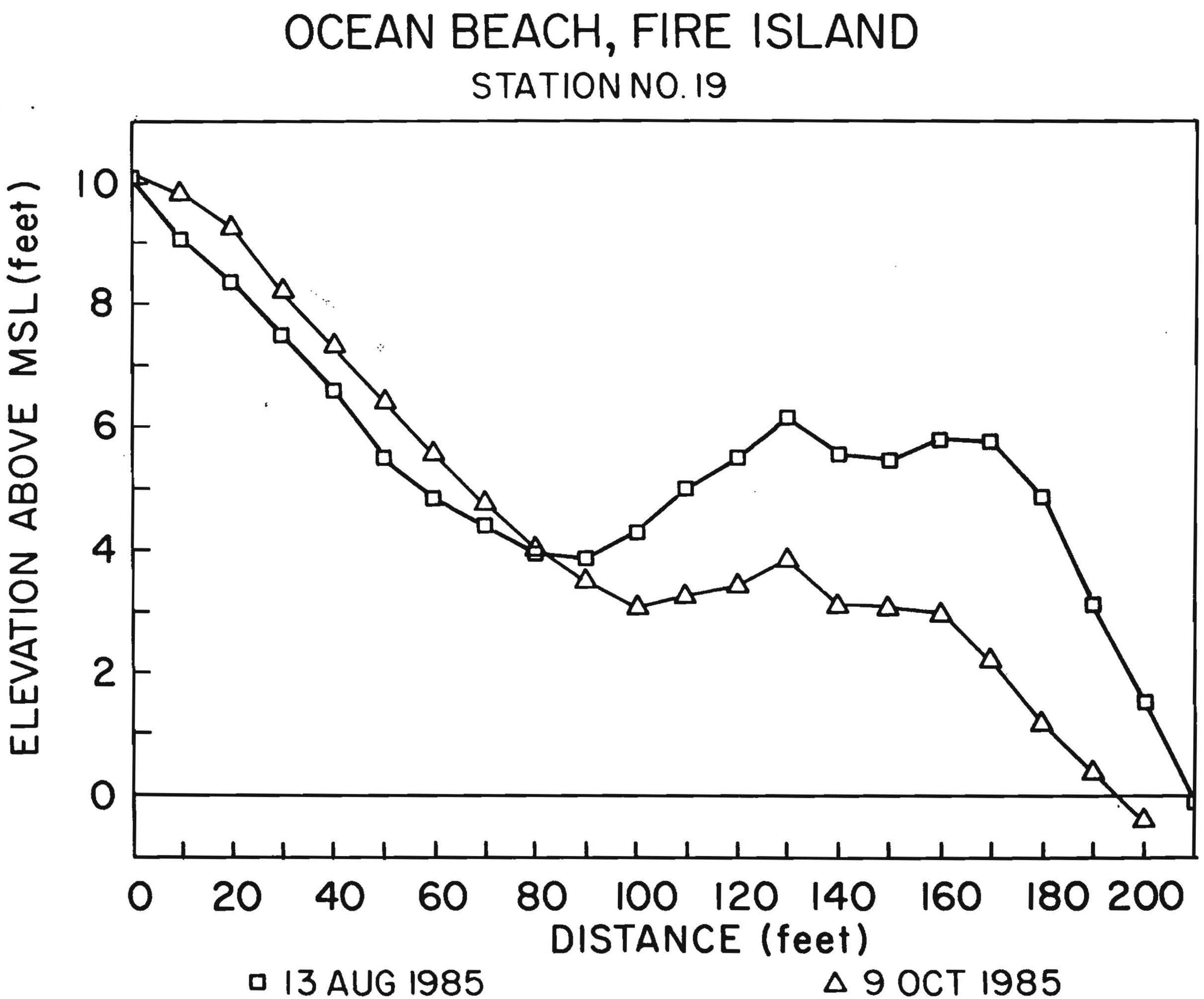


Figure 9. Cross-sectional profile at station 19, Ocean Beach, Fire Island, pre and post Hurricane Gloria. See text for explanation.


OCEAN BEACH, FIRE ISLAND
STATION NO. 19
ELEVATION ABOVE MSL (feet)
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160
180
200
DISTANCE (feet)
□ 13 AUG 1985
△ 9 OCT 1985

and accretion events at stations near the structures was comparable to changes observed at stations far from these structures. Stations 12 and 13 both lie in front of a wooden bulkhead. The long-term cumulative change in volume for station 12 was on the order of 10.16 cubic yards of sand gained per foot of beach front per year, whereas for station 13 it was 4.71 cubic yards. Station 20, which lies at the westernmost edge of the study area on a undisturbed dune, exhibited a long-term gain of 9.23 cubic yards of sand per year, comparable to that observed at station 12.

Over the study period, the beach at Ocean Beach, Fire Island has been exhibiting a long-term increase in volume. This may be due to an increase in the volume of sand transported through the study area by longshore currents (Bokuniewicz, Zimmerman and Henrichs 1984). Eighteen of the twenty stations measured exhibited a net gain in sand volume between October 1981 and January 1986. The average rate at which the stations gained sand was on the order of 5.98 cubic yards per year, with a gain across the study area of 20.9 cubic yards of sand per foot of beach length. Superimposed on this long-term trend towards increasing volume are abrupt cyclical patterns of erosion and accretion which appear to be tied to storm events. Seasonal patterns of erosion and accretion are evident at some stations, but are overshadowed by the longer-term trends.

Changes reported for the section of beach under study at Ocean Beach, New York, are similar to changes previously reported for the beach at East Hampton. The beach at East Hampton has been observed to fluctuate abruptly, dominated by storm events rather than seasonal cycles. These events, however, are superimposed on a longer-term trend towards increasing volume. In addition, there was no detectable long-term behavior that could be attributed to the presence of erosion control structures on the beach.

CONCLUSIONS

Over the past 4.3 years more than 800 profiles have been made at stations along the beach in the Village of Ocean Beach, Fire Island, New York. From the analysis of these data our principal conclusions are:

Beach changes. Surveys were conduducted approximately once a month at 20 stations in the Village of Ocean Beach. Between successive surveys, the average magnitude of change in beach volume was about 9.2 cubic yards of sand per foot of beachfront. The maximum observed magnitude of change was 14.9 cubic yards, and the minimum was 6.2 cubic yards. Any attempt to detect long-term beach changes must take into account these natural variations. As a result, long-term records are needed.

Patterns of variation. Between any successive survey dates both erosion and accretion were noted to occur at stations across the study area. Seasonal patterns were not strong and appeared to be dominated by abrupt storm events. Strong seasonal patterns in erosion and accretion should not be presumed.

Long-term trends. There is a detectable trend towards long-term accretion of the beach at Ocean Beach, Fire Island over the 4.3 year study period. Nineteen of the 20 stations show evidence of increasing volume over time. At stations 3, 4, and 8, however, the relationship was weak. Only station 19 appeared to be losing sand, but the relationship here was very weak. At several stations the trend seems to be linear and fairly gradual. The increase in volume at other stations is marked by several abrupt events which appear to be cyclic in nature. And at others, after an abrupt volume increase in late 1982, persistently higher volumes than had been observed early in the study period were maintained.

Erosion and accretion. The study area included sections of the beach near groins, sections in front of bulkheads, as well as sections backed by dunes. There was no detectable long-term behavior in either erosion or accretion that could be attributed to the presence or absence of structures on the beach. In fact, the beach as a whole exhibited a general and consistent increase in volume since the earliest avalible surveys.

Extreme events: Hurricane Gloria. There were no unusual departures from typical beach conditions that could be attributed to the passage of Hurricane Gloria on 27 September 1985. Two of the four stations surveyed after the storm were observed to have gained sand, while two eroded. These changes, however, were not atypical, and were comparable to fluctuations observed at these stations in the past.

ACKNOWLEDGEMENTS

This project was funded by a grant from the New York Community Trust. We are grateful to have had their continued support. The field work could not have been accomplished without the constant attention of Mr. James Romansky and the participation of the students of Bay Shore High School. Thanks also to Peter Morrison, George Agardi and Carroll Burke who helped supervise the students in the field. We are also indebted to C. R. Jones and C. L. Arnold for their assistance with the field measurements.

REFERENCES

Bokuniewicz, H.J. 1981. Monitoring seasonal beach response: An educational and public service program. Journal Geological Education, vol.29. no.3. p.121-127.

Bokuniewicz, H.J. and J. Tanski. 1982. Usefulness of coastal observations made by students. Geological Society of America Abstracts with Programs, New Orleans, Louisiana. vol.15. p.7.

Bokuniewicz, H.J., Zimmerman, M.S., and Henrichs, S. 1984. Beach Conditions at Ocean Beach, New York: October 1982 to October 1983. Unpublished manuscript. Marine Sciences Research Center, State University of New York, Stony Brook, New York. 17 p.

DeWall, A.E. 1979. Beach changes at Westhampton Beach, New York, 1962-1973. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Virginia. Misc. Rept. No.79-5. 129p.

Emery, K.O. 1961. A simple method of measuring beach profiles. Limnology and Oceanography. vol.6. p.90-93.

McCormick, C.L. 1972. Probable causes of shoreline recession and advance on the south shore of eastern Long Island. *In* D. R. Coates (ed.) *Coastal Geomorphology*, Proceedings of the Third Annual Geomorphology Symposium, Binghamton, New York. p.61-71.

Panuzio, F.L. 1968. The Atlantic Coast of Long Island. Proceedings 11th Conference on Coastal Engineering, American Society of Civil Engineers. p.1222-1241.

Ruzyla, K. 1973. Effects of erosion on barrier-island morphology, Fire Island, New York. *In* D. R. Coates (ed.) *Coastal Geomorphology*, Proceedings of the Third Annual Geomorphology Symposium, Binghamton, New York. p.219-237.

Sanders, J.E. and N. Kumar. 1975. Evidence of shoreface retreat and in-place "drowning" during Holocene submergence of barriers, shelf off Fire Island, New York. Geological Society of America Bulletin. vol.86, p.76-92.

Schwartz, M.L. 1967. The Bruun theory of sea-level rise as a cause of shore erosion. Journal of Geology. vol.75. p.76-92.

Taney, N.B. 1961. Geomorphology of the south shore of Long Island, New York. U.S. Army Corps of Engineers, Beach Erosion Board. Technical Memorandum No.128. 49 p.

Tanski, J. 1982. Fire Island Beach Program: Interim Report. Unpublished manuscript. Marine Sciences Research Center, State

University of New York, Stony Brook, New York. 25 p.

Tanski, J. 1983. Monthly beach changes at Ocean Beach, New York, on Fire Island by students of Bay Shore High School. Unpublished manuscript. Marine Sciences Research Center, State University of New York, Stony Brook, New York. 70 p.

Williams, S.J. 1976. Geomorphology, shallow sub-bottom structure, and sediments of the Atlantic inner continental shelf off Long Island, New York. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Virginia. Technical Paper No.76-2. 123 p.

Zimmerman, M.S. and H.J. Bokuniewicz. 1986. Multi-year beach response at East Hampton, New York. Appendix XI of Special Report 38, Marine Sciences Research Center, State University of New York, Stony Brook, New York. 27p.

Zimmerman, M.S., Bokuniewicz, H.J., Arnold, C.L. and Whitmore, F. 1985. Beach Changes at Ocean Beach, Fire Island, October 1983 through December 1984. Unpublished manuscript. Marine Sciences Research Center, State University of New York, Stony Brook, New York. 22 p.