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Coastal Inlets Research Program

Shinnecock Inlet, New York, Site Investigation

Report 1
Morphology and Historical Behavior

by Andrew Morang

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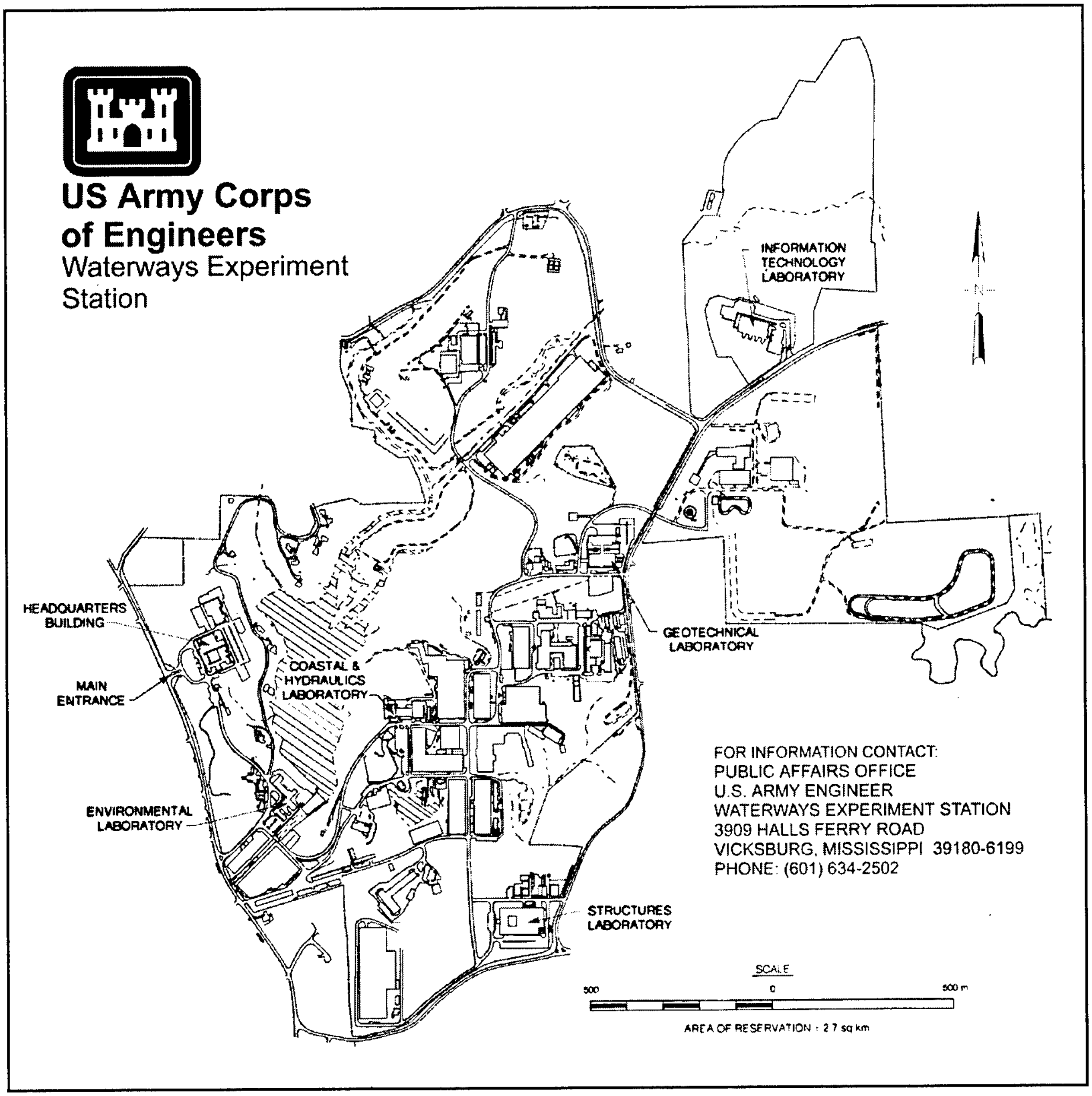
Prepared for U.S. Army Corps of Engineers

Under Inlet Geomorphology and Channel Evolution
Work Unit 32930



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Preface

This study was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) Coastal and Hydraulics Laboratory (CHL), Coastal Sediments and Engineering Division (CSED), Coastal Evaluation and Design Branch (CEDB). WES is a complex of five laboratories of the Engineer Research and Development Center (ERDC). Work was conducted under the Inlet Geomorphology and Channel Evolution Work Unit 32930, Coastal Inlets Research Program (CIRP). Mr. Edward B. Hands, CEDB, was the CIRP Principal Investigator; Dr. Nicholas C. Kraus, CSED, was the Technical Manager; and Mr. E. Clark McNair was the CHL Program Manager for CIRP. Messrs. John Bianco, Charles Chesnutt, and Barry W. Holliday were the Program Monitors at Headquarters, U.S. Army Corps of Engineers. The U.S. Army Engineer District, New York, provided additional support for data collection and field studies at Shinnecock Inlet.

Work was performed under the general supervision of Ms. Joan Pope, Chief, CEDB; Mr. Thomas Richardson, Chief, CSED; Mr. Charles C. Calhoun (retired), Assistant Director, CHL; and Dr. James R. Houston, Director, CHL.

The author acknowledges the assistance and advice provided by his coworkers, Drs. Kraus and Donald Stauble and Messrs. Hands, J. Bailey Smith, and Gregory Williams. Ms. Mary Allison helped compute ebb- and flood-tide volumes. Mr. Aram Terchunian scanned photographs at the offices of First Coastal Corporation in Westhampton Beach, New York. Historical data were generously provided by the following agencies and individuals:

- New York District - Mses. Lynn Bocamazo, Betsy MacMillan, Diane Rahoy, and Christina Rasmussen and Messrs. David Rackmales and Keith Watson.

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- Offshore and Coastal Technologies, Inc. - Mr. William Grosskopf

- Suffolk County Department of Public Works - Mr. Tom Rogers.

This report was reviewed by Dr. Kraus, Mr. Anders, Ms. Rahoy, and Mr. Tanski.

At the time of publication of this report, Commander of ERDC was COL Robin R. Cababa, EN. This report was prepared and published at the WES complex of ERDC.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02832	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. nautical)	1.852	kilometers
miles (U.S. statute)	1.609347	kilometers

1 Introduction

Shinnecock Inlet is the easternmost of six permanent openings in the barrier island chain that runs along the south shore of Long Island, New York (Figure 1). The barrier islands and spits enclose a series of coastal bays and tidal marshes. Shinnecock Inlet is located in the town of Southampton, 153 km[1] by sea east of the Battery, at Manhattan, and 60 km southwest of Montauk Point. The inlet is stabilized by two rubble-mound jetties constructed in the early 1950s (Figure 2). A Federal navigation channel connects the Atlantic Ocean to Shinnecock Bay, through which boaters can access the Long Island Intracoastal Waterway. Shinnecock Bay is an irregularly shaped body 14.5 km long (east-west) and 0.6 to 4.5 km wide, with water depths mostly less than 2 m. The Bay is connected by the Quogue and Quantuck canals to Moriches Bay to the west and by the Shinnecock Canal to Peconic Bay on the north. Several small creeks drain into the northern side of the bay, including Penniman, Stone, Phillips, and Weesuck. These creeks do not provide much freshwater input. The total water surface area of Shinnecock Bay is about 4,100 ha (10,240 acres). Commercial docks for a fishing fleet are located just west of the inlet on the north side of the barrier. The fishing fleet depends upon Shinnecock Inlet for access to offshore fishing grounds because the only alternate route is Moriches Inlet, several hours distant via the Quogue and Quantuck canals.

During the past two decades, the beach west of the west jetty has experienced chronic erosion, and Dune Road has been overwashed during many winter storms. In addition, Shinnecock is a dangerous inlet, and several boaters have been killed in accidents. Both jetties have needed repair, and scour holes over 10 m deep have needed filling.

Several shore protection studies are being conducted by the U.S. Army Engineer District, New York, along the south shore of Long Island. Shinnecock Inlet falls within the largest effort, the "Fire Island to Montauk Point Reformulation Study" (FIMPRS), which is examining coastal processes, shore protection, and flood damage reduction alternatives from Fire Island Inlet

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[1] Units of measurement in the text of this report are shown in SI units, occasionally followed by non-SI (British) units in parentheses. Elevations on all maps are shown in feet, to be consistent with units normally used by the New York District. Maps have been plotted in New York state plane coordinate system (in feet), consistent with the New York District project charts. A table of factors for converting non-SI units of measurement to SI units is presented on page ix.

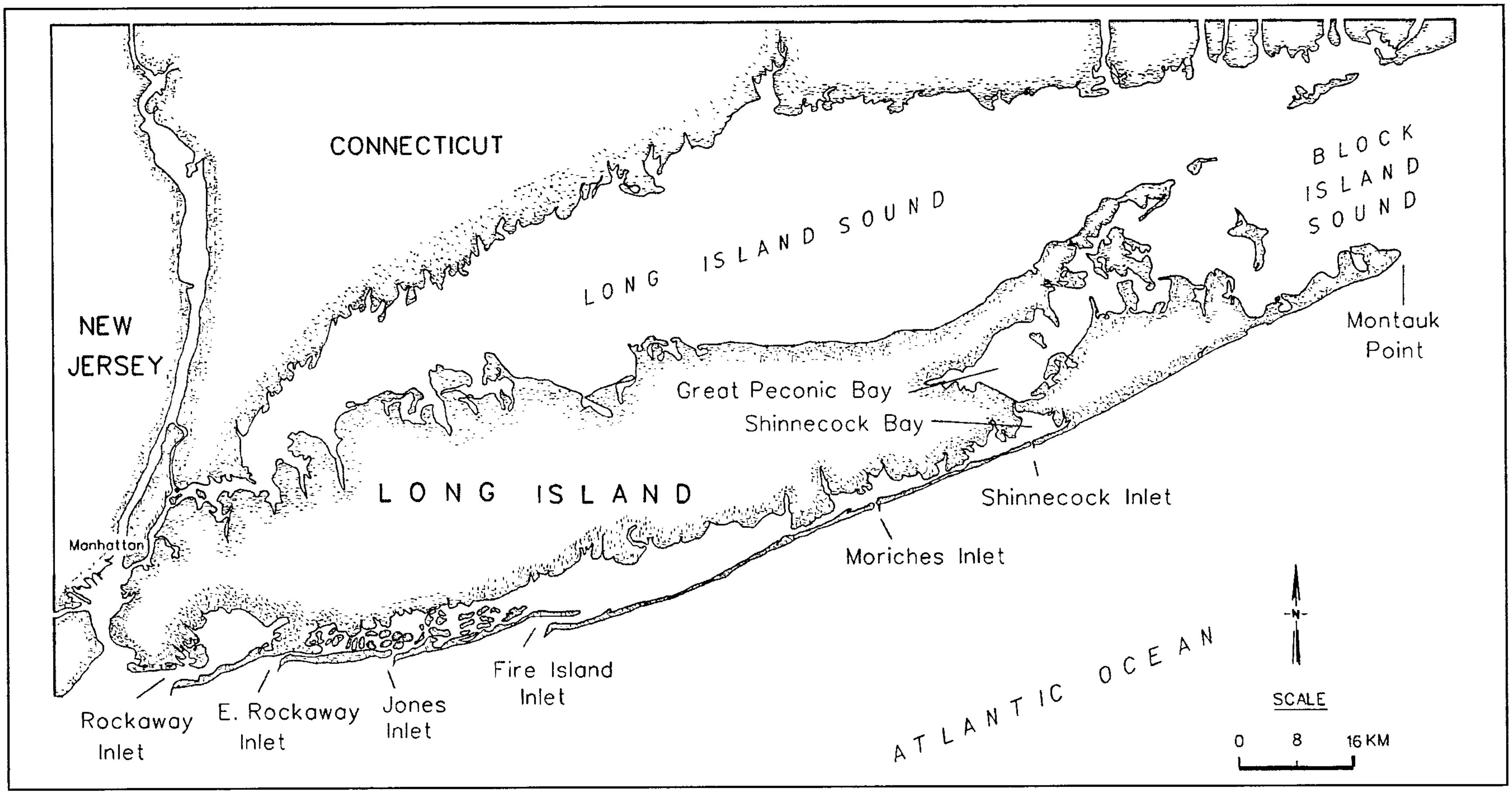

Figure 1. Study area, Long Island, New York

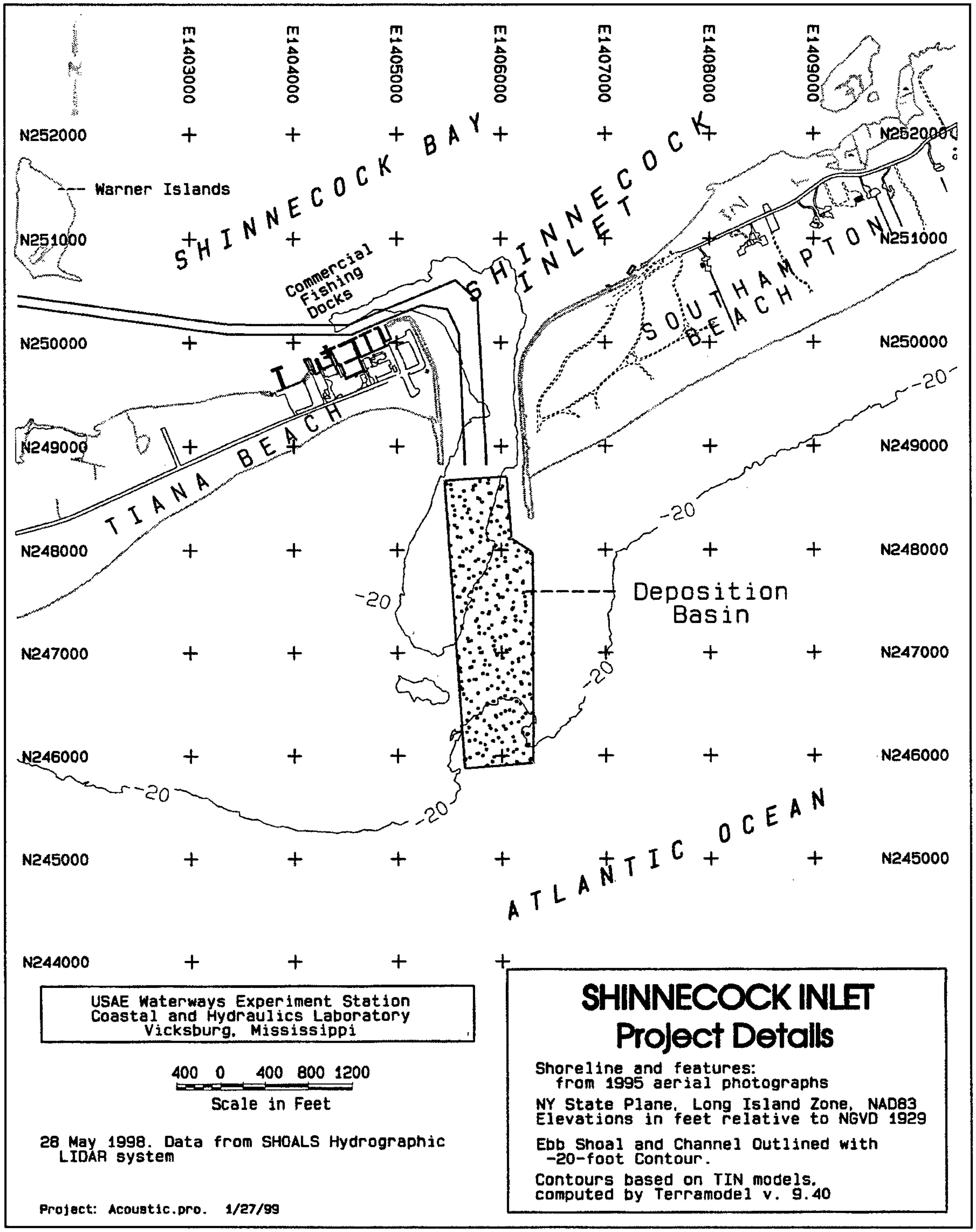

Figure 2. Shinnecock Inlet and vicinity (Shore and features based on 1995 aerial photographs. Tick marks are 1,000 ft (300 m) apart. Spacing between jetties is 800 ft. Photographed at approximately low tide, shoreline is water position in photographs, but is not mean low water (mlw). Adapted from topographic maps prepared by Erdman Anthony Engineers, Inc., for New York District. This base map is used in subsequent figures in this report)

eastward to Montauk Point. One part of the FIMPRS is an evaluation of inlet sand management alternatives at Shinnecock Inlet to address the interruption of regional longshore transport.

The Coastal Inlets Research Program (CIRP) sponsored field monitoring at Shinnecock Inlet during 1998. Field work included wave and current measurements and sediment sampling in the channel, the Atlantic Ocean, and Shinnecock Bay. The results of these studies will be presented in a series of CIRP Shinnecock Inlet Technical Reports. A similar series was produced for CIRP activities at Ponce de Leon Inlet, Florida. The present report documents morphology changes and engineering works at Shinnecock Inlet. This document is also intended to provide information for developing CIRP numerical models of hydrodynamics and morphology change. Sand bypassing options are addressed in the second report in this series (Williams, Morang, and Lillycrop 1998).

The objectives of this report are as follows:

a. Collect, inventory, and assemble in one volume historical and recent geomorphic data from Shinnecock Inlet and vicinity. These data include aerial photographs (Appendix A), bathymetric surveys (Appendix B), and profile surveys (Appendix C).

b. Tabulate a chronological history of natural and engineering activities at the Inlet (Appendix D), and list other references pertaining to Long Island meteorology and history (Appendix E).

c. Analyze morphologic changes since the Inlet was cut in 1938. This analysis includes determining ebb- and flood-shoal changes, thalweg migration, channel location, shoreline changes, and channel stability.

2 Regional Geologic Setting

Long Island

Long Island is the largest island adjoining the continental United States. It is 190 km long and extends from the Narrows at the entrance to New York Harbor eastward to Montauk Point, due south of the Connecticut-Rhode Island boundary. Long Island has a surface area of about 3,600 km^2, and its maximum width is 37 km. It is bounded on the north by Long Island Sound, on the east and south by the Atlantic Ocean, and on the west by New York Bay and the East River. Peconic Bay, which is about 46 km long, divides the eastern end of the island into two long, narrow peninsulas that are locally referred to as the North and South forks. Montauk Point, commonly referenced in this report, is located at the eastern tip of the South Fork.

The island is part of the Atlantic Coastal Plain, with basement of Cretaceous age rock and some older metamorphic rocks that outcrop in the extreme west near Long Island City. Coastal plain deposits are exposed only in the western part of the island. Most of both the surficial and the underlying materials are Pleistocene morainal and outwash accumulations associated with continental glaciers (Fuller 1914). Two morainal ridges run the length of Long Island, with the southern one, the Ronkonkoma, extending to Montauk Point. Most of the north shore facing Long Island Sound consists of bluffs 10 to 30 m high and is indented by deep bays that form good harbors for small craft. South of the southern ridge, a glacial outwash plain of fine gravel and sand stretches for 1 to 15 km to the Atlantic Ocean (Fuller 1914). In places, the outwash is less than 1.5 m thick, and the topography and drainage are controlled by the underlying Manhasset formation. In other areas, the outwash is thicker and fills former channels (Taney 1961a).

Two physiographic provinces characterize the south shore of Long Island, a barrier island/spit zone and a bluff zone. From Coney Island eastward to Southampton, a more or less continuous barrier encloses broad, shallow Jamaica, Hempstead, Great South, Moriches, and Shinnecock bays. Coney Island, once the westernmost extension of the barrier chain, is part of New York City and was artificially attached to the mainland during the late 1800s. At present, six permanent inlets provide access to the bays, as listed in Table 1.

Table 1
Inlets along the South Shore of Long Island

Inlet	Bay or Sound	Island or Beach to West	Island or Beach to East	Distance from West Tip of Coney Island, km
Rockaway	Jamaica	Coney Island	Rockaway Beach	5.5
East Rockaway	Hempstead via Reynolds Channel	Rockaway Beach and City of Far Rockaway	Atlantic Beach (west end of Long Beach Island)	23
Jones	Hempstead	Point Lookout (east end of Long Beach Island)	Short Beach (west end of Jones Beach)	38
Fire Island	Great South	Cedar Island Beach (east end of Jones Beach)	Robert Moses State Park, Fire Island	61
Moriches	Moriches	Fire Island	Westhampton Beach	111.5
Shinnecock	Shinnecock	Tiana Beach	Southampton Beach	136

The barrier ends at the east end of Shinnecock Bay, near the town of Southampton, and from there to Montauk Point, the coast follows a nearly straight line intersecting old headlands and crossing old bays. These bays are now shallow ponds, separated from the ocean by barrier spits. One of the ponds, Mecox, is occasionally open to the Atlantic via an intermittent inlet. Further east, bluffs are directly exposed to the Atlantic Ocean. These bluffs are generally considered to be the source of sediment that feeds the barrier beaches to the west. The direction of longshore drift is predominantly westward along the entire south shore, but local reversals occur near the inlets. Although the dominant westward drift has been recognized for decades, McCormick and Toscano (1981), Williams and Meisberger (1987), and even Fuller (1914) proposed that some sediment may be moving onshore from the shelf to augment that moved by longshore currents. Practically no sand is delivered to the coast by streams, but the bays behind the barriers are gradually filling with a combination of sand carried over the barriers during storms, silty sediments from rain runoff, and organic detritus.

Beach sand is primarily quartz and feldspar, although storm lag deposits of magnetite and garnetiferous (heavy mineral) sands are often found on the beach face after storms. Near Montauk Point, the beaches are covered with cobble, gravel, and coarse sand, which are deposited as the bluffs erode. Further west, gravel is generally scarce, but accumulations are sometimes seen where the beaches connect with the mainland, such as near Westhampton and Southampton (Fuller 1914).

Because most of Long Island is covered with glacial material, rainfall is absorbed rapidly into the porous surface. As a consequence, most surface streams are short and have simple dendritic patterns. Many streams are intermittent, not flowing during the dry seasons, and most end in marshy areas at their mouths. Along the south shore, the streams rise at the foot of the nearest moraine, flow southward across the outwash plain, and empty into the bays (Taney 1961a).

The marshes along the south coast are rich habitats for numerous species of birds and fish and support the productive growth of marsh grasses. The most common salt-marsh species include black grass (*Juncus gerardi*), various salt-marsh types (*Spartina patens* association), salt thatch (*Spartina glabra* Muhl.), and eelgrass (*Zostera marina* L.) (Fuller 1914). Submerged tree stumps and peat beds in various parts of Long Island, indicators of a relative sea level (rsl) rise, have been described by many writers (e.g., Rampino and Sanders 1980).

The beaches near Shinnecock Inlet provide nesting habitat for a number of bird species. The common tern (*Sterna hirundo*) and the least tern (*Sterno albifrons*) are of particular importance. In addition, the roseate tern (*Sterna dougallii*) has been sighted in the project area on Warner Islands (U.S. Army Corps of Engineers (USACE) 1988). Another colonial shore bird, the black skinner (*Rynchops niger*) also nests in the project area, as does the noncolonial piping plover (*Charadrius melodus*). Nesting habitat for all of these species must be preserved, which may place constraints on the times of the year when sand placement, dune reconstruction, and other engineering works can proceed.

Shinnecock Bay provides productive habitat for at least 50 fish species (USACE 1988). The bay is a prime nursery area for winter flounder (*Pseudopleuronectes americanus*), and marsh areas west and east of the inlet provide shelter and feeding habitat for juvenile bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and northern kingfish (*Menticirrhus saxatilis*). The project area also supports a diverse benthic community. The most important commercial invertebrate species is the surf clam (*Spisula solidissima*), found in the ocean from the surf zone to as deep as 80 m. Hard clams (*Mercenaria mercenaria*), mussels (*Mytilus edulis*), razor clams (*Ensis directus*), and conches (*Busycon* spp.) are harvested from Shinnecock Bay.

Barrier Island Migration and Sea-Level Change

One of the factors that affects shoreline position on sandy coasts is the rise or fall of the sea relative to land. This section summarizes findings that the Long Island barriers have retreated for thousands of years and evaluates the evidence that rsl is still rising in this area.

Along the northeast United States, sea level has risen about 90-100 m since the end of the Pleistocene epoch, about 12,000-15,000 years ago (Nummedal 1983). This Holocene transgression flooded the continental shelves and caused the retreat of barrier islands along much of the eastern seaboard. How do barriers respond to a marine transgression? Two contrasting hypotheses have been proposed: One states that as the sea rises, barriers migrate continuously landward. During this retreat, the breaker zone traverses the entire area that is submerged. Barrier retreat is most likely to occur along shores where there is a large sediment supply and where the rise in sea level is slow. This form of retreat in response to marine transgression has been documented in Rhode Island, where peat exposed on the ocean shoreface demonstrates how former lagoonal sediments are being unearthed (Dillon 1970).

The second hypothesis suggests that barriers can be drowned in place. As the sea rises, the barrier remains fixed while the lagoon on its landward side deepens and widens. Eventually, the breaker zone reaches the top of the dunes, the barrier is drowned, and the breakers skip landward a considerable distance to form a new barrier at the landward edge of the former lagoon. Under what circumstances could this "skipping" mechanism occur? A barrier might be drowned if there is limited or decreasing sediment supply. Because of the shallow slope of a typical barrier, a large and steady sediment supply is needed to accommodate even a minor rise of sea level (this is analogous to breakwater construction, where a minor increase in height requires a great quantity of extra rock). Without the copious input of sand, the barrier becomes narrower and narrower and is eventually overtopped. Even with a generous sand supply, a period of exceptionally rapid sea-level rise might overwhelm the barrier. In addition, if the barrier is densely vegetated, overwash is impaired, resulting in a steepening of the profile as the sea rises. The barrier is unable to migrate landward and can be drowned in place. Details of these theories and the original papers where they were proposed are reprinted in Schwartz (1973). More discussion on the balance between apparent erosion caused by sea-level rise versus accretion dependent on sediment supply is found in Headquarters (HQ) USACE (1995, p. 2-26).

Based on examination of cores and seismic records off Fire Island, Sanders and Kumar (1975) proposed the following explanation to describe the Holocene submergence of the barriers off Long Island:

When sea level stood 24 m below present mean sea level 9,000 years ago, a chain of barriers existed about 7 km offshore parallel to the modern shore. As the sea rose, the barriers remained in place until the sea reached 16 m below the present level, at which time it inundated the top of the dunes. The surf zone was then free to jump about 5 km landward to form a new shoreline about 2 km seaward of the present barrier line. New barriers formed at the -16-m shoreline, becoming ancestors of the modern south shore barriers. These barriers have migrated continuously landward as sea level rose from -16 m to its present elevation. Rampino and Sanders (1980) believed that the "skipping" mechanism explained why complete barrier sediment sequences have been preserved on the Long Island shelf, but Panageotou, Leatherman, and Dill (1985) have disputed this interpretation.

A question relevant to the present study is are the Long Island barriers still retreating? Some evidence shows that they are. Relict flood tide deltas (both submerged deposits and exposed islands) are common features along the barrier in Shinnecock and Moriches Bays and are also found on the bay shore of Fire Island (Kana and Krishnamohan 1994). The large number of relict flood tide deltas along Westhampton Beach and outcrops of tidal marsh material on the ocean shoreface provides geomorphic evidence of landward displacement for portions of this barrier island (Kana 1995).

In a mapping project based on charts and aerial photographs, Crowell and Leatherman (1985) measured annual net shoreline recession of 0.3 - 1.2 m along most of the south-shore barriers between 1834 and 1979. Accretion occurred in the immediate vicinity of Shinnecock Inlet because of the trapping of sand on the updrift fillet. Table 2 summarizes Crowell's and Leatherman's findings. Their evidence points to accelerated recession after 1933; presumably, much of this occurred after the inlet opened in 1938. Aerial photographs show that substantial overwash occurred during the September 1938 hurricane, but there is not enough evidence to determine if this one event might have caused a majority of the post-1933 recession.

Table 2
Shoreline Changes near Shinnecock Inlet

Period	Zone 3,000 m West of Inlet (average)	Near Inlet	Zone 3,000 m East of Inlet (average)
1834/1838 - 1873/1892	Variable: 1.2 m advance west of Ponquogue Pt; 0.6-0.9 m retreat east of Ponquogue Pt.	Variable	0.6-1.2 m retreat
1873/1892 - 1933	0.6-0.9 m advance	0.6-0.9 m advance	0.3-1.5 m advance
1933 - 1979	1.2-2.4 m retreat	3.0 m advance (updrift fillet)	0.3-0.9 m retreat
Annual average change 1834/1838 - 1979	0.3-0.9 m/year retreat rate	0.3-0.9 m/year advance (mostly updrift fillet)	0.3-0.6 m/year retreat rate

Source: Scaled from Figure 4-3 in Crowell and Leatherman (1985). Note that the accuracy of maps made in the 1830s is limited because of the lack of standard datums by which old maps can be referenced to contemporary coordinate systems (see Shalowitz 1964). Therefore, shoreline change statistics based on the 1834/38 charts must be used with caution.

Tide gauges near Long Island have recorded a rise in rsl during this century. As examples, National Oceanic and Atmospheric Administration (NOAA) tide-level curves for New York City and Montauk are plotted in Figure 3, and Table 3 lists rsl trends at four stations near Long Island. The New York station, located at the Battery at the southern tip of Manhattan Island, has a remarkable 125-year record showing an average 2.72-mm/year (0.0089-ft/year) rise in rsl. This means that over the 65 years since the 1933 U.S. Coast and Geodetic Survey (USC&GS) hydrographic data were collected off Shinnecock Inlet, a span less than the lifetime of some of Long Island's inhabitants, the sea has risen about 0.18-m. Assuming a beach slope of 1:20, a 0.18-m rise in water level translates to a 3.5-m horizontal movement landward. This is slightly greater than the retreat rate calculated by Crowell and Leatherman (1985) for the east end of Westhampton. At the four stations listed in Table 3, the 1950-1993 trend suggests that the rate of sea-level rise has decreased compared with the longer

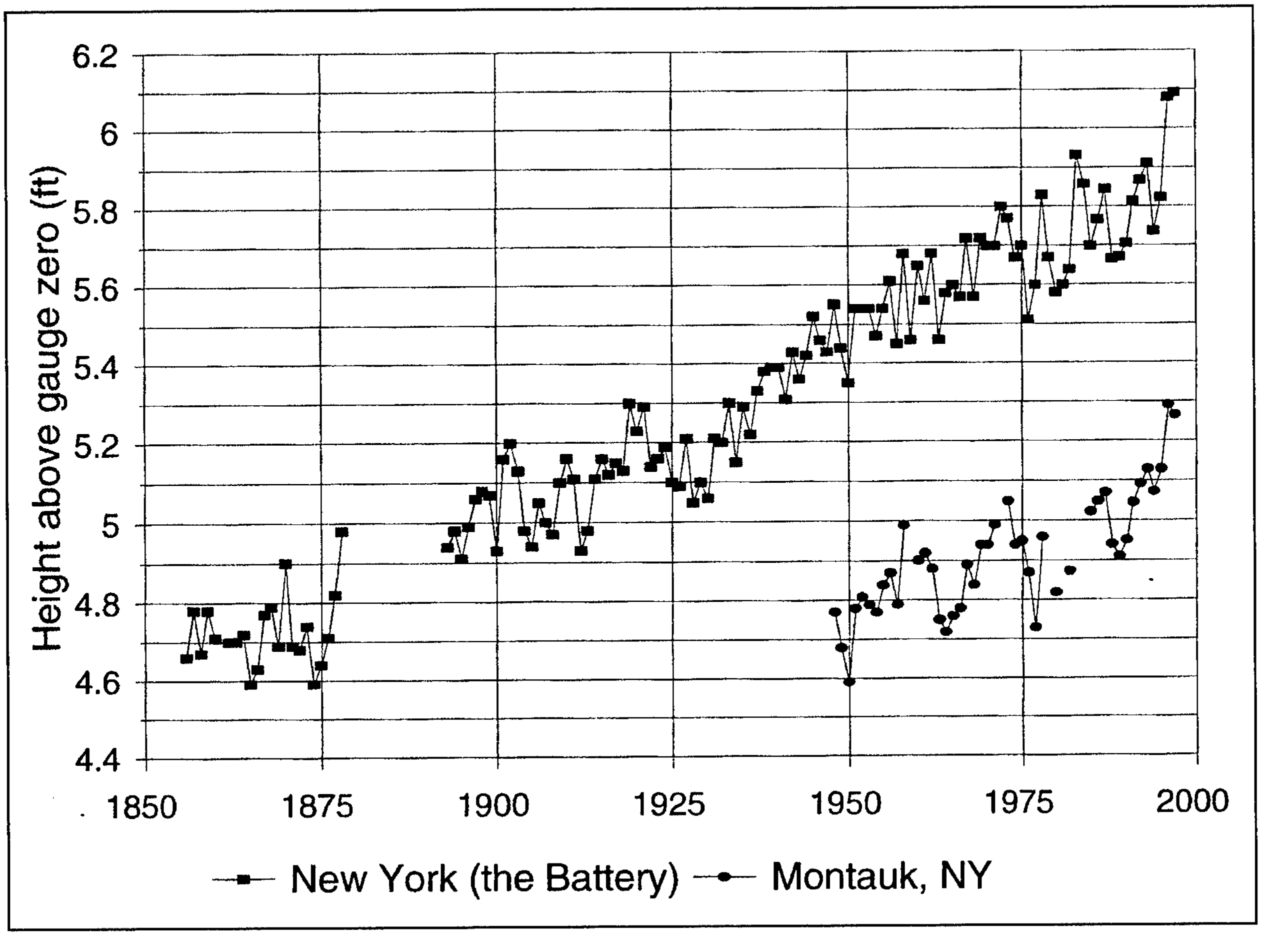

Figure 3. Yearly mean sea level at south tip of Manhattan (the Battery), Sta 851870, and Montauk Harbor, Long Island, Sta 8510560 (Note that Montauk tide gauge is in harbor facing Great Peconic Bay, not on Atlantic coast. Data from Lyles, Hickman, and Debaugh (1988) and NOAA Internet web page)

Table 3
Relative Sea-Level Trends near Long Island

		Entire Record Series				1950 - 1993		
NOAA Station	Name	Years of Record Used	Trend mm/year	Error [1] mm/year	Variability [2] mm/year	Trend mm/year	Error mm/year	Variability mm/year
8510560	Montauk, NY	39	1.85	0.35	28.09	1.78	0.38	28.56
8518750	New York (the Battery)	122	2.72	0.07	28.62	2.27	0.34	28.40
8516990	Willets Pt, NY (Long Is. Sound)	62	2.33	0.22	31.54	1.78	0.40	33.35
8531680	Sandy Hook, NJ	61	3.84	0.22	30.04	3.15	0.37	31.12

[1] Standard Error of Slope of the trend line.
[2] Represented by the Standard Error of Estimate, which is the standard deviation from the line of regression. The entire series is used for the best values at each station; the common series, 1950 through 1993, should be used for comparing stations.
Source: Statistics computed by NOAA, downloaded from NOAA worldwide web page (*http://www.opsd.nos.noaa.gov/seatrnds.html*, 1 March 1999)

term average; but at this time, we cannot speculate whether such a decreasing trend will continue.

Although historical data show erosion, since the 1920s, most of the south-shore beaches have remained essentially in place, largely because of multiple beach-fill projects. Between Fire Island Inlet and the east end of the barriers near Southampton, New York, the following volume of sand has been placed on the beaches:[1]

- 1933-1979: 13.5 million m^3 (17.7 million yd^3)
- 1980-1997: 11.1 million m^3 (14.5 million yd^3)

This sand has come from offshore borrow areas, from inlet dredging, from the back bays, and from inland sources. Some sand in the barrier system has been trapped by jetties, resulting in downdrift shoreline recession. At most of the inlets, some of this material has been reintroduced to the littoral drift by mechanical bypassing (dredging). But, sand pumped from offshore or back bays or trucked to the beaches by the highway department is, in effect, "new sand," material that, under natural conditions, probably would not have moved to the ocean shoreface. Table 4 summarizes the balance between sand loss because of sea-level rise versus gain from beach fill and bypassing.

Table 4
Sand Loss and Fill Estimates, Ocean Side of Barrier, Fire Island Inlet to Montauk Point

Reach	Annual Volume, m^3/year	Total Volume 1933-1979 (46 years), m^3	Total Volume 1980-1997 (17 years), m^3
Loss Because of Sea-Level Rise[1]			
Fire Island	98,000	4,500,000	1,700,000
Westhampton	49,000	2,300,000	840,000
Ponds + Montauk	98,000	4,500,000	1,700,000
Total Fire Island Inlet to Montauk		11,300,000	4,200,000
Gain from Channel and Back-Bay Dredging, Sand Trucking, Offshore Fill			
Total Fire Island Inlet to Montauk		13,500,000	11,100,000

[1] Assumptions: 0.003 m/year sea-level rise; active shoreface 10.5-m depth.
Source: Rosati, Gravens, and Smith (1999)

In summary, geologic studies and historic evidence from maps verify that the Long Island barriers have retreated during the Holocene era. It seems likely that the barrier retreat has been largely a result of rising relative sea level. But during much of the twentieth century, the barriers have not retreated, probably because

[1] Beach-fill volumes tabulated as part of ongoing sediment-budget studies being conducted by WES for the New York District (Personal Communication, January 4, 1999, J. D. Rosati, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS).

of numerous beach-fill projects that have added significant sand to the system. Specific regions, particularly downdrift of the inlets, continue to be chronic problems.

Climate

Long Island is located between 40° and 42° north latitude, and the climate is characterized by mild winters and relatively cool summers. Extreme fluctuations of temperature are rare because of the moderating effects of the Atlantic Ocean. The mean annual temperature in the project area is approximately 10 °C (50 °F). The coldest months (January and February) average about -2 to 0 °C, whereas the warmest month (July) averages 21 to 24 °C. Extreme temperatures range from about -23 to 38 °C. The average annual precipitation is approximately 112 cm (44 in.) and is fairly evenly distributed throughout the year. The prevailing wind direction is northwest during most of the year, except during the summer months, when south and southwest winds predominate (Franke and McClymonds 1972).

Tides and Datums

Tides on the south shore of Long Island are semidiurnal with a mean range of 0.88 m (2.9 ft) at Shinnecock Inlet entrance (ocean side) and a spring tide range of 1.1 m (3.5 ft) (National Ocean Service 1998). At the Ponquogue Bridge in the Bay, the mean range is 0.7 m (2.3 ft) and spring range is 0.85 m (2.8 ft). Table 5 lists water-level datums for Shinnecock Inlet, with mean lower low water (mllw) set to 0.00. The most commonly used survey datum, the National Geodetic Vertical Datum (NGVD, 1929 adjustment), is 0.38 m (1.26 ft) above mllw, based on an elevation measured by the New York District surveyors on a nearby benchmark. This value of 1.26 ft has been used for conversions of bathymetric data in this report. Note that an NGVD elevation of 1.5 ft above mlw was listed on a March 1998 chart from the New York District. The discrepancy amounts to 0.4 ft, greater than Corps of Engineers Class 1 depth measurement accuracy specified for shallow water.[1]

Tidal Prism

Measurements of tidal prism at Shinnecock Inlet vary greatly (Table 6). Prism was most recently computed in the early 1990s using current measurements made with acoustic Doppler current profilers (ADCP).

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[1] Corps of Engineers specifications for depth measurement accuracy using automated (digital) depth collection systems are listed in Table 3-1 of the Engineer Manual (EM) 1110-2-1003 (HQUSACE 1991). Depth measurement accuracy for Class 1, contract payment, is specified as ±0.2 ft for depths <20 ft and ± 0.5 ft for depths >20 ft.

Table 5
Shinnecock Inlet, Atlantic Ocean; Elevations of Tidal Datums Referred to Mean Lower Low Water [1]

Tidal Level	Elevation, m	Elevation, ft
Highest observed water (12/25/1978)	2.19	7.17
Mean higher high water (mhhw)	1.15	3.78
Mean high water (mhw)	1.06	3.49
Mean tide level (mtl)	0.56	1.83
NGVD (1929 adj.)[2,3]	0.38	1.26
Mean lower water (mlw)	0.049	0.16
Mean lower low water (mllw)	0.00	0.0
Lowest observed water level (3/28/1979)	-0.51	-1.67

[1] Elevations from NOAA.
Publication date: 7/20/1987
Length of series: 12 months
Time period: June 1978 - May 1979
Tidal epoch: 1960-1978
Control tide station: The Battery (851 8750)

[2] NGVD based on survey data from New York District (Personal Communication, Mr. Steven Couch, 1 Aug 1996). Surveyors recorded elevation of 4.13 m (13.54 ft) at Benchmark No. 1, 1974.

[3] NGVD elevation of 1.5 ft above mlw shown on New York District bathymetric survey sheet dated 12 March 1998. Based on benchmark BM SHINN, elevation 4.76 ft NGVD.

Table 6
Tidal Prism

Date	Prism, m^3	Prism, yd^3	Notes
Sep 1940	10,600,000	13,900,000	Measurement method not specified, probably surface drogues. From Memorandum for the Chief, Engineering Division, by S. Gofseyeff, 5 Dec 1951, New York District.
1941	9,300,000	12,200,000	Measurement method not specified, probably surface drogues. From Memorandum for the Chief, Engineering Division, by S. Gofseyeff, 5 Dec 1951, New York District.
21-23 July 1993	24,300,000	31,800,000	Flood phase of tide. CERC[1] field study using ADCP.
15 Sep 1993	38,600,000	50,500,000	Flood phase of tide. CERC field study using ADCP.
20-21 July 1994	33,200,000	43,400,000	Flood phase of tide. CERC field study using ADCP.

[1] Coastal Engineering Research Center.

Sediment Grain Size

The most comprehensive sediment-sampling program along the south coast of Long Island was conducted in the 1950s by the Beach Erosion Board (BEB)

(Taney 1961b). Overall grain sizes decrease from east to west. Taney reported that the coarsest material is found in the headland zone extending about 7 km west of Montauk Point. From there west to Shinnecock Inlet, the average median diameter lies between 0.4 and 0.5 mm. Between Shinnecock and Moriches, the sizes vary greatly, possibly because of patches of gravel. Near Shinnecock, overall sediment is slightly coarser than further downdrift to the west.

McCormick (1971) conducted a sampling program in the inlet and on the ebb shoal for the Town of Southampton. Sediment ranged in size from 0.2 to 0.9 mm. The coarser sizes were restricted to the axis of the inlet and in a zone extending westward from the mouth. The sand became progressively finer offshore. Coarse sand and gravel, found in the center of the inlet, appeared to be encrusted by marine growth, suggesting that it was not often mobilized. Histograms showed that the most common grain size on the ebb shoal was in the band from 1.3 to 1.5 phi (0.41 to 0.45 mm). Although the mean grain size of the flood and ebb deltas was nearly the same as on the adjacent beaches, the deltas had a broader distribution of sizes. McCormick (1971) concluded that sand in the ebb and flood deltas had the correct textural and size properties to be suitable for beach nourishment.

During July 1998, 116 samples were collected on the Shinnecock flood and ebb shoals and on the adjacent beaches as part of CIRP's field studies. The samples were sieved at quarter-phi intervals, and statistics were calculated using the method of moments (Friedman and Sanders 1978). Shinnecock Inlet had a wide range of mean grain sizes, from fine to coarse sand with shell and gravel components. Silt was present on the low-energy, bay side of the flood shoal, while gravel was present in the higher energy regions of the inlet throat and in the surf zone along the adjacent beaches. Table 7 summarizes these results. Note that although a mean size has been calculated for different regions of the inlet, the statistic may not be meaningful because of the wide size range composing each population. Report 3 of this series will contain a detailed description of the sediment-sampling program and an analysis of the results.

Table 7
Average Sediment Characteristics, August 1998 CIRP Sampling Program, Shinnecock Inlet and Vicinity

Location (relative to inlet)	Mean Size, ø phi[1]	Mean Size, mm	Range of Sample Means, mm[2]
Throat/channel	0.43	0.74	0.41 - 2.77
Ebb shoal	1.53	0.35	0.13 - 0.72
Flood channels	0.91	0.53	0.19 - 3.06
Flood shoal (excluding channels)	1.69	0.31	0.13 - 0.52
East beach (<5 km)	-0.037	1.03	0.4 - 3.04
West beach (<6 km)	1.23	0.425	0.27 - 3.07

[1] Samples sieved at ¼-phi (ø) intervals. Statistics computed using method of moments.
[2] Larger sizes are gravel or shell hash.

McCormick's (1971) results cannot be compared with the 1998 samples to evaluate textural changes in the flood and ebb shoals. McCormick's samples were measured with settling tubes, and his report does not document his technique. Also, positioning information for the samples was not provided.

Storms

Two types of storms cause beach erosion and coastal flooding in Long Island, tropical (hurricanes) and extratropical (northeasters). *Tropical storm* is a general term for a low-pressure, synoptic-scale[1] cyclone that originates in a tropical area. At maturity, tropical cyclones are the most intense and destructive storms in the world. By convention, once winds exceed 33 m/sec (74 mph), tropical storms are known as *hurricanes* in the Atlantic and eastern Pacific oceans. *Extratropical cyclones* are cyclones associated with migratory fronts occurring in the middle and high latitudes (Hsu 1988).

Hurricanes

Hurricanes are the most severe storms experienced at the study area. The tropical storm threat exists from July through November. Between 1900 and 1996, one hurricane made landfall on Long Island in August and four in September. In most cases, tropical storms have moderated considerably from their peak intensity before reaching the latitude of New York, but notable exceptions to this generalization have occurred, and hurricanes of devastating intensity have struck Long Island (Figure 4). The worst storm damage usually occurs when high astronomical tides and the storm surge coincide. The combined elevated water levels allow waves to penetrate inland, causing erosion and flooding. For example, the hurricane of 1635, described by Governor John Winthrop, coincided with a Perigean spring tide (Wood 1976). A more recent example of when storm surge coincided with high tide was the Great New England Hurricane of September 21, 1938, which breached the present Shinnecock Inlet (discussed in detail later). Statistics for hurricanes between 1900 and 1996 are listed in Table 8, and notable hurricanes from the 1600s to the present are listed in Tables 9 and D1.

Even hurricanes that do not directly pass over Long Island can contribute to beach erosion. During the summer of 1995, 11 hurricanes and 8 tropical storms generated swell-type waves that traveled across the Atlantic, resulting in weeks of high wave energy along the beaches. The resulting erosion left the beaches poorly protected before the onset of the winter (Moffatt & Nichol 1996).

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[1] Synoptic-scale refers to large-scale weather systems covering tens or hundreds of kilometers as distinguished from local patterns such as thunderstorms.

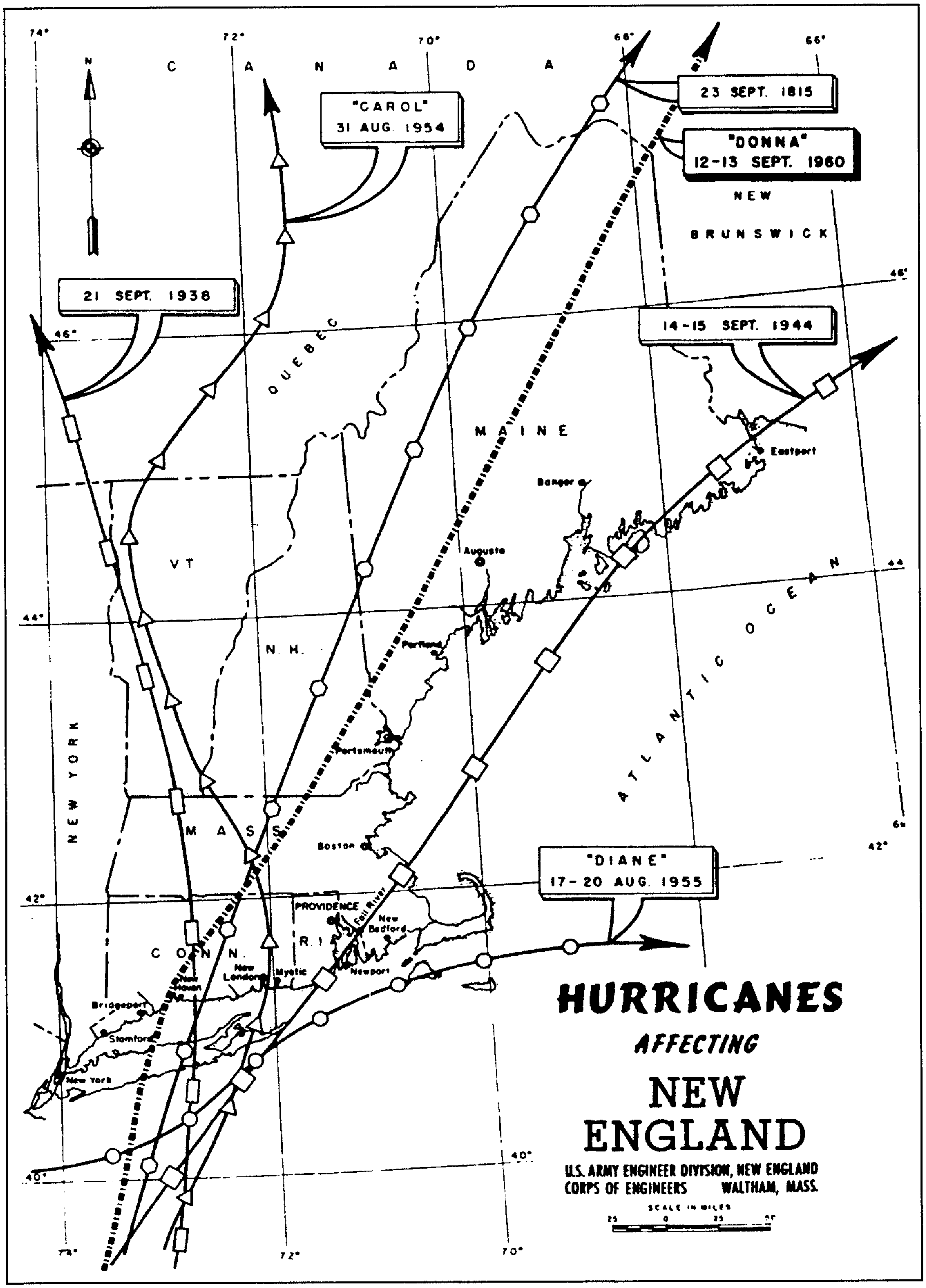

Figure 4. Major hurricanes crossing Long Island and New England (Map prepared by New England Division, reproduced in Parkman (1978; p. 199))

Table 8
Hurricane Statistics, 1900-1996, Long Island and New England

State	Category[1] 1	2	3	4	5	All Hurricanes 1,2,3,4,5	Major Hurricanes 3,4,5
New York	3	1	5	0	0	9	5
Rhode Island	0	2	3	0	0	5	3
Connecticut	2	3	3	0	0	8	3

	Month June	July	Aug	Sep	Oct	All Hurricanes - Direct Hits
New York	0	0	1	4	0	5
Rhode Island	0	0	1	2	0	3
Connecticut	0	0	1	2	0	3

[1] Saffir-Simpson Hurricane Scale from 1 to 5, with:
1 - minimal damage, winds 119-153 km/hr (74-95 mph)
2 - moderate damage, winds 154-177 km/hr (96-110 mph)
3 - extensive damage, winds 178-209 km/hr (111-130 mph)
4 - extreme damage, winds 210-249 km/hr (131-155 mph)
5 - catastrophic damage, winds > 249 km/hr (>155 mph)
Source: Rappaport and Fernandez-Partagas 1995 (from National Hurricane Center Internet web page: *http://www.nhc.noaa.gov*, 12/23/98)

Extratropical storms

Although hurricanes are the most destructive storms to pass over the U.S. Atlantic coast, less powerful extratropical cyclones, more commonly known as winter storms or *northeasters,* have also damaged ships, eroded beaches, and taken lives. Northeasters are not as clearly defined as hurricanes, and their wind speeds seldom approach hurricane strength. On the other hand, extratropical storms usually cover broader areas than hurricanes and move more slowly. Therefore, extratropical storms can generate wave heights that exceed those produced by tropical storms. Increased storm duration, with the result that at least part of the storm will coincide with one or more high tides, is the main factor accounting for large coastal damages during these events. Most Atlantic northeasters occur from October/November through April. Dolan and Davis (1992) have tabulated historic extratropical storms and calculated that the most severe ones are likely to strike the east coast in October and January. Several powerful northeasters have caused erosion and coastal flooding in Long Island during the twentieth century (Table 10):

An extratropical storm on 25 November 1950 produced tides 1.55 m (5.1 ft) above normal at Shinnecock Inlet. Suffolk County authorities reported that all dunes with a crest elevation lower than 12 ft above msl were breached (USACE 1958a,b). The revetment along the west side of Shinnecock Inlet was damaged.

Table 9
Hurricanes Crossing or Passing near Long Island [1]

Date	Name	Notes [2]
15 Aug 1635		Effect on Long Island unknown. Much coastal flooding and property destruction in New England, as described in the *History of Plymouth Plantation, 1620-1647,* by William Bradford and in the *Journal* by Governor John Winthrop.
3 Aug 1638		Effect on Long Island unknown. Devastating effects in New England, as described in the *History of Plymouth Plantation, 1620-1647*, by William Bradford and in the *Journal* by Governor John Winthrop.
29 Aug 1667		Effect on Long Island unknown. Much flooding in New York City.
29 July 1723		Effects on Long Island unknown. Much damage in New York City.
30 Oct 1723		Effects on Long Island unknown. Much damage recorded in Rhode Island.
19 Aug 1788		Reported to be a "most terrifying storm." Probably a hurricane, may have caused an opening in Moriches Bay. Much flooding in New York City.
22-23 Sep 1815		One of the most violent storms to strike Long Island, comparable to the 1938 hurricane. Flooding in the vicinity of Hook Pond equal to or greater than the 9- to 11-ft inundation in 1938. "The dunes were flattened along the coast and the shoreline was altered."
3 Sep 1821		As reported in the *New-York Spectator,* "The tide on the Long Island shore was four inches higher than recollected by the oldest inhabitant; and much damage was done to mills and milldams, and some flour and grain were destroyed." Twenty-one lives lost on boats that floundered.
8 Sep 1869		The *Sag Harbor Express* reported this to be the most severe storm since 1815. Damage was greatest in the east; at Napeague Harbor, many fishing vessels destroyed.
18-19 Aug 1879		Much property and crop damage. Many small boats damaged.
24 Aug 1893		Southampton: 17 men lost on a tug. East Moriches: 45 yachts and fishing boats sunk. Babylon: waves washed over Fire Island, great damage along the shore for miles (beach erosion?). Great South Bay: 200 vessels sunk. The *New York Times* reported the storm was exceptionally severe at Coney Island, with waves sweeping 600 ft inland to a height of 30 ft. Hog Island, a popular resort off Rockaway Beach, destroyed by the storm.
10 Oct 1894		Many boats destroyed. Landfall around Moriches.
16 Sep 1903		Widespread flooding at Coney Island. Geologic effects or damage to south shore not recorded.
14-15 Sep 1904		Many trees destroyed; buildings at Bridgehampton damaged. Much of Coney Island flooded. Geologic effects along south shore not recorded.
8-9 Sep 1934		Widespread wind damage; many boats washed ashore, but no reports of south shore geologic effects.

(Continued)

[1] See Table D1 for more detailed information, including sources of information. Note that some of the listed storms did not make landfall or may have weakened to tropical storm strength when they reached Long Island. Therefore, more storms are listed here than the nine used for the NOAA statistics (Table 8).
[2] Saffir-Simpson Hurricane Scale from 1 to 5.

Table 9 (Concluded)		
Date	**Name**	**Notes [2]**
21 Sep 1938	Great New England Hurricane (also known as the "Long Island Express")	Category 3. One of the most devastating storms in New England history, resulting in 680-700 deaths and great property damage throughout the region. Caused massive washovers all along south shore of Long Island. Eye crossed over Moriches Bay. Clowes (1939) described four inlets opening to Shinnecock Bay. Three closed naturally, but one widened and became the present inlet (after subsequent engineering modifications). Vast property damage in coastal Connecticut and Rhode Island; flooding throughout New England.
14 Sep 1944		Category 3, caused 390 deaths in northeast U.S. (344 on ships at sea). Passed just east of Montauk Point. In Moriches Bay at Westhampton Beach, tide reached 5.8 ft above msl, about 5 ft above predicted. Severely damaged dunes that had been repaired after the 1938 hurricane. Sixty-three sluiceways counted by Suffolk Co. officials.
31 Aug 1954	Carol	Category 3. Crossed Long Island approx. at Moriches Bay. Wind gusts of up to 96 mph recorded at Westhampton Beach. a. Shinnecock: Carol devastated east jetty and bayside revetment. Land adjacent to east jetty flooded by storm surge and dunes washed away. Revetment damage caused by ebb flow of surge from bay. West of inlet, large zone of overwash extended clear across barrier island. Ten breaks in dunes between Quogue and inlet. b. Westhampton Beach: two deep 1,000-ft breaches across barrier, 14 homes destroyed. c. Southampton: 26 washovers. d. Moriches: Damage to jetties also severe. Inlet shoaled and rendered impassible for navigation.
11 Sep 1954	Edna	Category 3.
13 Aug 1955	Diane	Category 1.
12 Sep 1960	Donna	Category 4 (downgraded to 3 at Long Island). Donna crossed Long Island over Great South Bay. Caused numerous washovers and extensive property damage. Peak gusts 97 mph at La Guardia Airport. High water 8.4 ft NGVD at the Battery and 8.35 ft at the Battery.
9-10 Aug 1976	Belle	Peak storm-tide elevations ≈4.0 ft at Swan River at East Patchogue.
27 Sep 1985	Gloria	Category 3. Peak storm-tide elevations >4 ft at Swan River at East Patchogue and at Connetquot River near North Great River. Overall damage less than expected.
19 Aug 1991	Bob	Category 2. Eye passed 25 miles east of Montauk Point. Maximum sustained winds 115 mph. Worst impact in eastern Long Island, but damage limited because storm passage coincided with low tide.
5-14 July 1996	Bertha	Landfall near Wilmington, NC, $270 million in damage. Some erosion but no damage reported on Long Island.
5-6 Sep 1996	Fran	Little damage reported on Long Island. Category 3 off North Carolina.

The *Ash Wednesday Storm* of 6-8 March 1962 claimed 33 lives and caused great property damage in Delaware, New Jersey, and New York. On Long Island, it was responsible for over 75 breaks (washovers) between Fire Island Inlet and Southampton (USACE 1963). The largest breach, about 400 m wide, was at Westhampton Beach. In the Moriches to Shinnecock Reach, large stretches of Dune Road and 46 houses were destroyed.

The *Halloween Storm* of 30-31 October 1991 was one of the most destructive northeasters to ever strike the Atlantic coast. The system's lowest pressure dipped to 972 mb on October 30. Sustained winds of 50-70 mph persisted for

Table 10
Notable Extratropical Storms, Long Island [1]

Date	Notes
22 May 1720	Effects on Long Island unknown. "A storm, described as the most terrible 'in the Memory of man' visits New York, destroying life and property."
23-24 Dec 1811	"The greatest blizzard of all time" caused severe damage to barrier islands. The *History of Long Island* by Thompson described it as, "Great Storm - On the night of the 23 D December, 1811, commenced one of the most remarkable snowstorms and gales of wind ever experienced together, upon Long Island. It came from the north-east, and swept over Long Island with dreadful violence. An immense amount of property was destroyed, and many lives lost."
3 Feb 1880	High surf along south shore. Damage to Concourse at Coney Island.
12 Mar 1888	The Blizzard of 1888 caused over 400 deaths, including 200 in New York City alone. Snowfall averaged 40-50 in. over southeastern New York State and southern New England with drifts to 30-40 ft. Highest reported drift was 52 ft in Gravesend, NY. 80 mph wind gusts were reported, although the highest official report in New York City was 40 mph and 54 mph at Block Island. From Chesapeake Bay through the New England area, over 200 ships were either grounded or wrecked, resulting in the deaths of at least 100 seamen. Melting snow after the storm caused severe flooding especially in Brooklyn, which it was susceptible to because of topography. Effects on south-shore beaches not reported.
24-25 Oct 1897	The *New York Times* reported, "A Terrific Northeaster.... Buildings were undermined and destroyed, roads washed out, lowlands flooded, peninsulas made into islands and new inlets gouged out by the terrific bombardment of the high seas, and railroad traffic was interrupted."
4 Mar 1931	Reportedly led to reopening of Moriches Inlet. By 1933, inlet 1,300 ft wide. Original opening about 3,600 ft east of present inlet (see USACE 1958b, Plate A1). Migrated west until stabilized by revetment in 1947. Much flooding at Rockaway Beach, Jamaica Bay.
17 Nov 1935	Cottages destroyed at Southampton; some flooding.
25 Nov 1950	Peak storm-tide elevations ≈3.5 ft at Swan River at East Patchogue and at Connetquot River near North Great River (both draining into Great South Bay). In New York Harbor, tides higher than during 1938 and 1944 hurricanes. Ocean tide levels above msl: Jones Inlet: 9.4 ft Oak Beach: 9.1 ft Shinnecock Inlet: 5.1 ft Montauk Point: 5.2 ft Coast Guard reported 20-ft waves at Jones Inlet. Three breaks (washovers) occurred east of Quogue, opening into Shinnecock Bay. A new inlet formed at Westhampton beach (closed using bulldozers). Revetment on west side of Shinnecock Inlet damaged.
6-7 Nov 1953	Storm center moved inland near New York City. Estimated wave heights about 20 ft along south shore. Numerous homes in Fire Island area were damaged. Jetties at Moriches and Shinnecock inlets damaged. "A sand bar was formed approximately 500 feet offshore from Shinnecock Inlet, and the inlet shoaled to over half way across from west to east."
6-8 Mar 1962	*Ash Wednesday Storm.* Responsible for over 75 breaks (washovers) between Fire Island Inlet and Southampton. The largest breach, about 400 m wide, was at Westhampton Beach. In the Moriches to Shinnecock Reach, large stretches of Dune Road and 46 houses were destroyed. Notable offset at Shinnecock Inlet: west side eroded, accretion along east side. President Eisenhower declared the south shore a disaster area eligible for Federal aid. Under authority of Public Law 875, 81st Congress, the USACE performed engineering and construction of emergency shore protection and rehabilitation. 2,210,000 yd^3 sand pumped onto beaches, mostly from back bays.

(continued)

[1] See Table D1 for more detailed information, including sources of information. The list is incomplete because few historical records are available from the 1600s and 1700s.

Table 10 (Concluded)	
Date	**Notes**
6-8 Feb 1978	*Blizzard of '78.* Northeaster deposited record amounts of snow and caused overwash and beach erosion along entire northeast United States. Because of shore orientation, Long Island was less severely affected than the Massachusetts coast. Peak storm-tide elevations ≈3.5 ft at Swan River at East Patchogue and at Connetquot River near North Great River.
28-30 Mar 1984	Near-hurricane winds caused storm tides 5-6 ft above normal, with maximum tide 7.1 ft NGVD at Sandy Hook.
30-31 Oct 1991	*Halloween Northeaster.* Included three, possibly four high tides. Extensive beach erosion and overwash along mid-Atlantic seaboard.
11-14 Dec 1992	Intense storm affected mid-Atlantic and northeast coast of United States, producing gale-force winds and gusts over hurricane strength. Caused extensive coastal flooding and beach erosion along all of the New Jersey and New York coasts. Peak storm-tide elevations (11-12 Dec): 4.23 ft NGVD at Swan River at East Patchogue; 4.0 ft at Connetquot River near North Great River; 7.96 ft at the Battery. Two breaches opened at Westhampton, destroying numerous homes.
12-14 Mar 1993	Massive storm, now called *The Storm of the Century*, struck the eastern seaboard. Passed almost directly over New York City, dropping 10-20 in. snow. Widespread coastal flooding. Total death toll in U.S. over 270. At least 18 homes fell into the sea on Long Island because of the pounding surf, and the storm further eroded the south-shore beaches, which had been damaged in the Dec. 1992 northeaster.

48 hr, generating high seas and storm surges and causing extensive beach erosion and overwash along the mid-Atlantic seaboard (Dolan and Davis 1992).

Only a year later, from 11-14 December 1992, another intense storm with gale-force winds and gusts over hurricane strength pounded mid-Atlantic and northeast coasts of the United States. Westhampton Beach just west of the groin field was cut in two locations near Pikes Beach. The USACE closed Pikes Inlet (the western of the two cuts) in January of 1993 with 60,000 yd^3 of sand dredged from the bay (augmented with natural littoral drift). Winter storms plus tidal currents caused the second cut, Little Pikes Inlet, to grow to almost 1,500 m wide with a 6-m-deep channel by May 1993. To finally close this breach, 1,500,000 yd^3 of sand was pumped from an offshore borrow area in late 1993 (USACE 1995).

Only 3 months later, on March 12-15, 1993, a storm now called *The Storm of the Century* struck the eastern seaboard. The death toll for the United States exceeded 270, with 48 of these missing at sea. Highest recorded wind gusts in New York were 89 mph on Fire Island and 71 mph at La Guardia Airport (Lott 1993). At least 18 homes fell into the sea on Long Island because of the pounding surf, and the south shore beaches, which had been badly damaged by the December 1992 storm, were further eroded. Based on storm surge and wind speed, this storm could be compared with a Category 3 hurricane.

Historical storm statistics

The following quote from USACE (1958a) discusses storm intensity and frequency:

49. Available records show that of 126 storms recorded between 1635 and 1956, nine were unusually severe, 17 were severe, 41 were moderate, and 59 others threatened the area. Damaging effects on the study area have been unusually severe during the following hurricanes:

1635, Aug. 15
1638, Aug. 3
1723, Aug 19
1788, Aug. 19
1815, Sept. 22-23
1821, Sept. 3
1869, Sept. 8
1893, Aug. 24
1938, Sept. 21

50. Storm frequency. The distribution of recorded storm occurrences in the study area by estimated degree of intensity and the estimated frequency of occurrence for each intensity are shown in Table 5. The frequency of the unusually severe storms of 2.8 per 100 years is based on the entire period from 1635 to 1956 because it is believed that the record is reasonably complete for the storms of this intensity. Other periods of record were selected in determining the frequency of the storms of lesser intensity on the basis of availability of records for these storms.

Table 5 - Estimated storm frequency

Intensity	Period of record	Number of occurrences	Frequency per 100 years
Unusually severe	1635-1956	9	2.8
Severe	1801-1956	14	9.0
Moderate	1901-1956	13	23.2
Threatened the study area	1901-1956	36	64.3

3 History of Long Island and Shinnecock Inlet

Explorers and Early Settlers

The first European mariner known to have gazed upon the Long Island shore is Giovanni da Verrazzano, an Italian explorer who sailed the coast of the New World under the flag of France. On April 17, 1524, Verrazzano sailed his ship, the *La Dauphine,* into New York Bay and anchored in the Narrows, now renamed after him and spanned by the Verrazzano Bridge. A change in the winds forced him out to sea after only a day, after which he sailed east along the Long Island coast. He and his mariners were most impressed with the richness and beauty of this fair land and the friendliness of the natives (Morrison 1971).

Before the arrival of European settlers, south-central Long Island was inhabited by the Shinnecock, a Native American tribe of the Algonquian language family and of the Eastern Woodlands culture area. After 1788, many Shinnecock settled on land given to them in present-day Oneida County, New York, and, in 1833, they moved on to Wisconsin. A small number of Shinnecock remained on Long Island, and in 1990, 1,500 people in the United States claimed to be of Shinnecock descent (Microsoft 1997).

The English settled Long Island in the 1600s, where they built prosperous farms and towns. The first English in Southampton were Puritans who arrived in 1640 from Lynn, Massachusetts. Towns like Southampton and Bridgehampton still feature elegant colonial-era churches, schools, and homes that testify to thriving commerce and institutions of learning, religion, and self-government. The early settlers found the south-shore barriers inhospitable, useful only for animal forage and hunting. Until the end of the nineteenth century, the beaches remained largely uninhabited. As a result, there are few maps or descriptions of the barriers, despite the presence of towns and farms only a short distance across the salt ponds.

Shipwrecks

The uninhabited Long Island barriers, unmapped and completely dark at night, were treacherous to shipping, especially during storms. Sheard (1998) writes:

> ... During the nineteenth century the islands were sparsely inhabited, and the closest civilization lay on the mainland to the north, across a series of wide bays and salt marshes. Offshore, a few hundred yards to seaward and running parallel to the barrier islands lies a series of constantly shifting sand bars. On a dark night or during a storm, the islands were almost invisible from seaward, and often a ship's first sign of danger was the sound of the surf breaking on the beach. It is hard to envision a better ship trap.
>
> And trap ships is what these beaches did. At least 300 ships are known to have run aground along the south shore of Long Island, from Rockaway Point to Montauk Point, during the nineteenth century, which equates to an average of three wrecks per mile. There were undoubtably many other wrecks whose histories remain obscure. ... The vast majority of these wrecks were sailing vessels - schooners, brigs, brigantines, barks, and sloops - that had fallen victim to the great ship trap. But rusting iron steamers lay in the surf line as well, long defying the destructive power of the breakers. While many of these grounded ships were pulled off and refloated by wrecking crews, an equal number became total wrecks. Their backs broken by the relentless surf, they were abandoned and left for the sea to dismantle.
>
> Aground and helplessly caught in a winter storm's pounding breakers, the human crews of these vessels often found themselves stranded only a few hundred yards from the safety of the beach. Inexperienced at handling a small boat in the breaking surf, these men were often unable to escape their ships for the dry land only a stone's throw away. For those lucky enough to reach shore, there remained the challenge of survival on the sparsely inhabited islands. Low-lying sand dunes carpeted with razor-sharp grasses and tightly-knit, wind-sculpted shrubs provided little shelter from the biting cold of a winter storm. After struggling ashore through mountainous breakers, it was all too easy for the salt-drenched and exhausted men to perish from exposure.
>
> During the first half of the nineteenth century, most of those who did survive shipwrecks along the south shore owed their lives to the few local inhabitants who had made their homes along the beach. Mostly fishermen, the residents were experts at handling small boats in the surf, and out of human compassion, lent a helping hand to those unfortunates cast upon the shore...

With the growth in traffic caused by America's boom in merchant shipping during the 1800s, there was a corresponding increase in the number of shipwrecks. Some wrecks were accompanied with terrible loss of life, and the public began to call for the establishment of a life-saving system to offer assistance and succor to shipwreck victims. In 1849, the Life-Saving Benevolent Association of New York was incorporated in the legislature of New York and successfully lobbied Congress for an appropriation to build stations along Long Island's shore. As a result, 24 life-saving stations were built along the New

Jersey and New York coasts. Eight of the stations were on the south shore of Long Island, at Amagansett, Bridgehampton (Mecox), Quogue, Moriches, Mastic (Bellport), Fire Island, Long Beach, and Barren Island (Rockaway). In 1854, 14 additional stations were established along Long Island, one of which was at Shinnecock. The average distance between stations was narrowed to 5 miles, a manageable distance for the station crews to patrol on foot. Finally, in 1878, the United States Lifesaving Service was formally established as a separate entity (Sheard 1998). The stations at Moriches Inlet, Westhampton, and Shinnecock stood until 1938, when they were destroyed by the storm surge from the 21 September hurricane (the crews escaped in their own lifeboats; Clowes 1939).

Evidence of Early Inlets

Charts of Long Island and the approaches to New York Harbor and historical documents note the irregular existence of openings in the barrier between Shinnecock Bay and the Atlantic Ocean. Because of the limited records, it is impossible to chart the exact times and locations where inlets have existed. Before the middle of the twentieth century, little scientific study had been devoted to the geology and dynamic processes of beaches, and even Fuller's (1914) highly detailed U.S. Geological Survey Professional Paper 82, *The Geology of Long Island,* devoted only three pages to beaches and marine deposits. Limited evidence suggests that these old inlets opened during major storms and then closed naturally. Some appear to have remained open for decades, whereas others closed within months. The majority of historical inlets have occurred along Westhampton Beach (Kana and Krishnamohan 1994).

USC&GS charts from 1889-1890 provide evidence of several inlets into Shinnecock Bay, but all had closed by 1891 (Figure 5). One of the former openings was opposite Shinnecock Neck. Another was slightly west of Ponquogue Point, and two others were east and west of Gull Island, opposite East Quogue. U.S. Geological Survey maps of 1903 and 1904 (Sag Harbor Quadrangle) show no inlets into either Moriches or Shinnecock bays (Leatherman and Joneja 1980). Fuller (1914) stated that at the time of writing, Shinnecock Bay had no direct connection with the ocean. He also provided an interesting historical note, "An artificial cut made to the ocean was soon closed by the waves." Fuller's footnote probably refers to the artificial cut made in 1896 as part of the Shinnecock and Peconic Canal project:

> In 1895 another part of the project was authorized. An inlet was directed to be cut between Shinnecock bay and the Atlantic ocean, so as to have a further beneficial effect on the fishing, oyster and clam industries, and to relieve the stagnant condition of the bay. The bay is separated from the ocean by a strip of land from one to two thousand feet wide, which is low and flat, excepting at the beach, where the dunes rise to an elevation of twenty to thirty feet above sea-level. A channel--thirty feet wide at bottom, six feet deep, with slopes of one on one and one- half--was cut through the low land to the foot of the dunes, about three hundred feet from the ocean. This had been excavated during 1896, with the intention of completing the cut in the spring, when the high water in the bay and a

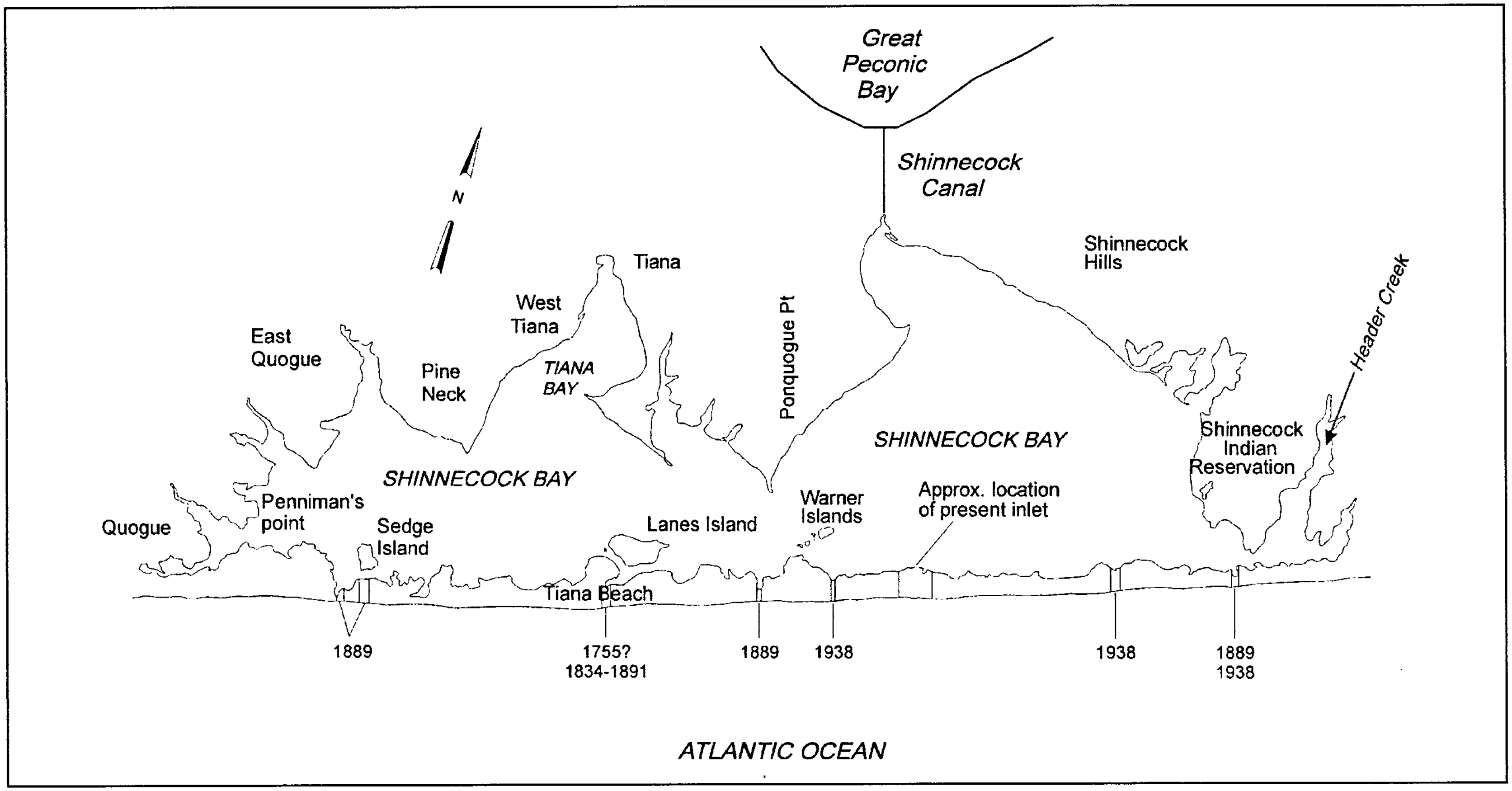

Figure 5. Location of historical inlets opening into Shinnecock Bay (Based on 1989-1890 USC&GS charts (modified from Leatherman and Joneja 19980))

low tide in the ocean would produce a head of five or six feet to assist in opening the channel. When this was attempted, the neighboring inhabitants donated their services, as funds had been exhausted, (Chapter 932, Laws of 1895, appropriating $5,200, supplemented by chapter 950, Laws of 1896, providing $5,000 for this inlet and the tide-gates.) but it proved a failure, the waves quickly forming the dunes again, so that few traces of the channel now remain. (Whitford 1906).

In the late 1930s, the barrier adjacent to Shinnecock Bay was continuous, and the paved Dune Road crossed the site of the present inlet (Figure 6). A shoal area about 1,000 m wide paralleled the exposed beach except for a narrow channel that connected deep water in the bay with an indentation in the barrier beach (Nersesian and Bocamazo 1992). Possibly the location of the 1896 cut, the barrier breached at this spot during the 1938 hurricane.

Great New England Hurricane of 1938

The present Shinnecock Inlet was formed as a result of waves and extremely high water during the Great New England Hurricane of 21 September 1938. This hurricane, one of the most destructive storms to strike New England, killed over 600 people and devastated coastal communities in Long Island, Connecticut, Rhode Island, and Massachusetts (Allen 1976; Federal Writers' Project 1938; Minsinger 1988) (Figure 4). The storm moved quickly up the Atlantic seaboard at a speed of about 90 km/hr, therefore gaining the name "Long Island Express." On the preceding day, seas and winds were not particularly high, and New England coastal residents had little warning that severe weather was headed their way. The winds grew gradually during the morning of the 21st, and through the afternoon and evening, 80- to 100-mph winds crushed houses, knocked down trees, and lifted barges and boats onto land. Throughout New York and New England, the wind and water felled 275 million trees, seriously damaged more than 200,000 buildings, knocked trains off their tracks, and beached thousands of boats (Haberstroh 1998). Damage from the storm was estimated at $600 million. This value is in 1938 dollars, and multiplying by 10 provides an estimate in present currency. Considering that wind and rain damage extended as far north as Rutland, Vermont, that entire city blocks burned in New London and other industrial towns, and that downtown Providence, Hartford, and other cities were flooded, if this storm were to occur today, the cost of the damage wrought would be staggering.

Storm characteristics

The following quote from USACE (1958a) (Appendix G, History of Storms) describes the storm's characteristics:

66. Hurricane of 21 September 1938 (Category A). This hurricane was the most destructive in the 20th century to strike the study area. It was detected about 300 miles northeast of Puerto Rico on 18 September 1938 and traveled west to within about 200 miles of the Florida coast, at which point its path was deflected

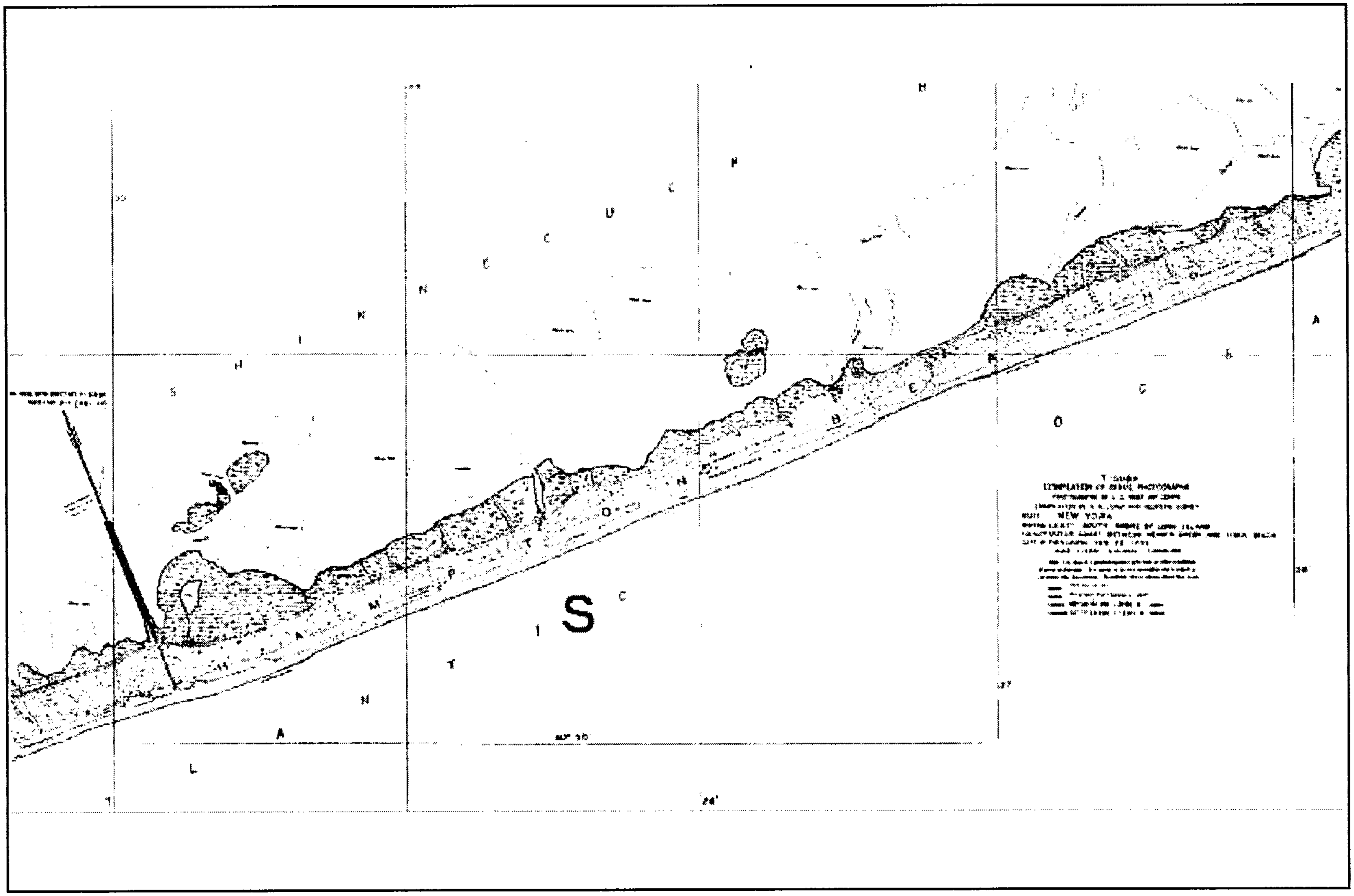

Figure 6. Pre-inlet topography (This is a portion of USC&GS T- (topographic) sheet T-5080, 1933. At this time, there were no open inlets leading into Shinnecock Bay. The letter "**S**" marks location of modern (present) inlet. The narrow channel that extends from bay about halfway across barrier can also be seen in June 1938 aerial photograph (Figure A1). Digital raster image downloaded from NOAA Internet site)

> to the north. On the morning of 21 September the storm was reported off Cape Hatteras proceeding northward at a velocity of about 40 miles per hour. The center of the storm skirted the east coast of New Jersey and struck the south shore of Long Island near Moriches Inlet, less than 10 miles west of Westhampton Beach, on the afternoon of 21 September during a rising predicted tide. The predicted stage of the tide for that time was one foot above mean sea level near Moriches Inlet. Wind velocities of up to 80 miles per hour from the northwest were recorded at New York City, and the barometer at that station dropped to a low of 28.72 inches. At Bellport Coast Guard Station about 15 miles west of Westhampton Beach, the lowest recorded barometric pressure was 27.94 inches. The central pressure of the hurricane at the time the center passed the south shore of Long Island was estimated by the Weather Bureau as 27.86 inches. A maximum wind speed of 96 miles per hour was reported near the east end of Long Island. A 5 minute average wind velocity of 82 miles per hour was observed at the Block Island Weather Bureau Station. It is estimated that waves reached a height of 10 to 12 feet along the south shore. Abnormally high tides accompanying the hurricane caused damages along the Long Island coast line. No tide readings are available for this area. Computations indicate that the still water elevation in the ocean was about 10 feet above mean sea level.

Clowes (1939; pp. 9-10) describes how the seas overwhelmed Long Island's south shore beaches:

> Soon after three o'clock the situation on the beaches became critical, especially on that long strip from Shinnecock Bay to Moriches Inlet where the dunes were mostly low and had at their backs a succession of bays and canals.... By three, the sea there was all over the beaches and beating and breaking at the foot of the dunes. By half-past three, it was breaking over and through the dunes at many places and sometime toward four o'clock the final catastrophe occurred. Before the onslaught of that terrible tide, itself perhaps ten to fifteen feet above normal height and crested with breakers towering fifteen feet higher or more, the whole barrier of the dunes crumbled and went down save here or there where a higher dune or bulkhead held....

The "final catastrophe" described by Clowes refers to the passage of the hurricane's eye. Before the eye reached land about 3:30 p.m., the winds were from the northeast and east. The eye provided about 20 min of calm, followed by furious south/southwest winds. Survivors from Westhampton Beach reported that, within minutes, a 30-ft wall of water overwhelmed the barrier, smashing houses into sticks.

Ocean water levels during the storm are not available. Surge computations indicated that the still-water level in the ocean was about 3 m (10 ft) above mean sea level, or about 2.5 m (9 ft) above astronomical tide (USACE 1958a). High-water marks measured in some of the bays indicated that the maximum height, including wave uprush, exceeded 5 m (15 ft) above msl. Total accumulated rainfall was 9.9 in. at Freeport and 11.0 in. at Mineola.

By 5:30 p.m., the hurricane had passed Long Island and the wind began to drop steadily. The next morning dawned clear, calm, and sunny. Survivors who returned to the beach reported that the absolute silence was overwhelming. There were no seagull, dogs, or other sounds of normal day-to-day life.

Property damage

Although the worst damage was in Connecticut and Rhode Island, Long Island was not spared and suffered over a $6 million damage (1938 prices). Effects of the storm have been documented in a number of volumes of personal recollections (Bennett 1998; Clowes 1939; Perry and Shuttleworth 1988; Quick 1939 - see Appendix E). Montauk village was largely destroyed, and most of the fishing fleet was tossed on land or sunk. According to newspaper accounts, there were a total of 45 dead and missing on Long Island, of which 29 died and 7 were missing at Westhampton Beach (USACE 1958a). Before the storm, there were 179 houses on the barrier in Westhampton Beach. Of these, 153 vanished completely, and in some stretches, there was little evidence that there had ever been human habitation on the beach. If the storm had occurred 2 weeks earlier, before summer vacationers returned to their permanent homes, the loss of life would have been much greater. If the storm had passed after dark, some of those who did escape might have perished.

The following quotes from Federal Writers' Project (1938) provide more graphic details:

> When the gale swept up from Jersey, the exposed back of LONG ISLAND was lashed by a wind wave. The entire coastline, fringed with fashionable resorts and vacationists' cottages, shivered under the blow. At Long Beach, *grotesque pyramids of bricks and shingles* replaced comfortable homes.
>
> The Merrick Road at Center Moriches was covered with marsh grass and stubble. Autoists worked far into the night exhuming their cars from layers of hay and topsoil piled high on the roadways.
>
> A *Long Island railroad express* was derailed at East Hampton. Tracks were squeezed into bulging loops of steel. The town's locusts and elms, which formed a half-mile arch down the Main Street crashed. Old residents wept at the destruction of the trees immortalized on canvas by Childe Hassam.
>
> The Coast Guard found nine women, two men, and a child cowering on a dune the next morning. Said one of the women, "I struggled out and managed to crawl to a high knoll. It was sometime before I even realized that there were others with me. One of the men was crippled. We just huddled together all through the night."
>
> The great waves redrew the topography of the beach, carving a mile-long inlet into the very center of town.
>
> Scores of houses and boats were wrecked on Fire Island, six miles south of Bay Shore. Kismet, Fair Harbor, Saltaire, and Cherry Grove were all but wiped out. Point O'Woods, Seaview, and Ocean Beach, protected by sand dunes, escaped with slight scars.
>
> A ferryboat captain rescued 43 residents before the sea roared over their homes. Through the heart of the village of Saltaire the tide cut a channel eight feet deep. Three hundred of the island's inhabitants spent a sleepless night staring

across Great South Bay to the mainland. Next morning they were evacuated by the Coast Guard ice-breaker AB-25 and a ferry boat. *Guardsmen carried the maimed* down from the Saltaire village hall. One of the victims tried to swim to the mainland. *He was pulled out, exhausted,* by *heroes in underwear.*

Viewing these events after six decades, we wonder why people were caught so unaware by this storm. Three factors may account for the tragedy. First, the storm moved quicky up the coast from Florida to New England, and weather forecasters, without the benefit of satellites or storm-chasing aircraft, were unable to effectively track it. In that era, many forcasters discounted the possibility of a hurricane making landfall in New England, and the weather service was accused of grossly underestimating the danger of the storm and not issuing adequate warnings. Second, because the storm moved so quicky, radio stations and newspapers were unable to spread warnings to all the affected areas. The afternoon newspapers had not yet been distributed by the time the storm struck Long Island. Finally, an intriguing note from Clowes (1939; p. 60) says, "However, reports received by the Weather Bureau indicate that owing to the general alarm over the European situation the public took little interest in news regarding the weather." September 21, 1938, was one of the fateful days that Neville Chamberlain was in Munich negotiating with Adolf Hitler about the partition of Czechoslovakia in the attempt to avert war (Churchill 1948). That day, the hapless Czech parliament capitulated to Hitler, and Americans and Europeans, terrified that another world conflagration would break out, anxiously listened to the wireless broadcasts from Germany hoping that Chamberlain might appease the German dictator.

Geological effects

The barrier beach from Fire Island Inlet to Southampton sustained the greatest damage. The seas washed over the barrier and destroyed or damaged over 1,000 houses. Some of the summer communities, such as Saltaire, Fair Harbor, Point O'Woods, and Westhampton Beach were insufficiently protected by dunes and therefore suffered greater damage than other towns. The section of the Long Island Intracoastal Waterway between Westhampton Beach and Quogue was almost completely blocked by sand and debris. "One fact of importance concerning the effect of this storm on the dunes is that, generally, dunes with a crest height of 18 feet or more above mean sea level withstood all attacks of the sea and storm and protected the leeward area. Those areas in which the dune crest was less than 16 to 18 feet above mean sea level were generally damaged by wave overwash or breached" (from USACE 1958a, p. C-3). For the most part, the area east of Southampton was not damaged as severely as the western communities as a result of the generally higher elevation of the land, but severe inundation occurred at Napeague Harbor and Montauk. Three of the coastal ponds, Mecox Bay, Sagaponack Lake, and Georgica Pond, were breached in the storm (Howard 1939).

The center of the eye of the storm crossed eastern Long Island over Moriches Bay (Figure G-1 of USACE 1958a). Therefore, the strongest onshore winds and highest surge buffeted the shoreline east of Moriches Bay. Four openings were cut into Shinnecock Bay during the storm, one near Warner's Islands, 0.8 km east of Ponquogue Point, a second opposite Cormorant Point, a third opposite the Shinnecock Hills, and a fourth opposite the Shinnecock Indian Reservation. Figure 7 is a mosaic of aerial photographs taken on 24 September, only 3 days after the hurricane. The many washover fans, some of which cross the entire barrier, attest to the fury of the storm. The mosaic shows three inlets, although the one furthest to the west (left) had almost closed. All three were oriented left of perpendicular (i.e., pointing to the southeast). The largest breach is the one that became the present inlet. The spits at the ocean end of the breaches had grown from west to east, indicating that poststorm longshore drift was to the east.

It is interesting to note on a series of 24 September photographs flown from Southampton to Fire Island Inlet (not reproduced in this report) that most coastal morphological changes were restricted to Moriches and Shinnecock bays and Fire Island east of Davis Park. The photographs show the massive amount of washover at both bays, and many breaches were cut. Moriches Inlet became four wide openings. Along Fire Island beyond Davis Park, there were fewer washover fans, and the beach looked surprisingly untroubled. The edge of the dune is straight, indicating a storm scarp. Only a few of the washover fans on Fire Island crossed the entire barrier, whereas this was common at Moriches and Shinnecock bays.

Three of the breaches into Shinnecock Bay closed by the end of 1938, but one stabilized and continued to widen until it was over 200 m across in 1939. By 1941, the inlet was 300 m wide, an inner and outer bar had formed, and a tortuous channel connected the Atlantic with Shinnecock Bay. Although in places the channel was over 6 m deep, the controlling depth was only about 1.2 m.

Posthurricane Dune Reconstruction

After the 1938 hurricane, extensive dune rehabilitation was financed by local communities and Suffolk County, with support from the Works Progress Administration (WPA) (Howard 1939; USACE 1958a).

At the time, dune restoration was soundly criticized. The Long Island State Park Commission revived an ambitious plan to extend the parkway system along the entire length of Fire Island, from Fire Island Inlet to Shinnecock Inlet (Andrews 1938). In an introduction letter, the president of the board of commissioners, Robert Moses, wrote, "On the subject of predictions, let me predict further that the silly temporary, makeshift, haphazard brush and fence-work now being done with relief and other forces, where the dunes were wiped out along the ocean front on Fire Island, will not survive the inevitable early Spring storms and will indeed, in many cases, be wiped out long before then." The Park Commission's plan called for a low, wide embankment to be built from hydraulic fill, planted with grass and shrubs, and topped with a roadway, similar

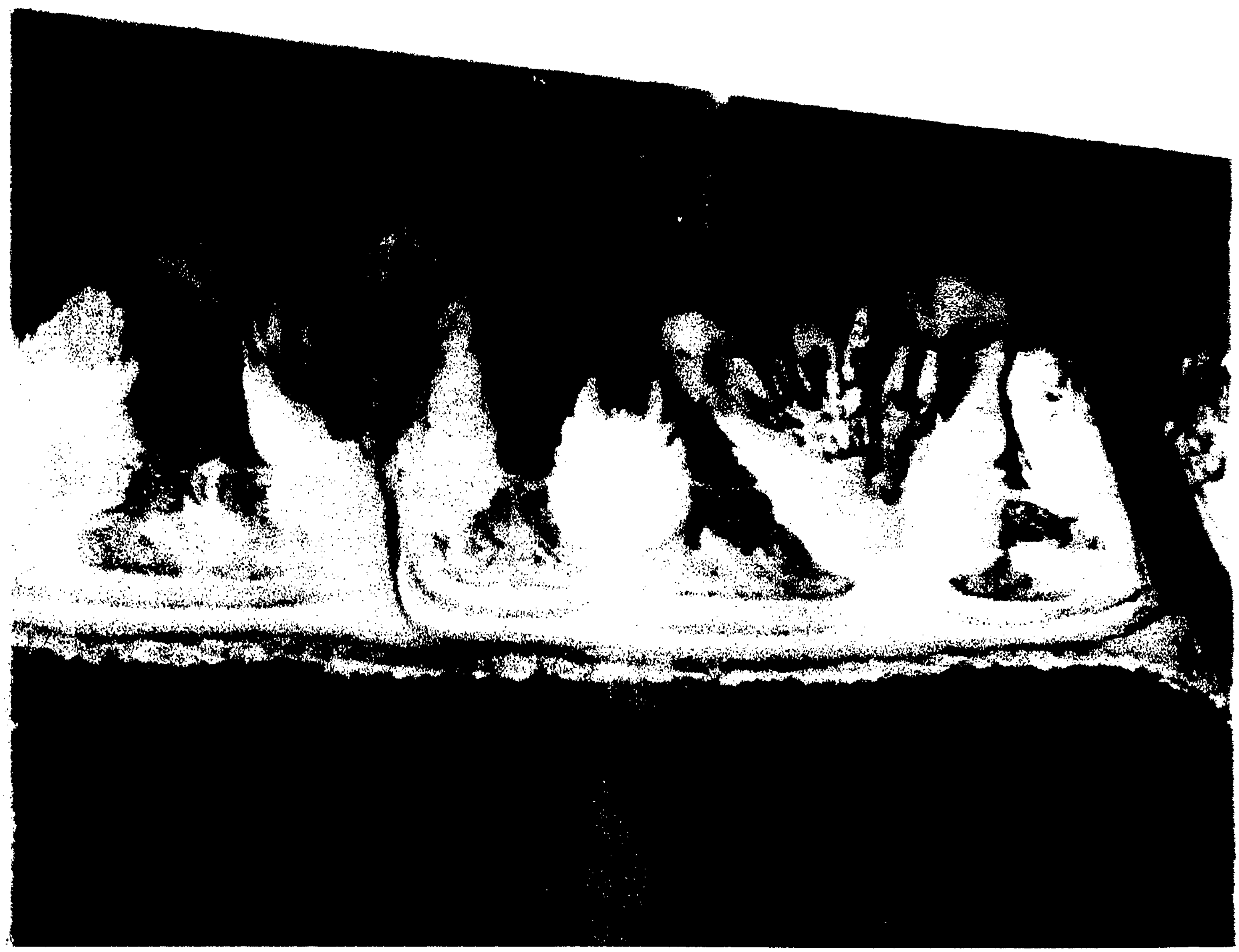

Figure 7. Mosaic of posthurricane aerial photographs taken 24 September 1938 (The tremendous power of this storm can b large numbers of washovers. Three breaches through barrier were cut, although westernmost one had almost clos one widened over time and became present Shinnecock Inlet. Mosaic prepared by BEB or possibly USC&GS, fron Engineer Waterways Experiment Station archives in Vicksburg, Mississippi. Shalowitz (USC&GG cartographic eng measurements of inlets using these photographs (Howard 1939))
(Original photograph is 55 in. wide. This figure is 78 percent of full size.)

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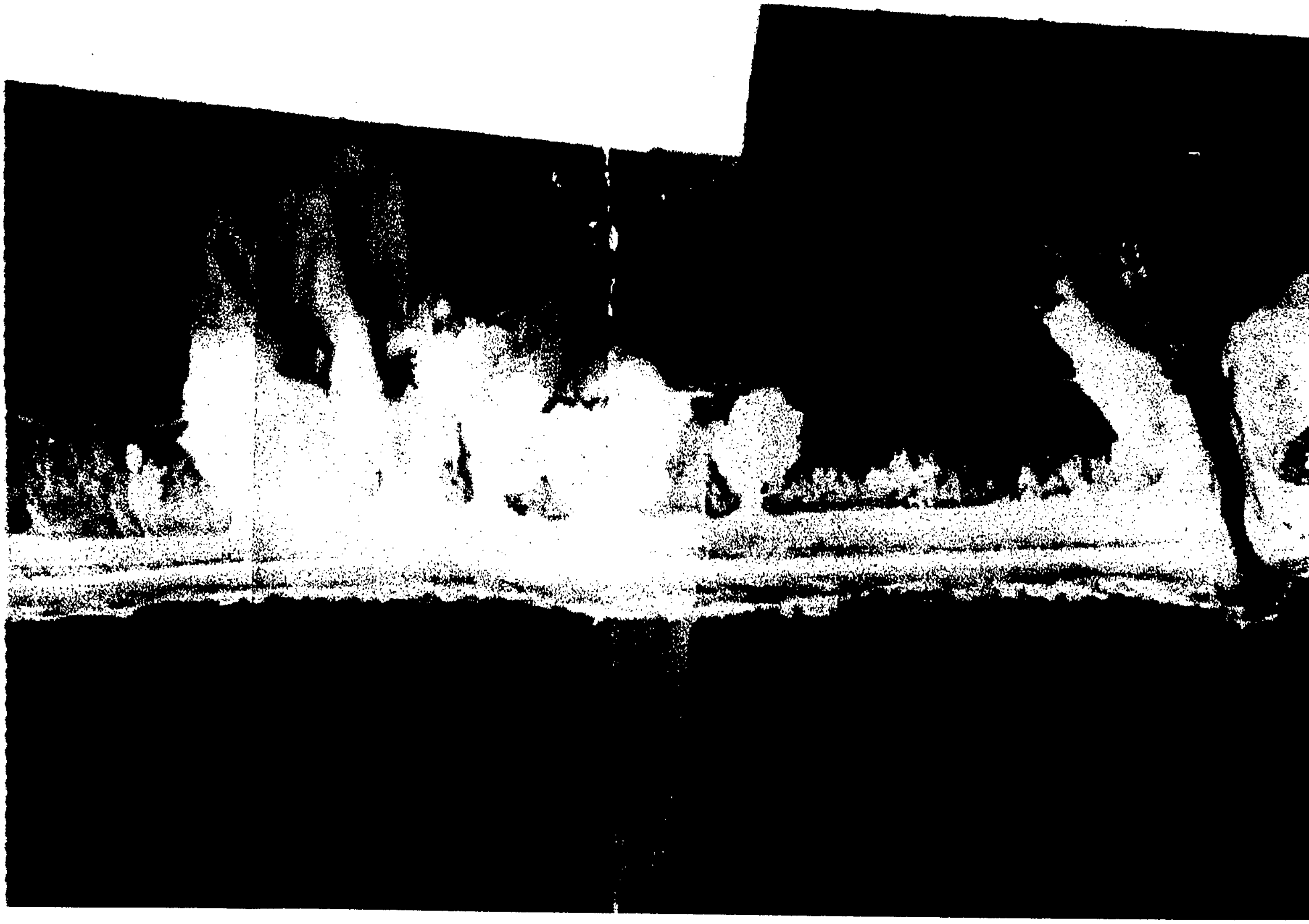

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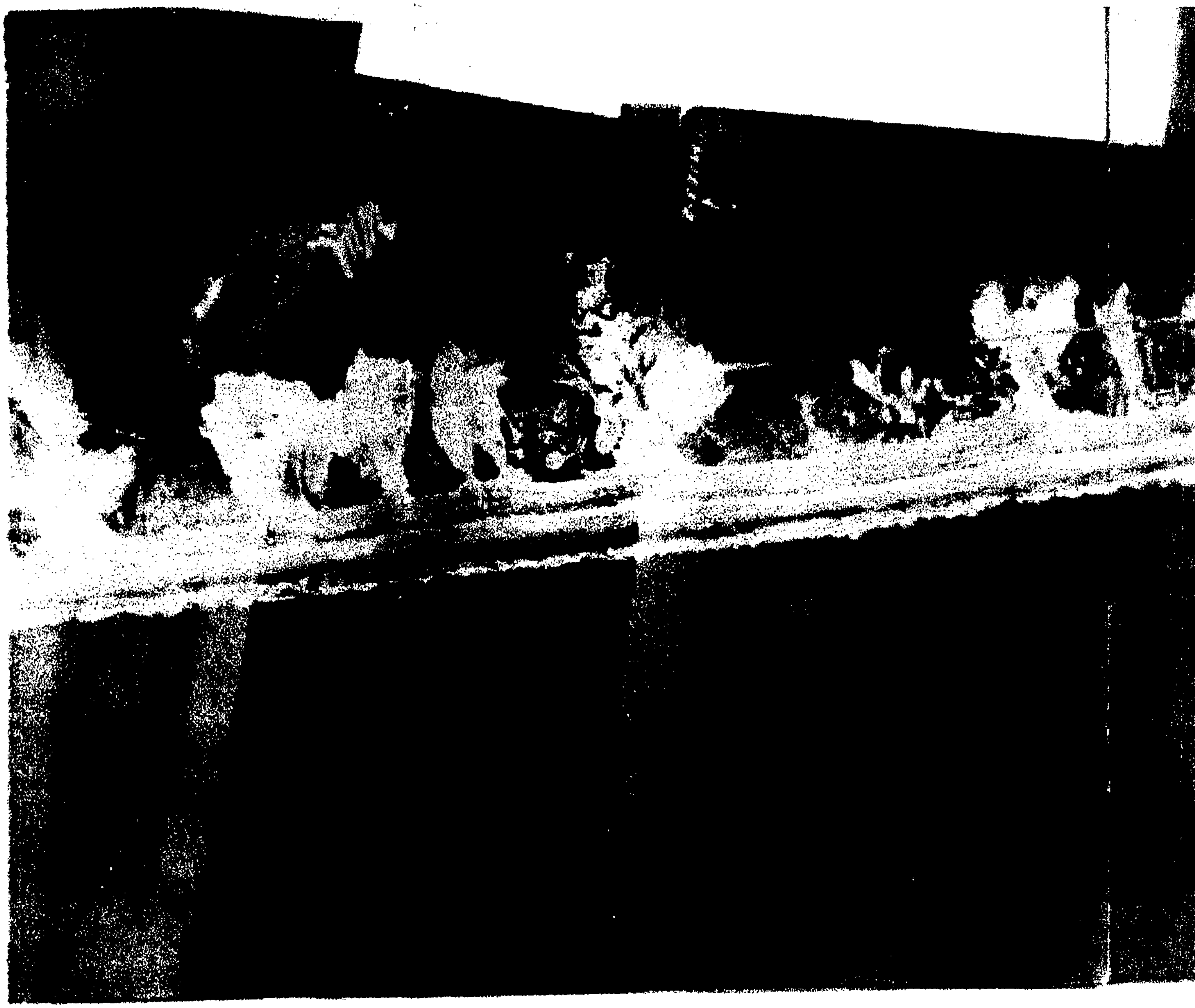

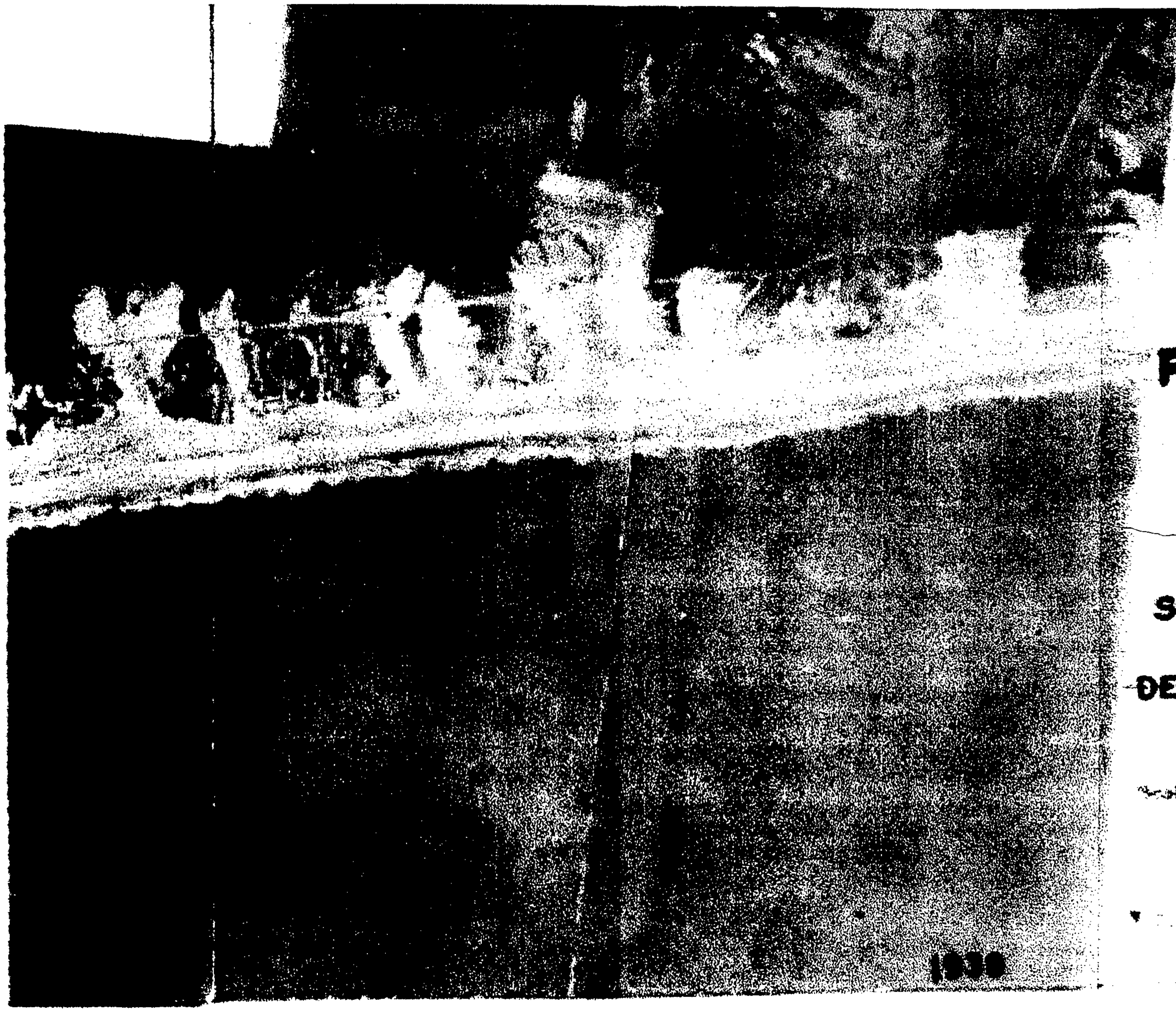

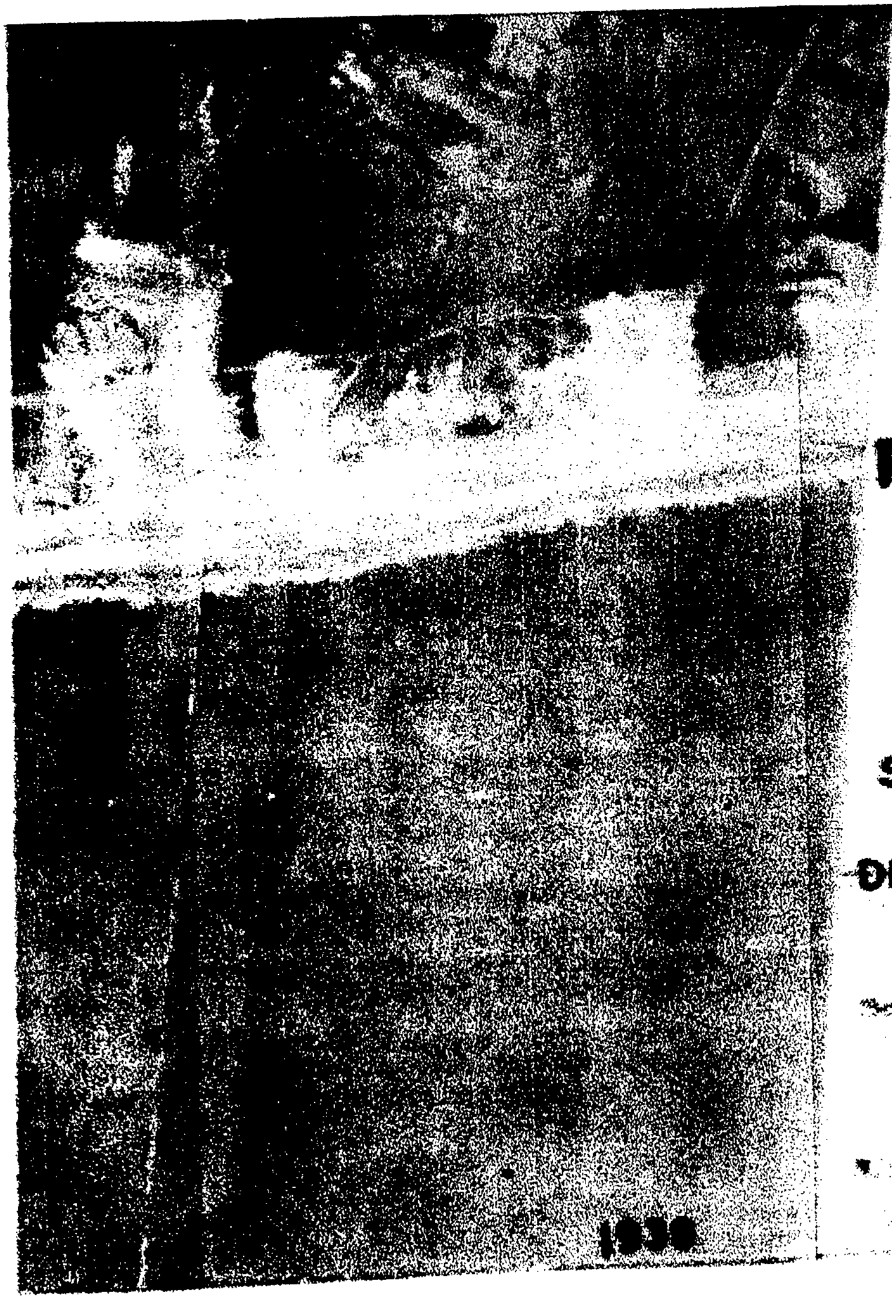

EFFECTS OF

1938 HURRICANE

FIRE ISLAND N.Y.

PHOTOGRAPHED

SEPT. 24, 1938

4:15 P.M.

SOUTHAMPTON

TO

DEMOCRAT POINT

Scale 0 ——— 1000 ft

Approx. 1/6500

(7)

to the parkway built on Jones Island in the 1920s. The purpose of the wide embankment was to dissipate energy through wave runup. In addition, no homes or structures would be allowed on the seaward side of the roadway, allowing plants to grow and trap sand without impediment and giving the beach flexibility to adjust to wave forces. The Park Commission's plan was rejected by Suffolk County because of cost and opposition from Fire Island residents.

Clowes (1939; p. 52) describes the dune and inlet repair procedures that were used:

> So the plan was defeated and the rehabilitation work started on the old plan of filling in with brush and stumps. From early days this has been a successful way of building up the dunes. The brush and stumps hold the drifting sand and soon the beach grass begins to grow and tie to the sand with its long, tough roots.
>
> After promising success at first, this method of beach restoration showed serious weakness. Inlets which were stopped would be broken through again by the sea at high tides which so raised the level of the bays that they rose above much of the mainland formerly always above their reach. Stumps used as ballast for sandbags were too buoyant and after a heavy storm would float away. Late in the winter the idea of dumping old automobile bodies into the inlets was conceived and carried out. Auto "graveyards" were combed for old hulks and hundreds of these were finally used. They were dropped into the inlets by cranes, sandbags were added and, as the latter appeared above the water, sand was pumped over and around them by dredges. This did the trick and by March 1, all inlets were stopped except the old Moriches inlet and the one at Shinnecock Bay. It was intended to let these stay open.

Howard (1939) explained that it was very difficult to complete the final closure of an inlet. As sand was bulldozed into the gap, the velocity of tidal currents in the channel increased to the stage where rate of scour matched the rate of infilling. Howard did not mention the use of automobiles but described a form of gabion: "Sandbags weighing tons and enclosed with wire netting are lowered into the channel by crane. Nature is aiding the work by building a sandpit across the mouth of the funnel, thus cutting down on the volume of water entering the inlet." He also confirmed that the largest inlet into Shinnecock Bay was to be maintained as an aide to navigation.

Suffolk County ultimately shaped, filled, and replanted over 68 miles of dunes. As a result of the project, 9 of 10 inlets opened by the 1938 hurricane were closed, and the dunes were raised to a level where little danger from damage by ordinary high tides was expected.

During the following 6 years, the dunes were not maintained or filled when damaged, and, as a result, they offered little resistance to the hurricane of September 1944. The hurricane breached the dunes in many places (from USACE 1958a, Appendix G, "History of Storms"):

> 69. The beaches and dunes along the study area were hit hard. A survey by Suffolk County authorities after the storm disclosed that 63 sluiceways had been cut across the barrier beach between Fire Island Inlet and Southampton Beach and

that 53 had broken through on the mainland from Southampton eastward. Approximately 25,000 feet of dunes were lowered. In the vicinity of Napeague Harbor, Montauk Highway was flooded and about one mile of railroad track was washed out. The U.S. Coast Guard Station near Mecox Bay was evacuated due to tidal inundation.

Shinnecock Inlet Construction and Project Work, Post-1938

Various revetments and jetties have been built at Shinnecock Inlet since 1939. The newly opened inlet remained unstructured for only 5 months. Local officials and fishermen had long wanted Atlantic Ocean access from Shinnecock Bay and must have realized that the new inlet was susceptible to shoaling and closing naturally, as had happened to all previous inlets. To stabilize the shore and reduce inlet migration, the first bulkhead was built by Suffolk County along the west side of the inlet in 1939 (Figure A7). The WPA may have also helped support the bulkhead construction at the inlet (Figure 8). The structures consisted of a bulkhead 1,470 ft long with 20 short spur groins normal to the bulkhead (USACE 1958a). The works were constructed of two rows of closely driven timber piling with the intervening space filled with riprap and sand and cement-filled bags in galvanized wire cages. The structures were effective in preventing erosion of the west shore of the inlet for about 10 years.

The bulkhead deteriorated, and a 243-m stone revetment and 40-m groin were built in 1947 by local and State agencies. However, navigation through Shinnecock Inlet was hazardous because of shoaling and constantly shifting sand bars, and Suffolk County concluded that jetties would be necessary to stabilize the channel. In 1951, consulting engineers advised that, should jetties be built, annual renourishment of the west beach would be necessary to prevent erosion (Dent 1951). The engineers suggested that sand could be taken from the impoundment area on the east side. Stone rubble-mound jetties were finally built in 1953-1954 by the State of New York, Suffolk County, and the Town of Southampton. The east jetty was 415 m (1,461 ft) long and the west 257 m (846 ft). The jetties and revetments along both shores cost \$1,264,390 (USACE 1958a). An annual program of renourishment was never implemented. Table 11 lists construction and dredging at the inlet, and a more detailed chronological list of events is presented in Table D1.

In 1956, Suffolk County purchased a hydraulic dredge for dune rehabilitation and channel dredging. In December of 1956, 5,000 ft of the dunes immediately east of Shinnecock Inlet was raised to elevation of 20 ft above msl by the placement of 343,400 yd^3 of sand at a cost of \$170,000 (USACE 1958a).

The jetties deteriorated over time, and much stone was lost from the tip of the east jetty. The north (bay) ends of the jetties also suffered stone loss beginning in the mid-1960s (first seen in the 18 February 1966 photograph, Figure A21). As the east jetty deteriorated, scalloped indentations formed in the

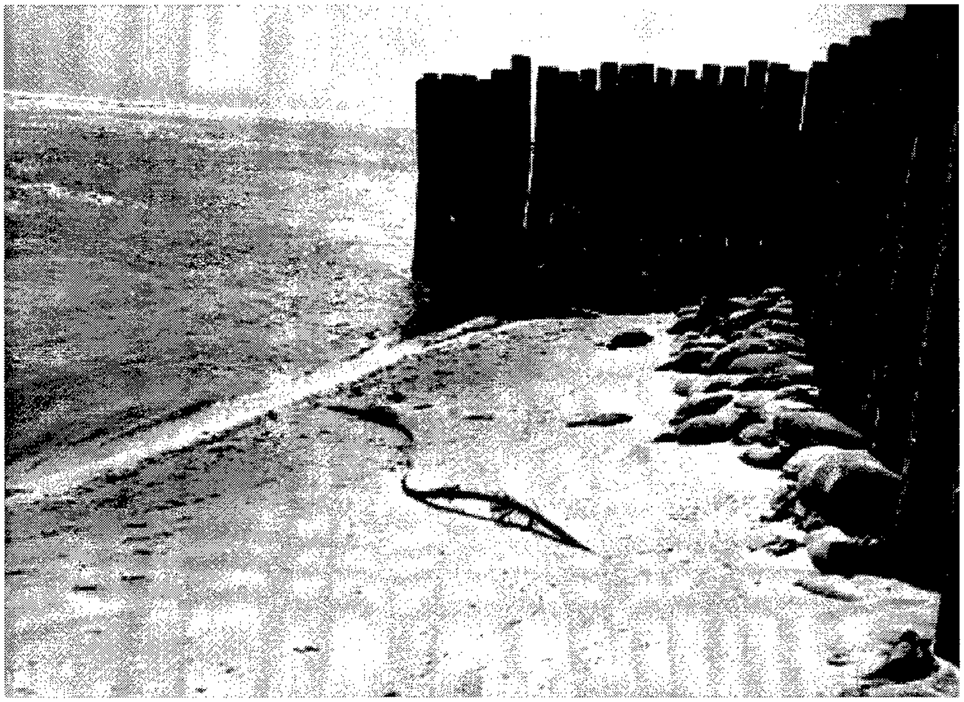

Figure 8. West bank of Shinnecock Inlet, 13 April 1939 (Black and white photograph from WPA archives, Control No. RG 69 Neg. 21000-D. Photographer unknown)

shoreline, and by 1992, the indentation in the east shore extended back about 200 ft from the former jetty position. The east revetment was repaired by the Federal Government in 1993-94. During the 1970s, the west shore also retreated as the stone collapsed. In the 10 August 1976 photograph (Figure A25), waves can be seen refracting into this pocket. The revetment was repaired in 1983 by Suffolk County Department of Public Works (Figure A27).

Shinnecock Inlet was adopted as a Federal project by the River and Harbor Act of July 14, 1960. The project was authorized for three project purposes: (a) navigation, (b) water quality, and (c) beach erosion. Water quality was of particular concern because fish and shellfish yields declined greatly in Moriches Bay between 1951 and 1953, when Moriches Inlet closed, and fishermen did not want a repeat of this situation in Shinnecock Bay should the inlet close naturally (United States 1959). Also, decreased salinity in Moriches Bay during 1952 and 1953 led to serious infestations of a flying insect, the *tendipes decorus*, known locally as the "fuzzbill." Navigation through Shinnecock Inlet was difficult because of shallow water and constantly shifting sand bars, and the controlling depth was only 1.8 m (6 ft).

Funds were not appropriated in 1960, so, although various engineering studies were conducted (USACE 1971; 1988), there was little tangible Federal presence at the site for 24 years until the emergency dredging of the inlet by the Federal dredge *Currituck* in 1984. The Federal Government took over

Table 11
Shinnecock Inlet Project History, Dredging, and Construction [1]

Date	Event	Notes	Reference
1939	Bulkhead	Bulkhead along west side, 1,470 ft long. Suffolk Co.	Table 2 of USACE (1971)
1947	Stone revetment	800-ft stone revetment and 130-ft groin, west side. Built by NY State, Suffolk Co., and Town of Southampton.	Table 2 of USACE (1971)
1951	Channel dredged	2,000 by 100 by 9 ft at inner bar. Suffolk Co.	Table 2 of USACE (1971)
1953	East jetty	1,363-ft stone rubble-mound jetty and 700-ft rock revetment. Built by NY State, Suffolk Co., and Town of Southampton.	Table 2 of USACE (1971)
1953	West jetty	850-ft stone rubble-mound jetty. Same sponsors.	Table 2 of USACE (1971)
1954	West jetty extension	West jetty extended to total length of 946 ft. NY State, Suffolk Co., and Town of Southampton.	Table 2 of USACE (1971)
1960	Federal project adopted	Existing project at Shinnecock Inlet adopted by the River and Harbor Act of July 14, 1960 (H. Doc 126, 86th Cong., 1st sess.). Authorized for three project purposes: 1. Navigation 2. Water quality 3. Beach erosion Although adopted, no Federal work conducted.	Ann. Rept. of Chief of Engineers, U.S. Army, 1961; United States (1959)
1983	West revetment repair	Revetment near commercial docks repaired by Suffolk County Department of Public Works	Mr. Tom Rogers, Suffolk Co. Dep. of Public Works (Personal Communication, 1/15/99)
1984	Dredging	*Currituck* removed 176,000 yd^3 emergency dredging from various locations in inlet to -14 ft mlw. Disposal west of inlet at -10 ft mlw.	Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication, 11/13/95)
7 Jun 1990	Cost-share agreement, navigation project improvements	Local Cooperation Agreement executed with New York State Dep. of Environmental Conservation. Cost allocation 69 percent Federal and 31 percent non-Federal.	Report of the Sec. of the Army on Civil Works Activities for FY 1990
1-23 Oct 1990	Dredging	668,000 yd^3 dredged from deposition basin (ebb shoal). Disposal: 1. 138,000 yd^3 west of west jetty 2. 77,000 yd^3 to fill scour hole by west jetty (channel side) 3. 193,000 yd^3 stockpiled on east side of inlet to use as fill behind revetment 4. 260,000 yd^3 at Ponquogue Beach Sand placed in scour hole lost within 1 year. Final contract amount $2,261,526	Report of the Sec. of the Army on Civil Works Activities for FY 1991; Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication, 11/13/95)
10 Dec 1991	Cost-share agreement, jetty reconstruction	Local Cooperation Agreement executed with New York State Dep. of Environmental Conservation.	Report of the Sec. of the Army on Civil Works Activities for FY 1992
21 May 1992 - Nov 1994	Jetty repair	Rehabilitation of jetties, including rebuilding east and west tips to bring jetties back to original, pre-Federal length. New underlayer and bedding stone added to some areas along with new facing stone.	Report of the Sec. of the Army on Civil Works Activities for FY 1992; 1995

[1] See Table D1 for a more comprehensive list of engineering and natural events at Shinnecock Inlet and vicinity.

(Continued)

Table 11 (Concluded)[1]			
Date	**Event**	**Notes**	**Reference**
29 Jan - 14 May 1993	Dredging	475,000 yd^3 dredged from deposition basin (ebb shoal). Contract 92C0032. Disposal: 1. 371,000 yd^3 west of west jetty 2. 104,000 yd^3 to fill scour hole	Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication, 11/13/95)
27 Jun - 11 Jul 1998	Shinnecock Inlet dredging	Phase 1: Government dredge *Currituck* removed 35,000 yd^3 from entrance channel and deposition basin from above -14 ft contour. Placed in surf zone of west beach starting 500 ft and ending 1,800 ft from west jetty.	Project notes, Construction Div., New York District (Adam Devenyi, Personal Communication, 08/09/98)
13-25 Sep 1998	Shinnecock Inlet dredging	Phase 2: 405,000 yd^3 removed from entrance channel and deposition basin from above -22 ft contour. Material specified to be placed on west beach between west jetty and 3,500 ft west, forming a berm 225 ft wide and 9.5 ft high.	Project notes, Construction Div., New York District (Adam Devenyi, Personal Communication, 10/05/98)

responsibility for maintenance of the Shinnecock Inlet channel in 1990, and Construction General funds were used for construction between 1990 and 1995.

The revised project design, as specified in the General Design Memorandum (USACE 1988) was for navigation improvement only. The other two purposes specified in the 1960 authorization, water quality and beach erosion, were no longer considered necessary or desired by local interests (USACE 1988; p. 18-19). The new design called for the navigation channel that crossed the ebb shoal to be enveloped by a deposition that would allow advance maintenance and storage of littoral sediments. The basin, to be located seaward of the jetties, was to be 790 m (2,600 ft) long, 240 m (800 ft) wide, and have an elevation of -6 m (-20 ft) mlw (Figure 2). The basin was first dredged in October 1990, when 660,000 yd^3 of sand was removed and placed in several locations around the project.

The jetties were rehabilitated between 1992 and 1994 with the addition of new underlayer, bedding, and facing stone in various areas and repairs to the east and west tips to bring them up to their original, pre-Federal, length. Part of the rehabilitation consisted of filling a 10- to 15-m-deep scour hole east of the tip of the west jetty (maximum depth, -22 m NGVD in June 1987). After the hole was filled with sand, a rock apron was placed on the seafloor to prevent further scour. Recent hydrographic surveys show that the channel has been deepening southeast of the original scour hole.

Because of severe erosion, the Federal Government, State of New York, and Suffolk County have placed sand from various sources on the west beach many times. Records are incomplete, but known quantities are listed in Table 12.

Table 12
Sand-Placement Volumes, West of Shinnecock Inlet [1]

Date	Agency	Volume (yd^3) [2]
1948	Suffolk County	40,200
Total 1940-1949		**40,200**
1951	Suffolk County	120,000
Total 1950-1959		**120,000**
1968	Suffolk County	270,300
1969	Suffolk County	113,000
Total 1960-1969		**383,300**
1972	Suffolk County	14,000
1973	Suffolk County	250,900
1973	Suffolk County	176,300
1977	Suffolk County	10,000
Total 1970-1979		**451,200**
1983	Suffolk County	42,500
1984	USACE	176,000
1989	Suffolk County	83,000
Total 1980-1989		**301,500**
1990	NY State?	106,000
1990	USACE	398,000
1992	?	12,000
1992	?	8,000
1993	USACE	371,000
1995	NY State	3,000
1996	NY State	16,000
1997	NY State	250,000
1998	USACE	35,000
1998	USACE	405,000
Total 1990-1998		**1,604,000**
Total 1940-1998		**2,900,000**

[1] West Jetty to Ponquogue Bridge area, not including Quogue or Westhampton beaches.
[2] Data may be incomplete, with emergency fill after winter storms not listed.
Sources: Records from New York District general design memoranda and survey reports, and data provided County and local governments (see Table D1).

4 Inlet and Barrier Morphology, 1938-1998[1]

Phase 1 - Breach and Natural Inlet, 1938

30 June 1938 (Figure A1). This is the only known pre-inlet photograph of the barrier south of Shinnecock Bay. It shows a barrier with bare beaches and partly vegetated dunes. About half the width is vegetated. Shoal areas in the bay suggest that there may have formerly been an inlet near here, and no fresh overwash fans are visible.

During the 21 September 1938 hurricane, four openings were cut in the barrier. The largest opening, the present inlet, formed where an older channel cut about halfway across the beach. This cut appears to be man-made because it is narrow and is located at the southern end of a channel that crosses shoal areas of the bay. Most likely, this cut was all that remained of the inlet dug in 1896 by the Shinnecock and Peconic Canal Company (Whitford 1906).

How was the inlet formed? During storms, a barrier can be breached in either of two directions: ocean waves can erode the ocean shoreface and finally crash through the barrier; or the back bay can fill with rainwater and runoff and then burst forth through the barrier at a low, vulnerable spot. In the case of Shinnecock Inlet, both mechanisms probably played a role. Initially, the storm overwashed Southampton Beach, eroding dunes and depositing fans of sand in Shinnecock Bay. As the storm progressed, the water in the bay rose and finally cut through the barrier at several locations. As the beach was already partly penetrated by the 1896 canal, the bay waters were readily able to scour the remaining distance out to sea and enlarge the cut during the following days as the water drained out. The 24 September photograph shows a small ebb shoal at the seaward end of the inlet, probably formed from sand eroded from the barrier.

24 September 1939 (Figures 7 and A2). The first posthurricane photographs were taken by the Army Air Corps only 3 days after the storm. The seas had

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[1] Vertical aerial photographs discussed in this section are presented chronologically in Appendix A.

calmed, but the large number of overwash fans attest to the violence of the waves only 3 days before. The prestorm shoreline in this area trended at an azimuth of 66 deg (southwest-northeast). In the 24 September photographs, the breach had an azimuth of 130 deg, only 65 deg from the shoreline trend. Drift was to the east because spits had grown from west to east across the mouths of the new openings.

29 November 1939 (Figures A3, A4, and A5). The inlet had begun to turn clockwise and was about perpendicular to the shoreline trend. The mouth was wider as the west shore eroded. The ebb shoal was more U-shaped and protruded further out to sea. Some shoals in Shinnecock Bay attest to the beginning of flood shoal growth.

20 December 1939 (Figure A6). In a month, the inlet's mouth had widened further. The ebb shoal had flattened and spread against the shore. From the data at hand, it is unclear if the shoal had gained sand or simply changed shape.

Summary. The natural inlet widened rapidly after it was formed. The flood shoal's growth was supplied by sediment carried in from the open coast by tidal currents. The ebb shoal changed shape rapidly from oval to flattened, depending on the balance of tidal current versus wave energy. Based on the photographs, it is not possible to confirm if the natural inlet was migrating westward, as has been stated in the literature (Nersesian and Bocamazo 1992; Panuzio 1968).

Phase 2 - Inlet Stabilized on West Side, 1939 - 1951

24 February 1939 (Figure A7). Trucks and building materials can be seen at the end of the road on the west beach. A revetment appears to have been built near the seaward mouth of the inlet (this may be the scene shown in Figure 8). Compared with 29 November, the flood shoal had grown considerably, while the ebb shoal was more rounded than in 20 December.

21 March 1939 (Figure A8). Much of the revetment had been completed along the west side, reinforced with short groins. The oval shape of the ebb shoal is outlined by the change in wave crests off the mouth of the inlet. The bay side of the east shore had receded by action of the tidal current in the channel that curves east and then north around the flood shoal. Erosion of this bay-side shore would prove to be a problem for the next four decades.

11 April 1939 (Figure A9). The revetment was complete, and the short groins ran along the west side of the channel and curve to the southwest on the south end of the inlet. The seaward shore of both the east and west beaches had eroded since the March photograph. Breaking waves outline the ebb shoal.

1941 (Figure A11). This photograph is from a series of high-altitude images that cover all of eastern Long Island. The exact flight date is unknown, but

“1941” was written with a grease pencil on one of the frames. In 2 years, the inlet had widened greatly, to about 275 m (900 ft) from the revetment to the protrusion on the east shore. The channel east of the flood shoal was the main access between Shinnecock Bay and the Atlantic Ocean. A complex of marshes and sand bodies, some of which are vegetated, existed west of the new flood shoal. These are evidence of former flood shoals and washovers. In the inlet, the deep channel hugged the west shore. The channel disappeared when it reached the ebb shoal, and there did not seem to be any deep water that could serve as a navigation channel. The ebb shoal had grown greatly since 1939 and in 1941 was asymmetric, extending more to the west than the east. The downdrift junction with the shoreline was about halfway between the inlet and the Ponquogue Bridge.

22 April 1946 (Figure A12). The main channel still hugged the west side of the inlet. The flood shoal had expanded, but there were no emergent areas. The channel still ran along the west shore revetment, and the east two-thirds of the inlet was shallow. The west part of the ebb shoal appears to have been removed. In contrast to 1941, the west side of the shoal ended just west of the inlet, and a marginal flood channel ran along the west shore. Growth of the flood shoal and contraction of the ebb shoal suggest that sediment transport was into the inlet during this phase of the inlet’s life.

1 April 1947 (Figures A13 and A14). A sudden change: in only a year, the deep channel had turned anticlockwise (to the southeast) compared with 1946. As a result of the channel turning to the east, a beach formed at the base of the revetment, running the full length from Shinnecock Bay to the Atlantic. At the mouth of the inlet, a spit had grown out to sea from the west beach. The east shore of the inlet continued to erode and at this time had an orientation of almost east-west (Figure A14). In addition to the spit extending from the west beach, two sand shoals emerged in the mouth of the inlet. The flood shoal is prominent in these photographs (probably taken at low tide when the water was unusually clear).

In 1947, two channels followed the east and west edges of the flood shoal and joined together at the inlet. The east channel, which was dominant in the past, shoaled near the top of the photograph and where it joined the inlet (i.e., the thalwegs were not continuous). The most direct path from the Atlantic Ocean to the bay was via the west channel, and here the thalwegs were continuous. The most recent dredging had been in 1943, but the records are unclear exactly where this navigation channel was dug. The change in dominance from the east to the west channel appears to be a natural shift.

29 November 1950 (Figure A15). The channel had rotated clockwise again and once again followed the west-beach revetment. The beach at the base of the revetment had completely eroded away. The spit that formerly extended out from the west beach had disappeared, as had the two exposed shoals in the mouth. The east two-thirds of the inlet was a shallow platform that merged into the east beach. Waves breaking straight across the mouth of the inlet suggest that the ebb shoal had flattened against the shore. This photograph was taken

4 days after a major northeaster, noted in several references (see Table D1), affected the area. Three breaks opened into Shinnecock Bay near Quogue, and a major breach opened at Westhampton. However, no obvious storm damage can be seen in this photograph.

Early-1951 (?) (Figure 9). The mouth of Shinnecock Inlet was almost completely blocked by a spit that grew west from the east shore. Navigation would have been difficult or impossible under these conditions. This blockage of the inlet may have been the deciding evidence used to secure authorization and funding for jetty construction.

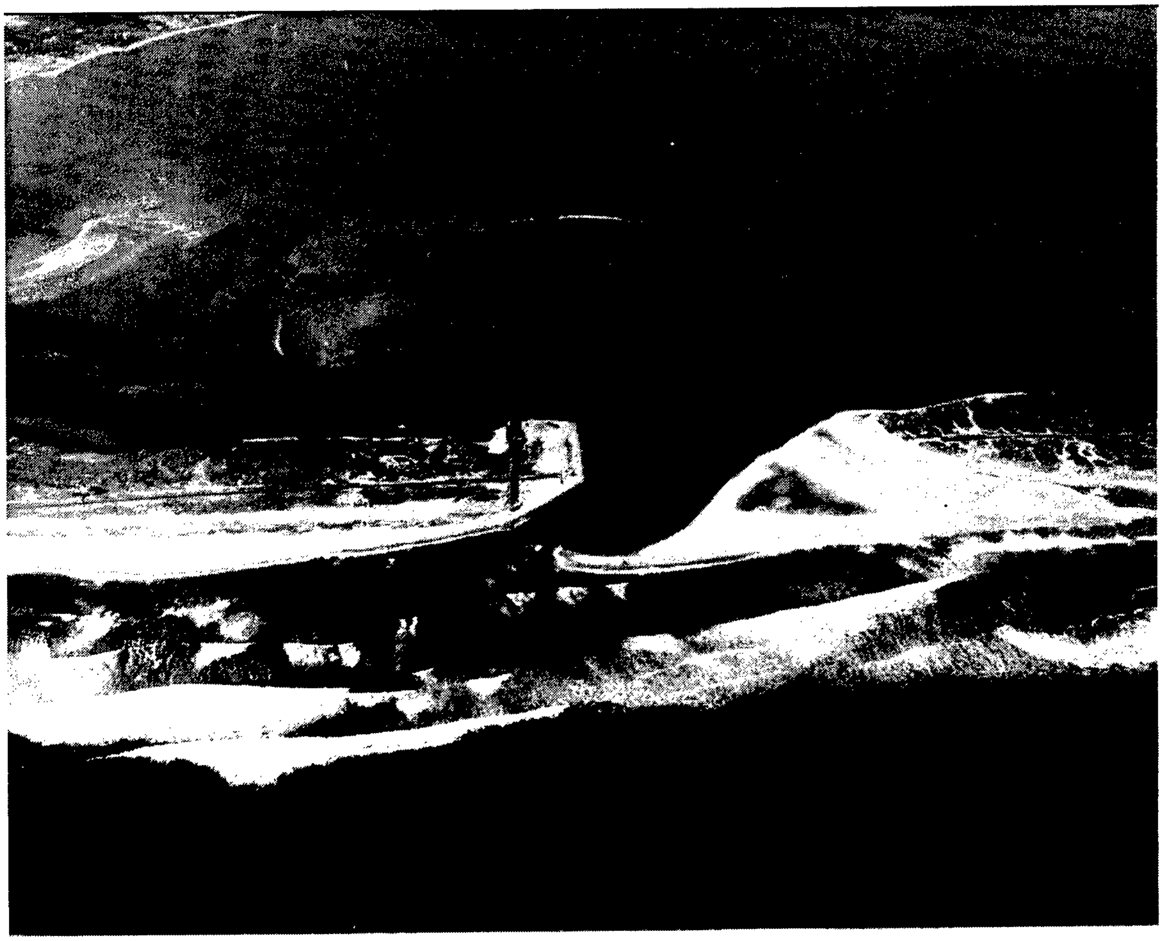

Figure 9. View looking south to Atlantic Ocean, 1951 (A sand spit has almost blocked mouth of Shinnecock Inlet. Photograph not dated but most likely is late 1950 or early 1951, based on comparison of geomorphic features) (Westhampton Photo Studio, from Suffolk County Department of Public Works)

Summary. Between 1939 and 1951, the revetment on the west side of the inlet anchored the inlet in its present location. For most of the decade, the thalweg followed the west side of the inlet, but for a short period (1947), the inlet rotated to a more east-west orientation. This is similar to the orientation that existed just after the 1938 hurricane. The change in orientation probably occurred during an interval when littoral drift was directed west to east, although it may reflect changes in flow through and around the back bay. In late 1950 or early 1951, the mouth of the inlet was almost blocked by a spit that projected from the east beach. Between 1939 and 1951, most sediment transport was probably directed into the bay because the flood shoal grew noticeably in area. The ebb shoal changed shape often, sometimes being flattened against the shore and sometimes protruding further out to sea. There are insufficient data to determine if ebb-shoal volume increased during this period.

Phase 3 - Stabilized Inlet, Dual Jetties, 1952 - Present

18 August 1952 (Figure A16). Construction of the stone rubble-mound east jetty was underway. The north side of the east beach had scoured and a spit extended out into the Atlantic from the west beach. An oblique aerial photograph from 24 August shows that the channel at this time ran approximately northeast-southwest, closely following the revetment on the west shoreline (Figure 10). In the back bay, three channels merged just north of the inlet. The west channel was dredged and appeared to be navigable. The former east channel just north of the inlet had shoaled, and the channel directly north of the east beach had also shoaled. It is unknown if either of these were maintained regularly.

30 April 1953 (Figure A17). The east jetty had been completed. The inlet channel had rotated to a NE-SW orientation, eroding the inner shore of the east beach right up to the stone jetty, and a spit extended out from the west beach into the inlet. A dredged navigation channel ran to the northwest through shallow portions of Shinnecock Bay, but apparently this channel did not carry much water in comparison with the east channel. In the flood shoal, an island had emerged just north of the inlet.

10 March 1956 (Figure A18). The west jetty had been completed, and the channel was now restricted to a north-south direction. This orientation is to the right (clockwise) of perpendicular. It seems as if the designers oriented the jetties to approximately follow the path that the inlet followed in the early 1950s. In this photograph, a spit extends out from the west beach into the inlet. The updrift (east) fillet had grown seaward since the previous photograph was taken (1953). Note that the west beach was straight and aligned with the seaward tip of the west jetty. The ebb shoal barely projected beyond the east jetty, but it already extended down the west beach for 300 or 400 m.

Hurricane Carol in August of 1954 damaged the dunes and east jetty and bay-side revetment according to published reports (see Table D1). In the 1956 photograph, damage is difficult to detect, but the bay end of the east revetment is missing compared to 1953.

Figure 10. Photograph taken during construction of east jetty, 24 August 1952 (Channel runs northeast-southwest, closely following revetment on west shoreline and heads out to sea just east of a spit on Tiana Beach. Ebb shoal has an almost straight seaward margin. On flood shoal, three channels merge at bay end of inlet. Two of these channels, east and central, have shoaled) (Westhampton Photo Studio, from Suffolk County Department of Public Works)

8 March 1962 (Figure A19) This photograph was taken at the end of the Ash Wednesday storm (6-8 March) (see Table D1). Waves were breaking on the ebb shoal, which was beginning to form a U-shaped body off the mouth of the inlet. The spit in the inlet had disappeared. The ocean side of the west beach had noticeably eroded, a problem that still persists. Docks for the fishing cooperative had been built on the bay side of the west beach.

25 March 1962 (Figure A20). The seas were much calmer than in the 8 March photograph. The bulge on the west beach where the ebb shoal attaches to the shore was about halfway between the inlet and the Ponquogue Bridge. In the following 35 years, the bulge would migrate west until it was adjacent to the bridge. The entire flood shoal is visible in this high-altitude image. There were two channels in Shinnecock Bay. The west one, which led to the Ponquogue

Bridge, was the navigation channel that was dredged on irregular intervals. The east channel forked north of the east beach, with both forks leading into shoals.

18 February 1966 (Figure A21). This is the first photograph in which damage can be seen at the bay (north) end of the west jetty. The shoreline on the east side of the inlet had scalloped where part of the jetty had collapsed. Wave crests diverged near the seaward end of the east jetty; some waves continued through the inlet, while others impinged directly on the west beach. Wave energy concentrating in this 300- to 400-m-wide stretch of beach may be the main cause of the persistent erosion.

23 February 1972 (Figure A22). The west beach had retreated compared with 1966. The north ends of the east and west jetties had deteriorated, and scalloped indentations in the shore had formed. Additional berthing areas at the fishing cooperative had been excavated by this date.

6 April 1976 (Figure A23). Sometime before this picture was taken, the beach west of the west jetty had eroded as far as the road, destroying the vegetated dunes. The white beach seen in the image must be a recent repair (documentation unavailable - see Table D1). The bulge in the shoreline west of the inlet marked where the ebb shoal attached to the shore.

The vegetated island known as Warner Islands remained almost unchanged during the 1960s and 1970s. This island is a constant feature in the Bay and has lasted long enough to have been named.

Between 1962 and 1976, various features on the flood shoal moved and changed shape, although it is unclear if the overall shoal increased in volume. In 1976, a linear sandbar protected grassy areas on the lee side. The most noticeable change was a circular shoal, about 500 m wide, that had grown northward into Shinnecock Bay, located directly in line with the bay-side mouth of the inlet. A closeup view of the north (bay) end of the inlet shows how this shoal formed: circular wave crests, a result of wave diffraction, propagate out of the inlet and over the shoal (Figure A24). Waves can also be seen refracting into the scalloped indentation in the shore immediately north of the end of the west jetty.

10 August 1976 (Figure A25). The west beach was almost flush with the end of the west jetty. Only minor changes in the flood shoal had occurred compared with the previous (April) image. The new circular shoal is easy to see in this image. Compared with 1962, the ebb shoal had grown and extended much further offshore.

24 March 1980 (Figure A26). The west beach had eroded since the previous photograph was taken 4 years earlier. The dune just west of the west jetty had been revegetated. Exposed sand spits on the flood shoal had changed shape. Three oblique aerial photographs provide a clear view of conditions at Shinnecock in January of 1980 (Figures 11, 12, and 13).

Figure 11. View south to Atlantic Ocean, 18 January 1980 (Waves can be seen bending over ebb shoal and concentrating on pocket west (to right) of west jetty. Note deterioration of both the east (left) and west jetties) (Topo-Metrics image 08013 0-13)

2 April 1983 (Figure A27). This image does not show major changes compared with 1980. The most seaward part of the ebb shoal had moved west. A spit had begun to grow out from the tip of the east jetty. The west beach had eroded, and the wet sand line was near the road. The U-shaped erosion hole in the west side of the inlet (near the fishing docks) had been repaired.

21 April 1983 (Figure A28). In this high-altitude photograph, the oval shape of the ebb shoal is outlined with breaking waves and light-colored water. The bulge where the ebb shoal connects to the downdrift (west) shoreline had moved about 500 m west compared with 1976.

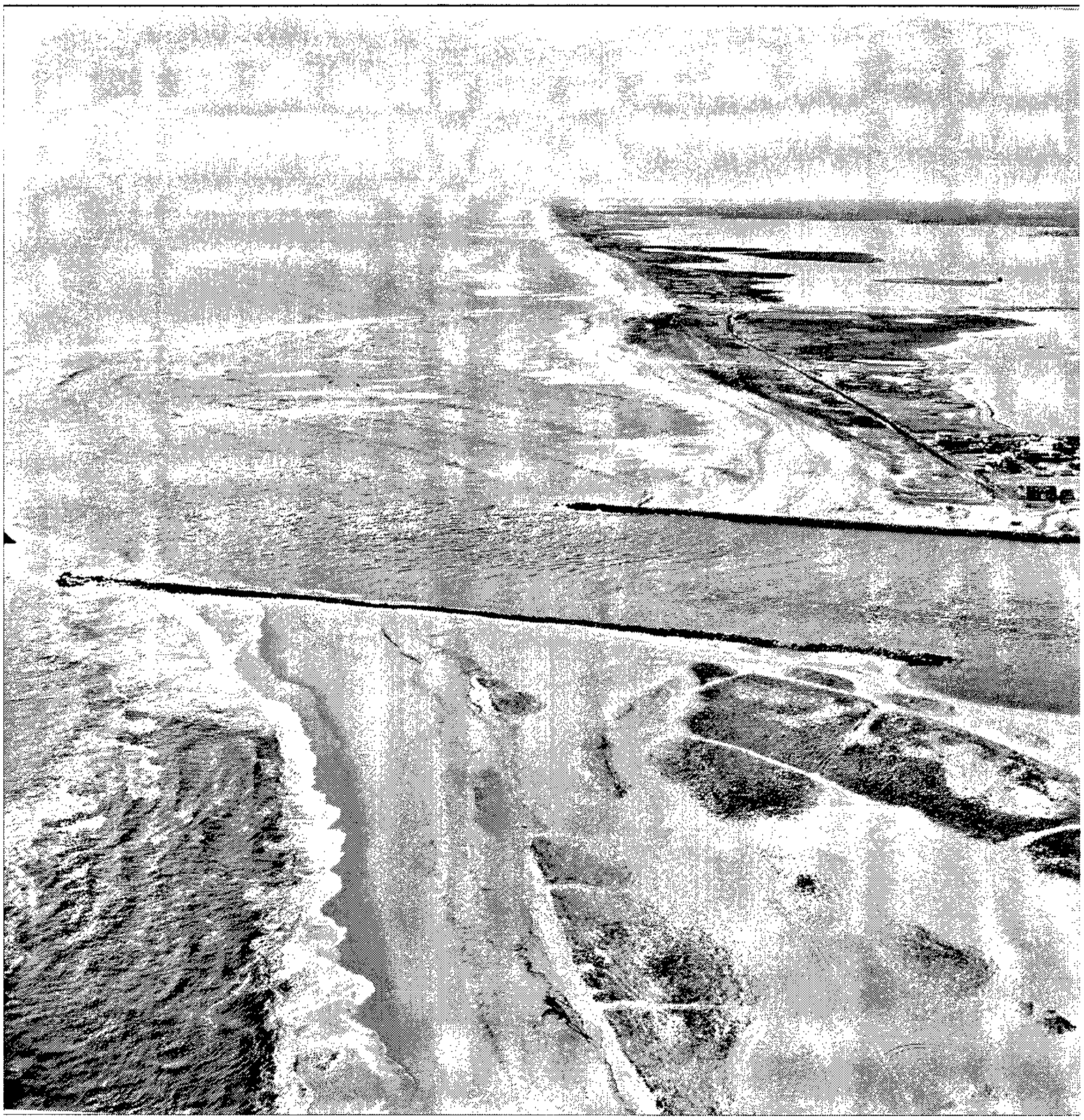

Figure 12. View west along Long Island shoreline, 18 January 1980 (Atlantic Ocean is to left and Shinnecock Bay is to right. Just beyond west jetty is pocket where wave energy appears to be regularly concentrated. Further west, adjacent to Ponquogue bridge, a shoreline bulge marks where ebb shoal attaches to shore. A line of foam outlines edge of shoal. Barrier island shoreline further west is straight for many kilometers. A sandbar parallels shore with only a few breaks) (Topo-Metrics image 08013 0-11)

27 April 1984 (Figure A29). Only minor shoreline changes occurred since 1983. However, the dune had eroded further, and the vegetation line stopped well west of the fishing docks.

1985 - 1992 (Figures A30-A36). During 1987-1988, the west beach eroded and was renourished in 1989. The Halloween Northeaster of 30-31 October

Figure 13. View east, with Atlantic Ocean to right, 18 January 1980 (Triangular-shaped updrift fillet is pronounced just beyond east jetty. Original, pre-inlet dune line approximately followed white line that marks dune crest in distance. Road paralleled dune crest and continued west before inlet was cut in 1938. Tip of west jetty has deteriorated. Remains of 1940 revetment are not visible in this image) (Topo-Metrics image 08013 0-16)

1991 caused extensive erosion along Long Island, but, surprisingly, prestorm and poststorm photographs show little shoreline change near the inlet (Figures A34 and A35). Additional fill may have been added during winter emergency repairs, but these quantities are not documented. Sandbars/shoals moved and reformed on the flood shoal. The main mass of the flood shoal appears to have moved north further into Shinnecock Bay between the 1960s and 1990s, but the photographs may be deceptive. Bathymetry data show that the channels just north of the barriers were dredged for navigation. Therefore, the overall flood shoal may not have migrated, but, rather, the southern portion was mechanically removed.[1]

29 Sep 1992 (Figure A36). By 1991-1992, the east jetty had deteriorated badly and the bay side of the east beach had eroded severely. From 1992 to 1994, the New York District repaired the jetties to their original condition. In this image, a barge can be seen moored in the east channel in Shinnecock Bay, near the scalloped scour indentations in the shore. The west beach had also eroded severely.

18 Dec 1992 (Figures A37, A38, and A39). In 3 months, the east beach advanced almost to the tip of the east jetty. The west beach continued to erode until waves were breaking only a few meters from the highway. The shoreline bulge where the ebb shoal joined the beach was opposite of the Ponquogue Bridge. This was in contrast to 1983 and 1988, when the bulge was smaller and located further east. During the northeaster of 11-14 December, a 400-m-wide section of the barrier just west of the docks was overwashed.

A close-up of the inlet shows wave crests propagating up the inlet and diffracting at the bay opening (Figure A39). Starting from a zone of disturbed water left of the tip of the east jetty, some waves propagate directly toward the west beach. Wave energy appears to be concentrated in this pocket across the street from the fishing docks. The photograph was fortuitously taken under the right conditions to show the waves breaking in the pocket, but the continuing erosion over four decades suggests that this had been a common process since the jetties were built.

1993 - 1998 (Figures A40-A53). This period was characterized by the following:

- *Continued erosion of the west beach.* In January-May of 1993, the west beach was renourished with 371,000 yd^3 of sand dredged from the deposition basin. In March, the highway department placed stone parallel to the road and backfilled the beach between the stone and the road. A photograph taken 14 June 1993 (Figure A41) shows a wide, healthy beach, but within a year, the beach had eroded badly again (Figure A43). From 1993 to the present, the beach has eroded every winter, and the highway department has been forced to make numerous emergency repairs to protect the road.

- *Ebb shoal - continued growth.* As stated earlier, by 1991, the ebb shoal extended west as far as the beach opposite the Ponquogue Bridge. During the 1990s, the ebb shoal was an approximately symmetric oval of sand, but compared with the 1960s and 1970s, it had been pushed about 500 m west of the inlet mouth. This is best seen in the spectacular photograph of 24 October 1996 (Figure A48) where the water is clear enough to see the bottom. The most

[1] Flood shoal volumes are discussed later in this report.

seaward projection of the shoreline bulge was located about 400 m east of the bridge, but breaking waves showed that the west end of the shoal still attached to the shore across from the bridge. Fluctuations in the direction of longshore drift may cause the bulge to move back and forth. The overall shoal appears to still be growing, but this is not confirmed with hydrographic surveys (discussed later in this report).

- *Flood-shoal mobility.* Shoals and sandbars on the flood shoal continued to move and change shape. The overall flood shoal may possibly have moved further north into Shinnecock Bay, but without rigorous mapping, this cannot be confirmed. The east and west channels seemed to become more deeply entrenched compared to the 1960s and 1970s, but this may have been the result of more regular maintenance dredging.

- *Hazardous navigation conditions.* Shinnecock Inlet has a reputation as a dangerous inlet, and several boats have overturned near the mouth. The photograph of 24 October 1996 (Figure A48) was taken on a clear day with high seas. Confused waves can be seen within the channel, and there are breaking waves about 60-100 m in from the tip of the west jetty. This is exactly where a ridge of sand crosses the inlet. The ridge separates the east thalweg from the scour hole near the end of the west jetty (discussed later).

Summary. From 1952 to the present, Shinnecock Inlet has been confined between stone rubble-mound jetties. During this period, the ebb shoal grew seaward and westward in the form of a half oval. The most seaward projection of the oval is not aligned with the inlet but is shifted to the west 200 to 300 m. A bulge in the west shoreline marks where the ebb shoal attaches to the shore. Over 40 years, the west edge of the shoal moved about 1,200 m from just west of the inlet mouth to opposite the Ponquogue Bridge, an average of 30 m per year. Although the flood shoal changed shape as sand bodies moved around, it did not appear to grow larger. This suggests that the jetties prevented most sediment from entering the inlet because the flood shoal grew steadily before the jetties were built.

Since the jetties were built in 1951-1953, the west beach has experienced persistent erosion, to the degree that the road has been threatened and the barrier is in danger of being breached. One possible reason for the erosion is that wave energy is concentrated in the pocket just west of the west jetty. Several photographs showed that this phenomena occurred when waves were from the south (Figures A21, A32, A37, A39, and A40). It is likely that once sand is eroded from the beach and mobilized, currents carry it offshore past the jetty on to the ebb shoal.

5 Bathymetric Data and Ebb-Shoal Morphology

1933

The most complete pre-inlet regional hydrography was collected by the USC&GS in 1933 (Atlantic Ocean: Charts H-5324 and H-5325; Shinnecock Bay: Chart H-5323). These data are conveniently available from the National Geophysical Data Center on CD-ROM and have been used in this report to depict the baseline conditions in the area. The 1933 tracklines are not as tightly spaced as lines in more modern surveys, but still are comprehensive considering that, at least in shallow water, measurements were made with sounding poles or lead lines (Shalowitz 1964). Figure B1 shows the 1933 data contoured at 2-ft intervals. In these figures, a modern shoreline has been included for reference, but the reader must remember that Shinnecock Inlet was not open then. This shoreline, also shown in subsequent figures, is based on 1995 aerial photographs. Information on these and other data sources are listed in Table B1.

In 1933, the Atlantic shoreline was almost straight and showed no obvious evidence of older inlets (Figure 6). From the shore to about 7 m, a series of bars are evident in the contoured bathymetry. Deeper than 7 m, offshore contours are reasonably straight and parallel.

Behind the barrier, Shinnecock Bay was less than 3 m deep until approximately 1 km north of the barrier. A deeper finger pointing south toward the present inlet location may be a remnant of the channel dug in 1896 for the Peconic and Shinnecock Canal project.

The 1933 data were referenced to mlw. However, in 65 years, rsl in this area has risen about 0.18 m, based on the annual trend computed by NOAA for the Battery in New York Harbor (Table 3). In other words, the 1933 mlw datum was lower than the contemporary mlw datum, and, therefore, any individual 1933 depth point must be made deeper to be directly comparable with contemporary data. In this report, the 1933 soundings were increased by 0.177 m, a value obtained by multiplying the trend, 2.72 mm/year × 65 years. Note that the adjustment is based on the average trend, but in any one year, actual rsl may deviate greatly from the trend because of numerous oceanographic and climatologic factors. Finally, the 1933 points were increased by 0.34 m to adjust from mlw to NGVD (1929) to allow direct comparison with modern surveys that are referenced to NGVD. Adjustments are summarized in Equation 1 and described in more detail in Appendix F:

$$\begin{aligned} Z_{(MODERNm)} - Z_{(1933\ mlw)} &= 0.177\text{ m} \\ Z_{NGVD} - Z_{(MODERN\ mlw)} &= \underline{0.34\text{ m}} \\ Z_{NGVD} - Z_{(1933\ mlw)} &= 0.517\text{ m} \end{aligned} \tag{1}$$

1949

Shinnecock Inlet and its ebb and flood shoals were surveyed by the USACE in July and August of 1949. By this time, the State of New York, Suffolk County, and the Town of Southampton had built a 240-m stone revetment on the west side by the inlet. Only 11 years after the inlet was breached, a broad, oval-shaped ebb shoal had already formed (Figure B3). It extended about 1,500 m to the west, 400 m offshore, and at least 600 m to the east of the inlet's mouth (the survey did not extend far enough east to cover the full shoal). The top of the shoal was at a depth of about 3 m, and the bar front dropped steeply from 3 m to the seafloor beyond 6 m. In the flood shoal, two dredged channels are evident, one extending from the landward end of the inlet to the west and another extending northeast and then north.

1994

In June and August of 1994, Shinnecock Inlet and the ocean coast between Moriches and Shinnecock inlets were surveyed with the SHOALS[1] helicopter-borne hydrographic LIDAR survey system. The tremendous data density recorded by the SHOALS system provided unprecedented seafloor detail. Unfortunately, the 1994 surveys were not flown far enough out to sea to cover the entire ebb shoal. The contoured data (Figure B16) show that the ebb shoal attached to the downdrift shore about 2 km west of the west jetty. The shoal platform had depths about 3 m below NGVD. The deep area seaward of the jetties was the deposition basin from which 363,000 m^3 (475,000 yd^3) of sand were removed in early 1993.

Based on comparisons with other hydrographic data, it appears that the tidal corrections made during the SHOALS survey may be in error, so these data cannot confidently be used for volume computations.

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[1] Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) is a survey system based on a helicopter-mounted laser. Surveys can be conducted in clear water to about -20 m depth (Estep, Lillycrop, and Parson 1994; Lillycrop and Estep 1995). Off Long Island, maximum water penetration of the laser signal was about 10 to 12 m in 1994, 1996, 1997, and 1998.

One unusual morphologic feature is a deep pit - almost a channel - located about 300 m west of the west jetty trending approximately in a north-south direction. The pit was offshore of the portion of the beach experiencing the greatest erosion. No data were collected directly offshore, so the maximum depth of the pit is not known.

1996

The SHOALS helicopter system surveyed Shinnecock Inlet again in 23 May 1996 and an area off Westhampton Beach on 2 June. This survey covered the ebb shoal more completely than the 1994 survey, as shown in Figure B20.

The shoal was shaped in the form of two irregular lobes that flanked the mouth of the inlet. These are outlined by the 20-ft isobaths. The east lobe was narrow and projected seaward parallel to the east jetty. The west lobe was approximately triangular-shaped, with the seaward edge dropping off to the south. The bar front on this west lobe was marked by closely spaced contours that extended from about 3.0 to 6.7 m. The west end of the lobe approached the shore about 1,800 m west of the west jetty.

The west edge of the ebb shoal is much shallower than the east edge. The 10-ft isobath outlines a spit that projects out the west edge of the shoal from the shoreline bulge. The shape would suggest that sediment was moving out from the shore towards the east.

A north-south channel ran from the mouth of the inlet seaward between the two lobes. This is the area that was dredged as a deposition basin in 1993, which in 1996 was still deeper than the surrounding ebb-shoal lobes. Seaward (south) of the channel, the shoal dropped off into deep water, with the bar front extending from 9 to 12 m. The distance from the end of the jetties to the seaward edge of the shoal was about 1,100 m.

The deep pit adjacent to the west jetty, seen in 1994, was still present. Depths greater than 5.5 m were found within 150 m of shore. The pit extended perpendicular to the shore and did not resemble marginal flood channels found at many other inlets (these are typically parallel to the shore and channel the flood tide into unjettied inlet mouths). The linear pit must be maintained by a combination of waves and tidal currents. In the aerial photographs, waves often seem to be concentrated in this region. Current and wave data are now being collected (1998) to evaluate the mechanisms responsible for the erosion.

1997

The SHOALS system surveyed Shinnecock Inlet again on 13 August 1997 (Figure B21). This coverage extended further north into the flood than the 1994 and 1996 flights. The east channel can be seen running east and then north through the flood shoal. The west channel near the boat docks was not surveyed.

On the ebb shoal, the overall shape remained almost unchanged from 1996. The 10- and 20-ft isobaths closely matched the equivalent 1996 ones. One noticeable change was a tongue of sand that grew out from the west side of the entrance channel about 600 m seaward (2,000 ft or two tick marks) of the inlet mouth. The tongue is outlined by the 20-ft isobath. The shape suggests sediment transport directed from west to east, opposite the normal prevailing direction of longshore transport.

1998

The 1998 SHOALS survey was flown on 28 May (Figure B23). This survey provided the most comprehensive flood-shoal coverage since 1955. Because the SHOALS system's laser could not penetrate to the deepest parts of the inlet, some acoustic data collected on 4-6 March 1998 were included in this contour plot (the March survey data are shown in Figure B22).

On the ebb shoal, the 30-ft isobath closely matched the 1996 and 1997 lines, but the 20-ft contour showed more change. The deposition basin had filled to such a degree that the east and west lobes had joined, and the 20-ft isobath continued around the whole shoal. The 10-ft tongue had changed shape, filling in an area close to shore.

Ebb-Shoal Volume Changes

To compute changes in volume of the ebb shoal, the region around the mouth of the inlet was subdivided into forty-eight 1,000-ft squares (Figure 14). Volumes were computed by subtracting the pre-inlet base condition (1933) with 1949, 1984, 1996, 1997, and 1998. These five surveys were the only ones with coverage sufficient to provide a reasonable estimate of the volume of the shoal. The purpose of the square areas was to allow a comparison of identical subregions of the shoal. The following steps outline the procedure:

a. An initial (1933) and final data surface was selected.

b. Using the volume function in Terramodel™ v. 9.40 software, the volume difference in Box 1 was computed if data coverage was adequate to include the box.

c. The cut and fill volumes (if available) were entered in a spreadsheet.

d. Steps *b* and *c* were repeated for the remaining 47 boxes.

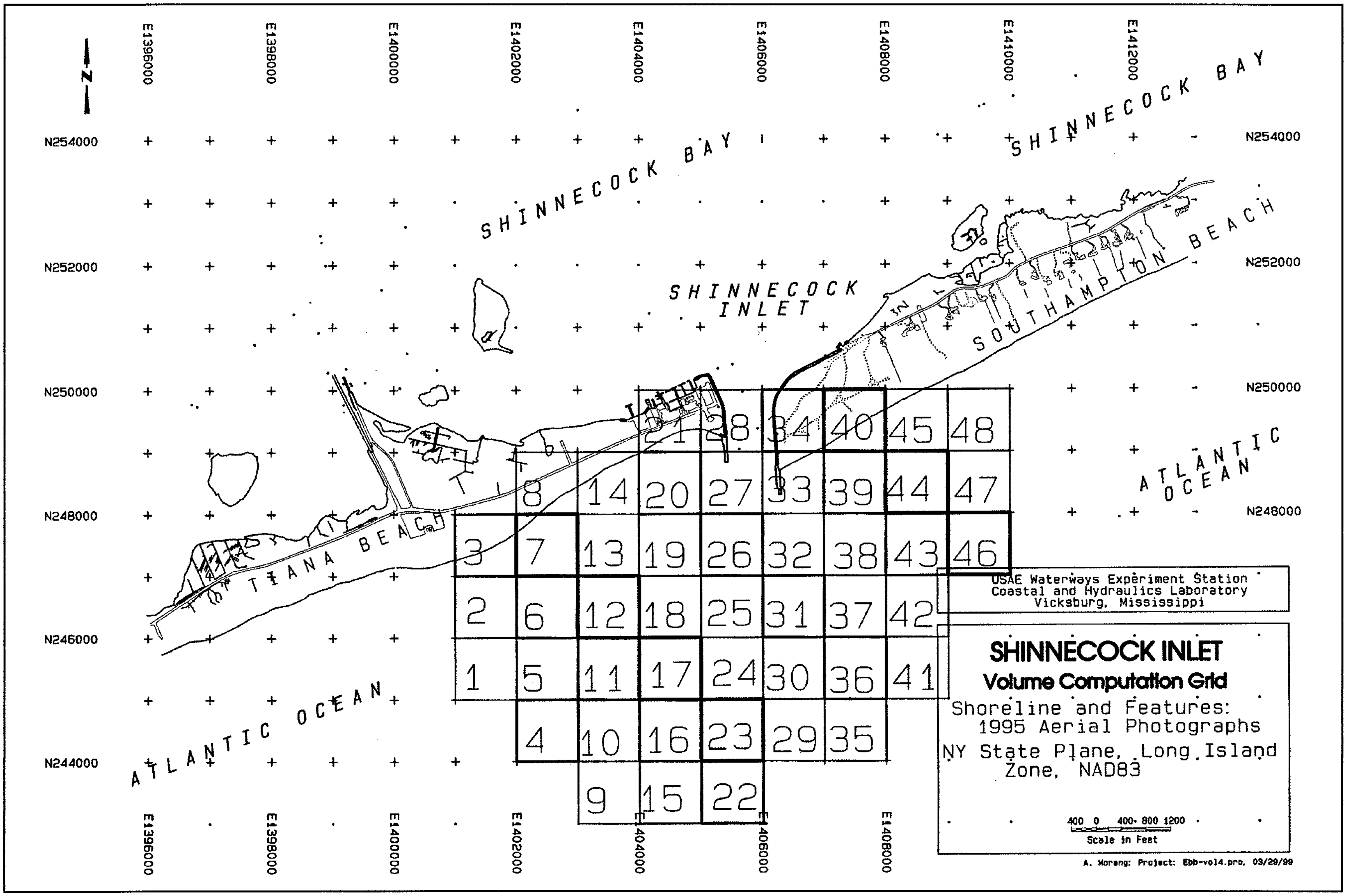

Figure 14. Reference squares (48) used for ebb-shoal volume computations (Boxes 8, 9, 10, 15, 21, 22, 35, 36, and 41 were not needed because they extended beyond overlapping data coverage)

e. The cut and fill volumes were summed.

f. Steps *a* through *e* were repeated for the next survey date.

Table 13 summarizes the volume computations, and the results are graphically shown in Figure 15. The contoured difference from 1933-1998 is shown in Figure 16.

Table 13
Change in Shinnecock Ebb-Shoal Volume [1]

Survey Date	Cut, yd^3	Fill, yd^3	Total, yd^3	Total, m^3
Jul-Aug 1949	17,500	1,043,000	1,025,000	784,000
June 1984	747,000	5,245,000	4,498,000	3,439,000
May 1996	856,000	8,446,000	7,590,000	5,803,000
Aug 1997	712,000	8,544,000	7,832,000	5,988,000
May 1998	933,000	9,385,000	8,453,000	6,463,000

[1] Volumes indicate change from pre-inlet condition, based on 1933 USC&GS data. Does not include sand losses and gains from the barrier because the 1933 data did not include barrier topography. Volumes computed with Terramodel™ v. 9.40 software.

The results suggest that Shinnecock Inlet's ebb shoal is still growing. From 1984 to the present, the volume almost doubled, to 6,400,000 m^3. The last three data points (1996, 1997, 1998) are clustered at 1-year intervals and, therefore, cannot be used to project if the growth trend will continue. The fact that measured volume was greater in 1998 than in 1997 or 1996 may be due to slightly greater survey coverage. Another comprehensive hydrographic survey in 5 or so years will reveal if the shoal is continuing to grow.

Average Annual Change

The total accumulation of sand (fill minus cut) over 60 years (1938 to 1998) was 8,453,000 yd^3. This represents average ebb-shoal accretion of 141,000 yd^3/year. This value surely understates the total sediment transport in the area because one cannot assume that all littoral material is trapped on the ebb shoal; some proportion is certain to be bypassing the shoal and continuing down the coast. Also, some littoral material may be entering the inlet and moving to the flood shoal. In addition, in 1993 the New York District removed 363,000 m^3 (475,000 yd^3) from the deposition basin, a significant loss from the local shoal and inlet system. The computed annual accretion of 141,000 yd^3 is similar to the 150,000 yd^3 estimated in USACE (1958b; page A4) and the 100,000 yd^3 estimated in USACE (1988). Moffatt & Nichol (1996) estimated ebb-shoal deposition of 122,000 yd^3/year for the period 1938 to 1956, but a lower rate after 1956. Calculations of net and gross littoral transport rates in the Shinnecock area vary greatly. The New York District estimated a value of 300,000 yd^3/year

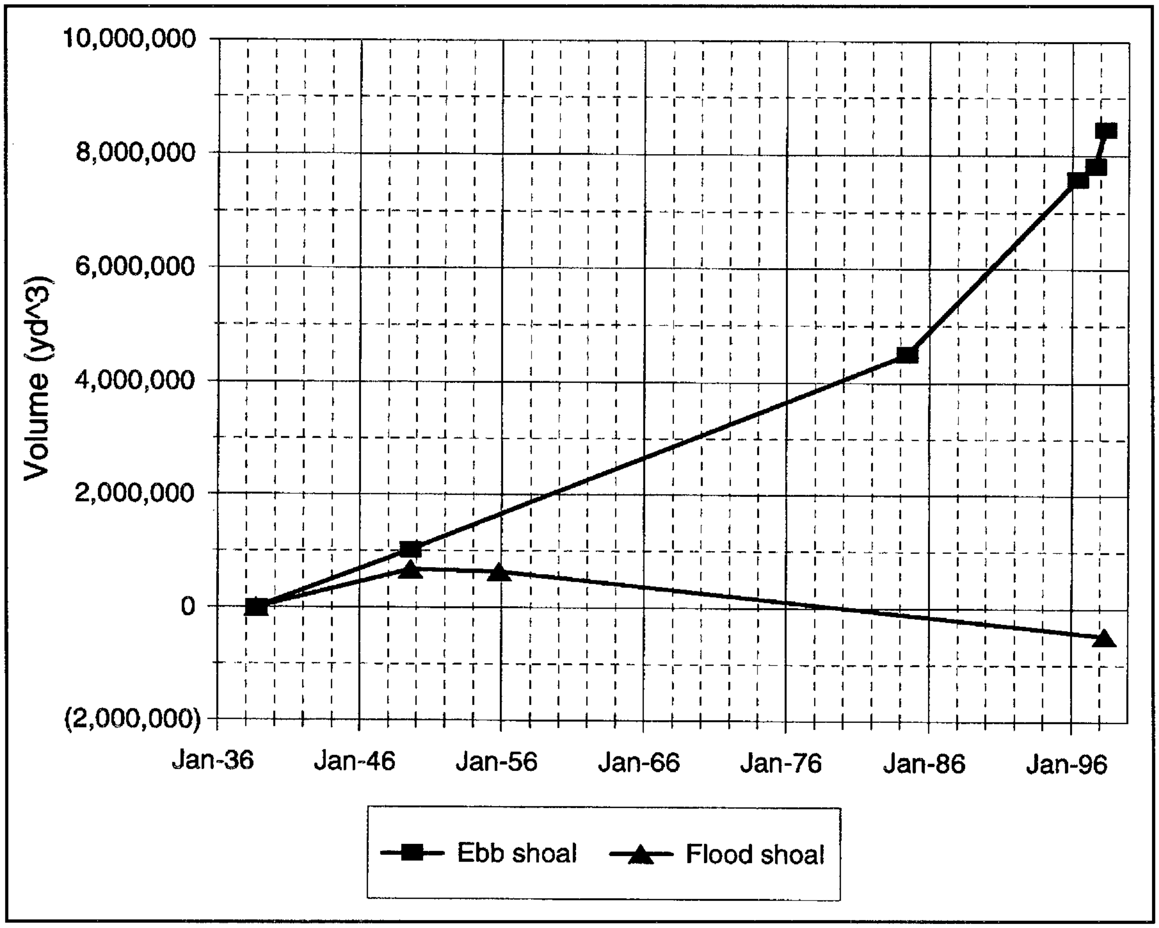

Figure 15. Volume changes, ebb and flood shoals (Although original survey data were collected in 1933, base condition (zero) is plotted at 21 September 1938, when inlet was cut by Great New England Hurricane

net transport to the west (USACE 1988), and Research Planning Institute (1983) estimated westward movement of 264,000 to 304,000 yd^3/year.

Uncertainty Estimates

The SHOALS hydrographic LIDAR surveys are conducted to USACE Class 1 (Contract Payment) standard, with a resultant vertical depth measurement one-sigma standard error not to exceed ±0.5 ft (Morang, Larson, and Gorman 1997; HQUSACE 1991). The standards used for the 1949 and 1984 surveys were not specified and are assumed to be Class 2 (Project Condition), with vertical error not to exceed ±1.0 ft. The 1933 USC&GS data were probably of varying accuracy. Shallow-water depths, (measured with sounding rods) may have error of less than ±0.5 ft, whereas offshore lead-line soundings probably exceed ±1.0 ft, depending on sea state, currents, and other conditions (HQUSACE 1991).

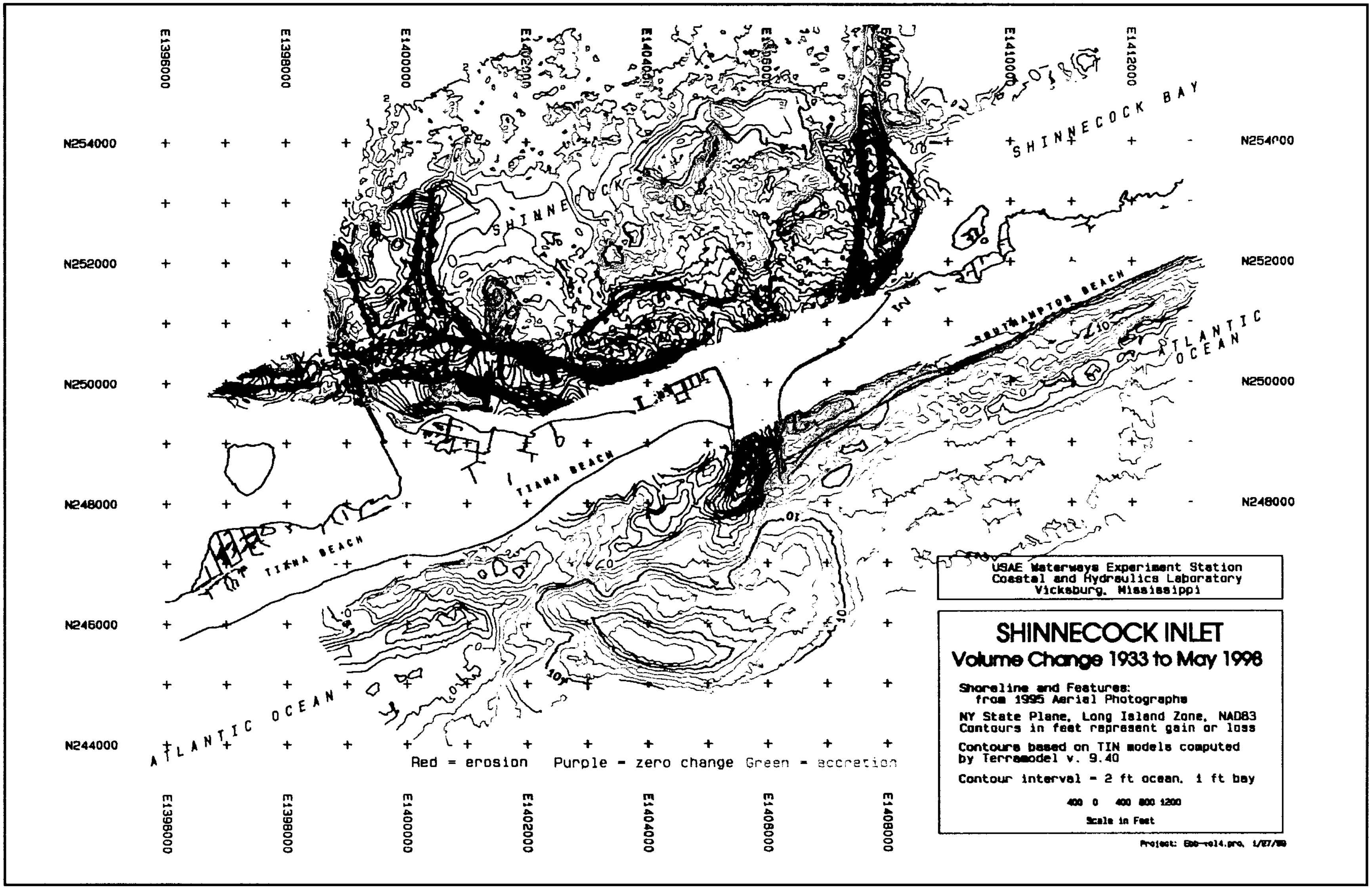

Figure 16. Difference plot, 1933 (pre-inlet) - May 1988, Shinnecock Bay and ebb shoal (Close to barrier, channels have been dredged many times and are now deep troughs, representing a significant loss of sand from system. Flood-shoal accumulation to north is typically less than 1 m thick. Pre-inlet beach topography is not available)

The error in the depth difference between surveys was estimated by computing how much the average depth in each square changed compared with the base (1933) pre-inlet condition and then computing the average depth change (ΔZ_{ave}) over all the squares. *Maximum error* (ME) is:

$$ME = \frac{(one\text{-}sigma\ error)_{1933} + (one\text{-}sigma\ error)_{2nd\ survey}}{\Delta Z_{ave}} \qquad (2)$$

ME is the worst possible error that might occur when comparing two bathymetric data sets. However, it is highly unlikely that all the data points from a single survey are clustered at the extreme limits of the one-sigma standard error specified for that particular class of survey. For example, if data collected on one day were biased high, data from the following day might be biased low. Therefore, *likely survey error* (LE) is defined here as:

$$LE = \frac{ME}{2} \qquad (3)$$

Note that positioning errors (ΔX and ΔY) are assumed to be random and have insignificant effect on the volumes compared with systematic errors in water-depth measurements and data reduction.

Using this procedure, error estimates for the five volume comparisons are listed in Table 14.

Table 14
Error Estimates of Ebb-Shoal Depth Differences

Survey Dates	Maximum Possible Error of Single Sounding, ft	ΔZ_{ave}, ft	Maximum Error, %	Likely Error %
1933 - 1949	1.0 + 1.0 = 2.0	3.3	60.4	30.2
1933 - 1984	1.0 + 1.0 = 2.0	6.6	30.3	15.1
1933 - 1996	1.0 + 0.5 = 1.5	6.1	24.7	12.3
1933 - 1997	1.0 + 0.5 = 1.5	7.1	20.9	10.4
1933 - 1998	1.0 + 0.5 = 1.5	7.5	20.0	10.0

Note: Survey error for 1933 USC&GS data is assumed to be ±1.0 ft.

Table 14 provides bounds for interpreting the volumetric changes computed for the Shinnecock ebb shoal. For example, the volumes computed for 1996, 1997, and 1998 cannot be considered statistically different, and no inferences should be made regarding continued ebb-shoal growth from these three data points.

Summary

Based on the SHOALS surveys in 1994, 1996, 1997, and 1998, most sediment movement on the ebb shoal occurs above the 10-m (30-ft) depth. The 20-ft isobath outlined how the deposition basin filled between 1996 and 1998. It appears as if the infilling occurred via a plume or tongue of sand that moved from west to east. A shallow spit, with depths less than 3 m (10 ft) extends out from the west shore along the edge of the ebb shoal. The east side of the ebb shoal was deeper, without a similar spit.

The ebb shoal presently has a volume of about 6,400,000 m^3 (8,500,000 yd^3). Based on the data in Table 13, it appears to be still growing. Over 60 years, the average ebb-shoal accretion rate has been 141,000 yd^3/year.

6 Flood-Shoal Morphology and Volume Changes

In aerial photographs, the flood shoal in Shinnecock Bay appears to be a massive sand body with lobes and channels and exposed sand islands. At first sight, one might assume that this is a large reservoir of sand suitable for mining. The 1998 SHOALS survey provided the first broad coverage of the flood shoal since the 1955 survey. The base survey was the 1933 USC&GS data collected before the inlet opened.

The comparison between 1998 and 1933 bathymetries yielded an unexpected result. Despite its prominent appearance in aerial photographs, the present flood shoal is only a thin veneer of sand (<1-2 m thick typically) lying on what was formerly a shallow bay floor. Near the present barrier island, the navigation channels are deep troughs with depth of at least -6 m. The surprising result is that the bay has lost sand since 1933 because sand removed from the channels has exceeded the quantity deposited further north on the flood shoal (Table 15). Note that these results do not include the region immediately north of the jetties where the two navigation channels converge (because of insufficient data coverage). If this channel were included, the cut volume would be even greater. Three north-south cross sections demonstrate how great the sand loss in the channels was compared with the gain in the flood shoal (Figures 17, 18, and 19).

Table 15
Change in Shinnecock Flood-Shoal Volume [1]

Survey Date	Cut, yd^3	Fill, yd^3	Total, yd^3	Total, m^3
Jul-Aug 1949	445,000	1,123,000	678,000	518,000
Nov 1955	507,000	1,145,000	638,000	488,000
May 1998	4,163,000	3,684,000	-479,000	-366,000

[1] Volumes indicate change from pre-inlet condition, based on 1933 USC&GS data. Does not include sand losses and gains from the barrier. Cut values should be greater because 1933 coverage did not include the area directly north of the present barrier where navigation channels have been dredged. Volumes computed with Terramodel™ v. 9.40 software.

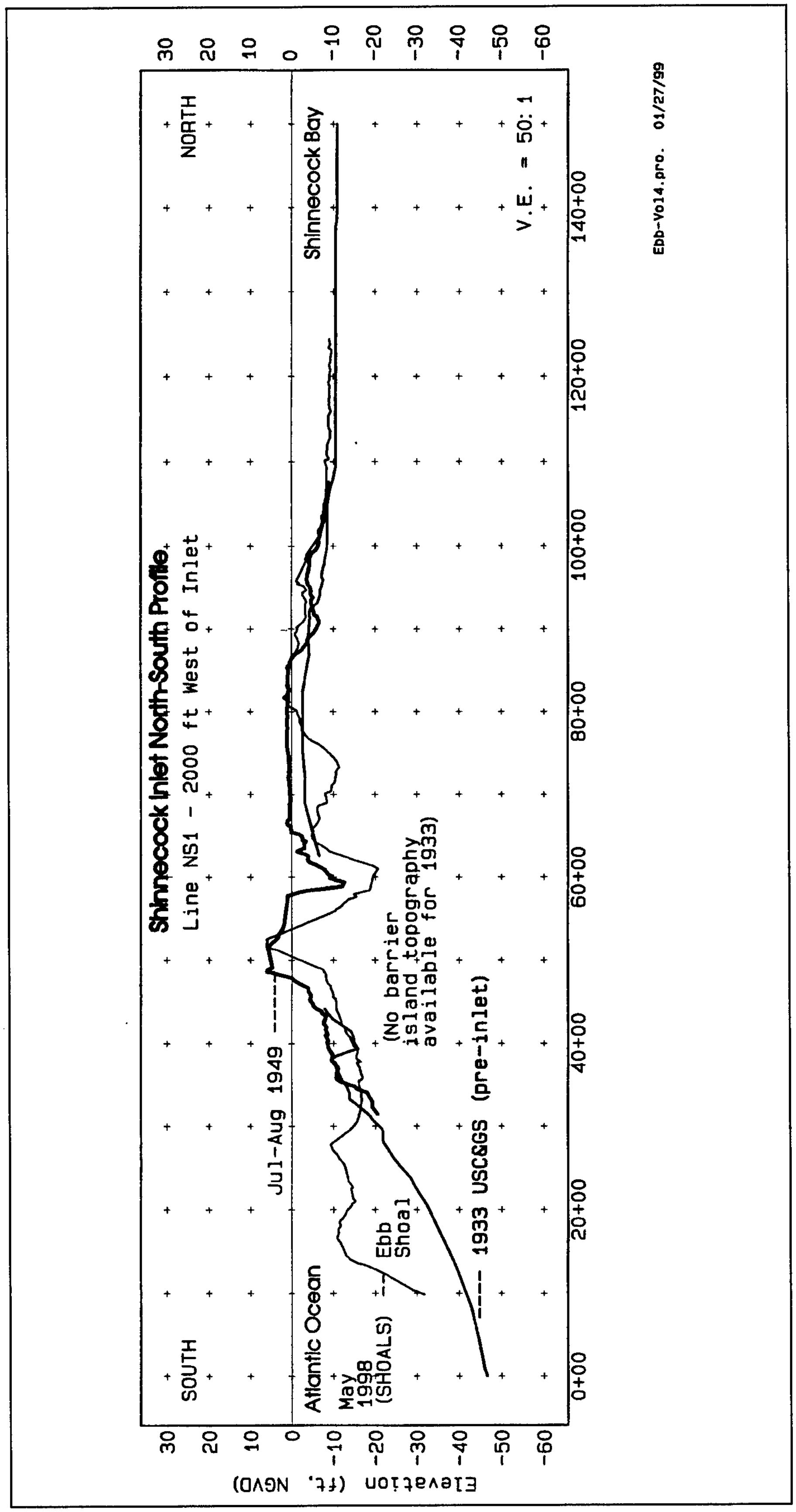

Figure 17. North-south profile cut 2,000 ft west of inlet (Modern ebb shoal is large accumulation on left (seaward) side of plot)

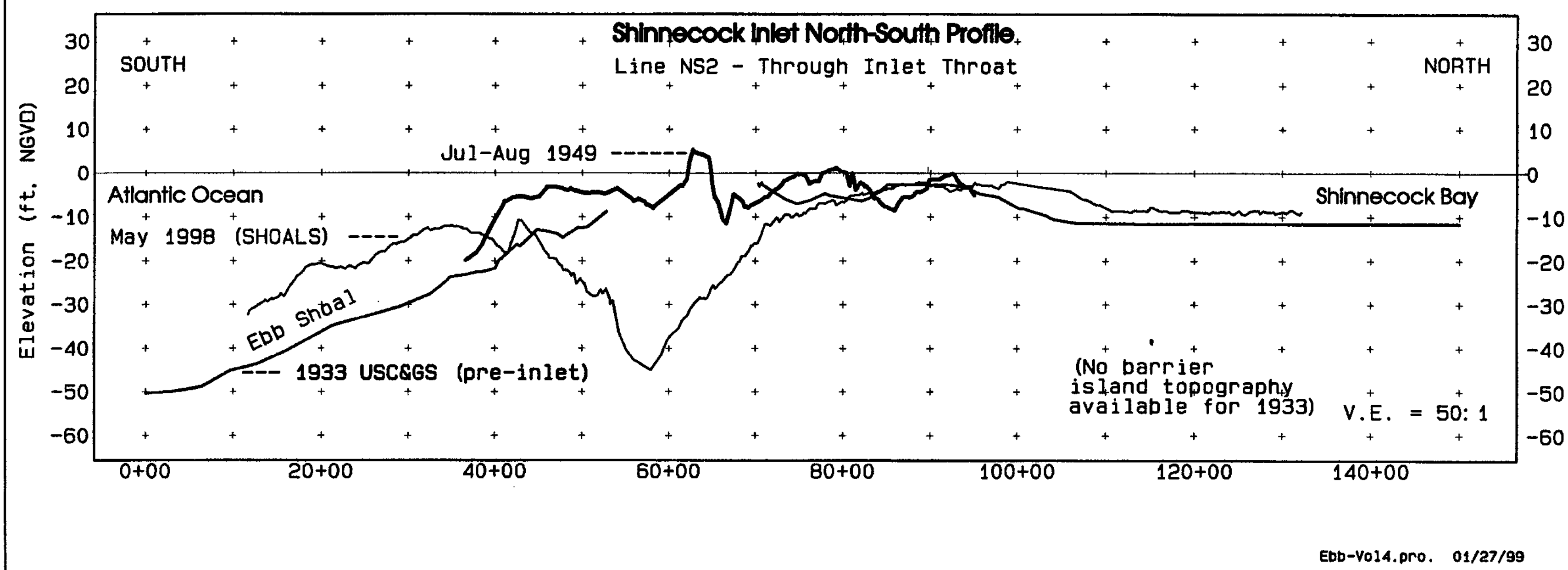

Figure 18. North-south profile cut through Shinnecock Inlet (It is evident that the present inlet, greater than 40 ft deep in some places, represents a great sand loss compared with pre-inlet barrier. Modern ebb shoal is to left, and flood shoal is to right)

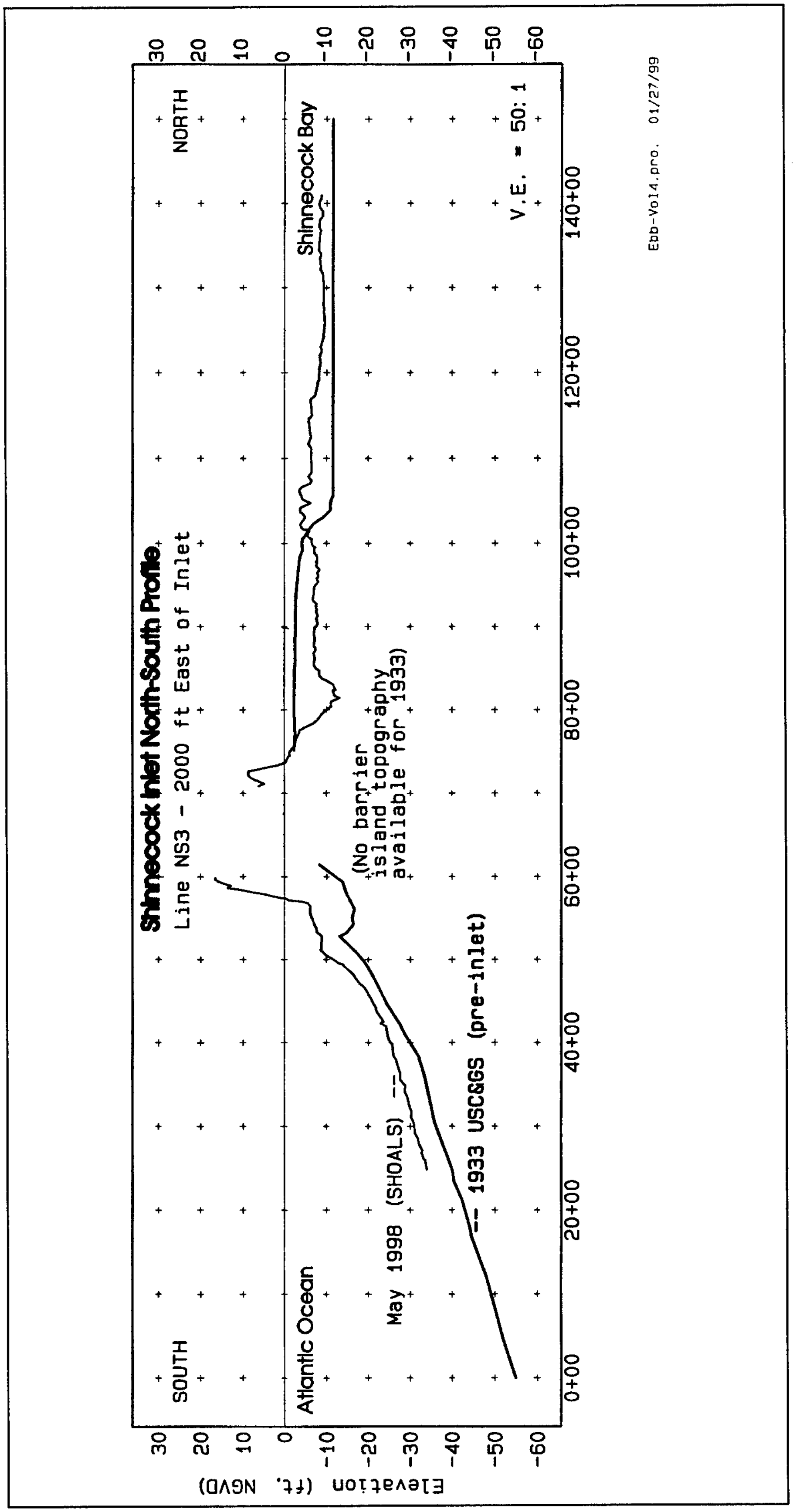

Figure 19. North-south profile cut 2,000 ft east of inlet (Here, there is no ebb shoal, but modern beach has advanced compared with 1933)

Other than the surveys listed in Table 15, little quantitative information is available about evolution of the flood shoal. McCormick (1971) wrote that the flood shoal experienced slow growth from its beginning in 1938 until 1953, when construction of the jetties began. He concluded that between 1950 and 1955, the shoal grew rapidly, approximately doubling its size. The rapid growth was caused by the increasing size (cross section?) of the inlet, but growth slowed after 1955 because of the gradual constriction of the tidal channels that crossed the flood shoal. The west portion of the shoal was stabilized by the spread of salt marsh grasses. While the west area was stable after the mid-1950s, the northern margin of the shoal continued to grow into the bay. McCormick estimated the flood-shoal growth rate between 1955 and 1969 to be 45,000 m^3/year (59,000 yd^3/year). Results of the present analysis contradict McCormick's conclusion of flood shoal doubling between 1950 and 1955. Possibly McCormick only included the addition of sand to the system, while ignoring the loss because of channel dredging. If one divides the total fill of 3,684,000 yd^3 by 60 years, the annual amount is 61,000 yd^3, similar to the value derived by McCormick. But, this is only part of the shoal's sediment budget, and the loss due to channel dredging must not be neglected.

The modern Southampton and Tiana beaches are examples of beaches that have been artificially modified to such a degree that overwash sediment transport has been largely eliminated. On a natural, undeveloped barrier, sand eroded from the ocean beach may be carried over the island and deposited as washover fans in the back bay. Over time, the fans accumulate and coalesce, building up thick wedges of sand on top of lagoonal sediments. This is part of the rollover mechanism by which a barrier is able to accommodate sea-level rise by migrating landward (Dillon 1970; Nummedal 1983). But, in many developed coastal areas, navigation channels on the back sides of the barrier are sediment sinks. Sand that would have normally gone into building a platform for landward migration of the barrier instead attempts to fill the channel. As the channel shoals and navigation is impaired, the sand is excavated. The end result is ocean-side erosion without the concurrent bay-side deposition. The barrier becomes narrower, increasing its vulnerability to breaching.

At some projects, sand dredged from back-bay channels is conveniently placed nearby in the bay. The sand is moved around but not lost from the system. But at Shinnecock, most of the sand dredged from the navigation channel (at least in recent decades, based on the records available) has been deposited on the seaward side of the barrier west of the jetties, from where it was soon eroded and removed. In effect, since the 1940s, the back side of the barrier has been mined to feed the littoral drift.

7 Inlet Cross Section

At Shinnecock Inlet, the cross section along five east-west profile lines (P5 to P11, shown in Figure 20) has been plotted. Results of the analysis are tabulated in Table 16 and plotted in Figures 21 and 22. These results lead to four conclusions:

a. In 1949 and 1955, the overall cross-sectional area was only about one-third the size in the 1980s and 1990s, about 5,000 to 6,000 ft^2 versus 17,000 (+) ft^2 (Figures 23 and 24). In 1949, the inlet was anchored on its west side with a revetment, but the east side was still unstructured. Therefore, sediment from littoral drift was free to enter the channel, and the inlet's cross section represented a dynamic balance of scour caused by tidal currents versus sediment infilling. In 1953-1954, parallel stone jetties were built and the inlet's sides were fixed. Yet, the November 1955 survey shows that the channel had not yet scoured. In fact, the cross section was less at lines P7, P9, and P10 because the channel was restricted by the jetties and no longer free to pass over a broad, shallow area on the east beach. The tripling in cross section from the 1940s to the 1980s is reflected in the approximate tripling in tidal prism over this same period (Table 6).

b. Because of the unavailability of bathymetric data from 1955 to 1984, the evolution of the inlet scour is not known.

c. During the 1980s and 1990s, cross-sectional area remained approximately constant at profile lines P7, P9, P10, and P11. The area near Line P5, at the very northern end of the jetties where the inlet opens into Shinnecock Bay, has fluctuated more than at the other lines. This greater variation may be related to channel dredging.

d. Shinnecock Inlet's minimum cross section occurs at line P10, averaging about 1,540 m^2 (17,000 ft^2).

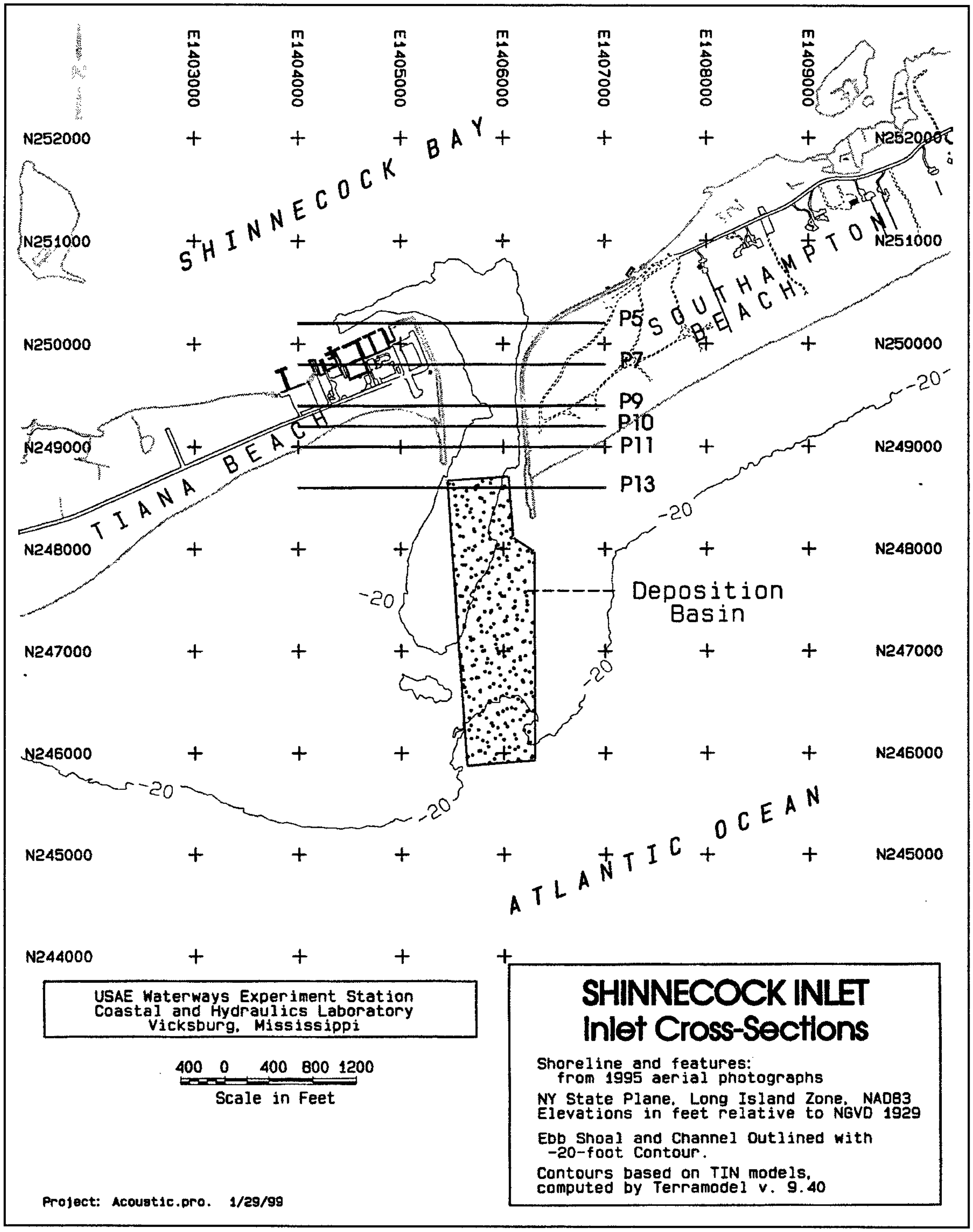

Figure 20. Profile lines across Shinnecock Inlet defining locations of cross-sectional area measurements

Table 16
Cross-Sectional Areas, Shinnecock Inlet

Date	Profile Line (area in ft^2)				
	P5	P7	P9	P10	P11
Jul-Aug 1949	5,990	6,680	5,500	5,740	(ocean)
Nov 1955	11,720	3,850	4,640	4,870	5,360
Jun 11, 1984	24,170	18,680	16,970	16,270	18,220
Jul 1986	(no data)	17,620	15,480	15,090	18,790
Jun 1987	30,010	20,900	16,610	16,020	21,390
Nov 1989	34,900	21,700	16,610	16,260	21,250
Aug 9, 1990	(no data)	21,470	17,390	17,280	22,510
Dec 1990	37,480	22,160	17,290	16,330	20,930
Aug 1991	37,960	22,160	17,620	18,130	21,700
Dec 21, 1992	27,990	21,070	17,000	16,370	21,110
Dec 1993	29,520	21,240	16,890	16,980	19,320
Aug 3, 1994	30,080	20,350	16,740	16,660	19,380
Sep 8, 1995	31,560	21,160	16,460	16,970	18,880
Oct 5, 1995	31,270	20,390	16,950	16,780	18,680
Mar 4-6, 1998	31,620	21,450	17,130	16,580	19,940
Average 1980s and 1990s, ft^2	29,860	20,800	16,860	16,600	20,160
Average 1980s and 1990s, m^2	2,770	1,930	1,570	1,540	1,870

Note: Areas computed with Terramodel™ software v. 9.40. Values rounded to closest 10 ft^2.

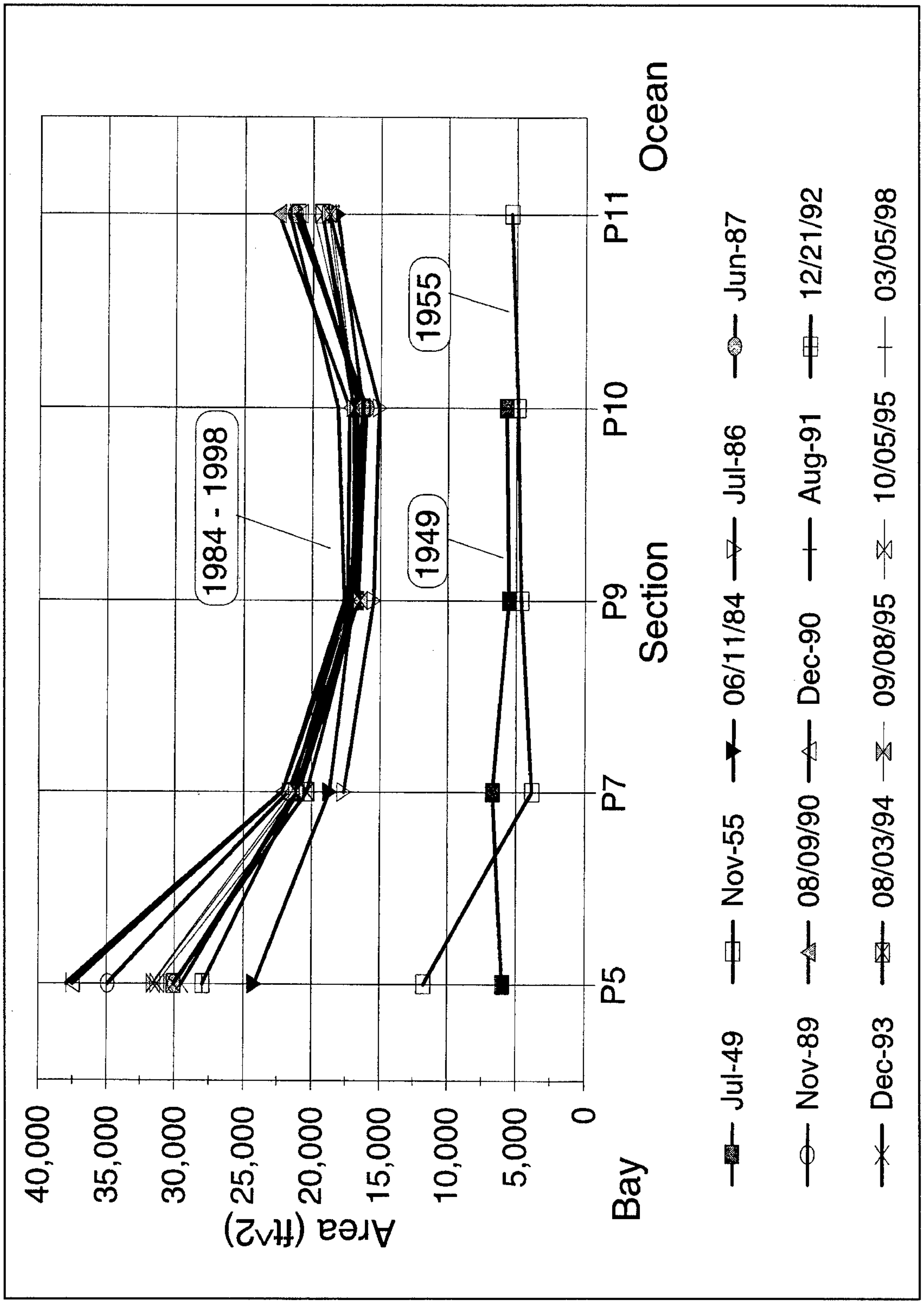

Figure 21. Change in cross-sectional area over time, Shinnecock Inlet

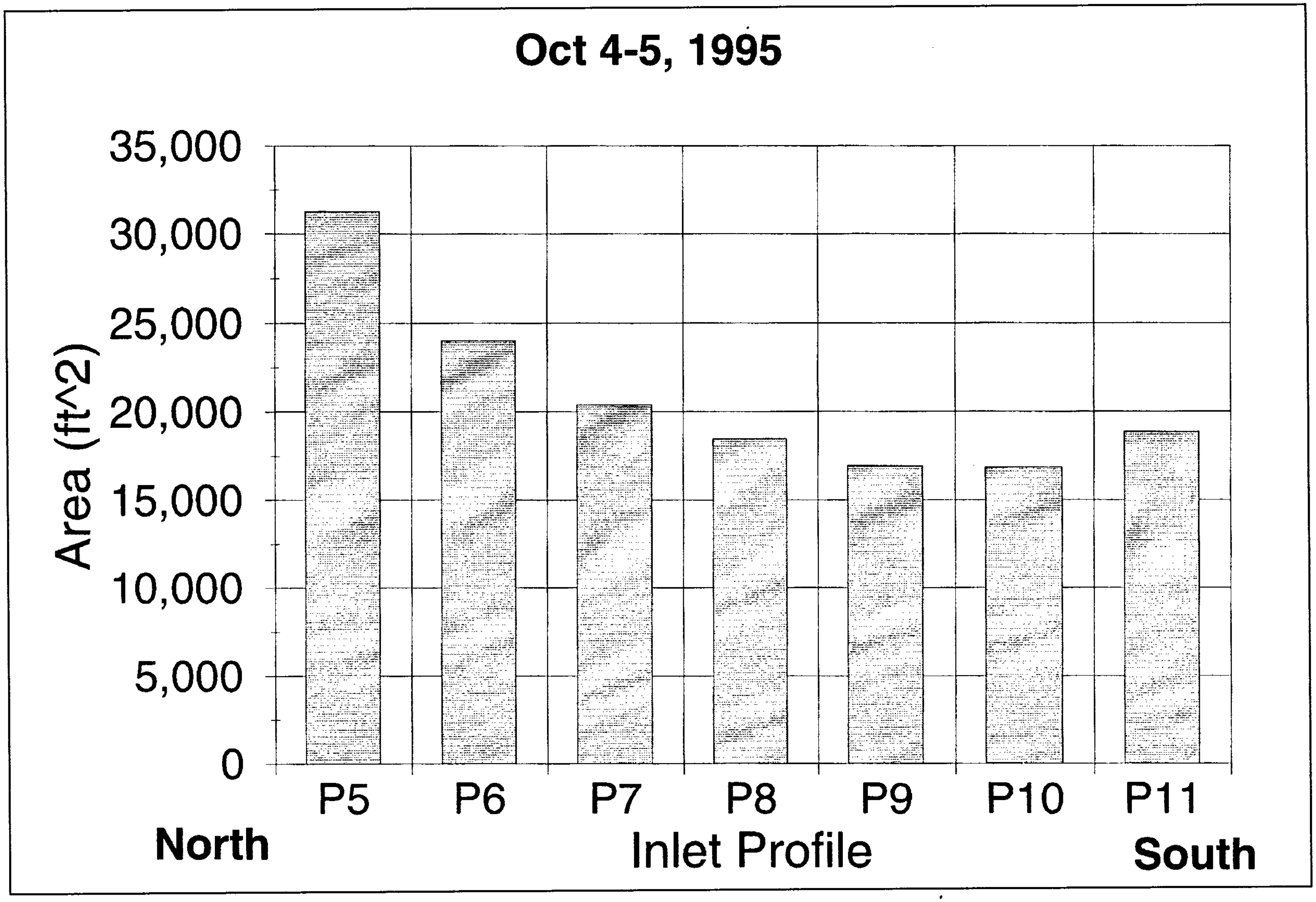

Figure 22. Variation in cross-sectional area along axis of Shinnecock Inlet, October 1995

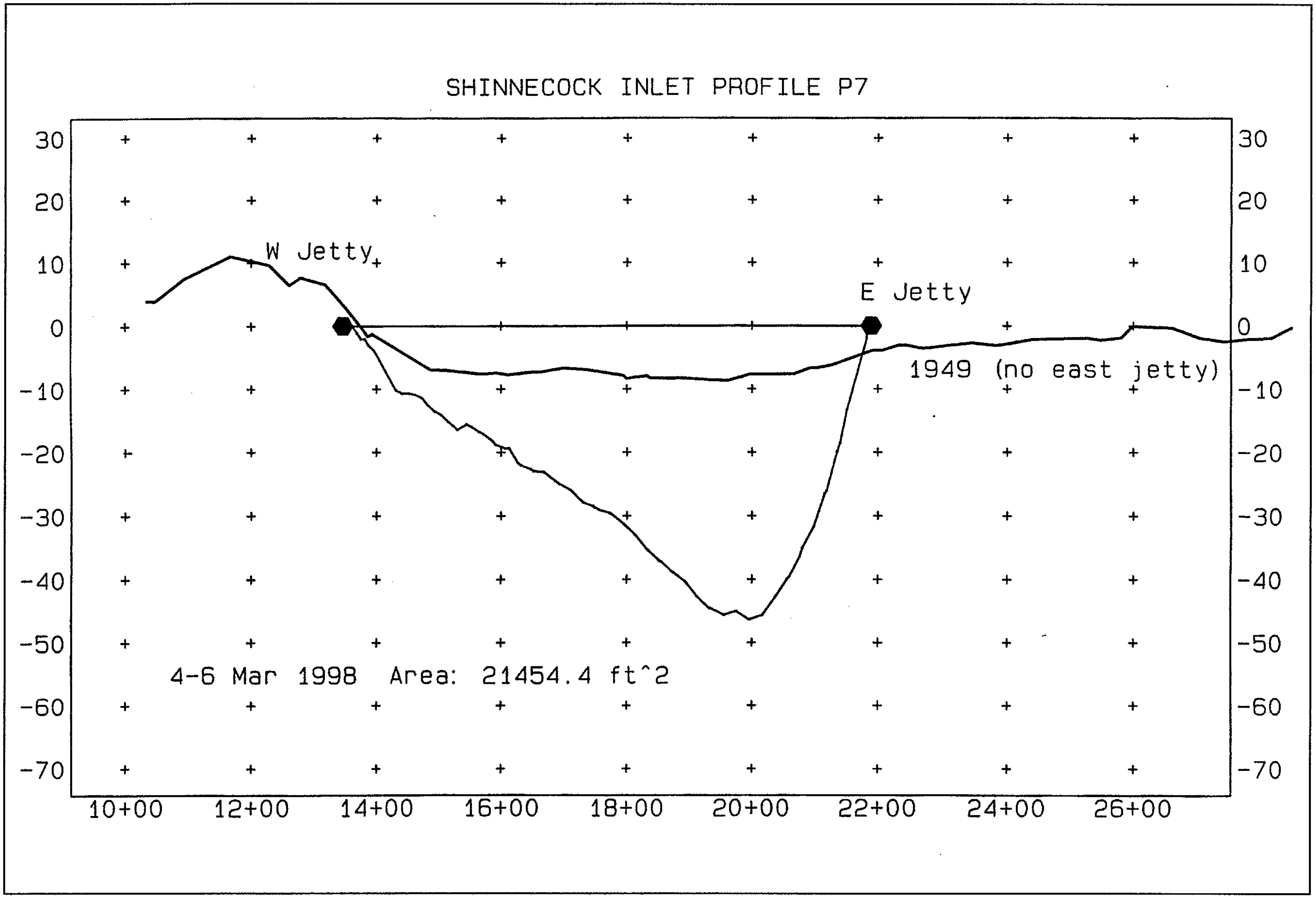

Figure 23. Comparison of 1949 and 1998 cross sections, Line P7 (In 1949, inlet was wider and extended further to east than present inlet)

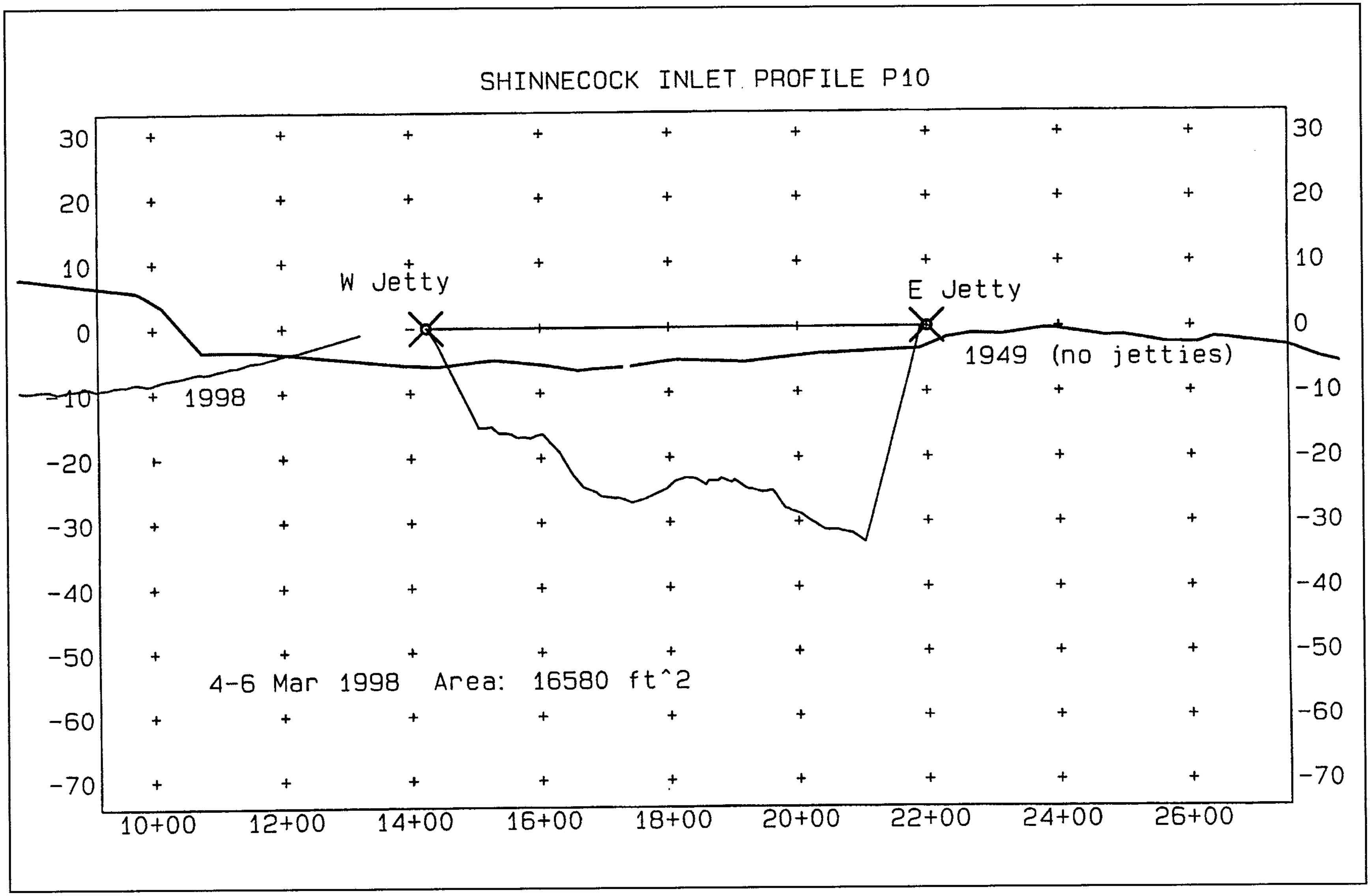

Figure 24. Comparison of 1949 and 1998 cross sections, Line P10 (In 1949, inlet was located seaward of east-beach revetment. Unconfined inlet was less than 10 ft deep and did not have an obvious thalweg. Presently, shoreface west of west jetty is almost 20 ft deeper than in 1949 (i.e., what was dry beach in 1949 is now underwater))

8 Inlet Thalweg

A thalweg is "the deepest or best navigable channel, used in defining water boundaries between states. (Etymol: German. "valley way")" (Bates and Jackson 1984). At Shinnecock Inlet, the thalweg has been mapped visually using contour plots of the historical hydrographic surveys. No data are available for the inlet in its completely unstructured phase.

Phase 2 - Inlet Stabilized on West Side, 1939 - 1951

Two hydrographic surveys are available for this period, 1940 and 1949. In 1940, the thalweg approached the inlet from the north via a single channel. It then ran out to sea to the southeast. In 1949, two channels merged north of the inlet, after which the thalweg ran out to sea on a north-south direction (Figure 25). At this time, the inlet was less than 3 m deep. By 1955, the thalweg had rotated back to northwest-southeast. The eastward movement of the thalweg between 1940 and 1949 outlines how the flood shoal grew with an influx of sand from the Atlantic Ocean.

Aerial photographs show that during the 1930s and 1940s, the thalweg normally followed the revetment along the west shore, but occasionally migrated to the east for short intervals. The limited bathymetry data from this period indicates that the channel did not migrate far enough east to be outside of the confines of the present jetties.

Bathymetry data and aerial photographs confirm that the channel changed its orientation frequently before the sides of the inlet were jettied. But it is not possible to determine if the movement was cyclic or occurred on an irregular pattern. Aerial photographs, particularly from the 1938-1940 period, indicate that the channel could change its orientation rapidly, apparently in only a few months.

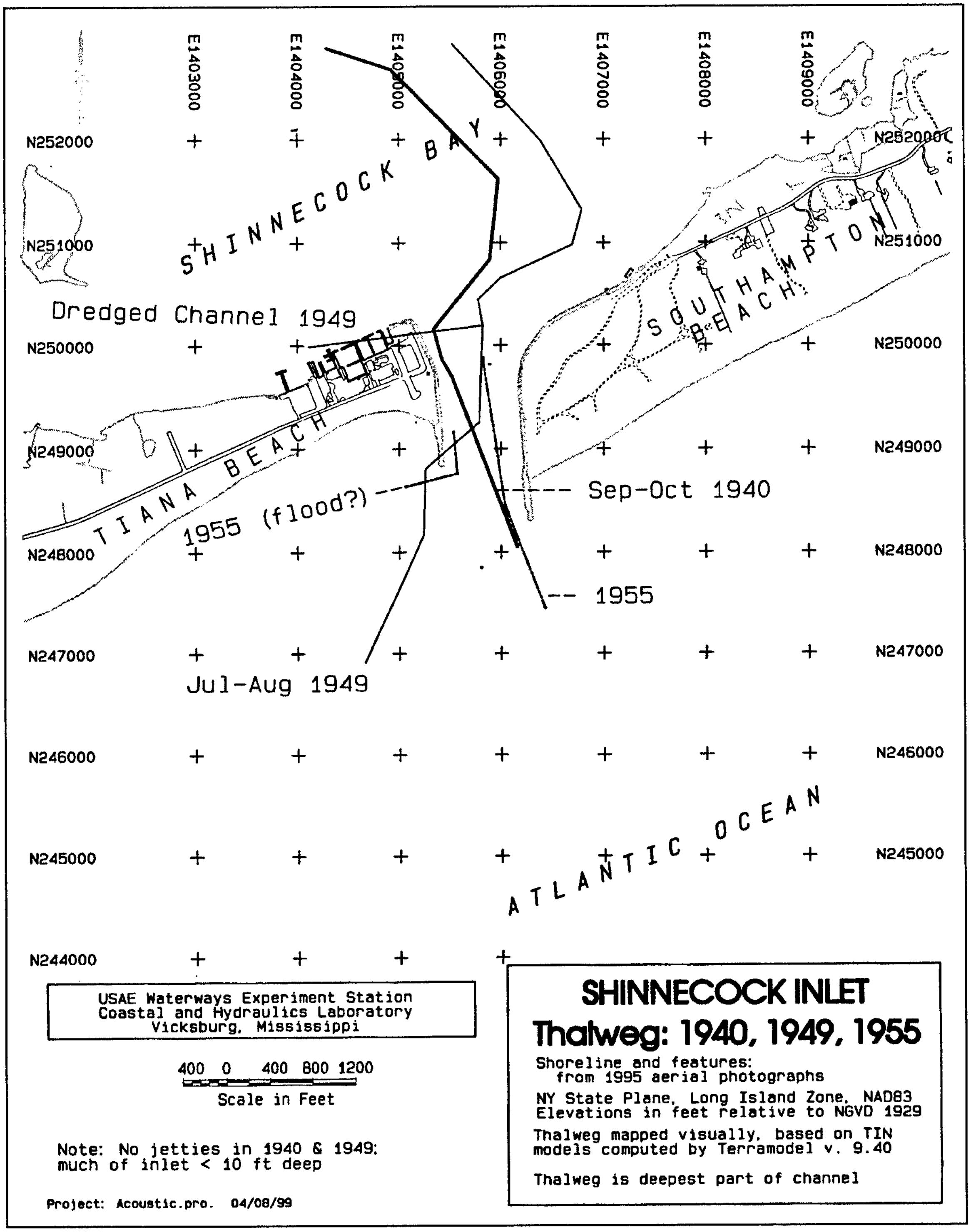

Figure 25. Thalweg: 1940, 1949, and 1955 (In 1940 and 1949, only west side of inlet had been stabilized. Nevertheless, thalweg was in about same location as present. As flood shoal grew, east channel moved eastward, as shown by 1940 and 1949 thalwegs. In 1955, two gorges emerged from newly jettied inlet)

Phase 3 - Dual Jetties, 1952 - Present

The first survey made after jetty construction was in late 1955. At this time, two thalwegs emerged from the newly jettied inlet. A marginal flood channel entered the inlet from the west, while the main channel ran approximately down the middle of the inlet (Figure 25). After this survey, there is a gap of almost 28 years, until 1984, for which no bathymetry data could be located.

Since 1984, the thalweg has followed a surprisingly consistent pathway between the jetties (Figure 26). Presently, there is not a single deep channel leading from the Atlantic to Shinnecock Bay. The thalweg is discontinuous, interrupted by a ridge of sand that runs northwest-southeast across the inlet. The ridge approximately parallels a line drawn from one jetty tip to the other. The ridge has usually been less than 20 ft deep and is therefore usually outlined by the 20-ft isobath (Figure 27). All the thalwegs shown in Figure 27 have been drawn with a break to reflect the presence of the ridge. In Figure 28, the ridge is marked by sand waves with clearly defined crests and troughs.

North of the inlet, the two navigation channels converge. Acoustic survey data were available for the west channel near the commercial fishing docks, but the east channel was out of the data coverage area. Uniformly between 1984 and 1998, the west channel ran east and then swung south into the inlet. It crossed to the east jetty and than followed along the east side until it is was about 230 m from the jetty tip. Because of the concentration of tidal currents along the east side of the inlet, part of the thalweg is greater than 20 m (60 ft) deep. The damage sustained by the east jetty during the 1970s and 1980s was most likely caused by scour and instability as rock was lost down into the thalweg.

After the jetties were built, the portion of the thalweg seaward of the inlet mouth was still able to move across the ebb shoal. The three 1980s surveys show the thalweg running to the southwest. But during the 1990s, the thalwegs emerged from the inlet mouth in a southwest direction but then turned south or southeast, following the west side of the deposition basin. Immediately seaward of the jetties, the thalwegs had minor changes in orientation, but the general path followed the west side of the deposition basin. In general, it appears that during the 1990s, the thalweg no longer rotated or migrated in any detectable pattern or cycle.

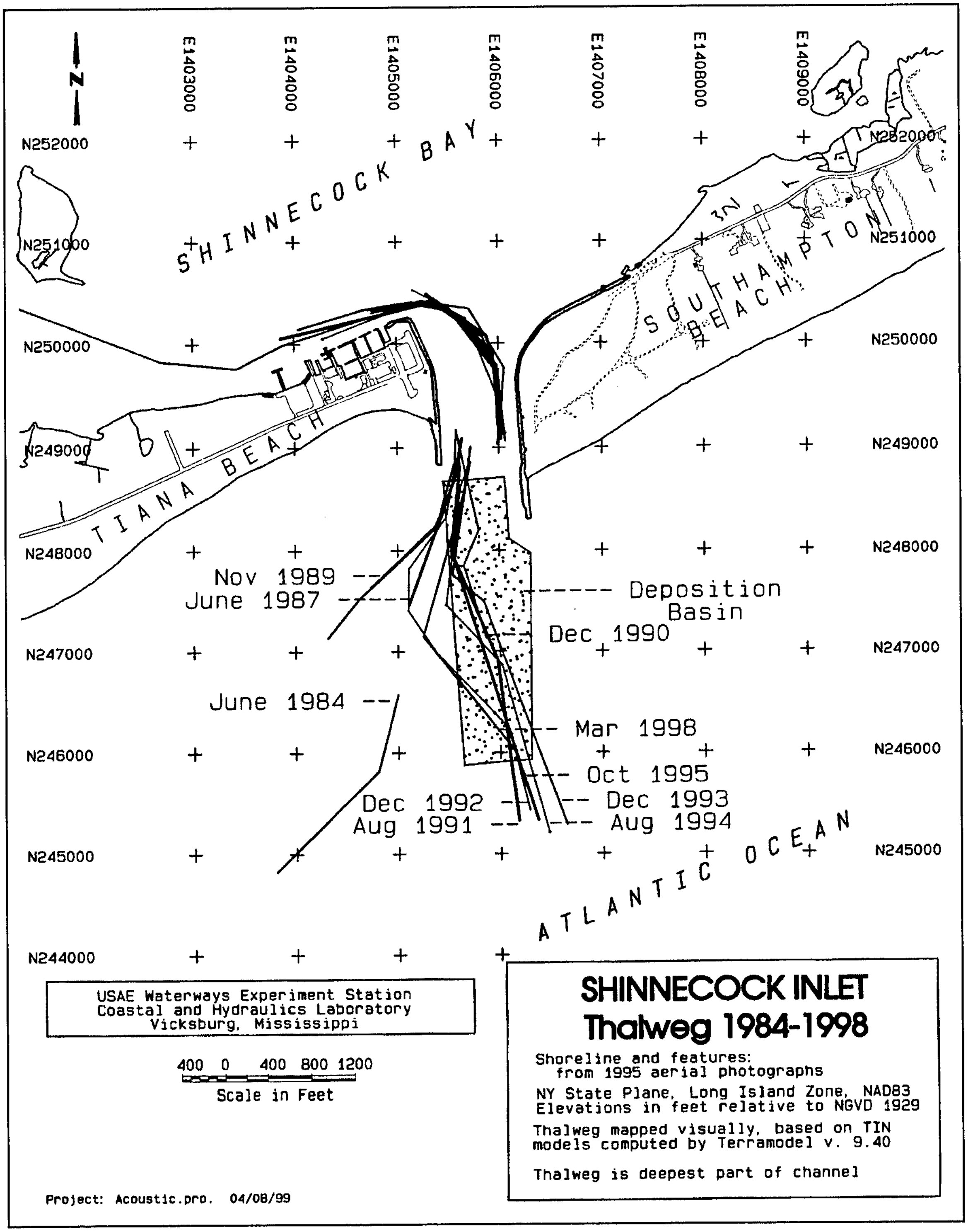

Figure 26. Thalweg: 1984 to 1998 (Within inlet, thalweg has been stable, following same path for 14 years. Out on ebb shoal, June 1984 and November 1987 thalweg emerged from inlet oriented to southwest. All other thalwegs were bent back to east, such that they crossed ebb shoal approximately to south. Deposition basin is shown with stipple pattern. No hydrographic data are available for period 1955 to 1984)

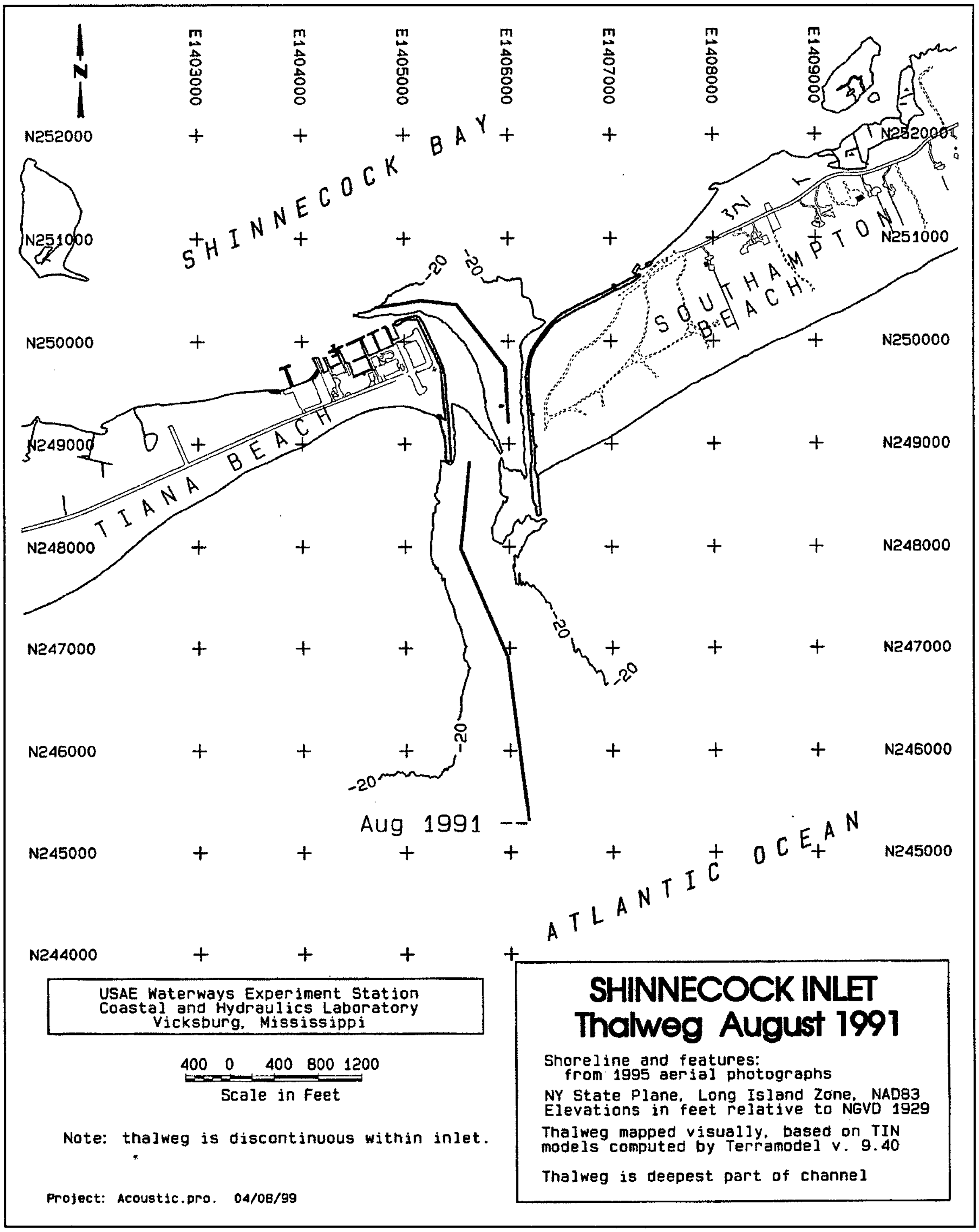

Figure 27. Thalweg: August 1991 (20-ft isobath outlines ridge that crosses inlet from northwest to southeast. North of ridge, thalweg follows east shore. South, it emerges near west jetty tip, where scour hole has been as deep as -22 m (-74 ft) NGVD in past (about 15 m below inlet bed))

Figure 28. Multibeam acoustic data, 31 October 1998 (Sand waves are evident in inlet. Edge of sand ridge (discussed in text) is marked by line where the sand waves join featureless inlet floor. Highly irregular bottom near tip of west jetty indicates scour holes and remnants of scour blanket. Acoustic data processed at 1-m grid size, shaded with simulated sun position at 315° azimuth and elevation of 45°. Data collected and processed by Marine Sciences Research Center, State University of New York, Stony Brook, NY)

9 Shoreline Changes and Cross-Shore Profiles

Cross-shore profiles have been collected by the New York District and various State agencies since the 1930s. Most of the older data have been lost or are unusable because of inadequately defined datums and coordinate systems. One set of long profiles from 1979, known as the "Strock" lines, have recently been digitized and inspected. Since 1995, the Atlantic Coast of New York Monitoring Project (sponsored by the USACE, State of New York, and New York Sea Grant) has conducted biannual surveys at about 300 stations from Fire Island Inlet to Montauk Point at a spacing of about 300 m (1,000 ft). No bay-side surveys are available for Shinnecock Bay. All profiles have been referenced to fixed monuments located in the dunes, at the edge of roads, or on other structures. Profiles are a mixture of short (wading-depth) lines and long lines that extend to a depth of about 10 m (30 ft).

Shorelines

Figure 29 shows the location of the Spring 1998 profile lines. The shoreline, 0.0 ft NGVD, and the 30-ft isobath were generated by contouring three-dimensional (X-Y-Z) profile data using Terramodel™ software. The jagged appearance of the zero contour in some areas is an artifact of the contouring algorithms because the data were dense in the onshore-offshore direction but widely spaced along the shore.

From Spring 1995 to Spring 1998, there was no consistent pattern of retreat or advance near Shinnecock Inlet. The shoreline curves crossed each other in a confused pattern, and the overall barrier island remained in place. The greatest variations in shoreline position over the 4 years occurred west of the west jetty. Here, the most seaward shoreline was Spring 1997, while the most landward line was Spring 1998. In February-March of 1997, the State of New York placed sand dredged from the flood shoal on the west beach. The profiles were surveyed on 25 March, immediately after the fill operations. The shore proceeded to erode, and by 14 February 1998, when the Spring 1998 surveys were made, the shoreline had retreated 60-75 m (180-230 ft), depending on location. Further west, across from the Ponquogue Bridge, the most seaward line was Spring 1998.

The 30-ft isobath runs approximately parallel to the shore except between lines W41 and P1, where the bulge marks the boundary of the ebb shoal. The different date curves cross one another without a consistent advance or retreat pattern.

Profiles

West of the inlet, profile lines W35, W36, W37, W38, W50, W39, W49, and W40 resemble the typical open-coast shoreface with a bar in shallow water and a concave seafloor.[1] Depth of closure along Westhampton Beach ranges from 17 to 25 ft, with an average of 22 ft below NGVD.[2]

Lines W41 to W48 cross the Shinnecock Inlet ebb shoal. The top of the shoal at line W42 is a flat platform at a depth of about 15 ft with bars marking the seaward edge (Figure C8). Further east, the top of the shoal is more irregular, with prominent bars at the seaward edge. Just west of the west jetty, a deep trough occurs about 1,500 ft offshore from the monument (Figure C10). This trough is part of the channel that extends northeast-southwest from the mouth of the inlet (Figure B23). Monument W44 was lost sometime during the winter of 1996 because of erosion. This accounts for the ragged appearance of the W44 profiles near the shore where new monuments were placed following beach fill. At Line W44, profile data were available for 1979. The 1979 curve resembles an open-coast profile, and there is only slight evidence of an ebb shoal.

East of Shinnecock Inlet, profile lines P1 to P5 have an open-coast (nonebb-shoal) appearance with a single sandbar. Closure in the Ponds region ranges from 15 to 27 ft, with an average of 20 ft. At Line P1 (Figure C11), the updrift fillet has filled since 1979, and the profiles reveal that the shore has advanced at least 70 m (200 ft) in about 15 years. The dune line has also advanced and the crest is higher. East of the inlet, the 1995-1998 shorelines do not display a consistent retreat or advance patten.

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[1] Plots of profile line are provided in Appendix C.
[2] Depth of closure and other statistics from ongoing studies being conducted at the U.S. Army Engineer Waterways Experiment Station to support the New York District.

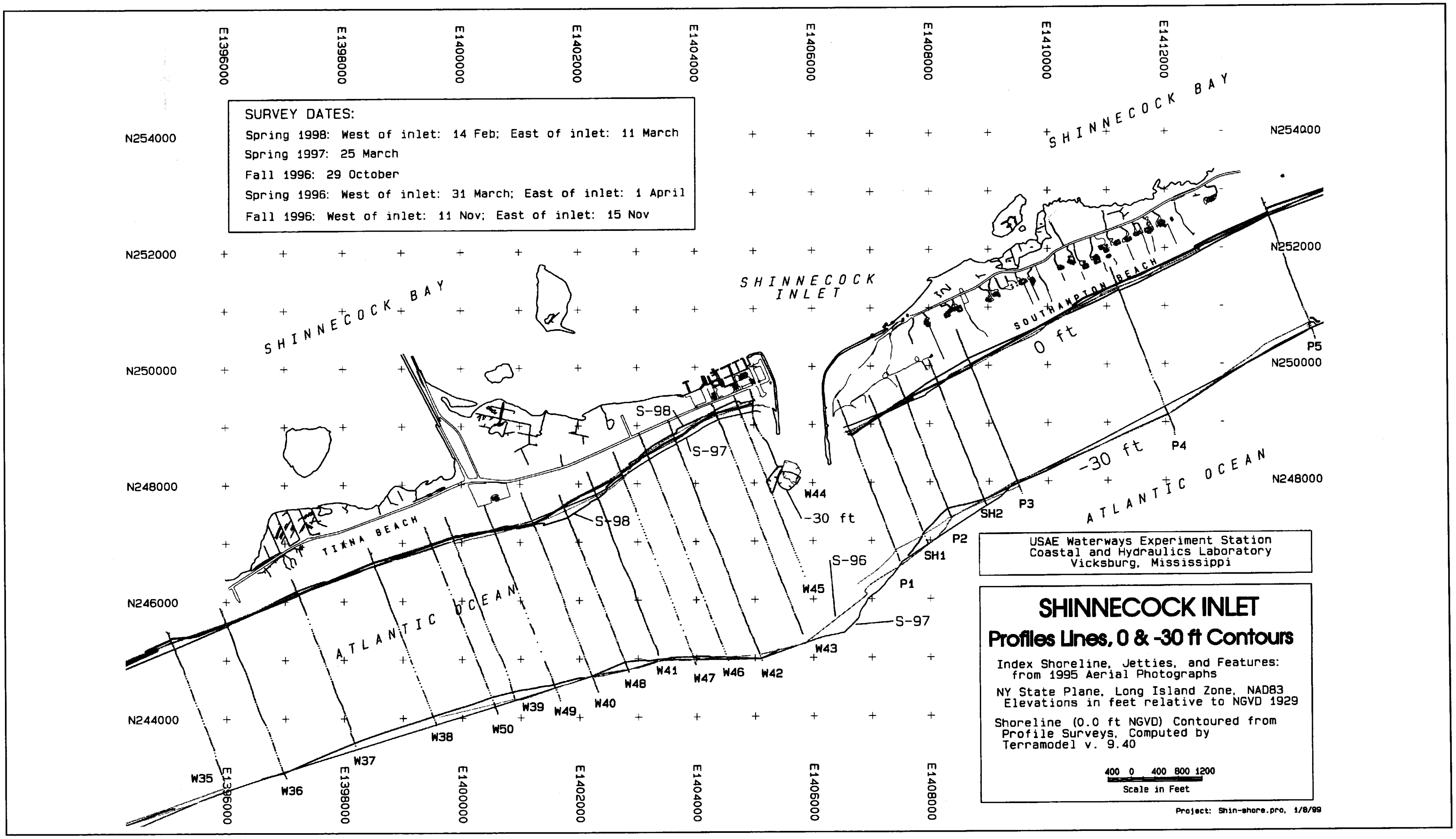

Figure 29. Shoreline changes and cross-shore profile locations (Spring 1998 profiles shown; other years follow almost identical azimuth. Shoreline curves represent 0.0 ft NGVD, as contoured with Terramodel™ software from profile data)

10 Summary and Conclusions

Shinnecock Inlet Geomorphic Stages

The modern Shinnecock Inlet was formed by the Great New England Hurricane of 21 September 1938, and its subsequent condition and geomorphology have been largely controlled by jetties and navigation channel dredging. The inlet's history can be divided into three phases:

Phase 1 - Breach and Natural Inlet, 1938

Phase 2 - Inlet Stabilized on West Side, 1939 - 1951

Phase 3 - Stabilized Inlet, Dual Jetties, 1952 - Present

The inlet was natural (unstructured) for only 7 months. By March 1939, construction of the revetment along the west side of the inlet was already underway (see Figure A8). Why was the revetment built so soon after the hurricane? Previous inlets along this stretch of coast always closed. According to the Shinnecock *General Design Memorandum,* "the structure acted as a brake to the tendency of the inlet to move westward" (USACE 1988; p. 8). However, the aerial photographs show that although the shorelines within the inlet changed during the 7 months, the overall inlet did not move along the coast. The engineers from the State of New York and Suffolk County must have anticipated that inlet migration and shoaling would occur in the future and concluded that a revetment along the west side of the inlet was necessary to stabilize the channel.

Ebb-Shoal Volume and Growth Rate

The total accumulation of sand (fill minus cut) over 60 years (1938 to 1998) in the ebb shoal was 8,453,000 yd^3, representing an average accretion rate of 141,000 yd^3/year. This value almost certainly understates the total sediment transport in the area because it cannot be assumed that all littoral material is trapped on the ebb shoal; some proportion is likely to be bypassing the shoal and continuing on down the coast. Also, some littoral material may be entering the inlet and moving back to the flood shoal. The ebb shoal appears to still be increasing in volume (see Figure 15). Another full-shoal hydrographic survey in 5 or so years will confirm if the growth is continuing.

Inlet Stability

Since 1984, Shinnecock Inlet has been stable with respect to position along the coast, cross-sectional area, and thalweg orientation. The first structure built at Shinnecock, the revetment on the west side, succeeded in anchoring the inlet in its present location. Although the thalweg occasionally migrated a short distance to the east (e.g., see Figure A14), most of the time the thalweg butted up against the revetment. However, with the east side unstructured and tidal currents free to flow over a broad expanse of shoal and beach, the inlet remained shallow. Boat traffic was difficult and hazardous, especially across the bar at the seaward margin of the ebb shoal.

After the jetties were built in the early 1950s, the inlet was anchored in its present location on both sides. The inlet scoured and its minimal cross-sectional area increased from about 6,000 to 17,000 ft^2 (see Figure 20). It is not known if the increase in cross section occurred rapidly (within a few years) or gradually over two decades because bathymetric data between 1955 and 1984 are not available. Presently, the minimum cross section is located between profile lines P9 and P10, about 150 m north of the tip of the east jetty (Figure 19). Since 1984, the cross-sectional area has been remarkably constant, indicating that sedimentation and erosion caused by tidal currents are in balance.

Jetty Damage

During the 1970s and 1980s, the north end of the east jetty was undermined and large sections collapsed. As blocks slumped away, the beach behind the jetty eroded. The cause of the initial scour was most likely strong tidal currents flowing against the east shore. Throughout the 1980s and 1990s, the thalweg has crossed from the west channel to the east side, directing the current against the vulnerable jetty. As seen on the aerial photographs, under certain conditions, waves propagate up the inlet and refract into the openings, further eroding the beach. Currents still impinge on the east jetty, and it is vulnerable to being damaged again.

Flood-Shoal Mining

The flood shoal looks substantial in aerial photographs. However, the amount of sand in this feature may be less than expected. The volume comparisons between the 1933 (pre-inlet USC&GS) and 1998 (SHOALS) data show that the present shoal is only a 1- to 2-m-thick veneer above the 1933 bay floor.

The present flood shoal formed between 1938, when the inlet was first breached, and 1951-53, when the jetties were built by Suffolk County and State of New York. During this interval, the inlet's east shore was unstructured, and the inlet was a wide, shallow opening that allowed flood currents to carry sand into the bay without restriction. After the jetties were built, photographs show the flood shoal changing shape as sand bodies moved about, but it is difficult to determine if there was much new growth. The jetties probably stopped or greatly reduced new (open-coast) sand from entering the bay.

From 1953 to the present, the ebb shoal grew wider and projected further out to sea. At present, it is unknown if sediment from Shinnecock Bay has moved out onto the ebb shoal or if all the growth was due to sand supplied by littoral currents. During the summer of 1998, grab samples from various locations on the ebb and flood shoals and within the inlet were collected. Sediment characteristics and pathways will be discussed in Report 3 of this series. The thalweg's pathway has been stable since the 1950s, and the cross section has also been surprisingly constant since 1984. Although some sand probably moves through Shinnecock Inlet, there is no evidence that large amounts of sand are presently moving landward or seaward.

The region of Shinnecock Bay occupied by the present flood shoal has lost sand since 1938 (cut volume: 4,163,000 yd^3; fill volume: 3,684,000 yd^3). The loss is largely a result of dredging the navigation channels. The sand is placed on the west beach, from where it is eroded and lost out to sea (or possibly moves onto the ebb shoal). The navigation channels are just north of the inlet, so as a result, the barrier now is a taller, narrower structure than it was in 1933. Under present conditions, this artificial removal of sand from the back bay is a permanent loss.

The pre-inlet bay floor was almost flat, sloping from above water at the barrier to a depth of only 3 m about 1 km north. This bay bottom was probably largely sand supplied through washover over hundreds of years. If the washover were recent, the sand should resemble closely the material being transported in littoral drift along the Atlantic side of the barrier. But, if the sand had not been regularly renewed, there may be a large organic or fine content (making it less suitable for beach fill). McCormick (1971) reported that the sand on the flood shoal resembled sand on the ocean side of the barrier, but he did not have access to cores to examine deeper material.

There is not much sediment input from land, although in major rainstorms, runoff from farms probably supplies some silt and clay to Shinnecock Bay. Whether this material reaches the south side of the bay near the barrier island is not known. At the barrier, there is probably some input of sand into the bay from occasional overwash (during northeasters) and from aeolian sources (sand blowing from the beach and dunes). Also, sand bodies within the bay move around, so some maintenance dredging of the channels will continue to be required.

The ebb shoal is an accumulation of about 8,400,000 yd^3 of sand, and it appears to still be growing. The New York District dredged 440,000 yd^3 in 1998 from the deposition basin at the mouth of the inlet (Figure 2). This represents 5 percent of the total volume, about a 3-year accumulation assuming an average growth rate of 140,000 yd^3 (as computed from the 1998 SHOALS survey data). The ebb shoal definitely receives a greater annual sediment input than the flood shoal and, therefore, is a more likely source of sand that can be mined on a regular basis.[1]

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[1] Bypassing options using various systems are discussed in Report 2 of this series (Williams, Morang, and Lillycrop 1998).

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Appendix A
Aerial Photographs

Background

All known professional vertical aerial photographs of the Shinnecock Inlet area are listed in Table A1. Select historical oblique photographs are listed in Table A2. Scanned copies of most of these images are reproduced in this appendix. For some dates, additional photographs covering many kilometers of the shoreline are available.

An informative collection of photographs, assembled by the Beach Erosion Board,[1] has been recovered at the U.S. Army Engineer Waterways Experiment Station (WES). The archives include aerial photographs taken on 24 September 1938, just 3 days after the Great New England Hurricane. Many of the poststorm images were mosaicked on cardboard backing, and labels indicate that the BEB conducted erosion studies of the area. Some of the findings are presented in Taney (1961a,b),[2] but reports specifically dealing with storm effects have not been recovered. Many of the older photographs were brought to WES when the Coastal Engineering Research Center moved to Vicksburg from Virginia in 1982.

Other aerial photographs were provided by the U.S. Army Engineer District, New York, and Suffolk County Department of Public Works and were purchased from survey contractors.

Technical Notes

Many of the early BEB aerial photographs have discolored because of inadequate fixing and chemical residue from the rubber cement used to mount

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[1] The Beach Erosion Board (BEB) was the predecessor organization to the Coastal Engineering Research Center, now located at WES in Vicksburg, Mississippi.

[2] References cited in the appendix are located at the end of the main text.

Table A1
Shinnecock Inlet Aerial Photographs - Vertical

Date	Color Pan	Scale, altitude	Coverage	No.	Contractor	Notes
30 Jun 38 and 6 Jul 38	P	1:20000	Barrier, most of Shinnecock Bay	ASA-1-98 to (?)	U.S. Army Air Corps?	(Mosaicked together - BEB study). Prehurricane; shows canal at site where inlet breached. Back of photos have label, "This photograph contains information affecting the national defense of the United States with the meaning of the Espionage Act, 50 U.S.C., 31 and 32."
24 Sep 38 4:15 pm	P	Approx. 1:6,500	Barrier, minimal bay	M125-11 and 12	8th Photo Section Air Corps, Mitchel Field (?). (BEB archives)	Taken 3 days after the Great New England Hurricane, showing many inlets and overwash fans. Part of a series of 157 photos, Fire Island Inlet to Southampton.
29 Nov 38 10:30-11:30 am	P	Low alt.	Moriches to Southampton	M-128 51 to 58 (Shinnecock area)	8th Photo Section Air Corps, Mitchel Field. (BEB archives)	Views of overwash and inlets. Shinnecock: tiny flood shoal, U-shaped ebb shoals (shows inlet was breached bay to sea).
20 Dec 38 10:00 am	P	1:6,500	Barrier - minimal coverage of bay	M130-34 to M130-40	8th Photo Section Air Corps, Mitchel Field (?). (BEB archives)	Part of a series. Ebb shoal has flattened against the coast.

(Sheet 1 of 5)

Notes:
1. Format: All photographs paper prints only; availability of original negatives or transparencies for black & white images before 1950 unknown.
2. Contractors:
   Aerographics = AeroGraphics Corp., Bohemia, NY.
   American = American Air Surveys, Pittsburgh, PA.
   CTM = C.T. Male Associates, P.C., Latham, NY.
   Fairchild = Fairchild Aerial Survey, Long Island City, NY
   Grumman = Grumman Ecosystems Corporation, Bethpage, NY.
   LKB = Lockwood, Kessler & Bartlett, Inc., Consulting Engineers.
   OSI = Ocean Surveys, Inc., Old Saybrook, CT.
   SB = Sidney B. Bowne & Son, Mineola, NY.
   TMI = TopoMetrics, Inc., Happauge, NY.
   TVGA = TVGA Engineering, Surveying, P.C., Elma, NY.
3. Sources:
   ACNY: Atlantic Coast of New York Monitoring Project, 1995-present. Profiles and aerial photographs.
   BEB archives: Photographs assembled by the BEB into mosaics, recovered from file cabinets at WES, Vicksburg, MS, in Sep-Oct 1998.
   Suffolk: Suffolk County Department of Public Works, Division of Bridges, Structures & Waterways.
4. Other photographs:
   Available from LKB but not purchased for this project: 1955, 1962, 1964, 1966, 1969, 1972, 1978, 1984, 1992, 1996

Table A1 (Continued)

Date	Color Pan	Scale, altitude	Coverage	No.	Contractor	Notes
24 Feb 39 10:30-12:00 am	P	1:6,500	Barrier and bay	132-34 to 132-39 (?)	8th Photo Section Air Corps, Mitchel Field (?). (BEB archives)	Part of a series "Long Island Coastal Erosion." Shinnecock: minimal ebb shoals but flood already grown since 1938.
21 Mar 39 10:30-12:00 am	P	1:6,500	Barrier and bay	M133-36-881-A-E-1-97 (?)	8th Photo Section Air Corps, Mitchel Field (?). (BEB archives)	Part of a series "Long Island Coastal Erosion" from Moriches to Shinnecock
11 Apr 39 2:00 to 3:00 pm	P	1:6,500	Barrier and bay		U.S. Army Air Corps 97th Obs. Sq. (C&A) AC., Photo Section, Mitchel Field. (BEB archives)	West side stabilized with revetment. Minimal ebb shoal, flood shoal growing. Part of a mosaic "Fire Island, N.Y., Democrat Point to Amagansett, Aerial Photographic Mosaic Showing Condition of Beach after September 1938 Hurricane."
1941	P	1:20000	Complete flood shoal	L-13-7 and L-14-9		13- by 16-in. prints; series covers entire Long Island
22 Apr 46	P	Med alt.	Complete barrier, <½ of flood shoal	133-140	U.S. Army Air Corps?	Channel follows revetment on west shore.
1 Apr 47	P	12,000 ft alt.	Full ebb shoal and nearby area. Wide inlet, two nav. channels.	51-76		Tide +0.3 mlw
12 Apr 49	P	1:12,000	Full ebb shoal. Wide inlet, two nav. channels.	8785-32	Fairchild (Suffolk Co.)	Channel still running along west shore.
29 Jun 49	P	1" = 446"	Inlet and ebb shoal.	104129	Fairchild (Suffolk Co.)	Channel moved toward center of inlet, sand spit extends out from west revetment.
27 Nov 50 3:39 pm	P	Med alt.	Beach, no flood shoal	93-95	LKB	No east jetty. Channel still follows west shore. No ebb shoal, waves breaking in straight line across inlet mouth.
18 Aug 52 12:09 pm	P	1:400 (1" = 400'?)	Partial flood shoal	93 02	LKB	Low tide: 12:21 pm. East jetty construction. Spit extends out from west shore.
30 Apr 53	P	High alt.	Partial flood shoal, need one more photo E.	J525, J526		East jetty complete. Erosion of shore north of east jetty.

(Sheet 2 of 5)

Table A1 (Continued)

Date	Color Pan	Scale, altitude	Coverage	No.	Contractor	Notes
10 Mar 56	P	High alt. 1" = 800'	Much of flood shoal	23-73 to 23-76	LKB	West jetty complete. Spit projects into inlet from west shore. Some evidence of ebb shoal.
8 Mar 62	P	Med. alt.	Partial flood shoal	656-184, to 186	LKB	High-quality prints. Slight ebb shoal bulge.
25 Mar 62	P	High alt.	Barrier and flood shoal	S3566 and S3567		Good view of Shinnecock Bay, overall landforms.
18 Feb 66	P	Low alt.	Barrier only	1543-130 to 132 and 1543-133 to 140	American	Excellent beach detail. Suitable for shoreline analysis.
23 Feb 72	P	1" = 400'	Barrier only	05472 8 069 to 073 (whole series covers Shinnecock - Moriches)	Grumman	Low altitude, highly detailed. Ice floes. Good series for shoreline mapping
6 Apr 76	P		All flood shoal	67075 68-1940, 69-1961 to 69-1963, 70-1988 to 70-1990	Aero-Graphics	Scallops at bay ends of both jetties. West beach fill in progress (from back bay).
10 Aug 76	P	High alt. 1" = 800'	Much of flood shoal	3201-066 to ?	LKB	Scallops at bay ends of both jetties. Big ebb shoal.
24 Mar 80	P		All flood shoal	8093 68-0512, 69-0515 to 69-0517, 70-0566	Aero-Graphics	Erosion 2,000 ft west of west jetty. Excellent view of flood shoal, can detect outline of ebb shoal (69-0515).
2 Apr 83	P		<½ of flood shoal	7-353, 7-355		Can detect approx. outline of ebb shoal from breaking waves.
21 Apr 83	C	1:19,200	Much of flood shoal	820-27-500		Shore erosion and dune loss ≈2,000 ft west of west jetty.
27 Apr 84	C		<¼ of flood shoal	84836B-5-191		Provided by Mr. Gray Smith, Moffatt & Nichol. Original source unknown.
29 Sep 85	P		Most of flood shoal	58299 3-122 to 3-127	Aero-Graphics	West beach healthy. Minimal visibility through water.
2 Mar 88	P	High alt.	Most of flood shoal	LKB8019 3971-50-209	LKB	Ebb shoal not visible. Bay shore of east side scalloped.
5 Apr 88	P	High alt.	All flood shoal	88180 1-271 to 1-274	Aero-Graphics	East-west sand ridge on flood shoal. Bay shore of east side scalloped.
22 Mar 89	C	1:10,300	All flood shoal	89888, No. 6 152 to 156		East-west sand ridge on flood shoal. (153 avail. as 36- by 36-in. print.)

(Sheet 3 of 5)

Table A1 (Continued)

Date	Color Pan	Scale, altitude	Coverage	No.	Contractor	Notes
4 Sep 91	C	Med. alt.	Some of flood shoal	910809 1-13 to 1-15	TMI	Flood shoal has moved bayward (north). Bay shore of east side scalloped.
20 Dec 91	C	Med. alt.	Some of flood shoal	911204 10-32, 10-33 and 11-4	TMI	Bay shore of east side scalloped.
29 Sep 92	C	High alt.	Much of flood shoal	V2	TMI	East-west sand ridge on flood shoal.
29 Sep 92	C	Med. alt	<½ of flood shoal	I-34 to I-36	TMI	Erosion west of west jetty. East bay revetment being rebuilt.
18 Dec 92	C	Med. alt.	<¼ of flood shoal	921207 11-1 to 11-5	TMI	Erosion west of west jetty. East bay revetment being rebuilt.
21 Dec 92	P		⅔ of flood shoal. Ebb shoal not visible.	29203 1-158 to 1-163	Aero-Graphics	Severe erosion 1,000 ft west of west jetty
14 Jun 93	C		All flood shoal	39122 1-39, 1-40		East revetment almost complete. (1-40 is 36- by 36-in. print.)
13 Oct 93	C		Partial shoal	934015 2-3		East revetment complete. (18- by 18-in. print.)
8 Apr 94	P		All flood shoal. Ebb shoal not visible, no waves.	49020 0-419 to 0-424		Erosion of west beach.
15 Sep 94	C	1:9,600	All flood shoal	V 94-38		36- by 36-in. print
15 Sep 94	C	Med. alt.	≈⅔ of flood shoal	I-29 to I-32		Minor erosion of west beach compared with 1993.
26 Mar 95	C	1:9,600	Full shoal (all s. shore bays covered)		TVGA	Monuments flagged by TVGA.
10 Apr 95	C	1:9,600	Full flood shoal, no ebb shoal	EAA 95-2S 19-585 and 19-586	Erdman Anthony	West beach healthy. Avail. as topographic maps, Intergraph format, made by Erdman Anthony Engineers, Inc.
5 Nov 95	C	1:9,600	<½ of flood shoal	4-41 to 4-43	OSI	Monuments flagged by CTM
30 Mar 96	C	1:9,600	ACNY: Coney to Montauk		SB?	(Avail. from New York District.)
15 Apr 96	C		<⅓ of flood shoal	10-648 to 10-652	Aero-Graphics	No waves; water too dark to see ebb shoal.
21 Sep 96, 24 Oct 96	C	1:9,600	ACNY: Coney to Montauk. ≈⅔ of Shinnecock flood shoal.	96-152B 4-230 to 4-232	SB	Severe erosion 1,000 ft west of west jetty. (Avail. from New York District.)

(Sheet 4 of 5)

Table A1 (Concluded)

Date	Color Pan	Scale, altitude	Coverage	No.	Contractor	Notes
10 Apr 97	P		Full flood shoal	79040 8-173 to 8-177	Aero-Graphics	West beach good condition.
22 Apr 97	C	1:9,600	ACNY: Coney to Montauk		SB	Monuments flagged by SB. Every second image avail. in digital .jpg format, scanned at 1,100 dpi (not rectified)
31 Oct 97	C	1:9,600	ACNY: Coney to Montauk; most of flood shoal	97-293 3-224 to 3-227	SB	Monuments flagged by SB
20 Nov 97 10:54	C	1:9,600	ACNY: Coney to Montauk; ⅔ of flood shoal	97-293 4-229 to 4-232	SB	Monuments flagged by SB
12 July 1998	C	1:9,600	ACNY: Coney to Montauk; ½ of flood shoal	7-73, 74, and 75		Flown for ACNY (first flight of 1998)

(Sheet 5 of 5)

them. The nonmounted (loose) prints were 7¼ by 9¼ in. The post-1950 aerial images were 9 by 9 in. monochrome or color prints.

Most photographs were scanned at 150 × 150 dots per inch (dpi). Color images were scanned on the "sharp millions of colors" setting and monochrome images on the "sharp black and white" setting (8-bit grey density or $2^8 =$ 256 grey shades). For many of the prints, the shape of the density curve was manually adjusted to preserve detail on the beaches and prevent them from reproducing as washed out and featureless. Even the discolored BEB photographs yielded good-quality scans.

Images are reproduced on the following pages at approximately two-thirds of full size (i.e., a 9-in.-high photograph is reduced to about 6 in. high). Because the scanner platter was only 8½ in. wide, a strip of each 9 by 9-in. square photograph has been lost. The lost strip of image was usually selected to be the side opposite of where date and image number were printed.

All photographs are reproduced with north approximately to the top (the modern jetties are aligned almost due north-south). In this orientation, Shinnecock Bay is at the top of the figures and the Atlantic Ocean is on the bottom.

Table A2
Shinnecock Inlet Aerial Photographs - Oblique

Date	Color Pan	Altitude	Coverage	No.	Contractor	Notes
29 Jun 49	P	High	View north-east. Full ebb and flood shoals, east end of Shinnecock Bay.	104125	Fairchild (Suffolk County archives)	Low tide. Ebb shoal only minor bulge compared with 1990s.
2 Sep 49	P	High	View north to Great Peconic Bay.	104563	Fairchild (Suffolk County archives)	Marginal spits on both sides of inlet mouth.
27 Nov 50	P	Med	Inlet area, barrier	50-2762 to 2765	Fairchild (Suffolk County archives)	
Oct 50	P	Various	West revetment and cribs, flood &ebb shoals,	50-2274, 2278	Fairchild (Suffolk County archives)	Vegetated dunes, only one boat slip, shallow water along back side of barrier.
1951 (?)	P	Various	Shinnecock Bay, inlet mouth		Westhampton	Spit has almost blocked seaward mouth of inlet. (2 photos)
30 Nov 51	P	Med	Shinnecock Inlet, part of bay		Thomas (from Dent 1951)	Spit has partially blocked inlet, similar to 1951 above.
28 Mar 52	P	High	Shinnecock Bay view north		Westhampton	Low contrast image. Channel hugging west revetment.
20 Jul 52	P	Various	Flood and ebb shoals		Westhampton	Very flat ebb shoal, little protrusion offshore. (2 photos)
18 Jan 80	P	Oblique, low altitude	Shinnecock, Moriches, Westhampton Beach	08013 0-01 to 0-46	?	High resolution, low altitude, taken with 9- by 9-in. aero photography camera

Notes:

1. Format: All photographs paper prints only; availability of original negatives or transparencies unknown.
2. Contractors:
   Fairchild = Fairchild Aerial Survey, Long Island City, NY
   Thomas = Thomas Airviews, Bayside, NY
   Westhampton = Westhampton Photo Studio (no longer in business, archives lost)
3. Sources:
   Suffolk: Suffolk County Department of Public Works, Division of Bridges, Structures & Waterways
4. Other photographs:
   Numerous 1990s photographs taken with hand-held 35 mm camera available from First Coastal Corp., Westhampton Beach, New York.

Figure A1. 30 June 1938 (Photograph taken before the Great New England Hurricane of 21 September cut barrier island in numerous locations. During the storm, the present Shinnecock Inlet breached where a channel crosses from bay to road. Channel may be a remnant of an inlet that was dug by Shinnecock and Peconic Canal Company in 1896. Another identifier of inlet's location is left-right jog in road, which disappeared when storm washed away this part of barrier. This image is part of a mosaic prepared by BEB)

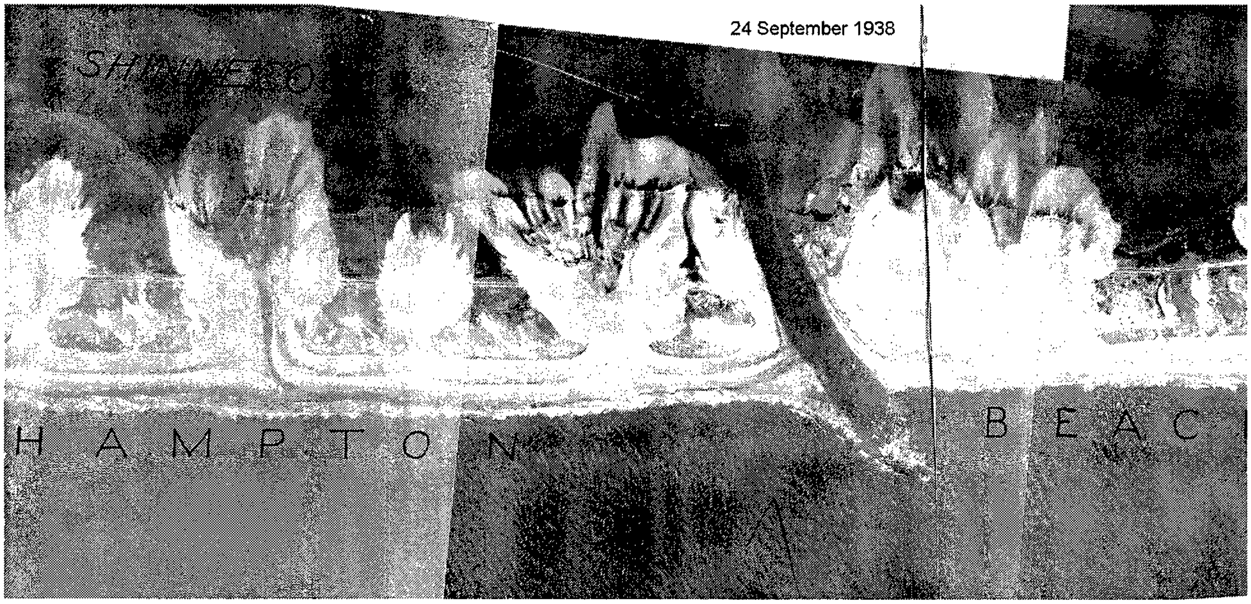


Figure A2. 24 September 1938 (Taken 3 days after the Great New England Hurricane, image shows new Shinnecock Inlet and many overwash fans along adjacent shore. All inlets along this stretch of coast trended left of shore-perpendicular. This image is a portion of a mosaic prepared by BEB. These frames are part of a series of 157 photographs covering Fire Island Inlet to Southampton. Photographs probably taken by U.S. Army Air Corps from Mitchel Field, Long Island)

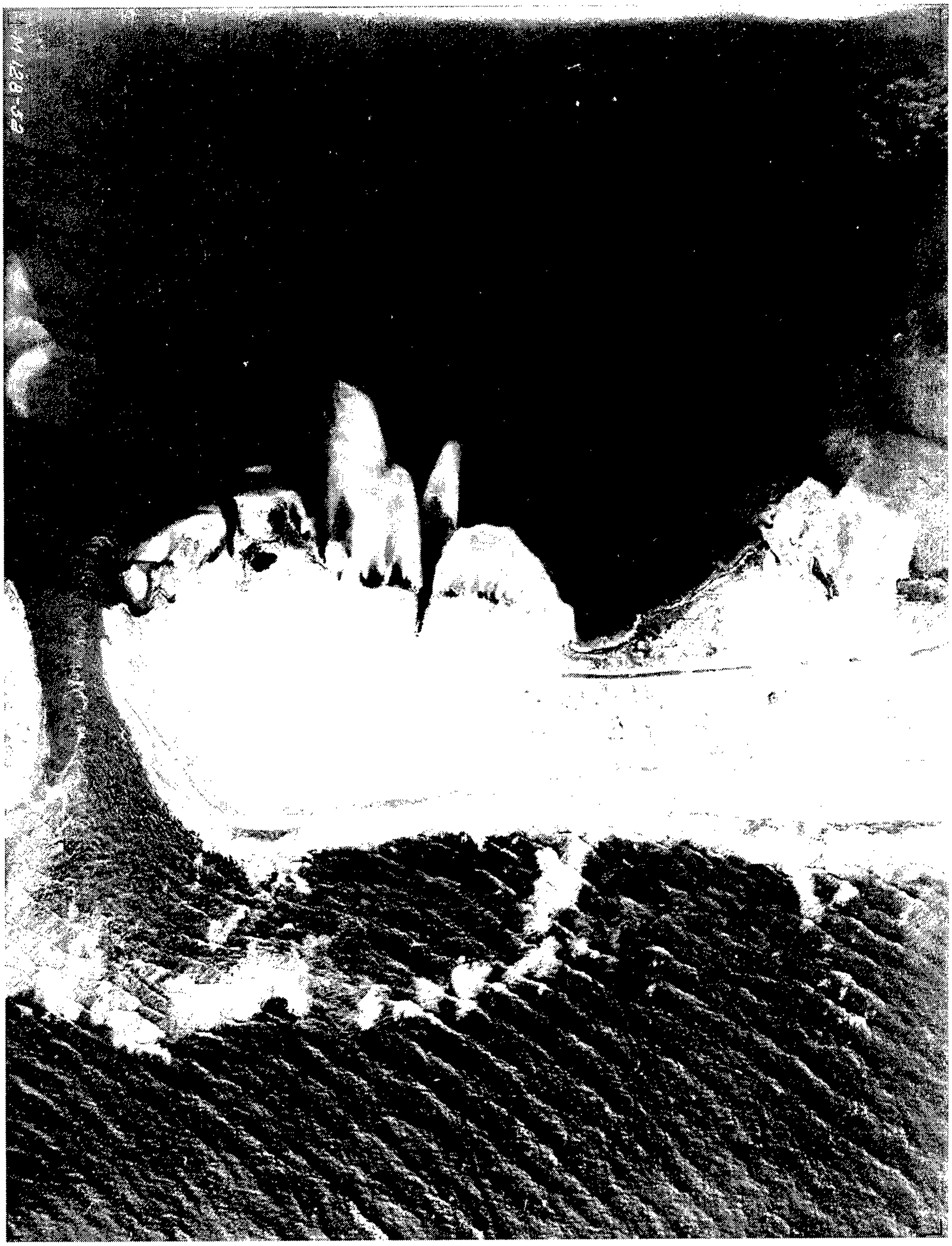


Figure A3. 29 November 1938 (Photograph one of three (east of inlet). Taken 1 month after the 21 September hurricane breached the barrier island. Washover deposits have covered most of the paved road. Breaking waves outline recently formed ebb shoal. Series of photographs taken by the Army Air Corps)

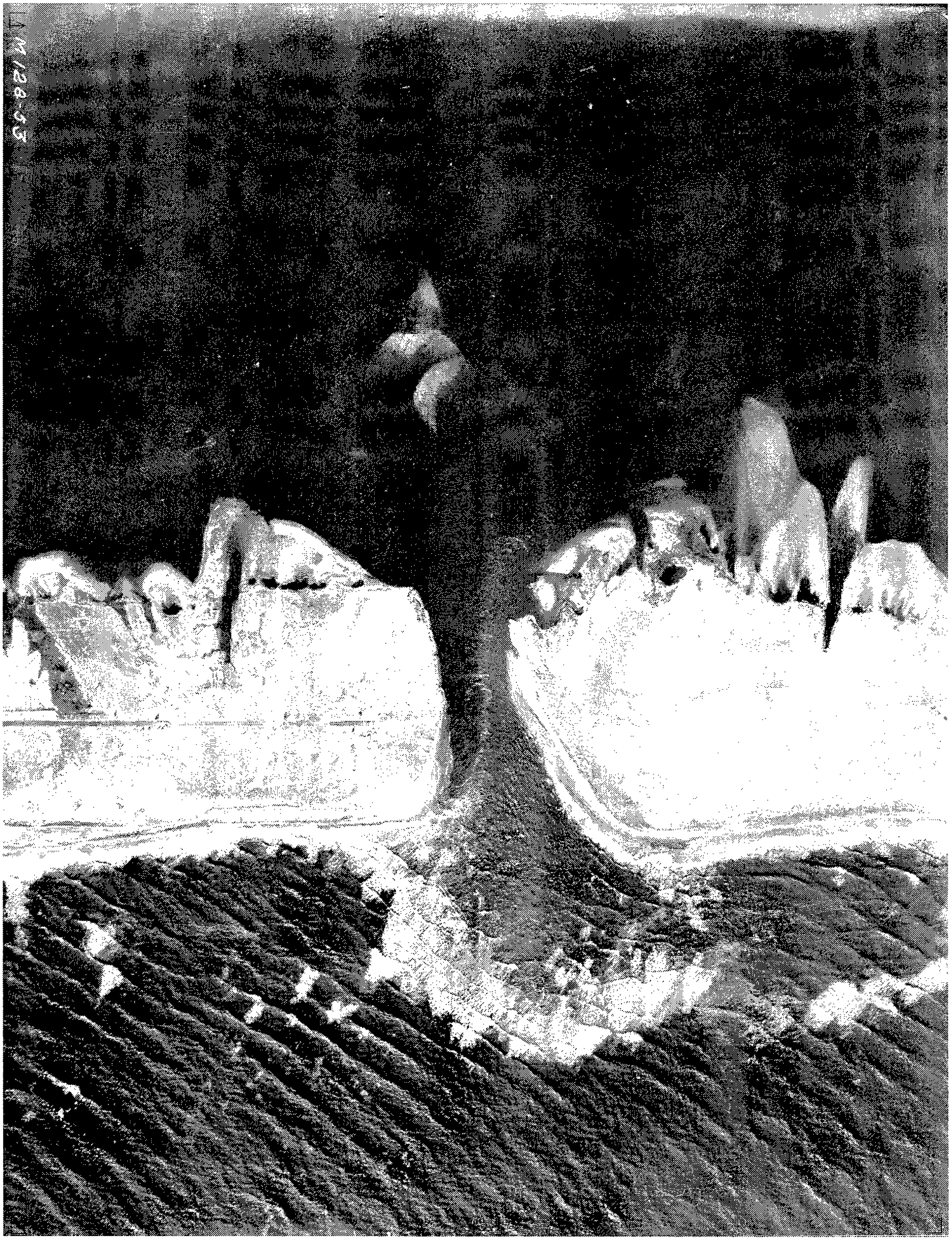


Figure A4. 29 November 1938 (Photograph two of three (centered on inlet). Ebb and flood shoals are already forming)

Figure A5. 29 November 1938 (Photograph three of three (west of inlet). Minor inlet, in the leftmost overwash fan, has closed (see Figure A2))

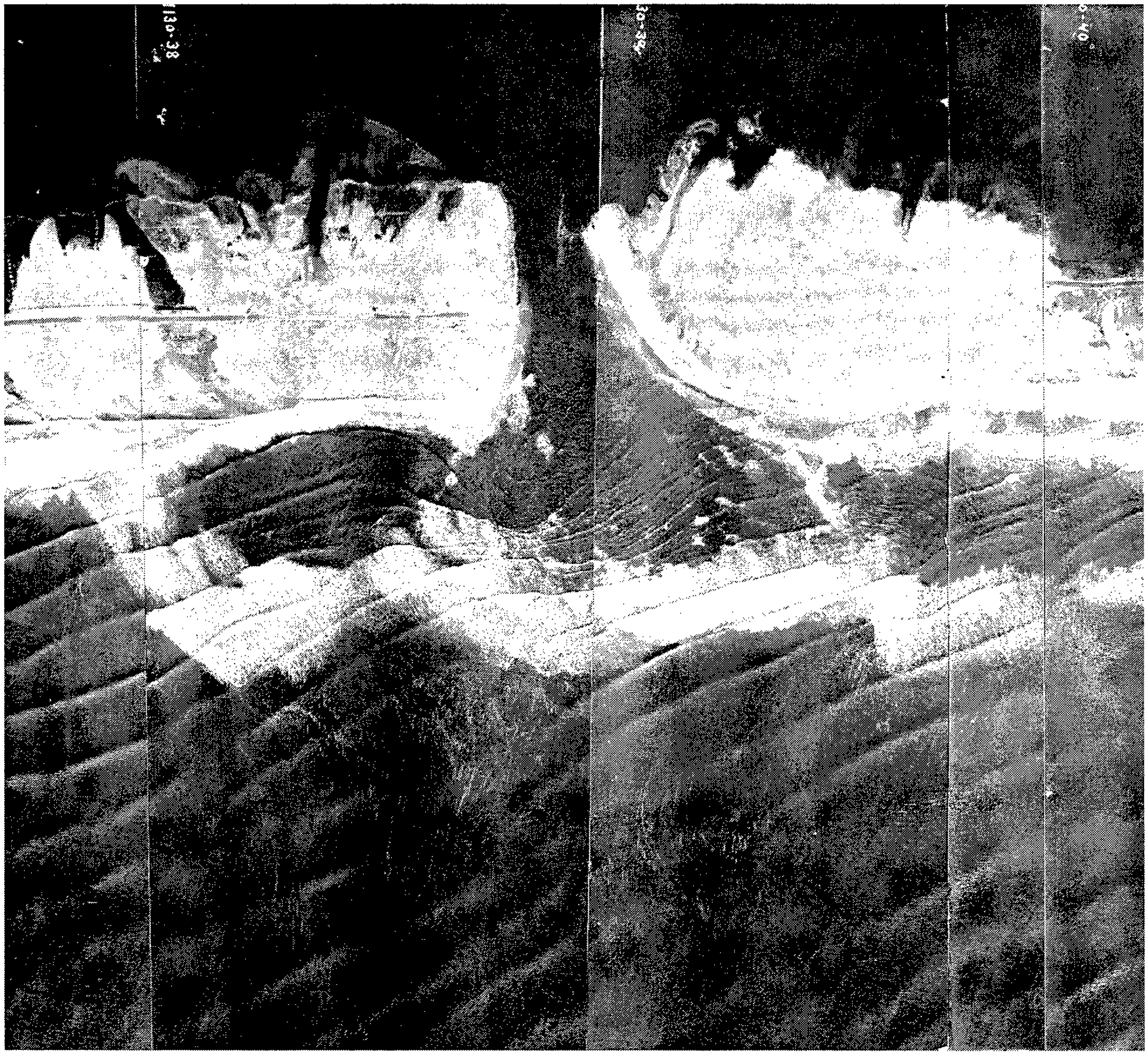


Figure A6. 20 December 1938 (Mosaic prepared as part of a BEB study of shoreline erosion. Formerly U-shaped ebb shoal has flattened and spread along shore)

FIRE ISLAND, N.Y. (21)

HAMPTON BEACH

SCALE 500 0 500 FT. APPROX. 1/6500

PHOTOS TAKEN FEB. 24, 1939

(10:30-12 M)

Figure A7. 24 February 1939 (Five months after the hurricane, a prominent flood shoal has formed in Shinnecock Bay, while ebb shoal appears to have diminished since December 1938. Construction equipment is stockpiled on road just west of inlet in preparation for construction of a bulkhead. Ocean shore east of inlet has eroded. Photographic mosaic prepared by BEB)

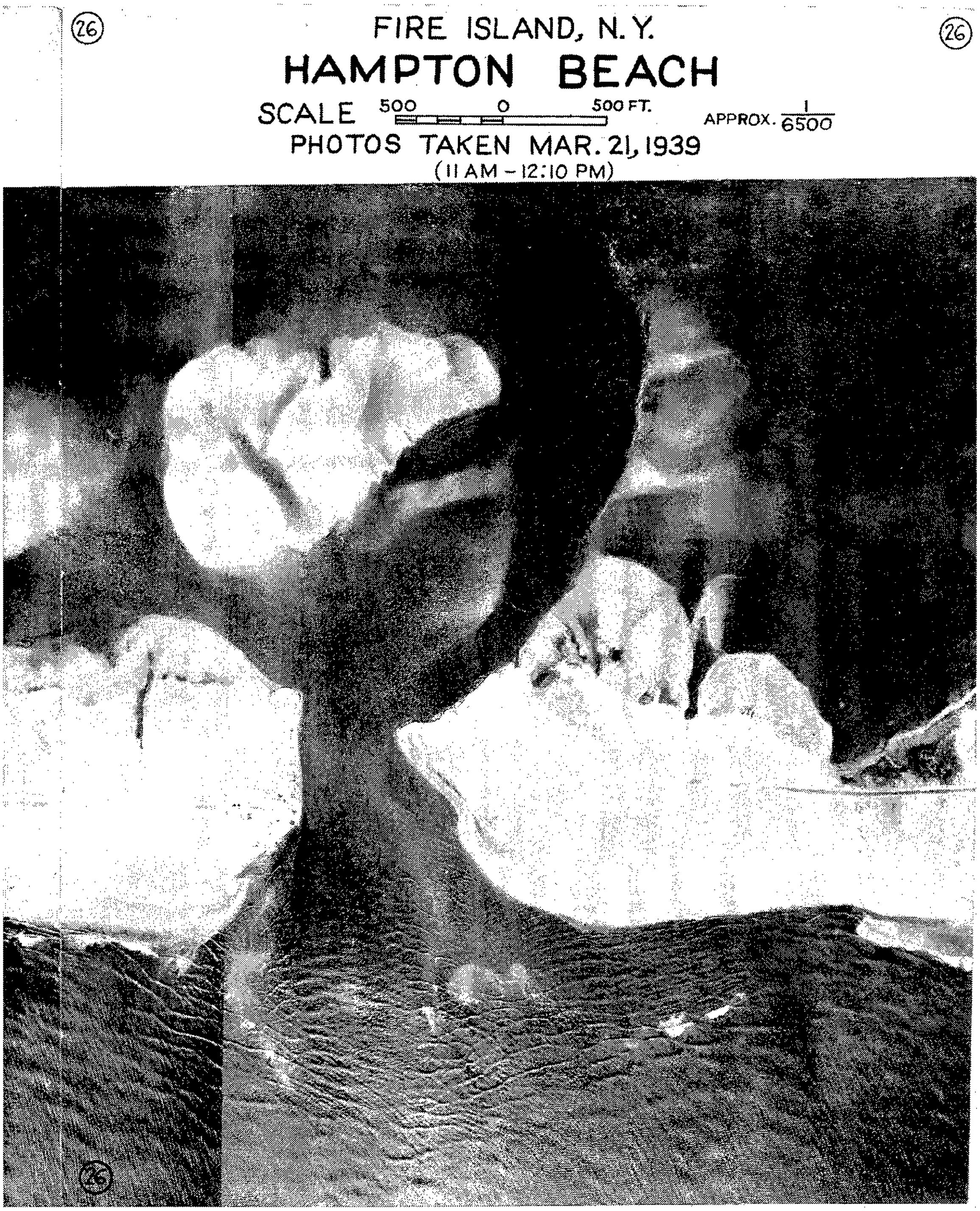


Figure A8. 21 March 1939 (Flood shoal continues to grow. An area of wave disturbance outlines ebb shoal. Main Shinnecock Bay channel runs east of the flood shoal. Construction of revetment on west side of inlet is underway. Mosaic prepared as part of a BEB study of shoreline erosion)

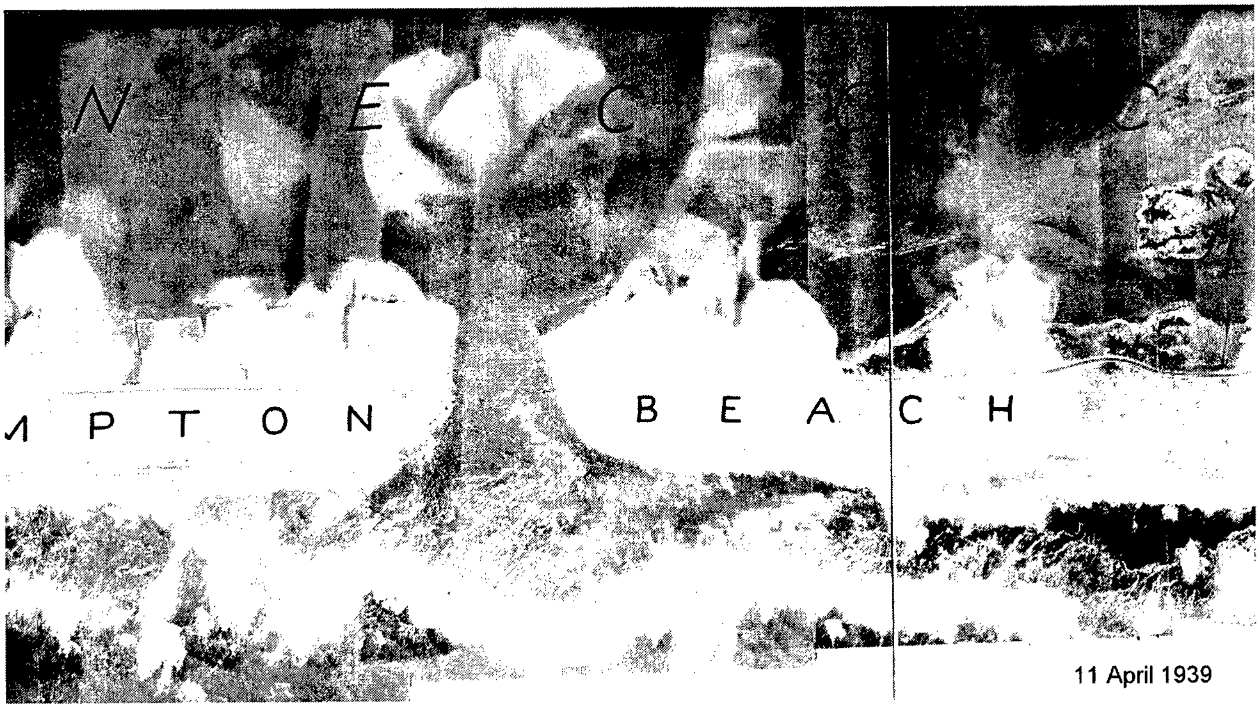
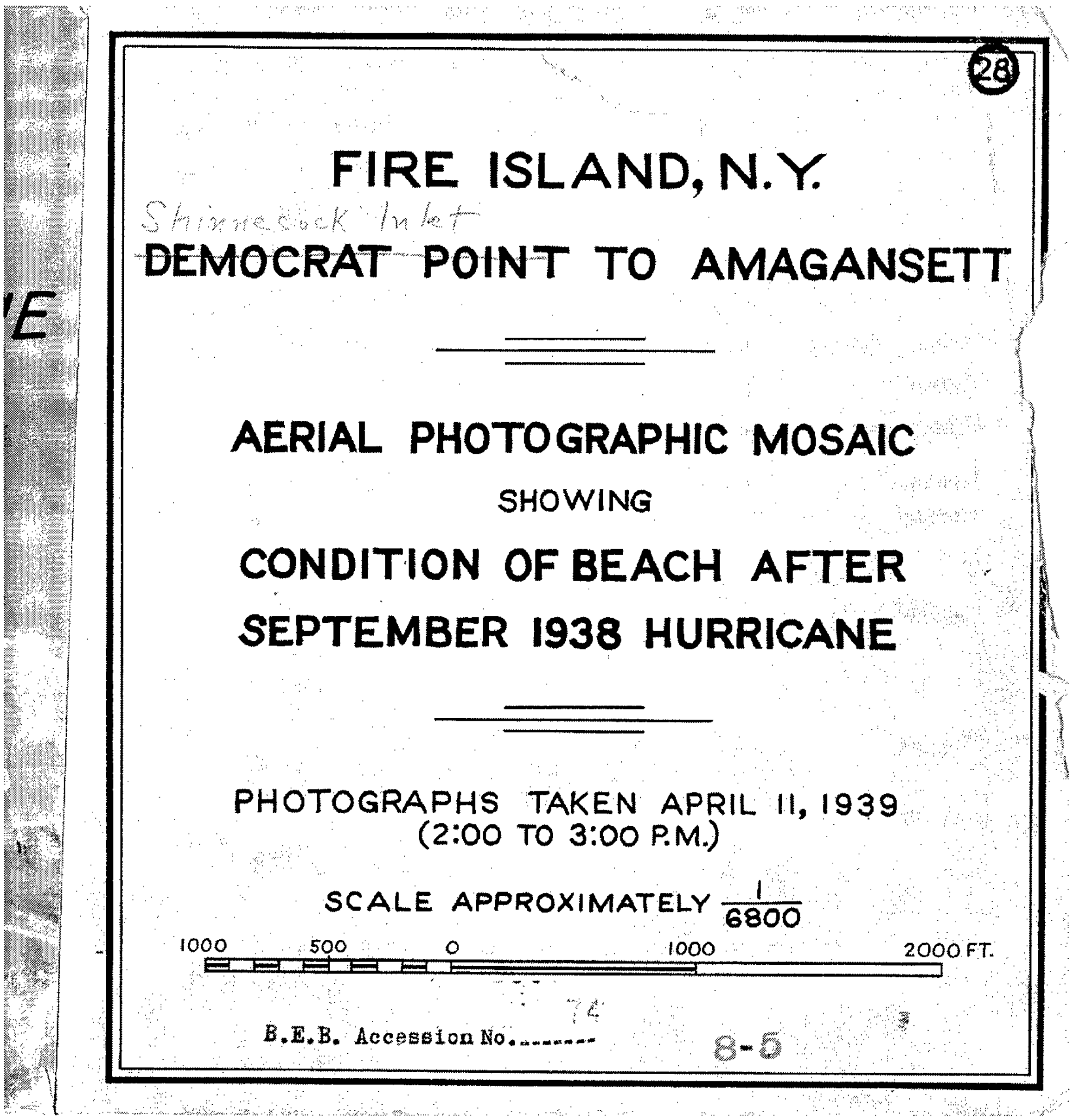


Figure A9. 11 April 1939 (West side of inlet has been stabilized with a revetment. Ebb shoal is minimal, and flood shoal has not noticeably changed since March. Part of a mosaic, "Fire Island, N.Y., Democrat Point to Amagansett," assembled by BEB. Credit line states, "Photo by U.S. Army Air Corps, 97th Obs. Sq. (C&A) AC., *Photo Section,* Mitchel Field, *L.I., N.Y.*")


28

FIRE ISLAND, N.Y.

Shinnecock Inlet

~~DEMOCRAT POINT~~ TO AMAGANSETT

AERIAL PHOTOGRAPHIC MOSAIC

SHOWING

CONDITION OF BEACH AFTER SEPTEMBER 1938 HURRICANE

PHOTOGRAPHS TAKEN APRIL 11, 1939 (2:00 TO 3:00 P.M.)

SCALE APPROXIMATELY $\frac{1}{6800}$

1000 500 0 1000 2000 FT.

B.E.B. Accession No. 74

8-5

Figure A10. Identification label from 11 April 1939 mosaic prepared by BEB (This well-crafted mosaic is about 20 m long)

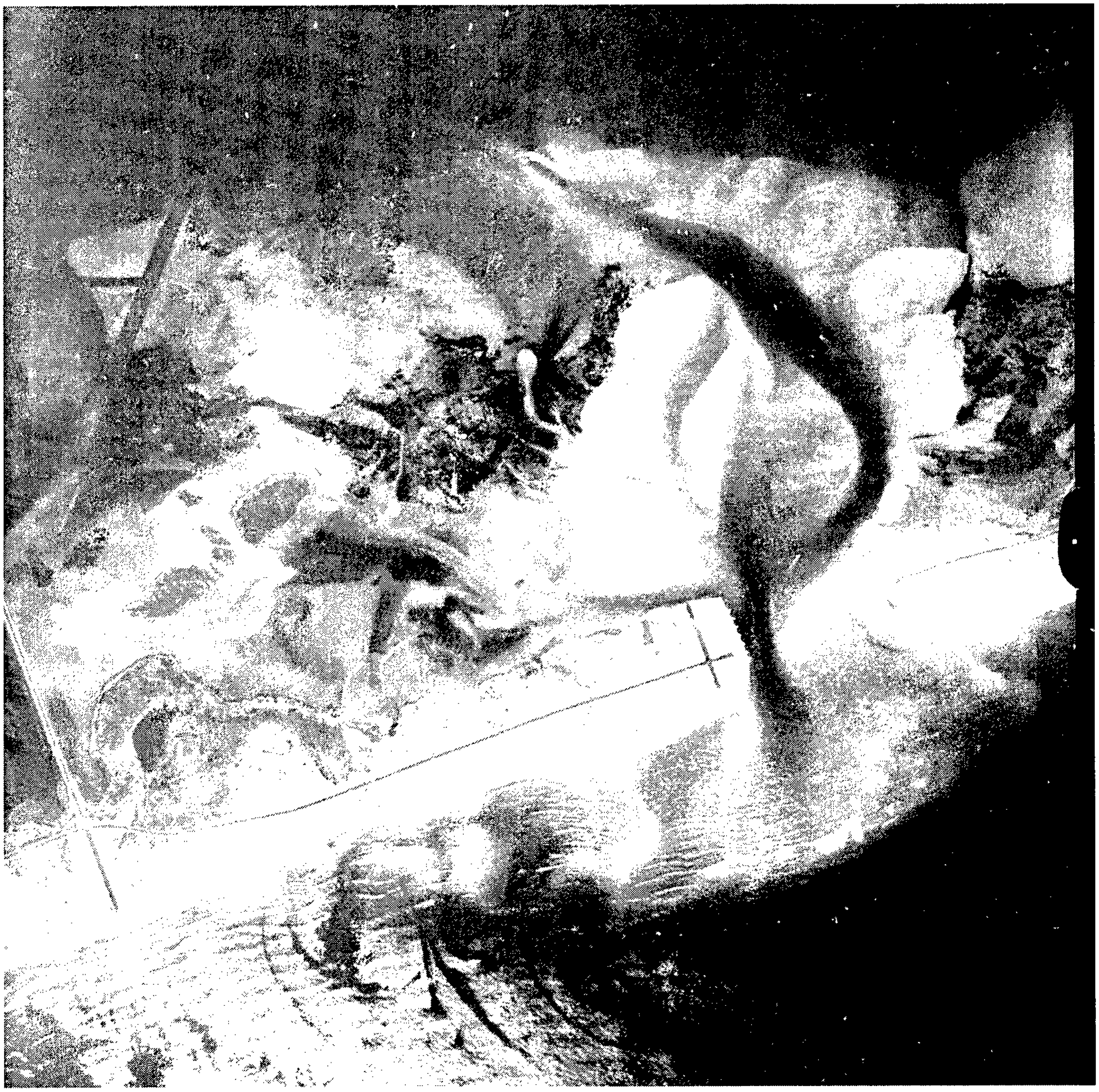


Figure A11. 1941 (date written with grease pencil on an adjoining frame) (Part of a high-altitude image that covers west third of Shinnecock Bay. Channel east of flood shoal is main access between Bay and Atlantic. West of the new flood shoal is a complex of marshes and sand bodies, evidence of former flood shoals and washovers. Inlet width between west revetment and protrusion that bulges out of east shore is 900 ft, based on scaling distance of 5,200 ft between Ponquogue Bridge road and cross road just west of inlet)

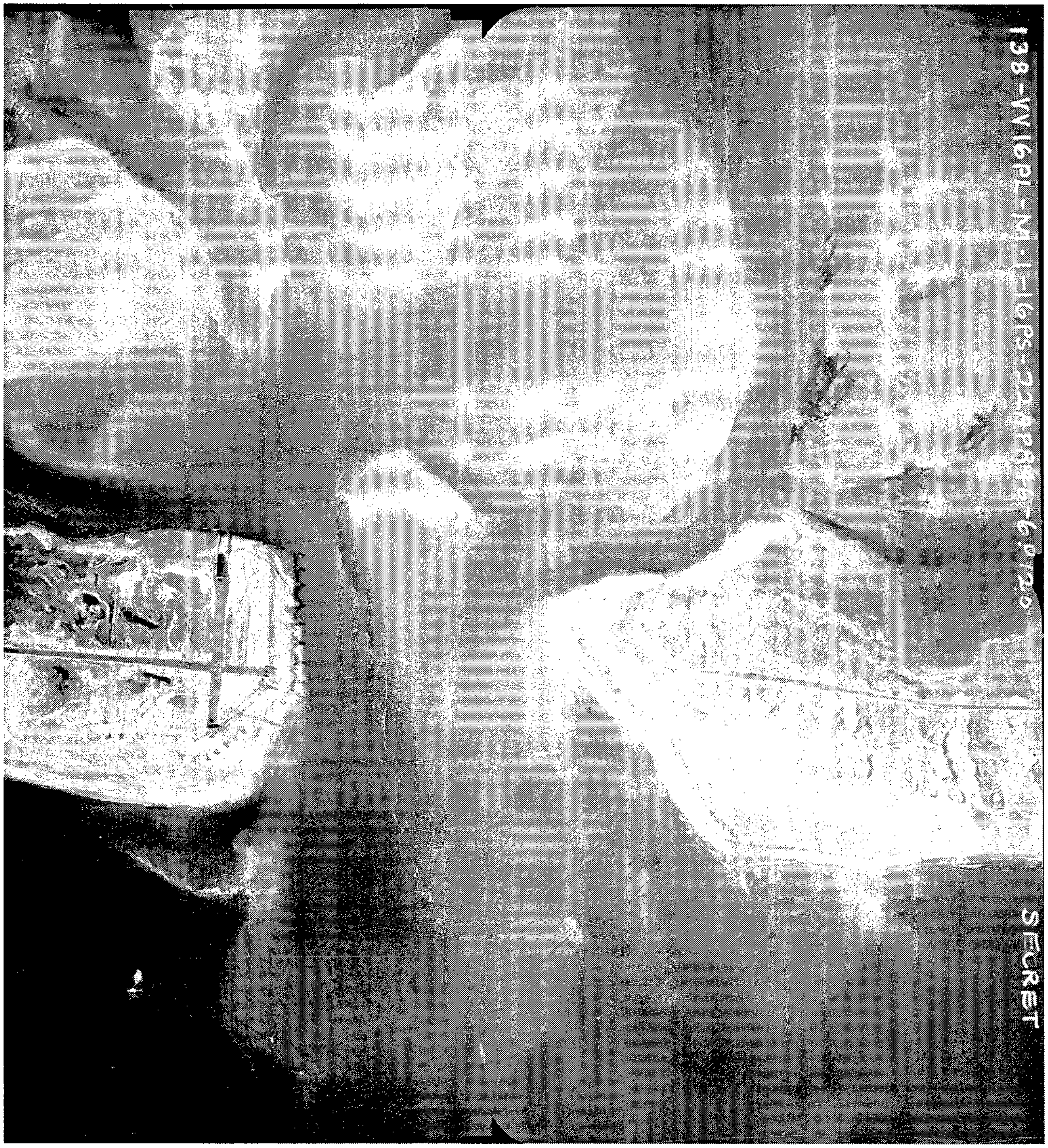


Figure A12. 22 April 1946 (Channel borders west side of inlet. Channel north of west beach connects to Long Island Intracoastal Waterway (dredged in 1943))

Figure A13. 1 April 1947 (Photograph one of two (inlet and west beach). Flood shoal has grown notably since 1941. Main channel through inlet has migrated away from west shore revetment and extends out to sea in a NW-SE direction. On flood shoal, east channel has shoaled next to east shoreline of inlet. Main channel now turns west and follows bay shoreline of west beach)

Figure A14. 1 April 1947 (Photograph two of two (inlet and east beach). Inlet's mouth contains two exposed sand shoals, and a spit has emerged from the west beach. Predominant longshore drift appears to have been west to east for a period before image was taken)

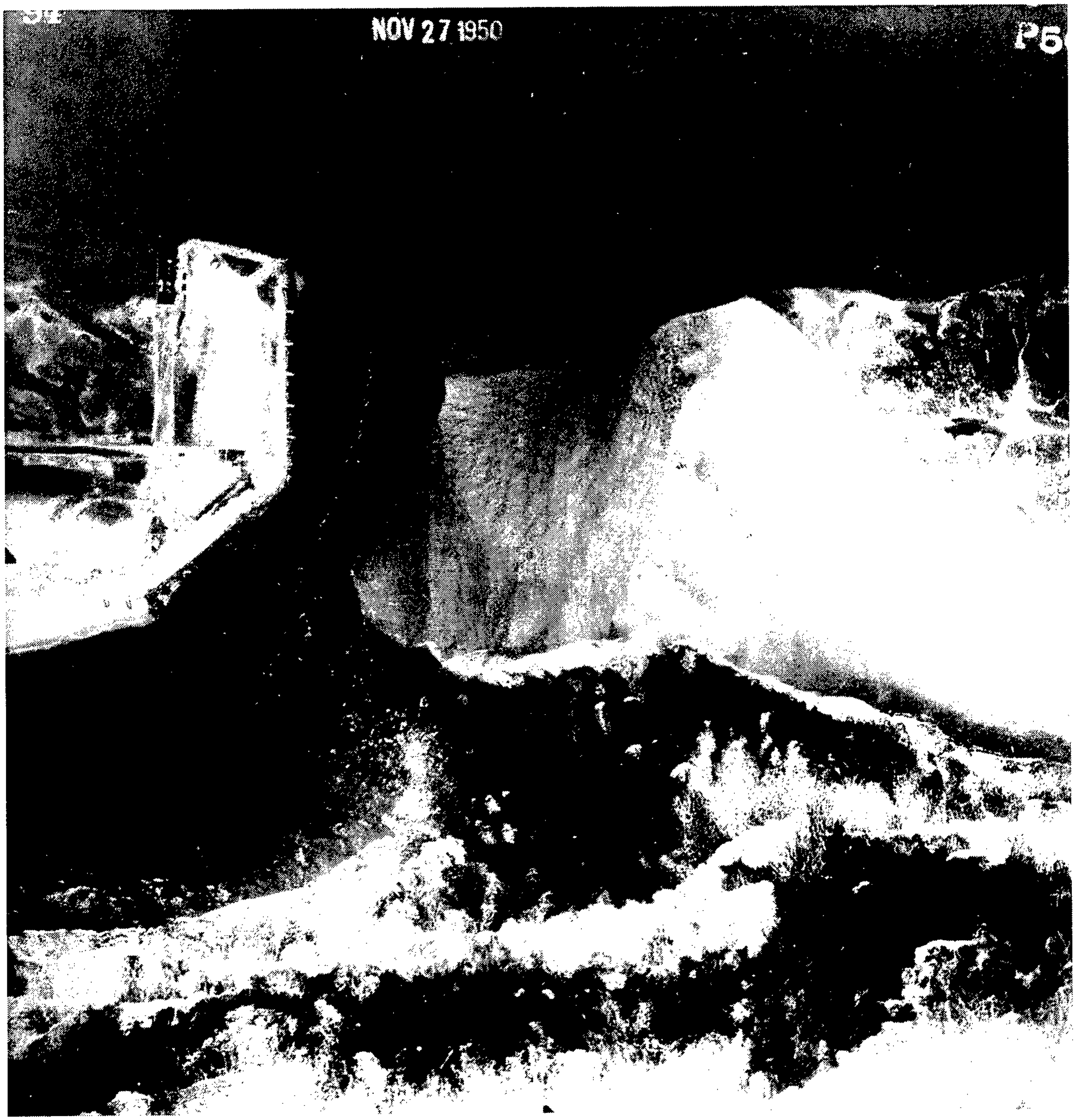


Figure A15. 27 November 1950 (Channel has changed orientation since 1947 and now follows the revetment on the west side of inlet again. A spit that formerly extended out from the west beach has disappeared, as have two exposed shoals in the mouth. East side of inlet is a shallow platform that merges into east beach. This photograph was taken 4 days after a major northeaster struck area, but no obvious storm damage is evident)

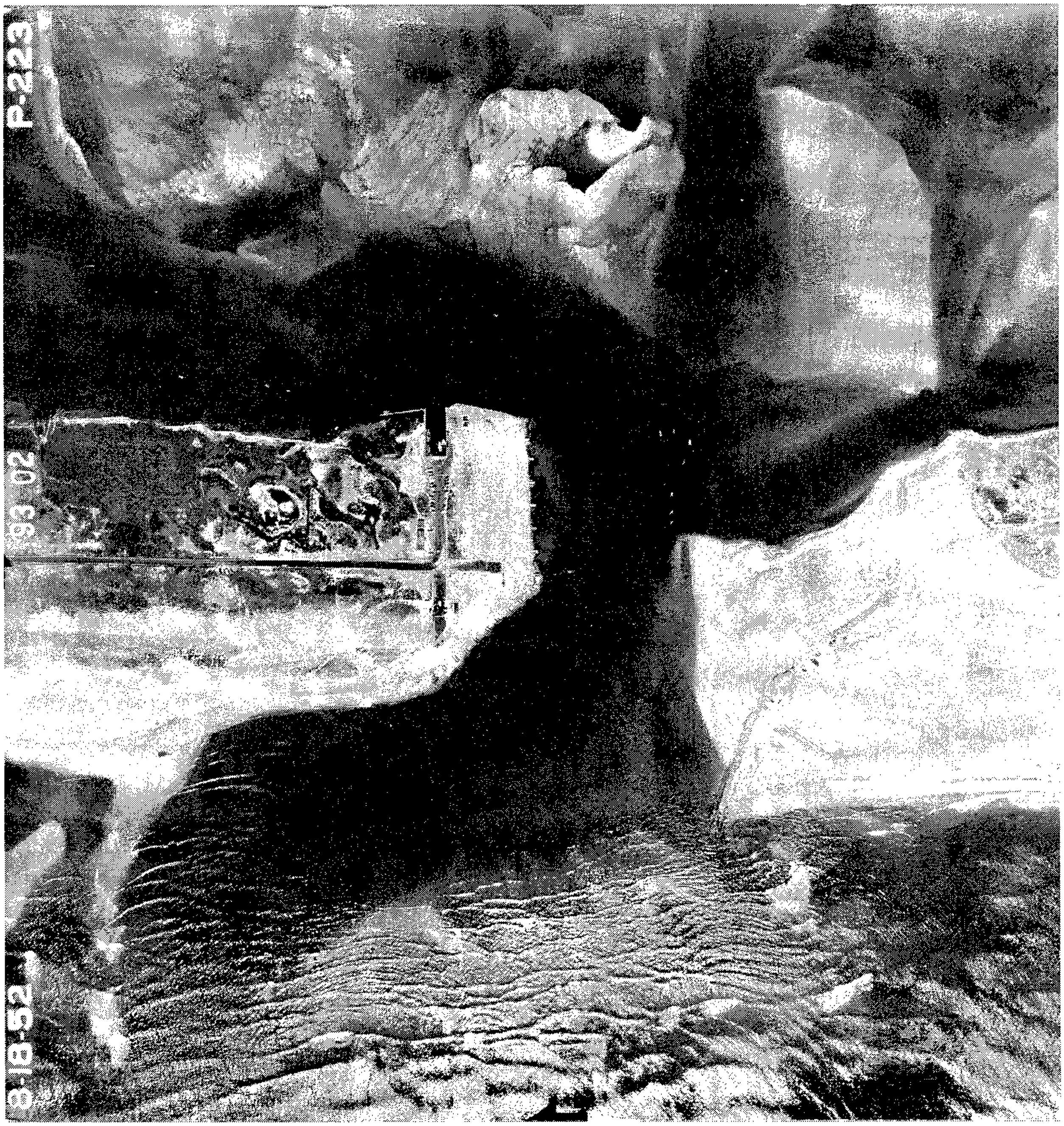


Figure A16. 18 August 1952 (Construction of east jetty is underway. North side of east beach has scoured, and a spit extends out to Atlantic from the west beach. This suggests that the main tidal currents ran approximately northeast-southwest)

Figure A17. 30 April 1953 (East jetty has been completed. Channel has rotated to a NE-SW orientation, eroding inner shore of east beach to stone jetty, and a spit extends from the west beach into the inlet. A dredged navigation channel runs through the flood shoal to the northwest, where it meets Long Island Intracoastal Waterway at Ponquogue Bridge)

Figure A18. 10 March 1956 (West jetty has been completed, and the channel is restricted to a N-S direction. A spit still protrudes from west beach into inlet. Updrift fillet has grown seaward since previous photograph was taken (1953). Note that west beach is straight; area directly west of west jetty has not yet eroded)

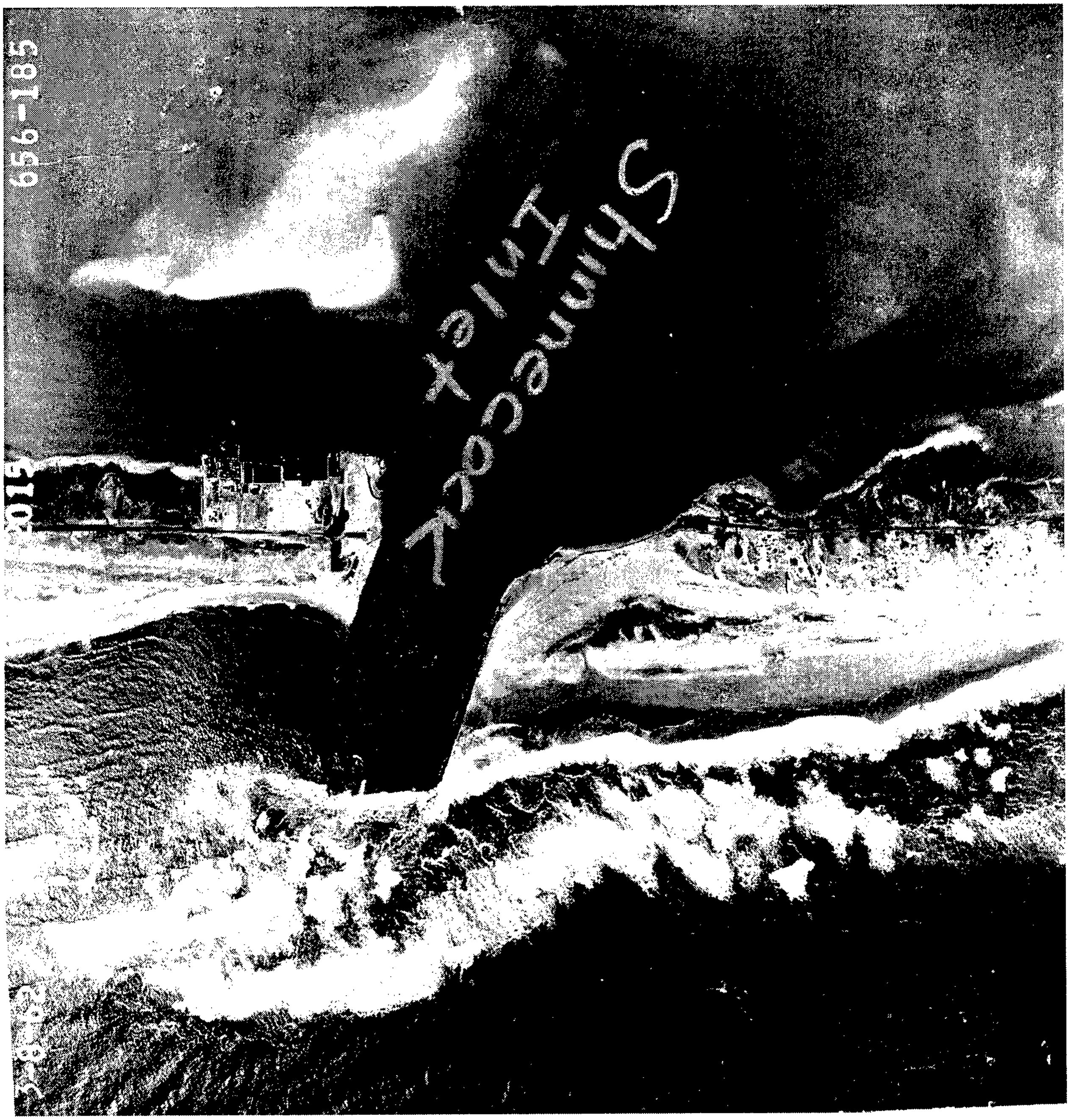


Figure A19. 8 March 1962 (during waning phase of Ash Wednesday storm of 6-8 March) (Waves are breaking on the ebb shoal, which is beginning to form a U-shaped body off mouth of inlet. Spit in inlet has disappeared. Ocean side of west beach has notably eroded, a problem that is to persist for the next 37 years. Docks for fishing cooperative have been built on bay side of west beach)

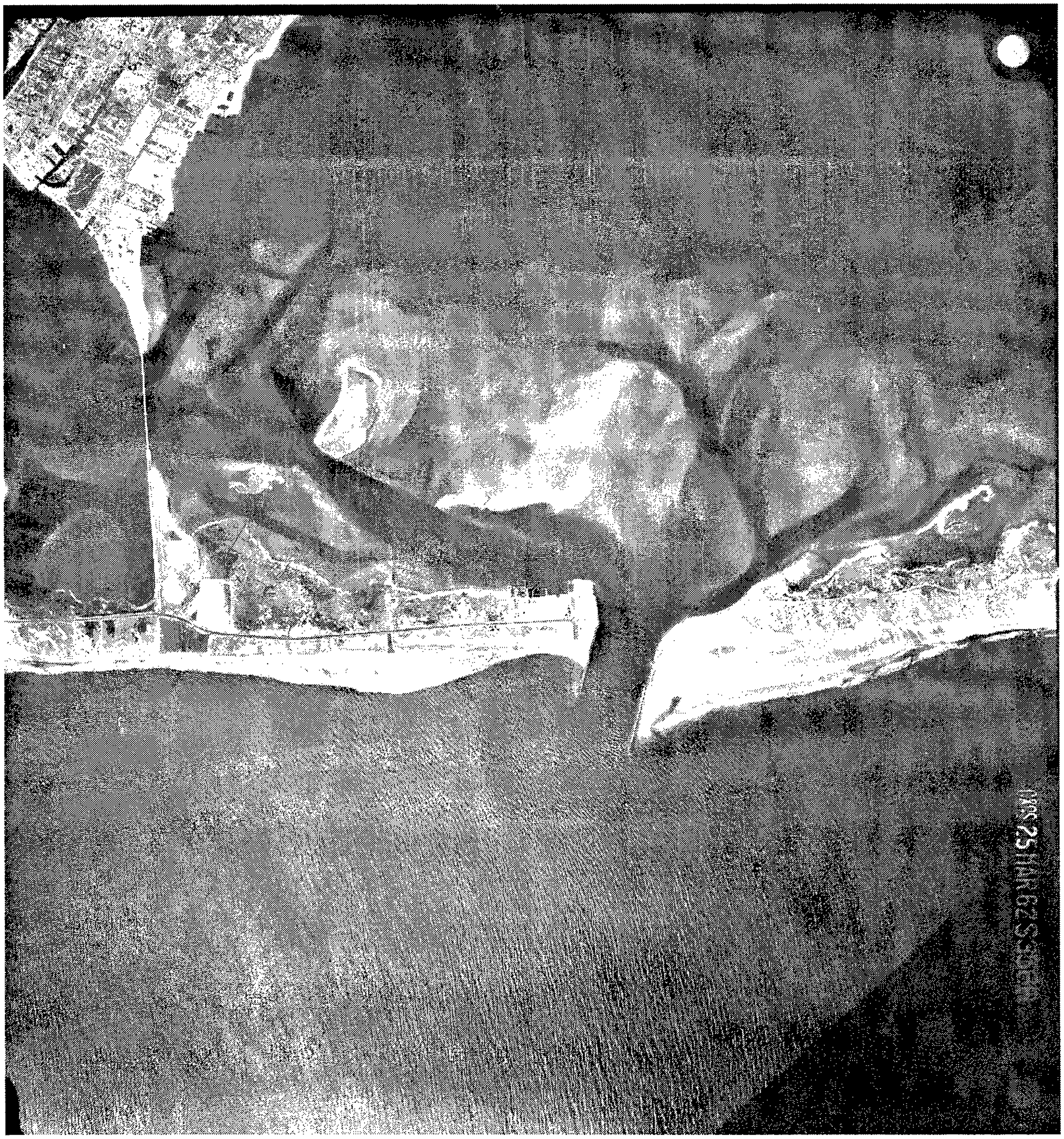


Figure A20. 25 March 1962 (Seas are much calmer than in 8 March photograph. Bulge on west beach where ebb shoal attaches to shore is about halfway between inlet and Ponquogue Bridge. Over the following 35 years, the bulge will migrate west until it is adjacent to the bridge)

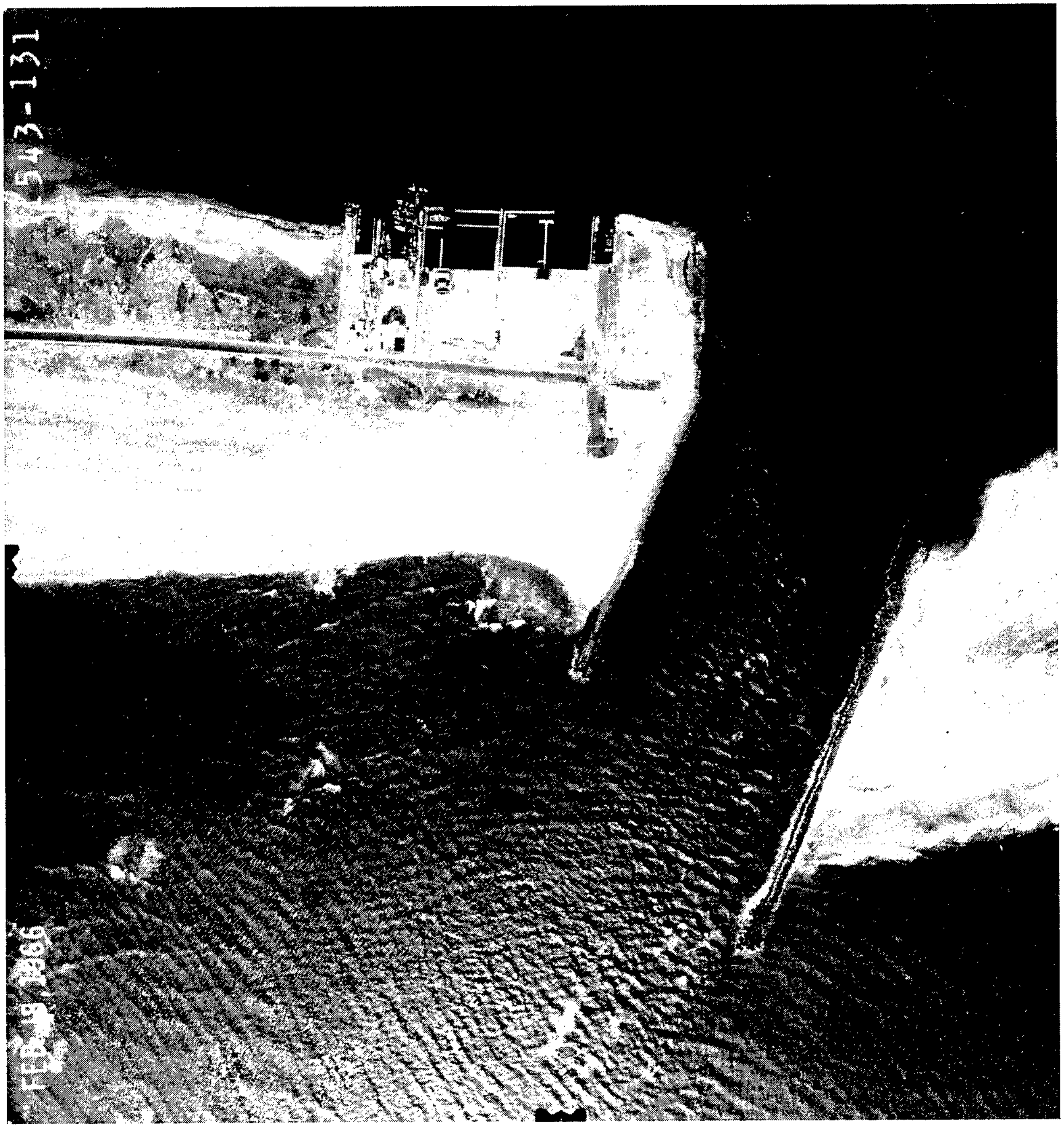


Figure A21. 18 February 1966 (Damage can be seen at bay (north) ends of east and west jetties. Wave crests diverge near seaward end of east jetty; some waves continue through the inlet while others impinge directly on the west beach)

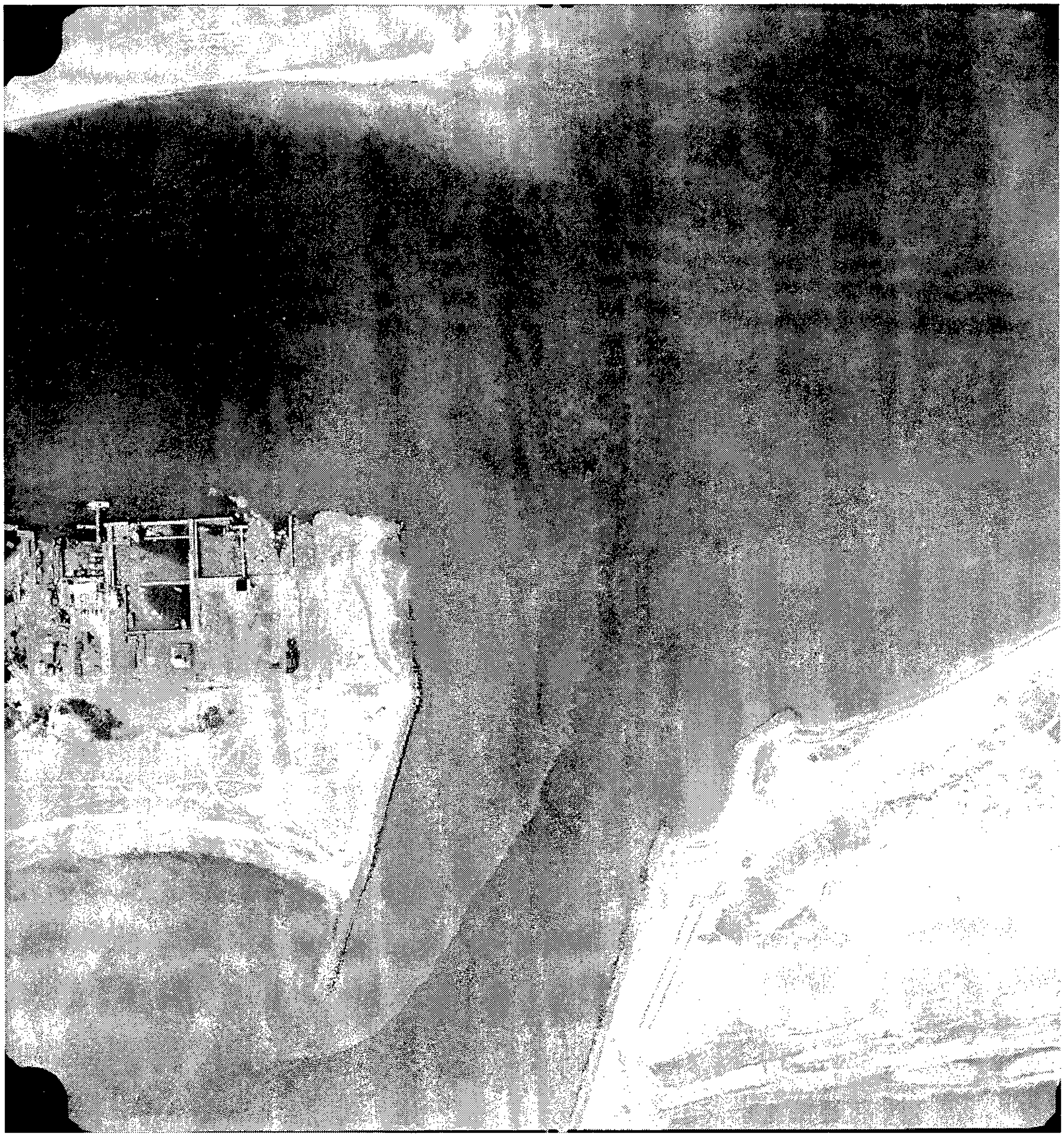


Figure A22. 23 February 1972 (Photograph, taken at lower altitude than previous images, shows damage to west and east jetties. Flood tide is entering inlet on east (right) side. A discontinuity marks where the flood tide entrains slack water. On west beach, dunes are vegetated as far east as cross road)

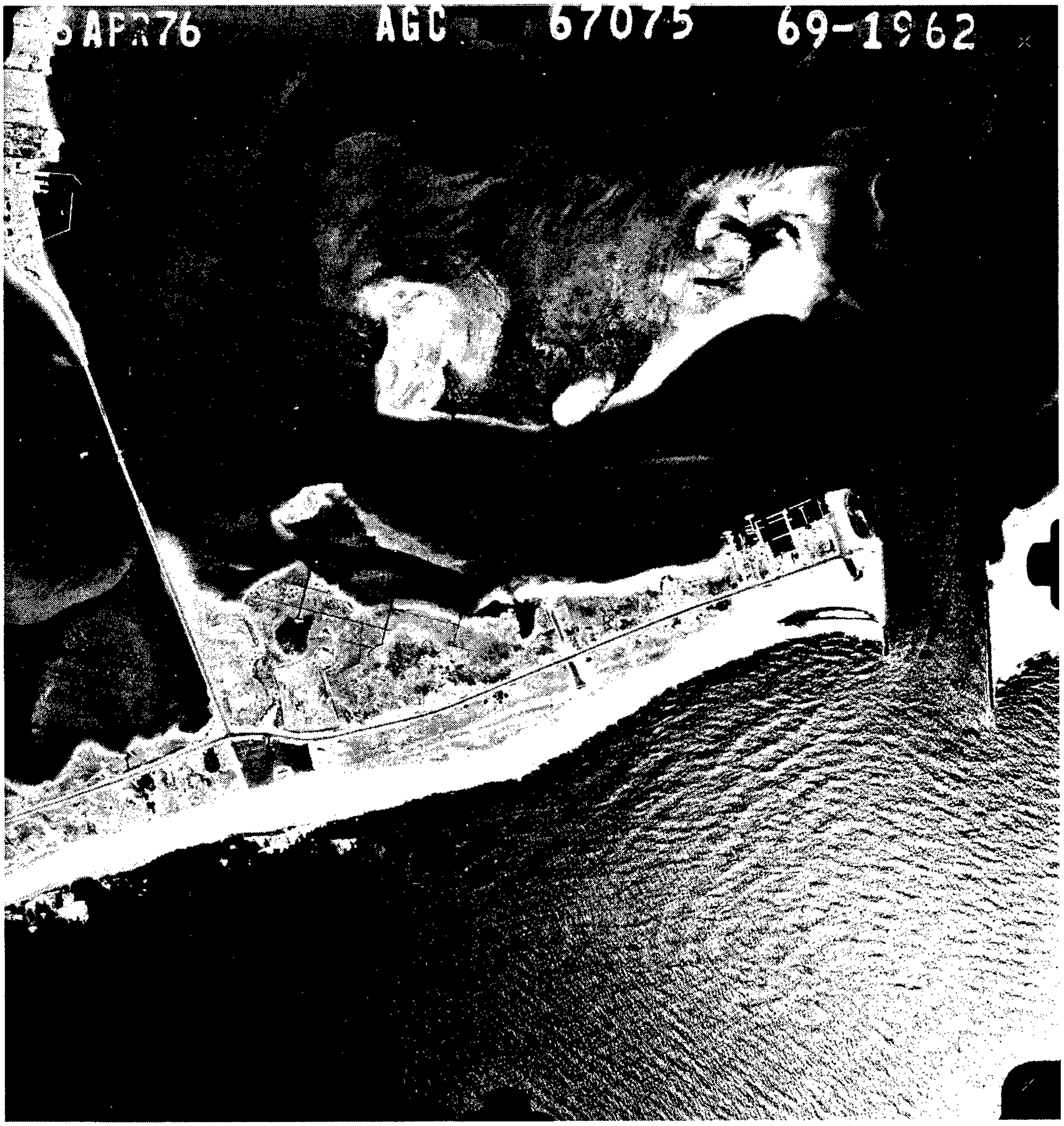


Figure A23. 6 April 1976 (Sometime before this picture was taken, the beach west of the west jetty had eroded as far as the road, destroying vegetated dunes. White beach seen in image must be a recent repair (documentation unavailable). Bulge in shoreline west of inlet marks area where ebb shoal attaches to shore. A new lobe of flood shoal has formed directly north of inlet)

Figure A24. 6 April 1976 (Closeup view of north (bay) end of inlet. Sun glint reveals circular wave crests, a result of wave diffraction. Waves can be seen refracting into indentation in shore directly north of end of west jetty)

Figure A25. 10 August 1976 (Photograph was taken 1 day after Hurricane Belle crossed area. West beach is flush with end of west jetty. Only minor changes in flood shoal had occurred compared with April image. Compared with 1962, ebb shoal had grown and seaward edge moved further offshore. Four black lines crossing west beach appear to be drawn with a pen on photographic paper print)

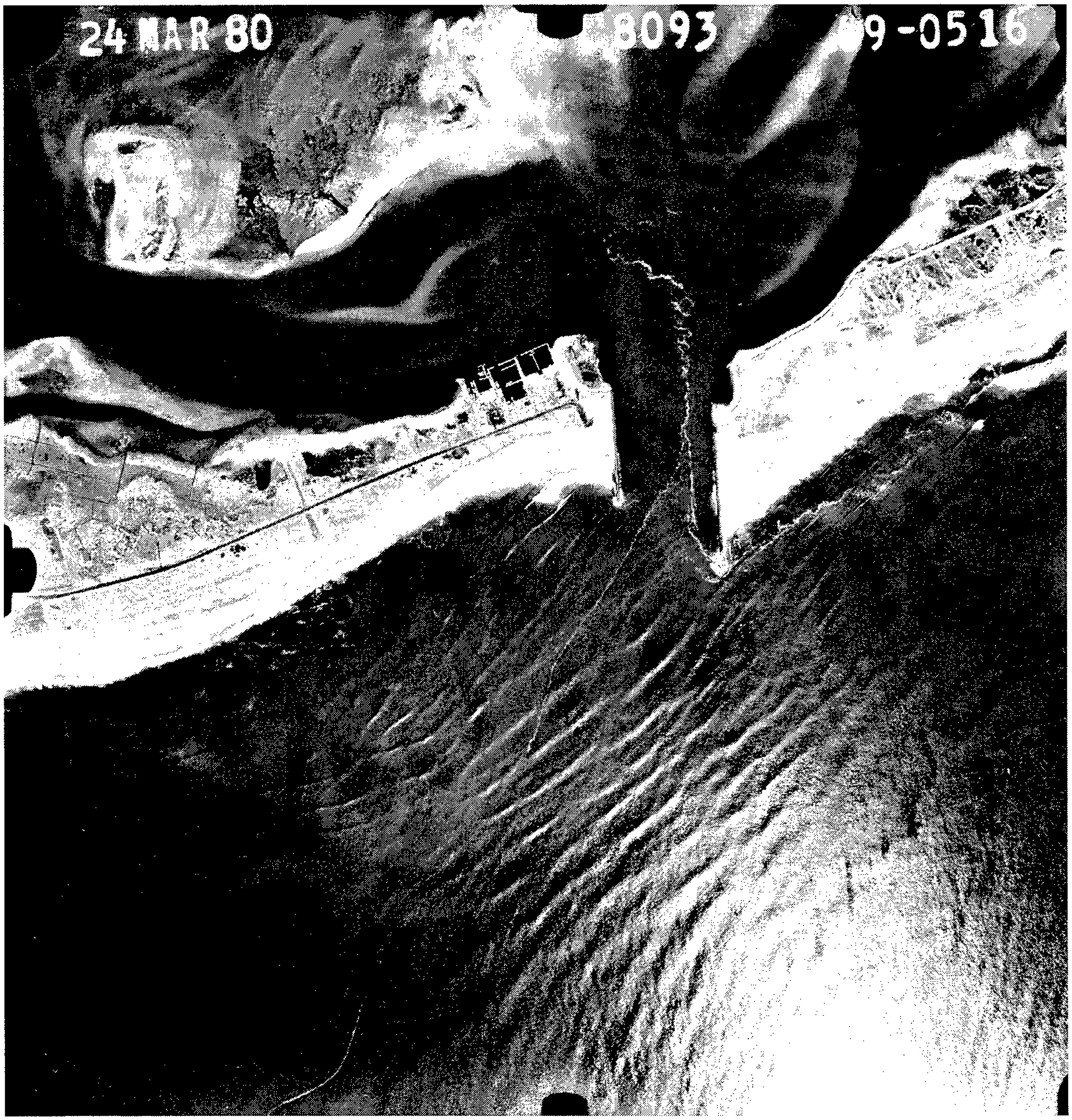


Figure A26. 24 March 1980 (West beach has eroded since previous photograph was taken 4 years earlier. Dune just west of the west jetty has been revegetated. Exposed sand spits on flood shoal have changed shape)

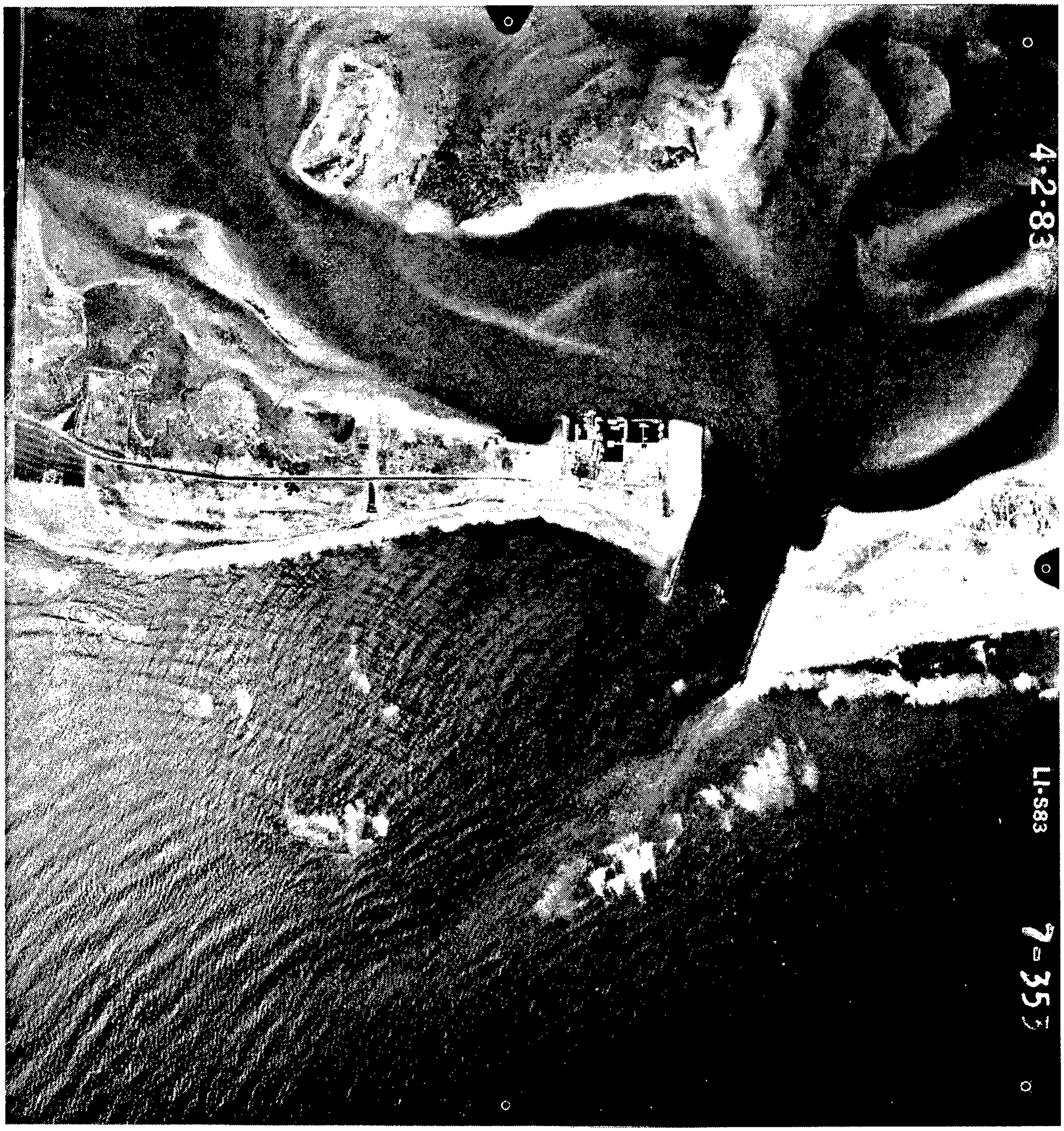


Figure A27. 2 April 1983 (Image does not show major changes since 1980. The most seaward part of ebb shoal had moved west, and a spit had begun to grow from tip of east jetty. West beach has eroded, and wet sand line is near road. U-shaped erosion hole in west side of inlet (near fishing docks) has been repaired)

Figure A28. 21 April 1983 (Oval ebb shoal is outlined by breaking waves. The shoal attaches to downdrift (west) beach at the bulge in the shoreline. Bulge has moved about 500 m west compared with 1976)

Figure A29. 27 April 1984 (Only minor shoreline changes have occurred since 1983. However, the dunes on the west beach have eroded further, and vegetation line now stops well west of the fishing docks) (Photograph courtesy of Moffatt & Nichol Engineers))

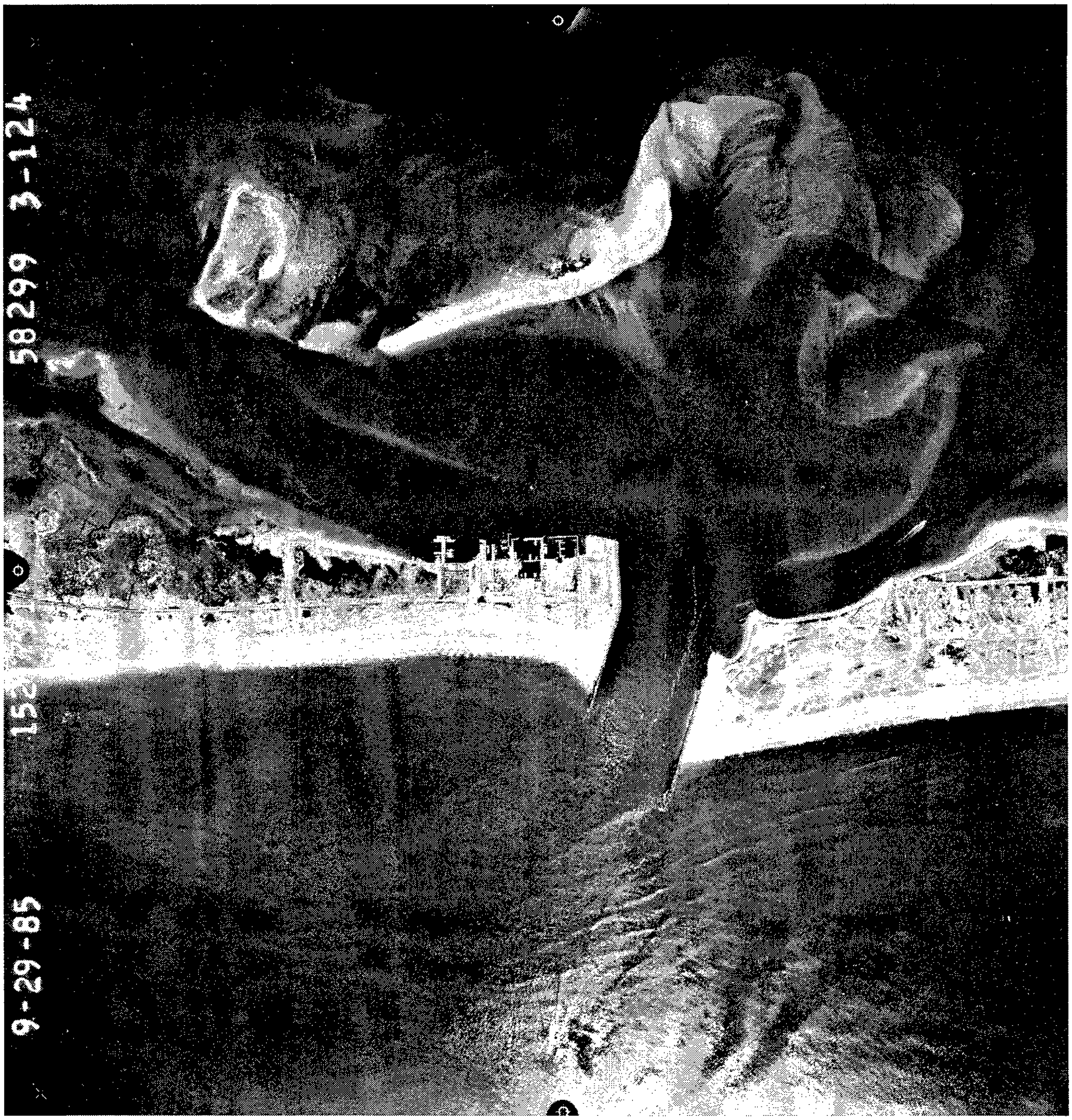


Figure A30. 29 September 1985 (West beach is wider than in 1984 because of placement of material dredged from inlet (see Table D1). East flood channel hugs north side of east beach)

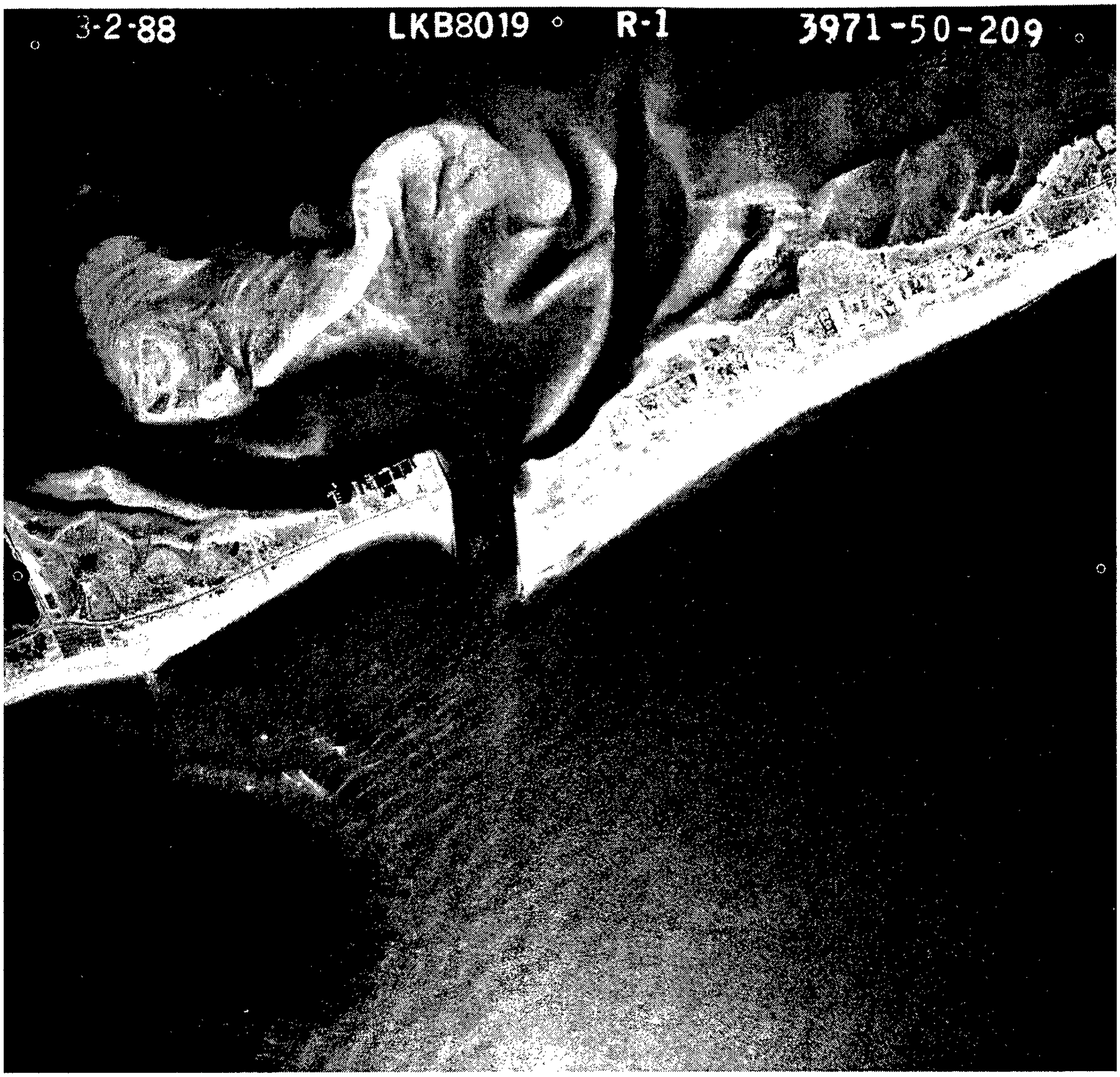


Figure A31. 2 March 1988 (West beach has eroded compared with 1985, but east beach has advanced to near tip of east jetty. East flood channel continues to push against the bay side of the east beach, but it is unclear if the shoreline has eroded since 1985)

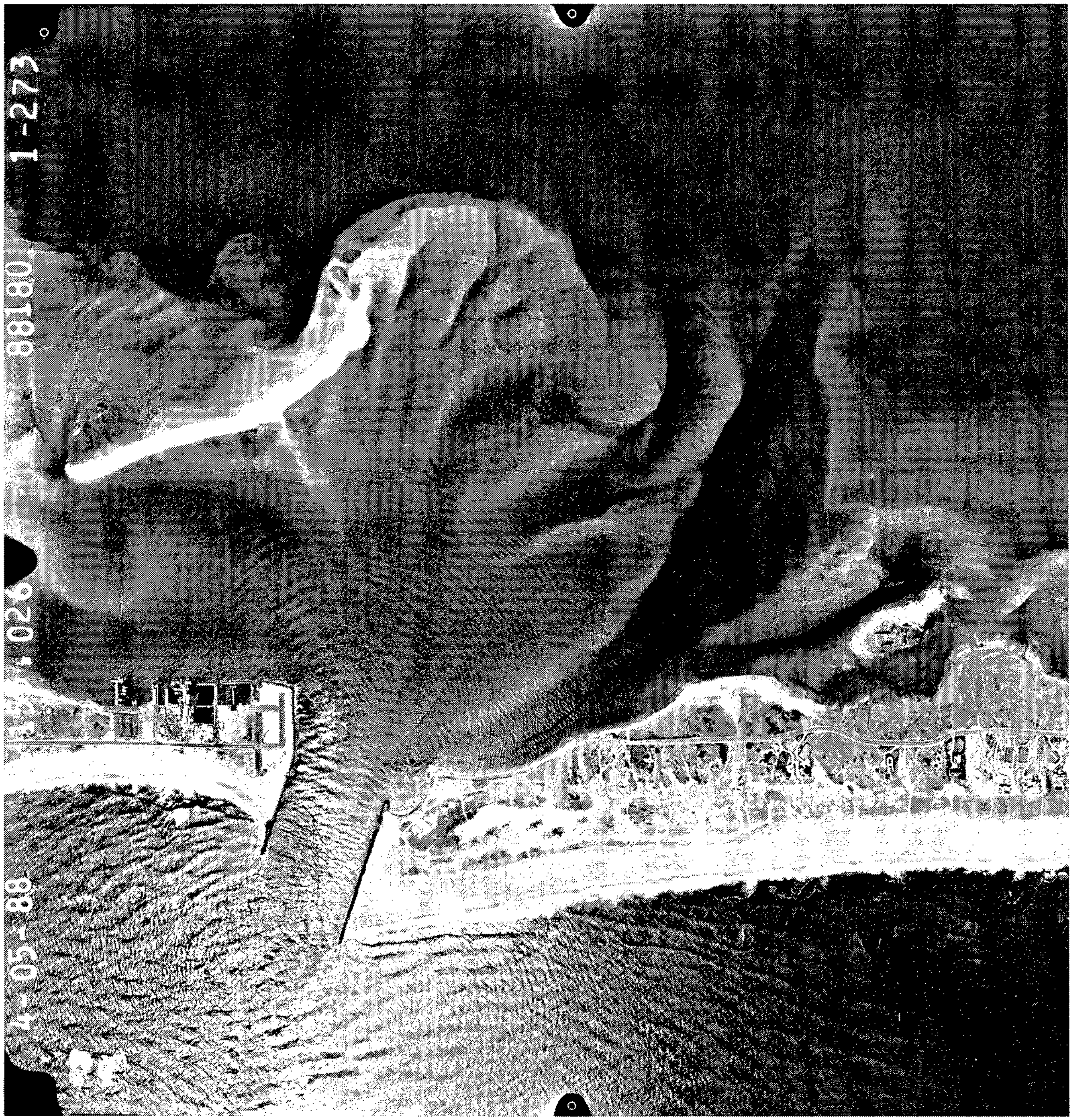


Figure A32. 5 April 1988 (Lower altitude photograph taken 1 month after previous image. Waves can be seen entering inlet and diffracting in a circular pattern in Shinnecock Bay. An exposed sandbar in the flood shoal, previously straight or V-shaped, now resembles a "T" with growth of a spit southeast toward the inlet)

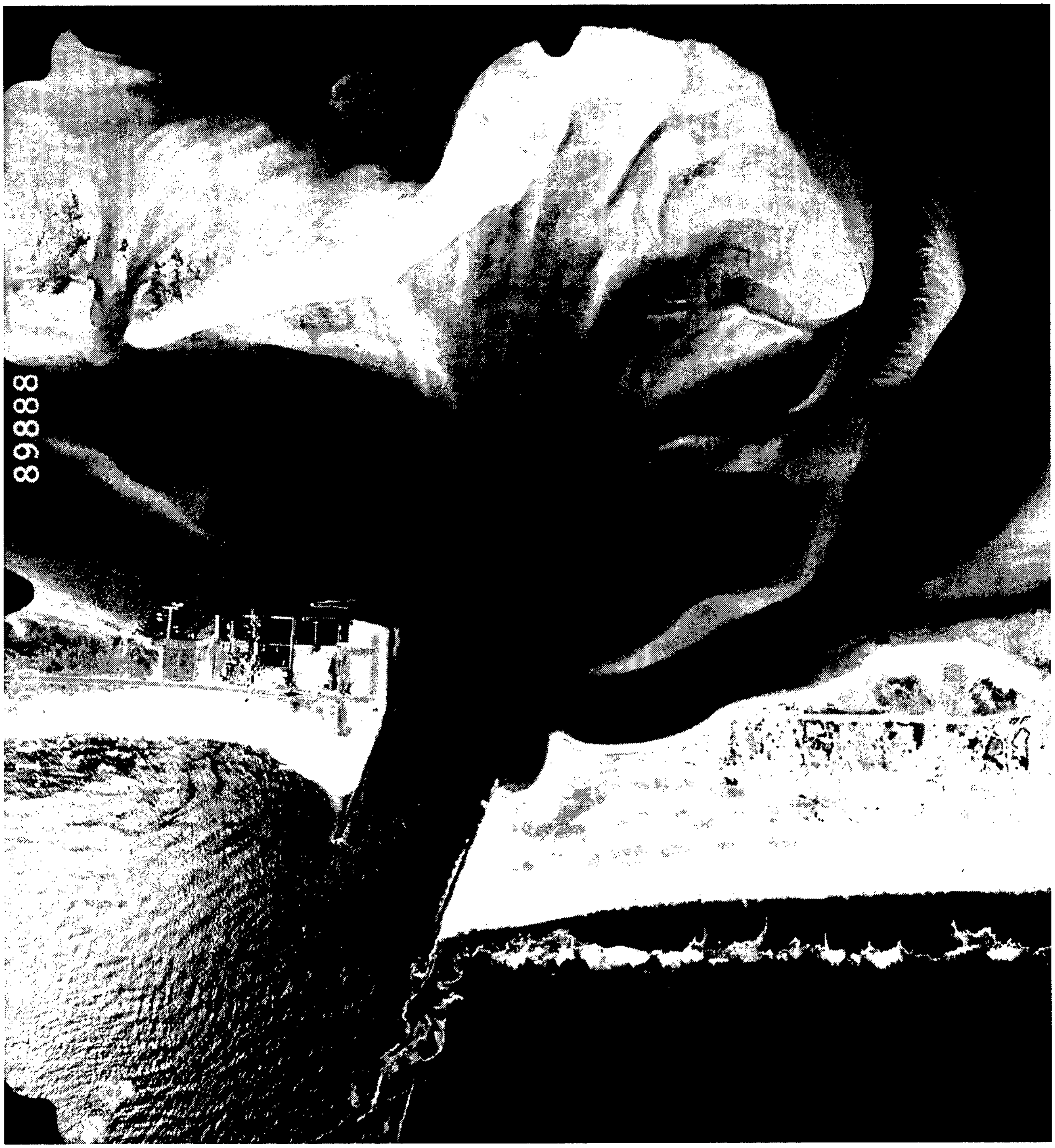


Figure A33. 22 March 1989 (East beach has retreated to landward end of jetty tip compared with 1988. Waves are breaking on a sandbar that parallels the east beach. Flood shoal has about same configuration as in 1988, although sandbars and shoals are more visible in this image)

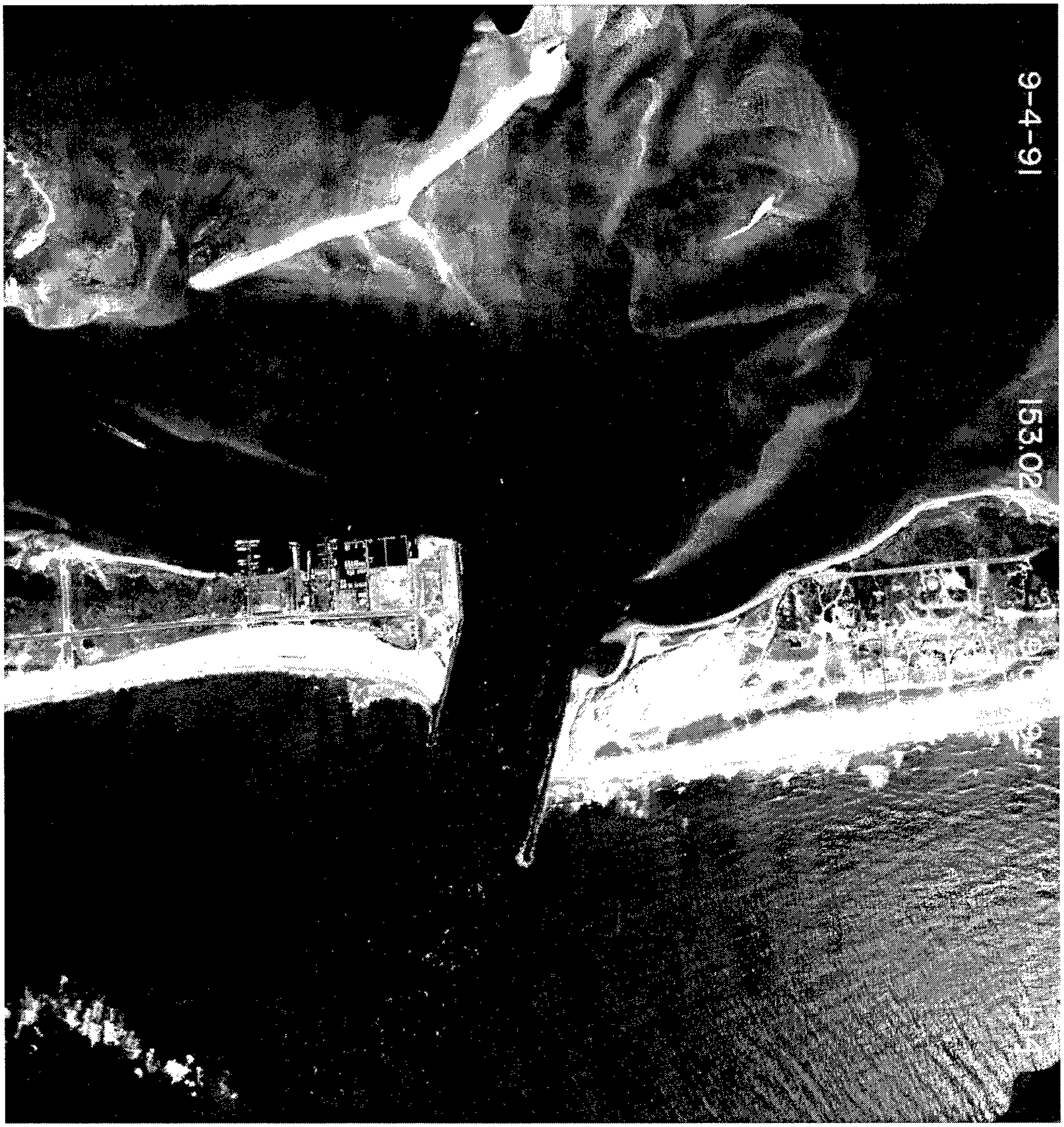


Figure A34. 4 September 1991 (East beach has receded about 100 m compared with 1989, and an erosion hole located on the east shore of inlet, behind the revetment, has enlarged. Flood shoal configuration is about the same as in 1989. T-shaped sandbar is prominent)

Figure A35. 20 December 1991 (Most features are unchanged from the previous figure, taken in September. Lack of change is surprising because the Halloween Northeaster of 30-31 October was reported to have caused erosion and damage along much of Long Island shore. Erosion pocket in east revetment has shoaled, and west beach has advanced about one-half of the distance to the jetty tip)

Figure A36. 29 September 1992 (East beach has advanced about 70 m compared with December 1991, and west beach has receded severely. More of the east revetment has deteriorated, accompanied with erosion of east shore. Jetty repair has begun, and a barge containing rock is moored in east channel in Shinnecock Bay. On the flood shoal, the right arm of the T-shaped sandbar has moved north)

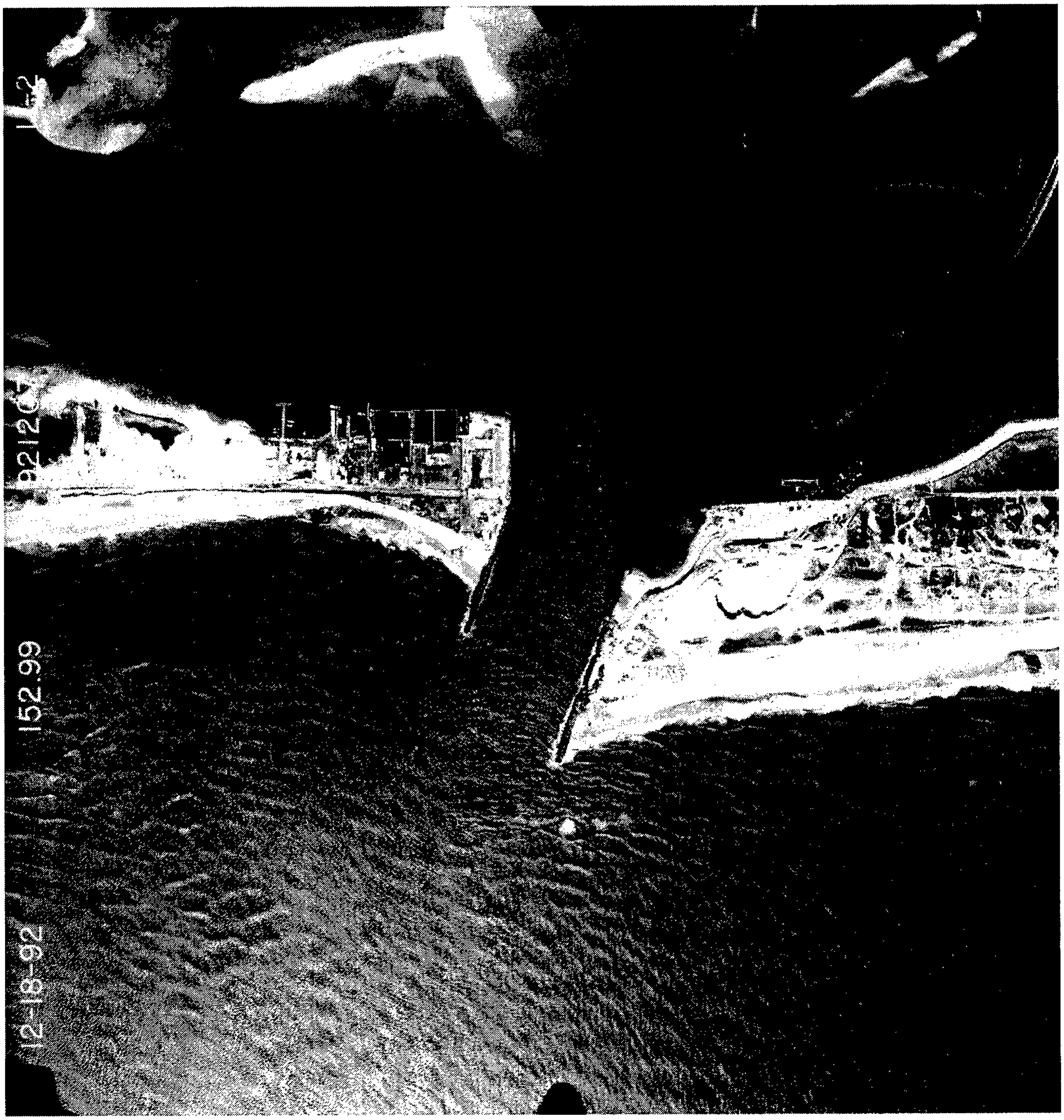


Figure A37. 18 December 1992 (One of three photographs for this date) (In 3 months, the east beach has advanced almost to the tip of the east jetty. West beach has continued to erode, and waves are breaking only a few meters from Dune Road. More work barges are in position near the east revetment)

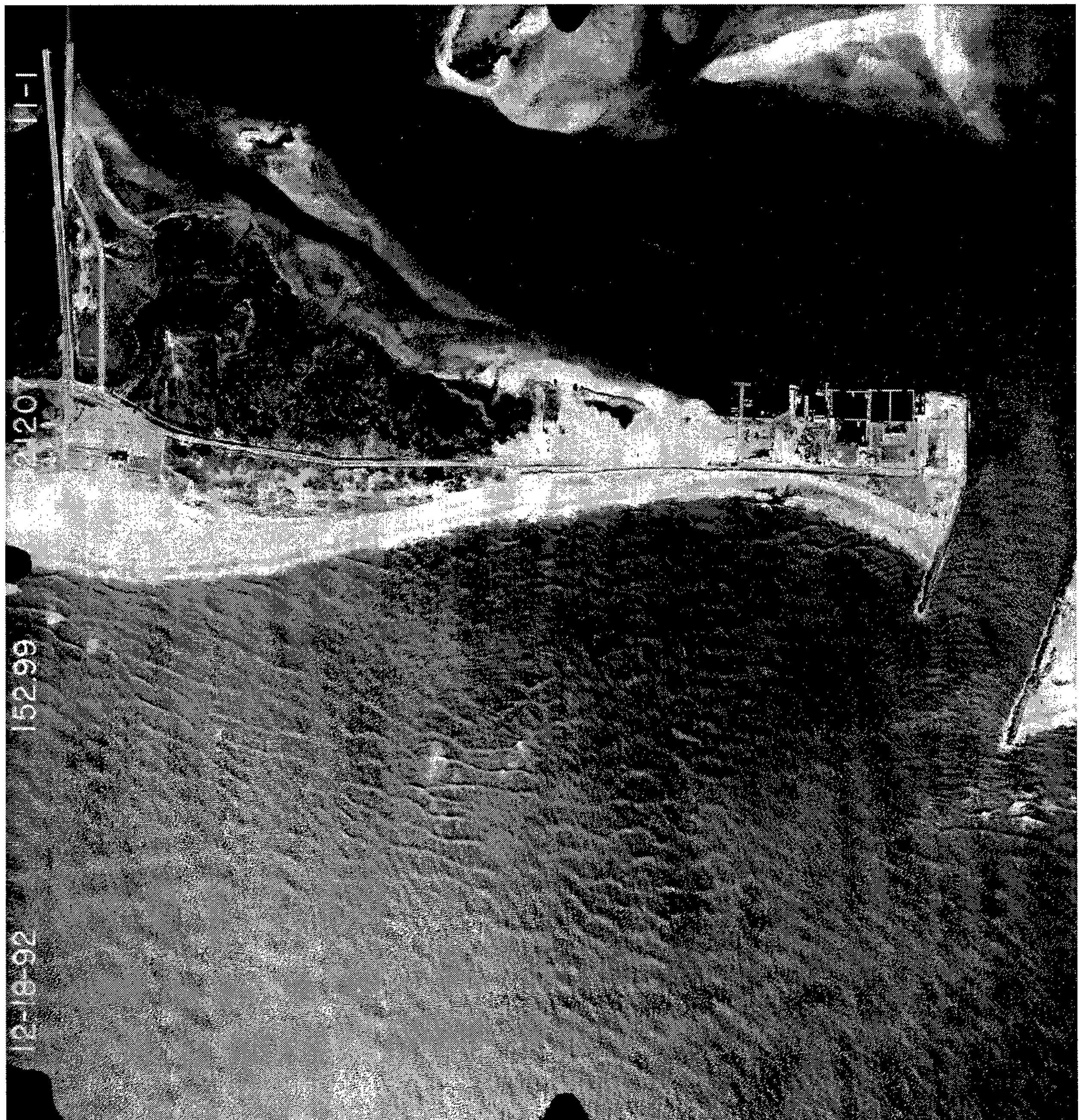


Figure A38. 18 Dec 1992 (No. 2 of three images this date) (This photograph shows how severely the west beach has eroded west of the west jetty. Shoreline bulge, where the ebb shoal joins the beach, is adjacent to the Ponquogue Bridge road intersection. This location is in contrast to 1983 and 1988, when the bulge was much smaller and located further east. Disturbed wave crests approximately outline ebb shoal. Note fresh washover fans just west of the docks. Barrier was overwashed during powerful northeaster of 11-14 December)

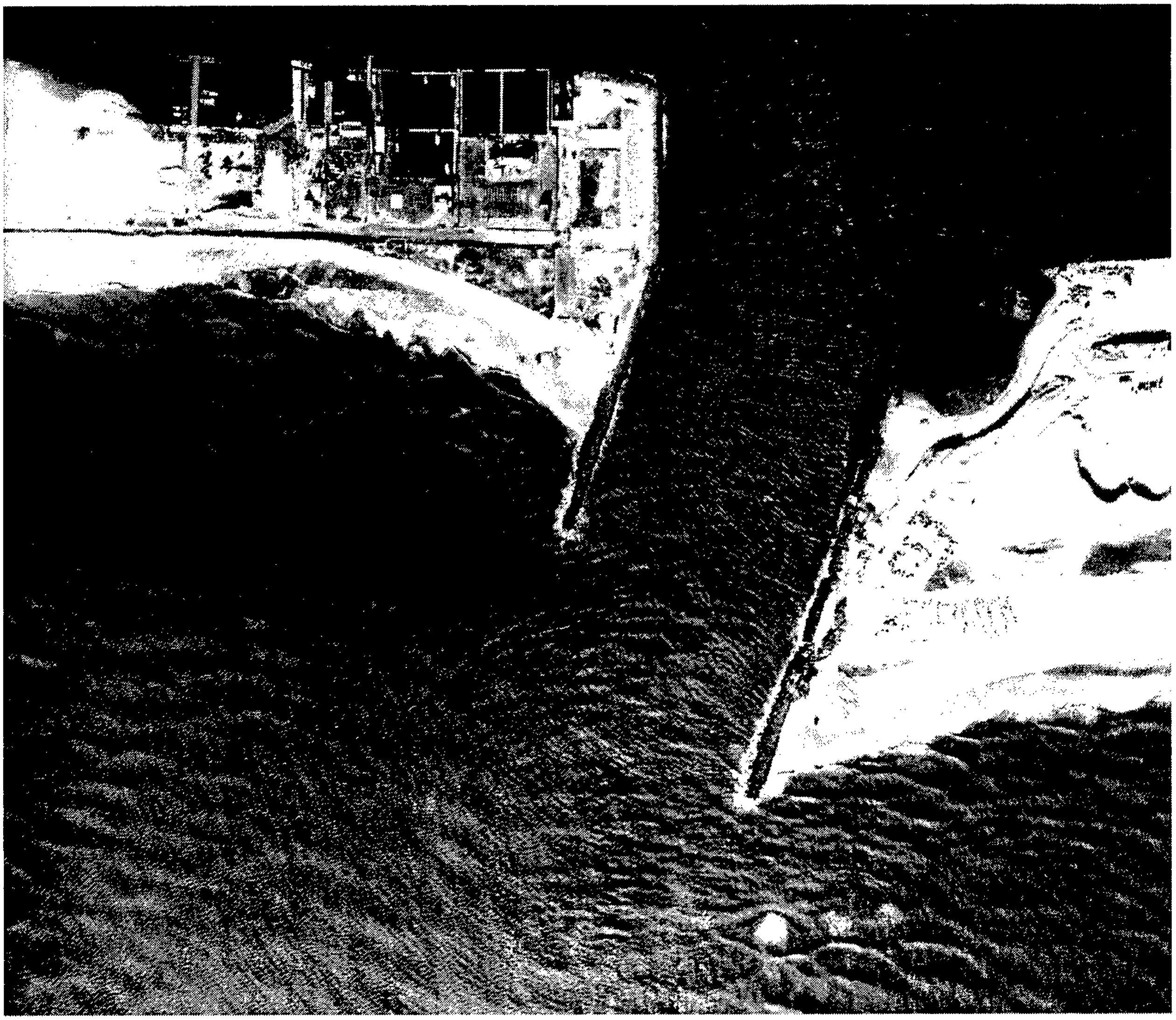


Figure A39. 18 Dec 1992 (No. 3 of three images) (Close-up of inlet showing wave patterns. Some waves propagate directly up the inlet. Starting from a zone of disturbed water left of the tip of the east jetty, some waves propagate directly toward the west beach. Wave energy appears to be concentrated in this pocket across the street from the fishing docks. Photograph was fortuitously taken under conditions that show waves breaking in the pocket, but continuing erosion over four decades suggests that this had been a common process since the jetties were built)

Figure A40. 21 December 1992 (Similar conditions as previous photographs taken 3 days earlier. Waves still appear to be concentrated along the east shore where part of the jetty has failed. T-shaped sandbar in flood shoal has been divided into two sections)

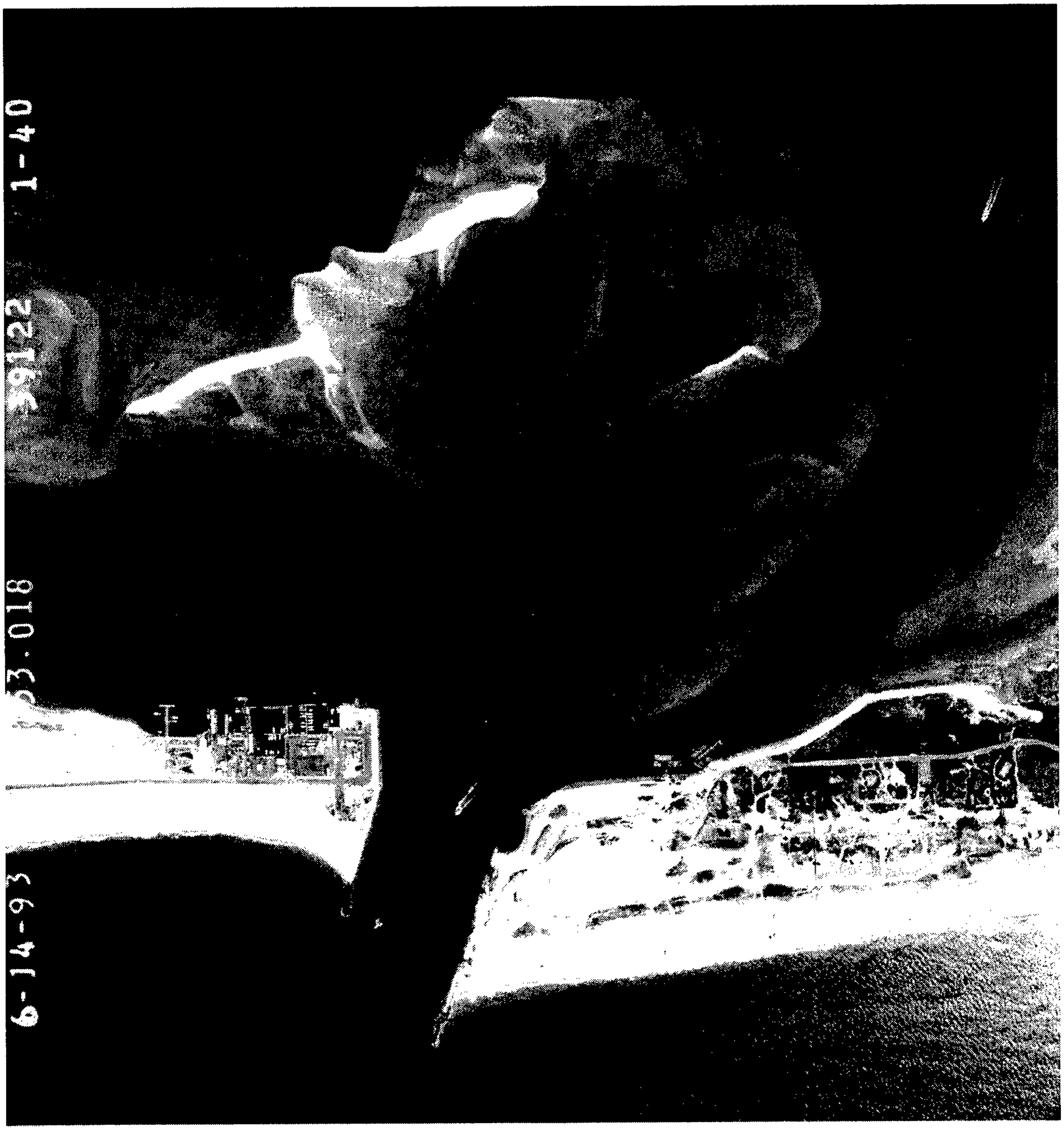


Figure A41. 14 June 1993 (East beach has been renourished with sand dredged from the deposition basin (see Table D1). Repair work on the east revetment continues)

Figure A42. 13 October 1993 (Ocean shorelines have not changed since the previous photograph was taken in June. Repair of the east revetment is almost complete)

Figure A43. 8 April 1994 (West beach has eroded again, and east beach has also retreated. Repair of east jetty and revetment is complete. Repairs are underway on west jetty, and rock and materials are stockpiled in parking lot)

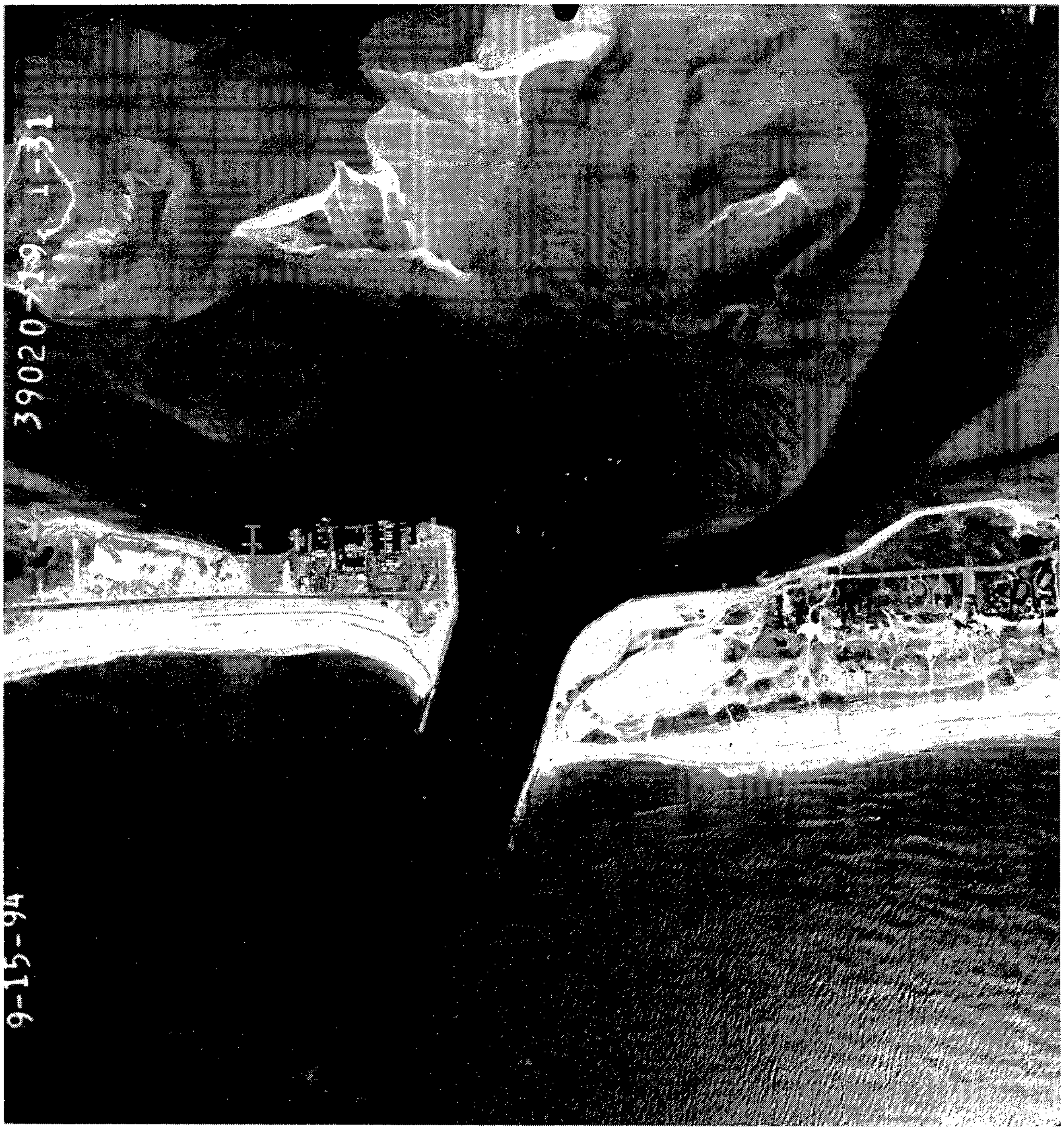


Figure A44. 15 September 1994 (East beach has eroded compared with previous image, while west beach has advanced. No beach fill is recorded for this period, suggesting that accretion was natural)

Figure A45. 10 April 1995 (East beach has advanced compared with September 1994, while west beach has eroded. A spit projects from the west beach, as shown by breaking waves)

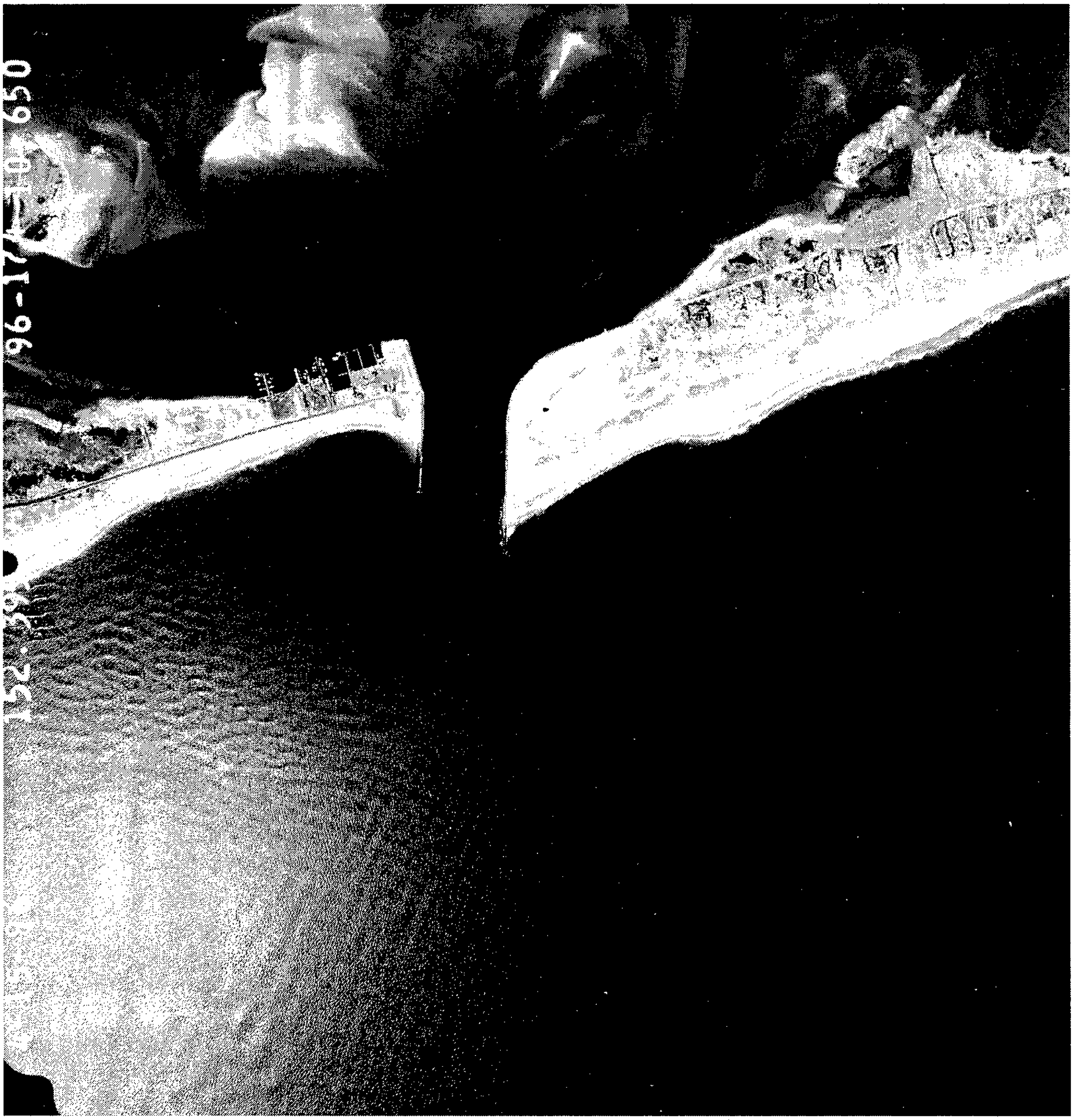


Figure A46. 15 April 1996 (West beach has further eroded, while east beach has advanced almost to the tip of the east jetty)

Figure A47. 24 October 1996 (No. 1 of two photographs for this date) (The west beach has continued to recede since April, while the east beach is largely unchanged, extending out to near the end of the east jetty. Breaking waves outline the east edge of the ebb shoal. Shoal merges into shore-parallel sandbars about 200 m east of the east jetty)

Figure A48. 24 October 1996 (No. 2 of two photographs for this date) (Breaking waves show where the west edge of the ebb shoal joins the west beach. Ebb shoal is still approximately a symmetric oval of sand, but compared with 1960s and 1970s, it has been pushed about 500 m west of the inlet mouth. Rough water can be seen between the jetties and across the mouth of the inlet. With wave conditions on this day, a boat leaving the inlet would encounter breaking waves on forward port quarter)

Figure A49. 10 April 1997 (East beach has receded about 100 m from tip of west jetty. West beach was repaired with sand dredged from channel in February and March (see Table D1). Active portion of flood shoal is now symmetrically positioned in line with axis of inlet. This is east of its 1970s position)

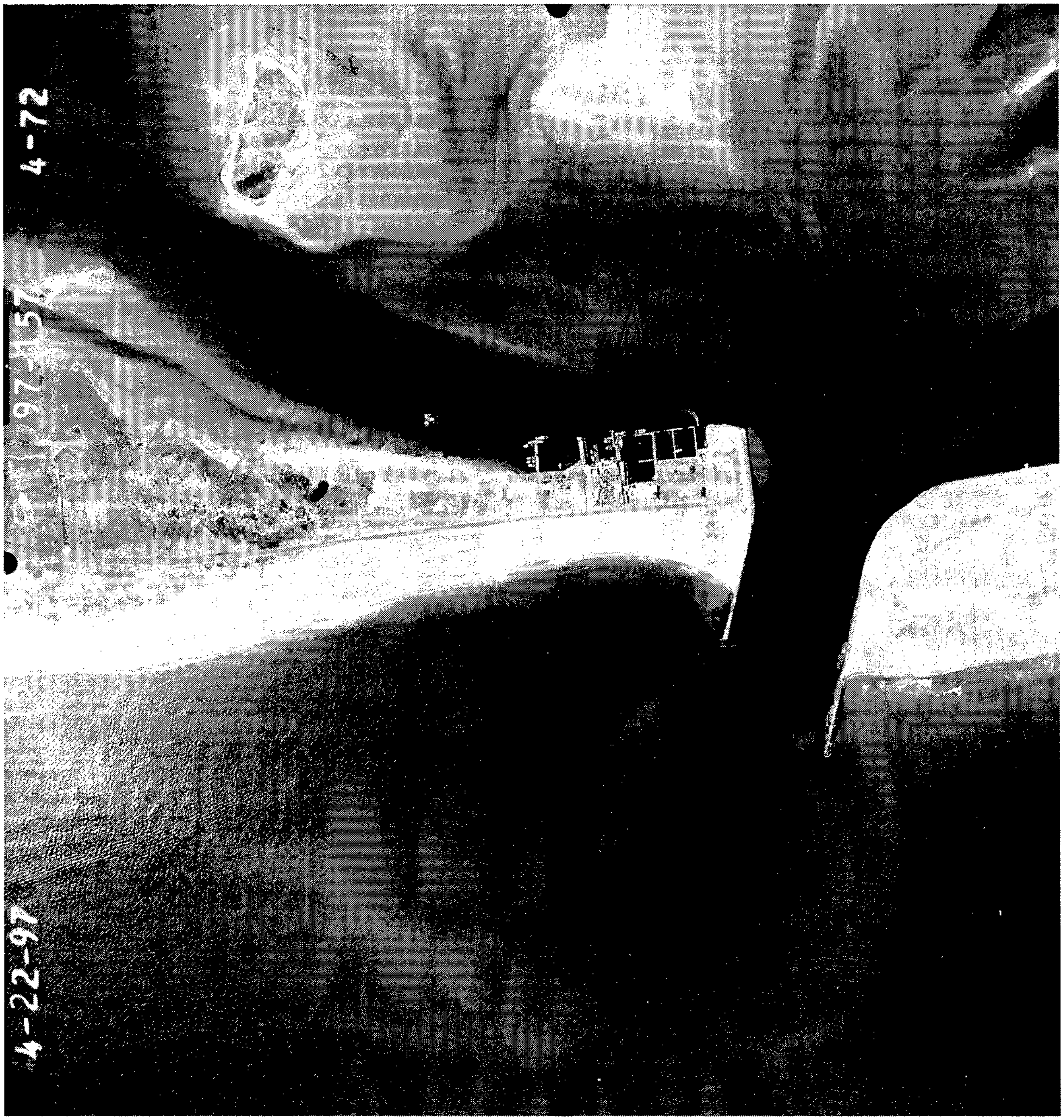


Figure A50. 22 April 1997 (Edge of ebb shoal is clearly visible in this image, taken on a day with almost no waves. Water depth at the bar is about 3 m (10 ft). Dark water off the mouth of the inlet is the dredged deposition basin. A ridge of sand that projects seaward from the west jetty and a deep hole to its west were measured by bathymetric surveys (see Appendix B))

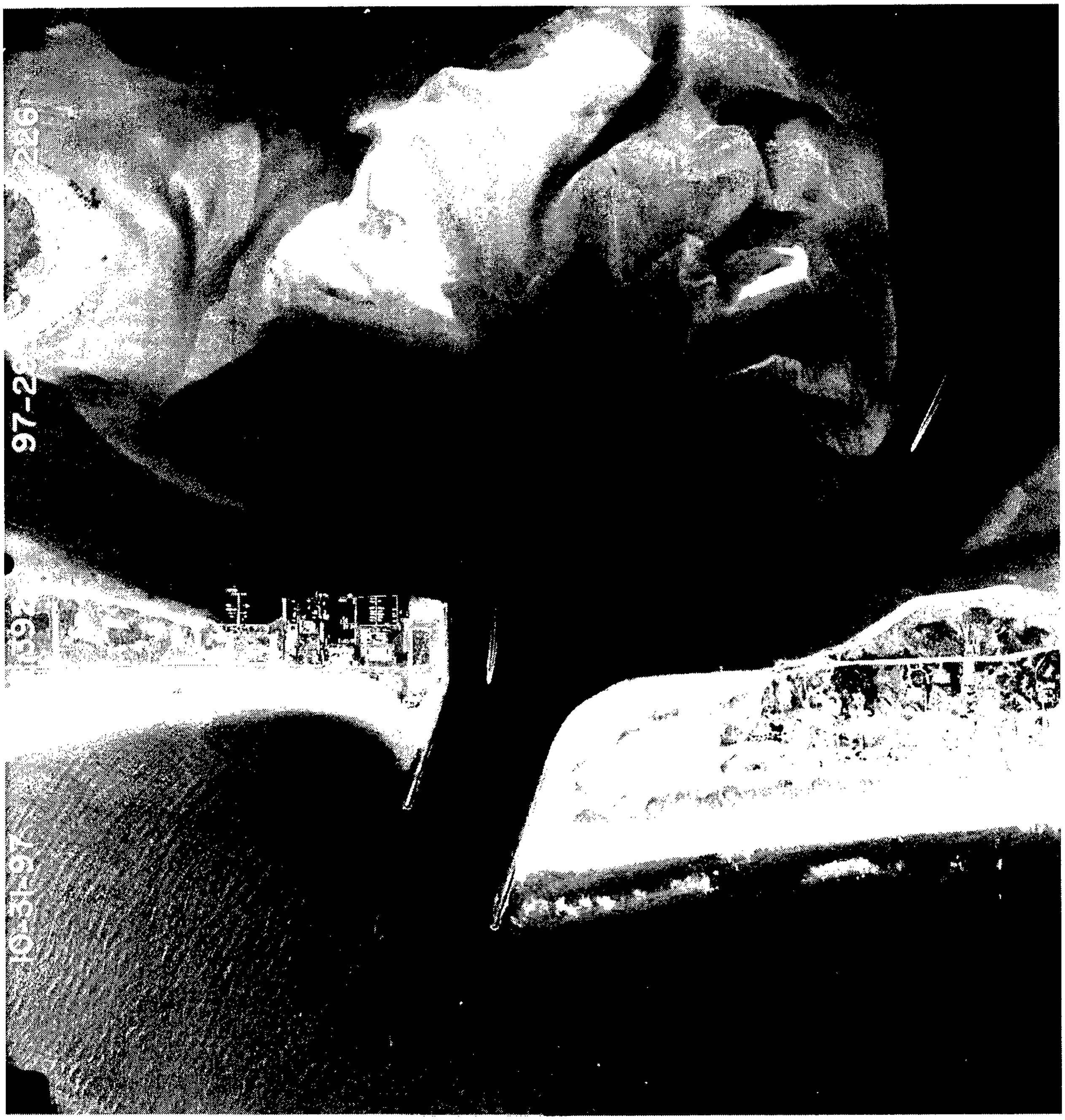


Figure A51. 31 October 1997 (East beach has advanced since April while the west beach has eroded again. Image also shows symmetric flood shoal)

Figure A52. 20 November 1997 (In only a month, west beach had notably receded. Image shows how narrow the west beach is near fishing docks and, therefore, how vulnerable to breaching. The shoreline bulge where ebb shoal attaches to beach has continued to advance seaward. Because of clear water, sandbars off the east beach are visible)

Figure A53. 12 July 1998 (Taken on a summer Sunday, active boat traffic shows how much local boaters rely on Shinnecock Inlet. Shorelines are similar to those in November 1997. The west beach has just been renourished with sand dredged from the navigation channel (see Table D1). Work was completed the day before the photograph was taken)

Appendix B
Bathymetric Surveys

Table B1 lists all known hydrographic surveys at Shinnecock Inlet. The table also lists datum corrections and adjustments as applied in this project. All of these surveys have been digitized (or were available in digital form from the U.S. Army Engineer District, New York) and have been plotted using the following coordinate systems:

Horizontal: New York State Plane grid, Long Island zone, NAD83 (units in feet).

Vertical: National Geodetic Vertical Datum (NGVD), 1929 adjustment.

Water depths are shown in feet, in accordance with the units used for the original data collection. Contour Interval is 2 ft, with bold lines indicating 10-ft isobaths.

Availability of data:

a. U.S. Coast & Geodetic Survey (USC&GS) data can be purchased in digital form from the National Geophysical Data Center in Boulder, Colorado.

b. Surveys from private contractors or from New York District's Survey Branch can be obtained from the New York District. Some of theses data are digital and some are in the form of paper charts.

c. The SHOALS helicopter LIDAR system is operated by the Corps of Engineers' SHOALS Center of Expertise in Mobile, Alabama. Data should be obtained from the New York District, who sponsored the Shinnecock Inlet surveys.

Table B1
Shinnecock Bay and Inlet, Bathymetric and Geographic Data and Conversions

Date of Survey	Source	Original Coordinate System and Units	Terramodel™ Conversions, Functions
Shoreline (unknown date)	National Oceanic and Atmospheric Administration (NOAA) medium-resolution digital vector shoreline - mhw or mhhw line as shown on NOAA hydrographic charts	Latitude longitude NAD83	Coordinate Conversion (COORDCON) from LL83 to NY83-LIF
1933 Shoreline	USC&GS T-sheet T-5080. Available paper or digital raster image	Latitude longitude NAD27	Not used
1933	USC&GS hydrographic survey data from National Geophysical Data Center (provided in digital form)	Latitude longitude NAD27; depths in m below mlw	COORDCON conv. from LL27 to NY-LI; FACTZ multiply depths by 3.281; FACTZ add -1.66 ft to convert to modern NGVD
4,5 Sep, 11 Oct 1940	Soundings and topography submitted by Fredrick T. Hughes and John P Birk (to Suffolk County?) Paper charts, digitized by Applied Research Associates, Vicksburg, MS (March 1998)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29
2-5, 9, 11-15 Mar 1943	Paper chart of bay near Ponquogue Bridge - other sheets available? (NOTE: other sheets lost)	L.I. Lambert, NAD27, mlw (0.2 ft below msl)	Not used - not enough data
1949	U.S. Army Corps of Engineers hydrographic and profile data, digitized from paper charts by Moffatt & Nichol Engineers	Unknown. Supplied to WES in digitized form: State Plane, NAD27; depths in ft below NGVD	COORDCON conversion from NY-LI to NY83-LIF.
1955	Unidentified paper chart (from the New York District). Digitized by Moffatt & Nichol Engineers and converted to NGVD29	Unknown. Supplied to WES in digitized form: State Plane, NAD27; depths in ft below mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to convert from mlw to NGVD29
Nov 1955 - Jan 1956	Mylar chart, from House Document No. 126, 86th Congress, 1st Session, 1,085 pts. Digitized by A. Morang, May 1998 (NOTE: seaward portion is same survey but fewer points than 1955 listed above)	State Plane, NAD27; depths in ft below mlw (water) and elev in ft above msl (land)	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29 (water); MODIFY ELEV. RELATIVE +0.57 ft to conv. from msl to NGVD29 (land)
11 Jun 1984	J & D Kasper & Associates, Bridgeport, CT. Paper charts, 5,822 pts. DACW.51.84.C.0018 Digitized by Applied Research Associates, Vicksburg, MS (March 1998)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29

(Sheet 1 of 3)

Notes on vertical datum conversions:
1. At Shinnecock Inlet, mean low water (mlw) is 1.10 ft below NGVD 1929 based on measurement at benchmark No. 1 1974 (from facsimile sent by the New York District, 1 August 1996). Therefore, a mlw elevation will be 1.10 ft deeper when converted to NGVD. Using Terramodel™ function MODIFY ELEV RELATIVE,-1.10 ft is added to all elevations to convert from mlw to NGVD.
2. No adjustment for sea-level changes made for 1950s through 1990s surveys.
3. Label on March 1998 survey stated mlw is 1.5 ft below NGVD.
4. Contractors:
   OSI = Ocean Surveys, Inc., Old Saybrook, CT.
   SUNY = Marine Sciences Department (Dr. Roger Flood), State University of New York, Stony Brook, NY.
   John Chance = John Chance & Associates, Lafayette, LA.
5. Tidal correction based on tide gauge at Shinnecock Inlet commercial docks.

Table B1 (Continued)			
Date of Survey	**Source**	**Original Coordinate System and Units**	**Terramodel™ Conversions, Functions**
6 Nov 1984	J & D Kasper & Associates, Bridgeport, CT. Paper charts, 1,368 pts. DACW.51.84.C.0018 Digitized by Applied Research Associates, Vicksburg, MS (March 1998)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29
8 Mar 1985	J & D Kasper & Associates, Bridgeport, CT. Paper charts, 2,053 pts. DACW.51.84.C.0018 Digitized by Applied Research Associates, Vicksburg, MS (March 1998)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29
30 Jun 1985	J & D Kasper & Associates, Bridgeport, CT. Paper charts, 714 pts. DACW.51.84.C.0018 Digitized by Applied Research Associates, Vicksburg, MS (March 1998)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.10 ft to conv. from mlw to NGVD29
Jul 1986	Acoustic, 441 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Jun 1987	Acoustic, 459 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Nov-Dec 1989	Ocean Surveys, Inc., Old Saybrook, CT. Sheet CC-SNK-206, 775 pts Sheet CC-SNK-320, 1000 pts Sheet CC-SNK-317, 1962 pts Digitized by Applied Research Associates, Vicksburg, MS (Jan 1999)	L.I. Lambert, NAD27, mlw	COORDCON conv. from NY-LI to NY83-LIF; MODIFY ELEV. RELATIVE -1.20 ft to conv. from mlw to NGVD29
Aug 1990	Ocean Surveys, Inc., Old Saybrook, CT. Paper charts, 4416 pts. Digitized by Applied Research Associates, Vicksburg, MS (Jan 1999)	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Oct 1990	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 635 pts. (more data avail?)	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Dec 1990	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 3,404 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Aug 1991	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 28,255 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
15 & 17 Jul 1992	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic	L.I. Lambert, NAD27, NGVD	(not used)
21-22 Dec 1992	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 14,500 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Dec 1993	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 14,374 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
21 Jun 1994	SHOALS LIDAR bathymetry survey from Coastal Engineering Research Center archives. Includes inlet area and ocean coast between Moriches and Shinnecock inlets	Latitude longitude WGS 84; depths in m below mllw (Note: tidal corrections may be erroneous - not to be used for volumetric computations)	COORDCON conversion from LL84 to NY-LI; FACTZ multiply depths by 3.281. Total number of points reduced from 160,000 to 40,000
			(Sheet 2 of 3)

Table B1 (Concluded)

Date of Survey	Source	Original Coordinate System and Units	Terramodel™ Conversions, Functions
3-9 Aug 1994	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 19,500 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
8-15 Sep 1995	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 9,170 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
4-5, 9-11 Oct 1995	Ocean Surveys, Inc., Old Saybrook, CT. Acoustic, 9,062 pts.	L.I. Lambert, NAD27, NGVD	COORDCON conv. from NY-LI to NY83-LIF
Aug -Sept 1996	SHOALS LIDAR bathymetry survey from John Chance & Associates. Includes inlet area and ocean coast off Westhampton Beach	Latitude longitude WGS 84; depths in m below NGVD	COORDCON conversion from LL84 to NY-LI; FACTZ multiply depths by 3.281. Total number of points reduced from 492,000 to 123,000
13 Aug 1997	SHOALS LIDAR bathymetry survey from John Chance & Associates	L.I. Lambert, NAD27, NGVD 1929	COORDCON conv. from NY-LI to NY83-LIF. Approx 644,000 points; decimated to 1/50 of original density, 12,893 points
3-6 Mar 1998	Acoustic, New York District, 6,420 pts.	NAD83, depths in ft below mlw (1.5 ft below NGVD)	MODIFY ELEV. RELATIVE -1.50 ft[3] to conv. from mlw to NGVD29
28 May 1998	SHOALS LIDAR bathymetry survey from John Chance & Associates	NAD83, NGVD29	Approx 377,000 points; decimated to 1/10 of original density, 37,728 pts.
15,20,25 Oct and 1,5,6 Nov 1998	Acoustic data, SUNY	NAD83, mtl which is 0.62 ft below NGVD29	53,700 points. MODIFY ELEV. RELATIVE -0.62 ft to conv. from msw to NGVD29[5]
31 Oct 1998	Multibeam (EM-3000) acoustic, SUNY		

(Sheet 3 of 3)

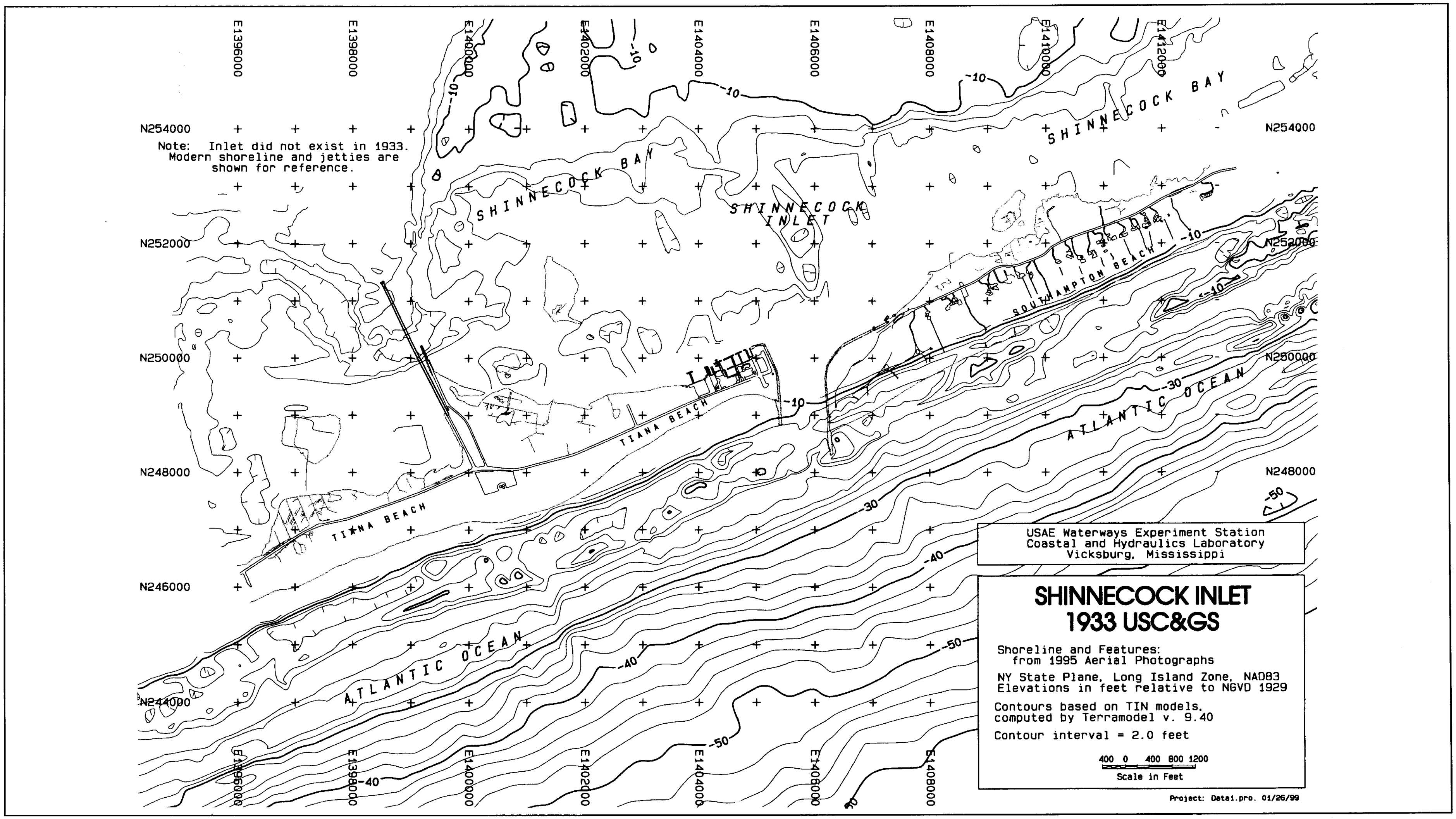


Figure B1. 1933 USC&GS (Note that Shinnecock Inlet was not open when these surveys were made. Modern shoreline and structures are shown for reference. Ocean contours are parallel to shore except for sandbars at about 10-ft water depth)

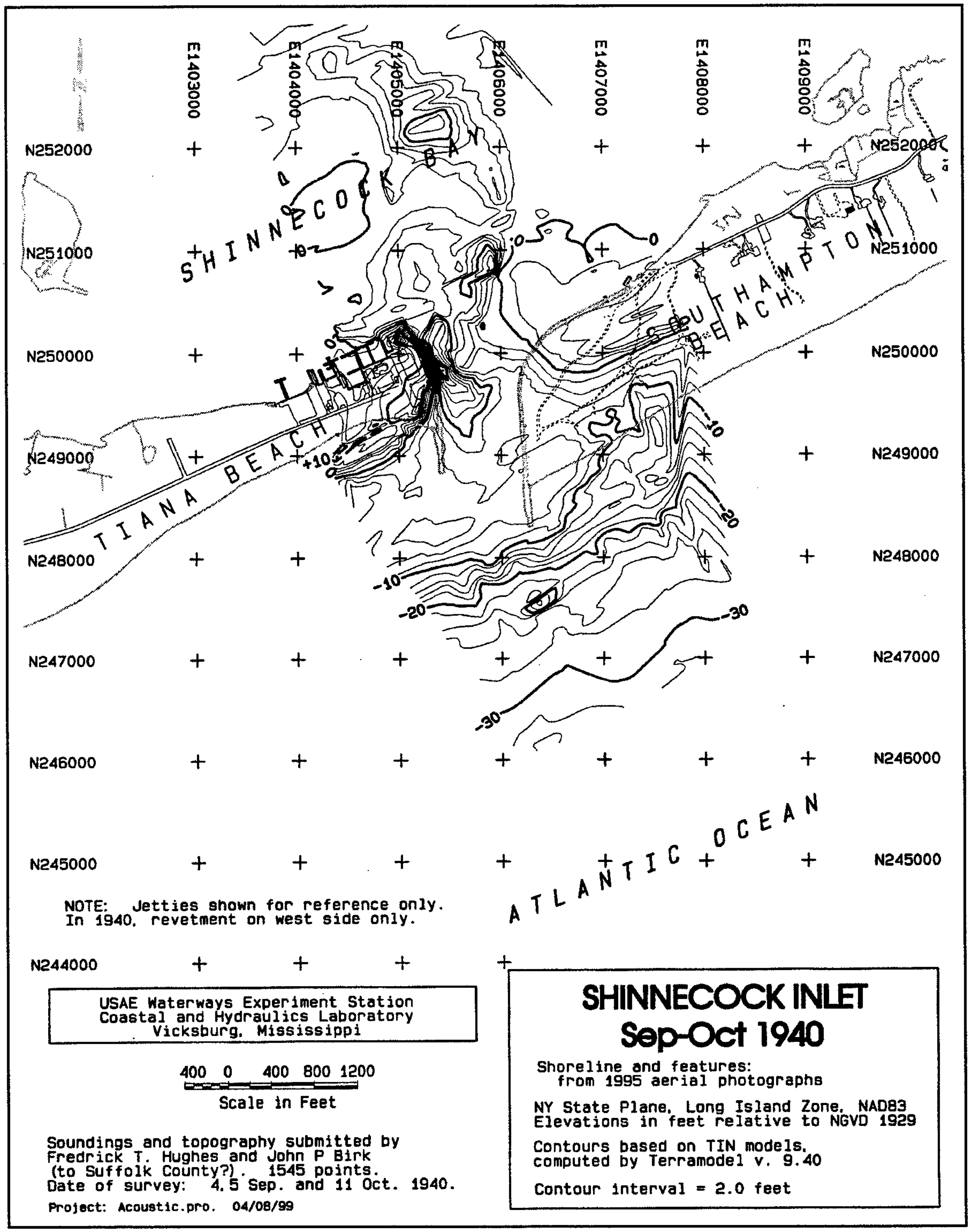


Figure B2. 4, 5 September and 11 October 1940

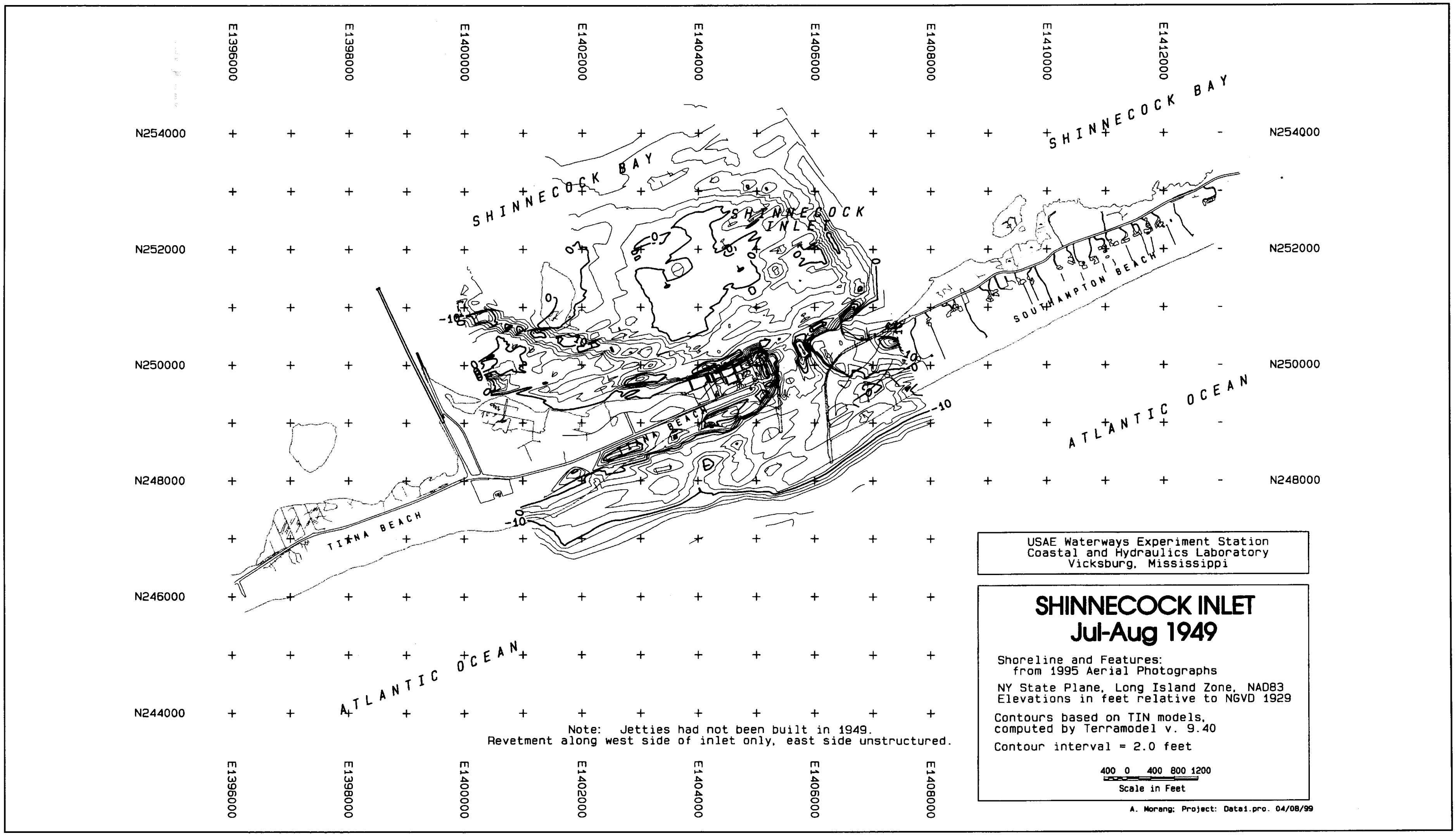


Figure B3. 22 July - 12 August 1949 (Note that a revetment existed on west side of inlet at this time, but east side was unstructured)

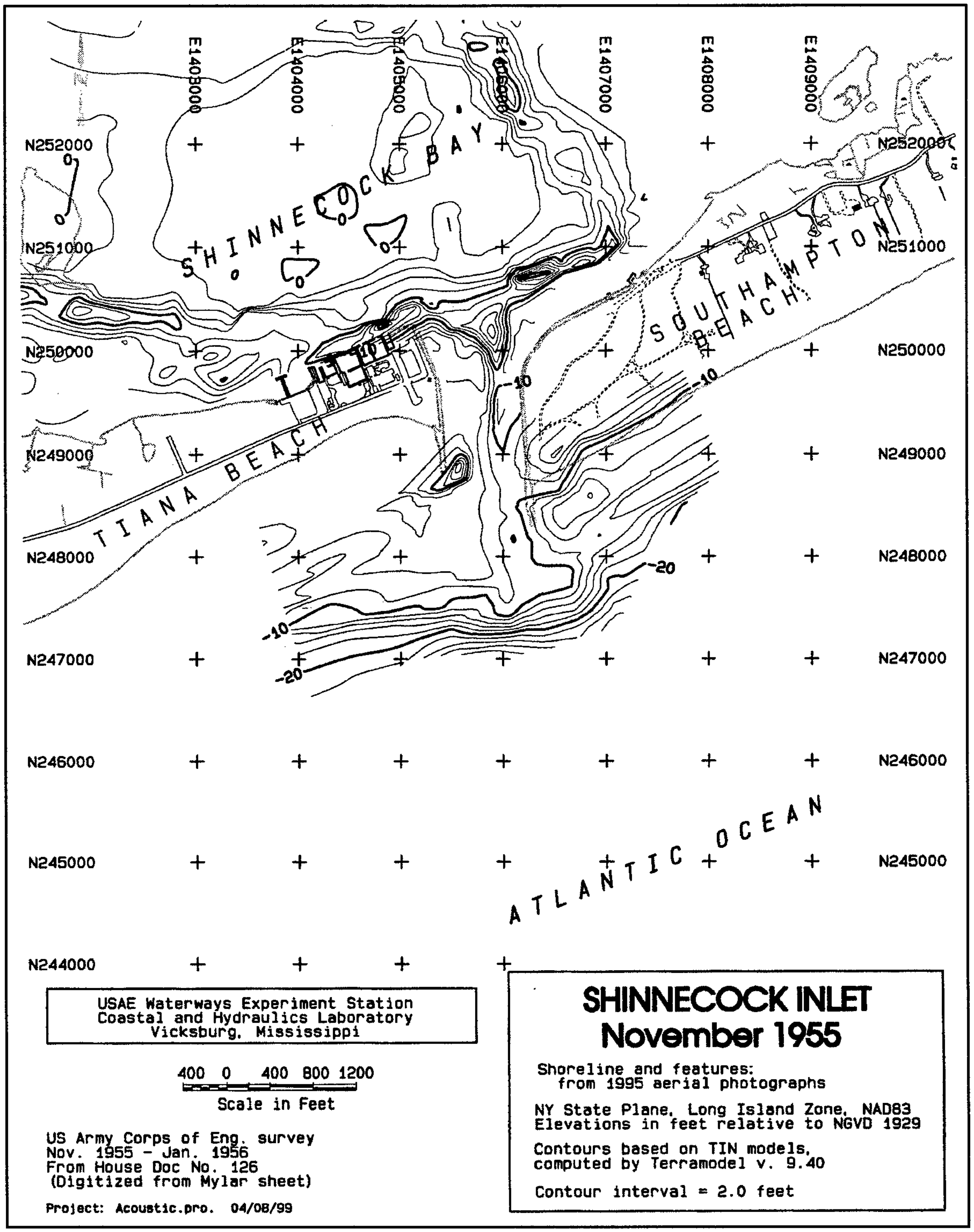


Figure B4. November 1955 - January 1956 (Data points digitized from plate in House Doc. No. 126. Original survey sheets upon which sheet was based have been lost)

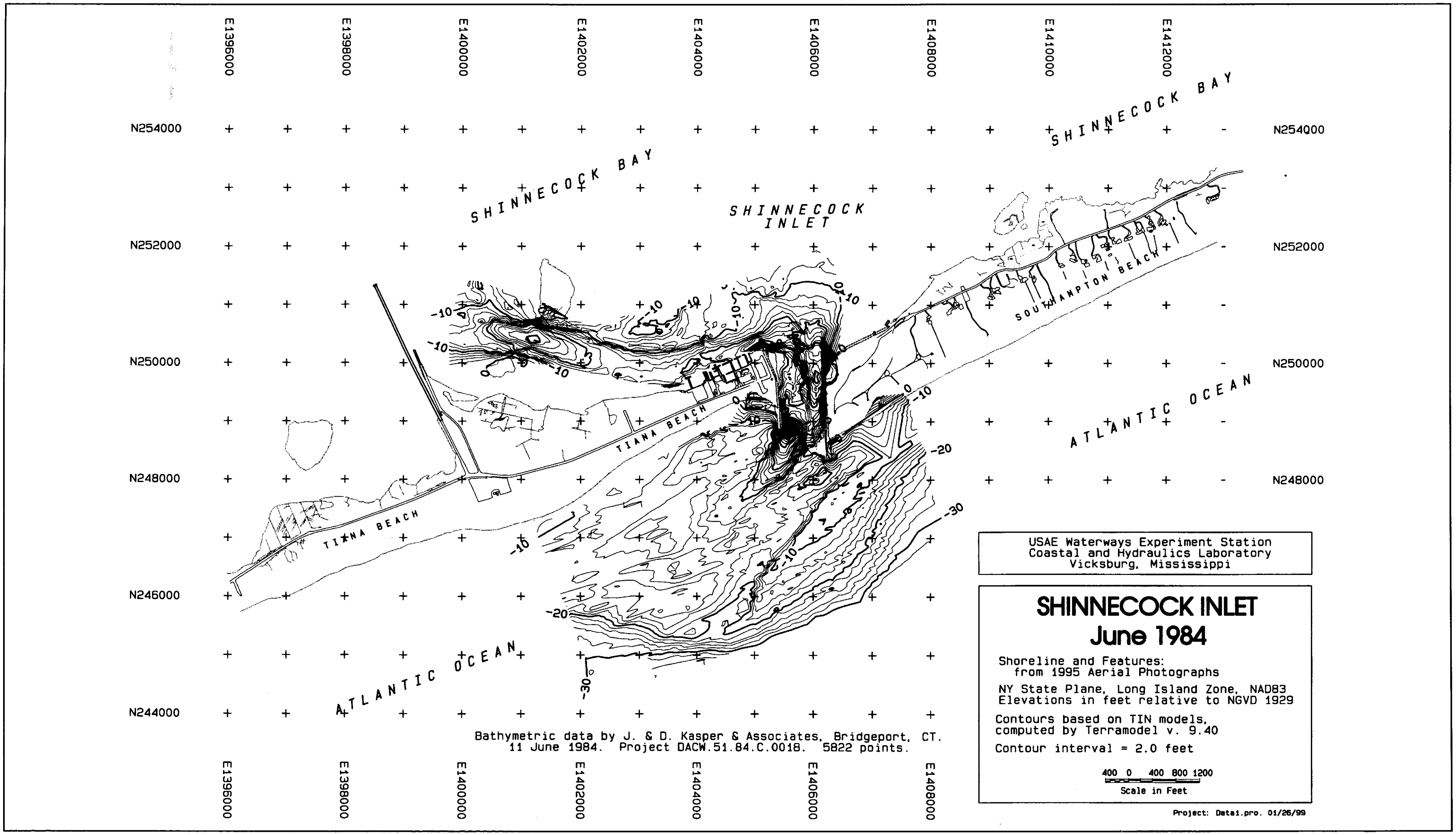


Figure B5. 11 June 1984 (First available survey since 1956)

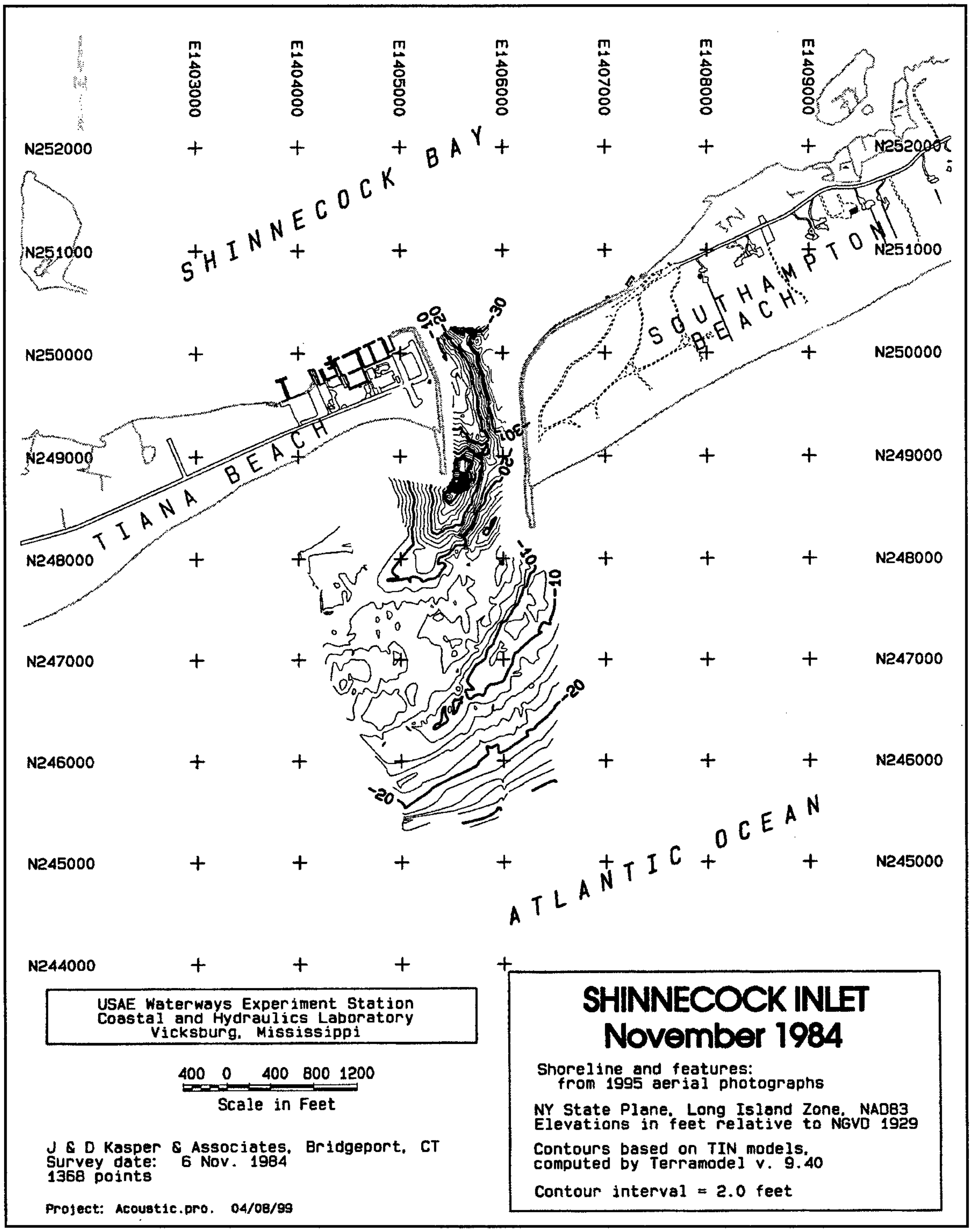


Figure B6. 6 November 1984

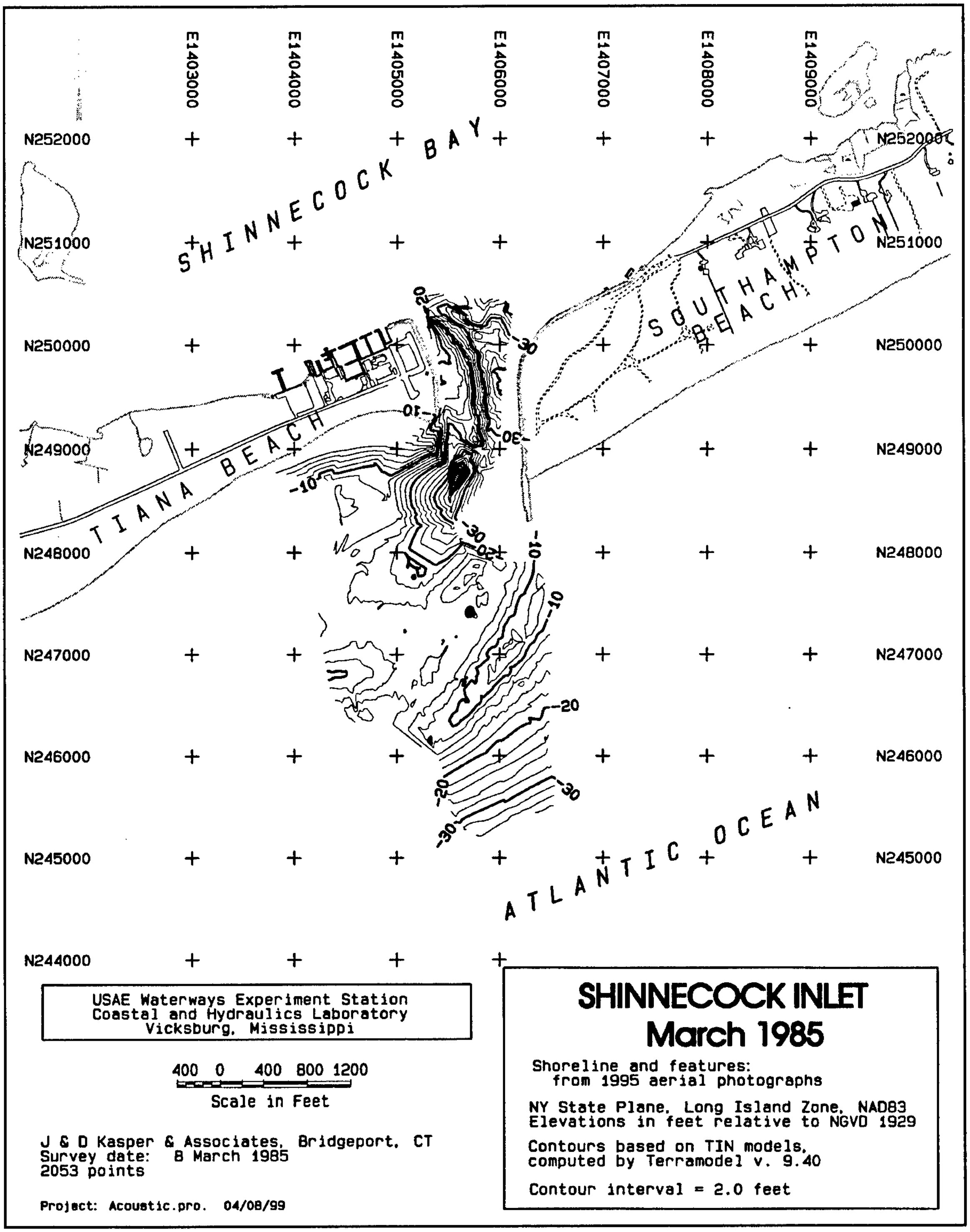


Figure B7. 8 March 1985

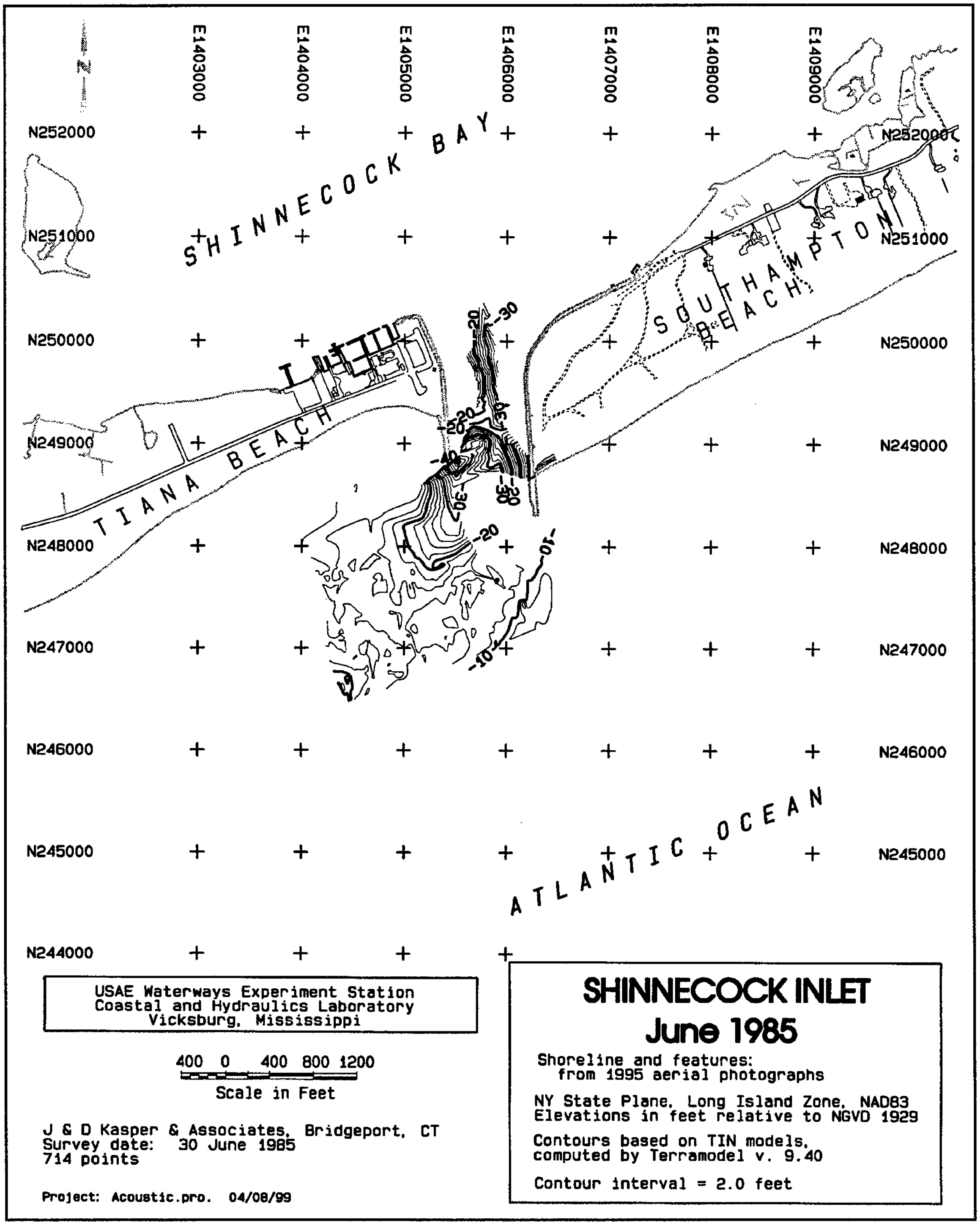


Figure B8. 30 June 1985

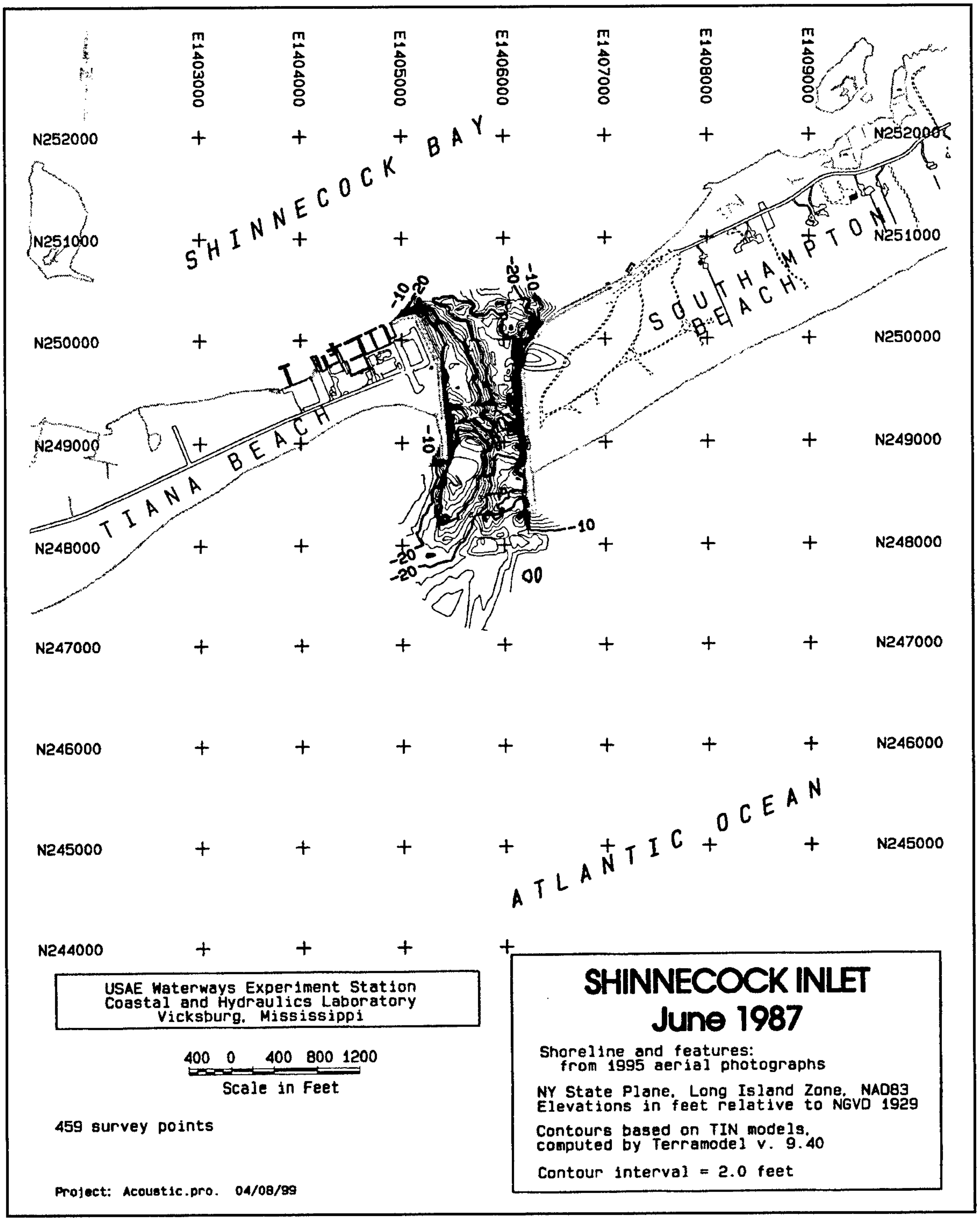


Figure B9. June 1987

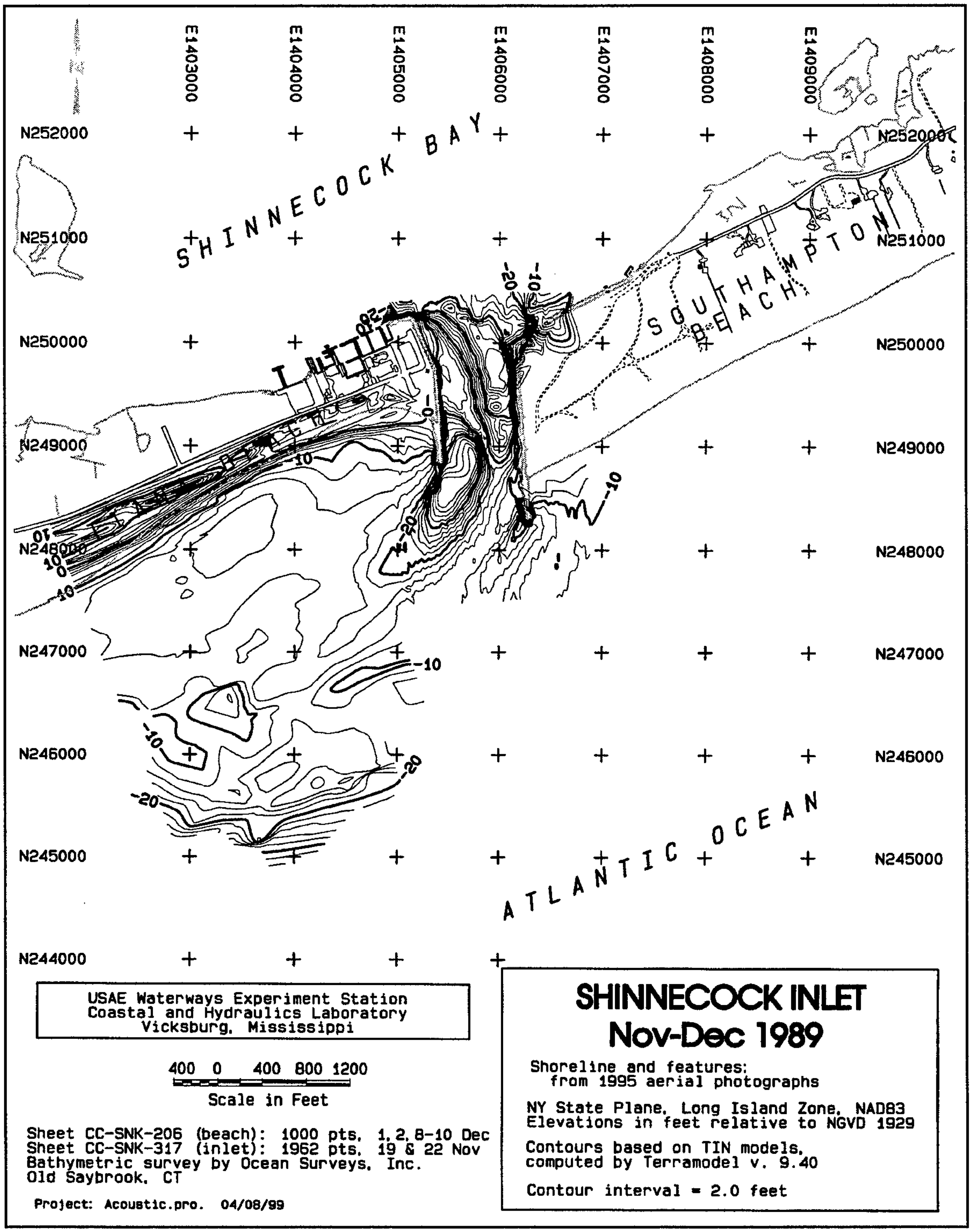


Figure B10. 15-22 November and 1, 2, 7-10 December 1989

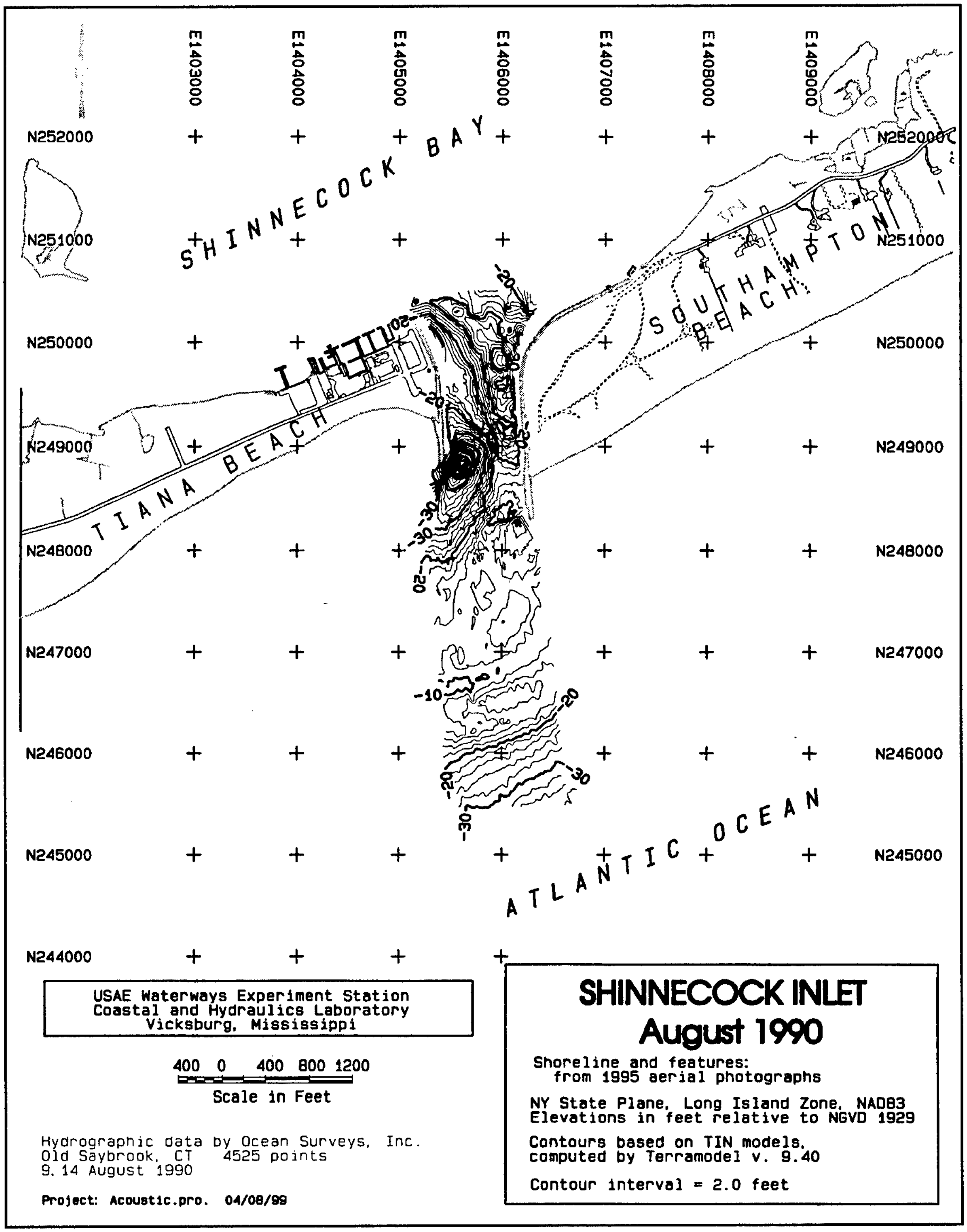


Figure B11. 9, 14 August 1990

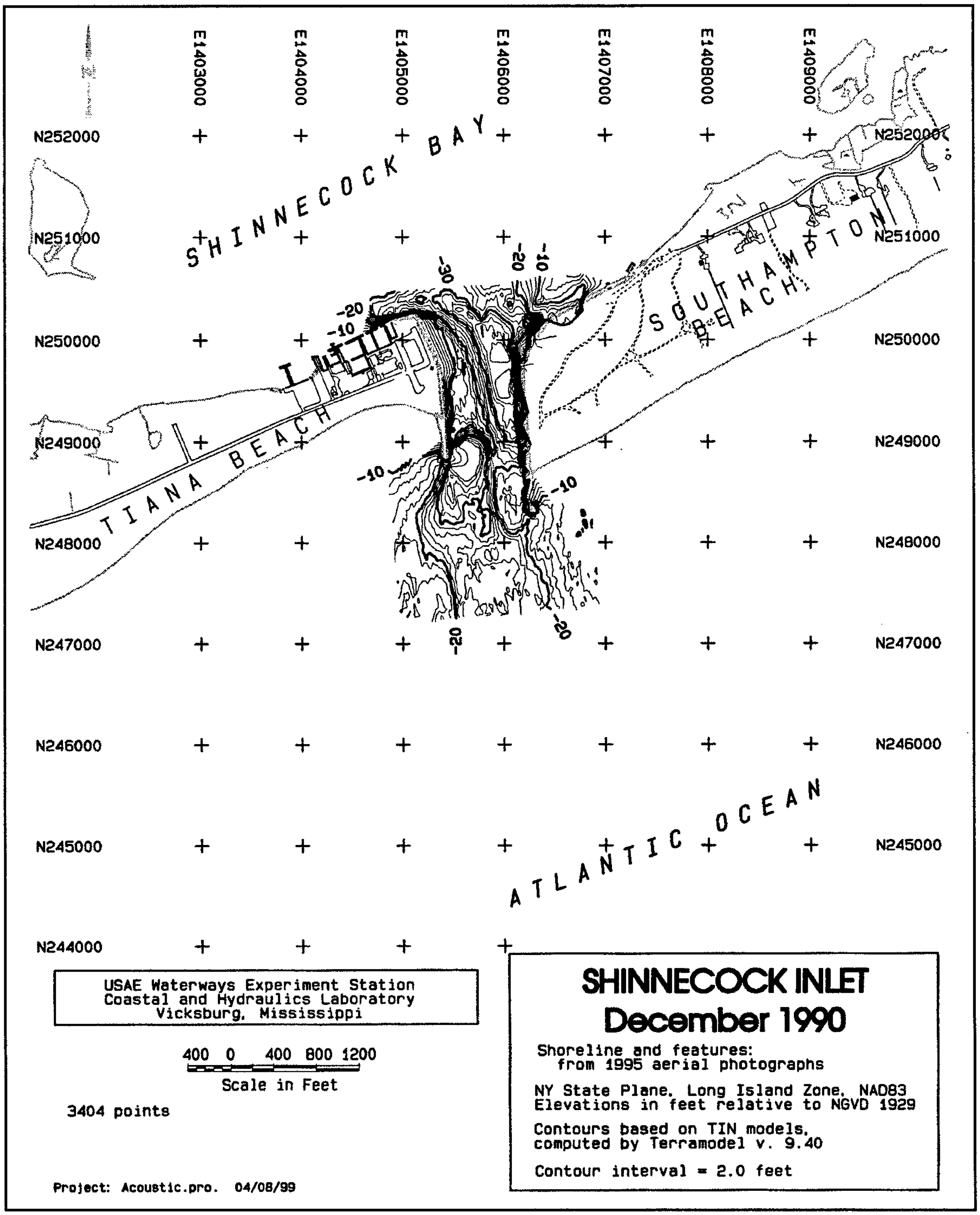


Figure B12. December 1990

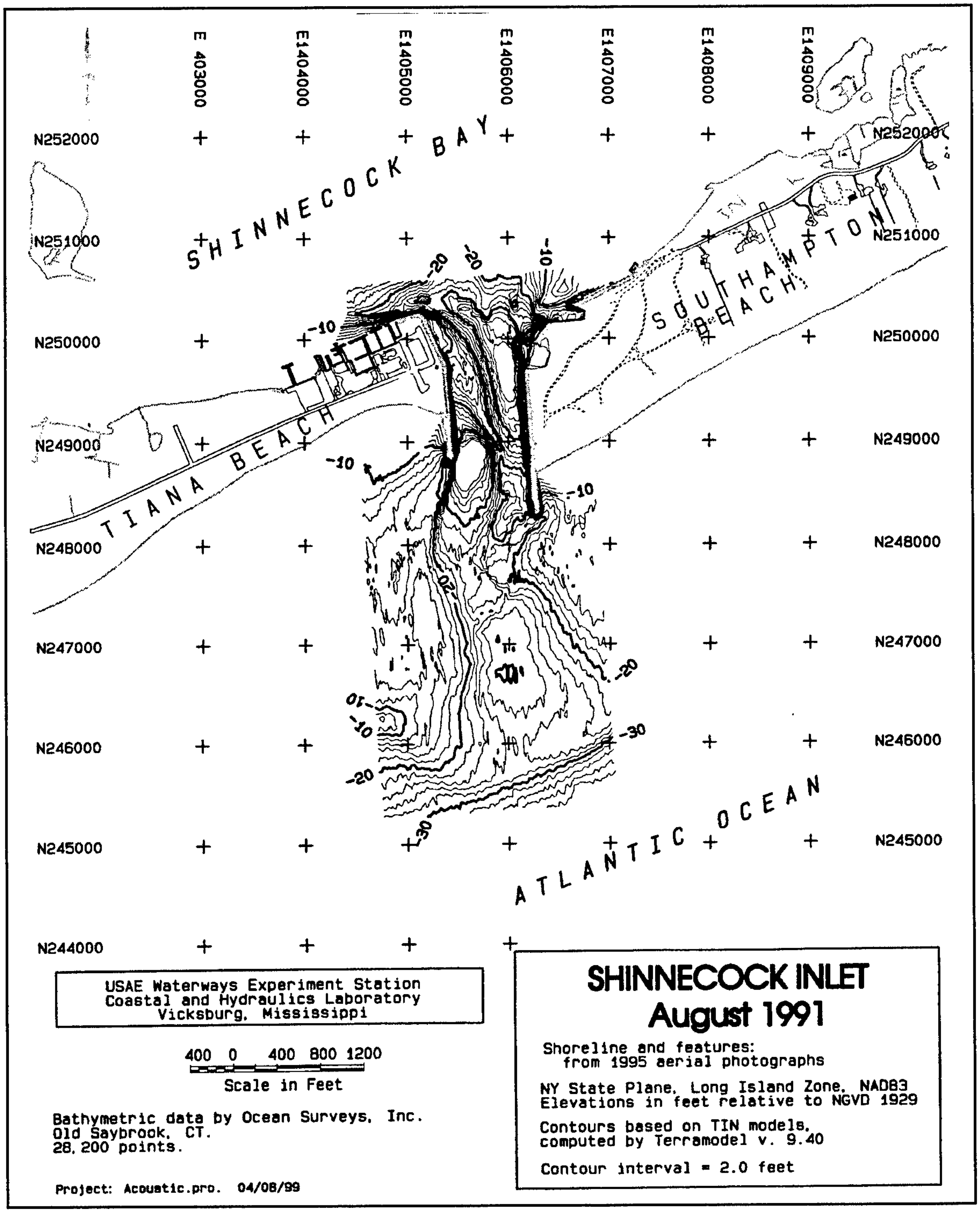


Figure B13. August 1991

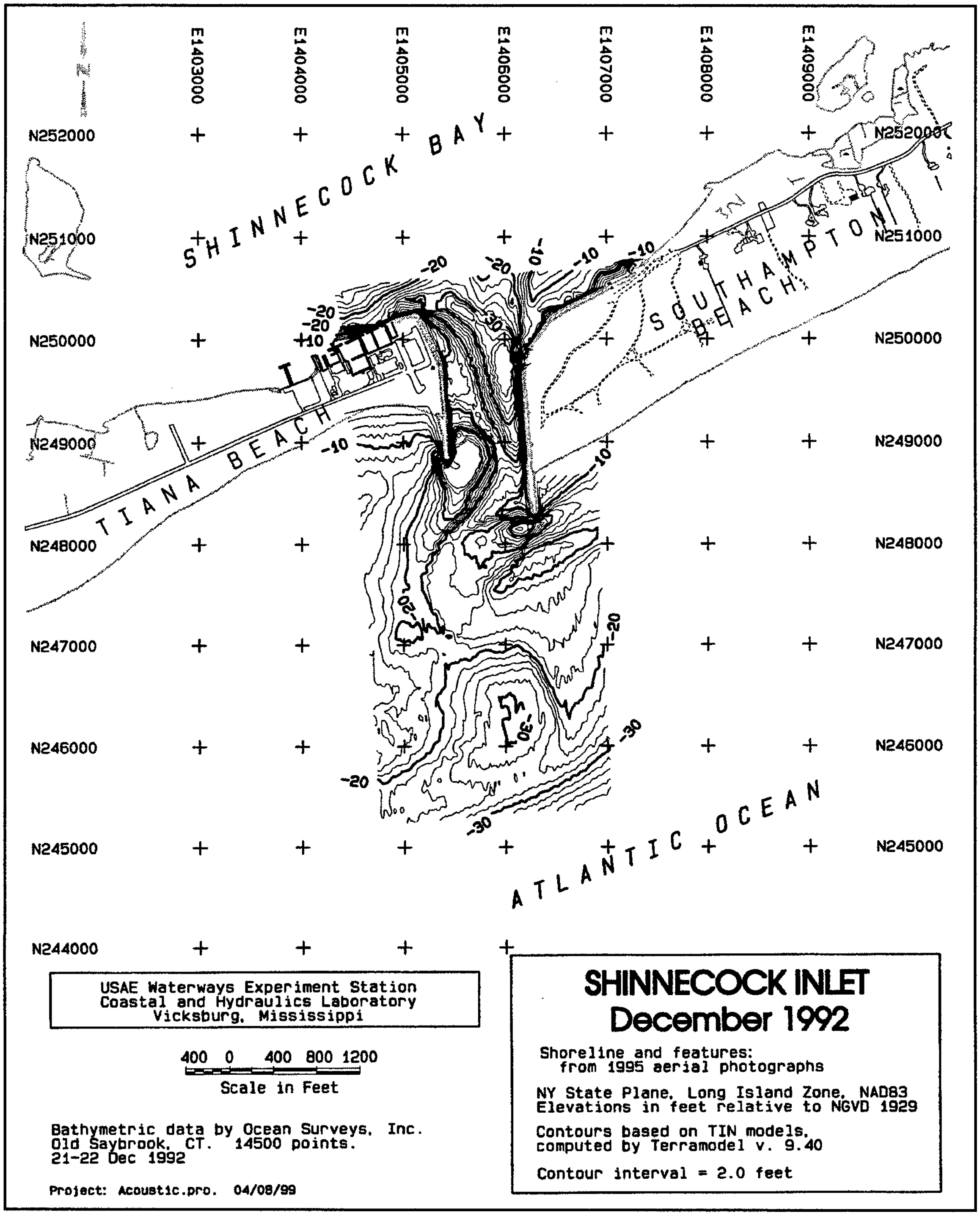


Figure B14. 21-22 December 1992

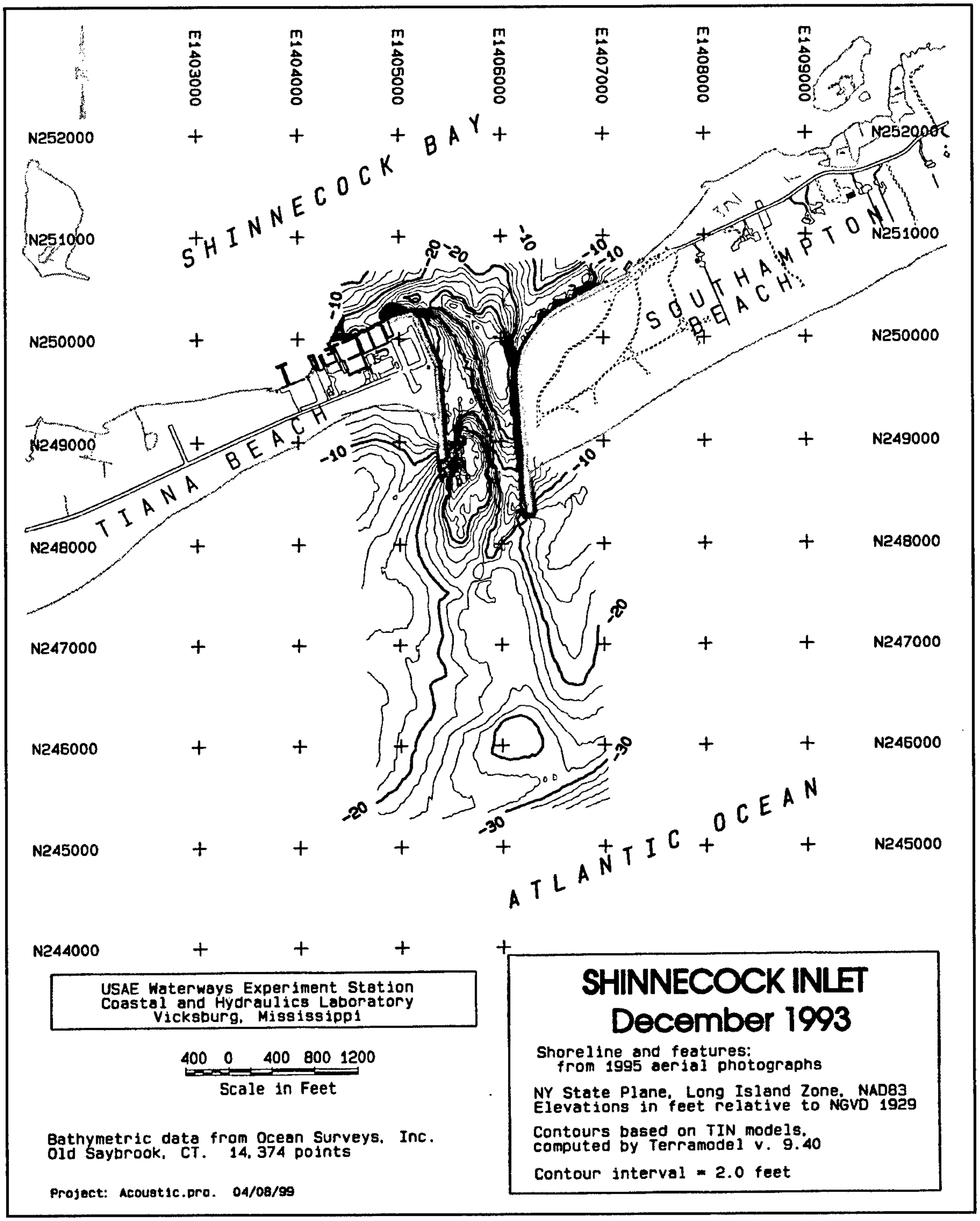


Figure B15. December 1993

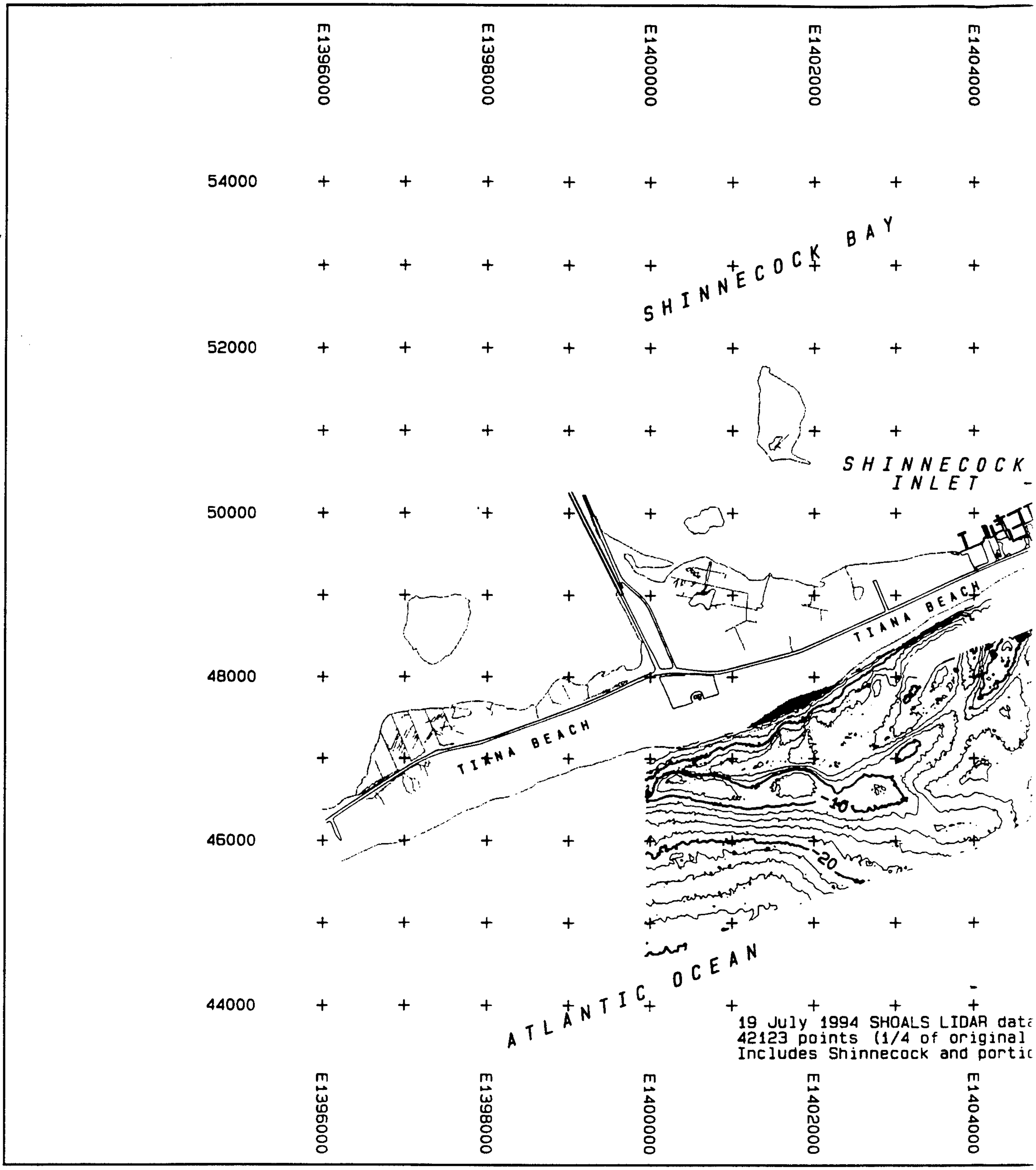
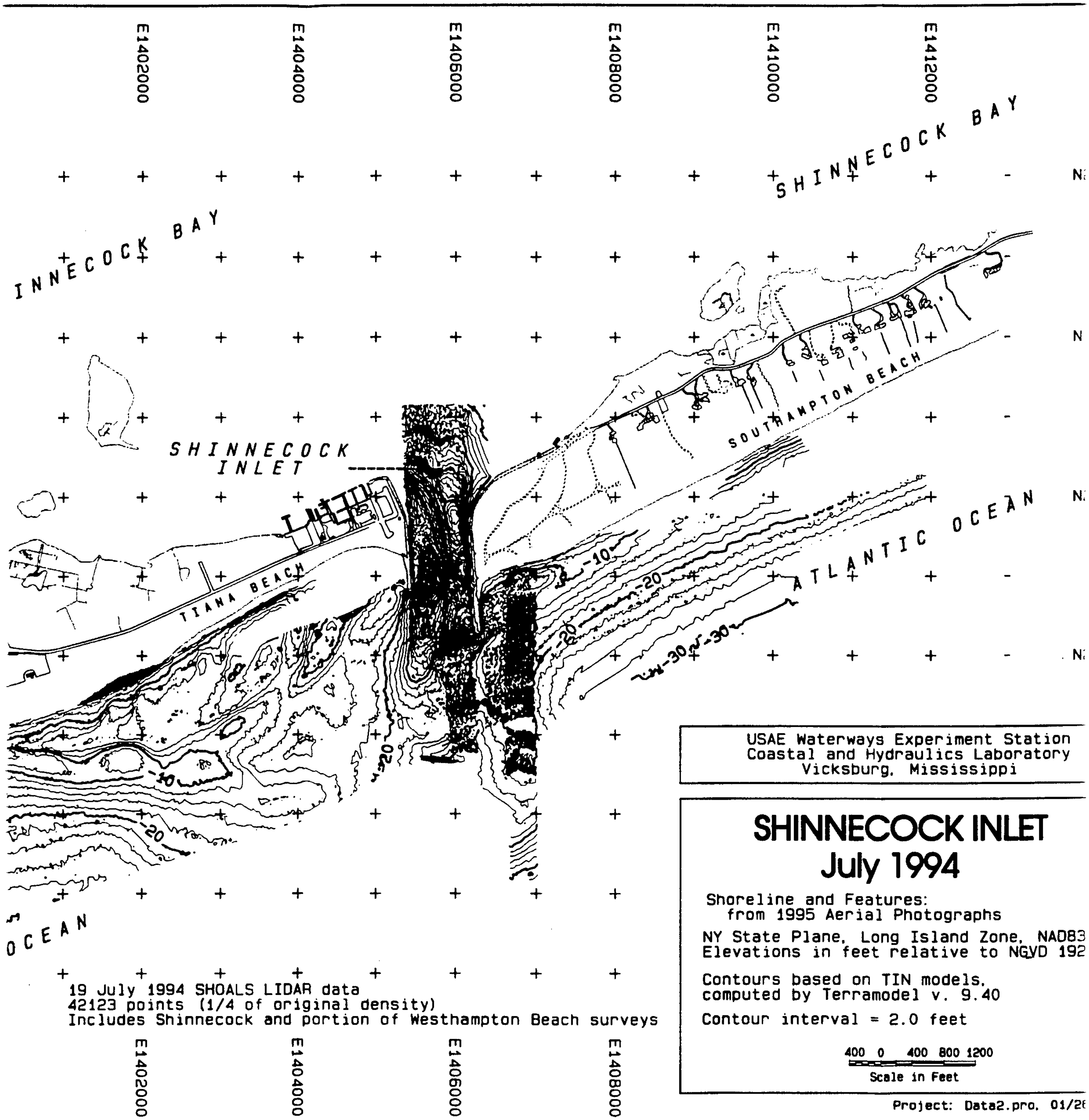
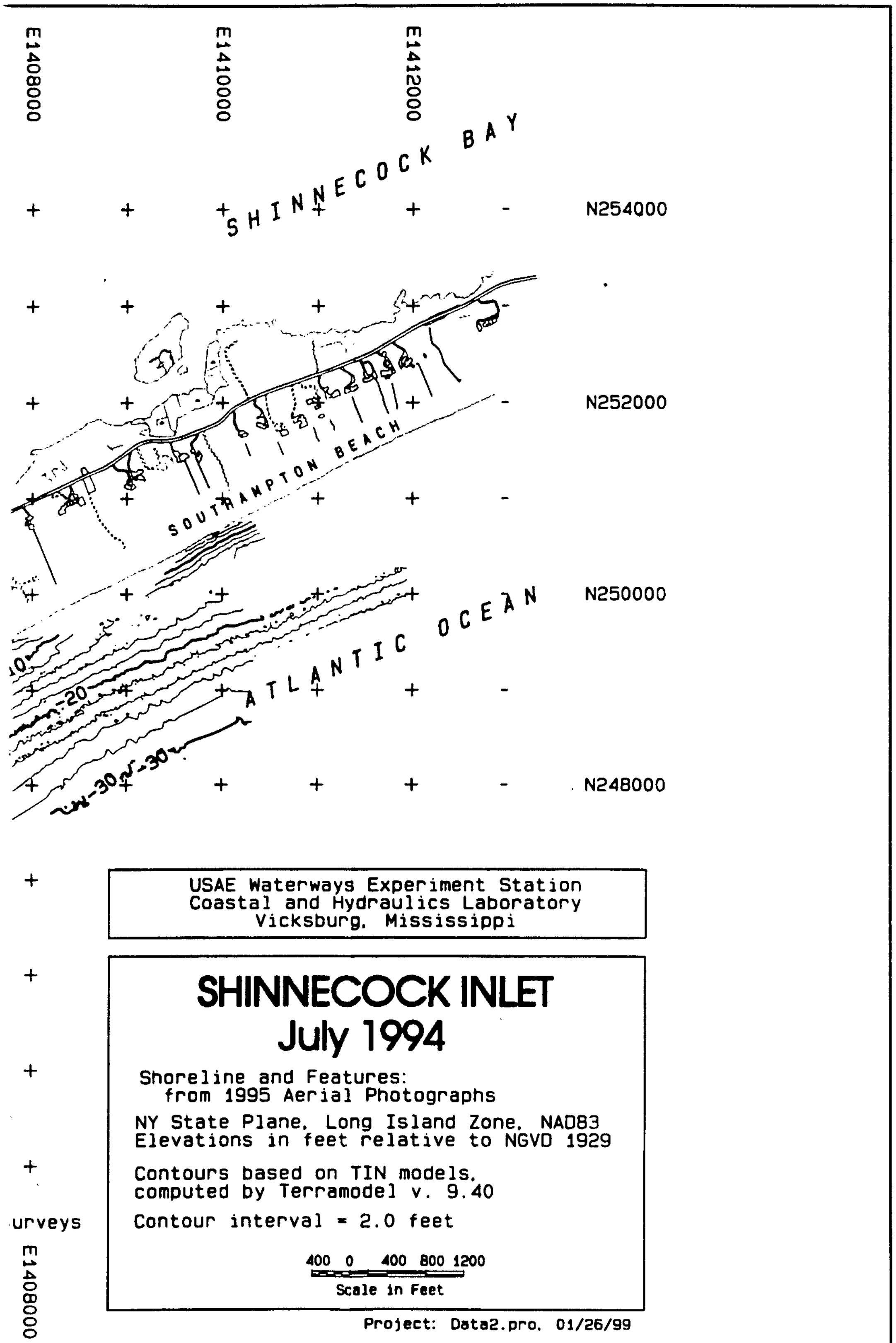


Figure B16. 19 July 1994 (Survey data collected using SHOALS hydrographic LIDAR system. Data shown includes two su Moriches inlets)



.IDAR system. Data shown includes two surveys, one run north-south through inlet, and a second run parallel to Westhampton Beac



rough inlet, and a second run parallel to Westhampton Beach between Shinnecock and

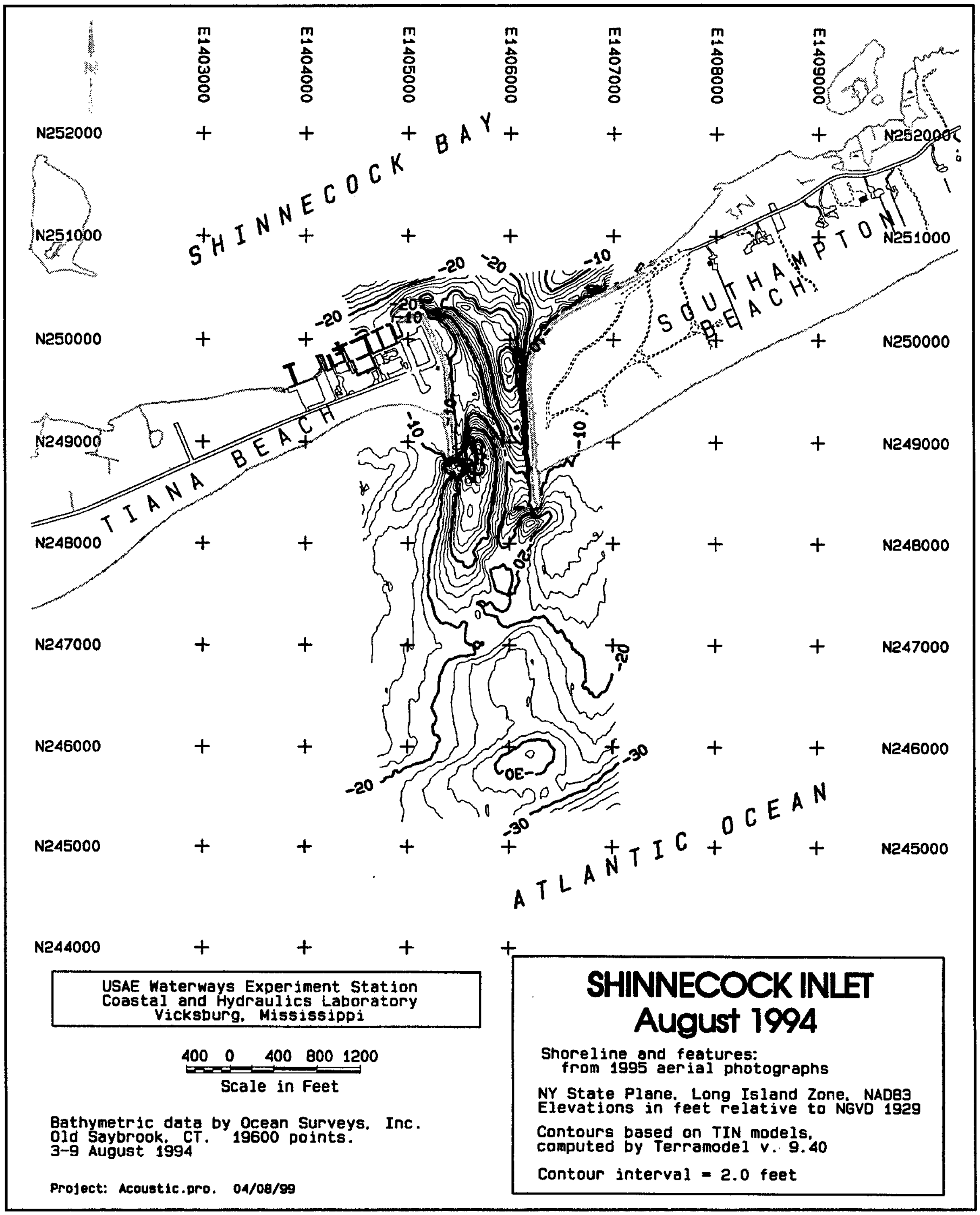


Figure B17. 3-9 August 1994

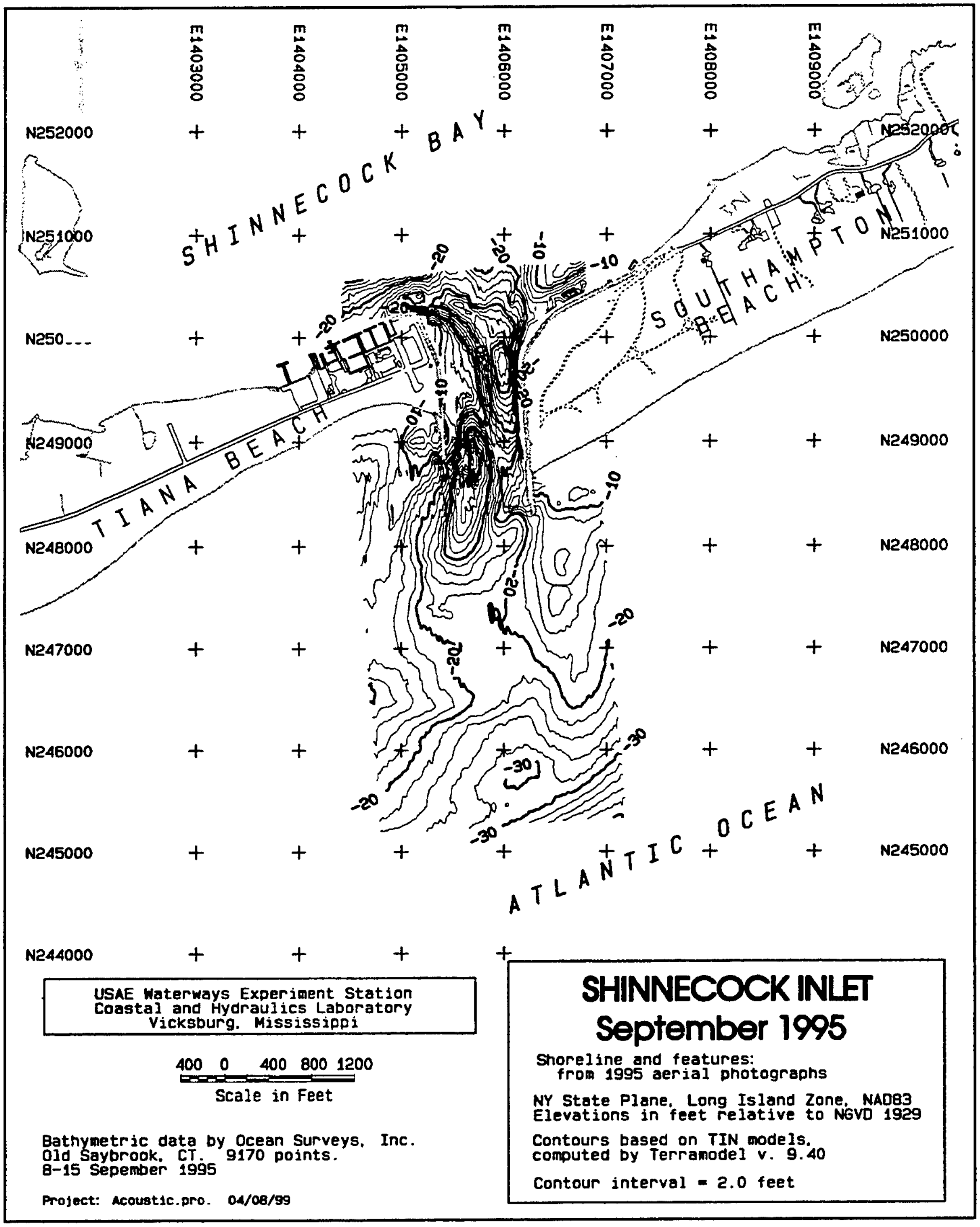


Figure B18. 8-15 September 1995

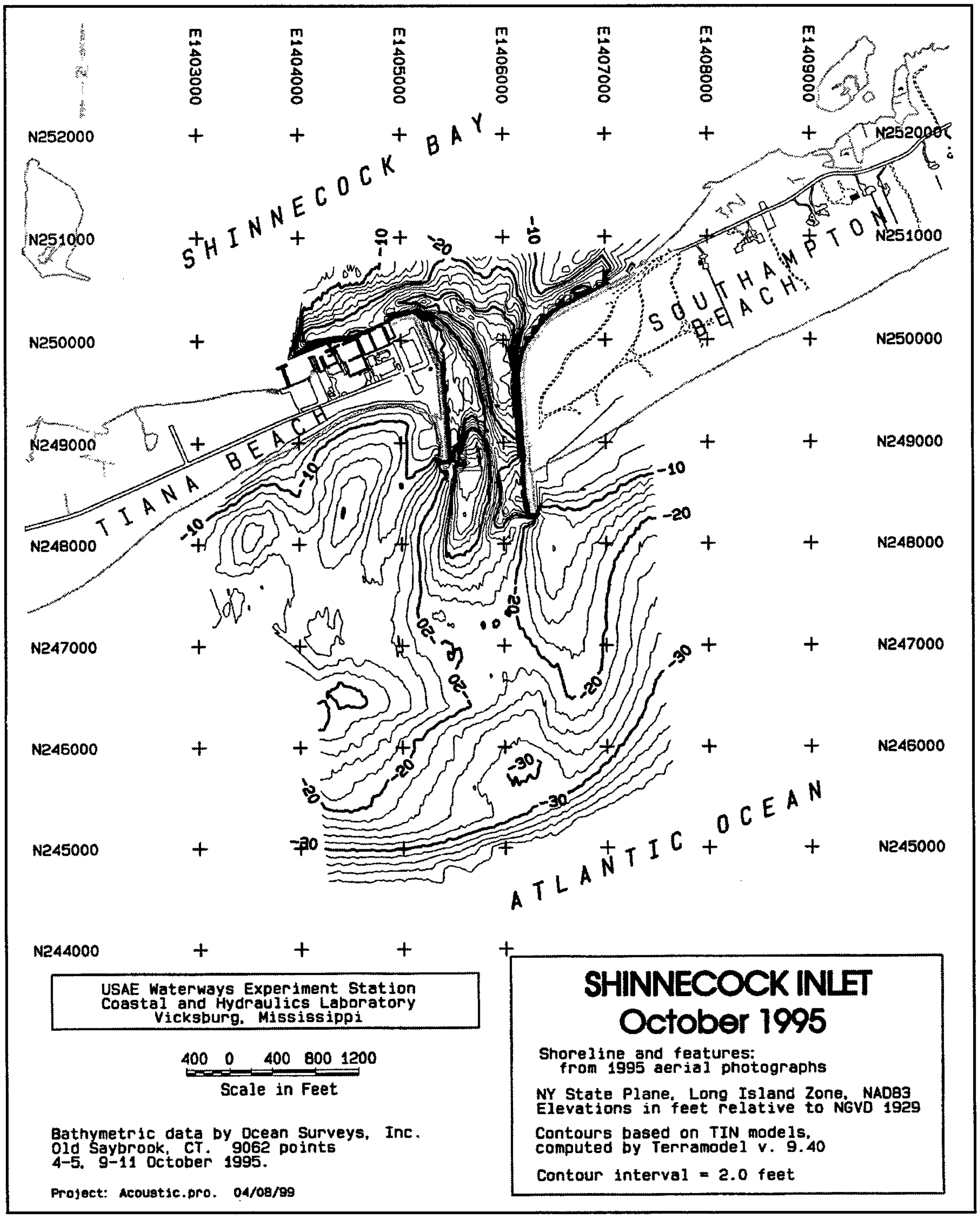


Figure B19. 4-5 and 9-11 October 1995

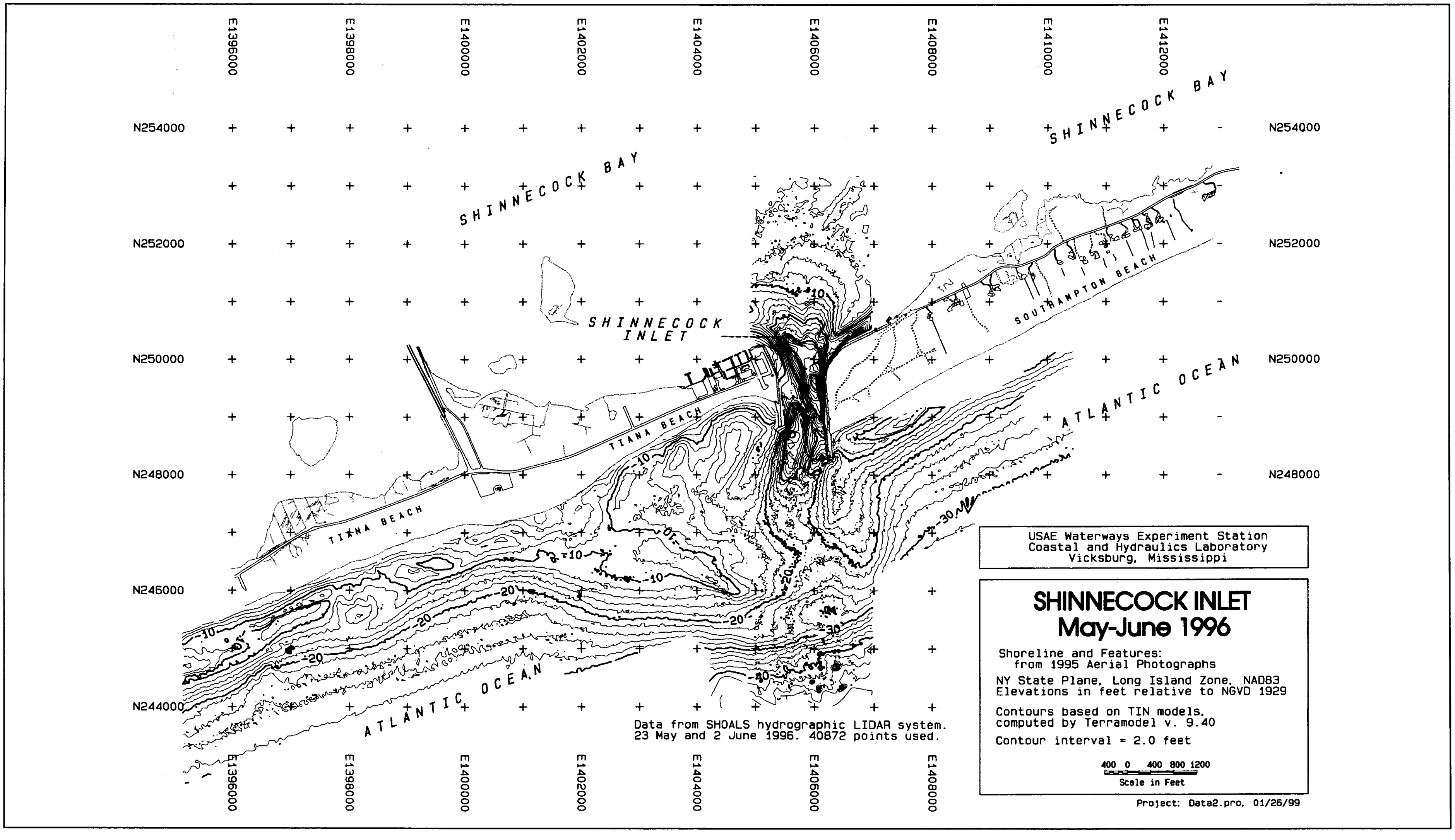


Figure B20. May-June 1996 (Data collected with SHOALS hydrographic LIDAR system)

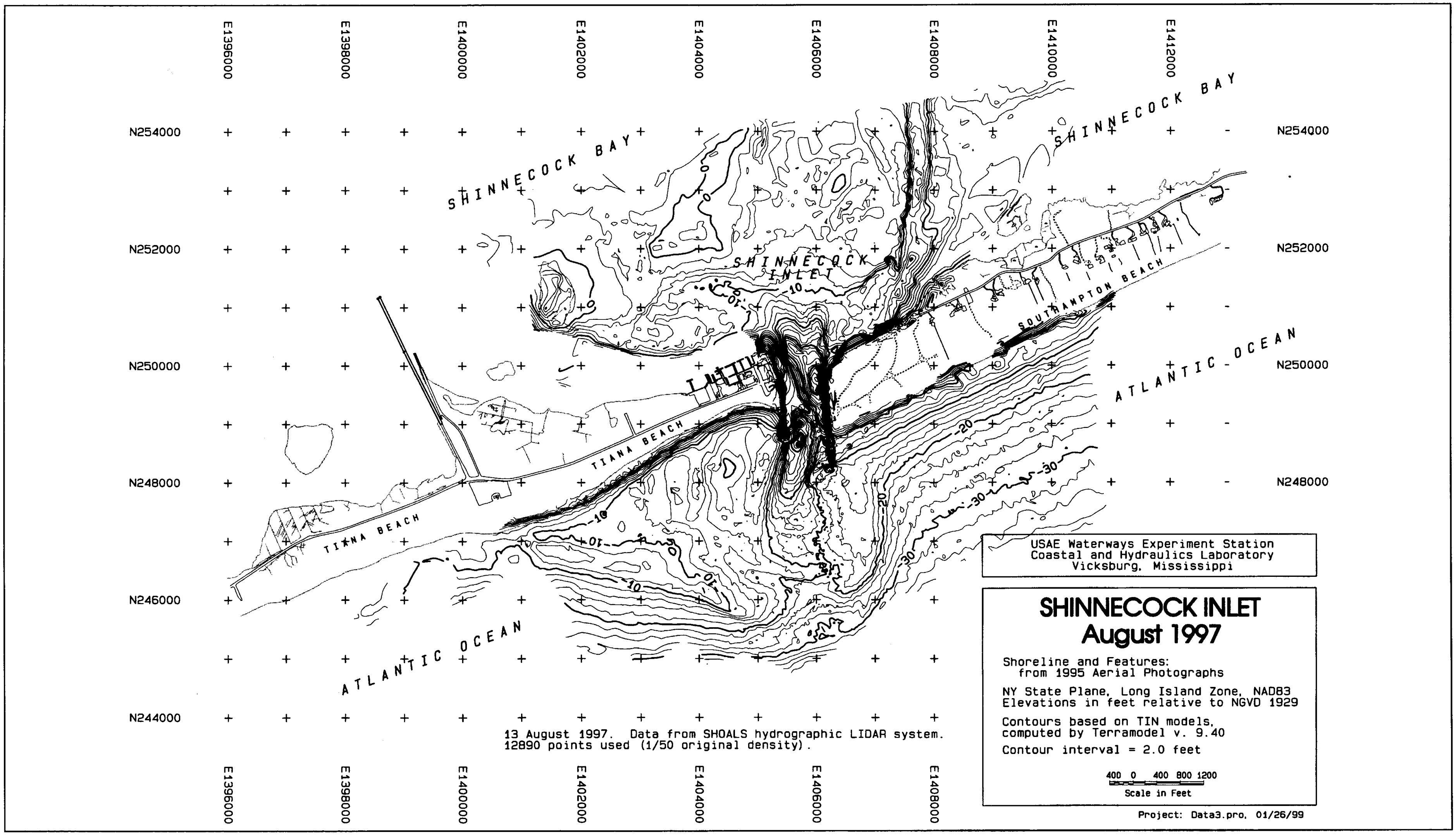


Figure B21. 13 August 1997 (Data collected with SHOALS hydrographic LIDAR system)

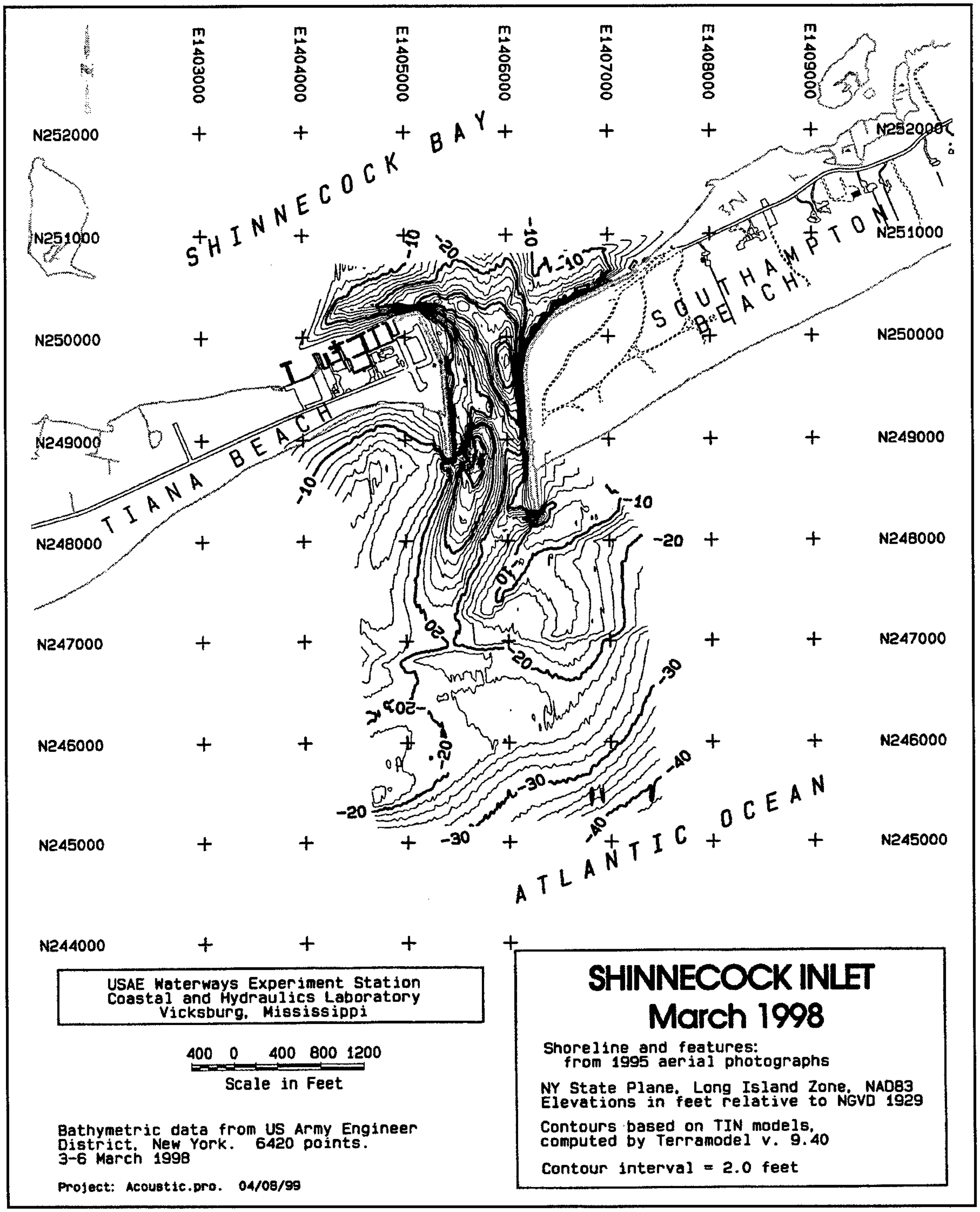


Figure B22. 3-6 March 1998 (Data from the New York District survey branch)

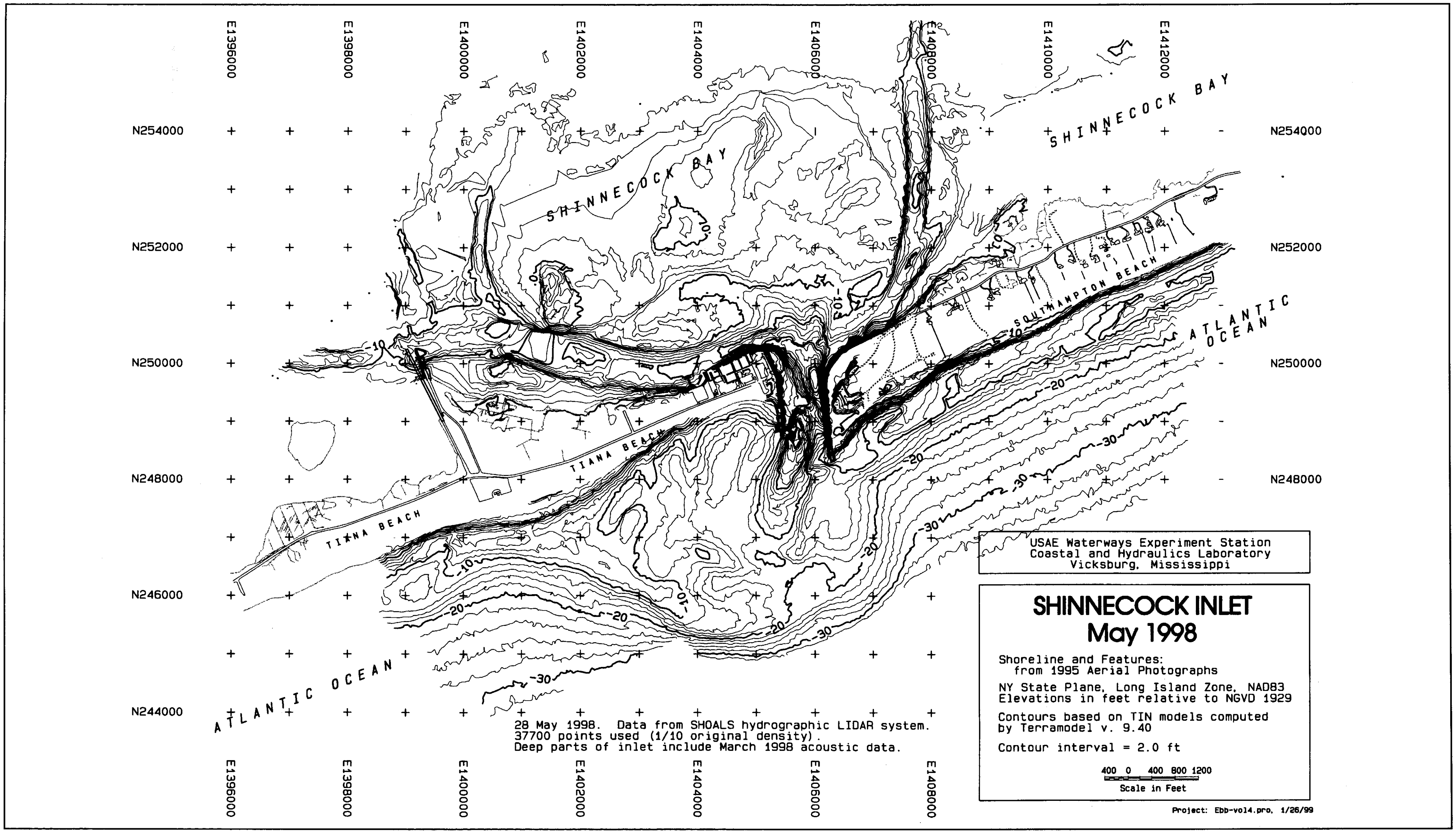


Figure B23. 28 May 1998 (Data collected with SHOALS hydrographic LIDAR system. Because of a limited signal penetration, areas of inlet deeper than

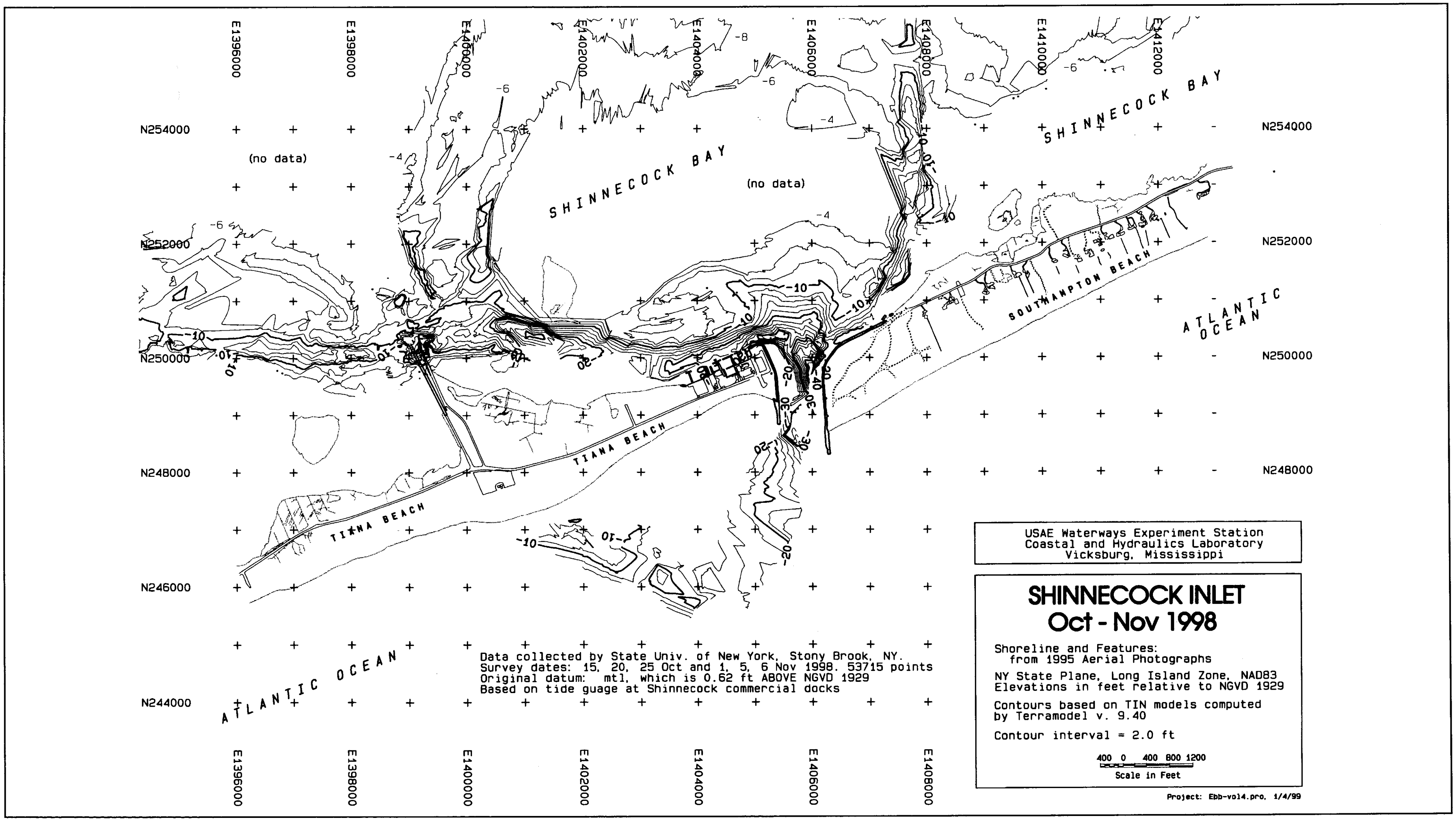


Figure B24. 15, 20, 25 October and 1, 5, 6 November 1998 (Data collected acoustically by State University of New York as part of Coastal Inlets Research Program field studies in Shinnecock Bay. No data collected in shallow parts of Shinnecock Bay)

Appendix C Profile Surveys

Profile Nomenclature

Profiles have been collected along the Long Island shore since the 1940s by the U.S. Army Engineer District, New York, and State and local agencies. From 1995 to 1998, a comprehensive survey program consisting of cross-shore profiles taken every 300 m (1,000 ft) between Fire Island Inlet to Montauk Point has been sponsored by the Atlantic Coast of New York (ACNY) Monitoring Program (Morang, Rahoy, and Grosskopf 1999).[1] These profiles include a mixture of short (wading-depth) and long (-30 ft National Geodetic Vertical Datum (NGVD)) lines. A series of long profiles from 1979 have recently been inspected and digitized. Some 1979 lines, when their locations coincide with modern lines, have been included in the plots below.

At the initiation of the ACNY program in 1995, a uniform numbering convention was adopted by the New York District and the New York State Department of State. The profiles between Moriches and Shinnecock inlets are in the Westhampton Reach and are labeled with a prefix "W." Originally, the easternmost Westhampton profile line was W44, but in Spring 1998, lines W45 to W50 were added to provide more comprehensive coverage (see Figure 29 of main text).

Profiles east of Shinnecock Inlet are in the Ponds Reach and are labeled with a "P." The western part of the Ponds Reach is a barrier spit that encloses the east half of Shinnecock Bay. The spit extends from the inlet northeast for 6 km until it joins Long Island proper at Halsey Neck. Beyond Halsey Neck, the shoreline runs past a series of low morainal ridges and shallow ponds. Two additional lines, SH1 and SH2, were added in Spring 1998.

[1] References cited in this appendix are located at the end of the main text.

Data Analysis

Profile data were provided by the New York District in two-dimensional (X-Z) or three-dimensional (X-Y-Z) form. Plots reproduced below were made with the Coastal Engineering Research Center's (CERC's) Beach Morphology and Analysis Package (BMAP) software.[2] Only the lines with multiple survey dates are presented below, organized from west to east.

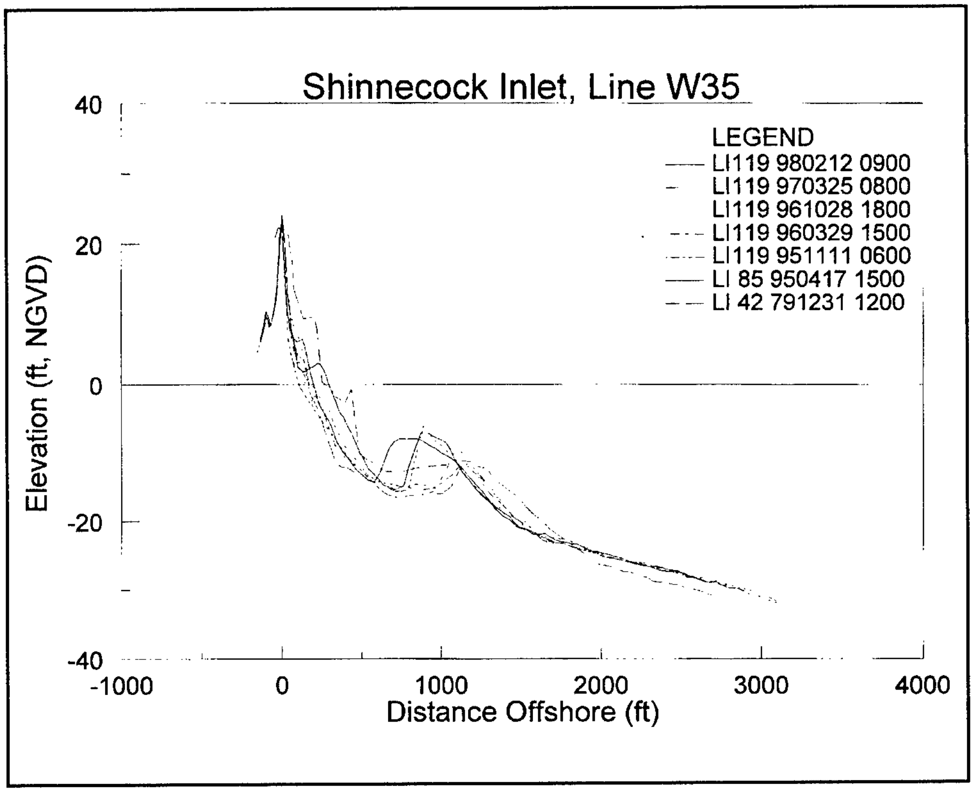


Figure C1. Profile line W35 (Profiles further west along Westhampton Beach resemble this line)

[1] BMAP software can be downloaded from the CERC web page.

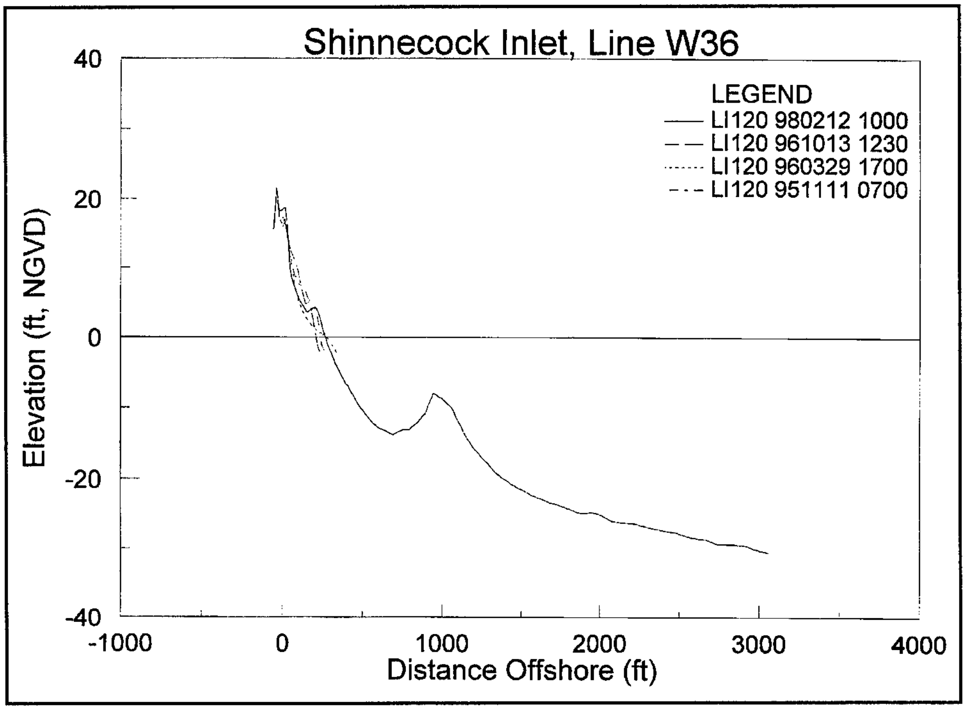


Figure C2. Profile line W36

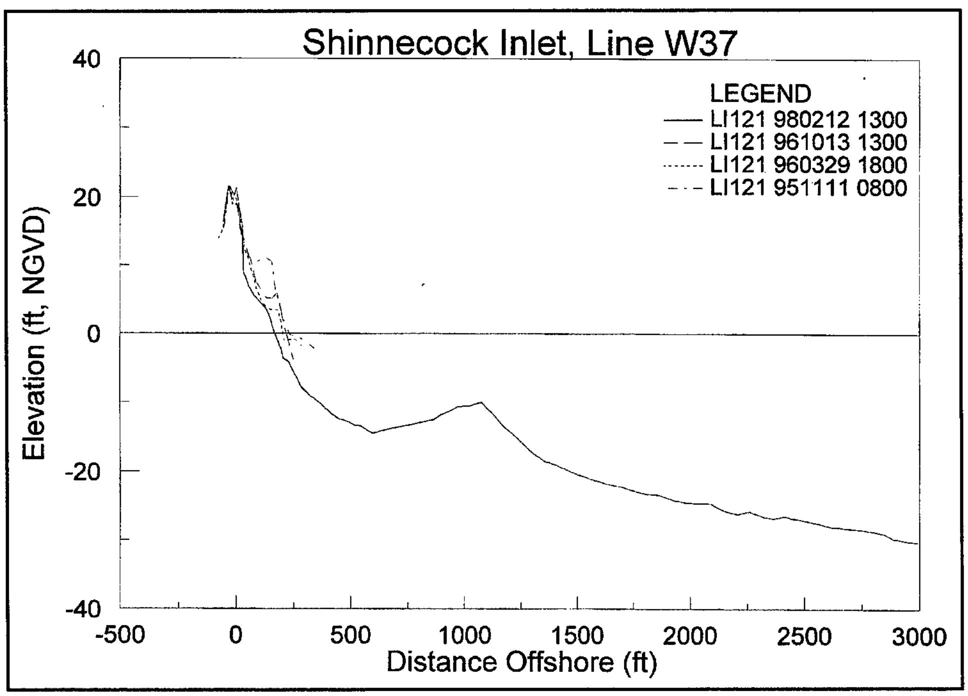


Figure C3. Profile line W37

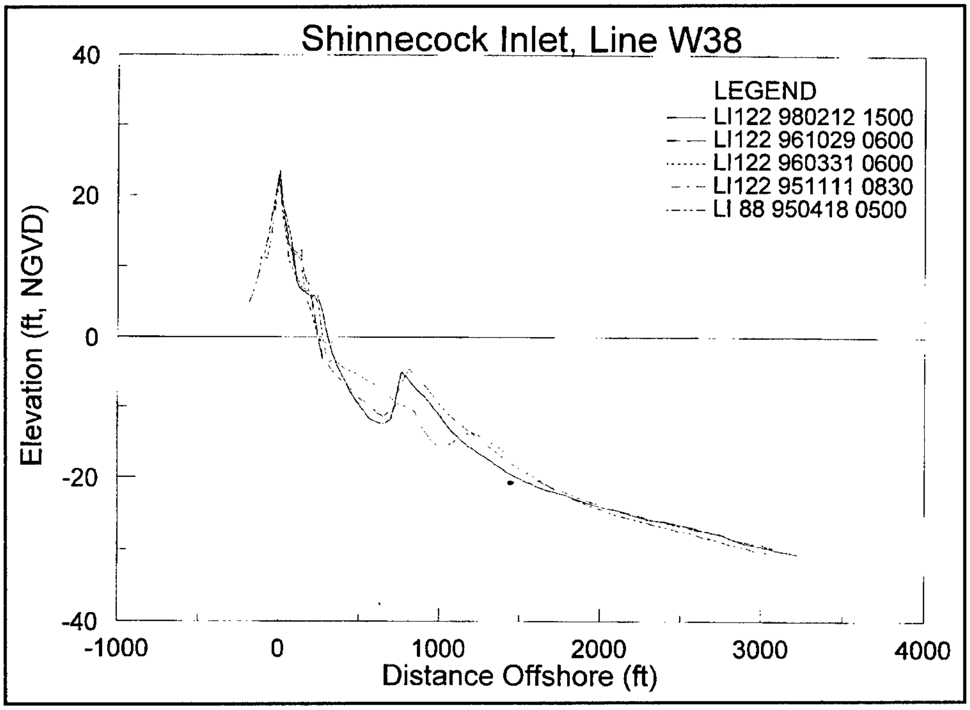


Figure C4. Profile line W38

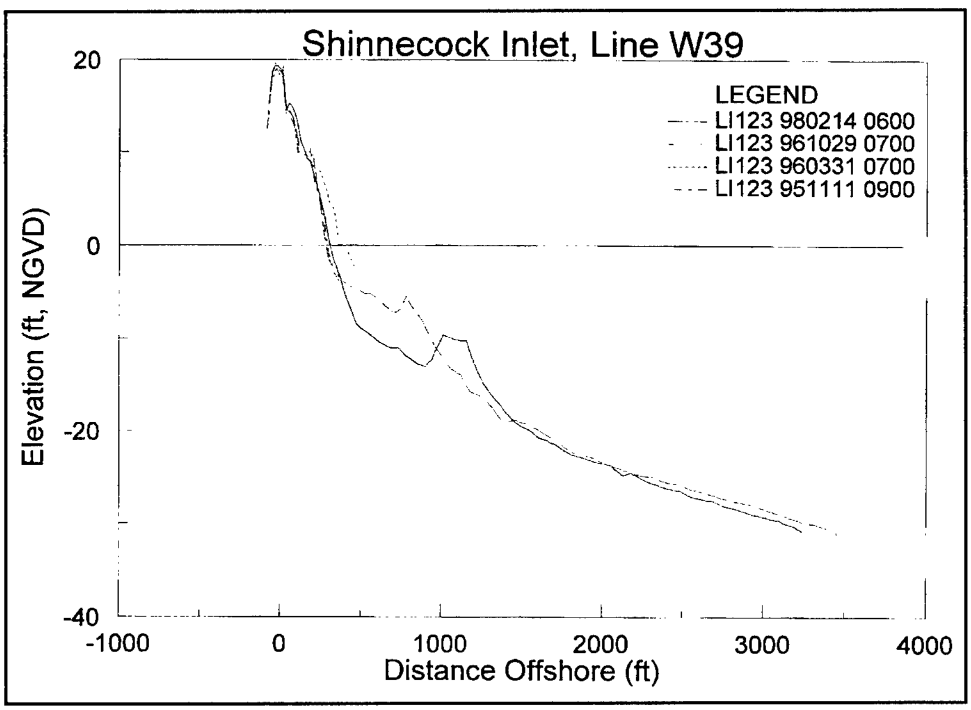


Figure C5. Profile line W39

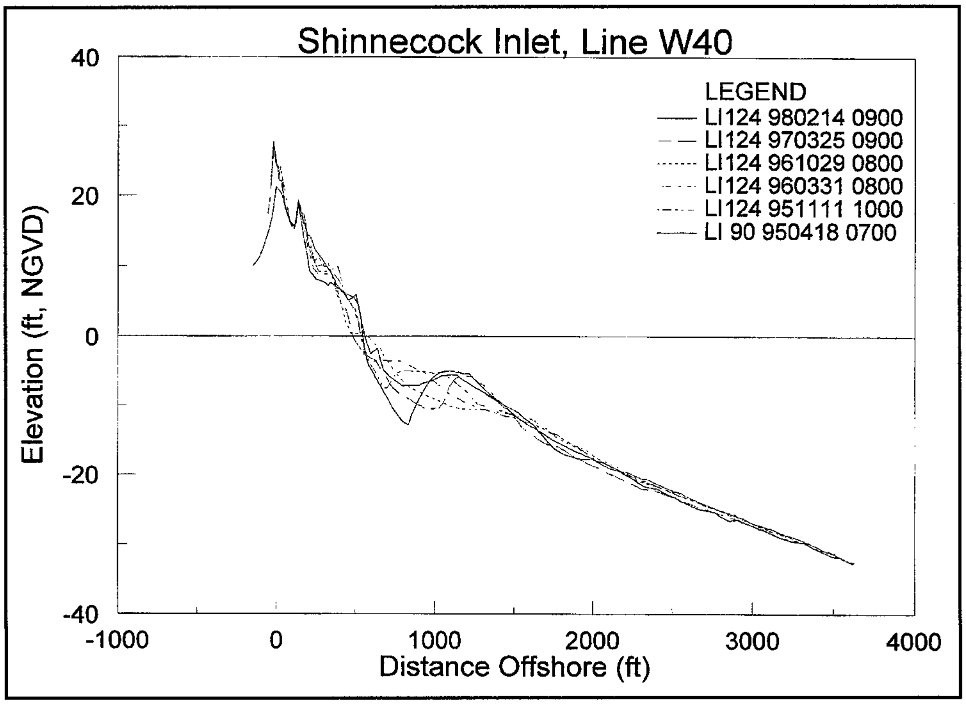


Figure C6. Profile line W40 (west edge of ebb shoal)

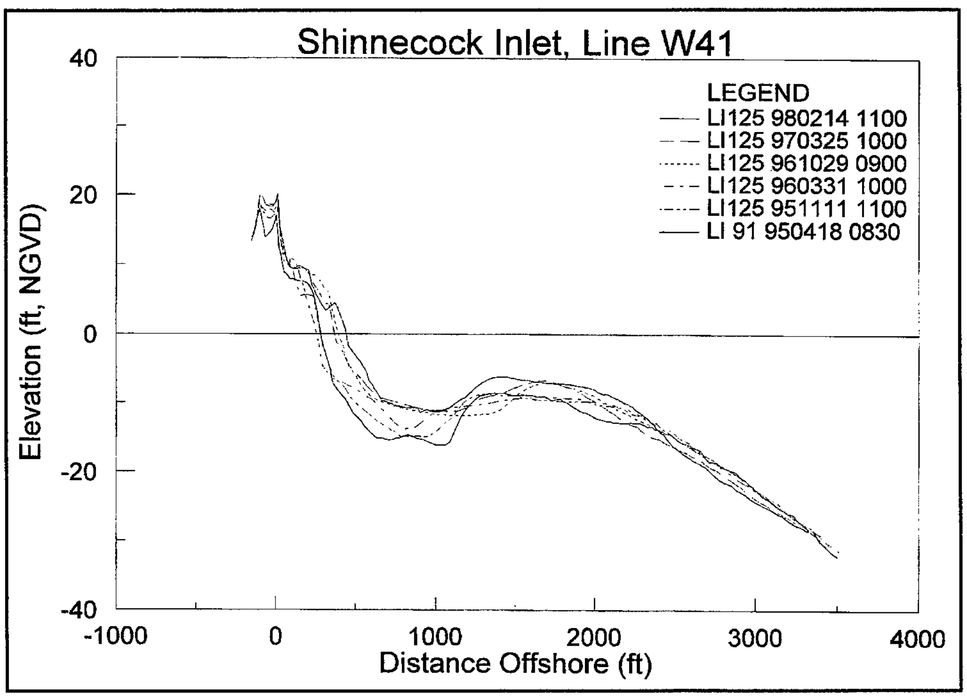


Figure C7. Profile line W41

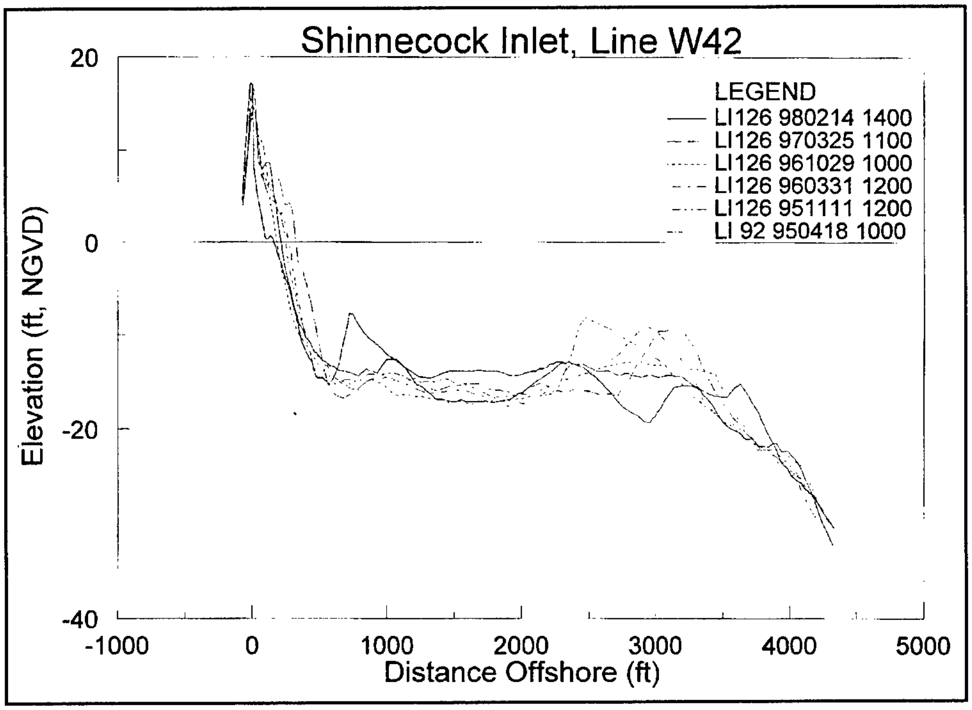


Figure C8. Profile line W42

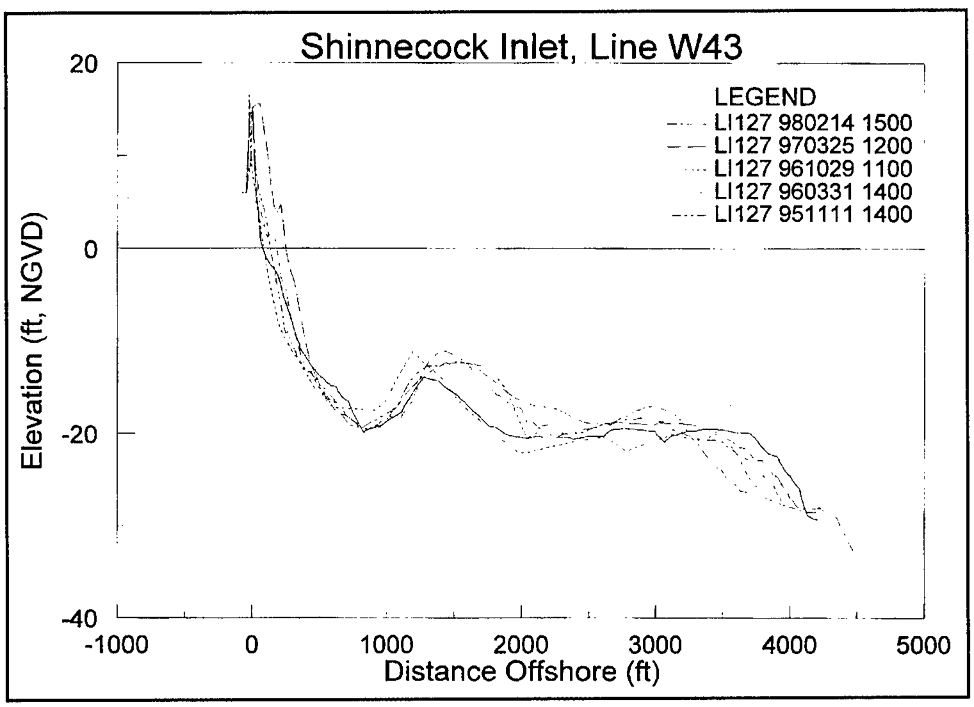


Figure C9. Profile line W43

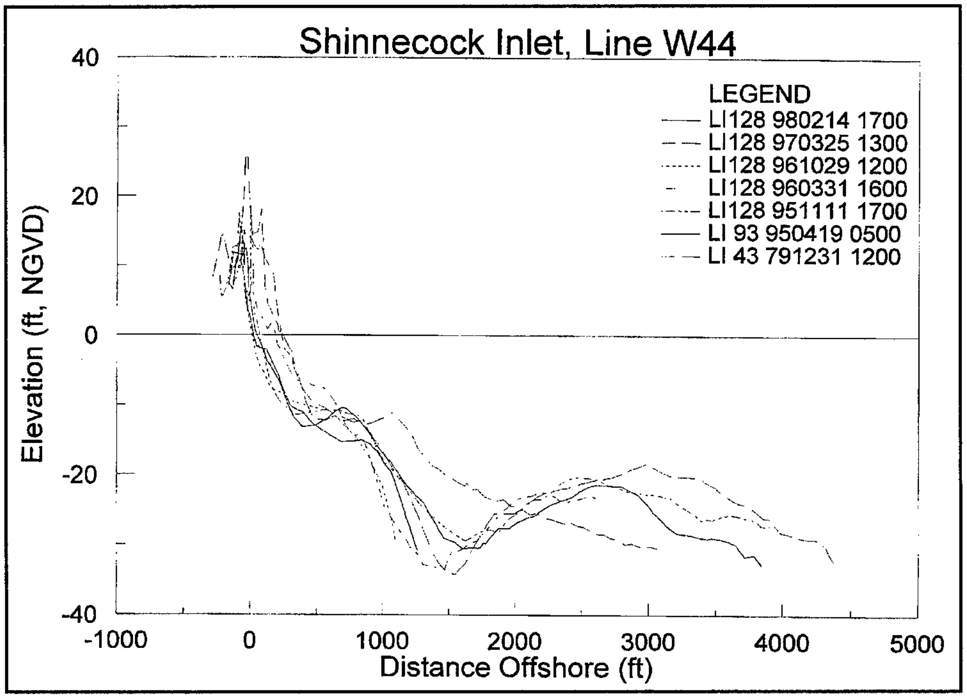


Figure C10. Profile line W44 (Easternmost line in the Westhampton Reach)

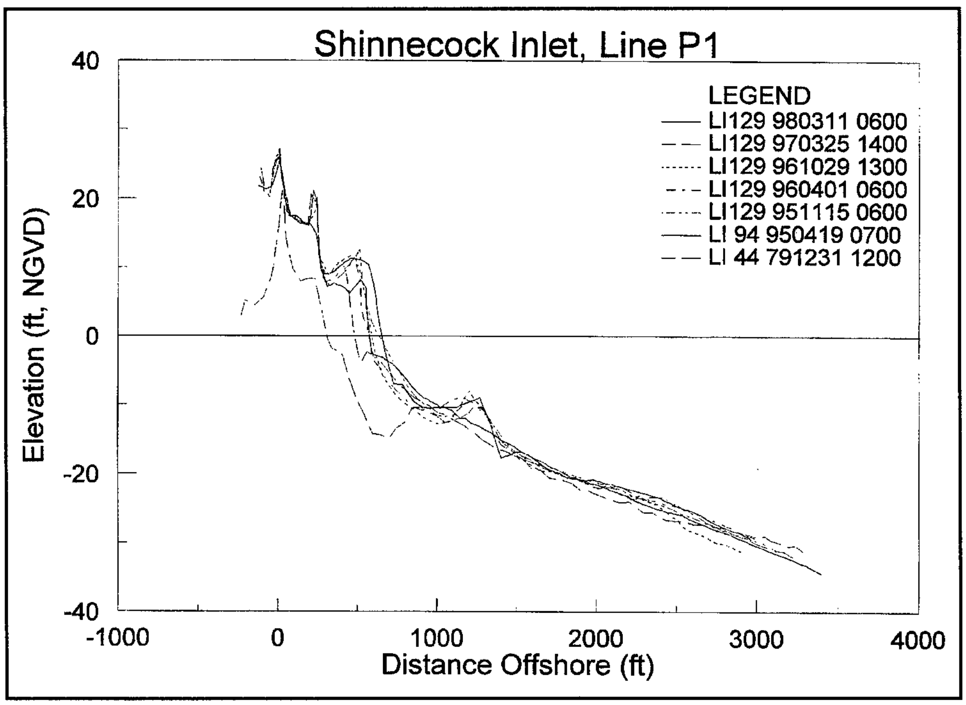


Figure C11. Profile line P1 (Westernmost line in Ponds Reach. Recent curves show shoreline advance compared with 1979)

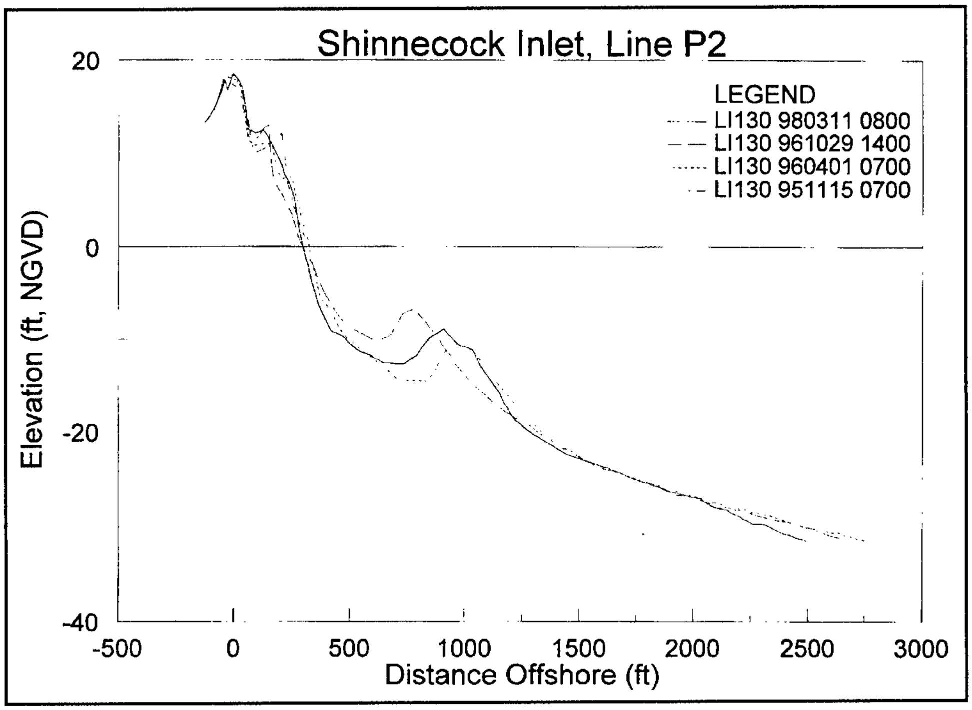


Figure C12. Profile line P2

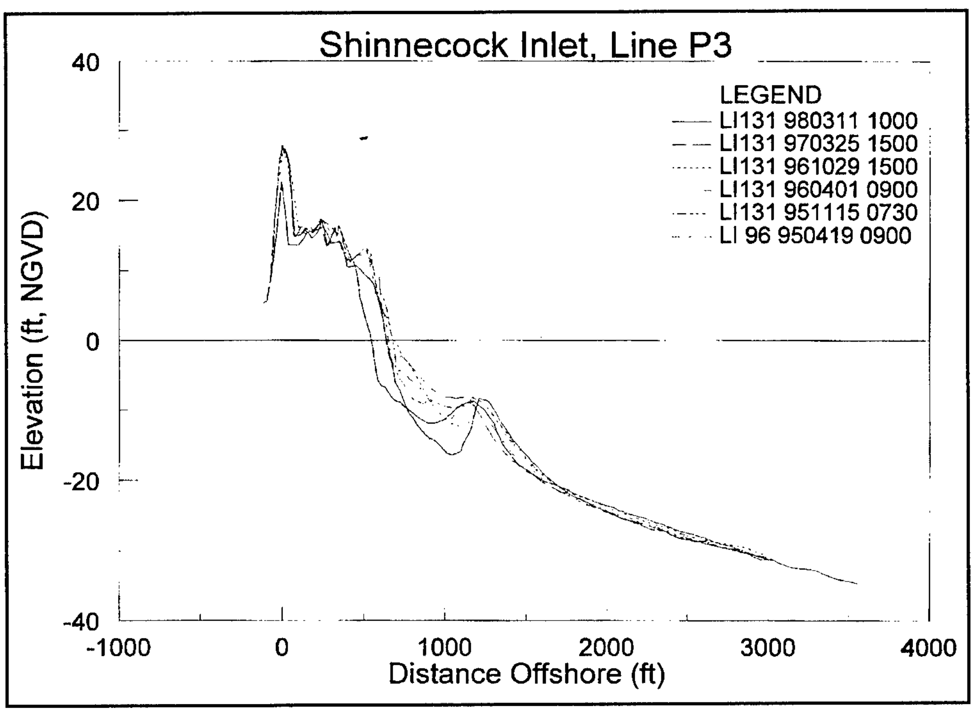


Figure C13. Profile line P3

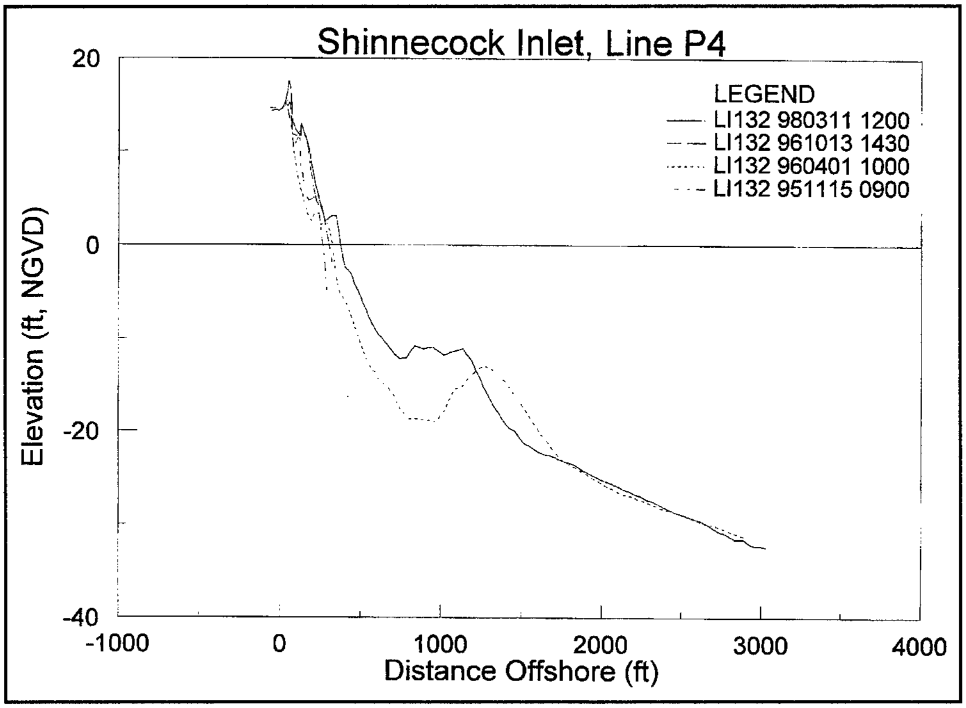


Figure C14. Profile line P4

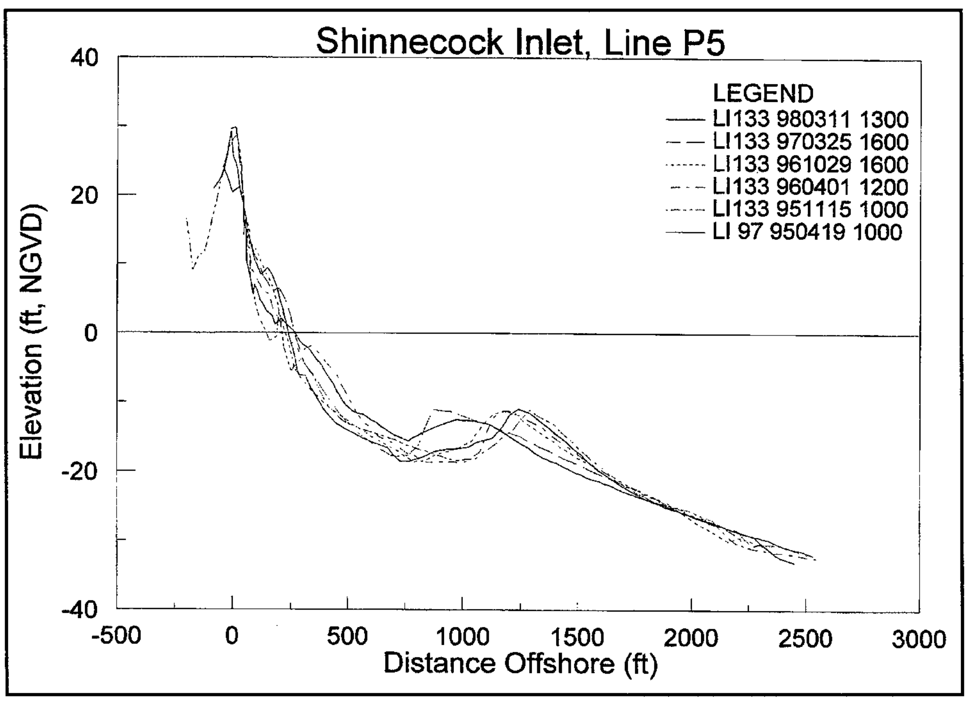


Figure C15. Profile line P5

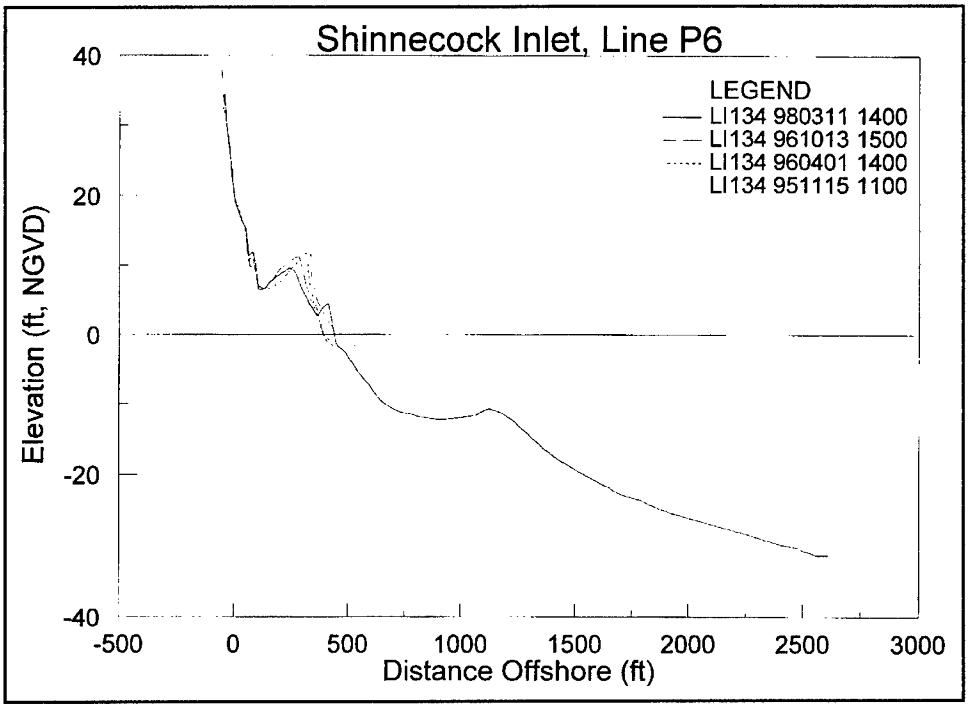


Figure C16. Profile line P6

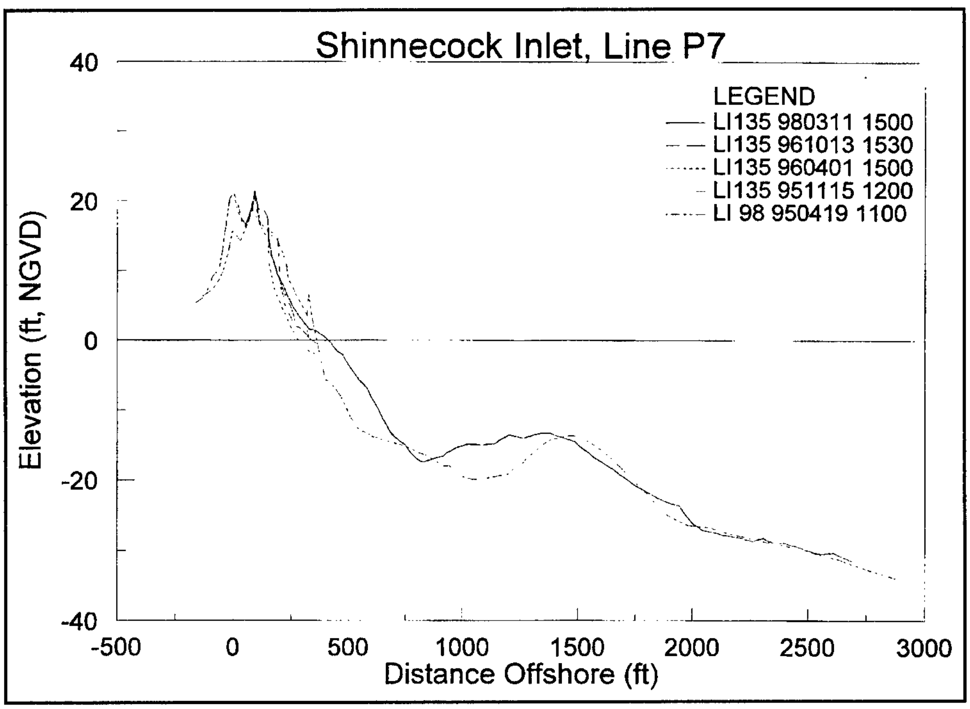


Figure C17. Profile line P7

Appendix D
Event and Activity Chronology

Table D1 lists engineering, natural, and cultural events that have occurred at or near Shinnecock Inlet. Early hurricanes are listed, although for most of them, no information is available describing their morphologic effects on Long Island beaches. There were few inhabitants on the south-shore beaches before the early 1900s; therefore, there are no first-hand accounts describing beach erosion and damage. Early newspaper accounts emphasized damage to boats and commercial structures in or near the towns where the papers were published. Data on beach fills are probably incomplete because many agencies have been involved over the decades and records have been lost. Some sources provide conflicting information. Readers who have additional information are encouraged to contact the author at the Coastal and Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS.

Table D1
Event and Activity Chronology, Shinnecock Inlet, New York

Date	Event [1]	Description	Source
15 Aug 1635	Hurricane	Effect on Long Island unknown. Much coastal flooding and property destruction in New England, as described in the *History of Plymouth Plantation, 1620-1647* by William Bradford and in the *Journal* by Governor John Winthrop.	Appendix G of U.S. Army Corps of Engineers (USACE) 1958a; Wood 1976
3 Aug 1638	Hurricane	Effect on Long Island unknown. Devastating effects in New England, as described in the *History of Plymouth Plantation, 1620-1647* by William Bradford and in the *Journal* by Governor John Winthrop.	Appendix G of USACE 1958a
29 Aug 1667	Storm (hurricane?)	Effect on Long Island unknown. Much flooding on Manhattan Island, as documented in *The Iconography of Manhattan Island* by J. N. Phelps Stokes. "Two small barkes ... were broken to pieces upon the Towne side, for want of good tackle. Much Tobacco and Salt damnified in Cellars."	Appendix G of USACE 1958a
22 May 1720	Storm	Effects on Long Island unknown. "A storm, described as the most terrible 'in the Memory of man' visits New York, destroying life and property." (From *The Iconography of Manhattan Island* by J. N. Phelps Stokes).	Appendix G of USACE 1958a
29 Jul 1723	Hurricane	Effects on Long Island unknown. The storm was probably a hurricane, causing much damage on Manhattan Island. "A north-east storm of wind and rain broke up the wharfs from one end of the City to the other, drove all Vessels ashore, except three, and broke three Sloops to pieces: the Tide higher than ever known here." (From *The Iconography of Manhattan Island* by J. N. Phelps Stokes).	Appendix G of USACE 1958a
30 Oct 1723	Hurricane	Effects on Long Island unknown. Much damage recorded in Rhode Island.	Appendix G of USACE 1958a
1755	Inlets	Seven inlets reported to be open east of Fire Island. Shinnecock Inlet probably open before 1755, according to Osborne (1970).	Leatherman and Joneja 1980
19 Aug 1788	Hurricane	Reported to be a "most terrifying storm." Probably a hurricane, it may have caused an opening in Moriches Bay. Much flooding in New York City. From the *Daily Advertiser* (20 August), "The ravages it committed on the battery were remarkable: - In the more exposed parts, the facing was torn away - and a considerable extent of solid stone work, seven feet in thickness, was totally demolished by the impetuosity of the sea."	Leatherman and Joneja 1980; USACE 1958a

(Sheet 1 of 12)

Note: References cited in this appendix are located at the end of the main text.

[1] Shinnecock Inlet dredging is listed when majority of dredged sand was placed on the beach or in the surf zone. Sand sources of locally funded renourishment often not specified; could be trucked from upland site, dredged from back bay, or dredged from offshore.

[2] Event log prepared by Research Planning Institute as part of 1981 south-shore sediment budget (Covell, Dow, and Kana 1981). Numerous permits are listed for dredging in Moriches and Shinnecock bays and possibly within the inlets, but no details available regarding actual dredge volumes or disposal.

[3] Engineering data sent by facsimile on 3/10/97 by Mr. William Lifford, Suffolk County Department of Public Works (courtesy Ms. Julie Rosati, WES) and notes acquired at Suffolk Co. offices by Andrew Morang, Nov. 1998.

[4] Engineering data sent by facsimile on 2/20/97 by Ms. Thelma Georgeson, Mayor, Village of Quogue, NY (courtesy Ms. Julie Rosati, WES).

[5] Hurricane category refers to the Saffir-Simpson scale from 1 to 5.

Table expanded from:

Morang, A., 1998. "Atlantic Coast of New York Monitoring Project, Report 1, Analysis of Beach Profiles, 1995-1996." Draft report prepared for U.S. Army Engineer District, New York, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table last updated: 17 March 1999

Table D1 (Continued)

Date	Event [1]	Description	Source
23-24 Dec 1811	Storm	"The greatest blizzard of all time" caused severe damage to barrier islands. The *History of Long Island* by Benjamin F. Thompson described it as, "Great Storm - On the night of the 23[D] December, 1811, commenced one of the most remarkable snowstorms and gales of wind ever experienced together, upon Long Island. It came from the north-east, and swept over Long Island with dreadful violence. An immense amount of property was destroyed, and many lives lost. ... It is supposed that more than sixty vessels were cast ashore upon the north side of Long Island."	Leatherman and Joneja 1980; USACE 1958a
22-23 Sep 1815	Hurricane	One of the most violent storms to strike Long Island, comparable with the 1938 hurricane. Flooding in the vicinity of Hook Pond equal to or greater than the 9- to 11-ft inundation in 1938. "The dunes were flattened along the coast and the shoreline was altered. Mecox Bay was filled with the sea so that it flowed backwards over the mill at Water Mill." (From *The Hurricane of 1938 on Eastern Long Island* by Clowes). Agustus Griffin, who kept a diary, wrote on 23 September, "After 11 A. M. Wind Shifted -- - S. W. and blew with uncommon violence, taking in its course in this and other places of 20 miles around, thousands of trees up by the roots ... It was one of the most Destructive Storms that the East end of Long Island ever felt - and perhaps many parts of Connecticut."	Clowes 1939; Appendix G of USACE 1958a
3 Sep 1821	Hurricane	As reported in the *New-York Spectator* of 7 September, "The tide on the Long Island shore was four inches higher than recollected by the oldest inhabitant; and much damage was done to mills and milldams, and some flour and grain were destroyed." 21 lives lost on boats that floundered.	Appendix G of USACE 1958a
1829	Inlet	Shinnecock Inlet shown open near the east end of the bay according to Osborne (1970)	Leatherman and Joneja 1980
1838	Barrier morphology	U.S. Coast and Geodetic Survey (USC&GS) chart T-58 shows mainland at Quogue connected to barrier by low marsh, suggesting no open waterway between Quontuck and Shinnecock bays. Bay shoreline is smooth along Tiana Beach, and the island is rather narrow compared with present configuration.	Leatherman and Joneja 1980
Pre-1854	Inlet	USC&GS chart shows Shinnecock Inlet open south of Rampasture, about 2.4 miles west of present location. Islands in this area now may represent former flood shoal. Closed by May 1889.	Leatherman and Joneja 1980
8 Sep 1869	Hurricane	The *Sag Harbor Express* reported this to be the most severe storm since 1815. Damage was greatest in the east, and at Napeague Harbor, many fishing vessels were destroyed. A three-masted schooner with a cargo of coal came ashore 8 miles west of Montauk Point. The severity of the gale only lasted from 20 to 25 min. Coney Island was nearly submerged, and the bathing houses swept into the bay.	Appendix G of USACE 1958a
18-19 Aug 1879	Hurricane or tropical storm	Much property and crop damage, trees uprooted. Many small boats damaged.	Appendix G of USACE 1958a

(Sheet 2 of 12)

Table D1 (Continued)

Date	Event [1]	Description	Source
3 Feb 1880	Storm	High surf along south shore. Damage to Concourse at Coney Island.	Appendix G of USACE 1958a
12 Mar 1888	Blizzard of '88	Blizzard of 1888 caused over 400 deaths, including 200 in New York City alone. Snowfall averaged 40-50 in. over southeastern New York State and southern New England, with drifts to 30-40 ft. Highest reported drift was 52 ft in Gravesend, NY. 80 mph wind gusts were reported, although the highest official report in New York City was 40 mph and 54 mph at Block Island. From Chesapeake Bay through the New England area, over 200 ships were either grounded or wrecked, resulting in the deaths of at least 100 seamen. Melting snow after the storm caused severe flooding, especially in Brooklyn, which it was susceptible to because of topography. Effects on Long Island beaches not reported.	Lott 1993
24 Aug 1893	Hurricane	*The Sun* on 25 August reported, "From all quarters of storm-swept Long Island come tales of havoc wrought by the gale. Forests were uprooted and stripped, houses blown down, highways turned into roaring rivers, and miles of farm land inundated and the crops destroyed." Southampton: 17 men lost on a tug. East Moriches: 45 yachts and fishing boats sunk. Babylon: waves washed over Fire Island, causing great damage along the shore for miles (beach erosion?). Great South Bay: 200 vessels sunk. The *New York Times* reported the storm was exceptionally severe at Coney Island, with waves sweeping 600 ft inland to a height of 30 ft, washing over the elevated train station. Hog Island, a popular resort off Rockaway Beach, was destroyed by the storm.	Appendix G of USACE 1958a; *New York Times* 18 March 1997
10 Oct 1894	Hurricane	Many boats destroyed. Landfall around Moriches.	Leatherman and Joneja 1980; Appendix G of USACE 1958a
1896	Peconic Canal tide gates	Automatic tide gates built at south end of Shinnecock and Peconic Canal to keep Shinnecock Bay water level high and prevent erosion of banks and growth and decay of vegetation.	Whitford 1906
1893-1933	Inlet closed	Osborne (1970) stated Shinnecock Inlet closed this period. 1889-1890 USC&GS charts provide evidence of different inlets into Shinnecock Bay, all of which closed by 1891. One of the former openings was opposite Shinnecock Neck. Another was slightly west of Ponquogue Point. Two others were east and west of Gull Island, opposite East Quogue. 1903 and 1904 U.S. Geological Survey (USGS) (Sag Harbor Quadrangle) showed no inlets into either Moriches or Shinnecock bays.	Leatherman and Joneja 1980
1896	Inlet cut	As part of the Shinnecock and Peconic Canal project, a channel 30 ft wide, 6 ft deep cut through the barrier island dunes with the purpose of increased flushing of Shinnecock Bay to relieve stagnant conditions. Local inhabitants donated services. Dunes said to be 20-30 ft high. "...It proved a failure, the waves quickly forming the dunes again, so that few traces of the channel now remain."	Whitford 1906
24-25 Oct 1897	Extratropical storm	The *New York Times* of 26 October reported, "A Terrific Northeaster....Buildings were undermined and destroyed, roads washed out, lowlands flooded, peninsulas made into islands and new inlets gouged out by the terrific bombardment of the high seas, and railroad traffic was interrupted."	Appendix G of USACE 1958a

(Sheet 3 of 12)

Table D1 (Continued)

Date	Event [1]	Description	Source
16 Sep 1903	Hurricane	Widespread flooding at Coney Island. Geologic effects or damage to south shore not recorded, but "the northeast winds driving extremely high tides in our bays and coves." (From the *Sag Harbor Express* of 15 October)	Leatherman and Joneja 1980; USACE 1958a
14-15 Sep 1904	Hurricane	Many trees destroyed, fishing boats driven ashore, and buildings at Bridgehampton damaged. Much of Coney Island flooded, with the surf rolling unbroken up Orient Boulevard as far as Neptune Avenue. Geologic effects along south shore not recorded.	Leatherman and Joneja 1980; USACE 1958a
4 Mar 1931	Storm (northeaster); Moriches Inlet breach	The *New York Times* of 5 March reported, "High Tide and Gale Lash Atlantic Seaboard; Long Island Homes Undermined by Raging Sea. .. A high tide, fostered by an offshore gale and a full moon tore away great sections of beachfront yesterday in Long Island." The gale reportedly led to reopening of Moriches Inlet. By 1933, inlet 1,300 ft wide. Original opening about 3,600 ft east of present inlet (see USACE 1958b, Plate A1). Migrated west until stabilized by revetment in 1947. Much flooding at Rockaway Beach, Jamaica Bay.	Leatherman and Joneja 1980; USACE 1958a,b
8-9 Sep 1934	Hurricane	Widespread wind damage, many boats washed ashore, but no reports of south shore geologic effects. Liner *Morro Castle* caught fire and abandoned off New Jersey, 134 deaths.	USACE 1958a
17 Nov 1935	Storm (northeaster)	Cottages destroyed at Southampton, some flooding.	USACE 1958a
1937	Long Island Intracoastal Waterway Federal Project	River and Harbor Act, approved 26 Aug 1937: 1. Channel from Great South Bay opposite Patchogue to south end of Shinnecock Canal, ≈33.6 miles x 100 x 6 ft (at mlw). Completed 1940. 2. Central basin to head of navigation in Patchogue R.: 100 x 8 ft.	USACE 1958b
21 Sep 1938	Great New England Hurricane - Shinnecock Inlet breach	Category 3.[5] One of the most devastating storms in New England history, resulting in 680-700 deaths. Caused massive washovers all along south shore of Long Island. Eye crossed over Moriches Bay. High water levels: 1. Moriches Bay: 15.7 ft above mlw recorded at Hart Cove. 2. Shinnecock Bay: 7.2 ft above mlw estimated at south end of Shinnecock canal. No ocean water levels were recorded, but computations indicate the water level was about 10 ft above msl. Lowest recorded barometric pressure was 27.94 in. Max. wind speed of 82 miles per hr. recorded on Block Island. Clowes (1939) described four inlets opening to Shinnecock Bay: 1. Near Warner's Islands, 0.5 miles east of Ponquogue Point, 40.5 miles east of Fire Island lighthouse. Closed 1938? 2. Opposite Cormorant Point, 41.6 miles east of lighthouse. By 1939, over 700 ft wide. Still open. 3. Opposite Shinnecock Hills, 43.3 miles east of lighthouse. Closed 1938? 4. Opposite Shinnecock Indian Reservation, 44.2 miles east of lighthouse. Closed 1938?	Allen 1976; Leatherman and Joneja 1980; Rappaport and Fernandez-Partagas 1995; USACE 1958a, 1958b

(Sheet 4 of 12)

Table D1 (Continued)

Date	Event [1]	Description	Source
1939	Shinnecock bulkhead construction	Suffolk County constructed 1,470-ft bulkhead on west side of inlet: timber piles, riprap, gabions, and 20 short spur jetties. Purpose: retard westward inlet migration. Construction underway by Feb 1939 as seen on aerial photos. Total cost about $80,000.	Nersesian and Bocamazo 1992; USACE 1958a, 1958b, 1971, 1988
1939	Dune rehabilitation	Suffolk County, with support from Works Progress Administration, undertook 68 miles of dune rehabilitation. Consisted of snow fencing, brush, and beach grass. Hydraulic fill placed for 4 miles in Westhampton and Southampton, but this method was discontinued because of high cost. Drag-lines, bulldozers, and cranes also used. As a result, 9 of 10 inlets opened by the 1938 hurricane were closed. Total cost about $1,000,000, incl. $250,000 financed by the WPA.	USACE 1958a
Sep 1940	Tidal prism	Prism of 375,000,000 ft^3 (10,600,000 m^3, 13,900,000 yd^3), with mean current velocity of 3.5 ft/sec. Measurement method or party conducting study unknown.	Memorandum for the Chief, Engineering Division by S. Gofseyeff, 5 Dec 1951 (New York District archives)
1941	Shinnecock Inlet morphology	Inlet widened to the east to about 1,000 ft, inner and outer bar formed, tortuous channel connected ocean to Shinnecock Bay. Controlling depth only 4 ft.	Nersesian and Bocamazo 1992
1941	Tidal prism	Prism of 330,000,000 ft^3 (9,300,000 m^3, 12,200,000 yd^3). Measurement method or party conducting study unknown.	Memorandum for the Chief, Engineering Division by S. Gofseyeff, 5 Dec 1951 (New York District archives)
1943	Bay dredging	Channel dredged by USACE from Shinnecock Bay to L. I. Intracoastal Waterway at request of U.S. Navy.	USACE 1958b
Sep. 14, 1944	Hurricane	Category 3. Caused 390 deaths in northeast U.S. (344 on ships at sea). Passed just east of Montauk Point. Effects of this storm not as severe as the 1938 hurricane, but still it "Ravaged barrier islands." Wind gusts up to 55 mph from northeast recorded at Fire Island. Ocean tide of 8.4 ft above msl at Jones Inlet approximately the time the predicted tide would have been at msl. In Moriches Bay at Westhampton Beach, tide reached 5.8 ft above msl, about 5 ft above predicted. Severely damaged dunes that had been repaired after the 1938 hurricane, and 25,000 ft of dunes were lowered. 63 sluiceways counted by Suffolk Co. officials.	Leatherman and Joneja 1980; Rappaport and Fernandez-Partagas 1995; Parkman 1978: USACE 1958b
1947	Shinnecock revetment repair	800-ft stone revetment on west side and 130-ft stone groin added to north end by N.Y. State, Suffolk County, and Town of Southampton.	USACE 1958b, 1971, 1988; RPI Event Log 1981[2]
1947	Dune repair	465,000 yd^3 hydraulic fill, beach grass, sand fence. Exact location not specified (Town of Southampton), but possibly in conjunction with revetment repair.	USACE 1958a
1948	West of Shinnecock placement	40,200 yd^3 dredged from commercial docks, placed on ocean beach west of inlet. Suffolk County.	Suffolk Co. Planning Department 1985

(Sheet 5 of 12)

Table D1 (Continued)			
Date	**Event** [1]	**Description**	**Source**
25 Nov 1950	Storm (northeaster)	Peak storm-tide elevations ≈3.5 ft at Swan R. at East Patchogue and at Connetquot R. near North Great River (both draining into Great South Bay). In N.Y. Harbor, tides higher than during 1938 and 1944 hurricanes. Ocean tide levels above msl: Jones Inlet: 9.4 ft Oak Beach: 9.1 ft Shinnecock Inlet: 5.1 ft Montauk Point: 5.2 ft Coast Guard reported 20-ft waves at Jones Inlet. Suffolk Co. authorities reported that all dunes having top elevations of less than 12 ft were breached. Three breaks (washovers) occurred east of Quogue, opening into Shinnecock Bay. A new inlet formed at Westhampton beach (closed using bulldozers). Revetment on west side of Shinnecock Inlet was damaged because of erosion.	Leatherman and Joneja 1980; Schubert and Busciolano 1994; USACE 1958a, 1995
Sep (?) 1951	Shinnecock Inlet dredging	110,500 yd^3. Channel 2,000 x 200 x 9 ft through "inner sand bar" (flood shoal?). Disposal on beach west of inlet. Suffolk County.	Dent 1951; Suffolk Co. Planning Department 1985; USACE 1958b, 1971
Nov 1951 - Mar 1952	Tiana beach placement	120,000 yd^3 hydraulic fill (source unknown). Grass planted. NY State?	RPI Event Log 1981 [2]
Jul 1952 - May 1954	Shinnecock jetties	N.Y. State, Suffolk County, and Town of Southampton built stone jetties on both sides of inlet: East jetty: 1,461 ft with 700-ft riprap revetment. West jetty: 846 ft (extended in 1954 to 946 ft). Width of inlet fixed at 800 ft. Cost of works: $1,264,390	USACE 1958a, 1958b, 1971, 1988; Nersesian and Bocamazo 1992; RPI Event Log 1981 [2]
6-7 Nov 1953	Storm	Storm center moved inland near New York City. Estimated wave heights about 20 ft along south shore. Coincidence of the storm passage with predicted high tide resulted in extremely high levels. Numerous homes in Fire Island area were damaged. From Fire Island Inlet to about 2½ miles east, the ocean broke through the barrier island into the bay at five locations. Two major breaks in the barrier near Smith Point caused inundation of Mastic Beach and heavy property damage. At Westhampton Beach, the ocean broke through the barrier in eight places. Between Democrat Point and Moriches, the dunes were cut back from 10 to 50 ft. Jetties at Moriches and Shinnecock inlets damaged. "A sand bar was formed approximately 500 feet offshore from Shinnecock Inlet, and the inlet shoaled to over half way across from west to east."	USACE 1958b (p. G-19)
31 Aug 1954	Hurricane Carol	Category 3. Crossed Long Island approx. at Moriches Bay. Wind gusts of up to 96 mph recorded at Westhampton Beach. Max. height of ocean tide 6.9 ft above msl at Jones Inlet and 6.6 ft at Oak Beach. Suffolk Co. Highway Dep. estimated the ocean tide to be 10.4 ft above msl at Shinnecock Inlet. Damage in eastern Long Island greater than in west: a. Shinnecock: Carol devastated east jetty and bayside revetment. Land adjacent to east jetty flooded by storm surge and dunes washed away. Revetment damage caused by ebb flow of surge from bay. West of inlet, large zone of overwash extended clear across barrier island. Ten breaks in dunes between Quogue and inlet. b. Westhampton Beach: two deep 1,000-ft breaches across barrier, 14 homes destroyed. c. Southampton: 26 washovers. d. Moriches: Damage to jetties also severe. Inlet shoaled and rendered impassible for navigation. The President of the United States designated Suffolk Co. as a major disaster area.	Nersesian and Bocamazo 1992; Rappaport and Fernandez-Partagas 1995; Parkman 1978; USACE 1958a

(Sheet 6 of 12)

Table D1 (Continued)

Date	Event [1]	Description	Source
11 Sep 1954	Hurricane Edna	Category 3. The eye of the storm passed between Nantucket and Martha's Vineyard, Massachusetts at 2:30 PM. Because Edna arrived at low tide, high storm tides did not form. Maine suffered the greatest storm damage and deaths.	USACE 1958b
13 Aug 1955	Hurricane Diane	Category 1. Diane caused little damage as it moved into the continent; but long after its winds subsided, it brought floods to Pennsylvania, New York, and New England that killed 200 persons and cost an estimated $700 million in damage.	USACE 1958b; NOAA web page *www.aoml.noaa. gov/general/lib/*
Dec 1956	Dune rehabilitation	Hydraulic dredge purchased by Suffolk Co. for use in dune rehabilitation and channel dredging. Dunes east of Shinnecock Inlet raised to elevation of 20 ft above msl for distance of 5,000 ft. 343,400 yd^3 placed at cost of $170,000.	Suffolk Co. Planning Department 1985; USACE 1958a
Nov - Dec 1958	Westhampton beach fill	380,000 yd^3 hydraulic fill (source unknown). NY State?	RPI Event Log 1981 [2]
12 Sep 1960	Hurricane Donna	Category 4 in Florida, downgraded to 2 at Long Island. The storm made landfall in eastern Long Island, New York. When it did this, the eye was reported to be 50 miles wide, with a central pressure of 28.55 in. and winds of 95 mph at Block Island, Rhode Island. Caused numerous washovers and extensive property damage. Peak gusts 97 mph at La Guardia airport. High water 8.4 ft NGVD at the Battery and 8.35 ft at the Battery. Donna's impact was reduced in New England mainly because she made landfall during low tide.	Leatherman and Joneja 1980; Parkman 1978; Rappaport and Fernandez-Partagas 1995; USACE 1995b
1960	Federal project adopted	Existing project at Shinnecock Inlet adopted by the River and Harbor Act of July 14, 1960 (House Document No. 126, 86th Congress, 1st Sesssion). "This provides for an entrance channel 10 feet deep and 200 feet wide, from that depth in the Atlantic Ocean to Shinnecock Bay, thence an inner channel, 6 feet deep and 100 feet wide to the Long Island Intracoastal Waterway, rehabilitation of existing jetties and revetments, seaward extension of the west jetty about 900 feet, and construction of a fixed by-passing facility to transfer sand from the east side of the inlet to the west side." Authorized for three project purposes: 1. Navigation 2. Water quality 3. Beach erosion Although adopted, no funds appropriated and no Federal work conducted.	Ann. Rept. of Chief of Engr. 1961; United States 1959
1961	Sediment budget	Beach Erosion Board study concluded 300,000 yd^3/year to west.	Taney 1961a
1961	Cost estimate	$3,551,000 estimate to complete work.	Ann. Rept. of Chief of Engr. 1962
6-8 March 1962	Ash Wednesday Storm	Responsible for over 75 breaks (washovers) between Fire Island Inlet and Southampton. The largest breach, about 400 m wide, was at Westhampton Beach. In the Moriches to Shinnecock Reach, large stretches of Dune Road and 46 houses were destroyed. Notable offset at Shinnecock Inlet: west side eroded, accretion along east side. President of the U.S. declared the south shore a disaster area eligible for Federal aid. Under authority of Public Law 875, 81st Congress, the USACE performed engineering and construction of emergency shore protection and rehabilitation. 2,210,000 yd^3 sand pumped onto beaches, mostly from back bays.	Leatherman and Joneja 1980; USACE 1963
1962	Tiana beach placement	134,700 yd^3 dredged from Tiana beach channel, placed on barrier and on beach. Suffolk Co. (approx. 4 km west of inlet)	Suffolk Co. Planning Department 1985

(Sheet 7 of 12)

Table D1 (Continued)			
Date	**Event** [1]	**Description**	**Source**
1964-1966	Westhampton groins	11 groins built by New York District along Westhampton Beach ≈10 km west of inlet	USACE 1988
1965	East Hampton groins	Two groins built by New York District at East Hampton (east of inlet). In addition, two smaller groins built by New York State.	USACE 1988
1968	Shinnecock Inlet dredging	270,300 yd^3. Disposal on beach west of inlet. Suffolk County.	Suffolk Co. Planning Department 1985
1969	Shinnecock Inlet dredging	113,000 yd^3. Disposal on beach west of inlet. Suffolk County.	Suffolk Co. Planning Department 1985
1969-1970	Westhampton groins	Four more groins built west of 11-groin field at Westhampton Beach by New York District.	USACE 1988
1972	Ponquogue dredging	14,000 yd^3 dredged from near Ponquogue Bridge, placed on barrier island. Suffolk Co.	Suffolk Co. Planning Department 1985
1973	Shinnecock Inlet dredging	250,900 yd^3. Disposal on beach west of inlet. Suffolk County.	Suffolk Co. Planning Department 1985
1973	West of Shinnecock fill	176,300 yd^3 dredged from commercial docks, placed on ocean beach west of inlet. Suffolk County.	Suffolk Co. Planning Department 1985
1975	Ponquogue dredging	103,500 yd^3 dredged from Intracoastal waterway near Ponquogue, placed on ocean beach. Suffolk County. (Work approx. 2½ km west of inlet)	Suffolk Co. Planning Department 1985
9-10 Aug 1976	Hurricane Belle	Peak storm-tide elevations ≈ 4.0 ft at Swan R. at East Patchogue.	Schubert and Busciolano 1994
1977	Ponquogue dredging	10,000 yd^3 dredged from near Ponquogue Bridge, placed on barrier island. Suffolk County.	Suffolk Co. Planning Department 1985
6-8 Feb 1978	Blizzard of '78	Northeaster deposited record amounts of snow and caused overwash and beach erosion along entire northeast United States. Because of shore orientation, Long Island was less severely affected than Massachusetts coast. Peak storm-tide elevations ≈ 3.5 ft at Swan R. at East Patchogue and at Connetquot R. near North Great River.	Schubert and Busciolano 1994
1983	Sediment budget	RPI study commissioned for Reformulation Plan: 367,000 yd^3/year enters control volume; 247,000 yd^3/year leaves; approx. 100,000 yd^3/year deposited on ebb shoal. (Note: RPI study considered unsatisfactory by New York District reviewers. Computations and conclusions have therefore not been used for planning or design.)	Research Planning Institute, 1983
1983	West revetment repair	Revetment near commercial docks repaired by Suffolk County Department of Public Works	Mr. Tom Rogers, Suffolk Co. Dep. of Public Works (Personal Communication, 1/15/99)
Feb-Mar 1983	West of Shinnecock placement	42,500 yd^3 predominately sand dredged from commercial docks, placed on beach west of inlet. Suffolk County.	Suffolk Co. Dep. Pub. Works[3]
			(Sheet 8 of 12)

Table D1 (Continued)			
Date	Event[1]	Description	Source
1984	Shinnecock Inlet Dredging	*Currituck* removed 176,000 yd^3 emergency dredging from various locations in inlet to -14 ft mlw. Disposal west of inlet at -10 ft mlw.	Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication, 11/13/95)
28-30 Mar 1984	Northeaster	Near-hurricane winds caused storm tides 5-6 ft above normal, with max. tide 7.1 ft NGVD at Sandy Hook.	Moffatt & Nichol 1996
27 Sep 1985	Hurricane Gloria	Category 3. Peak storm-tide elevations >4 ft at Swan R. at East Patchogue and at Connetquot R. near North Great River. Overall damage less than expected.	Schubert and Busciolano 1994; USACE 1995b
1988	Tiana Cove (Bay?) placement	22,000 yd^3 predominately mud	Suffolk Co. Dep. Pub. Works[3]
1988	Shinnecock Inlet deposition basin	Revised project design called for the navigation channel to be enveloped by a deposition basin 2,700 × 800 ft, to be dredged to -20 ft mlw.	USACE 1988
Dec 1988 - Jan 1989	West of Shinnecock placement	83,200 yd^3, 100 percent sand (hopper barge in surf zone), emergency work by Suffolk County.	Suffolk Co. Dep. Pub. Works[3]
1990	Quogue dune restoration	1,600 yd^3 coarse fill from upland source placed along 855 ft of dune. Most lost in 1991-'92 storms.	Village of Quogue[4]
1990	West of Shinnecock placement	106,000 yd^3 (details unknown, probably non-Federal). NOTE: may be same dredge material disposal as listed below - records conflicting.	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
7 Jun 1990	Cost-share agreement, navigation project improvements	Local Cooperation Agreement executed with New York State Dep. of Environmental Conservation. Cost allocation 69 percent Federal and 31 percent non-Federal.	Report of the Sec. of the Army on Civil Works Activities for FY 1990
1-23 Oct 1990	Shinnecock Inlet dredging	668,000 yd^3 dredged from deposition basin (ebb shoal). Disposal: 1. 138,000 yd^3 west of west jetty. 2. 77,000 yd^3 to fill scour hole by west jetty (channel side). 3. 193,000 yd^3 stockpiled on east side of inlet to use as fill behind revetment. 4. 260,000 yd^3 at Ponquogue Beach. Sand placed in scour hole lost within 1 year.	Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication, 11/13/95)
1990 - 1993	Shinnecock Inlet deposition basin	Basin anticipated to fill with ≈ 425,000 yd^3 in 18 months. Unexpected result: less infilling than expected. From 1990-1993, <200,000 yd^3 was found in area, but not in prescribed basin.	Ms. Lynn Bocamazo, New York District (Personal Communication, 12/10/97)
19 Aug 1991	Hurricane Bob	Category 2. Eye passed 25 miles east of Montauk Point. Max. sustained winds 115 mph. Worst impact in eastern Long Island, but damage limited because storm passage coincided with low tide.	Schubert and Busciolano 1994; USACE 1995b
			(Sheet 9 of 12)

Table D1 (Continued)			
Date	**Event** [1]	**Description**	**Source**
30-31 Oct 1991	Halloween Northeaster	Incl. 3, possibly 4 high tides. Extensive beach erosion and overwash along mid-Atlantic seaboard. Peak storm-tide elevations: 4.63 ft NGVD at Swan R. at East Patchogue; 4.7 ft at Connetquot R. near North Great River	Schubert and Busciolano 1994
10 Dec 1991	Cost-share agreement, jetty reconstruction	Local Cooperation Agreement executed with New York State Dep. of Environmental Conservation.	Report of the Sec. of the Army on Civil Works Activities for FY 1992
11-14 Dec 1992	Northeastern	Intense storm affected mid-Atlantic and northeast coast of United States, producing gale-force winds and gusts over hurricane strength. Caused extensive coastal flooding and beach erosion all along New Jersey and New York. Breached Westhampton Beach at two locations (Pikes Inlets), which later had to be artificially closed by USACE. Peak storm-tide elevations (11-12 Dec): 4.23 ft NGVD at Swan R. at East Patchogue; 4.0 ft at Connetquot R. near North Great River; 7.96 ft at the Battery.	Schubert and Busciolano 1994; USACE 1995b
1992	West of Shinnecock placement	12,000 yd^3 (details unknown, non-Federal).	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
1992	Pikes Beach placement	53,000 yd^3 - source: Intracoastal waterway	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
1992	Ponquogue placement	8,000 yd^3 (details unknown, probably non-Federal).	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
21 May 1992 - Nov 1994	Jetty repair	Rehabilitation of jetties, including rebuilding east and west tips to bring jetties back to original, pre-Federal length. New underlayer and bedding stone added to some areas along with new facing stone.	Report of the Sec. of the Army on Civil Works Activities for FY 1992; 1995
1992-1994	Tidal prism	Field studies conducted by Coastal Engineering Research Center using acoustic Doppler current profilers. Prism based on flooding phase of tide: 21-23 July 1992: 24,300,000 m^3 (31,800,000 yd^3) 15 Sep 1993: 38,600,000 m^3 (50,500,000 yd^3) 20-21 July 1994: 33,200,000 m^3 (43,400,000 yd^3)	Memorandum for Record, 28 June 1995
12-14 Mar 1993	Storm (now called *Storm of the Century*)	Massive storm affected 26 eastern States and about 50 percent of the Nation's population. Passed almost directly over New York City, dropping 10-20 in. snow. Widespread coastal flooding. Total death toll in U.S. over 270. From Chesapeake Bay through New England, over 200 ships were either grounded or wrecked, resulting in the deaths of at least 100 seamen. On the Saffir-Simpson scale for hurricane strength, it equated to a Category 3 hurricane based on storm surge and minimum pressure. At least 18 homes fell into the sea on Long Island because of the pounding surf, and the storm caused further erosion of south-shore beaches, which had been weakened by the Dec. 1992 northeaster.	Kana 1995; USACE 1995; Lott 1993

(Sheet 10 of 12)

Table D1 (Continued)

Date	Event [1]	Description	Source
1993	Quogue dune restoration	Restoration after 1992 northeaster: 1,000 yd^3 fill from upland source placed along 150 ft of dune. Snow fences installed. 600 yd^3 fill from upland source placed along 100 ft of dune. Planted with grass.	Village of Quogue[4]
1993	West of Shinnecock placement	284,000 yd^3 (details unknown, probably non-Federal). NOTE: may be same fill as listed below.	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
29 Jan - 14 May 1993	Shinnecock Inlet dredging	475,000 yd^3 dredged from deposition basin (ebb shoal). Contract 92C0032. Disposal: 1. 371,000 yd^3 west of west jetty 2. 104,000 yd^3 to fill scour hole	Project notes, Construction Div., New York District (Mr. Don Braun, Personal Communication. 11/13/95)
Mar 1993	Dune Road repair	Stone placed parallel to road. Beach filled between road and stone row.	Mr. Bill Daley, NY State Dep. Environmental Conservation, (Personal Communication, 12/10/97)
Sep 95	Dune Road repair	1,359 yd^3 placed by NY State	Mr. Mohabir Persaud, NY State Dep. of State (Personal Communication, 9/3/96)
Nov 95	Dune Road repair	1,435 yd^3 placed by NY State	Mr. Mohabir Persaud, NY State Dep. of State (Personal Communication, 9/3/96)
1996	Quogue dune restoration	1,500 yd^3 coarse fill from upland source placed along 91 ft of dune.	Village of Quogue[4]
5-14 Jul 1996	Hurricane Bertha	Landfall near Wilmington, NC, $270 million in damage. Some erosion but no damage reported on Long Island	Ms. Diane Rahoy, New York District (Personal Communication, 12/28/98)
5-6 Sep 1996	Hurricane Fran	Little damage reported on Long Island	
Oct 1996	Dune Road repair	Northeaster caused erosion west of Shinnecock west jetty. State of NY repaired Dune Road with 14-16,000 yd^3 trucked sand.	Mr. Bill Daley, NY State Dep. Environmental Conservation (Personal Communication, 12/10/97)

(Sheet 11 of 12)

Table D1 (Concluded)			
Date	**Event** [1]	**Description**	**Source**
Nov 1996	Cores	Five cores (1 40-ft and 4 20-ft cores) taken at -6 m depth offshore of updrift fillet. Some clay layers detected. Proposed Punaise dredging tests cancelled.	Alpine Ocean Surveys, Inc., NY State Dep. of State
1997	Westhampton Beach fill	3,808,000 yd^3 - Westhampton Interim project. Dredged from offshore.	New York District project notes (Ms. Christina Rasmussen, Personal Communication, 1997)
Feb-Mar 1997	Channel dredging	250,000 yd^3 placed west of west jetty. Material dredged from eastern flood shoal channel.	NY State Dep. of Environmental Conservation (Mr. Bill Daley, Personal Communication, 12/10/97)
27 Jun - 11 Jul 1998	Shinnecock Inlet dredging	Phase 1: Government dredge *Currituck* removed 35,000 yd^3 from entrance channel and deposition basin from above -14 ft contour. Placed in surf zone of west beach starting 500 ft and ending 1,800 ft from west jetty.	Project notes, Construction Div., New York District (Adam Devenyi, Personal Communication, 08/09/98)
13-25 Sep 1998	Shinnecock Inlet dredging	Phase 2: Weeks Marine dredge *Beach Builder* removed 405,000 yd^3 from entrance channel and deposition basin from above -22 ft contour. Material specified to be placed on west beach between west jetty and 3,500 ft west, forming a berm 225 ft wide and 9.5 ft high. Berm to be built between dune line and water. (Note: more sand may have been removed than originally planned, and final berm may have been wider than 225 ft.)	Project notes, Construction Div., New York District (Mr. Adam Devenyi, Personal Communication, 10/05/98)
			(Sheet 12 of 12)

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Appendix F Adjustment of 1933 Hydrographic Data to Modern Datum

Adjustment for Sea-Level Rise

Battery, (Manhattan) sea-level trend (from National Oceanic and Atmospheric Administration Internet site):
2.72 mm/year = 0.107 in./year = 0.0089 ft/year

Time interval: 1998 - 1933 = 65 years

Adjustment: 2.72 mm/year × 65 years = 177 mm = 0.177 m = 0.58 ft

Note: Water now is 0.177 m *higher* than in 1933; *add* 0.177 m (0.58 ft) to water depths (i.e., if in 1933, a sounding point was -10.0 ft, it now would be -10.58 ft assuming no changes in seabed) - see Figure E1a.

Datum

At Shinnecock: mlw to National Geodetic Vertical Datum (NGVD) (1929 adj.): 1.10 ft

Note: NGVD is 0.335 m (1.10 ft) *higher* than mlw; *add* 0.335 m (1.10 ft) to water depths (Figure E1b).

Total Correction

0.177 + 0.335 = **0.512 m**
0.58 + 1.10 = **1.68 ft** (Figure E1c)

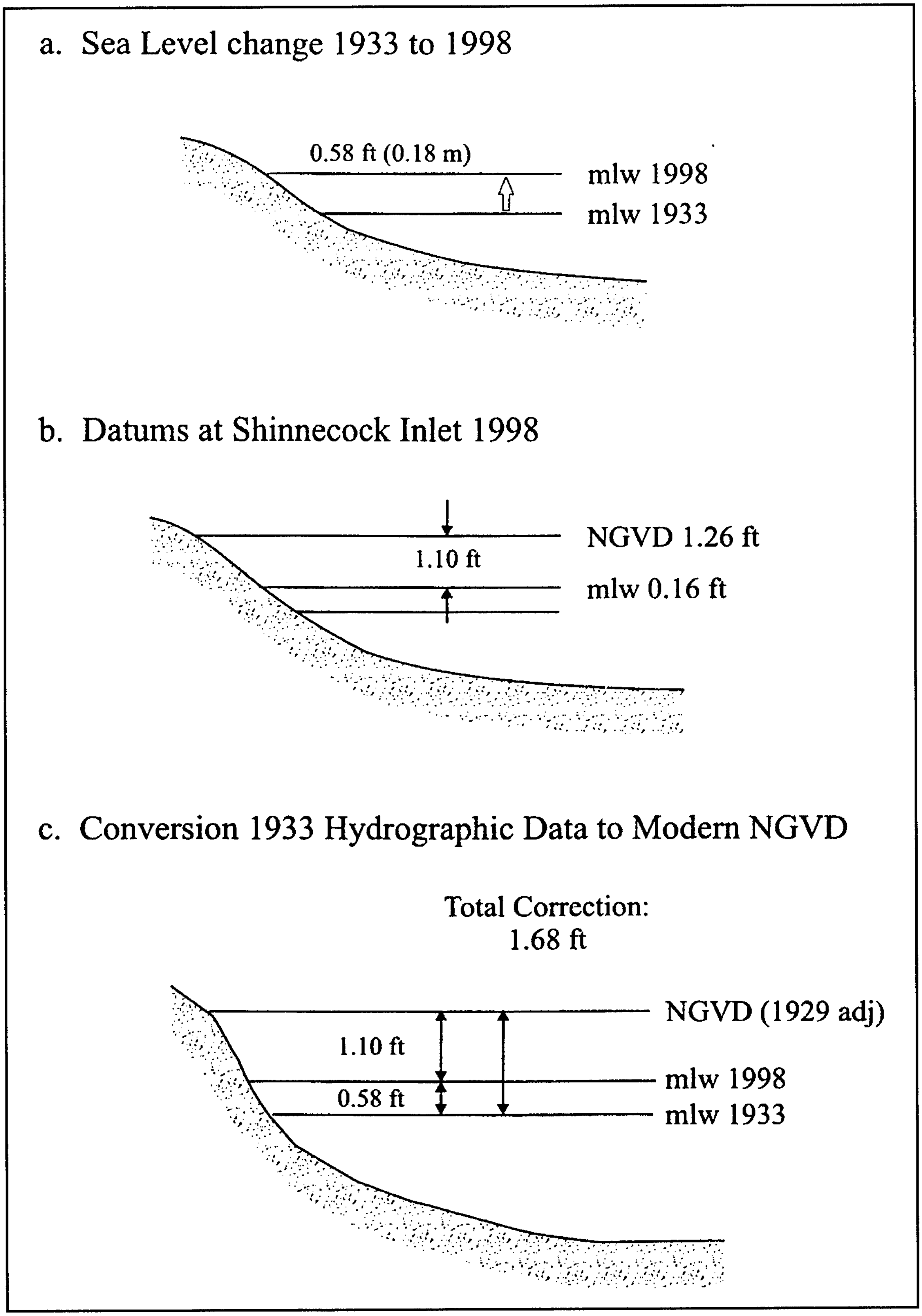

Figure F1. Conversion of 1933 hydrographic data to NGVD at Shinnecock Inlet

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13. ABSTRACT *(Maximum 200 words)*

Shinnecock Inlet is the easternmost of six permanent inlets in the barrier island chain that follows Long Island's south shore. Shinnecock Inlet is located in eastern Long Island in Suffolk County, near the town of Southampton, and connects the Atlantic Ocean to Shinnecock Bay. The inlet was formed during the Great New England Hurricane of 21 September 1938, when high waves and a storm surge overwashed the barrier.

The morphologic history of the inlet can be divided into three phases: (a) 1938 to 1939 - breach and natural inlet; (b) 1939 to 1951 - inlet stabilized on the west wide only with a stone and timber revetment; (c) 1952 to present - inlet stabilized in its present location with stone jetties. Since 1939, an oval-shaped ebb shoal has grown out into the Atlantic Ocean. The total volume of sand that accumulated in the shoal between 1938 and 1998 was 8,453,000 yd^3, representing an average growth rate of 141,000 yd^3/year. In contrast, the flood shoal has lost sand since 1938, largely as a result of dredging the navigation channels in the back bay. After the jetties were built in 1952, the thalweg has been stable. The minimum cross section, 1,6000 m^2 (17,000 ft^2), occurs about 150 m north of the tip of the east jetty.

14. SUBJECT TERMS

Aerial photographs
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Flood shoal
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