CHAPTER 85

Federal Jetty and Sand Dike at the Entrance to Fire Island Inlet, New York

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ABSTRACT

Prior to construction at Fire Island Inlet, Fire Island was moving westward at more than 200 feet per year, the north shore of the inlet was eroding severely, and navigation in the inlet was difficult. The Federal Jetty, completed in 1941, and the sand dike, built in 1959, have halted the westward migration, eliminated the severe erosion, and partially improved navigation, with minimal maintenance or repair to the structures. There has been a large net accretion of sand east of the jetty and west of the dike, an unknown part of which is at the expense of shores to the west of the inlet. At the State Park on the south side of the inlet interior, erosion accelerated, probably because of the dike.

The middle and ocean segments of the 4750-foot Federal Jetty are now (1987) in good condition, although the design implies a stability coefficient for the quarrystone jetty head at time of construction that would now be considered risky. Stability has been promoted by a stone blanket under and east of the jetty, a thick stone apron seaward of the jetty, a low (8 feet MLW) crest, and armor stone that has been partially keyed in place. Damage due to scour, common at other single-jetty inlets, is absent here because longshore transport, which easily overtops the low crest, keeps the inlet channel away from the jetty. Although the two seaward segments of the jetty remain in good condition, the inshore segment of the jetty is in poor condition, despite its apparently sheltered location. The cumulative effects of waves, possibly channeled to the site along recurved spits during storms, have damaged 1200 feet, and tidal scour has destroyed about 230 feet. The damaged segment has a design cross section which is one-fifth and one-twelfth the cross sections of the jetty trunk and head.

The dike was constructed with sand dredged from the inlet, and its seaward shore was later armored by dumped riprap. The dike moved the tidal channel away from the north shore, shifted the ocean entrance of the inlet eastward (against the direction of longshore transport), and shortened the distance to the ocean.

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INTRODUCTION

Background. Fire Island Inlet is a large permanent tidal inlet on the south shore of Long Island, New York, which connects Great South Bay with the Atlantic Ocean through an unusually long, shore-parallel channel (Figure 1). The entrance to the inlet is the site of two large coastal structures: the Federal Jetty constructed in 1939-1941 and the sand dike, known locally as The Thumb, constructed in 1959. Saville (1960) reviewed the history of these structures up to that time, based on personal experience. See also Gofseyeff (1953). An excellent recent view of both structures is the cover photo of the July 1986 issue of Shore & Beach, taken immediately after Hurricane Gloria made landfall in the vicinity (Terchunian, 1986).

The jetty fixed the position of the western end of Fire Island after that island had moved westward at a rate in excess of 200 feet per year for more than a century. The sand dike has alleviated severe tidal scour along the residential shore of the community of Oak Beach. Together, these structures have forced the inlet entrance into a relatively stable position. Neither structure has had major maintenance, despite the relatively exposed site. Perhaps because they have functioned well and almost without maintenance, these structures are not well known, either to the general public or to the coastal engineering profession.

Purpose. This paper identifies features in the design of the Federal Jetty and the sand dike that have made them functionally and structurally useful over a relatively long time. This knowledge is used to derive lessons which may be applied to coastal engineering projects elsewhere. Conclusions are based on historical information at the New York District, Army Corps of Engineers, and a knowledge of local coastal processes and existing conditions (Galvin, 1985).

Location. The south shore of Long Island, New York, is the northern part of the mid-Atlantic states in the United States. Long Island measures approximately 120 miles (192 km) from the entrance to New York Harbor on the west to Montauk Point on the east. Fire Island Inlet is at the western third of this shore, approximately 36 miles (58 km) east of the entrance to New York Harbor.

Units. Design data are taken from contract documents which use customary English units. Distances are in feet (1 foot = 0.305 meters) and rock weights are in pounds and (short) tons (1 pound = 2.2 kilograms; 1 ton = 0.907 metric tonnes). Locations are identified by surveyor's stations along the jetty centerline, so that Station 33+10, for instance, is 3310 feet measured along the curved jetty centerline from the inlet end of the jetty.

FEDERAL JETTY

Background. Construction of the Federal Jetty was a Depression-era project. The authorized jetty has the stated purpose of checking the westward littoral drift of sand and providing a greatly improved

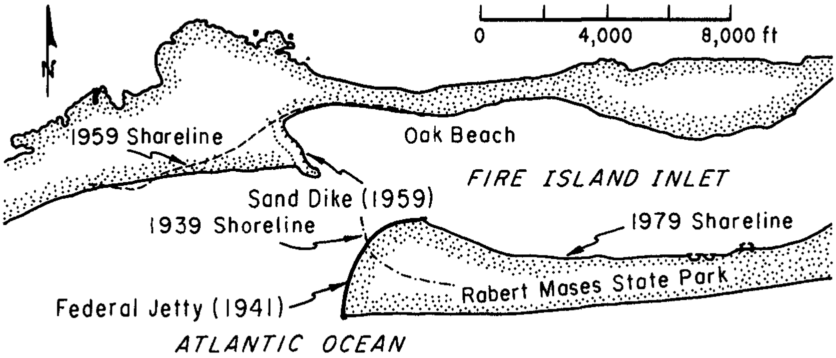

Figure 1. LOCATION OF FEDERAL JETTY AND SAND DIKE AT FIRE ISLAND INLET

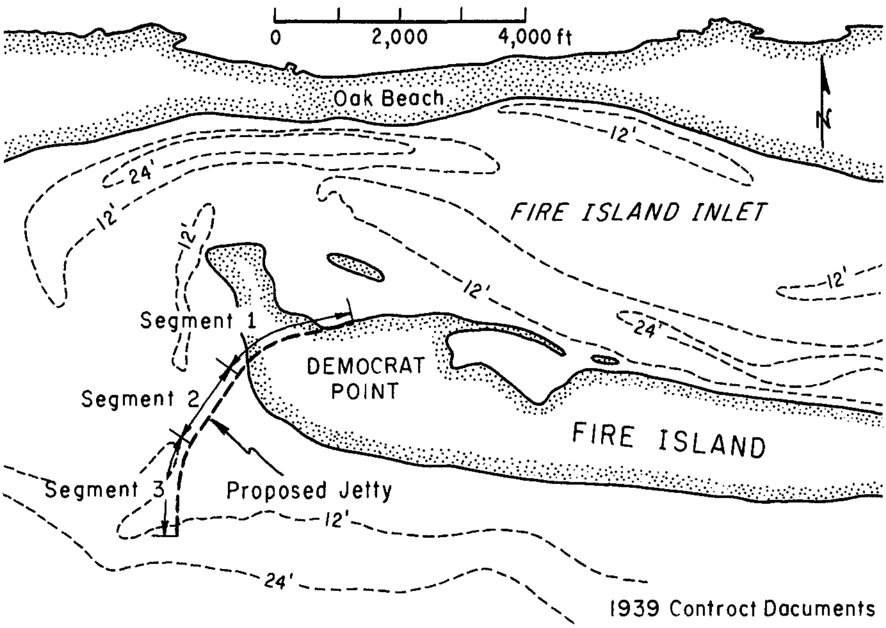

Figure 2. PLAN OF FEDERAL JETTY WITH 1939 SHORELINE AND BATHYMETRY

navigation channel (House Document 33, 75th Congress, 1st Session, Chief of Engineers to Chairman, Committee on Rivers and Harbors, paragraph 4, 13 May 1937). Apparently, appropriations took another year. On 28 September 1938, Robert Moses, President of the Long Island State Park Commission, announced that a jetty would be built at Fire Island Inlet by the Corps of Engineers for an estimated cost of $759,000 (New York Times, 29 Sep 38). (This estimated cost is the same as that in House Document 33.) The Moses announcement came only one week after the 1938 Hurricane, which remains the storm of record for much of Long Island, and it seems probable that the timing of the announcement was affected by that storm. As announced, construction was to be done during the next eight months, but after eight months, only the construction contract was ready. The contract was won by the firm of Spearin, Preston & Burrows, Inc. of New York and signed on 13 June 1939. Work began on 26 June 1939 and was completed on 15 April 1941, for a price that was approximately $75,000 less than the figure announced by Moses (District Engineer's Report, House Document 762, 22 Dec 48).

Design. Figure 2 shows the location of the jetty with respect to the preconstruction shoreline, redrawn from the 1939 contract documents. Total crest length was 4750 feet, and a submerged stone apron extended seaward for an additional 200 feet. The jetty was divided into three segments in plan. Segment 1 covered 2000 feet, crossing land that was exposed at low tide. Segment 2 covered 1350 feet, going from near the then existing shoreline out to a depth of about 8 feet. Segment 3 covered 1600 feet, including the 200 feet of submerged stone apron. Segments 1 and 3 are curved in plan, so that Segment 3 at the ocean is north-south, and Segment 1 at the inlet is almost east-west.

Depths are plotted from the plane of Mean Low Water (MLW), which was taken as 1.8 feet below the plane of mean sea level at the Sandy Hook, New Jersey, tide gage. Mean tide range is 4.1 feet at the ocean end of the jetty.

The design of the jetty is shown in longitudinal section in Figure 3 and in cross section in Figure 4. Noteworthy features of the longitudinal section (Figure 3) include the relatively low crest elevation (8 feet above MLW), and the stone blanket and apron at the seaward end. A stone blanket from 1 to 3 feet thick underlies the entire Segment 3 and extends landward to the 1939 -6 foot MLW contour, about 350 feet into Segment 2. Along the outermost 500 feet of the jetty, this blanket extended 50 feet east of the toe of the jetty side slope. For 200 feet along the centerline (extended) of the jetty, there was a stone apron 3 feet thick and approximately 90 feet wide.

Table 1 summarizes the stone weights and side slopes of the jetty.

Construction. We assume that the jetty was built according to contract plans, since the writers have not seen any as-built modifications of the contract drawings. Photos show that the contractor built

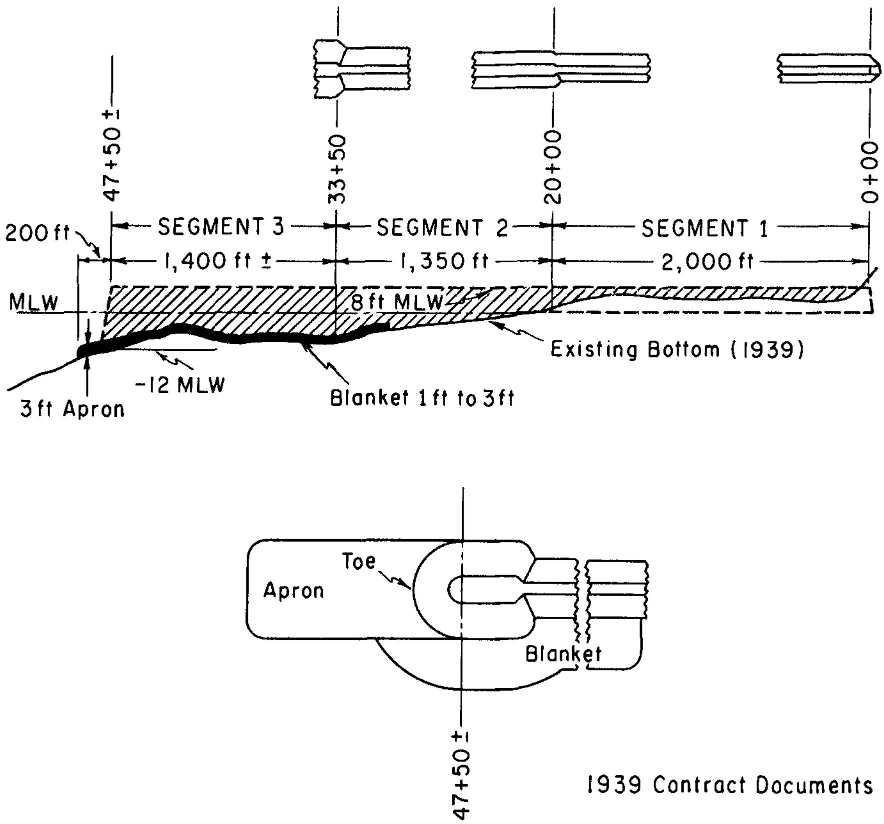

Figure 3. LONGITUDINAL SECTION ALONG JETTY CENTERLINE, WITH PLAN VIEWS OF SEGMENT TRANSITIONS AND SEAWARD END.

a pier at the inlet side of the western tip of Fire Island for unloading materials. A railroad was built on a wooden trestle along the line of the jetty. Stone was barged to the pier, loaded on flat bed rail cars, and taken to the active construction site. The core stone was tipped from the cars. Cap stone (armor stone) appears to have been removed and placed by crane.

Dated photos in the Corps of Engineers' records show that by 3 January 1940, core stone was being dumped at station 3+00 from the pile-supported railroad trestle. The core stone was being dumped into water beside the tracks, which is in agreement with the design (Figure 4) which calls for Section 1 to be excavated to MLW. The same photo shows what appear to be cap stone stockpiled along the route of the trestle. Later photos on 1 February 1940 show cap stone in place at Stations 1+60 and 0+15. At least at 0+15, the cap stone is immediately below the trestle beams, with only a few inches clearance.

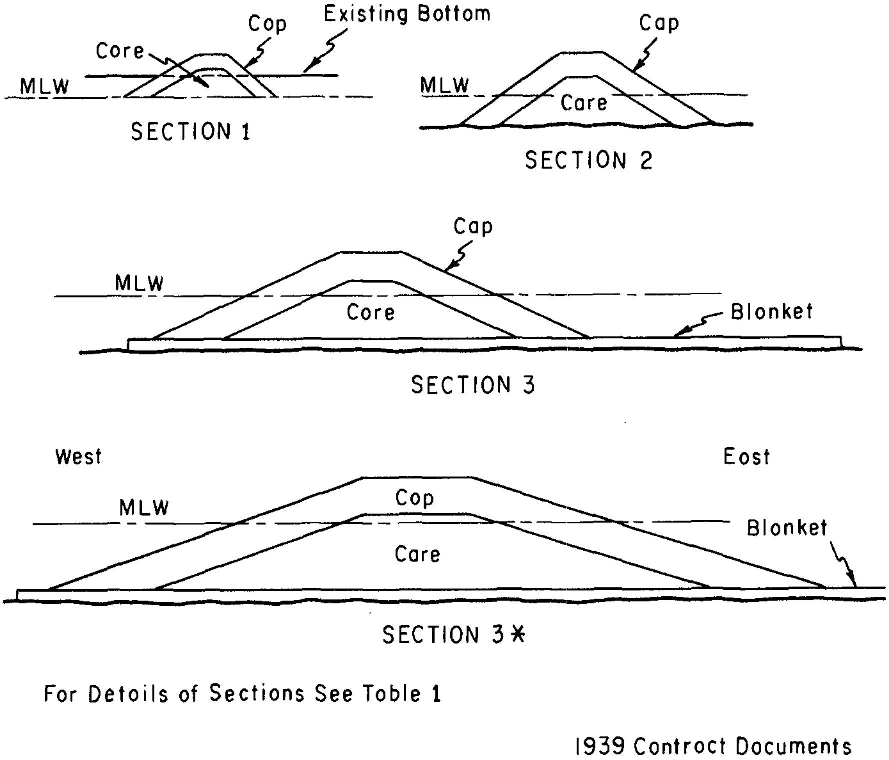

Figure 4. DESIGN CROSS-SECTIONS OF JETTY.

Table 1. FEATURES OF JETTY CROSS-SECTION

Section	Side Slopes West	East	Crest Width ft.	Cap Stone	Core Stone	Blanket Stone
1	1:1.5	1:1	6	3-4 tons	15 lbs-3 tons	
2	1:1.5	1:1.5	8	3-4 tons	15 lbs-3 tons	
3	1:2	1:2	12	≥ 6 tons	15 lbs-6 tons	15 lbs-500 lbs
3*	1:3	1:3	20	≥ 6 tons	15 lbs-6 tons	15 lbs-500 lbs

*(outer 50 feet of Segment 3)

Aerial photos taken on 4 June 1940, 3 October 1940, 8 November 1940, and 10 April 1941 are included here as Figures 5, 6, 7, and 8. These photos were found in the records of the New York District Corps of Engineers (reprinted by permission of the New York Daily News). The photos were taken from the same relative position, and provide a good record of the advancing construction.

Figure 5 suggests that Segment 1 of the jetty (Figure 2) was essentially complete by June 1940, approximately a year after the contract was signed. At this time, the trestle was constructed to Station 33+00, which is approximately the seaward end of Segment 2, and core stone had been placed for about half of Segment 2. The trestle bents in Segment 2 are more than double the width of the railroad. The rails are confined to the west half of the bents. It is evident from close inspection of Figures 5 and 7 that temporary timber platforms were laid on the pile caps east of the track to support cranes that placed the cap rock.

Figures 6 and 7 show the trestle to dogleg to the right at the seaward end, and the track moves from the west side of the trestle to the east side of the trestle after passing the change in direction. Isolated piles in the water along the pre-dogleg line of track suggest that the dogleg replaces a wave-damaged section of trestle.

The survey included in the 1939 contract shows that the three-foot thick stone apron would be placed in depths of 12 to 14 feet. However, after placement of the apron, a December 1940 survey (with probings) in the New York District files shows depths from 15 to 20 feet above the stone apron for at least the outer 100 feet of the apron. Probably, the advancing jetty constricted the preconstruction pattern of tidal flow feeding the marginal flood tide channel (Figure 2), causing scour seaward of the tip of the jetty prior to placement of the apron.

The four photos show rapid accretion of the shore east of the jetty and some erosion immediately to the west. By the end of construction, sand freely overtopped the jetty (Figure 8), as it does today. Even at the start of construction, there was a large sand spit west of the jetty, and a recurved sand spit along the inlet which reattaches near Segment 1 (see top of Figure 5). A recurved spit such as shown in Figure 5 is common today after severe storms.

Present Conditions. The present condition of the jetty varies from remarkably good along Segments 2 and 3 to severe damage along Segment 1. Although it was anticipated that maintenance would cost about $25,000 annually (House Document 33, 75th Congress, 1st Session), little maintenance has actually been done. The District Engineer's report in House Document 672 (printed December 1948) states that repairs up to March 1947 totaled $600.00 (six hundred dollars), and that a total of $50,000 was to be spent on rock repair in 1948. Files in the Navigation Branch, Operations Division, state that 165 tons of rock were placed on the jetty in 1948. Notations on plans indicate that repairs were made at Station 20+00 and between 23+00 and

Figure 5. SEGMENT 1 OF JETTY COMPLETE AND TRESTLE CONSTRUCTED FOR SEGMENT 2 ON 4 JUNE 1940.

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Figure 6. SEGMENT 3 UNDER CONSTRUCTION ON 3 OCTOBER 1940.

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Figure 7. CRANES WORKING ON SEGMENT 3 DURING STRONG WEST WINDS ON 8 NOVEMBER 1940.

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Figure 8. COMPLETED STONE JETTY ON 10 APRIL 1941.

24+00. These locations are in Segment 2, not at the seaward end. No other repairs are known, either from the files or from the memory of knowledgeable persons. The 165 tons is a relatively small amount, occupying, for example, a little more than six feet of the Section 2 shown on Figure 4.

When constructed, Segment 1 was on land (Figure 2), and had a weak cross section (Figure 4 and Table 1). Segment 1 now shows damage both by waves and by tidal currents. Waves have damaged and penetrated behind the jetty for at least 1200 feet, eroding significantly into the dunes east of the jetty (Figure 9). This damage occurs in a relatively sheltered position within the inlet, but the recurved spits, pointing at or terminating at Segment 1, may provide a wave channel which can concentrate ocean waves on the jetty. (During storms, the recurved spits may be submerged, and refraction would concentrate wave energy above the spit, delivering the waves to the jetty.) Recurved spits on the inlet side of the jetty have been a common feature through time. These spits appear across the top of photos in Figures 5, 6, 7, and 8, with shapes and relative positions identical to those observed in recent years. A recurved spit intersecting the damaged length of Segment 1 was especially well developed after the severe northeast storm of 29 March 1984 (Galvin, 1984). Figure 9, based on a June 1984 photo, shows a remnant of this March 1984 spit. However, such a spit was not well developed after Hurricane Gloria (Terchunian, 1986).

Tidal scour from the ebb current flowing out of Great South Bay impinges on the inlet shore of Robert Moses State Park (Figure 1). Scour from this ebb current has severely eroded the shore of the park, and along with the shore, removed about 230 feet of the jetty, i.e. Station 0+00 to about Station 2+30. Since the design section is relatively light and no lower than 0 feet MLW elevation, Segment 1 has no resistance to undermining by the tidal current in a channel that is 20 feet deep or more.

It is worth noting that the east jetty at Shinnecock Inlet (two inlets east of Fire Island Inlet) shows similar damage (Dean and Maurmeyer, 1977) at the same relative positions as the wave and scour damage to Segment 1 of the Federal Jetty. At Shinnecock, however, there are no recurved spits.

At the ocean shore east of the jetty, there has been a large accretion of sand since the jetty was constructed. This is made evident by comparing the 1939 shoreline and bathymetry on Figure 2 with the recent shoreline (June 1984) on Figure 9. The present accreted condition was reached rapidly, probably by 1950, according to Saville (1960).

The area of sand in the spit west of the jetty is, surprisingly, relatively unchanged between the 1939 design condition (Figure 2) and the 1984 photo traced on Figure 9. However, this spit has shifted seaward, from a position adjacent to Segment 1 in 1939 to a position adjacent to Segment 3 in 1984 (compare Figures 2 and 9).

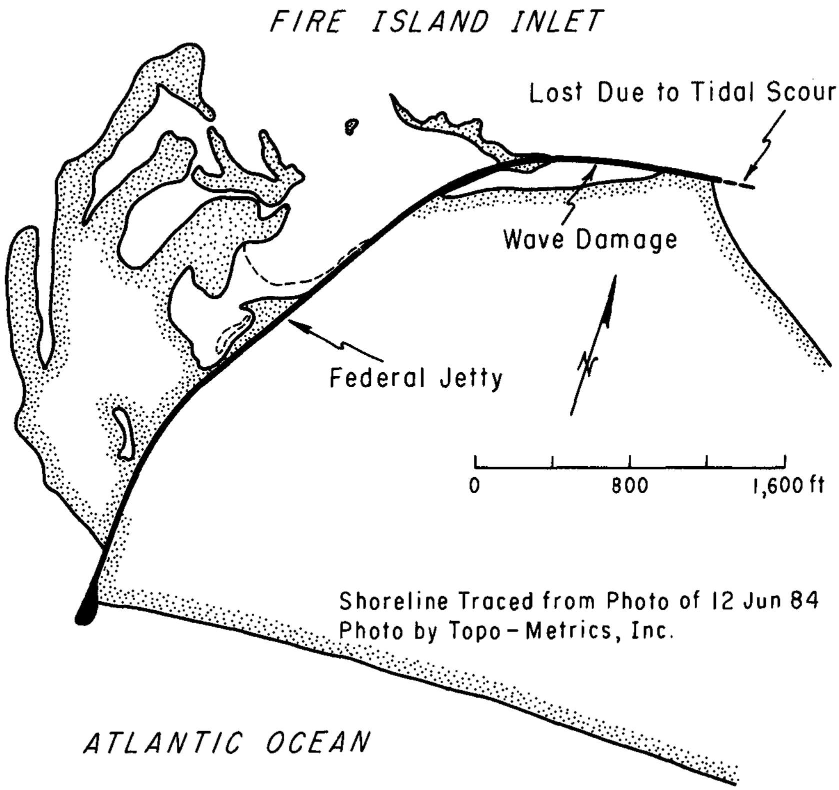

Figure 9. RECENT (1984) SHORELINE IN VICINITY OF FEDERAL JETTY

SAND DIKE

Erosion at Oak Beach. The community of Oak Beach, along the north shore of Fire Island Inlet, had a long history of erosion, mainly due to the deep tidal channel that existed along the shore (see the bathmetry on Figure 2). This erosion predated the construction of the jetty, and is one of the concerns addressed in House Document 33 (1937). The Town, County, and State had each attempted a solution to this problem prior to construction of the jetty, without success.

According to Saville (1960), proposed solutions were developed by the New York District in 1957, and these were reviewed by the Beach Erosion Board. At the time, Saville was himself one of the three civilian members of the Board (and consultant to the Long Island State Park Commission). The Board's review emphasized the need to deal with the tidal currents, ahead of anything else, including a model study.

Construction of Sand Dike. The adopted project required dredging sand from the inlet and placing part of it along the Oak Beach shore. After the project was approved (and apparently after the work had started), the Long Island State Park Commission in the fall of 1959 requested a change, to place the dredged material in a "closure dike" crossing the tidal channel. The Corps of Engineers approved this change on 16 November 1959, and the contractor placed 1,235,300 cubic yards of sand (pay quantity) in a dike (crest elevation 12 to 15 feet MLW) which closed off the channel (letter from New York District to North Atlantic Division, 2 May 61). Construction went from the seaward end of the dike landward (see Figure 1), and closure was complete on 3 and 4 December 1959 (Saville, 1960). This is remarkably swift movement on a major project without prior engineering or model studies. The changes are graphically shown by air photos identified as Figures 3 and 4 in the report of Kassner and Black (1983).

Subsequent History. The changes to this dike are indicated in part by the shorelines on Figure 10. Shortly after construction, local interests placed stone around the dike to armor it (mentioned in the 2 May 1961 letter, but not directly referred to by Saville, 1960). The dike initially had a boot-like shape, but most of the "foot" to the boot was eroded by 1965. The sequence of shorelines on Figure 10 suggest at least another effort at riprap revetment, after 1961. Since then the dike itself has been relatively stable, and its west side has been subject to much accretion (Galvin, 1985).

The effect of the dike on the channel is indicated by the shape and depth of the deepest part of the channel passing around the end of the dike (Figure 10). For most of the first decade after dike construction, the deepest part of the channel trended to the northwest. Gradually, however, the channel reoriented until now it has a northeast trend, and in the process, the old channel west of the dike was abandoned. The abandoned channel became the site of accretion as the ebb channel, forced eastward by the dike, bypassed a large part of the ebb tidal delta, which then accreted to shore. Analysis of the downdrift accretion is given in detail by Galvin (1985). The general bypassing process under natural conditions is discussed by FitzGerald (1983). The location of the ebb tidal delta and the shifting of the shoals in the inlet are shown in air photos by Barwis, et al. (1977).

DESIGN LESSONS

Stone Blanket and Apron. The one to three-foot layer of stone under the jetty provides both a foundation and a filter for the structure. The extension of the blanket east of the jetty probably prevented scour and reduced breaking waves during the time immediately after construction, before beach accretion. The extension of the stone apron seaward of the jetty also prevented scour immediately after construction, and probably still provides a floor for erosion during storms. The stone blanket seems a prudent requirement and the stone apron a necessary requirement for this structure. The data reinforce experience at other projects that scour must be expected

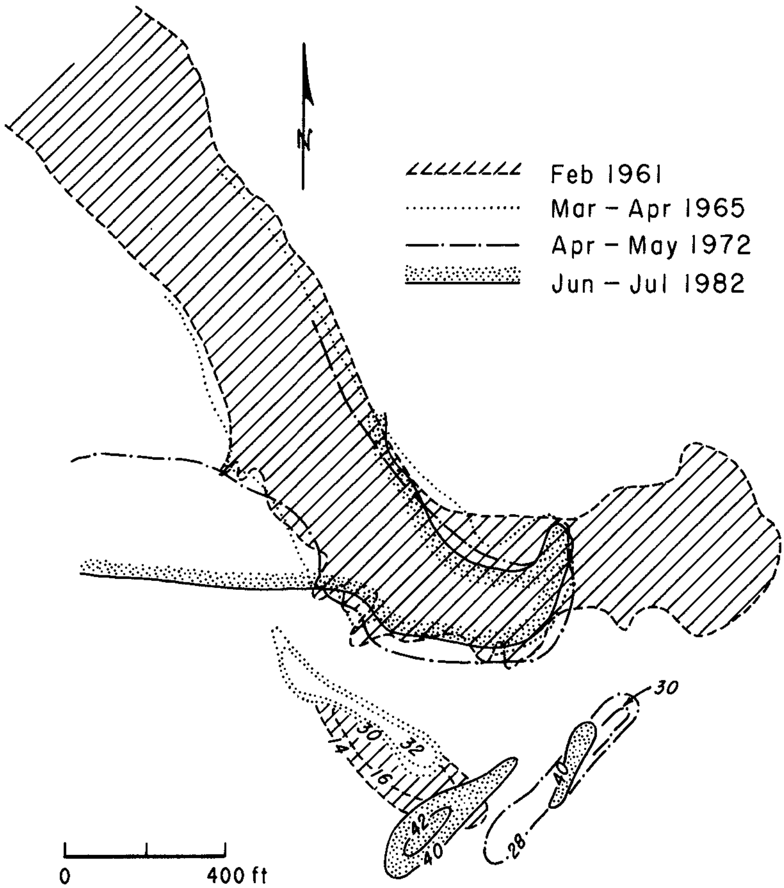

Figure 10. SHORELINE CHANGES AND THE DEEPENING AND REALIGNMENT OF CHANNEL AT THE SAND DIKE.

during construction, in front of the advancing jetty, prior to placement of the stone apron.

Design Wave Height. Using presently accepted practice in jetty design (U.S. Army Corps of Engineers, 1984, Shore Protection Manual, referred to hereafter as SPM), the jetty head at the Federal Jetty (as described in Table 1) would now be considered to have a questionable design. The most exposed direction is to the southeast. A profile to the southeast based on the December 1940 survey, after placement of the stone apron, shows the toe of the jetty in a depth of 15 feet (MLW). Seaward of this depth, the mean slope is nearly flat for 100 feet or more (not steeper than 0.020).

If the 1940 profile governs during storms, breaker travel considerations (Galvin, 1969; SPM, page 7-10) indicate a breaker height of 19 feet may reach the jetty at high tide. (Given the low crest elevations, severe storm surges would submerge the jetty, reducing the potential damage.) Using this height in Hudson's equation, along with the design parameters in Table 1, suggests that WK_D is 42.5 tons. Since the design requires W to be at least six tons (Table 1), and the contractor is not likely to exceed this requirement by much, but is likely to save larger stones for the jetty head, it is estimated that the actual W in the jetty head is eight tons. This implies K_D equal to 5.3, a value which is relatively high for the head of a stone structure (Table 7-8, SPM). This high K_D may have developed due to partial fitting of the cap stone in place, and the practice of grading the core so that the larger core stone is on top. But the armor stone is only a single layer, according to the design. Alternatively, it is possible that, seaward of the jetty head, shoals filter out the very large waves, before they reach the jetty.

The design lesson from this analysis is that care in construction and a long-term shoaling trend may permit a stable jetty head built with nominally underdesigned armor stone.

Single-Jetty Design. It is well known that single jetties at tidal inlets often have scour problems (Kieslich, 1981), but these problems have been absent at the Federal Jetty. Experience at Fire Island Inlet suggests that single-jetty inlets are feasible if there is nearly unidirectional longshore transport, combined with a low crest that permits overtopping (Figure 8). The unidirectional transport at Fire Island is the result of the position of the New Jersey coast, west of Fire Island, which reduces the maximum fetch from the west. The effect of this limited fetch is well illustrated in Figure 7, where the west winds are strong enough to produce foam streaks through the jetty, but these winds have not been able to produce large waves. The long-term effect of this unidirectional westward transport is reflected in the overlapping planform of Fire Island Inlet (Galvin, 1970).

Sand Accretion. The Federal Jetty and the sand dike are both aligned perpendicular to shore. Present knowledge would anticipate the large accretion of sand on the ocean shore east of the jetty (Figure 1), but the major accretion west of the sand dike (Figure 10), on the downdrift side, would perhaps still be unanticipated today. The large volume of sand in the ebb tidal delta is the source of this accretion, and the eastward shift of the channel freed this sand to move ashore.

Shore Erosion. In the two decades after the sand dike was constructed, the inlet shore of Robert Moses State Park (Figure 1) eroded severely (Galvin, 1985). This erosion is probably a reaction of the inlet system to construction of the Thumb. The large accretion west of the Thumb is not necessarily withdrawn from the littoral system, but may be shifted from the ebb tidal delta to shore. It is believed that sand now crosses the existing inlet channel by natural bypassing (Galvin, 1983), but how much of this sand reaches the downdrift shore of Jones Beach after passing the channel is not known. Thus, the sand dike has an undetermined responsibility for erosion of the recreational beaches to the west.

Role of Engineering Studies. The two major structures discussed in this paper were built without model studies or any of the environmental impact studies now necessary. A model study was subsequently made (Bobb and Boland, 1969), and this did not anticipate the major shoaling west of the sand dike that has since developed (Terchunian, 1986). The Federal Jetty has now (1987) endured without major repair for 46 years and the sand dike for 26 years. The sand dike was constructed on the basis of a major field change to a beachfill project already started.

The present paper, based on field inspection, knowledge of the local coastal processes, and a historical review of events leading to construction has yielded insight on coastal engineering design. Such retrospective studies would be useful on other projects. Considerably more technical detail on erosion, accretion, and dredging at Fire Island Inlet is given by Galvin (1985).

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