Erosion of Fire Island, N. Y.

A report prepared for the
U. S. National Park Service

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Summary of recommendations

1) The beach should not be disturbed. Attempts to widen the beach by artificial fill are unnecessary; widening and shrinkage takes place seasonally and naturally. Fill placed on beaches is rapidly carried away by littoral currents.

2) The crest of the foredune along the entire shore of the proposed Park Service holdings should be constructed and maintained at a height to be determined by further study. The dune line should coincide with the natural dune line. Dune construction in any other positions is wasteful. Borrow for artificial dune construction should be obtained by dredging from the bay north of Fire Island. Removal of sand from the sand apron behind the foredune or from the oblique dunes is not recommended.

3) A zone, with a minimum width of 150 feet behind the toe of the natural foredune line, should be maintained as a dune zone. The zone will form a catchment area for natural storm spillovers and permit the natural dune defense line of the island to form. Major structures should be eliminated from this zone.

4) Additional study of the erosional history and processes of Fire Island should be made. These are essential to arriving at a sound engineering program of shore stabilization.

Introduction

The writer was requested by Mr. Allen T. Edmunds, Assistant Regional Director, Northeast Region, U. S. National Park Service (letter dated July 19, 1963) to prepare a report on the erosion of Fire Island as part of a feasibility study leading to the development of the area as a National Seashore. The writer met with representatives of the National Park Service on Fire Island on July 30-31 and at that time viewed the area from the air and from the ground. Although this field study was brief, certain observations and conclusions concerning Fire Island can be made. This is possible because of the similarities of the erosional and depositional processes on Fire Island to other shores that have been studied by the writer.

Foundation of Fire Island

The low-lying plain, that makes up the mainland north and east of Fire Island, is underlain by sands and gravels that were deposited in front of the great Pleistocene ice sheet whose southern edge extends from east to west through the center of Long Island. During formation of this broad outwash plain, the sea level was lower than it is today by at least several hundreds of feet. In consequence, the outwash plain extended south of present day Fire Island. Most of this plain therefore now lies below sea level and Fire Island, which is of more recent origin, in effect rests on it. A well drilled on Fire Island will pass through the marine deposited sands of the island and strike at shallow depth sands and gravels that crop out on the mainland.

Origin and growth of Fire Island

As the ice sheets melted in late Pleistocene time, sea levels the world over rose until between 3,000 and 5,000 years ago they reached the approximate present sea level. Since that time the sea level has been relatively stable, though in this region it fluctuates as much as 18 inches above and below this level.

Fire Island came into being with the establishment of present sea level. Its initial form was probably a small sand spit that projected west from a headland that existed somewhat south and east of Southampton. At that time, the mainland shore between Montauk Point and Southampton was deeply embayed and extended an average distance of about $1\frac{1}{2}$ miles south of its present position. The present stretch of mainland shore lying between Montauk Point and Southampton is now straight; this is the result of erosion that has taken place during the past 3,000-5,000 years. The sands and gravels that were eroded from these headlands were carried to the west along the shore by littoral currents. This westerly littoral drift built sand spits from the headland points while further west sand bars formed which in time became barrier beaches. The entire system of spits and barrier beaches along the south shore of Long Island today probably owes its origin to the sand that was eroded from the headland section east of Southampton.

Fire Island therefore started out as a spit tied at its eastern end to a headland. It still is essentially a spit and continues to be tied to the mainland at Southampton. However, as a spit it has been elongated to an extreme degree and fragmented by two breaches into several sections.

Its form is therefore so close to that of the true barrier beaches (such as Jones Beach and the other linear islands to the west) that the term barrier beach can be--and has been--applied to it.

Fire Island spit continues unabated to grow to the west. Between 1834 and 1955 it grew westward 21,880 feet, or an average of 181 feet a year. If we assume Fire Island spit first began to develop 3,000 years ago, it would appear that the average rate of westward growth has been about 100 feet a year. Fire Island therefore has been built mainly by addition at its western end. The growth of the tip is not steady but is characterized by intervals of relative stability, or even by intervals of erosion, alternating with short intervals of rapid extension. The intervals of relative stability may last as long as 10 years and during this time well-defined foredunes form behind the beach. These old foredunes marking former stable strands can be clearly seen from the air and make up the system of northwest-trending oblique dunes of much of the island. They are particularly well-developed in the somewhat bulbous western tip of the island. Figure 1 shows some of the more recent of these former shorelines at the western tip. Each is marked by its respective foredunes. The dates of the shorelines have been determined by referring to Figure 22, Technical Memorandum 128, Beach Erosion Board, Corps of Engineers.

The growing tip of Fire Island only in part determines the shape of Fire Island. For one thing we know that the growing tip has probably always been much wider than the main body of the spit. Thus today the maximum north-south width of the west end is about 3,200 feet whereas the

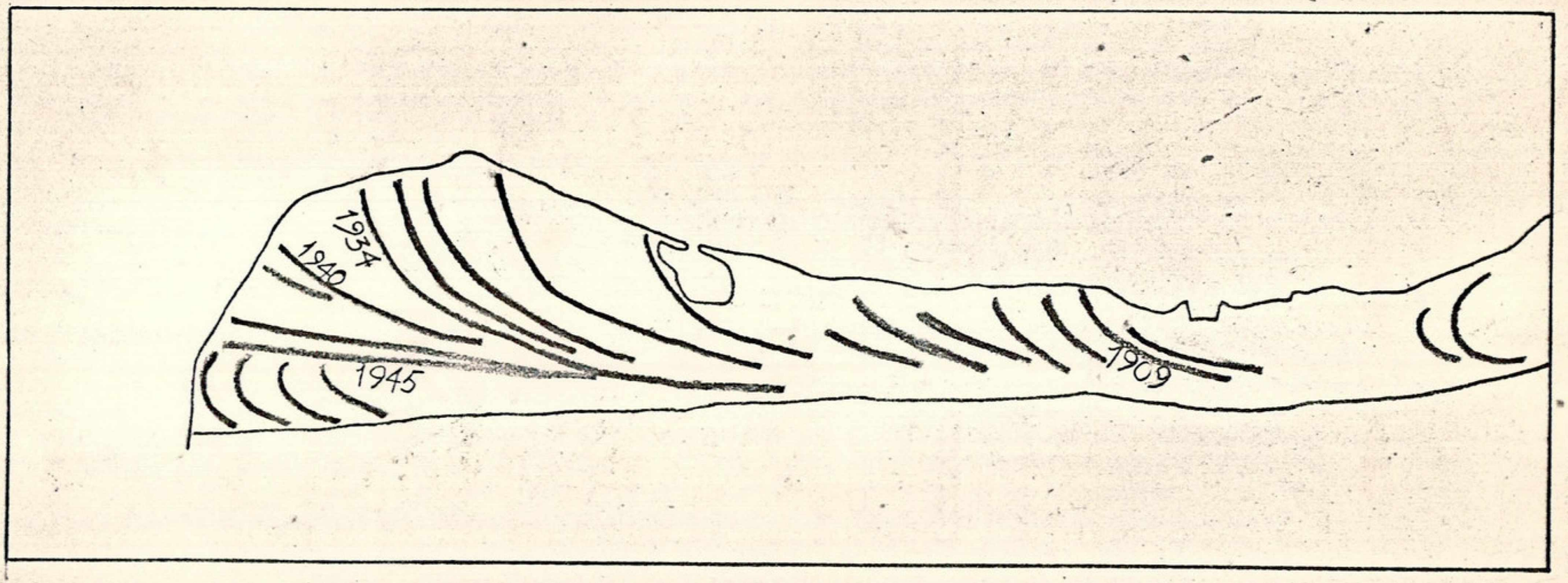


FIGURE 1. Western tip of Fire Island, 1954, traced from U. S. Geological Survey topographic map, showing former shorelines that are marked by foredunes. Dates of these shorelines are given. The old foredunes are shown by heavy line. These oblique dunes are to be distinquished from the foredune behind the present long South Beach.

average width of the spit is about 600 feet. The shape of the tip tends to be bulbous, somewhat hooked to the north. This form is imposed by the strong tidal flow in and out of Fire Island Inlet as it interfers with the littoral drift coming from the east. These tidal currents carry the easterly-derived sand partly into the inlet and the bay only partly to return it as the current reverses. A complex in-and-out movement of the sand in the inlet builds up the modified hook form of the tip. Later, the sweep of the tidal current channel as it moves back and forth in the inlet trims the northern edge of the tip and thereby reduces the shape to conform to that of the main body of the spit. Although Fire Island is the result of its tip moving westward, the spit's shape is continually being modified by wave action and currents on its ocean side and on the bay side by tidal current erosion and by slow sand deposition.

Figure 2 shows successive positions of the spit since its formation. It is readily seen that the spit has been displaced progressively northward and that the greatest displacement is at the eastern end. This northward migration has been brought on by the recession of the mainland shore at Southampton to which the spit is tied. It is estimated that the total northward migration of the spit at its eastern end is in the order of a mile, which would indicate a mean annual recession of Fire Island shore of about 1 ft. per year. East of Moriches Inlet, the spit has been displaced to the north to such an extent that none of it now contains sand that was deposited in the growing tip. West of Moriches Inlet, the spit is largely made up of sand that was deposited in the tip although the spit is continually being trimmed back along its south shore. This interpretation is confirmed by the fact that

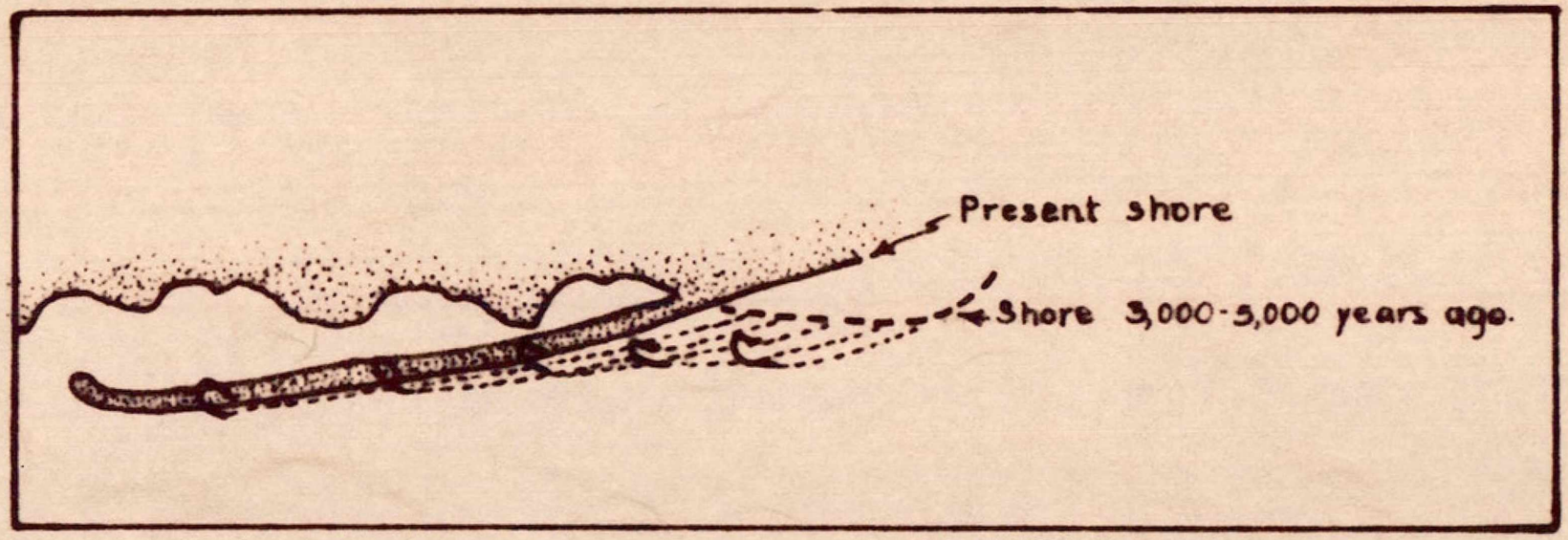


FIGURE 2. Successive positions of Fire Island spit showing westward growth and northward migration.

relics of the obliquely-trending foredunes that characterize the growing tip (Figure 1) are common west of Moriches Inlet but are not found to the east.

From the long range point of view--and by this is meant several hundreds of years and longer--stabilizing the spit to its present geographic coordinates (the spit has migrated northward without losing its identity or its size) depends in large part on stabilizing the shore at its eastern end. But to do this, the very existence of the spit may be jeopardized for the material making up the spit is derived in large part from the eroding shore to the east. However, the more pressing and immediate erosional problems can be considered independently of the gross northerly migration of the spit. These problems are discussed below.

Physiographic units

Fire Island can be readily divided into six parallel physiographic belts. Each is distinct from the others in form, origin, and the role it plays in the erosion and deposition processes. These belts are from south to north: Offshore, beach, foredune, oblique dune, sand apron, and salt marsh.

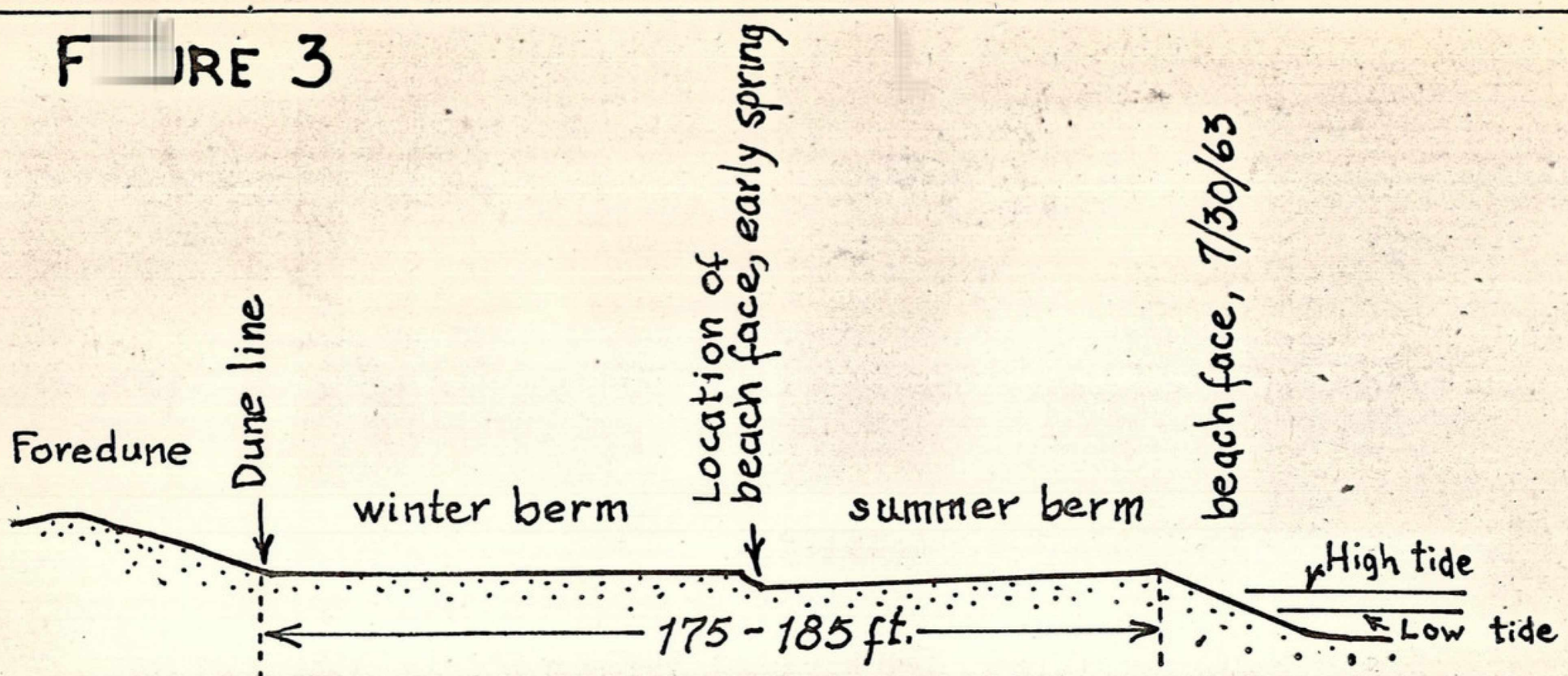
Offshore: By offshore is meant the bottom south of the low tide line (standard beach nomenclature breaks this down into two terms, offshore and inshore). The writer has no data on the bottom topography in this zone that is of sufficient detail to be of value to the present discussion. It is understood that several offshore profiles are given in the Corps of Engineers study (1958). When seen in the field, waves were breaking very close to the low tide line and it was clear that the dropoff was relatively

steep to waters 8 ft. or more in depth below low tide. However, there is a continual change in the bottom configuration in the surf zone and brief or isolated observations of this nature have little meaning. It is fairly certain that the offshore bottom is sandy although some fine gravel probably occurs. The sand offshore migrates onshore-offshore as it is stirred by waves and carried laterally by littoral currents. Most of the sand of the immediate offshore has undoubtedly been part of the beach one or more times. In effect, the offshore is a reservoir of sand for natural beach nourishment.

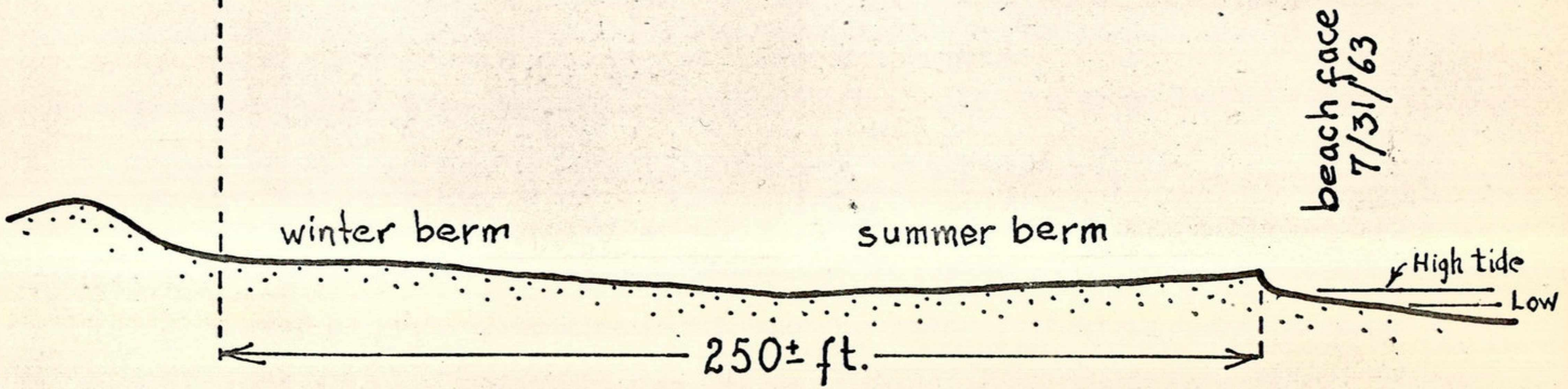
The topography of the bottom affects the waves that strike the beach. Waves break and begin to lose their energy when the bottom shoals to a certain depth (dependent on the height of the wave). Wave fronts bend or refract depending on the configuration of the bottom and this in turn determines the obliquity with which they strike the beach. Sharp channels in the offshore, such as those eroded by rip currents (strongly localized away-from-shore currents), may result in energy corridors. These are places at the shore where waves tend to concentrate. The effect of such energy localizations on shore erosion can be of first consequence. Thus the offshore hydrography and changes in this hydrography will inevitably influence the erosion-deposition pattern of the island. The offshore of Fire Island merits a separate study in order to properly assess its influence on the erosion problem.

Beach: Figure 3 shows the beach profiles at two localities when visited on July 30 and July 31. The profiles are only approximate and were not surveyed with an instrument. Nevertheless, they give a good picture of the general shape: The broad beach berm, the so-called "summer berm," and

FIGURE 3



PROFILE OF WESTHAMPTON BEACH, JULY 30, 1963



PROFILE OF BATHING BEACH, FIRE ISLAND STATE PARK, JULY 31, 1963

the rather steep beach face. The width of the beach berm (the nearly level expanse between toe of foredune and top of beach face) was pace measured at 4 stations and varied from a minimum at Westhampton of 175 ft. to about 250 ft. at the public bathing beach at Fire Island State Park. The beach face along much of the central section of Fire Island on July 30, was deeply scalloped by beach cusps. These were spaced at about 100 ft. intervals. It was noticed that the swash mark for the high spring tide about a week previous was at the toe of the foredune. In other words, high spring tide swash completely covered the berm. A thundershower in the early morning of July 31 must have caused beach erosion because the beach face when seen later that morning had obviously been eroded by the last high tide.

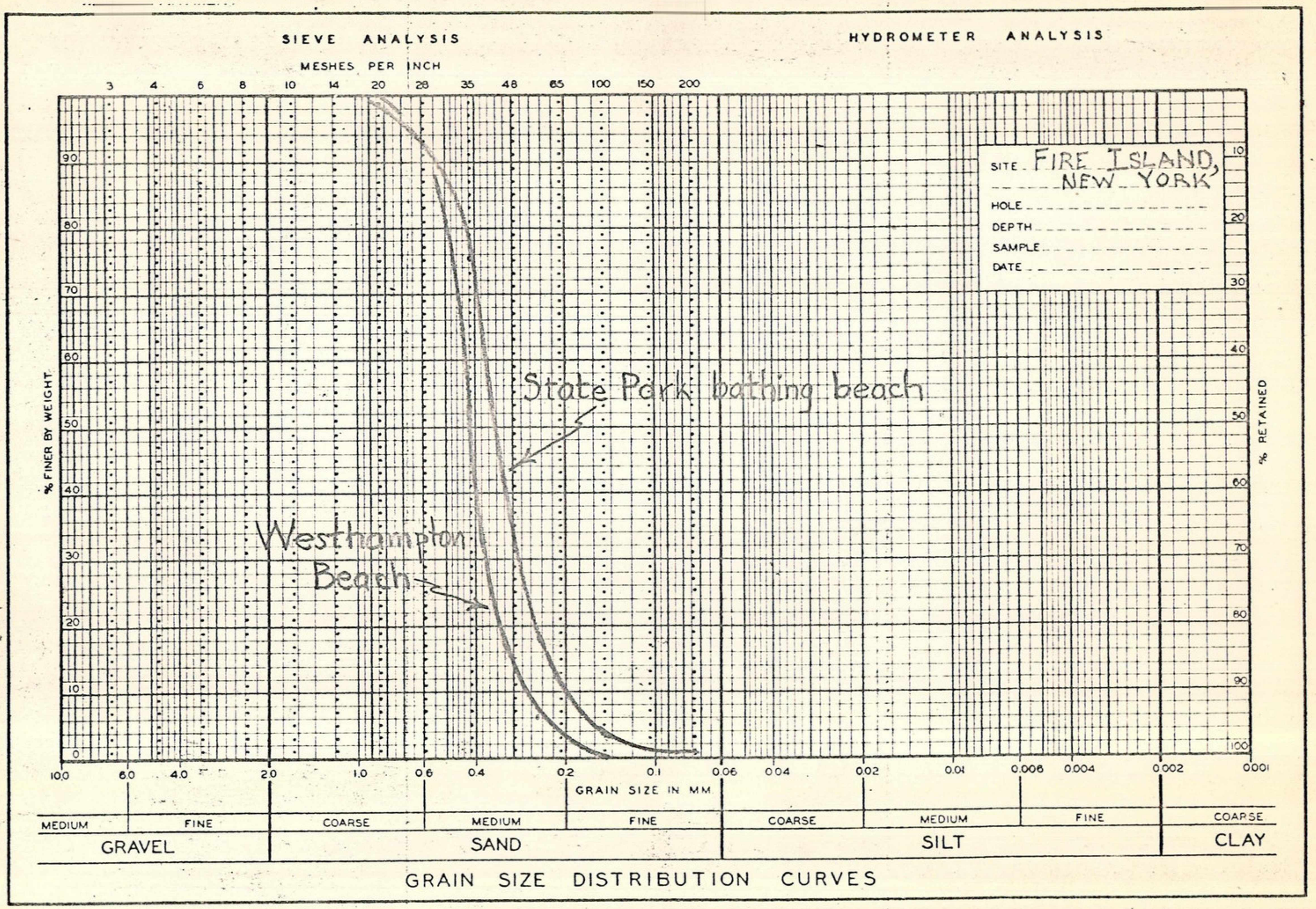
Samples of sand were taken from the beach berm at two stations and analyzed for grain-size distribution, shape of grains, and mineralogy. Figure 4 gives the grain-size distribution expressed as a cumulative curve. Both samples were taken about 15 ft. in front of the toe of the foredune. It will be seen that both samples are very uniform medium sands. The Westhampton sample is slightly more coarse-grained than that of the Fire Island State Park bathing beach, suggesting that the beach sand gets coarser to the east toward the source of supply. However, the differences between the two samples is small and the beach sand seemed remarkably uniform in appearance wherever seen.

The dominant shape of the grains is angular. This property is probably largely responsible for a moderately good bearing strength and trafficability of Fire Island beach.

The sand is estimated to be 85-90 percent clear quartz, 5-8 percent fresh feldspar, and the remaining 2-5 percent consists of dark minerals, of which the following were recognized (in order of importance): Garnet, ilmanite, magnetite, staurolite, hornblende, epidote, tourmaline, zircon, and sphene.

It should be born in mind that the width of the beach is everchanging. With each tide, sand is either added to the face of the beach or taken away. The amount of erosion or deposition per tide depends on the wave energies at the time. After a large storm or stormy interval the beach will be substantially narrower than after an interval of protracted fair weather and small waves. The late fall, winter, and early spring are normally characterized by a greater frequency of storms and large waves than the late spring and summer. This means that the winter and spring beach will generally be considerably narrower than when the writer measured it in late July. The difference in seasonal widths might be on the order of 100 ft. or more. This continual mobility of the beach face makes it impossible to construct by artificial nourishment a given beach width or to define to a fixed position a point such as the high tide mark. Artificial beach shaping which strives to do this becomes merely an exercise in futility.

The marked fluctuating change in width of beach also points to the fallacy of data that purports to show the amount of erosion or accretion of a beach over an extended period of time. Because the Fire Island high tide or low tide line may shift as much as 200 to 300 feet during the course of the year without there having been any net loss or gain of shore, two surveys made several years apart that show, for example, erosion of 100 ft. may measure nothing more than the usual back and forth motion of the beach face.



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FIGURE 4. Grain-size distribution curves of two beach sand samples, Fire Island, N. Y.

Foredune: The foredune is the ridge of sand parallel to and immediately behind the beach. In general, the toe and crestline of the dune closely parallel the foreshore and are fairly straight lines. For purposes of this report the line formed by the toe of the foredune will be called the dune line.

The foredune is formed from sand that is blown off the beach. Sand grains are rolled by the wind along the surface of the berm until they meet some obstruction where they stop. Eventually a foredune is formed. On Fire Island the foredunes in a few localities reach an altitude of 25 ft. above mean tide, but for the most part it is 15 feet or less above mean tide.

When a new stretch of beach is formed at the growing tip of the island, the initial obstruction that inaugurates the foredune is beachgrass (Ammophila breviligulata). This grass gets established within a year or two in newly deposited sandy sections that are not subjected periodically to wave action. Therefore, in a prograding beach that part of the berm that is too high and too remote to be inundated by high spring tides will become colonized by beachgrass. This establishes the location of the duneline. As the foredune develops it provides the obstacle to further sand movement.

A very steep slope may form the face of the foredune by erosion during a storm. In effect, the toe of the dune has been pushed back. Given time, however, drift sand coming from the beach will be deposited against the steep face of the foredune and eventually reconstruct the shape of the old dune. When this happens the former dune line will have been re-established.

Man can aid the process of natural dune construction by setting out obstructions if beachgrass is not already well-established. Snow fences are being effectively used for this on Fire Island. These are set both parallel to and oblique to the dune line. Beachgrass is also planted by the New York State authorities.

Since the beach provides the dune sand, it is helpful to natural dune construction to keep the surface of the beach berm in a state that will most readily permit the drift of sand by wind. In periods of dry weather the beach berm develops a friable curst about one-half to an inch thick from salt that has crystallized in the interstices of the sand. The crust prevents wind drift. It is easily broken however, by tracking with vehicles. In addition heavy rains, or artificial watering, effectively dissolve and leach away the salt.

Oblique dune: The oblique dune is found only west of Moriches Inlet. This type of dune trends northwest and as the name implies is oblique to the axis of the spit and to the beach and foredune. Commonly it is found just behind the foredune to which it may be connected. The oblique dunes are generally lower than the foredunes; rarely is their maximum altitude 20 ft. above mean sea level.

The oblique dunes are relics of the foredunes that formed at the hooked sector of the growing tip of Fire Island (Figure 1). The age of these oblique dunes therefore increases from west to east (Figure 2). They have been variously eroded since formed and many are pitted by large sand blowouts.

The effect these dunes have on island erosion is two-fold and somewhat contradictory. They act as additional bastions against serious erosion of the island by large spillovers. However, they also tend to provide channelways when serious overtopping of the foredune line does take place. This concentrates the overflow into narrow channels between the oblique dunes and may promote deep erosion and eventual breaching of the island.

Sand apron: North of the dune belt a sand flat of variable width slopes very gently to the bay shore. This sand apron is in part a relic of the growing tip of the island and in part (east of Moriches Inlet it is entirely so) it represents deposition by large storm spillovers. These occur when waves overtop the foredune and carry to the north side of the island beach and dune sand which is then deposited in lobate aprons. Over a long period of time the individual lobate deposits coalesce into a fairly continuous apron such as that which now forms the north side of much of Fire Island.

Salt marsh: In places the north edge of the sand apron passes into areas of salt marsh. The salt marsh is generally a thin peat deposit overlying sand; it supports a dense growth of salt marsh grasses. The altitude of the marsh generally falls between mean tide and mean high tide. The sand underlying salt marshes may have been deposited as part of the sand apron. However, some of the larger patches of salt marsh and the small marshy islands lying just offshore rest on sand that was deposited in the bay to the lee of former inlets that are now closed. This appears to be the origin of the broad salt marsh about 2 miles west of Moriches Inlet. A map made in 1829 shows an inlet directly in front of where this marsh is

today (Beach Erosion Board Technical Memorandum 128, figure 20). A broad sand shoal lies just north of the present Moriches Inlet. If this inlet were to close, this shoal very likely would become converted to a salt marsh.

Wind and waves

The movement of sand which is of concern to the engineer is entirely the work of wind-generated waves. The size of the waves depends on the wind velocity and the length of time the wind has acted on the waves. The direction of wave movement is parallel to the direction of the generating wind. The dominant winds in the region of Fire Island are westerlies, tending to be southwest in the summer and northwest in the winter. On the other hand, storm waves tend to be easterlies - northeast to southeast. During much of the year, therefore, the smaller fair-weather waves strike the shore obliquely from the southwest. The erosion and deposition produced by these waves is small in comparison to that produced by the large storm waves which generally sweep onto the beach from the southeast. In addition, severe winter storms far out to sea in the North Atlantic generate large waves which may reach Fire Island as large swells that also sweep in from the southeast. Hurricane waves may come from a westerly as well as an easterly azimuth depending on the path the center of the storm takes. Also, hurricane winds and waves may shift from an easterly to a westerly azimuth during the course of the storm.

When a wave breaks, its plunge stirs up sand on the bottom and this sand is carried up onto the face of the beach with the swash of the wave. When the crest of the swash is reached the flow of the wave is reversed and the wave washes down the face of the beach. All the sand that was

carried up may then be carried down again. If more sand is carried down than is carried up the beach face in this flow reversal, then erosion of the beach face takes place. If less sand is removed downslope than was carried upslope, then deposition on the beach face takes place. Whether or not sand is eroded or deposited in this manner depends on a number of factors, but mainly wave energy, grain size of sand, inshore slope, and absorption capacity of the sand. Because the equilibrium point separating the erosional surf from the depositional surf is very delicately narrow, equilibrium of the beach face is almost never attained and a certain amount of erosion or deposition takes place every day, even with the calmest of seas.

Littoral drift

If a wave front is parallel to the beach, that is if it strikes normal to the beach, the path taken by sand grains as they wash up and down the beach face, in the manner just described, is also normal to the beach and there is no lateral shift of sand along the beach (there will be a movement of sand onto the beach from offshore or to the offshore from the beach face, depending on whether the surf is eroding or depositing). More usually, however, waves strike the beach obliquely and the path of the swash and then the backwash is also oblique in the same sense. The path taken by a sand grain as it washes up and down a beach face, if plotted on a map, is a serrated line and the net movement is along the beach. Similarly the movement of the water in the inshore zone along the beach forms a littoral current, that also carries suspended sand. This lateral movement of sand brought on by waves striking the beach obliquely is called littoral drift.

Westerly winds cause east littoral drift on Fire Island and easterly winds cause west littoral drift. Because the storm winds are generally easterly the greatest amount of littoral transport for any year is westerly. There is therefore a net westerly transport. Breakwaters and groins therefore accumulate sand on their eastern sides at a substantially greater rate than on their west sides.

Tides

The tide tables of the U. S. Coast and Geodetic Survey give the mean tide range at Shinnecock and Moriches Inlets as 2.9 ft. and mean spring tide range as 3.5 ft. At Fire Island Inlet the tide range is slightly greater, 4.1 ft. for mean tide and 5.0 ft. for mean spring tide. In severe storms the levels of high tide may be 3 feet or more above the normal levels.

The principle of the straight beach

Because of littoral drift sandy shores tend to be straight or broadly curved lines without irregularities. The reason for the smooth line principle is not complex. A sharp re-entrant in a sandy strand will quickly fill up with the sand that is carried by littoral drift from either side, or from both sides alternately. The re-entrant acts as a trap to the sand moved by littoral transport until such time as it is filled; with disappearance of the irregularity the smooth shoreline is re-established. Likewise, a projection of the shore, whether done in the guise of "beach building" or for some other purpose

is immediately acted upon by the waves and littoral currents. The net result is erosion of the projection until the shoreline joins smoothly with that of the flanking shores. Engineering measures that tend to make irregularities on the shore often turn out to be short lived. Some justification may be made for piling sand on a beach to act as nourishment for impoverished beaches in a downdrift direction, but no stretch of beach on Fire Island appears to the writer to need this treatment.

Storm attack

Fire Island has three main lines of defense against erosional attack by storm waves. The first is the beach itself, and this is of great importance. It is only after waves succeed in removing much of the beach that they are able to work on the second line of defense, the foredune. If the foredune can be badly overtopped and eroded the rear defense zone, the oblique dunes and the apron remain to be removed before complete victory--breaching--is achieved by the sea.

The role played by the beach in protecting the island is based on the fact that the turbulent surf, rolling up a beach, loses energy (forward momentum) progressively. On the narrow beach a wave of given initial energy will be more destructive to the dune line than on wide beaches. On Fire Island the width of the beach varies considerably with the season and the weather. The effectiveness of the beach defense therefore varies during the course of the year. The broad berm, that existed in midsummer when seen by the writer, would provide considerable protection from a storm of short duration.

Unfortunately, most destructive storms come at times of the year when the beach width is reduced and when the beach provides only a minimum protection. Wave attack on the foredunes occurs in two ways. First, the waves wash away the sand at the face, particularly at the base, and secondly, they spill over the crest of the dune. Spillovers, of course, are most important where the foredune is initially low. However, they may also occur where the dune is high. These spillovers may be caused by the main body of the wave overtopping the dune crest or by water that is shot into the air as the wave strikes the steep face of the dune. It is the former type of spillover that can be damaging for if enough water can pass over onto the back slope of the dune it will erode sand from the crest of the dune and thereby open the way for spillovers of ever increasing volume and erosive power. Normally however, the small spillover is absorbed by the dune and does not flow very far down the back slope.

The large spillover is most damaging when the second defense line has been breached because it erodes a channel way through the foredune and spreads across the sand apron, depositing the sand removed from the foredune. The large-scale air photos of Fire Island taken at the end of the exceptionally severe storm of March 7, 1962, revealed that 11 large spillovers had occurred. Of these only 6 reached the bay shore and only one, at Westhampton Beach, created a breach. The breach at Westhampton Beach apparently was not deep and rapidly closed. Fire Island probably has been breached at many places in the course of its existance. Some of these may have persisted for many years, but eventually all breaches close unless protected indefinitely by man.

Recommendations

The following recommendations are the basic parts of a stabilization program for the National Park Service's holdings on Fire Island.

1) Beach: Fire Island beach is very mobile, varying markedly in width during the course of the year. In midsummer, 1963, it was very wide along its entire length. This was solely the work of natural processes (the few groins at Southampton were almost completely buried by the beach and evidently they had played no role in the formation of the present strand, which was equally well-developed where no groins existed). It is therefore recommended that the beach be left alone. Attempts to widen the beach by artifically placed fill will be unsuccessful because the sand fill placed during intervals of narrow beach will be carried away be littoral currents.

The beach should not be used as a source of borrow. The beach is the first line of defense against storm attack. The removal of sand from the beach for dune construction will weaken the beach defense.

Sand should not be borrowed from offshore or from just below low tide. This sand forms part of the natural reservoir of beach sand. Sand taken away here will not be available for natural beach nourishment.

2) Foredune: The crest of the foredune along the proposed National Seashore should be built up to a certain minimum altitude (this to be determined after adequate study of the effects of the 1962 storm). The position of the man-made dune should coincide with the natural dune line. Dunes built south of the dune line are vulnerable to wave erosion whereas those built north of the dune line are overly protective of an unnecessarily

narrowed stretch of apron. Moreover, in the case of the dune built north of the dune line, a natural dune will form in front of it, given time.

Sand for artificial dune construction should not be borrowed from the land surface; all island sand plays a defensive role against breaching. Borrow for dune construction should be dredged from the bay bottom immediately to the north.

To promote natural foredune formation, obstructive sand traps should be used in the natural dune line. Snow fences and beachgrass planting are effective. In addition, salt crusts on the berm should be broken, probably by tracking with vehicles.

3) Dune zone: It is suggested that a zone, having a minimum width of 150 ft. behind the natural foredune line, be established and maintained as the dune zone. The purpose of this zone is (1) to permit space to build and maintain an adequate foredune, and (2) to provide a buffer zone that will accommodate most of the destructive spillovers that develop during storms. It is recommended that the dune zone be kept clear of major construction.

4) Further study: The discussions and recommendations presented in this report point to the need for further study of the erosional history and the details of the erosional processes of Fire Island. Much remains to be learned from the information available from past storms. For example, there are indications that the major spillovers in the March 7, 1962, storm were localized by factors other than the height of the foredune. A certain regularity in the spacing of the spillovers points to the possibility that offshore and beach factors may have played an important role in localizing

these points. The effect of headland erosion and protection on the long range stability of Fire Island remains to be investigated in the field, as does the nature and capacity of the offshore sand reservoir as a source of beach sand. It is therefore suggested that a continuing study be set up to examine these questions.