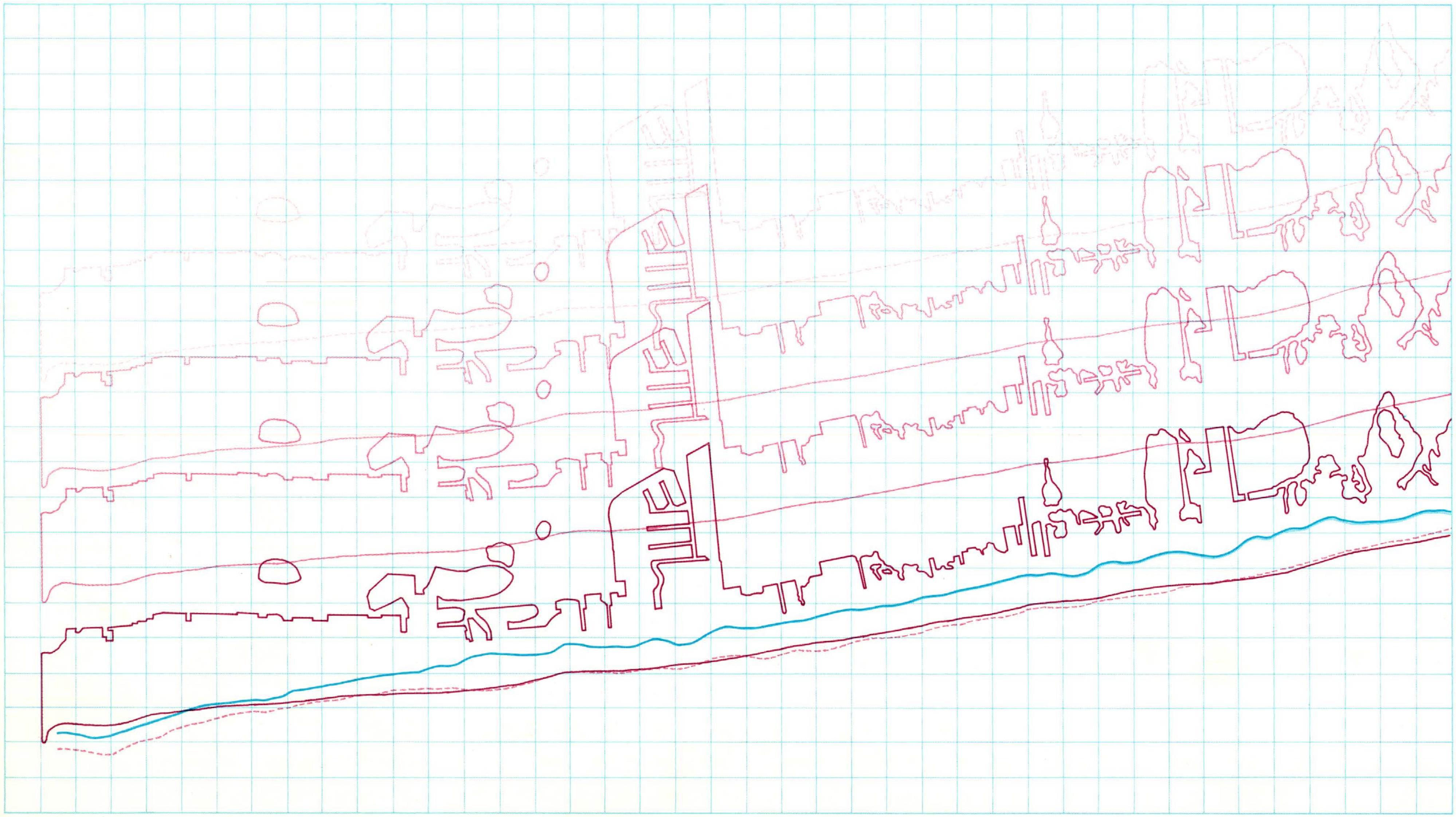
Geographical Analysis of **Fenwick Island, Maryland,** *a Middle Atlantic Coast Barrier Island*



Geological Survey Professional Paper 1177–A

Geographical Analysis of **Fenwick Island, Maryland,** *a Middle Atlantic Coast Barrier Island*

by Robert Dolan, Harry Lins, *and* John Stewart

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H. William Menard, *Director*

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Foreword

When the Geological Survey published Professional Paper 950, *Nature to be Commanded . . .*, it attempted to broaden the audience for earth-science information to include land use planners, managers, and developers. The response to that publication has been so overwhelming that *Nature . . .* has gone into a second printing. In keeping with its commitment to demonstrate and promote the applications of earth-science information to sound environmental planning and decisionmaking, the Geological Survey is offering this report, Professional Paper 1177-A, which analyzes the processes and hazards associated with coastal barrier islands. This is the first of several publications that follow the style begun with *Nature to be Commanded . . .*

It is important to realize that the hazards associated with natural processes and urban development are found all along the Atlantic and Gulf coasts. This publication focuses on Fenwick Island, Maryland, where the city of Ocean City is located. This urbanized island was selected because it is representative of many developed barrier islands and provides, therefore, a generally applicable example.

We believe that this book, and those that follow, will have a significant and positive effect on coastal planning. The documentation of natural process rates and recent land use provides planners and developers with key information for guiding future development to those areas of least hazard and for evaluating alternative hazard mitigation techniques.

H. William Menard

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Director

Introduction — the coastal zone

by Robert Dolan[1], Harry Lins[2], and John Stewart[3]

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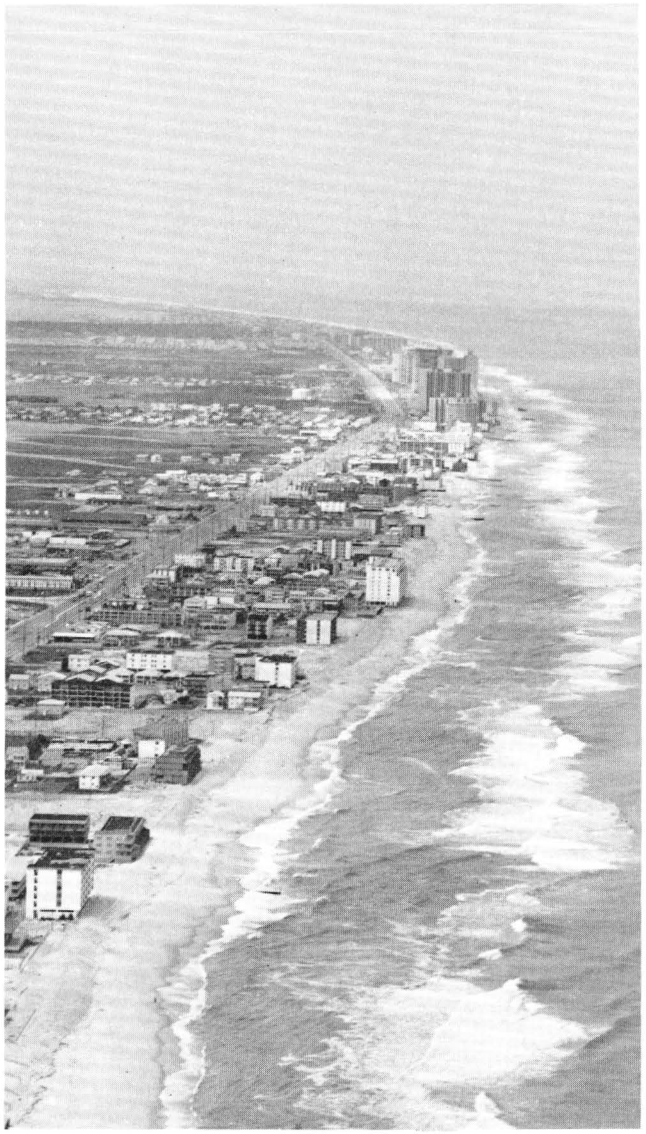

Fig. 1 *Ocean City, Maryland, 1977.*

The coastal zone is narrow in extent but of major importance to the people of the United States. We use coastal lands and waters for recreation, industrial and commercial activities, waste disposal, and food production. More than half the Nation's people now live within the coastal zone. Most of these people live in the large urban centers, but in recent years much of the population growth has been in areas associated with the expanding tourist industry. In 1978, more than half of all Americans vacationed on the coast, and the number has been growing rapidly. There are many reasons for this, but clearly, coastal areas offer many recreational activities ranging from swimming, sailing, and sport fishing to wildlife observation or simply walking along the water's edge (Commission on Marine Science, Engineering, and Resources, 1969).

Although living at the edge of the ocean can be a fascinating and relaxing experience, those who choose to live close to a large, dynamic body of water assume certain risks. Storm-driven waves, which build over hundreds of miles of ocean surface, can reach heights of 50 feet or more in the open sea, and hurricane wind speeds can exceed 200 miles per hour. Many scientists in government and research programs are deeply concerned about the threat of a severe hurricane. In a recent address, Richard A. Frank, Administrator of the National Oceanic and Atmospheric Administration said, "A hurricane will kill hundreds, if not thousands of Americans, and cause billions of dollars of property damage sometime soon. I do not know precisely when or where, but it will happen." (Frank, 1979).

The Atlantic barrier islands are among the most unstable of the coastal lands utilized by man. Beaches and dunes are temporary in location and form. The dynamic nature of these islands is linked to their aesthetic appeal and recreational potential. Unfortunately, development of these areas has taken place more rapidly than our understanding of barrier-island dynamics. Homes and commercial facilities are being constructed very close to the sea, and like the natural landscape, they too are unstable at times. Each year the wide range of landscape changes caused by natural processes takes its toll in human resources with costs measurable in millions of dollars.

Sometimes the changes on the barrier islands are catastrophic. During a "northeaster" storm in March 1962, damage to property along the mid-Atlantic coast amounted to more than $500 million, and 32 lives were lost (U.S. Army Corps of Engineers, 1963). This devastation was soon forgotten, however, and rapid development along the coast has continued into the 1970's. Today, formerly small villages have become urban centers for large summer populations. Since 1962, the year-round population on the Atlantic barrier islands has more than tripled, and investments are up tenfold. The reason for this rapid development is clear. People living by or visiting the coast want to be near the water's edge, and, knowingly or unknowingly, they assume a degree of risk to be there (Burton and Kates, 1965).

The purpose of this document is to summarize the current information on barrier-island dynamics and to describe some of the hazards associated with living on barrier islands. Fenwick Island is emphasized, but the characteristics outlined are indicative of other barrier islands on the Atlantic and Gulf coasts.

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Barrier islands

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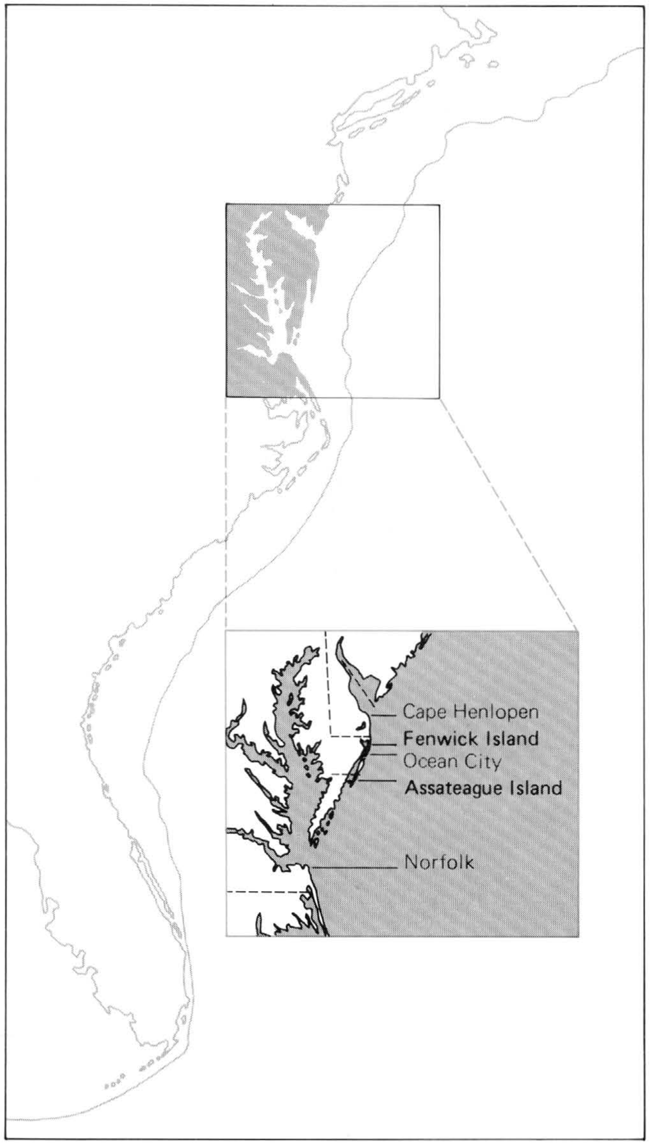

Fig. 2 *Barrier islands occur along the Atlantic coast from New England to Florida. Fenwick Island is a narrow strip of sand on the Delaware-Maryland coast.*

Barrier islands, which occur from Maine to Texas, are the primary terrestrial/marine interface along the Atlantic and Gulf coasts. They are among the most rapidly changing landscapes utilized by man. The range of physical changes that occur include those associated with tides, storms, responses to long-period trends in climate and sea level, as well as those associated with man's use of the land. Storms are especially important in changing the landscape. During storms, private property is often destroyed, communication and transportation facilities are disrupted, and lives may be lost. Despite these obvious hazards, with few exceptions development on barrier islands has been based on the concept that the landscape is stable or at least that it can be engineered to remain stable.

To marine scientists, managers, and coastal engineers, the shoreline on barrier islands has long been recognized as an element of a highly dynamic natural system. During the past several decades, there has been a net trend toward coastal recession (erosion) along the Atlantic coast. This trend has been attributed to a recent rise in sea level (Hicks and Crosby, 1975), a reduction in new sediments (Wolman, 1971), human alterations of coastal morphology (Dolan, 1972), and changes in storm frequency and magnitude (Hayden, 1975).

Barrier islands are the product of a gradually rising sea level, ample quantities of sand supplied to the coast, and waves large enough to move the sand. A continually changing relationship between storms, waves, and moving sediments produces islands that are unstable. They are unstable because the constant movement of the sand by waves and currents affects the shape of the islands, and the rising sea level results in shoreline retreat. Even though they are unstable, the estuaries and sounds that lie inland from barrier islands are among the richest and most productive ecosystems known, providing nurseries, shelter, and food for many species of fish, shellfish, and wildlife.

Because of these important characteristics, a number of barrier islands have been preserved in their undeveloped state. Nine of the most outstandingly scenic and natural islands or island groups have been set aside as national seashores by the U.S. Congress to be administered by the National Park Service, and many others are preserved as national wildlife refuges. Most of the coastal States have placed one or more barrier islands under protection as parks or wildlife refuges.

Although some barrier islands were settled during the colonial period, and others were used as sources of building materials or as coastal defense sites, Atlantic coast barrier islands did not come under development pressure until the 1900's. Recently, however, changing economic and social conditions have made development of the islands appear more economically feasible and desirable. Many people now have enough personal resources to acquire second homes, and their leisure time has also increased. Nevertheless, time has not changed the natural processes and hazards associated with the development of barrier islands. The dangers from hurricanes and severe northeasters are as great at the present time, and may be even greater, considering the larger number of people who now live on some islands.

Since 1900, 129 hurricanes have crossed our Atlantic and Gulf coasts. Fifty-three of these have been classified by the National Weather Service as "major" hurricanes, with peak winds in excess of 110 miles per hour and storm surges greater than 8 feet. The impact of some of these storms has been extreme. The two deadliest in this century killed over 6,000 people at Galveston, Texas, in 1900, and 1,800 people at Lake Okeechobee, Florida, in 1928. The two costliest storms were Hurricane Agnes, which caused \$2.1 billion in damage in the Northeastern United States in 1972, and Hurricane Camille, which caused \$1.4 billion in damage in 1969 in Mississippi and Louisiana.

Dynamic nature of barrier islands

Fig. 3 *Distribution of physical processes associated with land use and land cover zones.*

The dominant processes responsible for natural changes on barrier islands are shown in the figure, and the table gives the normal period of landscape response to these processes. An overriding factor for all of the landscape elements responding on a daily basis is the occurrence of extreme events which may cause catastrophic land alteration. In marshes, in estuaries, and on the beaches, a major oil spill or a dump of toxic pollutants can be considered an extreme event. With regard to natural processes, however, the term extreme event is generally used to indicate a storm of such magnitude that on a yearly basis it has a low expectation of recurrence.

An assessment of landscape vulnerability in terms of the frequency and magnitude of natural stress or the fragile nature of a particular land use class is presented in the table. Vulnerability of the classes indicates how susceptible unprotected structures or natural features would be to natural stresses from storms.

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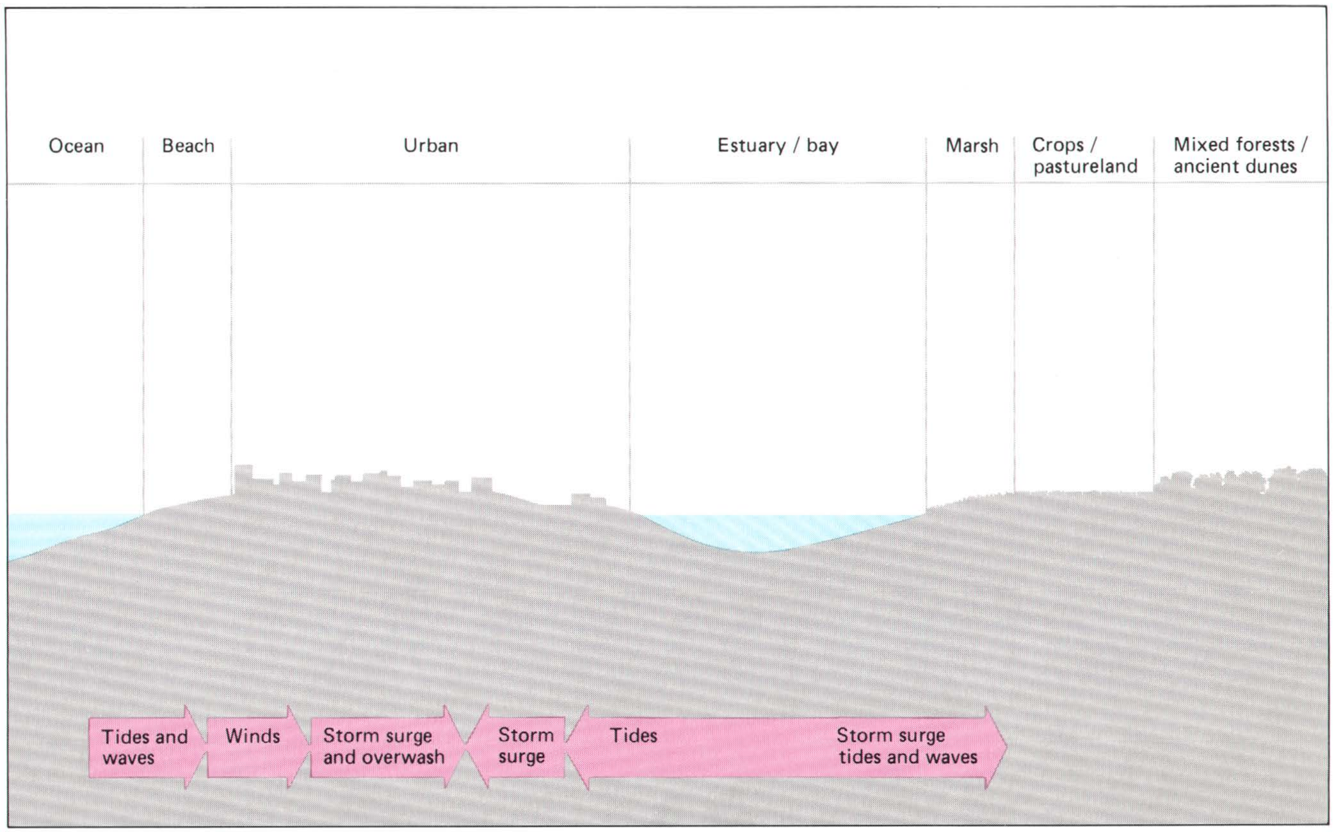

Table 1 *Dominant coastal processes associated with various land use and land cover types.*

Code	U.S.G.S. land classification	Processes and periods of response	Events causing alterations	Vulnerability
10	Urban	Episodic; storm surge	Construction; storm damage	Moderate
21	Grass and pasture lands	Surface runoff; slow trends	– – – – – – –	Low
31	Vegetated sand flats	Eolian; overwash; daily; extreme events	Storm deposition of sand; denudation	Moderate
35	Vegetated dune systems	Eolian; wave erosion (frontal); daily; extreme events	Storm erosion of dune mass; denudation	Low
43	Forests	Surface runoff; slow trends	Denudation	Low
53	Reservoirs	Siltation; slow trends	Siltation	High
54	Estuaries and bays	Tidal currents; daily	Pollution; alteration of flow patterns	Moderate
55	Fresh-water ponds	Rainfall runoff; daily	Siltation; saltwater intrusion	Moderate
61	Marshes	Biological; tidal overwash; slow trends; extreme events; daily	Overwash; deposition of sand, man-made; land fill restriction of water flux	High
62	Mudflats	Tidal; daily	Current erosion; revegetation	Moderate
72	Beaches	Waves; tides; storm waves; surge; daily (seasonally); extreme events	Storm-caused erosion; sea-level trend	Moderate
731	Dunes: unvegetated	Eolian; daily	Vegetation	
732	Sand flats: unvegetated	Eolian overwash; daily	Overwash deposition; revegetation	
750	Spoil banks	Tidal; surface runoff; daily	Revegetation; erosion	

Vulnerability high = natural changes occur frequently representing risk for development
Moderate = danger from flood or surge
Low = natural change low

Barrier island processes

The physical boundary between land and sea is in constant motion. On sandy coasts, each variation in the level of the sea alters the position of the boundary. Beach materials are always being carried offshore, onshore, and in the direction of the prevailing longshore currents. In this way, sandy coasts are constantly adjusting to different tide, wave, sediment supply, and current conditions.

Recently, the amount of sand leaving the mid-Atlantic coast, in general, has exceeded that being carried in. Periodic phases of erosion and deposition are being superimposed on a long-term trend of rising sea level, which submerges the beach, causes shoreline recession, and forces the barrier islands ever closer to the mainland.

In cross section, Fenwick Island is an assemblage of sedimentary layers, each made up of particle sizes reflective of their source and the processes responsible for their movement. The overwhelming bulk of the barrier island substrate consists of medium-sized quartz sand grains with a small percentage of heavy minerals and shell fragments. This beach material is carried and deposited by two dominant processes: by storm overwash and by currents flowing alongshore and through inlets. Interbedded within the layers of beach material are units of well-sorted finer grained sands and silts that are transported by wind or by hydraulic processes. The configuration of the island, both in cross section and plan view, is the result of both the along-the-coast and across-the-coast transport of sand. These processes remain active today.

Storms

Hurricanes and winter extratropical storms (northeasters) have been the principal causes of changes on the mid-Atlantic barrier islands since the islands formed. Change is brought about by the movement of sands from waves driven by strong winds. Both hurricanes and northeasters generate waves by the action of winds moving across the surface of the sea. The height of the waves produced is a function of the speed of the wind, the distance over the water which the wind blows (fetch), and the length of time that the wind blows across the sea surface.

Hurricanes are especially destructive when they hit a coast. The sea may rise more than 20 feet along a 50 mile stretch of the coastline (Mather and others, 1967). Records going back to the 17th century show that, although numerous storms have passed nearby, between 1693 and 1970 only three hurricanes (winds in excess of 75 miles per hour) have hit Fenwick Island. Comparative studies indicate that Fenwick and Assateague Islands and the 100 miles of coast to the north are less frequently hit by hurricanes than any other area on the U.S. Atlantic coast. Hurricanes occur most commonly in early September, but the season begins in early August and runs through October (Frank, 1974).

Unlike hurricanes, which form over the warm tropical waters of the Caribbean and North Atlantic, extratropical storms or winter northeasters develop along the weather fronts of the midlatitudes which separate cold dry polar air from warm moist tropical air. Each year between 30 and 40 such storms generate surge and waves at least 5 feet above normal. The most damaging storm to Fenwick Island in recent history was an extratropical storm that occurred in March 1962, and has become known as the Ash Wednesday Storm (U.S. Army Corps of Engineers, 1963).

The geomorphological effects of storm waves on barrier islands are frequently short lived. After a storm, for example, the beach immediately begins rebuilding to its prestorm condition. During the winter of 1977-78, however, a series of 28 northeaster storms resulted in severe erosion of Fenwick Island's coastline. By the time weather conditions improved long enough for natural beach rebuilding to take effect, so much sand had been removed from the nearshore area that complete natural rebuilding did not occur (Planning and Zoning Commission, 1978).

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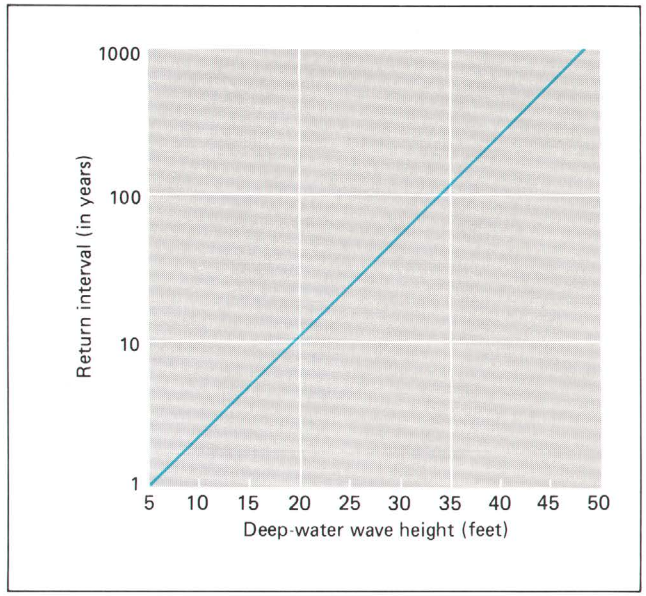

Fig. 4 *Expected return interval in years of storms producing given wave heights offshore of Fenwick Island.*

Waves

The normal deep-water wave height immediately offshore from Fenwick Island averages 3 to 5 feet. The cumulative effect of high tide, spring tide, storm surge, and stormwinds, however, can produce a wave of up to 30 feet. It is this kind of wave that overwashes the foredune line and floods the bayside of the barrier island. The most severe example of this activity in recent history occurred during the March 1962 Ash Wednesday storm (U.S. Army Corps of Engineers, 1963).

Statistics used to describe the storm and wave conditions at Ocean City are presented in graph form. The storm-return interval graph represents the frequency of occurrence of a storm which produces a given maximum wave height based on data from 1948 to 1974. For example, a storm which produces a maximum deep-water wave height

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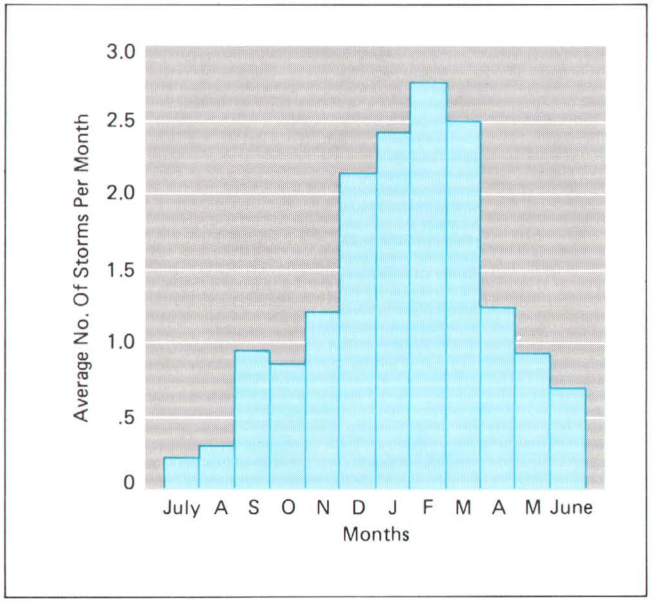

Fig. 5 *Monthly distribution of storms producing deep water waves in excess of 5 feet.*

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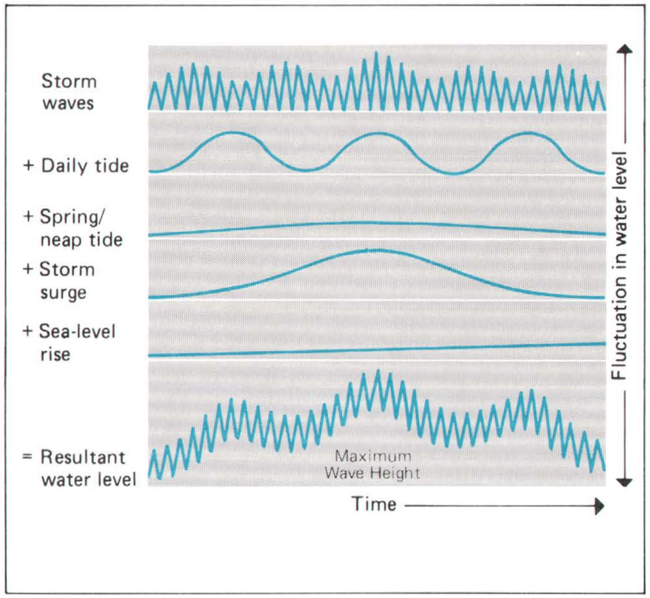

Fig. 6 *Cumulative effect of coastal processes on sea level.*

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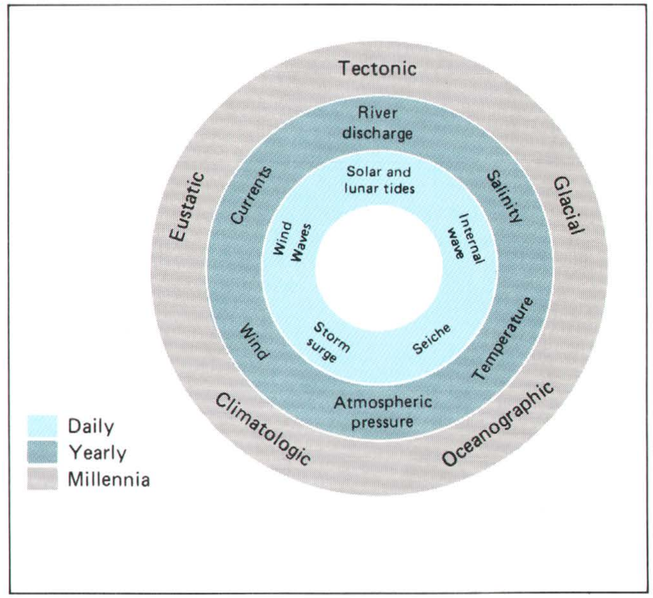

Fig. 7 *Sea level variations occur over a wide range of time intervals.*

of 25 feet offshore from Ocean City can be expected to occur every 25 years (Thompson, 1977).

The histogram of monthly distribution of storms represents the average number of storms per month that produce deep-water waves at least 5 feet high, based on 12 years of wave data from 1960 to 1972. It is evident from this plot that the stormiest months are in the winter from December through March.

Sea level

Sea level is always undergoing change, and during the present period of sea level rise the barrier islands are slowly moving towards the mainland (Kraft, 1978). Erosion along the Atlantic coast is a manifestation of this change. The barrier-island adjustment to variations in sea level occurs as gradual steps through tides, storm waves, and storm surge.

Another change in the level of the sea is caused by the constantly varying gravitational attractions associated with the Moon, Earth, and Sun. The astronomical tides along the mid-Atlantic coast are semidiurnal (12 hours and 25 minutes apart) and have an average range of 3 feet. The highest spring tides occur twice each month when the Earth, Moon, and Sun are aligned and result in an increase in tidal range of approximately 20 percent. Tidal action alone is of little significance in terms of longshore sediment transport. As storm surge and high waves are superimposed, however, the daily elevation and depression of the water level becomes important.

The tides affect man most adversely when coastal flooding occurs. Not all high tides cause flooding, nor do all coastal storms. Under certain circumstances, however, where uncommonly high tides, called perigean spring tides, coincide with strong onshore winds, the barrier islands will be flooded. The catastrophic Ash Wednesday storm of March 1962 along the mid-Atlantic coast is an example (Wood, 1978).

If sea level remained constant, and if only the waves and currents are considered in assessing shoreline erosion, the critical factor would be the amount and characteristics of the sediment (sand) available to the beach. A sandy beach can remain stable only if it receives sand at the same rate that waves and currents are removing sand. If there is a surplus of sand, the shoreline will advance seaward; if there is a deficiency, the coastline retreats landward. Coastal recession occurs, therefore, either when sediment is removed more rapidly than natural or manmade sources resupply the system, or when the level of the sea rises or the level of the land subsides.

Barrier island forms

Fig. 8 *Assateague Island was completely overwashed during the Ash Wednesday storm (northeaster) of March 1962.*

Fig. 9 *Inlet cut through Assateague Island during the Ash Wednesday storm of March 1962.*

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Continuous changes in sea level, wave action, storm surge, and sediment supply lead to rapid changes in barrier island configuration. Three classes of sand movement are responsible for most of the geomorphological forms of barrier islands. These are sand movement along the shore, across the shore, and eolian or wind-blown movement in various directions.

1. Movement along the shore: Waves approaching the coast at an angle set up sand-transporting processes along the coast termed "longshore currents." The direction and strength of the currents depend on wave heights and wave directions. Over the course of a year, however, there is usually a net flow of water and sediment in one direction. In the case of Fenwick Island, this direction is to the south.
   Atlantic coast barrier-island shorelines are seldom long and straight, when viewed in plan, but rather are sinuous in form. Some of the along-the-shore variation is in the form of organized crescentic patterns ranging in size from beach cusps (30-300 feet) to very large shoreline arcs (1-200 miles). The smaller features appear, disappear, and may migrate along the shoreline; the larger ones establish the pattern for along-the-shore processes, including the distribution of erosion and storm surge (Dolan and others, 1977).

2. Movement across the shore: During storms, waves and tides may combine to elevate water levels so high that the beach is breached and water and sediment move across the island. This process is called overwashing. Beach sediment may also be transported offshore by surf-zone processes and deposited or transported by longshore currents to other sections of the coast. Inlets and overwash provide a means for the movement of sediment from the beach zone to the baysides of the barrier islands.
   Inlets form when storm surge and high waves drive water across the barrier islands to the lower water levels of the sounds. As the seawater moves across the island, usually in areas of lower topography, channels (inlets) form and may erode to depths that permit a reverse flow (sound to sea) at low tide. Most inlets are temporary features of elevated water levels and last but a few days. The geological and ecological significance of inlet formation is considerable. The process results in the movement of great quantities of saline water and sediment from the ocean sides of the islands to the sound sides. The water contains nutrients and organisms, and the sediment forms shoals that provide new substrates for marsh grasses. Soon after the inlets close, shoal areas become incorporated into the island substrate. Inlet formation and closure is, therefore, one of the fundamental sediment transfer processes that move material from the ocean sides of the barrier islands to the fringing sound sides.

3. Movement by wind: Sands on the beach face, sand flats, and dunes can be transported across and along the islands by strong winds. All of the mid-Atlantic coast barrier islands have dunes of various sizes landward of the beaches. Most of the dune sand is transported across the beach face, the backshore, and then deposited within the overwash flats and vegetated zones. The wind speed necessary to initiate sand movement is in the 15 to 25 miles per hour range, depending on the sand grain size. Most of the dunes on Fenwick Island are low (less than 7 feet) in height and small in area.

Geological history of Fenwick Island

Fig. 10 *Map of the United States showing relative position of the shoreline 12,000 years ago.*
Fig. 11 *Sea level variation over the past 35,000 years.*

Fig. 12 *Sea level changes and coastal configurations over the past 12,000 years.*

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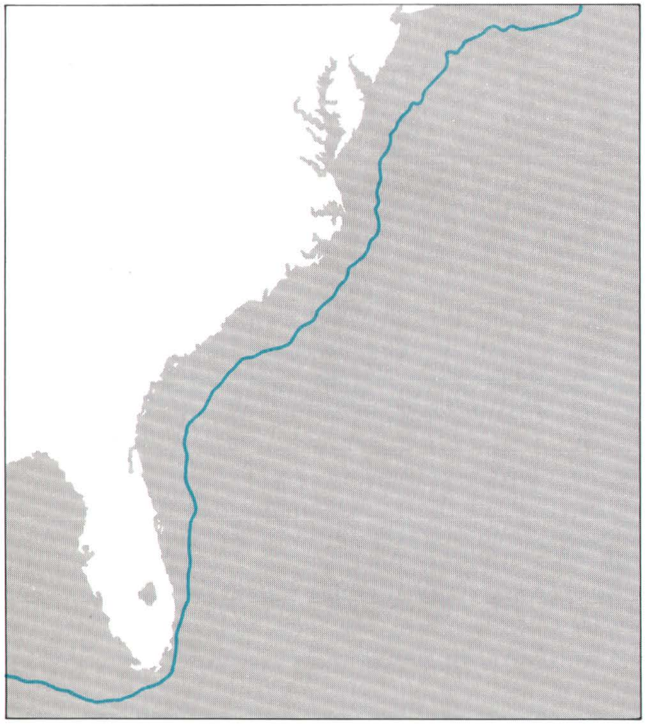

Many lines of evidence have established that sea level has oscillated several times during the past half million years. During the warmer interglacial periods, continental glaciers melted, and the shorelines of the ocean basins retreated inland across the continental shelves. During the cooler glacial periods, water was withdrawn from the seas and stored in the form of glacial ice, and the shorelines advanced seaward. The process involved great quantities of seawater, enough to lower the level of the sea over 400 feet.

The last era of major water withdrawal, the Wisconsin glacial period, began about 35,000 years ago and ended about 12,000 years ago. As the Wisconsin came to an end, sea level was approximately 350 feet lower than it is today, and the shoreline of Maryland and Delaware was about 100 miles east of Ocean City.

With the change from the glacial to the interglacial period about 12,000 years ago, the sea started to rise and continued to rise for about 8,000 years. It reached to within several feet of the present level approximately 4,000 years ago (Kraft, 1971).

As the level of the sea rose and the shore zone of the Atlantic coast moved across the Continental Shelf, a large mass of sand was moved landward along with the shoreline in the form of a broad beach deposit. Additional sediment, in deltas and terraces in the vicinity of the large river mouths, was reworked by wave actions, and the sediment was moved along the coast.

Once sea level stabilized about 4,000 years ago, waves, currents, and winds, working together on the sand surpluses, formed the barrier islands of the Atlantic coast. As long as the inshore zone contained a surplus of sediment, the barrier islands built seaward until an equilibrium was established. Equilibrium in the case of barrier islands is a function of wave energy, sea level, and the amount of sediment to be moved.

Based upon evidence and radiocarbon dates, the period of progradation, or island growth, continued to about 2,000 years ago. At that time, the barrier islands were much wider, perhaps as much as a mile or so, and although sea level has remained fairly stable, a rise of 5 feet or more has occurred since then (Kraft, 1971).

The slow upward adjustment of sea level has resulted in the progressive recession of the shorelines and enlargement of the bays and sounds. The rise in sea level between 1900 and 1974 has been very rapid, totaling almost 1 foot (Hicks and Crosby, 1975).

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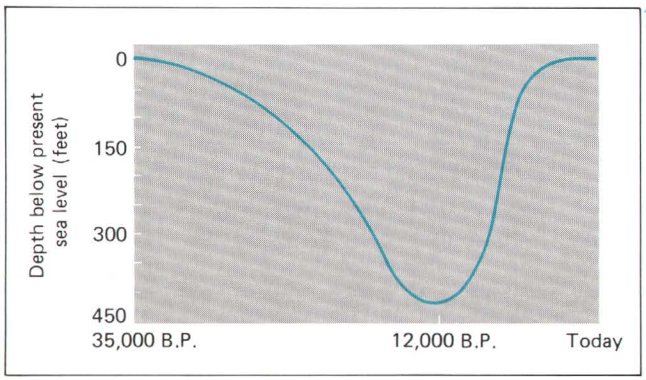

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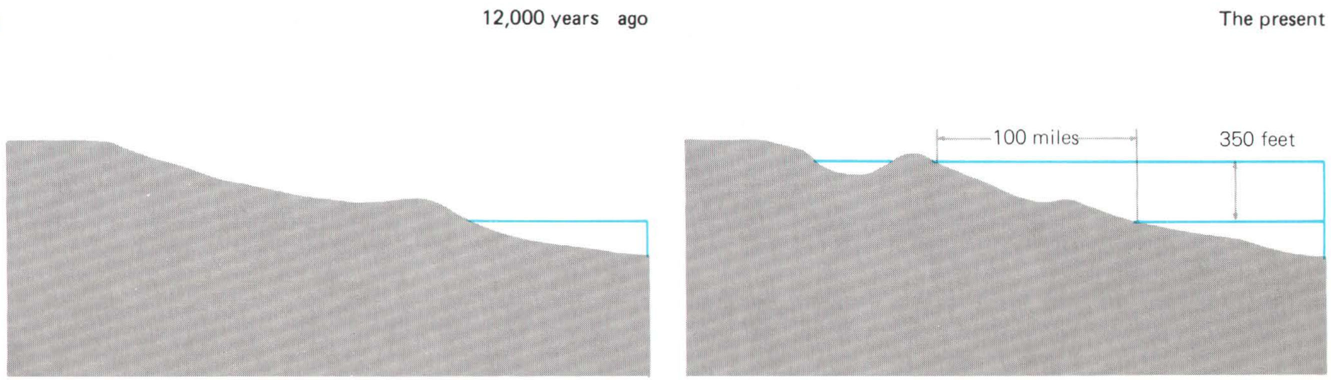

History and development of Fenwick Island

Fig. 13 *During the late 1800's most visitors reached Ocean City by train. Resort facilities were limited.*
Fig. 14 *By 1920 the boardwalk was developed fronted by a primitive sea wall. Several large hotels were constructed just inland from the beach.*
Fig. 15 *Today the trend continues, with development still dangerously close to the water's edge.*

The first known explorer to visit the Maryland seashore was the Italian, Giovanni da Verrazano, who sailed into Chincoteague Bay under a French charter issued by King Francis I in 1524. The British writer and explorer, Henry Norwood, was shipwrecked on Fenwick Island in 1649. In the early Colonial years, the principal use of the Maryland barrier island was as pasture for livestock. Properties on the barrier island did not prosper, though, and after a short succession of owners most of the area became vacant because of the limited arable soil and limited freshwater for domestic animals. Some animals were, however, able to survive the rigors of the environment. After ownership and tax payments ceased, public grazing became common (Truitt and Les Calette, 1964).

The livestock activities on the barrier island did not encourage settlement, although salvaging cargoes from shipwrecks encouraged a limited number of settlers. Starting with squatters, small communities developed very slowly. The market in the 1830's for local oysters, clams, diamondback terrapin, and waterfowl encouraged further settlement on Pope Island, Green Run, and North Beach. Development of Fenwick Island and Ocean City started in the 1870's (Truitt and Les Calette, 1964).

Ocean City has been a recreational area for over a hundred years. In 1872 several Worcester County people and some Baltimore businessmen joined to form the Sinepuxent Beach Corporation to promote a resort at what was to become Ocean City. In fact, the original name for Ocean City was Sinepuxent Beach. The corporation proceeded to build the Atlantic Hotel, a large structure for its time, which was opened in 1875. The opening of the hotel, and the extension of the railroad from Berlin, Maryland, to the shore directly across from Ocean City in 1872 marked the beginning of the community as an important coastal resort. The railroad was extended across Sinepuxent Bay in 1878 (Truitt and Les Calette, 1964).

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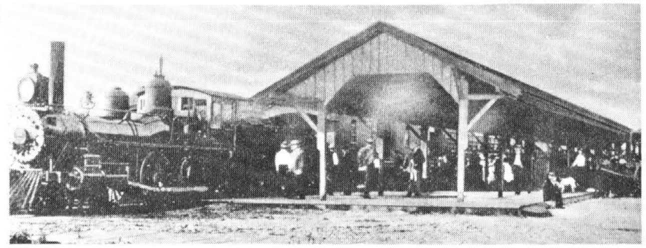

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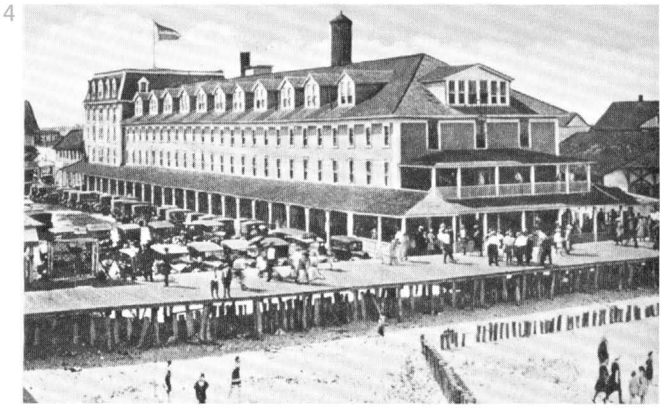

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Fig. 16 *Extent of urban or built-up development on Fenwick Island, 1901-72.*

Ocean City remained a small resort community, however, until after World War II. The five maps on this page show a 70-year period of the growth of Ocean City into a major seaside resort.

Starting from the small town center on the southern end of the present island, development in Ocean City has progressed northward toward the Delaware State line. Development along the bayside portion of the island has been curtailed by the establishment of a bulkhead line in 1965 and by the Wetlands Act of 1972. Most of the developable land in Ocean City is, therefore, limited to the existing vacant lands located in the northern part of the city.

The permanent residential population of Ocean City has always been relatively small. According to a 1975 estimate, the permanent population was 4,000 (Planning and Zoning Commission, 1978). As recently as 1960, the official population was only 983. The permanent residential population figures do not, however, accurately reflect the impact of urban development on the island. Recent estimates indicate that the peak weekend summer visitor population exceeds 200,000. Since 1970, many new condominiums and apartment buildings have been constructed to accommodate the summer population surges. Of 26,663 potential housing units for Ocean City in 1974, over 75 percent included hotel, motel, apartment and condominium units. Only 1,400 units (less than 7 percent) were single family dwellings, and these housed most of the permanent population (Planning and Zoning Commission, 1978).

Ocean City has been hit by three major storms this century: the 1902 hurricane, the "great" hurricane of 1933, and the winter Ash Wednesday northeast storm of 1962. In 1902, the Congress Hall Hotel was badly damaged, even though the center of the storm was well out to sea. The winds during the 1933 hurricane were estimated at 100 miles per hour, and waves 20 feet high. The most significant impact of the storm was the opening of Ocean City Inlet. Although this inlet very likely would have closed naturally within a year, the U.S. Army Corps of Engineers has maintained the inlet since 1933 in order to provide boat access to the bay. While maintenance of Ocean City Inlet has benefits, serious erosion problems have resulted on Assateague Island to the south of the inlet (Dean and Perlin, 1977).

The greatest storm damage in the history of Ocean City was caused by the Ash Wednesday northeast storm of March 1962. Water covered much of Fenwick Island for two days at depths of up to eight feet. Total damage to Ocean City was estimated at $7.5 million. Although 150 businesses and over 50 homes and apartments were damaged or destroyed, rebuilding commenced almost immediately after the storm (U.S. Army Corps of Engineers, 1963).

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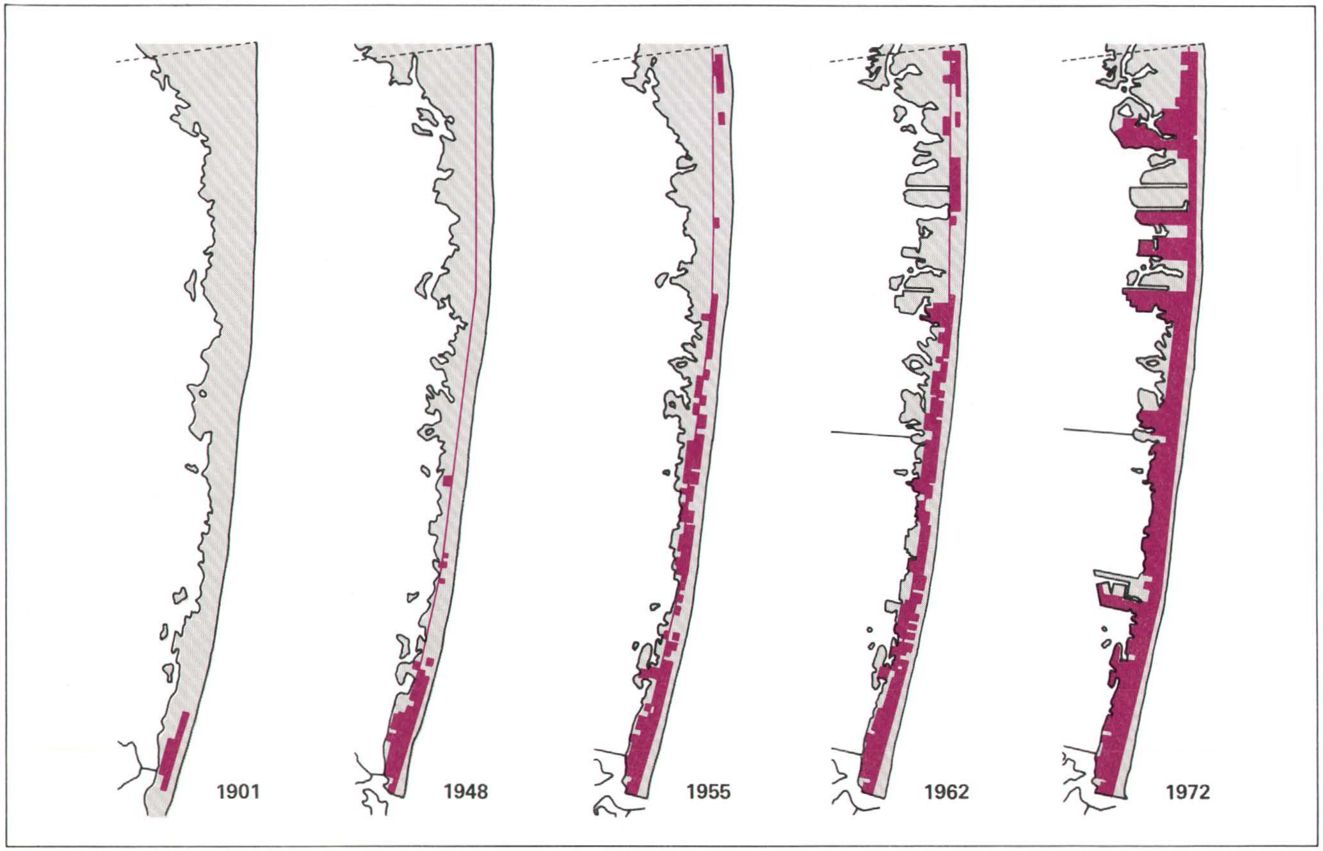

Recent land use patterns and trends

Fig. 17 *Land use and land cover of Fenwick Island and adjacent land areas.*

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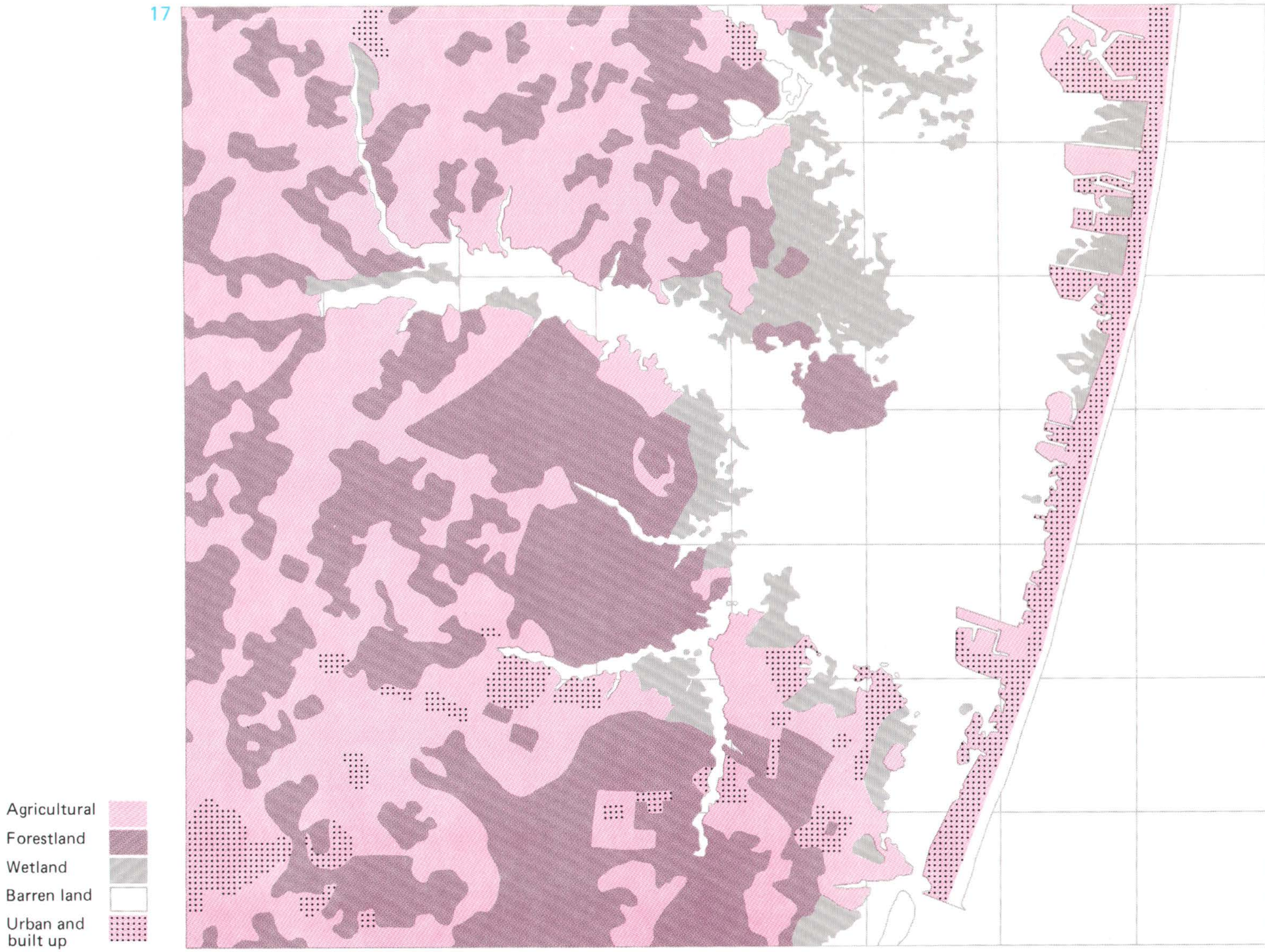

Fig. 18 *Recent development along the shorefront of Ocean City.*

Fig. 19 *The dashed line on this 1978 photo approximates the storm surge penetration distance during the Ash Wednesday storm of March 1962.*

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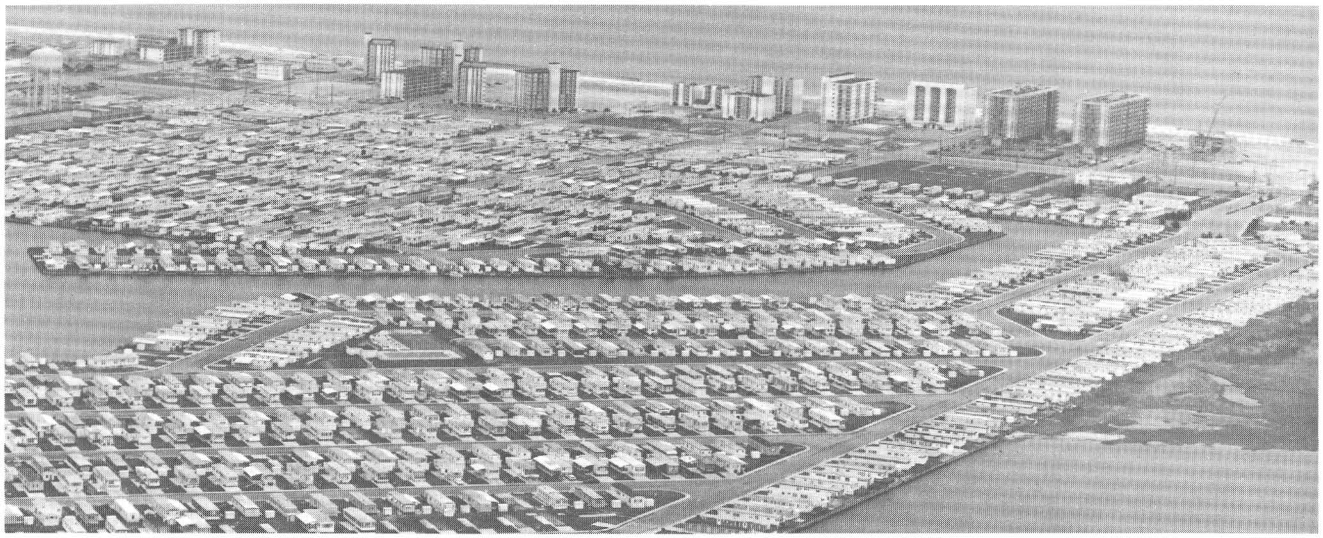

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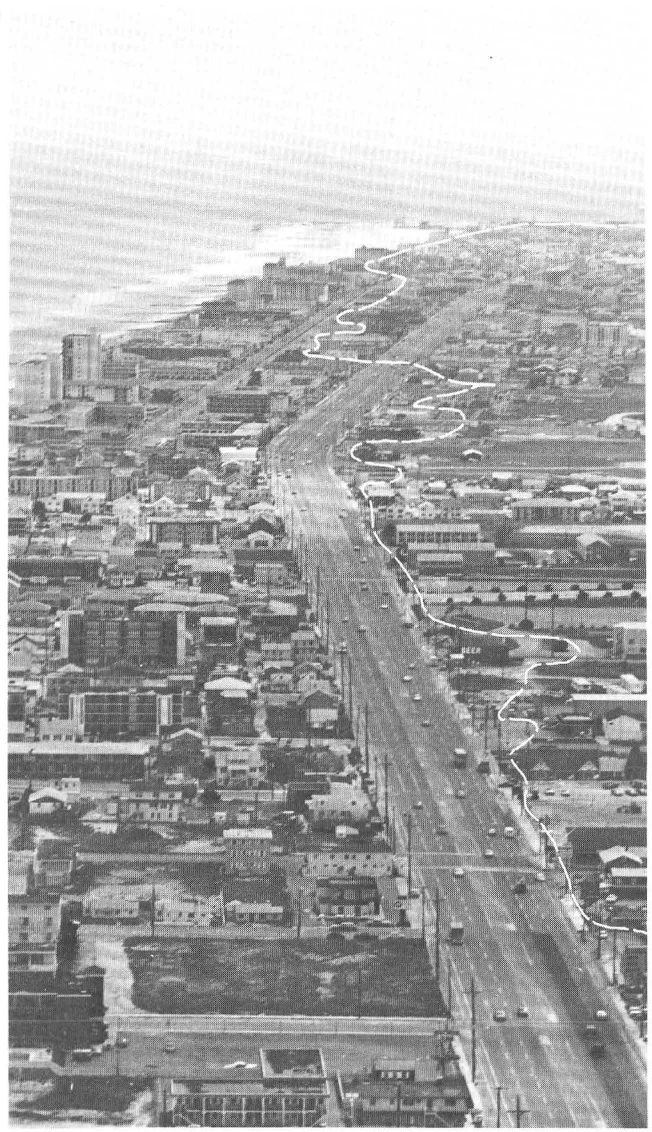

In recent years, increased urbanization has dominated the Fenwick Island landscape. For example, between 1950 and 1972 the area of urban land more than doubled, increasing more than 1,000 acres. Most of this increase occurred at the expense of wetland, which decreased by 950 acres during the same period (Lins, 1979).

Although the primary reasons for this rapid development was the aesthetic and recreational appeal of the area, much of this development was influenced by the transportation system. The most significant transportation factor was the Chesapeake Bay Bridge, connecting Sandy Point (on the western shore) with Kent Island (on the eastern shore), which opened in 1952. Before the opening of this bridge, the trip to Fenwick Island from Baltimore or Washington, via a ferry, took 3 to 4 hours. After the bridge opened, the travel time was reduced to 2.5 hours, which made the drive to Fenwick Island more appealing to more people. Also, as the population became more affluent, more money was available for recreation and investment. This condition fostered the acceleration of second home and condominium development during the 1960's and 1970's.

Recent development of the Atlantic coast barrier islands has been inversely related to the hazards characteristic of the shoreline. The most intense developments have been located close to the sea, while more stable areas on many islands have remained undeveloped. This inversion stems from man's desire to be near the water's edge, even when this location introduces a degree of risk. The waterfront development in Ocean City is indicative of this trend. Most of the larger buildings shown on the photograph have been constructed since 1970. The mobile home parks are also mostly post-1970. Together, these developments represent a capital expenditure in excess of $100 million (Planning and Zoning Commission, 1978). Most of this land is within the storm-surge penetration zone of the March 1962 northeast storm.

Fig. 20 *This aerial photo was taken on March 15, 1962, one week following the Great Atlantic Storm of March 7. The lightly colored areas are sand deposits that were washed over Fenwick Island during the March 7 storm surge. Some buildings were damaged by flood waters. Many were destroyed by the storm surge.*

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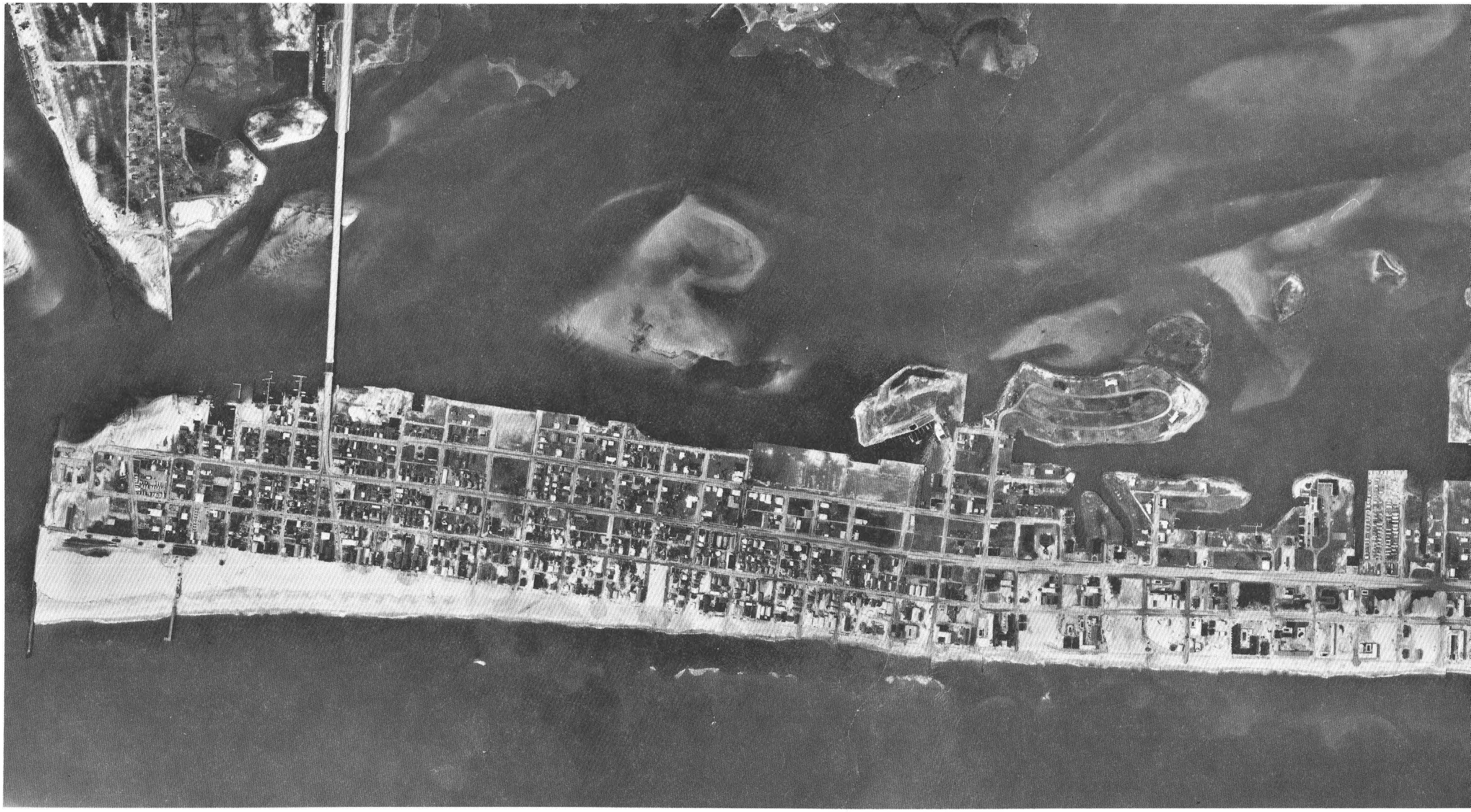

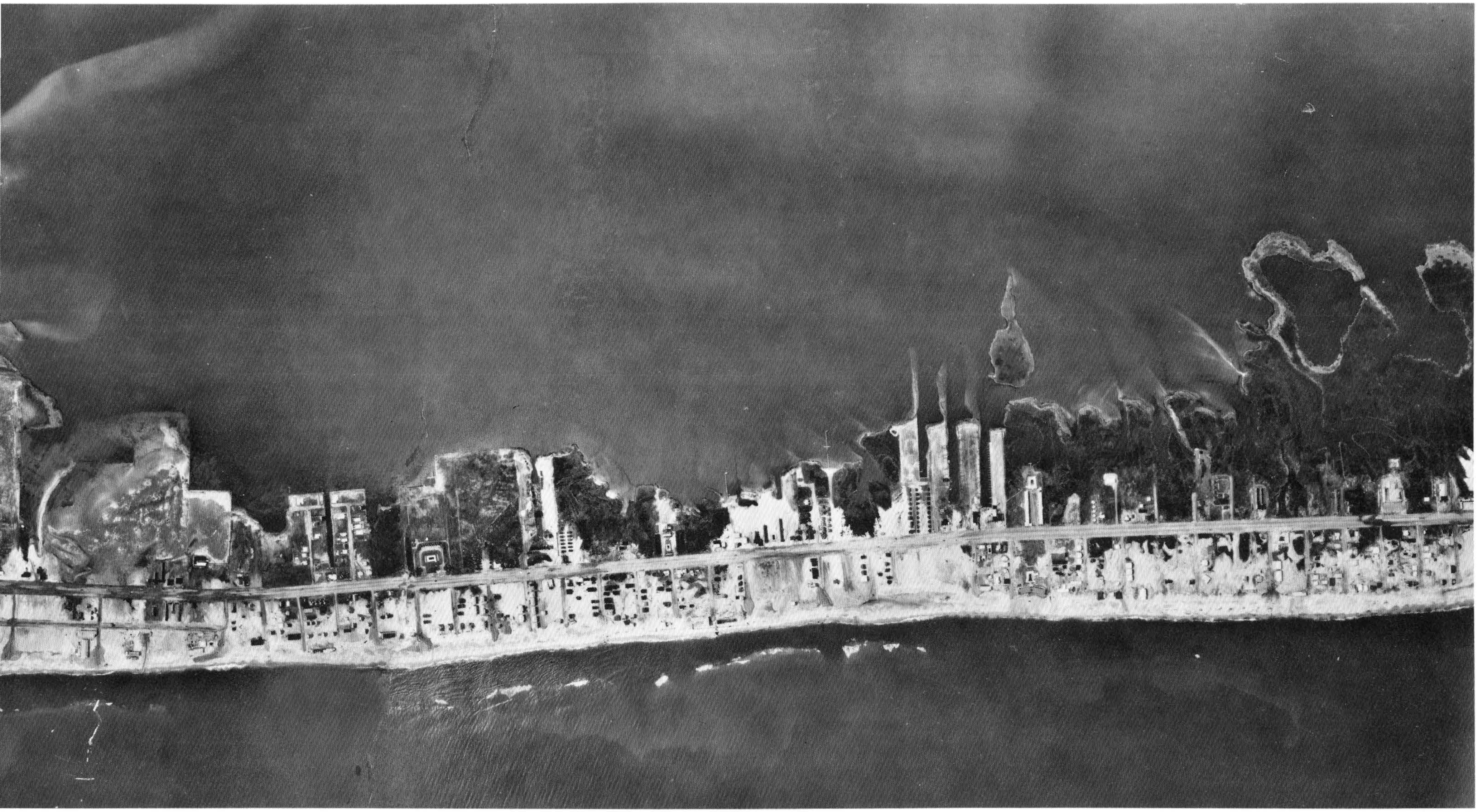

Erosion and storm surge penetration on Fenwick Island

Fig. 21 *These data strips permit rapid visual assessment of shoreline stability along Fenwick Island. Serious erosion problems start 4 miles north of Ocean City Inlet and continue on to the Maryland-Delaware border.*

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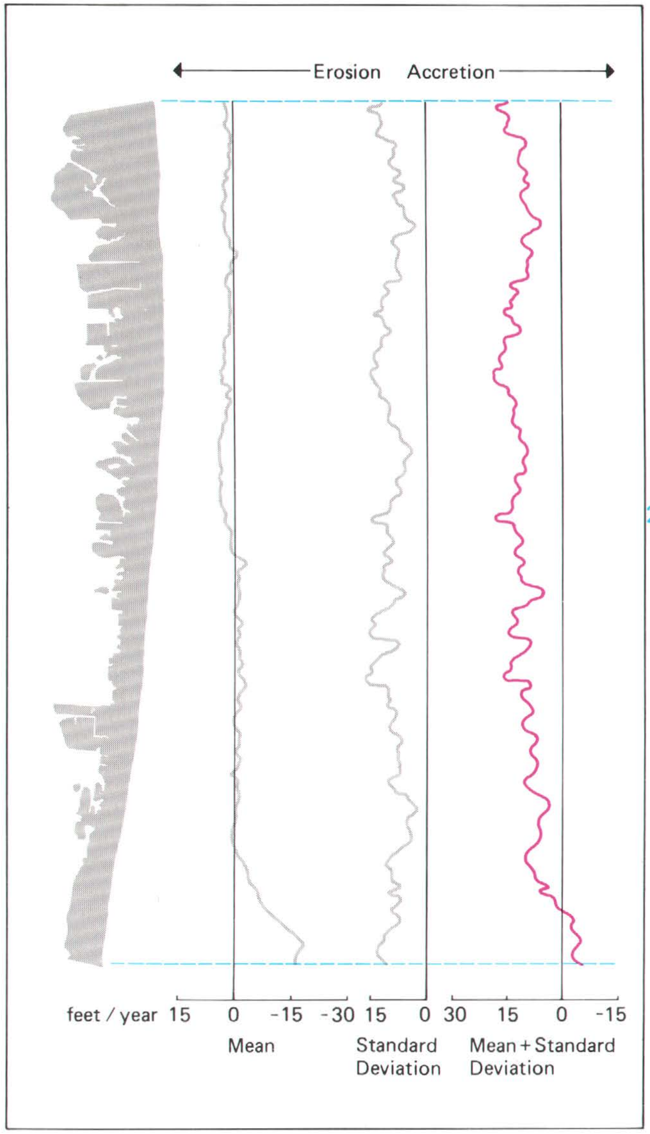

The entire Atlantic coast is one of the Nation's most dynamic environments. Extratropical and tropical storms generate waves and surge that frequently alter the coast. During the past several decades, there has been a net trend toward coastline recession (erosion) (Dolan and others, 1979). This trend has been attributed to a recent rise in sea level, a reduction in the amount of new sediment reaching the coast, human alterations of the coast, and long-term changes in storm frequencies and magnitudes. Changes along Fenwick Island are typical for the Atlantic coast. The average rate of recession is about two feet per year for the period 1938 to 1974 (Dolan and others, 1979).

Erosion

Coastal erosion and deposition are functions of three interrelated factors: (1) the amount and kind of sediment within a coastal area, (2) the power of the erosional forces, and (3) the stability of sea level. The shoreline recedes when the forces of erosion exceed the amount of sediment supplied to the system. The greater the deficiency of sand, or the higher the wave forces, the more rapid the rate of erosion. Any of the three factors (energy, sediment, or sea level) can vary through time and change the balance. Beach erosion is, however, a natural process and becomes a problem only when man's structures are placed in the path of shoreline recession.

Changes in the shoreline at any point can be measured from a sequence of aerial photographs and expressed in terms of average rate of change and the variation of the averages over the time span of the photographs. The sum of

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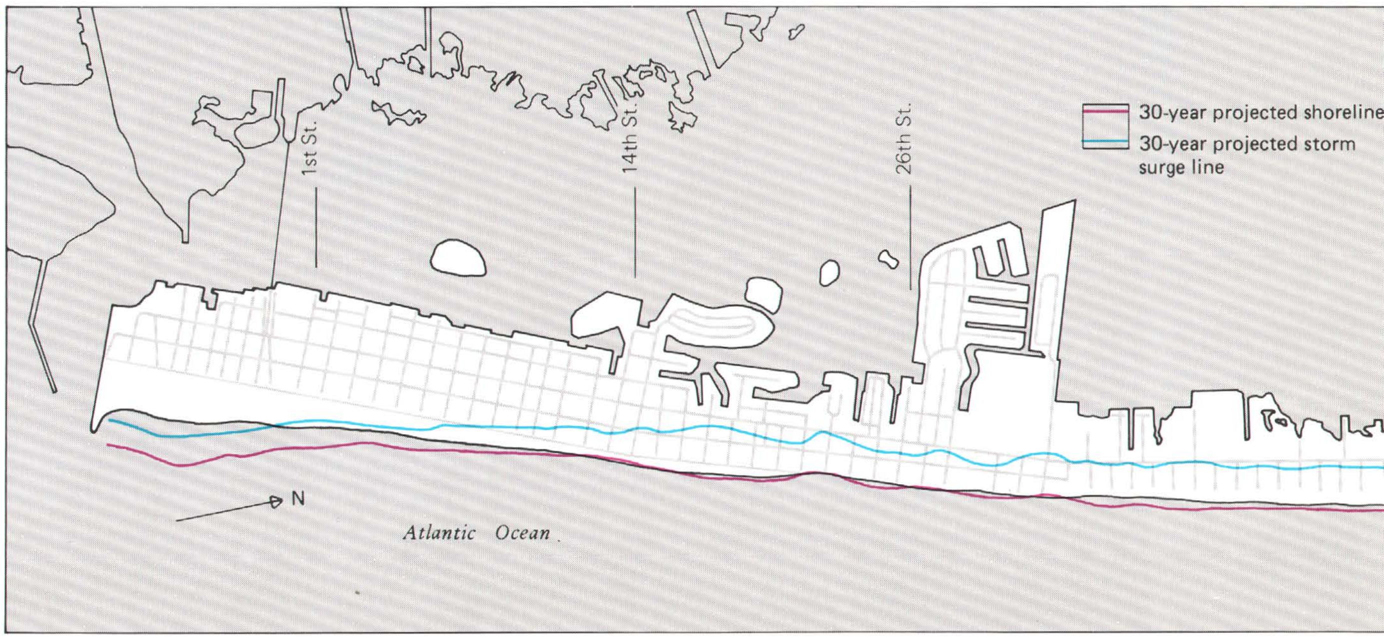


Fig. 22 *Predicted location of the shoreline and storm surge penetration line for 30 years in the future.*

these two measures is a good indication of the vulnerability or stability of the barrier island. The maps presented here allow visual assessment of shoreline stability.

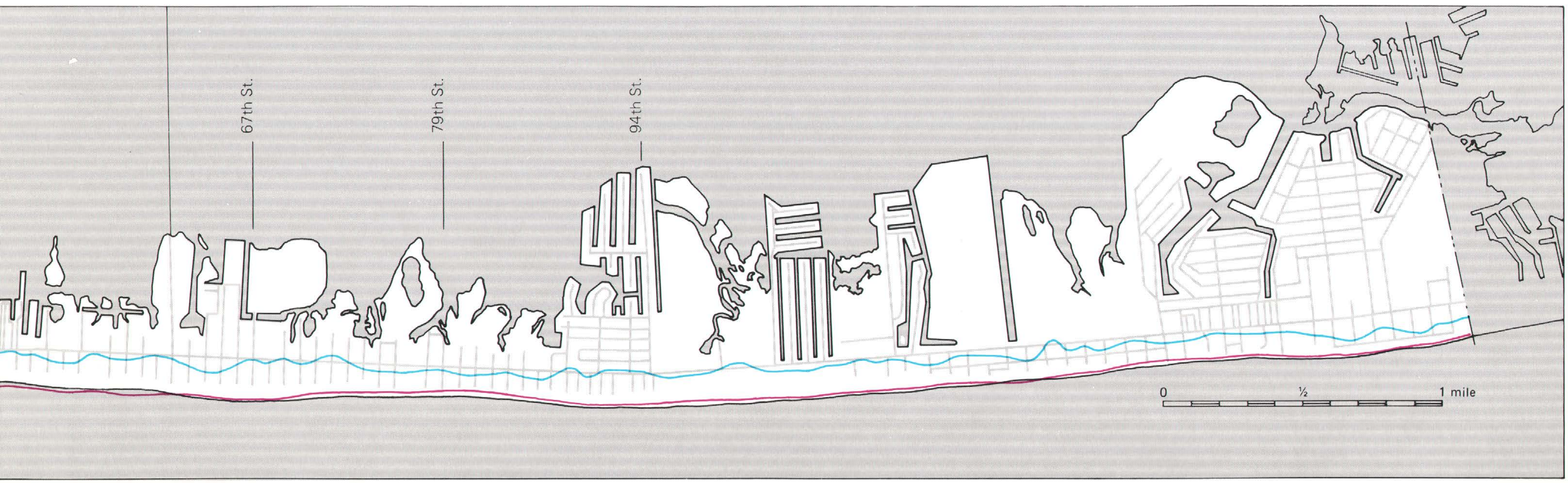
Storm surge penetration

Hurricanes and severe winter storms are responsible for frequent and sometimes dramatic landscape modification along the Atlantic coast. In addition to the physical and ecological changes, private land holdings are destroyed, communication and transportation facilities are disrupted, and the loss of life is not uncommon.

During periods of extreme storm activity (high waves and/or storm surge) low-lying coastal areas may be flooded and overwashed by seawater. The overwash is a bore of highly turbulent, sediment-laden water which moves across the beach and penetrates inland to more stable portions of the islands. As this bore moves inland, its velocity is reduced so that at some point it can no longer transport sediments. Thus a zone of sediment deposition is produced between the beach and the line of inland penetration of the bore. The overwash process occurs about once every year or two on the undeveloped (natural state) barrier islands of the mid-Atlantic region. The larger the storm, the greater the volume of water that overtops the beach and the greater the distance of penetration.

Overwashing has been described by Godfrey and Godfrey (1973) as a "constructive" process on natural barrier islands in that it results in deposition of sediment; however, overwashing can also be described as a "destructive" process in that it represents a major threat to developed property. During the March 1962 northeaster, the bore of overwash was so large in places that more than $500 million of property was destroyed between Cape Hatteras and Cape Cod (U.S. Army Corps of Engineers, 1963).

These illustrations show the predicted width of the storm surge penetration zone for 30 years into the future. Although the risk of ocean front flooding and storm surge damage decreases inland from the seashore, the shoreline is not a fixed feature of the coast. Recession and accretion occur throughout the year as the beach responds to waves, tides, and sea level changes, so the distance, and therefore the hazard, changes through time. The 30-year storm surge penetration zone presented here has been adjusted according to the past trends of the shoreline erosion (Dolan and others, 1977).



Alteration of the sediment transport processes on barrier islands, in an effort to provide a more stable landscape, has a profound effect on the geological and ecological processes. For example, by inhibiting overwash and concentrating wind-blown sands in the form of artificially created dunes, man alters overwash channels, changes vegetation communities, and interferes with landward migration of the islands. Also, by inhibiting longshore currents by constructing groins, the shoreline on the upcurrent side of a groin accretes while that on the downcurrent side erodes. Finally, by constructing roads, parking lots, and campgrounds, sediment processes are altered, freshwater runoff is changed, different types of plant communities develop, and animal habitats are altered.

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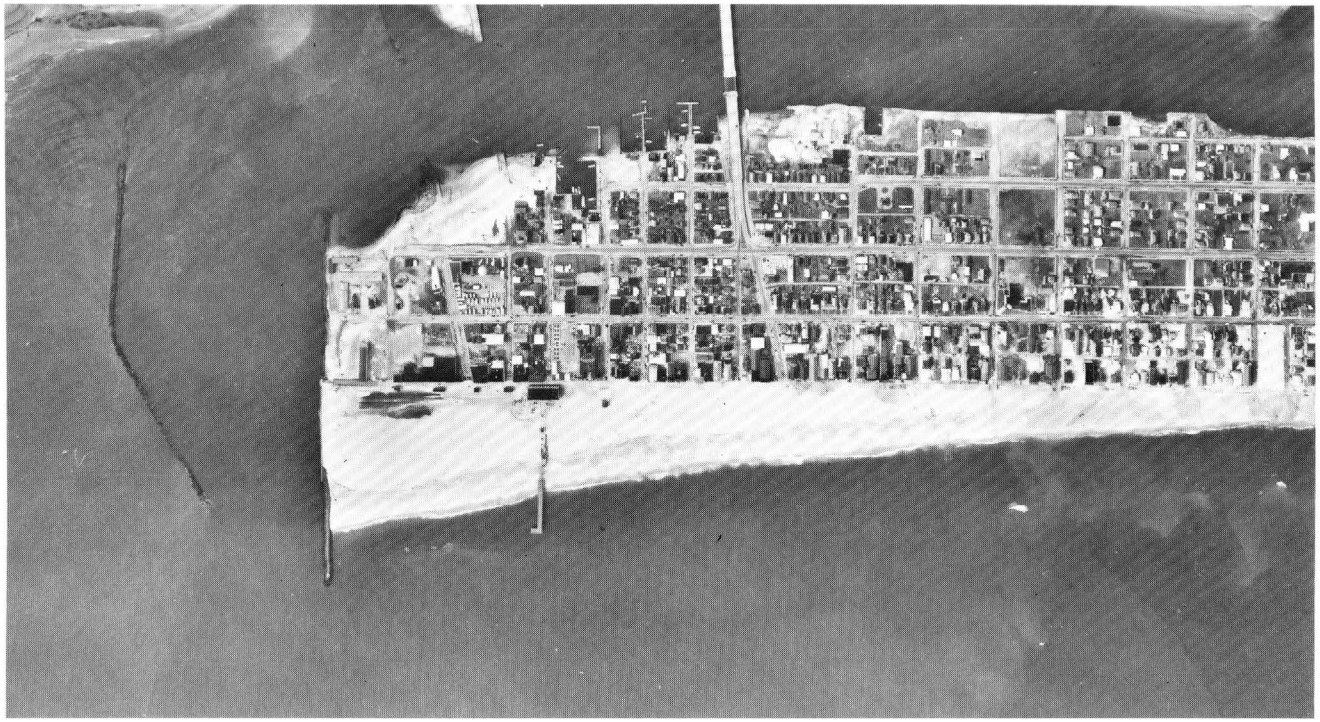

Fig. 23 *Jetties at Ocean City Inlet.*

Erosion control

As indicated earlier, the barrier islands recede when forces of erosion exceed the amount of sediment supplied to the beach. The greater the deficiency of sediment or the higher the wave forces (energy), the more rapid the rate of erosion. Any of the three factors – wave energy, sediment, or sea level – can vary and change the balance between erosion or deposition. Along the mid-Atlantic coast, wave energy ranges from modest to high, the sediment supply is mostly deficient, and sea level continues to rise. Unfortunately, all of these are factors that contribute to shoreline erosion.

Shoreline protection measures can be summarized under three categories. Protection designed to: (1) inhibit direct attack by waves, such as seawalls, bulkheads, and revetments; (2) inhibit currents that transport sand, such as groins and jetties; and (3) artificially nourish beaches.

Seawalls. A seawall is designed to absorb and reflect wave energy as well as elevate the land area behind the seawall above the high-water line. However, seawalls, bulkheads, and revetments do not prevent the loss of sand from in front of the structure. In fact, seawalls commonly accelerate the loss of sand as the wall deflects the wave forces downward into the beach deposit. Seawalls have not been used in erosion control on Fenwick Island.

Groins. Groins are obstructions placed in the path of the longshore currents for the purpose of trapping littoral drift. These structures work only when (1) littoral drift sediment is of a significant volume; (2) the material is at least sand size; and (3) the land down the beach from the groin is considered expendable. The reason for the latter is that groins trap sand, and the sand gained at one place must be lost to another. Beach replenishment is commonly needed to fill or refill the groin compartments as the sands are lost.

Beach nourishment. For more than a century, coastal structures, including jetties, groins, and seawalls, have been built in the inshore zone in an effort to trap sand and protect beaches. In general, these structures collectively have aggravated problems rather than resulted in solutions. Artificial beach nourishment, on the other hand, has long been considered the most desirable method of protection because:

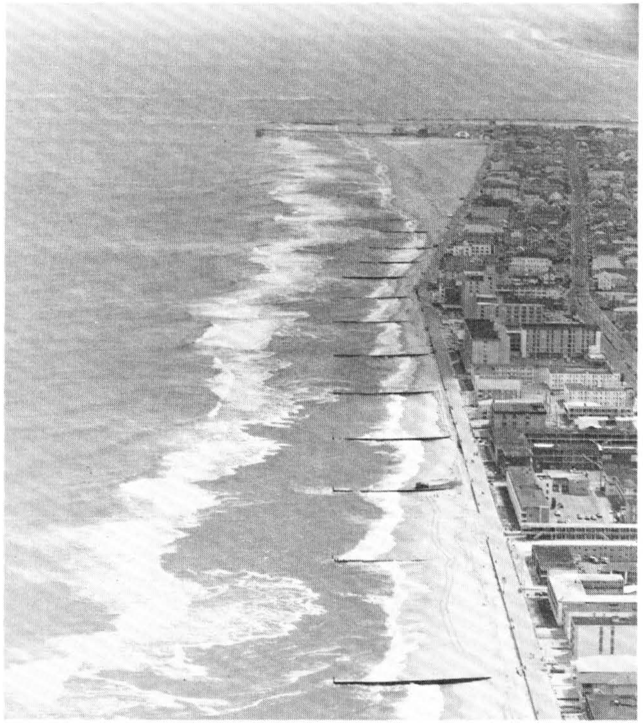

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Fig. 24 *Groin field along Fenwick Island.*

1. Placement of sand on a beach does not alter the suitability of the system for recreation;
2. Nourishment cannot adversely affect areas beyond the problem area; and
3. If the design fails, the results of the "engineering" are soon dissipated.

Perhaps the major disadvantage to artificial nourishment is that great quantities of sand of suitable quality (type and size) often are not readily available. In the past, sands were dredged from sounds and bays or transported from inland sources. With the recent concern about estuarine ecology, and because sediments in the bays behind barrier islands are generally too fine to be effective as beach nourishment, estuarine and bay sources are now less desirable. The only future prospect for large quantities of sand for nourishment purposes appears to be offshore sources and materials dredged from the coastal inlets. In fact, the U.S. Army Corps of Engineers has developed a shoreline protection plan for Fenwick Island that calls for a large initial nourishment project from an offshore source area, followed by annual re-nourishment of 100,000 to 200,000 yards^3 (Planning and Zoning Commission, 1978).

Ocean City has attempted to rebuild its beaches by artifically bulldozing sand from the inshore zone onto the beach face and berm. The idea of moving sand from the submerged inshore zone to the subaerial part of the beach may seem an attractive solution to beach erosion. The fundamental problem in pursuing this method is that the inshore-beach face profile is always in a quasi-equilibrium state, as a result of wave and tidal action. A change in one section of the profile leads to an immediate adjustment in other sections of the profile. The excavations in the inshore zone made by bulldozers at Ocean City immediately begin to fill in with sands transported by wave action from the beach face and the near-shore zone.

Ocean City Inlet

During fair-weather conditions at Fenwick Island, especially in the summer, there is a slow persistent movement of sand to the north in response to prevailing southeast waves. During storms predominantly in the winter months, northeast waves prevail, and the longshore current is southward. Thus, on an annual basis, a quasi-equilibrium is established between northward drift and southward drift, with a net movement of approximately 20,000 yards^3 of sand to the south (Dean and Perlin, 1977). Any engineering structure placed within the stream of the longshore currents will tend to disturb this system. For example, the installation of jetties at the Ocean City Inlet in the 1930's has resulted in a large triangular beach at the south end of Fenwick Island because of a combination of a net southerly longshore current and the jetty on the north shore of the inlet. Furthermore, entrapment of sediment by the jetty has hastened the erosion of the northern end of Assateague Island.

25

Fig. 25 *Use of bulldozers is a unique form of shoreline engineering.*

Hazards on barrier islands

Fig. 26 *The distances between these buildings and the shoreline leaves little room for natural processes during storms.*

Two of the most important issues to consider in barrier 26
island planning and management are the hazards associated with erosion and storm surge. With continuation of the current trend in long-term sea level rise and the frequent impact of storm waves and surges, barrier islands move toward the mainland. The rate of movement for Fenwick Island over the last four decades has averaged about 2 feet a year. There is nothing to indicate that the natural processes which have been forcing the barrier islands toward the mainland for many decades will change in the near future. On the basis of 20 to 40 years of shoreline–change data along the entire island, we can attempt to forecast what Fenwick Island may look like in another 25 years if historical trends continue.

This table shows the rates of shoreline erosion for Fenwick Island for the period 1940 to 1980. It can be seen from these data that the shoreline 4 miles north of the Ocean City jetties has built out into the sea as sand was trapped by the jetties. For the next 8 miles, the shoreline has receded (eroded) landward at rates averaging about 2.0 feet per year.

The complex patterns of barrier island dynamics preclude simple rule-of-thumb management guidelines. Charts and maps showing vulnerability to extreme storms, the persistent rise in sea level, and projections of island conditions into the future are among the most essential information needs (Vesper, 1964). These data should be continuously updated through a systematic monitoring program that includes both remote sensing and fieldwork. Only through this method can changes in nature's long-term trends in environmental dynamics be identified and appropriate management decisions be implemented.

Change in the shoreline at any point (landward or seaward) can be measured in terms of mean rate of change (long-term trend) and standard deviation of rate of change (periodic fluctuation). The sum of these two measures is one of the best indications of the hazards and vulnerability or stability of the shoreline. The graphs on pages 16 and 17 are designed for visual assessment of shoreline stability along the coast of Fenwick Island. More important than the absolute magnitudes of erosion is the capacity to compare relative magnitudes of erosion from point to point and area to area. The figures on pages 16 and 17 present means and standard deviations of shoreline rate of change for selected areas on Fenwick Island. These illustrations show that the rate of change is highly variable.

Development on Fenwick Island should take into consideration the hazards associated with erosion and storm surge. Funds spent for beach restoration and flood insurance should be spent so as not to encourage development in areas prone to flooding and erosion damage. Additional studies are underway to provide a thorough assessment of the erosion problem and possible shoreline protection measures. This will enable local land use managers to develop a coastal zone plan for eastern Worcester County which will provide for the protection of landowners and the long-term economic well-being of the community.

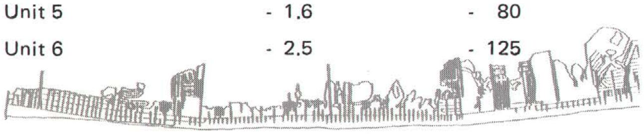
In an attempt to control development in the most hazardous areas, the Maryland State Legislature created the Beach Erosion Control District (BECD) in July 1975. The BECD includes a building limit line which more or less coincides with the west crest of the existing natural dune line on Assateague and Fenwick Islands. Land clearing, construction activity, or the construction or placement of permanent structures within the BECD is prohibited. The exact limits of the BECD building limit line have been delineated on a series of 1:1,400-scale official plat maps (Planning and Zoning Commission, 1978).

In order to help reduce the problem of coastal erosion at Ocean City, the U.S. Army Corps of Engineers has developed several preliminary alternative shoreline protection plans for different frequencies and magnitudes of storm occurrence. The most comprehensive alternative is called the Hurricane Protection and Beach Restoration Plan. This plan calls for the sand to be transported to Ocean City from an offshore shoal, construction of artificial dunes where feasible, and the construction of a bulkhead in the boardwalk area. The plan also calls for an annual beach replenishment program of 100,000 to 200,000 yards^3 of sand to replace anticipated seasonal erosion deficiencies. The size of the offshore shoal east-southeast of Ocean City Inlet is 7 million yards^3. The cost estimate for this project is \$8 to \$22 million. As local and Congressional approval as well as environmental impact assessments are required, it is likely to be a number of years before the project could be implemented (Planning and Zoning Commission, 1978). The most recent study (1979) of possible solutions to control erosion recommends installation of groins.

In addition to the problem of erosion, flooding of the coastal areas and barrier islands may occur during a storm as a result of the storm surge. As storm surges develop, because of a lowering of the barometric pressure (especially during a hurricane), the slope or gradient of the local drainage basin is reduced, thereby slowing the seaward movement of the runoff. If a large amount of rain occurs during the storm, extensive areas may be flooded by freshwater immediately landward of the overwash line. Development in the back-bay area should also take into account such conditions.

Table 2 *Rates of shoreline change for Fenwick Island–1940 to 1980.*

	Average rate of change per year (in feet)	Total change since 1940 (in feet) (- means erosion)
Unit 1	+ 6.0	+ 240
Unit 2	+ 1.2	+ 50
Unit 3	- 2.9	- 145
Unit 4	- 1.6	- 80
Unit 5	- 1.6	- 80
Unit 6	- 2.5	- 125



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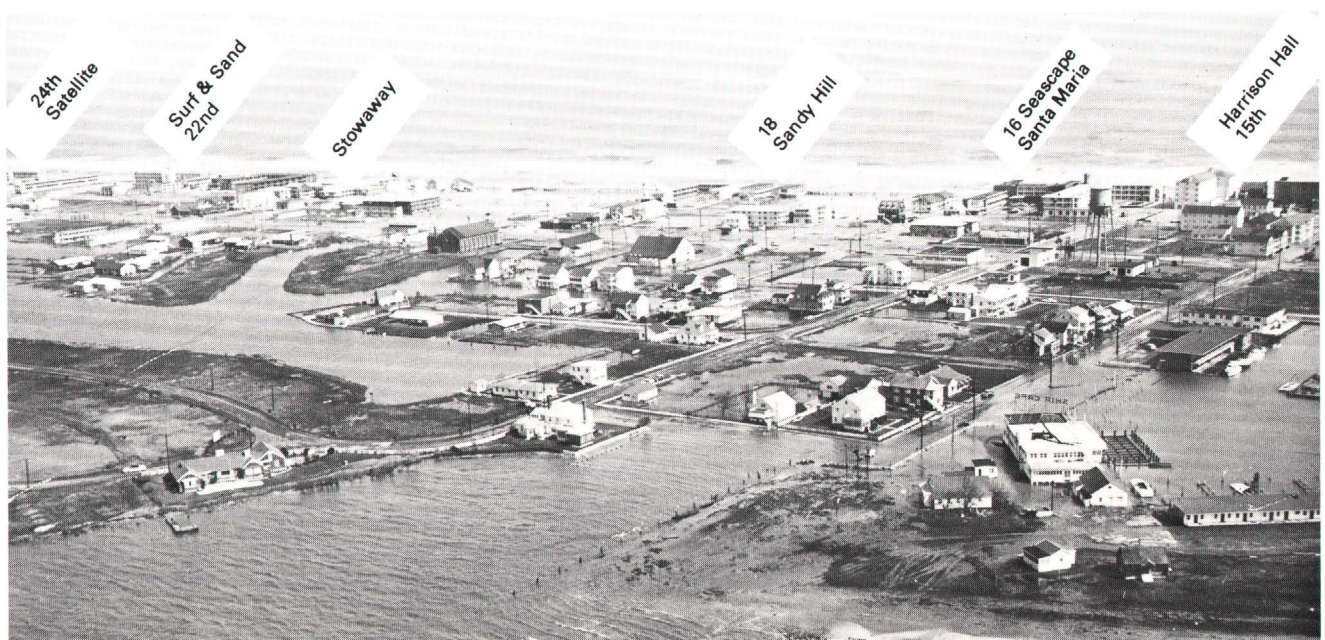

Fig. 27 *During severe storms, such as the Ash Wednesday storm of March 1962, these low areas are flooded and commonly subjected to storm surge and overwash.* *(Reprinted from U.S. Army Corps of Engineers, 1963.)*

Federal flood insurance program

The National Flood Insurance Program, administered by the Federal Insurance Administration (FIA) provides some assistance in reducing the potential property losses on barrier islands. The program's stated purposes are:

> "To . . . encourage State and local governments to make appropriate land use adjustment to constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses . . . [and] . . . to . . . guide the development of proposed future construction, where practicable, away from locations which are threatened by flood hazards" (U.S. Department of Commerce, 1975).

Although FIA structural requirements have tended to induce developers to construct buildings in such a way as to reduce their susceptibility to flood damage, these requirements do not cover all the hazards involved. For example, wave height and run-up, which considerably increase stormwater elevations and potential damage, are not included. Further, the requirements are more design-oriented than location-oriented. Therefore, buildings can be designed to meet the structural requirements but still be located in hazardous areas.

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Fig. 28 *Losses along the Atlantic coast barrier islands during the Ash Wednesday storm of March 1962 reached $250 million. Photograph courtesy of Accock Brown.*

Summary

Barrier islands are exciting places to visit and on which to live. They are, however, unforgiving at times. Nature provides many clear indications of land areas that could be endangered by natural processes. Development of these areas should be preceded by an identification of the hazards, and assessment of the risks, and an estimate of the costs and effectiveness of possible mitigation measures. Coastal resorts that allow development near the water's edge soon become dependent on engineering works.

In attempts to stabilize and protect property on the shoreline along the mid-Atlantic barrier islands, tens of millions of dollars of private and public funds have been invested over the past two decades. Unfortunately, there appear to be few effective methods available to stop erosion and minimize flood hazards. This condition has been recognized in tidewater Maryland for over 30 years. In a report issued by the Maryland State Board of Natural Resources in the 1940's, a plea was made to coastal communities and developers to exercise care in the planning and construction of building on or near the shoreline (State of Maryland, 1949). The report even suggested that the cost of protecting waterfront property from erosion should be paid entirely by the property owners.

Gilbert White of the University of Colorado recently stated that "the most rapidly growing site for catastrophic events in the United States is the Gulf and Atlantic Coast of the country. There one finds rates of growth within the 50- and 100-year flood frequency zones that are four, five, and ten times as great as in adjoining areas, and it is these areas that someday, perhaps next year, perhaps not for a hundred years, depending on the random occurrence, will be the sites of enlarged catastrophies" (White, 1975).

Despite the bleak overtones associated with these forecasts and experiences, positive alternatives are available to coastal planners and developers. Data on erosion and storm-surge penetration rates and land use, such as those contained in this report, can provide a strong basis for guiding future development away from the more hazardous areas and into locations of greater relative safety. Similarly, these data can be used effectively to evaluate various hazard mitigation techniques, and to choose those which offer the most protection with the fewest negative impacts.

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