A Guide to Coastal Hazards

Volume 1: Manomet Point to Sandy Neck

Massachusetts Coastal Zone Management

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Volume 1: Manomet Point, Plymouth, to Sandy Neck, Barnstable

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Massachusetts Coastal Zone Management

Preface

The coastal zone of Massachusetts is a unique blend of sandy beaches, productive estuaries, urban ports and protected harbors. Many of our coastal communities were founded on maritime-related activities and commercial fishing, tourism and energy-related activities continue to support the social and economic growth of our coast. Today, over 40% of the Commonwealth's population live in coastal communities.

With increasing popularity comes increasing pressure to develop available real estate. Continued development, however, brings with it very real problems. Water quality, wastewater treatment and refuse disposal are but a few of the problems coastal cities and towns are now encountering. Foremost among the immediate problems attending coastal development is the susceptibility of roads, dwellings and infrastructure to damage or destruction caused by coastal storms. Areas subject to flooding and storm wave action, shoreline retreat, and shifting beach and dune areas create situations that, if ignored, can endanger not only financial investments, but human lives as well.

This publication is intended to help the general public better understand the natural hazards existing along the shoreline. It is the first in a series of regional guidebooks to coastal hazards of the Massachusetts shoreline, and describes the shoreline between Sandy Neck, Barnstable and Manomet Point, Plymouth. Your comments and suggestions on this document are welcome. Please feel free to contact the Coastal Zone Management Office at (617) 727-9530 with any questions or for assistance.

Sincerely,

Richard F. Delaney, Director
Massachusetts Coastal Zone
Management Program

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Special recognition is given to Denise Leonard who helped coordinate and carry out much of the field work in the Towns of Plymouth and Bourne. Bill Taylor, Town Engineer of Sandwich, and members of the Massachusetts Department of Public Works assisted with the land surveying.

Russel Brami was the designer.

Jean Mills of the Plymouth Historical Society, Russell Lovell, Jr., of the Sandwich Historical Society, Barbara Gill of East Sandwich, and *Broadsider* newspaper contributed valuable historical photographs and information.

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How to Use This Guide

This guidebook describes the coastal hazards associated with the Cape Cod Bay shoreline between Sandy Neck, Barnstable and Manomet Point, Plymouth. Included are portions of shoreline in the towns of Plymouth, Bourne, Sandwich, and Barnstable. These hazards, which can result in costly storm damage, include flooding, wave damage, shoreline retreat and the shifting of beach and dune areas.

This guidebook is designed to provide town boards, public officials and private citizens with a better understanding of shoreline processes and potential hazards resulting from indiscriminate development along the coast. The information contained in this guidebook offers the basis for establishing substantive long term planning criteria, improved project review, and the saving of money, property and lives. The guidebook contains three chapters and appendices.

Chapter One presents an overview of the geology of the area, past and present. Before future changes can be adequately assessed, how the shoreline was initially formed and what forces continue to act upon it must first be understood.

Chapter Two describes the hazards associated with development activities which do not adequately consider the natural processes described in chapter One. Improper placement of dwellings, piers or inlets can create unnecessary and costly problems for the taxpayer.

Chapter Three discusses planning and management schemes necessary to minimize or eliminate coastal hazards. This chapter presents several alternatives to accomodate development in otherwise hazardous areas.

Finally, the Appendix of this guidebook contains several items to further aid the reader in dealing with coastal hazards. A list of references and selected readings is included as well as sources of additional technical assistance or information.

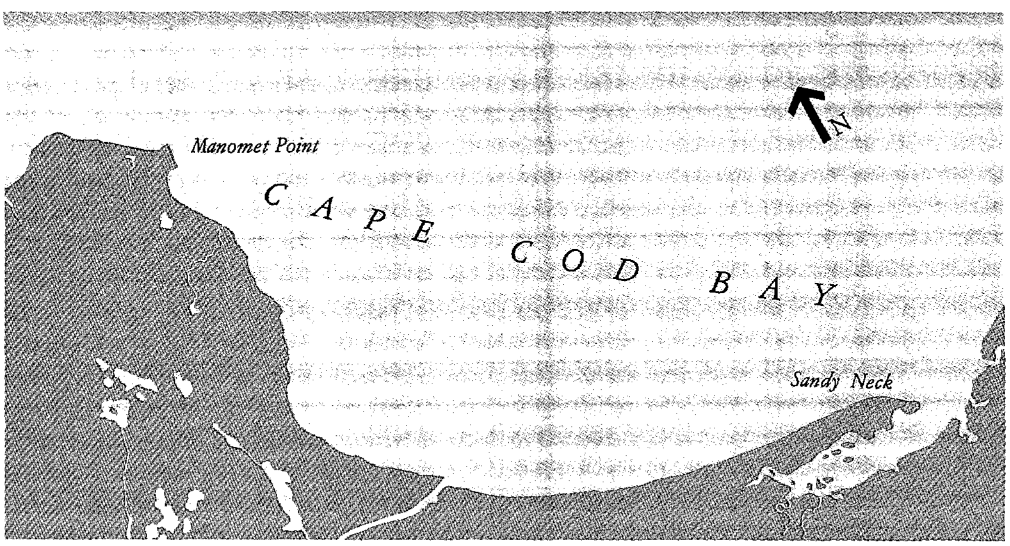
Contents

1 Evolution of the Coast

Geological Past

Most of the coastal upland bordering southwestern Cape Cod Bay was left much as it appears today by the retreating glaciers of the last great Ice Age. There is more to it than that, of course, for the surface materials overlie ancient rocks, worn survivors of former mountain ranges, now separated by thousands of miles from their counterparts across the Atlantic Ocean which began forming almost 200 million years ago.

As the ocean formed, the edge of the continent slowly sank and layers of sediment were deposited one on top of another. Often deposition was followed by erosion as the level of the sea fluctuated. The top layer of sediment was added about 15,000 years ago by the final retreat of the vast ice sheet that had once covered the northern part of the continent as far south as the present location of Long Island in New York.



1. *Location map. The area covered in this Guidebook.*

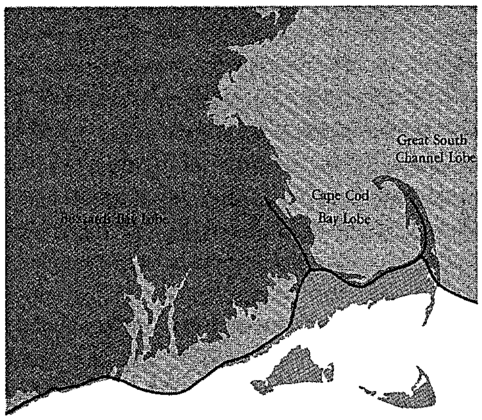
By the time the ice had retreated to this area, its front had taken the form of three vast lobes, referred to (from west to east) as the Buzzard's Bay lobe, the Cape Cod Bay lobe and the Great South Channel lobe. The ice front remained relatively stationary in this area releasing in bands large volumes of materials which had been carried by the ice to form glacial moraines. The Sandwich moraine formed at the front of the Cape Cod Bay glacial lobe when its rate of advance was essentially balanced by melting. This moraine forms the high "backbone" of the Cape, running east and west along the north shore of Cape Cod through Sandwich and Barnstable. The highest elevation on Cape Cod is found on this moraine at Telegraph Hill in Sandwich, which has an elevation of 295 feet above sea level.

The complex glacial history of northern portions of this area is still poorly understood. It is generally acknowledged that the deposits found here represent a region where two of the great lobes of glacial ice, the Buzzards Bay and Cape Cod Bay lobes, met and shifted back and forth.

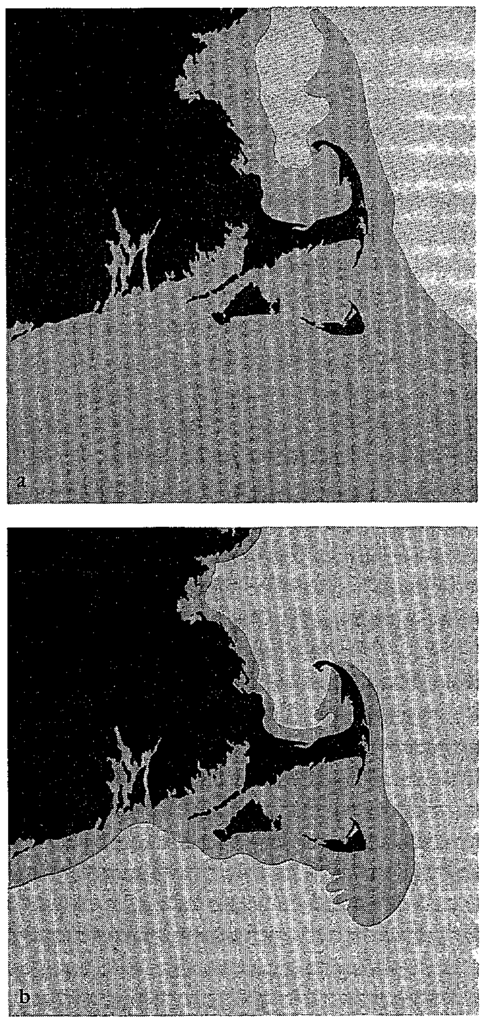
Following the period of the Sandwich moraine, the Cape Cod Bay lobe retreated a short distance further northward and again paused. The melt waters formed a long, narrow lake with banks formed by the Sandwich moraine on the south, the Cape Cod Bay lobe on the north, the South Channel lobe on the east, and high land south of Plymouth on the west. At one time the level of this lake reached a height of 50 feet above present sea level — a fact demonstrated by lake delta deposits found at that elevation on Scorton Neck in Sandwich and in the Manomet area. Similar lake deposits have been identified on Spring Hill and Town Neck Hill in Sandwich. This ancient lake — which has been named Lake Shaler after the geologist who first suggested its existence — had, as its principal outlet, Monument Valley, presently the site of the Cape Cod Canal. As Lake Shaler drained, it eroded Monument Valley and as a result, the lake level was lowered. However, final drainage only took place when the ice front finally retreated north of the outer arm of Cape Cod.

For several thousand years following the retreat of the glacial front from Cape Cod Bay, Cape Cod experienced a cold and windy "periglacial" (or near glacial) climate. The ground remained "permafrost," that is, frozen year-round so that surface water, unable to percolate into the soil as it does today, flowed swiftly and cut stream valleys. Strong winds easily transported the loose sediment, and the finer materials "sand blasted" the surface of pebbles and cobbles forming "ventrifacts" or wind faceted stones — commonly found in the surface soil today.

Finally, about 12,000 years ago, a milder climate melted the permafrost and ended the cutting of stream valleys. The remaining buried ice blocks melted, forming kettle holes and leaving the landscape much as it appears today.*



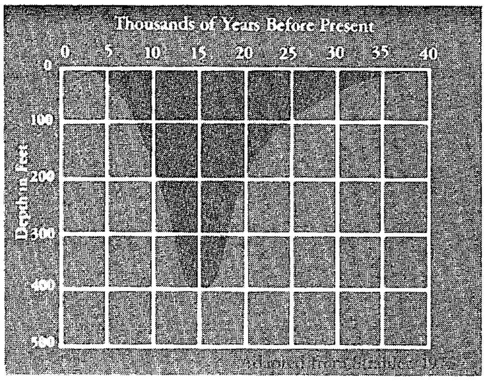
From that time until the present, sea level has risen, submerging the deposits left by the ice. For geologists, "sea level" means "relative sea level" — the level of the sea with respect to the level of the land at some particular place. It is often difficult to determine whether the sea is flooding the land because the sea is actually rising, or because the land is sinking. There is no doubt that much of the rise in our area has been caused by actual sea level rise due to the water released by melting glacial ice, but there is strong evidence that the sinking of the land is also a contributing factor. Despite the uncertainties of how much of the rise is contributed by each process, two things are generally agreed upon: first, the land in this area has been gradually flooded by the sea from the time it was freed of ice until the present; the second, relative sea level is now rising at a rate of about one foot per century. Later in the guide it will be demonstrated how important this rise in sea level is in determining shoreline changes.

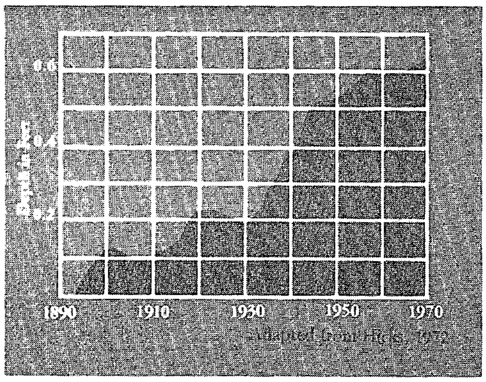


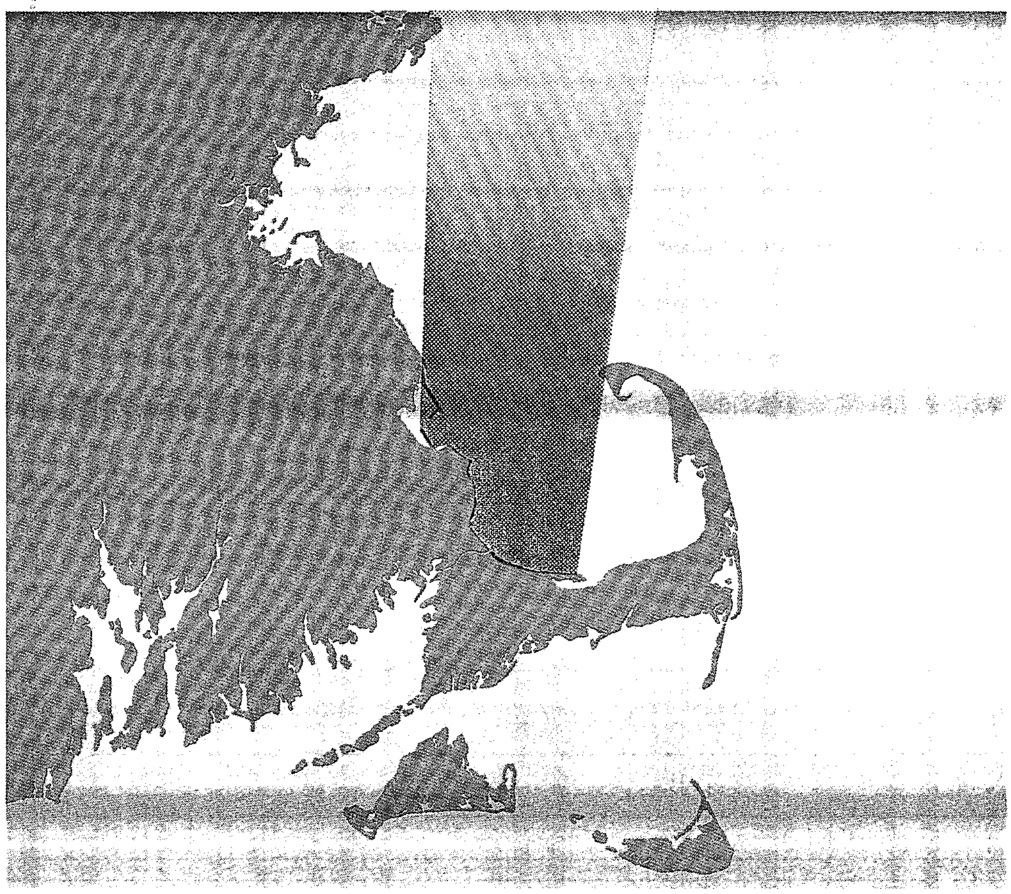
2. Ice margin during the deposition of the Sandwich Moraine.

**From Robert N. Oldale, 1974, whose writings have been freely used in this section.*

3. The changing shoreline of Cape Cod: a) 12,000 years ago, b) 6,000 years ago.







Coastal Forces: Winds, Waves, Tides and Storms

Winds

Winds are very important to coastal processes because they produce ocean waves which contribute to the characteristics of the coastline. The size of the waves produced is dependent on the wind's strength, duration, and fetch which is the distance of open water over which winds blow to build waves. Figure 6 shows that the direction of maximum fetch for most of the guide area is toward the northeast, the same direction from which blow the strongest onshore winds.

Waves

When a wave reaches shallow water, it breaks, generally at a depth approximately equal to the wave height, though the actual point at which it breaks is dependent in large part on the slope and topography of the bottom. After breaking, waves reform and continue moving landwards eventually breaking for the first time on the beach face. Sometimes wave height and water depth are such that the incoming waves break for the first time directly on the beach face. The uprush and backwash of water on the seaward face of the beach is called "swash."

Waves rarely come ashore exactly parallel to the shoreline. Even when the wind is directly onshore variations in the shape of the shoreline and nearshore topography cause waves to bend or refract as they approach the shore. Figure 8 is a diagram of the refraction pattern of a northeast swell approaching the portion of coast covered in this guidebook. This figure has been drawn for illustrative purposes from aerial

4. Changes in sea level along the Atlantic Continental Shelf.

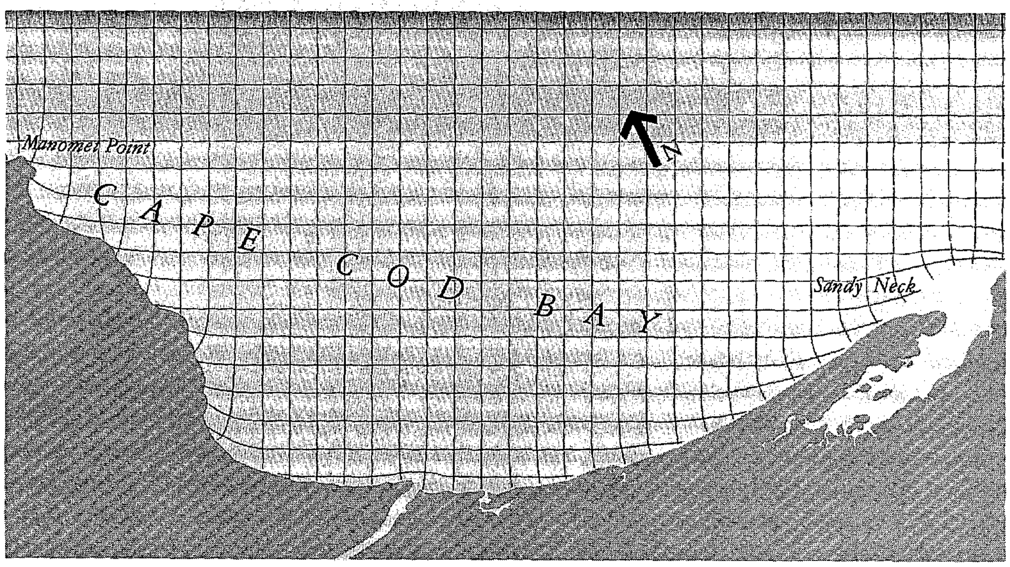
5. Mean Sea Level changes on the northern east coast of the United States.

6. Direction of maximum wave fetch in the Guide Area.

photographs and shows the distribution of wave energy along the shoreline.

Waves striking the coastline at an angle cause a movement of water and sediment along the shore in the direction of travel of the incoming waves. The alongshore movement of sediment is called "littoral drifting." The rate of littoral drifting is dependent on wave height and the angle of wave approach. As would be expected from the direction of maximum wave fetch, the dominant direction of littoral drifting for this area is from Manomet toward Sandy Neck. This is evident from the buildup of sand on the northern (updrift) sides of all groins in the area and the corresponding loss of sand on the downdrift sides. These effects are discussed more fully in the section on coastal engineering structures.

7. Waves breaking at an angle to the coastline produce littoral drifting.

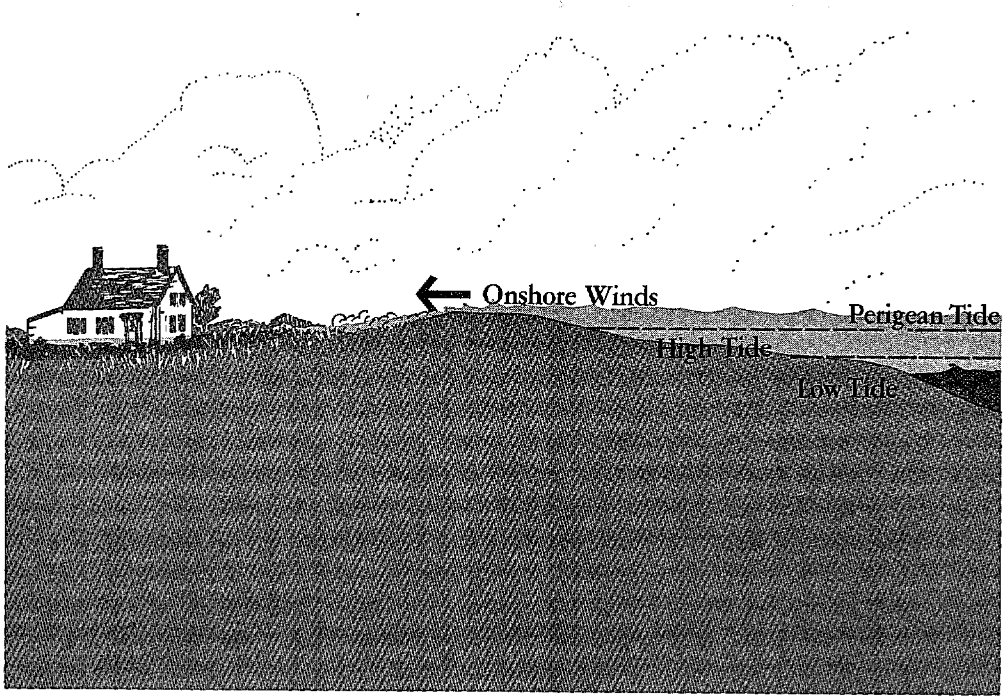


8. The general wave refraction pattern for the Guide Area.

Tides

The major daily variations in water level in Cape Cod Bay are due to astronomical tides. Astronomical tides are the result of the gravitational pull of the moon and sun on the earth's oceans. Of the two, the effect of the moon is much greater than that of the sun. Between Sandy Neck and Manomet Point, high and low tides occur twice a day (approximately 50 minutes later each day), and they have an average range of 9½ feet.

The changing positions of the moon, sun and earth cause varying ranges of astronomical tides. ***Spring tides*** — those with high ranges — occur near the time of the new and full moon, when the moon, earth and sun are all aligned. ***Neap tides,*** with low tidal ranges, occur near the first and last quarters of the moon. ***Perigean spring tides*** appear twice a year, when the moon is closest to the earth (perigee) coincidentally with a new or full moon. At these times, the tidal range is extremely high due to the added gravitational effect resulting from the moon's proximity to the earth.

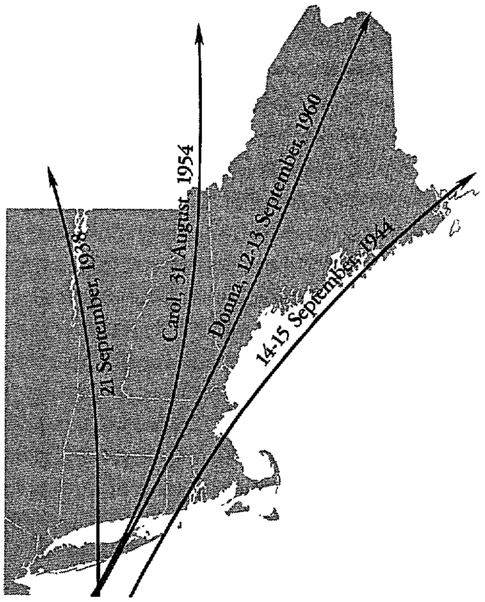


Storms produce dramatic changes to the shoreline both because of the flooding due to storm surges and because of the enormous energy of storm waves. The two types of storms which cause most damage to coastal New England are hurricanes and northeasters. Hurricanes strike New England less frequently than north-easterns, most often occurring in August and September. They originate as low pressure systems in low latitudes, and generally pass inland of the Massachusetts coast, bringing southerly winds which most severely affect the southern coast of New England.

The greatest storm damage along the southwest shore of Cape Cod Bay is not usually due to hurricanes, but rather to northeasters (or nor'easters as they are commonly called) which are the predominant storm patterns in this area. These storms result from low pressure systems moving northeastward over the coastal water off the east coast of the United States. When the system approaches New England its counterclockwise circulation draws in cool moist air from the maritime cold air mass over the North Atlantic. This air is drawn from the northeast to the southwest, causing sustained northeasterly winds to blow across the Gulf of Maine directly onto the shore of this area. Extreme flooding such as occurred during the "Blizzard of 1978," frequently results from the simultaneous occurrence of northeasterly gales and perigean spring tides.

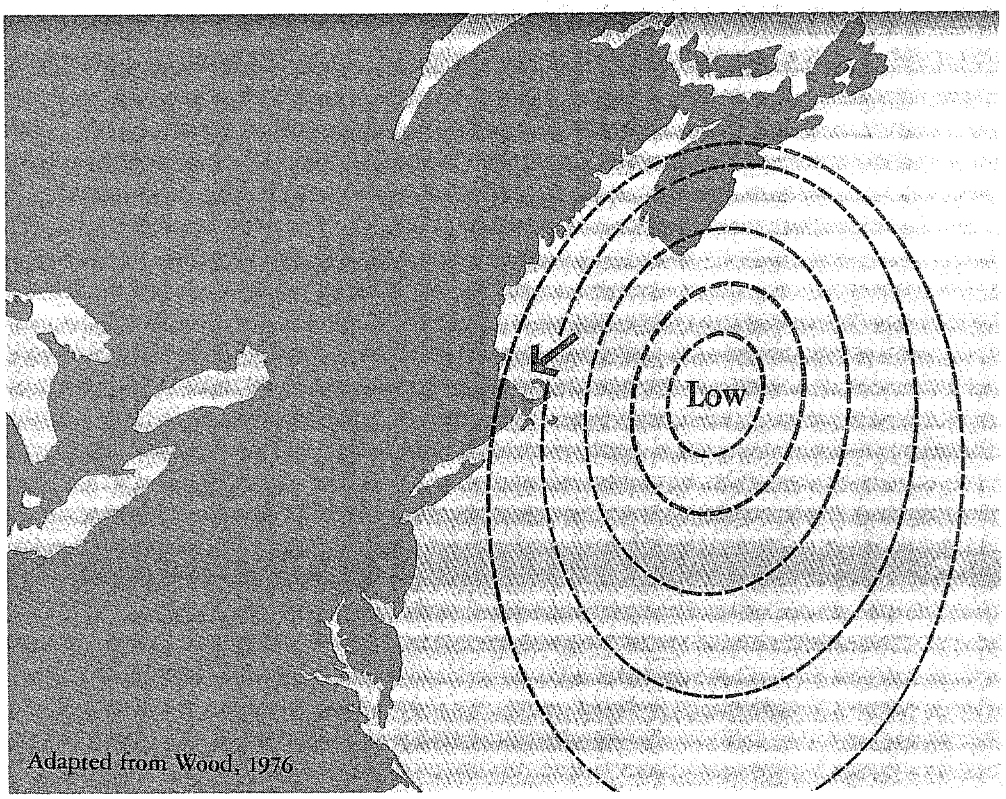
Storms

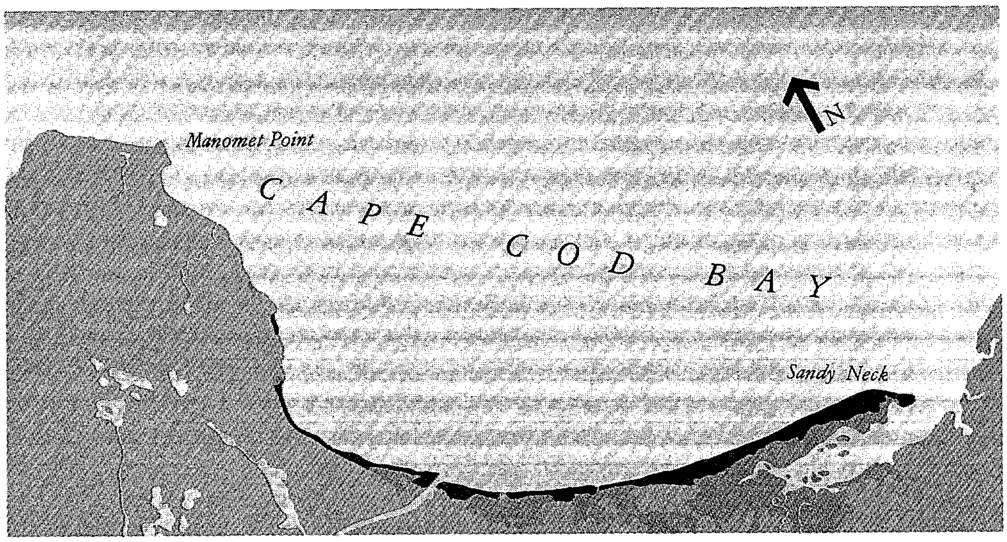
The tides are independent of water level changes caused by meteorological conditions, which cannot be predicted long in advance. Increases in sea level can reach impressive (and destructive) heights during storms, and for this reason are called "storm surges." Storm surges are often the result of a combination of effects including the piling up of water against a coast by onshore winds (referred to as "wind set-up"), and the rise of the sea surface in response to lowered atmospheric pressures which accompany intense storms. When large astronomical tides combine with storm surges the highest flooding and storm damage occurs.



9. The coinciding of astronomical (perigean) tides and sustained onshore winds produced flooding and storm damage.

10. Selected tracks of hurricanes that have passed through New England.





Coastal Environments

In order to assess the role of winds, waves, tides and storms on the shoreline, imagine the coast as it would appear today without any of these forces. As sea level rose, it would have slowly submerged the glacial deposits. Valleys would have been flooded, creating coastal embayments such as Ellisville Harbor. The shoreline southeast of Scusset Beach would have had the form of the boundary of the primary (upland) deposits. The shoreline north of Scusset Beach would have had a similar form, but it would have extended far seaward of the present coast.

That the actual shoreline is quite different from our hypothetical one, is primarily due to the effect of waves. As previously stated in the Coastal Forces Section, waves generate a "littoral drifting" from Manomet Point toward Sandy Neck. This section of coast represents a distinct coastal processes unit: sediment eroded from the exposed "primary" glacial deposits of the northwestern section is transported south then east where it is deposited to form the barrier beaches or "secondary deposits" of the southeastern section. The barrier beaches provide protected landward estuarine areas where "tertiary" salt marsh deposits form. Waves, tides and winds, interacting with the coast, produce a wide variety of shoreline forms and coastal habitats through the processes of sediment removal, transportation and deposition.

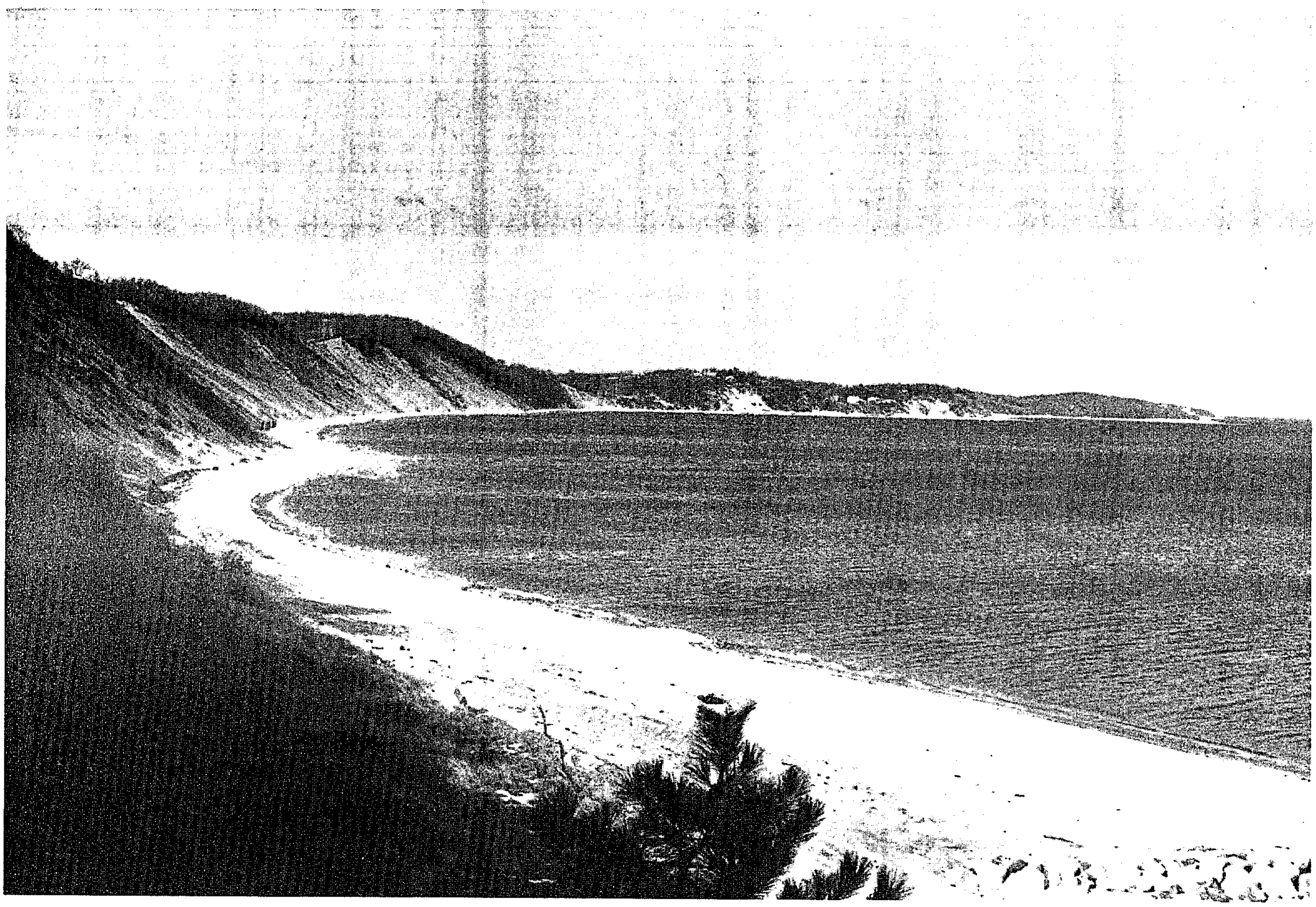
11. Two characteristic northeast storm patterns. Low pressure systems draw air form the North Atlantic, causing sustained high winds from the Northeast to blow over New England.

12. Coastal deposits in the Guide Area.

☐ Primary Deposits, Upland

■ Secondary Deposits, Beaches and Dunes

▒ Tertiary Deposits, Marshes



Primary Deposits

Perhaps the most striking of the primary deposits are the high coastal cliffs (or bluffs or banks, as they are also called) which line much of the coast from Manomet south to Sagamore Highlands. These cliffs are formed as waves, mostly storm waves, cut into the hills left by the glaciers.

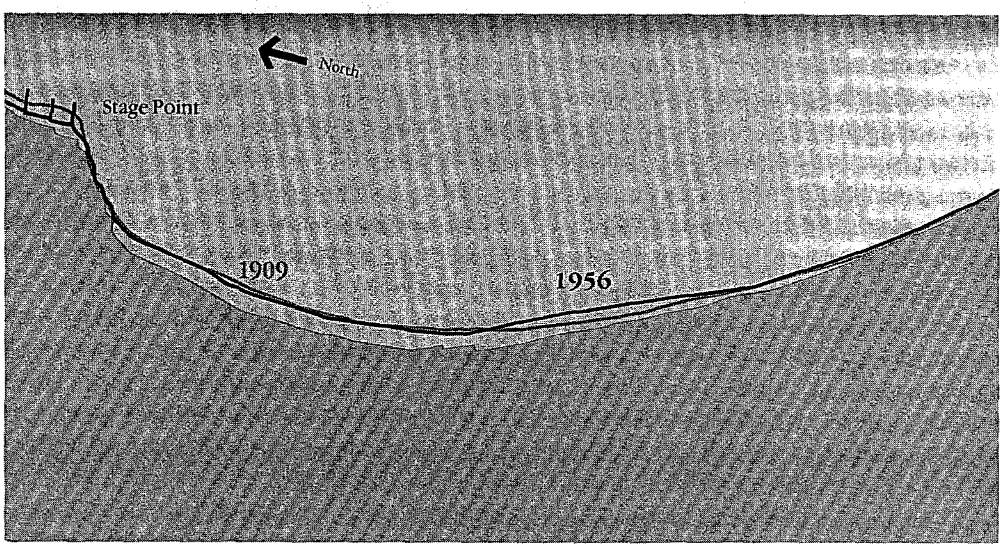
The loose glacial deposits scoured from these cliffs are the major source of the sediment which forms the offshore bars, beaches and dunes, the "secondary" deposits.

The rate of cliff erosion, and the types of materials supplied to shore systems by erosion vary considerably from place to place. They depend on the balance of many factors, chief among which are the geological composition of the cliffs and the amount of wave energy that they receive.

13. The cliffs of Sagamore Highlands are typical of eroding primary deposits.

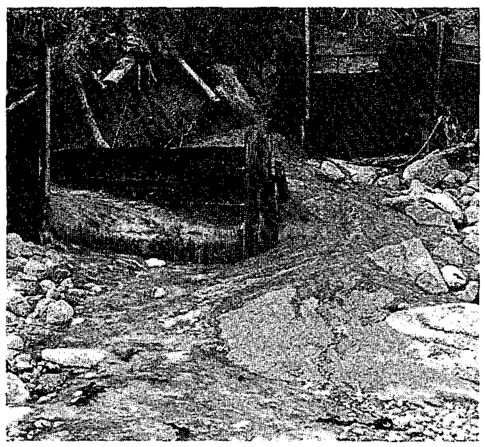
The complex geological history of the mid-Plymouth area, where there exist coastal cliffs, has produced deposits with a wide variety of characteristics. Generally, the headland areas — Manomet, State, Indian Hill and Center Hill points — are composed of unstratified glacial "till," which consists of materials with a wide range of sizes, varying from large boulders to fine clay particles. In some areas till deposits were left in place by the ice without much further transportation by streams or wind.

The cliffs composed of glacial till are relatively resistant to wave attack in part because their past erosion has left a residual apron of boulders on the shore in front of them. Too massive to be moved by waves, these boulders break up much of the force of incoming surf, and consequently the partially protected cliffs have not eroded as fast as adjacent cliffs composed of fine grained material. As a result, Manomet, Stage, Indian Hill and Center Hill points have undergone relatively little erosion. In contrast the areas between the headlands have eroded rapidly.



A comparison of shoreline positions on Figure 15 indicates that between 1866 and 1956, the shoreline of the embayment south of Stage Point retreated a maximum of about 125 feet. Between 1916 and 1956, rapid erosion averaging about 450 feet occurred south from Ellisville Harbor, around Lookout Point to Peaked Cliff.

It should be emphasized that cliff erosion is due chiefly to sea level rise and wave action. However, the resulting cliff forms are also modified by several other mechanisms. Strong onshore winds in dry weather move finer sediments both up and down the cliff face. Frost action, the alternate freezing and thawing of water-soaked sediments, loosens grains which then may fall or blow away more easily. Drainage from groundwater and surface water runoff may cause considerable localized erosion, as may be seen in the cliffs southwest of Stage Point and near Indian Hill.



14. Center Hill Point. Glacial till has eroded from the headland. Rubble in the middleground is slowing further erosion of the cliff and is producing secondary deposition.

15. Rapid erosion of the shoreline at Sagamore Highlands 1866-1956.

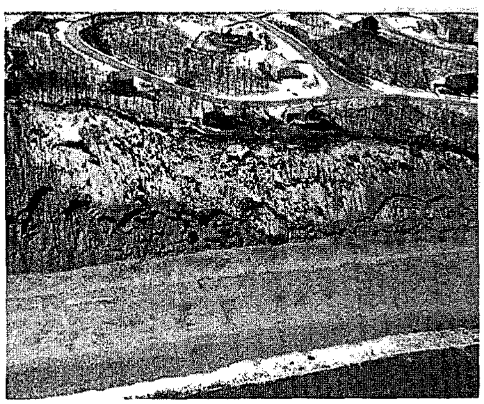
16. Near Stage Point. An example of localized erosion caused by groundwater runoff.

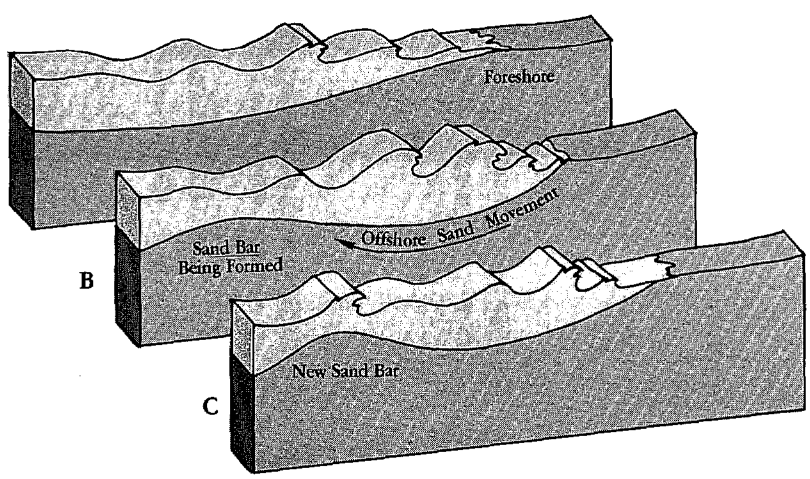
Secondary Deposits

Cliff erosion tends to be periodic and local, rather than constant. Of course very severe storms such as the "Blizzard of 1978," cause widespread cutting of the cliff face; but in general the amount of erosion depends upon the degree of protection afforded the cliffs by the adjacent beaches and offshore sand bars. The cliffs themselves, through their erosion, provide the materials to form the beaches and bars which then protect them from further erosion. Such "feedback" systems, producing — or rather approaching — stability, are common in nature.

The protection is not perfect for a number of reasons, important among which are continuing sea level rise, and sediment loss offshore and alongshore. Yet the movements of sediment serve protective functions also. The onshore and offshore movement of sand adjusts the form of the beach to the conditions of the sea. When waves are low and far apart and storms are few — as during the summer — the beach develops a steep foreshore and wide backshore.

During the stormy periods, however, high steep waves cut into the beach, carrying sand offshore where it is deposited to form elongated submarine sand bars. With the exception of Manomet Point and some of the other headland areas, offshore sand bars extend along the entire shore from Manomet to Sandy Neck. These bars serve to protect the beach during storms by causing the high waves to break offshore and lose much of their destructive energy. The waves which remain, or reform, continue on to the beach; but the foreshore has been changed to a gently sloping plane and the remaining storm waves break over its broad surface. Only when the tide level is very high will storm waves reach the cliff and cut a nearly vertical scarp into the base of the cliff, causing it to slump down under its own weight. When the storm waves subside, they are replaced by longer, lower waves which transport back to the beach some of the sand which had been stored in the bar.





17. Cedarville Landing. The cliff was undercut by the waters of the 1978 blizzard.

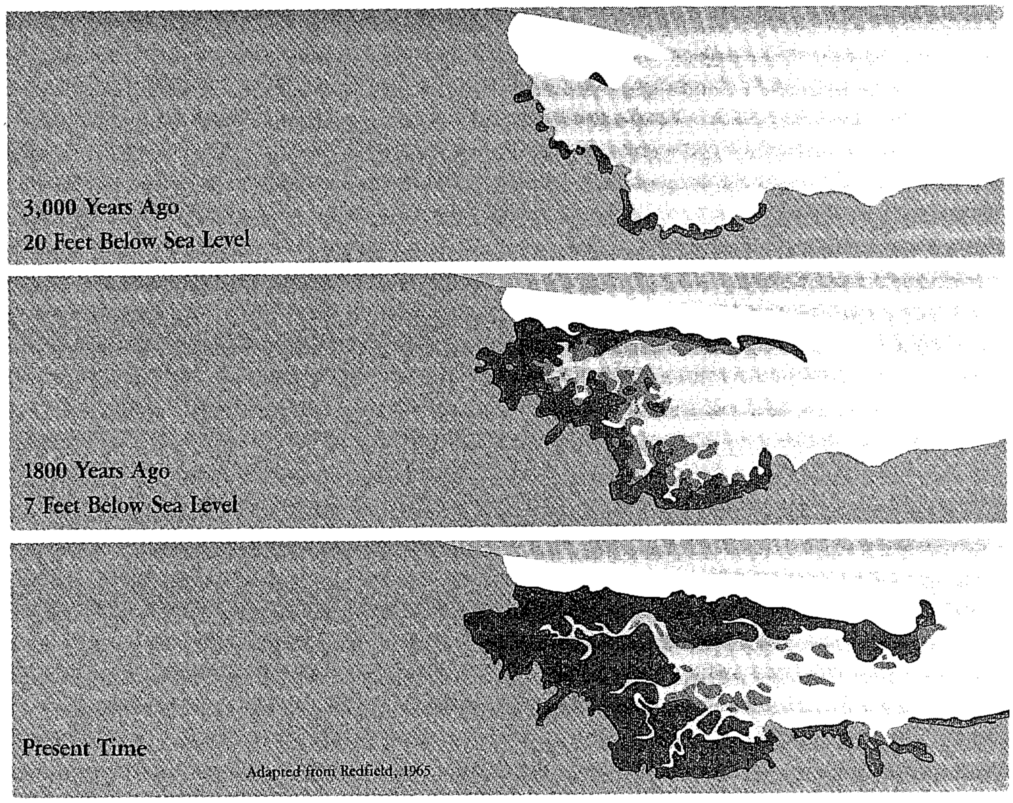
18. Material from eroding cliffs build beaches and bars that slow further erosion.

19. Beach Form. a) Pre-storm conditions b) Storm conditions c) Post-storm conditions.

Sand moving along the shore as littoral drift performs other protective functions. By removing sediment from some stretches and adding it to others, waves can model the shoreline into smooth forms which "face" the direction from which the waves arrive. Since the amount of sediment moved along the shore decreases as the direction of wave attack becomes more directly onshore, the shoreline develops an increasingly stable form. Again the feedback mechanism: the shoreline changes in such a way as to decrease the amount of change.

There are some good examples of this process in this area. The shoreline between Cape Cod Canal to Sandy Neck faces the direction of maximum wave fetch and has a stable form. However the coastal embayment south of Stage Point does not face the maximum fetch direction. The zone of erosion south of Stage Point was mentioned earlier. At a point about halfway from Stage Point to Indian Brook the erosion stops, and from that point south to Indian Brook the shoreline built seaward by as much as fifty feet between 1866 and 1956. These changes are re-directing the shoreline toward the direction of maximum fetch.

Similarly, south of Lookout Point to Peaked Cliff rapid erosion occurred between 1916 and 1956. However, southward from Peaked Cliff, the amount of erosion decreased, until, at Scusset Beach, erosion and accretion were about equal. Again, by means of sediment exchange, a shoreline is reorienting toward a more stable form.



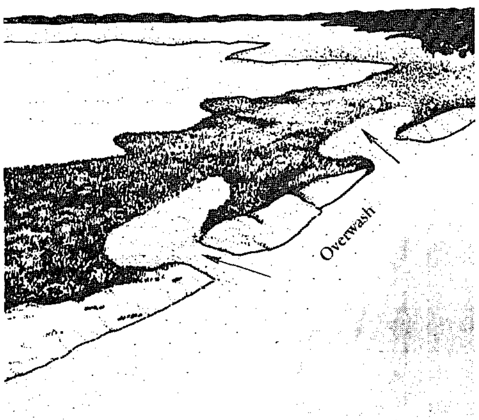
Waves move sand along the coast, creating shorelines with increasingly stable forms. Stability is always approached, but because sea level is rising, it is never achieved. In places, the beaches which are formed by these processes extend out past what would otherwise be the shoreline. The beaches are called barrier beaches, because they act as barriers against open sea waves, thus protecting salt marshes, lagoons and quiet bays between themselves and the upland. Small barrier beaches connect headlands at Center Hill Pond and Ship's Pond. The largest ones, which together account for more than half of the outer coast, are Ellisville Beach; Sagamore Beach; Town, Springhill and East Sandwich Beaches; and Sandy Neck — a string of four barrier beaches extending downdrift from the northwest to the southeast, each larger than its predecessor, each extending further offshore. The source of sand for them all is the eroding cliff line north to Manomet.

Barrier beaches are extremely dynamic features, changing continually in response to the forces acting on them, including sea level rise. Figure 20 illustrates the lateral downdrift growth of Sandy Neck in response to wave produced littoral drifting. Waves

20. The evolution of Sandy Neck.

Sand Dunes · Intertidal Marsh

Upland · High Marsh



also assist barrier beach growth — and their landward shift in response to sea-level rise — by means of overwash. During overwash, storm waves carry sediment across the lower portions of the barriers and deposit it on the inner side .

Much of the bulk and protective function of barrier beaches is provided by dunes, which are formed by sand moved landward from the beach by onshore winds. Above the spring high tide line this sand is "caught" by beach grass and other salt-resistant vegetation. The vegetation grows upward through the accumulating sand causing the dune crest to reach elevations well above the highest waves. Dunes provide storm wave and flood protection not only by means of their elevation, but also because they store sediment which is returned to the beach system when storm waves have eroded the beach to the point that the dunes are cut, or "scarped" by wave action.

Barrier beaches also change in response to the action of tides. Tidal inlets through barrier beaches, such as those at Ellisville, Sandwich and Scorton Harbors, and at the Cape Cod Canal, which is a man-made inlet, stay open as the result of the tidal currents which scour their channels. Deltas tend to form inside the inlets (flood tidal deltas) and outside of them (ebb tidal deltas).

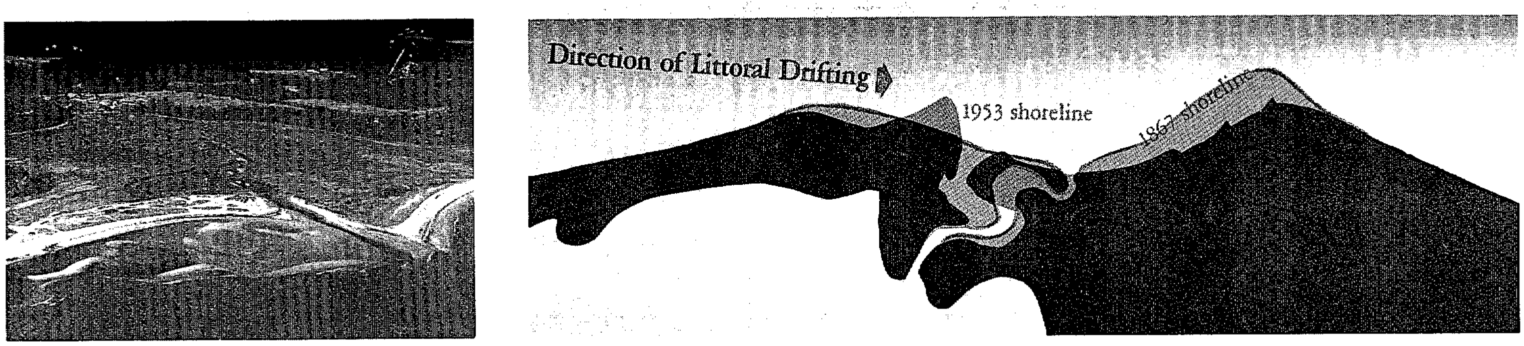
Tertiary Deposits

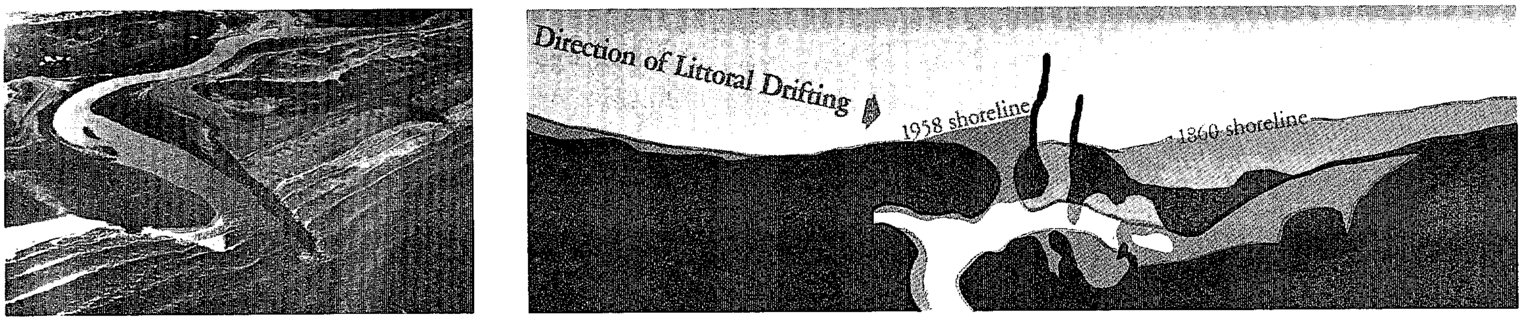
The tertiary deposits — those carried inside the barriers by winds, waves and tides — form the substrate for the growth of salt marsh vegetation which thrives in protected intertidal areas. Not only do the marshes form an important biologically productive resource, they also provide storm protection to the inner shore.

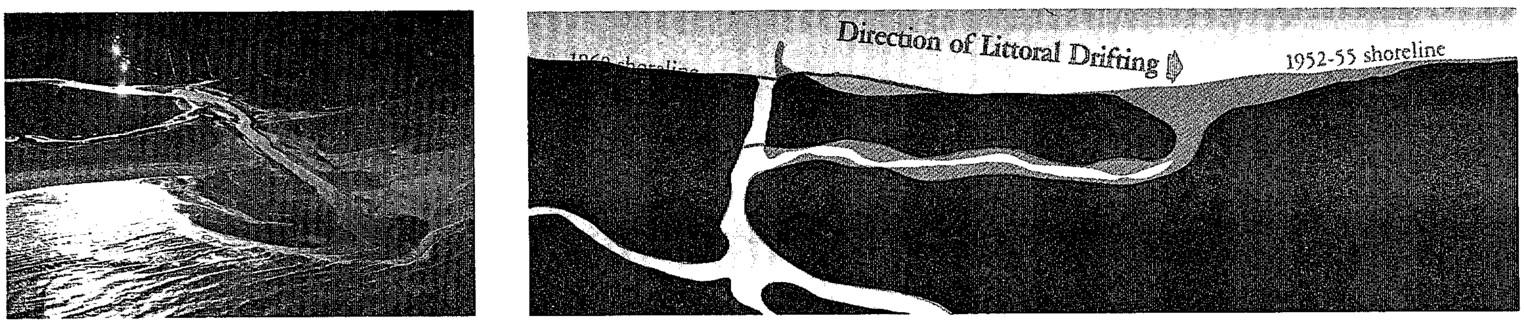
It is this inner shore, the shore of the uplands, which makes up most of the actual length of the shoreline. It winds in around valleys and out around hills, and because its seaward slope is relatively steep, the retreat of the inner shoreline due to rising sea level is very slow. It is protected from the sea by the bars, beaches and dunes of the barrier beaches, and by the marshes and flats which lie behind them. It is at this point that a true terrestrial environment begins.

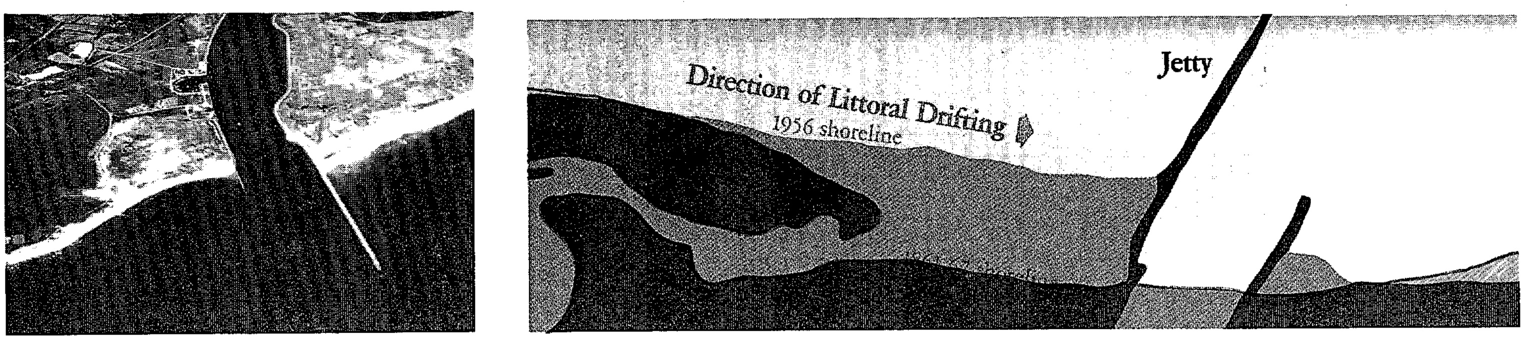
21. Landward shift of a barrier beach through overwash.

22. A scarped dune.









23. a) Ellisville Inlet, 1980. *b) Shoreline changes at Ellisville Inlet.*

24. a) Sandwich Inlet, 1980. *b) Shoreline changes at Sandwich Inlet.*

25. a) Scorton Inlet, 1980. *b) Shoreline changes at Scorton Inlet.*

26. a) The Cape Cod Bay entrance to the Cape Cod Canal in 1950. *b) Shoreline changes at the canal entrance.*

Accretion
Erosion

2 Coastal Hazards

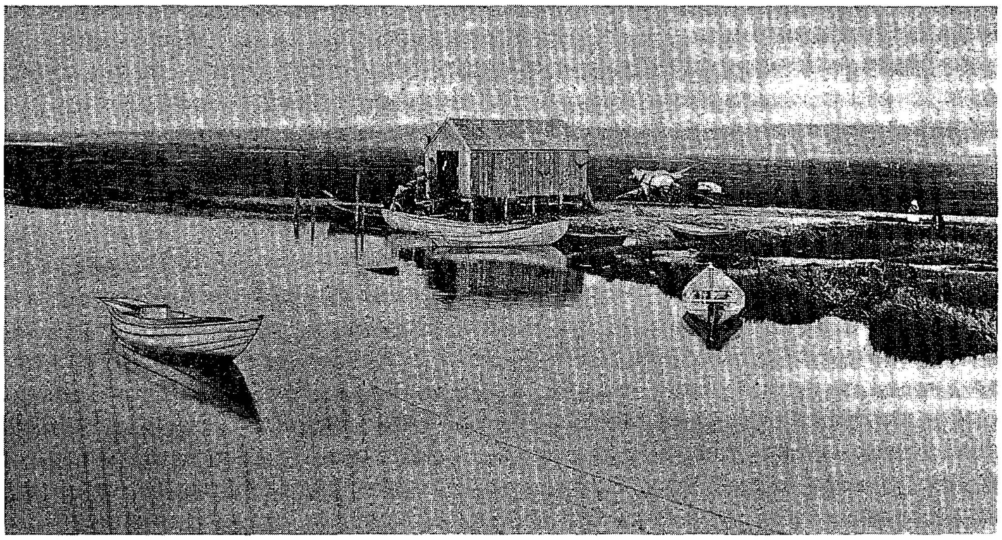
Coastal Land Use

The history of this coastal area reflects a number of different uses by man, ranging from cattle grazing to off-road vehicle recreation. Each of these uses reflects the differing values of the inhabitants, as well as their degree of knowledge of the natural systems.

Indians, the first human inhabitants of our coast, left little evidence of their presence and seem to have lived compatibly with the coast.

The first white settlers established Plymouth in 1620. Sustained by farming and fishing, these early residents utilized the abundant resources of the land and sea. The virgin forests provided the lumber for building homes and ships. Clay discovered in the Cliffs at Manomet Point and Ship Pond was mined for pottery.

In 1624, ten men received permission from the court in Plymouth to venture south to take advantage of the great salt marshes at Sandwich and Barnstable for grazing animals. Following an old Indian trail, they settled in an area now known as Sandwich. The vast marshes provided abundant feed for their cattle. Salt marsh grass and seaweed were also gathered for thatch-



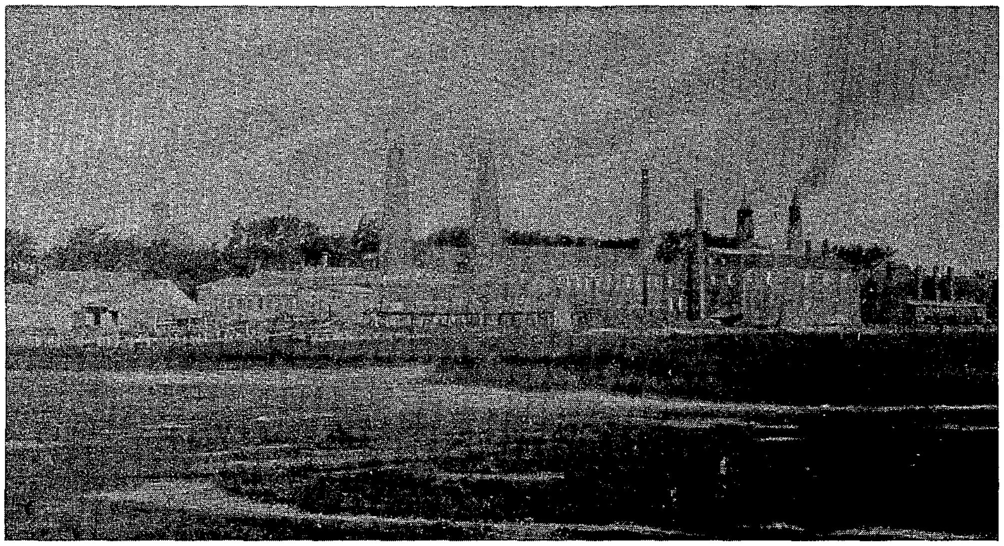
roof homes and utilized as insulation for their homes as well as fertilizer for their crops. The sheltered creeks and inlets served as harbors and navigation channels for coastal trading. Disputes often erupted between the farmers and the fishermen with respect to the use of the marsh areas. The farmers valued the land for farming and grazing cattle, but the fishermen valued it for eels and shellfish as well as access to fishing grounds in Cape Cod Bay.

These early settlers were wary of situating their homes and structures too close to the coast. They had observed tidal flooding along the coast during storms.

The town of Sandwich prospered during the 1800's. In 1825 the famous Sandwich Glass Factory was established adjacent to Mill Creek, which was used to transport goods in and out through Sandwich Inlet.

By the 1830's small settlements such as Ellisville dotted the coastline.

27. Fishing shacks and workboats near Sandwich, ca. 1900-1910.



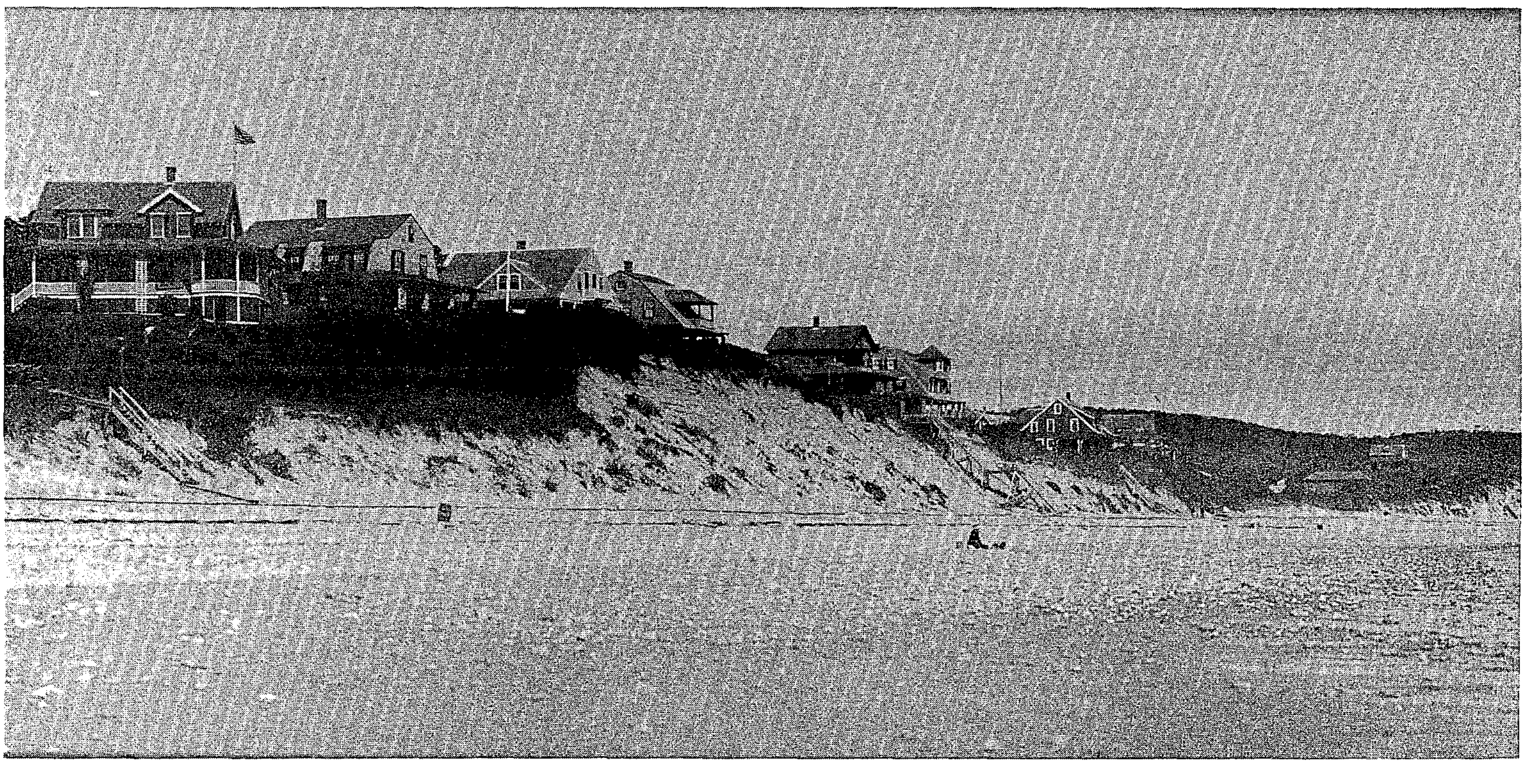
These tiny communities had developed a prosperous coastal trade. Ellisville Harbor became an outlet for trading of timber from the surrounding forests and "bog iron" from the numerous nearby wetlands. These were transported to Plymouth Center and Boston via small coastal packets.

The bogs were eventually depleted as a source of iron by the 1800's but another resource — cranberries — gained in importance. Plymouth became a major producer in Massachusetts, which along with New Jersey, led the nation in cranberry production around the turn of the century.

In 1914 the building of the Cape Cod Canal was completed. A wide man-made waterway was cut through Scusset marsh and the dredged material was deposited in the adjacent marsh. Jetties were constructed at the entrance to the canal to inhibit shoaling by sand transported alongshore by littoral drifting.

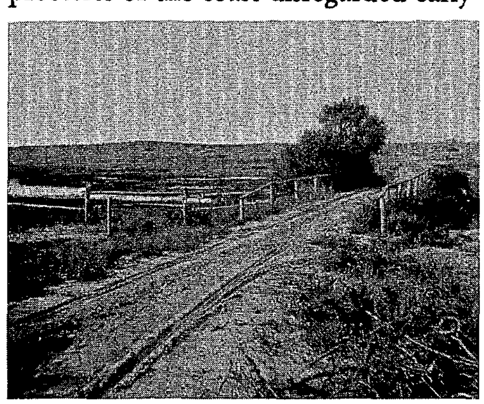
An important event promoting the development of the coastal region was the completion of the railroad in 1848. Railroad beds were constructed across the great marshes, cutting off daily tidal flushing and flow of nutrients to the coastal waters. The railroad provided a means for transporting goods which eventually phased out coastal trading by boat. The railroad also provided Bostonians with convenient access to the scenic coastal areas of Cape Cod.

28. The Sandwich Glass Works, ca. 1910.



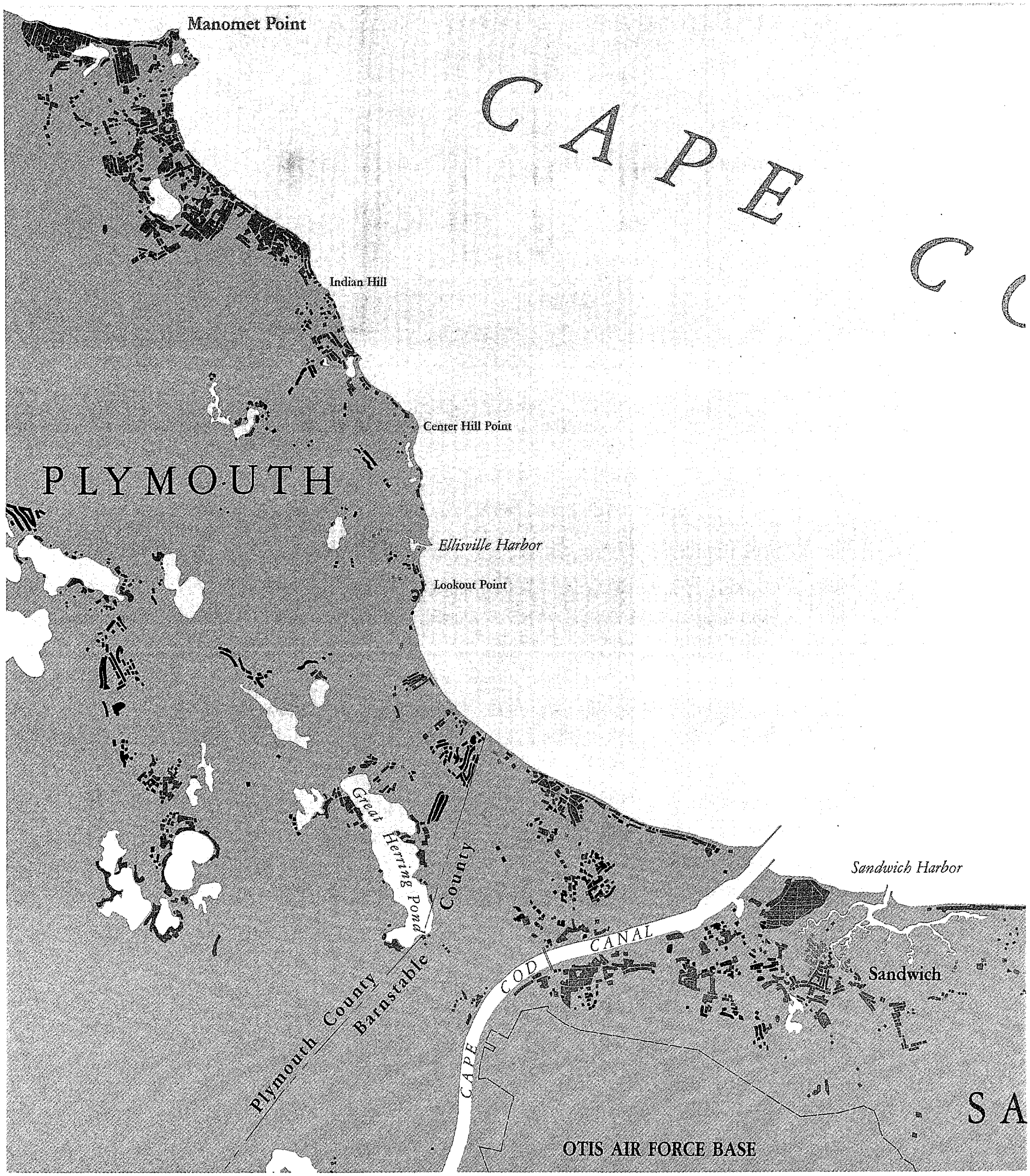
In the early 1900's shorefront development increased as these areas developed into resorts, a trend accelerated by the rising popularity of the automobile. Finally local, state and federal development of public access areas further increased popularity of beaches for recreation. Numerous pedestrian pathways now weave across the dunes at Scusset, Sagamore and Springhill Beaches. Parking lots and roads to waterfront homes also occupy areas of beach and dune areas. Sandy Neck became a popular recreational area for off-road vehicles. An intricate system of roads developed through the dunes along the entire length of Sandy Neck. Figure 35 illustrates the development trends of the Guide Area from prior to 1865 to 1977.

Unlike the early coastwise residents, summer dwellers and vacationers often unfamiliar with the natural processes of the coast disregarded early settlement patterns and built in areas that would have been considered unsuitable by the early settlers. By the 1950's the edges of the cliffs and dunes had become such valuable real estate that most of these areas had been developed. This resulted in problems that previous generations had not encountered.

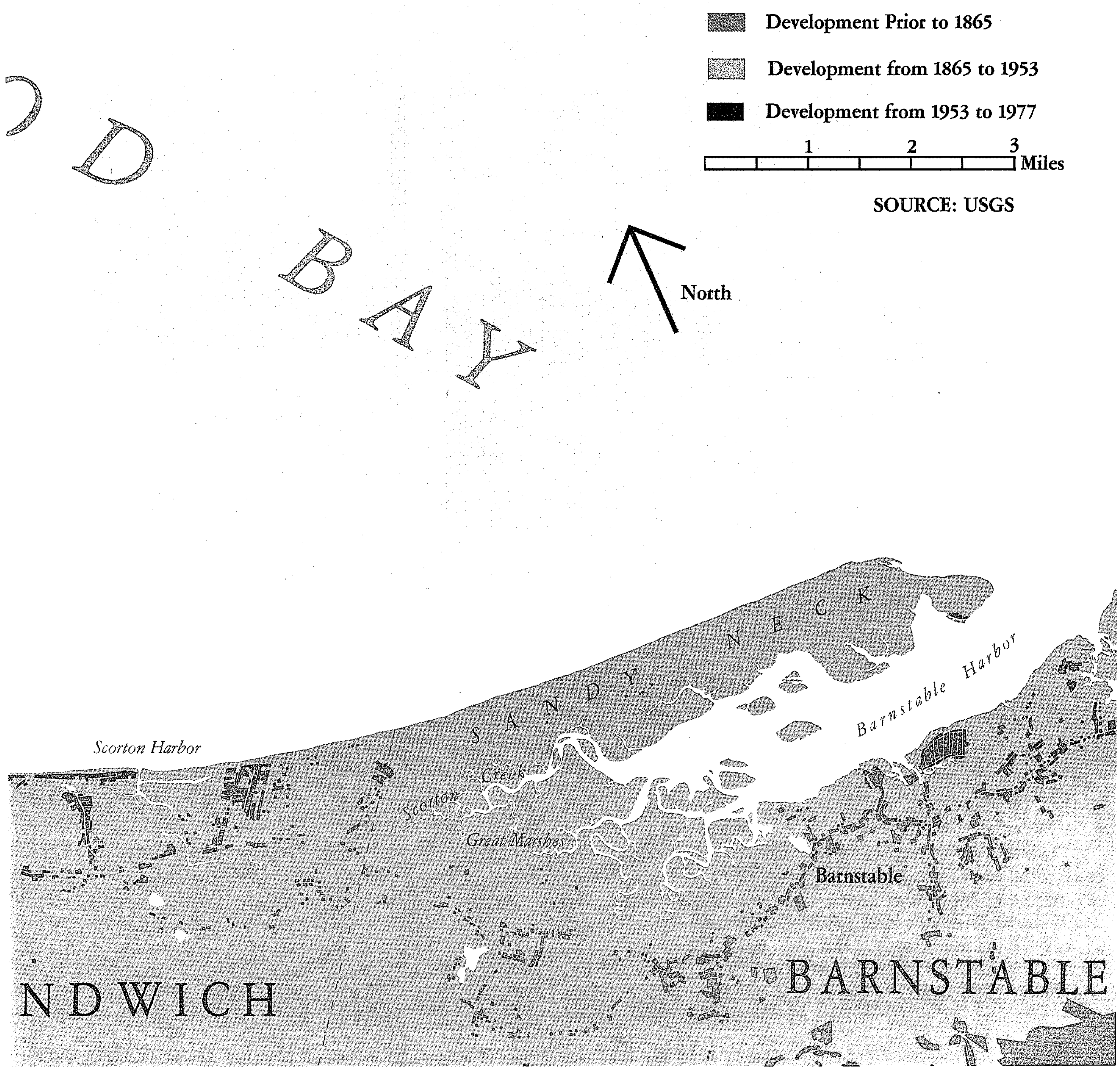


29. Oceanfront cottages at Sagamore Beach, ca. 1916.

30. The Beach Road Bridge in 1911. Houses on East Sandwich Beach are on the horizon.



35. Development trends of the Guide Area.


Development Prior to 1865
Development from 1865 to 1953
Development from 1953 to 1977
1
2
3
Miles
SOURCE: USGS
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D
BAY
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Scorton Harbor
Scorton Creek
Great Marshes
Barnstable
NDWICH
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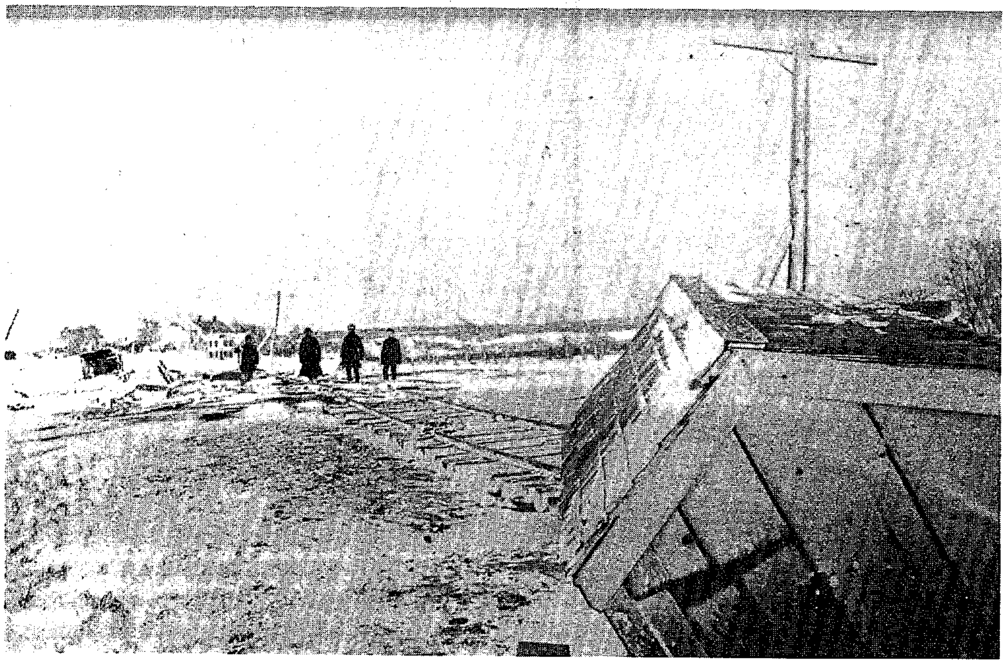
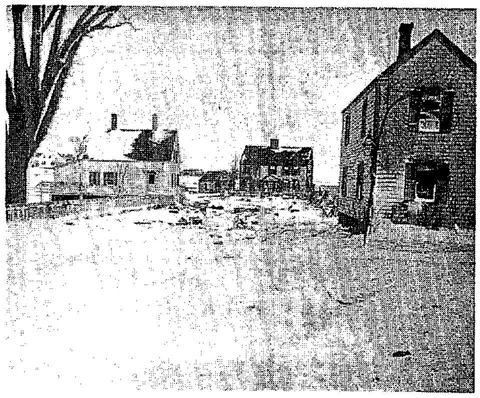




Coastal Flooding

Shortly after their arrival to the New World the early white settlers were beset by the disaster of coastal flooding. William Bradford accounts in 1635 of,

> "a might storm of wind and rain . . . it came with a violence, to the amazement of many . . . The signs and marks of it will remain for 100 years in these parts where it was sorest." (Wood, 1976)

The storm described by another,

> ". . . blew down houses and vessels were lost at sea . . . It caused the sea to swell in some places to the southward of Plymouth to 20′ . . . It began in the southeast . . . the greates force of it at Plymouth continuing for 5 to 6 hours." (Wood, 1976).

What these early inhabitants were experiencing was their first hurricane. This early encounter perhaps taught them of the effects of a storm on coastal areas and the resulting flooding that accompanies these events.

Similar storms were to follow. In 1722 a northeaster struck the coast of New England causing the water level to rise 15′ above normal.

Severe flooding occurred in Sandwich during the storm of 1851 when a gale pushed tide water up to flood the Sandwich Glass Factory 25 years after it was established, and to the north Minot's Lighthouse was partially destroyed.

The Portland Gale of 1898, the most damaging storm ever to hit Sandwich, caused extreme destruction to structures within its reach. The highest tide reported since 1851 washed a wall of water 4′ high over the lowlands. Overwash of the beach occurred in three places between Sandwich and Springhill. Many areas of the railroad were destroyed where it crossed the marsh. The main street in Sandwich was inundated to a depth of 3′ as 60-80 M.P.H. winds whipped the coast. More recently the storm of December 29, 1959 caused major flooding in Barnstable and Sandwich. Tidal flood water engulfed all coastal areas and waves battered man-made seawalls and other structures. The great "Blizzard of 78" a nor'easter not soon to be forgotten, battered the coast with 92 M.P.H. winds. The severe flooding and wave damage to coastal areas caused loss of life, property, and evacuation of 11,000 persons in New England. Figure 40 summarizes characteristics of the major storms affecting Cape Cod.

36. Damage from the Portland Gale of 1898 in Sandwich. The railroad bed in the mid ground was totally wrecked and the house in the foreground was knocked off its foundation.

37. Sandwich houses damaged by the Gale.

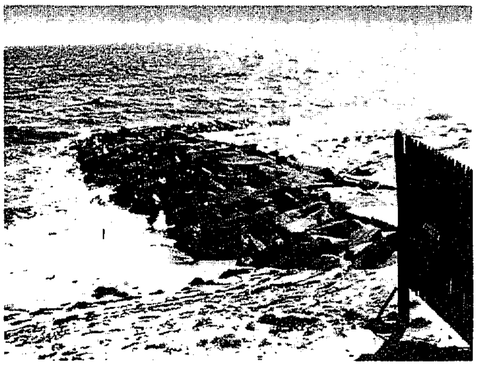
38. Severe erosion near Ships Pond caused by the 1978 blizzard.
39. A cliff side house severely undercut by wave action from the blizzard.

Figure 40 Table of Historic

August 15, 1635	Water level rose 20′	A hurricane, it was described by William Bradford as the first recorded storm in New England. It coincided with the perigean spring tide.
February 24, 1722	Water level rose 15′4″ above low water	The storm was a northeaster.
January 1, 1778		It was called the "Magee Storm" and had the highest tide reported in fifty years. The storm's rising water pushed ice floes into the marshes and destroyed the marsh hay stock structures.
April 17, 1851	Water level was 14′9″ above mean low water	Called "Minot's Gale", it produced extensive coastal flooding. In Sandwich, the tide waters reached the Glass Works.
April 12-24, 1888		The "Blizzard of 88" was a northeaster with extremely high winds.
November 26, 1898	The water level rose 14′ above mean low water	The "Portland Gale" was the most destructive storm in the history of Sandwich. Its 60-80mph winds pushed a wall of water four feet high over the marshes and destroyed parts of the dike and railroad bed. Main and River Streets in Sandwich were flooded. The passenger ship *The Portland* was lost off the coast of Cape Cod.
December 26, 1909	At Barnstable, the water rose 5′ above mean low water.	The storm was a northeaster.
March 3-4, 1927		A perigean spring tide, it coincided with onshore winds of 21-49 mph.
September, 1938	The water level rose 5′ above mean high water	This devastating hurricane took 187 lives and caused record flooding throughout New England. Winds of 186 mph were recorded.
February, 1940		This northeaster undermined beach front homes and caused shoaling in Sandwich Harbor.

Storms affecting the Guide Area

April 21, 1940	The water level rose 13′8″ above mean high water	This storm combined 31 hours of 30+ mph winds with a perigean spring tide.
September 14-15, 1944		This hurricane had 80-104 mph winds.
November 28-30, 1945	The water level rose 12′5″ above mean low water	This storm, like the storm of April 21, 1940, had sustained onshore winds with a perigean spring tide. There was much damage to shorefront property and erosion of as much as 15′.
April 31-September 1, 1954		Hurricane Carol's 100+ mph winds caused much damage to the south shore.
September 11, 1954		Hurricane Edna, closely following Carol, had winds of 100+ mph and caused additional damage to the South Shore.
December 29, 1959	The water level rose 15′ above mean low tide and in Boston was 2½′ above normal	This storm had ENE winds of 25 mph with strong gale forces. Its tidal flood waters engulfed all coastal areas, battering sea walls and causing flooding to within 50 yards of Main Street in Barnstable. 13 houses were inundated there.
September 12-13, 1960		Hurricane Donna.
November 28, 1967		This storm was another example of a perigean spring tide coinciding with sustained onshore winds.
January 8-9, 1978		This storm occurred on a higher than normal tide and caused flooding and severe coastal erosion.
February 6-7, 1978		The "Blizzard of 78" was a northeaster with record snowfall, flooding and erosion. An estimated total of 180 million dollars of damage in the most destructive storm of recent times.



Coastal Engineering Structures

Man's response to the loss or potential loss of property built within the reach of coastal processes has been the development of various coastal engineering structures. These include groins, jetties, seawalls, revetments and bulkheads. Each is designed to act either as a barrier to trap sediment being transported alongshore, or as a wall to protect cliffs and dunes from destructive wave action.

Examples of typical coastal engineering structures will be discussed in the following sections. A complete inventory of structures, including photographs, was completed for the stretch of shoreline discussed in this guidebook. The inventory is available for review or use at the Coastal Zone Management Office.

Groins

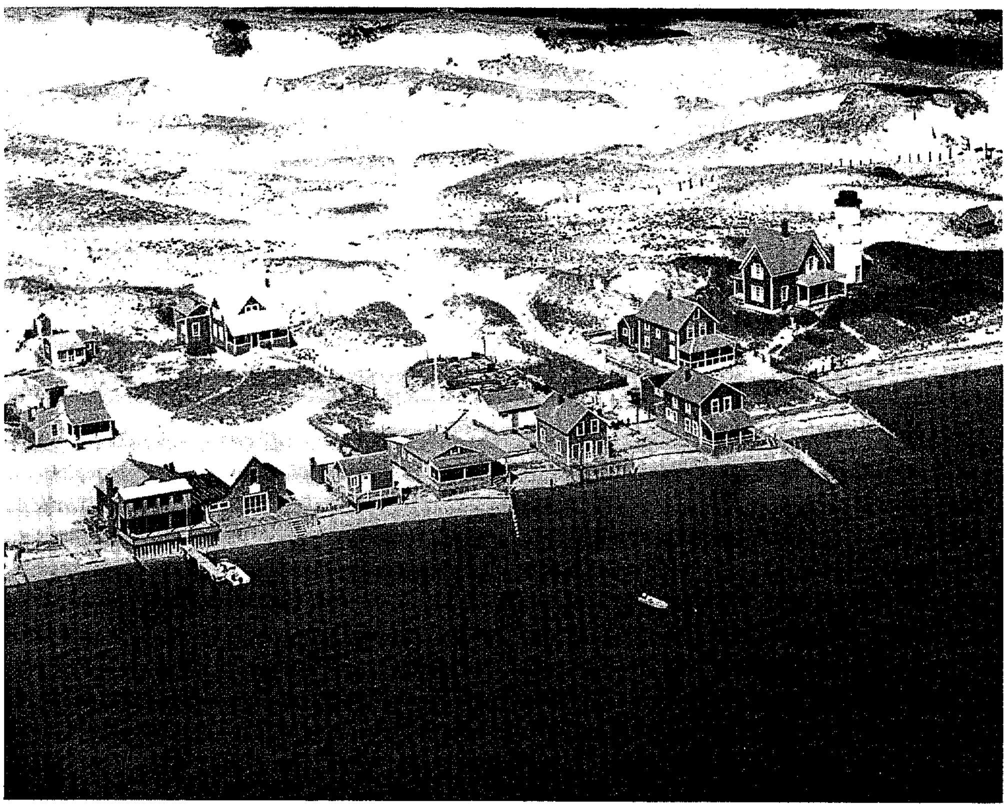
Groins are elongate structures usually oriented perpendicular to the shoreline and commonly constructed of rock, concrete, wood or different combinations of the three. Groins are designed to alter the shoreline by disrupting and slowing littoral drifting, thereby causing sand to be deposited updrift of the groin and widening the beach. When the updrift side of the groins is filled, sand may move around the groin, often into deeper water where it is lost from the littoral drift.

Jetties

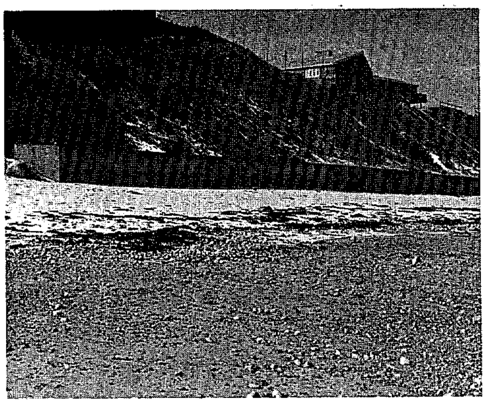
Jetties are elongate structures similar to groins except that they are built at the seaward side of a coastal inlet or harbor. Their purpose is two-fold: to stabilize the inlet and to prevent shoaling of the inlet by sand carried by littoral drifting. To completely halt transport of sand into the inlet, the updrift jetty must reach seaward to deep water beyond the littoral zone. As a result, sand nourishment to beaches downdrift on the inlet is severely restricted or cut off altogether causing starvation and rapid erosion.

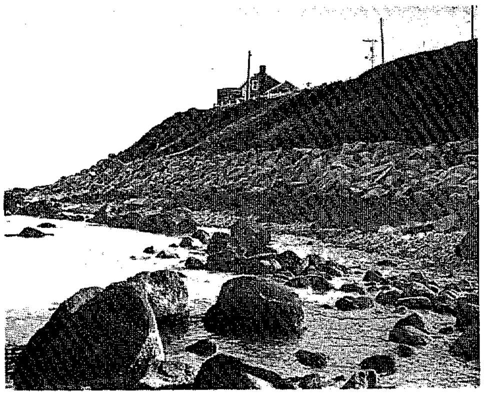
The long jetty on the northwest side of the Cape Cod Canal traps much of the sand which reaches it, causing severe erosion of the beaches of the canal. The small inlets such as Ellisville, Sandwich and Scorton Harbors have short jetties which do not completely disrupt littoral sand transport and sand can naturally bypass the inlet.

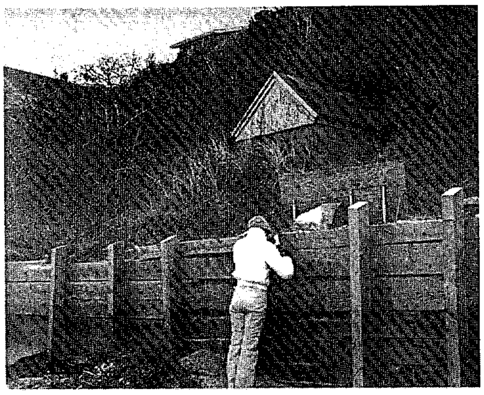
41. A groin. Littoral drifting is from right to left.

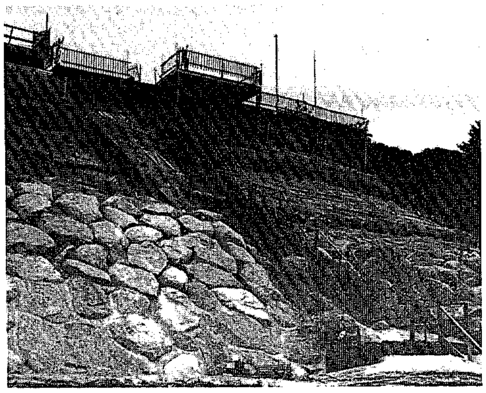


42. A groin field on Sandy Neck near Beach Point.









Seawalls, Bulkheads and Revetments

The most common structures found along the shoreline are seawalls, revetments and bulkheads. These structures are placed on or behind the beach in an orientation parallel to the shoreline. While distinctions between these structures are not always clear, they are designed to prevent erosion by wave attack.

The adverse impacts of these structures arise from their rigidity. Beaches naturally absorb wave energy. However, these rigid structures reflect incoming waves, causing turbulence which scours and removes the beach sand particularly at their base. Accelerated scour is commonly observed on the ends of the structures. Overtopping waves may scour away the earth backing these structures, leading to their premature failure. A more long term effect is the reduction of sediment supply to the beach. Without cliff and dune erosion the beaches are not provided nourishment and cannot fully replenish losses from storms or longshore drifting.

Terracing

Another method of coastal bank stabilization is the terracing and planting of the bank. The aim of this method is to prevent loss through slumping and gullying. However, it cannot prevent wave cut erosion of a bank. Cliff-terracing can give the cliff face a staircase relief by the construction of a series of wood or steel retaining walls. These reduce the speed of rain water running down the cliff face, thereby holding the cliff sediment in place. This can also be achieved by planting vegetation, usually grass and shrubbery, whose roots systems bind the sediment in place. Thorny shrubbery or poison ivy can be used to discourage pedestrian traffic on the banks.

43. A typical seawall construction.

44. A stone revetment.

45. A wooden bulkhead.

46. Cliff terracing.

3 Coastal Management

Existing Coastal Management Framework

Until the 1960's, engineering structures were perceived as the optimum solution to coastal hazards. With increased recognition of the natural processes governing coastal change came public pressure to preserve the features which provide the natural protection of the coast. Local conservation commissions were established to review proposed alterations of coastal systems.

The Massachusetts Wetland Protection Act of 1972 provided these conservation commissions with an important tool to further protect coastal areas "significant to the interests of storm damage prevention and flood control." During the same year Congress passed the Coastal Zone Management Act which eventually made available to the Commonwealth funds for the establishment of a state Coastal Zone Management (CZM) Program. Working together with the CZM Program, the Department of Environmental Quality Engineering in 1978 provided the conservation commissions with coastal wetlands regulations. The regulations identify the particular characteristics of coastal wetlands which should be protected because they provide storm damage prevention and flood control. A "Guide to the Coastal Wetlands Regulations" is available to assist conservations commissions and applicants in interpreting and applying these regulations. The appendix provides information on obtaining additional sources of assistance.

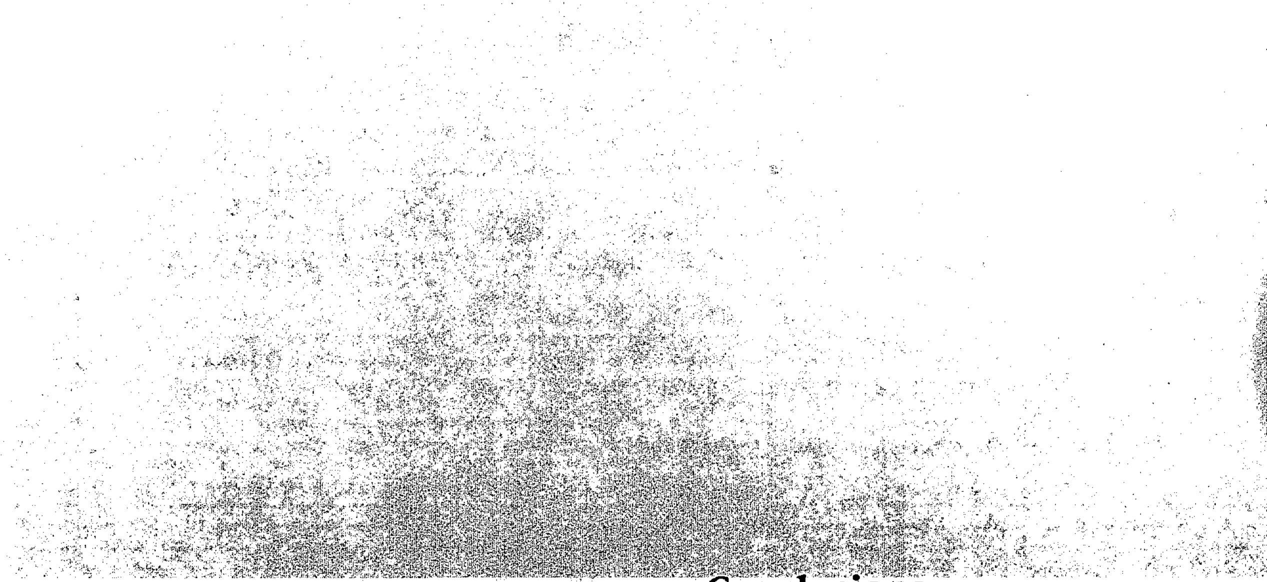
Planning for the Future

An adequate coastal management program should include 1) planning for future development based on existing knowledge of coastal systems, and 2) a program of research and education to increase knowledge of those systems. An introduction to the existing knowledge of the coast from Manomet Point to Sandy Neck is provided in this guidebook. Future changes may be approximated from past changes, except where processes have been altered by engineering structures or other man-made alterations. The major man-made obstacle to sediment transportation is the Cape Cod Canal and its jetties, which (unless corrective action is taken) can be expected to continue producing accretion of Scusset Beach and erosion of the Sandwich shoreline east of the canal. Lesser, but still significant effects will result from the existing seawalls, harbor jetties, and groins throughout the area. In planning for the future the protective characteristics of coastal features can be best preserved by:

a) not adding to existing disturbances, and
b) removing or minimizing disturbances.

Disturbances to the supply of primary coastal sediment include the building of coastal engineering structures at the base of coastal cliffs. The placement of buildings should be planned with recognition of the natural cliff retreat rate. A reasonable "set-back" distance may be derived by reference to the shoreline change maps (see Appendix) and the desired period between movement of the building. Care should be taken to provide for a sufficient area inland from such buildings to accomodate movings. Efforts should be made to encourage town and state funding or tax benefits to help defray the expense of such moves.

Disturbances to the transport of coastal sediment and to the features



formed by deposition of such sediment, include the jetties and groins mentioned above as well as other coastal engineering structures such as seawalls and breakwaters. Adding to such disturbances would include increasing the size of existing structures as well as adding new ones. Any further construction of buildings on the barrier beaches would disturb their protective characteristics.

Methods of improving currently disturbed coastal cliff areas include the revegetation of the cliff face and the use of light, removable steps on the cliff face. Disturbances due to coastal engineering structures may be reduced by modifying them to reduce their adverse effects when possible, and by not repairing or replacing them when they are damaged or destroyed. Periodic beach renourishment with suitable sediment may in some cases lessen the adverse effects of such structures. In the barrier areas, existing buildings, once destroyed, should not be rebuilt. Disturbances to vegetation may be reduced by use of appropriately designed walkways for pedestrians and by limiting access to off-road vehicles. Snowfences can temporarily stabilize disturbed dune areas while revegetation efforts are underway. Revegetation of disturbed marsh areas has also been successful.

Conclusions

It is clear that most historical and present day coastal hazards are in reality natural processes which adversely affect man because of improper development of coastal areas. In an attempt to reduce these hazards man has built coastal engineering structures which have in many areas diminished or destroyed the coast's natural defensive system. These structures have had a compounding negative effect by creating an illusion of security which has promoted further coastal development. The best way to be spared of the "hazards" is to avoid developing in areas which are subject to predictable change due to coastal forces and processes.

Appendices

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Glossary

Accretion — The gradual addition of new land by the deposition of sediment carried by wave action.

Backshore — Upper shore zone, beyond the reach of ordinary waves and tides.

Barrier Beaches — A narrow low-lying strip of land generally consisting of coastal beaches and coastal dunes extending roughly parallel to the trend of the coast. It is separated from the mainland by a narrow body of fresh, brackish or saline water or a marsh system. A barrier beach may be joined to the mainland at one or both ends.

Coastal Bank — The seaward face or side of any elevated landform, other than a coastal dune, which lies on the landward edge of a coastal beach or wetland.

Downdrift — The direction of predominant movement of littoral materials.

Erosion — The gradual wearing away of land through wind and wave action or runoff from the bank.

Embayment — An indentation in a shoreline forming an open bay.

Fetch — The continuous area of water over which sustained winds blow.

Foreshore — The lower shore zone, between ordinary low and high tide ranges.

Glacial Till — Unsorted sediment carried or deposited by a glacier.

Groin — A shore protection structure constructed perpendicular to the beach to trap sand being transported in the longshore current.

Groundwater — Water below ground level in the zone of saturation.

Headland — Glacial or preglacial landforms which project into the sea.

Littoral Drifting — Movement of sediment, including sand and gravel, along the coast caused by waves and currents.

Moraine — Ridges or mounds of material deposited at the margins of retreating glaciers.

Offshore Bar — An accumulation of sand in the form of a ridge, built at some distance from shore under water resulting chiefly from wave action.

Onshore Wind — A wind blowing landward over the coastal area.

Overwash — The transport and deposition of water and material over and through a dune system during periods of storm elevated water levels.

Periglacial — Refers to areas, conditions, processes, and deposits adjacent to the margin of a glacier.

Permafrost — Permanently frozen ground.

Seawalls — Man-made wall or structure built parallel to the shore.

Sediment — Solid material, both mineral and organic, that is either in suspension, is being transported, or has been moved from its site of origin by air, water, or ice and has come to rest on the earth's surface either above or below sea level.

Storm Surge — A local rise in sea level along the coast due to the stress of high winds and reduced atmospheric pressure.

Swash — Rush of water up the beach face following the breaking of a wave.

Tidal Inlet — An opening maintained by tidal flow which connects a bay or lagoon with a larger body of water.

Tidal Range — The vertical difference between the level of water at high tide and low tide.

Source of Assistance

Local

Conservation Commission
Planning Board
Building Inspector
Natural Resource Officer

Regional

Regional Planning Authority
County Extension Service
Sea Grant Programs

State

Department of Environmental Quality Engineering — Wetlands Division
Department of Environmental Management — Wetlands Restrictions Program, Natural Heritage Program
Coastal Zone Management
Department of Public Works — Photogrammetry Section
FEMA/State Assistance Flood Mitigation Program

Federal

Federal Emergency Management Agency
U.S. Army Corps of Engineers
National Ocean Survey
Soil Conservation Service
U.S. Geological Survey

Other organizations which provide advice on coastal hazards

Several universities, non-profit research organizations, and private consultants in S.E. Massachusetts provide site-specific information on coastal processes and hazards. Information concerning these organizations may be obtained from the CZM Office.

Shoreline Change Maps

Coastal Zone Management has, in the course of preparing this guide produced a set of maps that delineate the shoreline changes of the Study Area. Overlain on appropriate USGS 1:25,000 scale orthophotograph* sheets are delineations of historic shorelines dating from 1899 to 1977. Diazo prints of these maps are available from CZM for those interested.

The historic positions were compiled using maps, charts and aerial photographs supplied by the National Ocean Survey. Digital Graphics Inc. of Rockville, Maryland processed the material. Jet Bately and Peter Gibson of National Ocean Survey provided additional technical assistance.

The maps give a reliable determination of how the shoreline has changed in the past. From this information general shoreline change trends can be identified and applied to future changes. It is recommended that these maps be used when planning, designing or reviewing projects in the Guide areas.

*Orthophoto maps combine a surveyed coordinate grid system with the detail of aerial photographs. At the scale of 1:25,000, one inch equals 2,083 feet.

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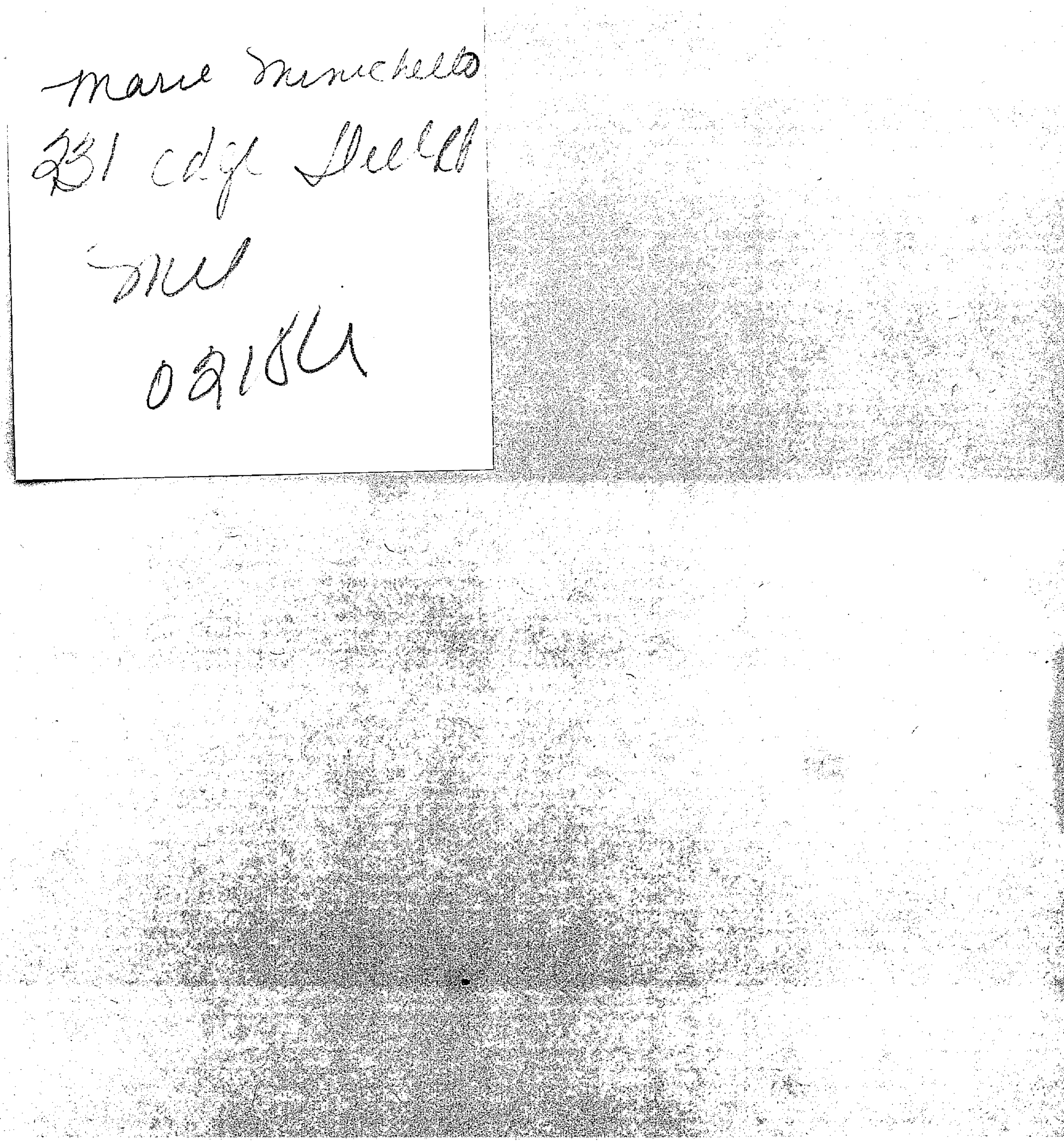

Photographic Sources

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Ms Barbara Gill, (Collection) 27, 28, 30, 32, 33,

Mr Ben Harrison 18

Mr Stan Humphries 38

Kelsey Aerial Photo 34, 42

Mr Eugene Peck 13, 14, 16, 48, 49, 50, 51

Sandwich Historical Commission 26, 29, 31, 36, 37

Mr Les Smith 17