Tales of the Coast

November 2009

Dynamic Sustainability:

Shoreline Management on Maryland's Atlantic Coast

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Dynamic Sustainability details the history of Ocean City and Assateague Island, Maryland, on the Atlantic coast of the United States. As coastal communities, these locations have been significantly impacted by the waters surrounding them, the storms that strike them and the inlet that passes between them. This case study examines the ways in which residents and officials have managed the issues inherent to living next to an ocean and how the U.S. Army Corps of Engineers has participated in these management efforts.

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Institute for Water Resources

Rose Rankin
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Rose Rankin

Preface

Dynamic Sustainability details the history of Ocean City and Assateague Island, Maryland, on the Atlantic coast of the United States. As coastal communities, these locations have been significantly impacted by the waters surrounding them, the storms that strike them and the inlet that passes between them. This case study examines the ways in which residents and officials have managed the issues inherent to living next to an ocean and how the U.S. Army Corps of Engineers has participated in these management efforts.

Introduction

The people who live and work along Maryland's Atlantic coast have contended with the changing nature of Ocean City and Assateague Island for hundreds of years. The land itself retreats in places where sand is eroded, and in other places the land grows where sediment gathers, or accretes. Ocean City Inlet, an important economic engine for the region, is kept open by structural intervention, which has altered the currents and other oceanic processes that affect the Town of Ocean City and the undeveloped territory of Assateague Island.

Maintaining the beaches and inlet has presented many challenges because of the various ways the land and water are used. Fishing and tourism are key industries in these locations that require navigable waterways and sandy beaches, while environmental preservation of these unique coastal ecosystems grew in importance during the late twentieth century. The Corps, along with many other local, state and Federal agencies, has tried to balance multiple management objectives for this region so that diverse goals can be met.

Scientific and technological advancements have influenced the decisions made along Maryland's Atlantic coast. The Corps and other stakeholders have used these innovations to change and refine their responses to sediment management. Over time, the Corps has developed a regional outlook for sediment management that encompasses the multiple ways that resources are used and the interconnectedness of coastal areas. This form of management also advocates using methods that can be maintained for many years. The evolution of regional and sustainable management principles is the story of coastal and shoreline management at Ocean City and Assateague Island.

The ephemeral nature of these coastal areas necessitated a flexible and responsive form of management. Ocean City and Assateague Island are barrier beaches, which are narrow strips of land along the coast. Their eastern edge faces the Atlantic Ocean while their western side meets the bays that wash up against the mainland shore. As such, barrier beaches provide protection to the mainland coasts across the bays, but they are continually changing because of their exposure to the ocean and bays. The protective value of Ocean City and Assateague Island as barrier beaches, along with their dynamic nature, has made it crucial to manage them in a sustainable manner. Thus, the Corps' management principles have changed and evolved, like the barrier coasts themselves.

Prologue: Barrier System Basics

To view a shoreline is to gain a sense of impermanence. Shorelines are the places where constantly moving wind and water meet the land that is continually adjusting to that movement. For millennia, humanity has tried to respond to, and occasionally control, the earth's ever-changing water and adjoining landforms. These efforts remain at the center of peoples' interactions with the coastlines of the world.

Humanity's responses to the planet's evolving coasts have differed, depending on the particularities of the shore and situation. The shape and topography of a continent can affect its edges, which become beaches. Where large cliffs and headlands abruptly meet the water, rocky shores or small pocket beaches can occur. Examples of these types of beaches are found in New England and the Pacific Northwest, where there is little or no beach between the rocks and the water, or at most, small pockets of sand trapped between cliffs. When those cliffs have been exposed to erosive forces for long periods of time, often accompanied by sediment deposition from rivers reaching the coast, long mainland beaches develop, as can be seen around the Great Lakes and along the East Coast in southern New England.[1]

Rivers can also affect coastlines by creating marshy deltas from sediment that is carried downstream and deposited at the river's mouth, such as where the Mississippi River meets the Gulf of Mexico.[2] Yet another type of beach is a barrier, which commonly takes the form of an island or spit that lies between the open ocean and a bay adjacent to the mainland shoreline. These beaches are found along the Atlantic and Gulf coasts of the United States, where they protect the bays and shorelines to their landward sides from the full force of the ocean's waves. Combinations of sand, vegetated dunes and marshes, barriers have been characterized as “typically low lying, flood prone, and underlain by easily erodible, unconsolidated sediments. Thus, these land forms are especially difficult to develop because they are so dynamic.”[3] This dynamism is exemplified by the experiences of two Atlantic coastal barrier features, Fenwick Island and Assateague Island, and the ways in which humans have responded to their continual changes.

Barrier Beginnings

Certain geological processes dictate the formation of barrier features. Fenwick Island is actually a 10-mile-long (16 km) barrier spit that is attached to the Delaware-Maryland-Virginia (Delmarva) Peninsula, and Assateague is a barrier island because it was severed from the rest of the spit.[4] Both features are the results of eroded sediment being carried and deposited by currents. Dr. Stephen Leatherman explained in *Barrier Island Handbook* that “Barrier systems form as sand is transported from a source, such as sea cliffs and associated beaches, toward a region of accretion and sedimentation in open water.”[5] When the sediment remains attached to the source, it becomes a spit. In the case of these features, sediment that had eroded from the Delaware headlands formed the spit, and Assateague Island was separated from Fenwick by the opening of an inlet in 1933, leaving the 37-mile-long (60 km) barrier island unattached to a sediment source or larger landform.

The sediment of the Delaware headlands was eroded and moved by rising seas at the end of the last Ice Age. “The volume of water in the sea increased very rapidly after ice melt intensified about 15,000 years ago,” Leatherman stated, and these rushing waters flooded previously dry land and brought large amounts of sediment into the growing ocean.[6] Approximately 3,500 years ago the rate of sea level rise began to stabilize, and wave and current action shaped the sediments into barrier features along the continental coast. "The decrease in the rate of rise allowed coastal environments to evolve differently than when sea level rise was faster. It allowed the steady or semi-steady migration of landforms across the continental shelf," summarized Mark Byrnes, principal coastal scientist at Applied Coastal Research and Engineering. [7] The gentler waves of the slowly rising seas were able to shape the spits and islands without sweeping them out of existence. Fenwick and Assateague Islands developed into "microtidal" barriers because tidal range is relatively low in their vicinity (near 6 ft), and as such they are impacted by other oceanic processes as well as daily tides.[8]

Figure 1: Ocean City Inlet, the northern tip of Sinepuxent Bay and the boundary between West Ocean City and Assateague Island. Photo: J Woerner, IAN Image Library (www.ian.umces.edu/imagelibrary)

Continued Evolution

Ocean waters constantly affect the shape of barriers, namely through current and wave energy. When waves strike the shore at an angle, they generate a "longshore current" that travels parallel to the shore. Longshore currents move sediment along the shore in a process known as "littoral drift" or "longshore sediment transport." At Fenwick and Assateague Islands, waves from the northeast are the most significant because they tend to be highest. These waves create longshore currents that travel from north to south and consequently move large amounts of sediment to the south. Leatherman summarized, "Spit formation through the mechanism of longshore sediment transport is the principal process of shaping barriers. Rates of littoral drift average 200,000-300,000 cubic yards per year along the mid-Atlantic coast."[9] Sediment deposition occurs persistently along barriers, which become elongated and even curved by sand accreting on the

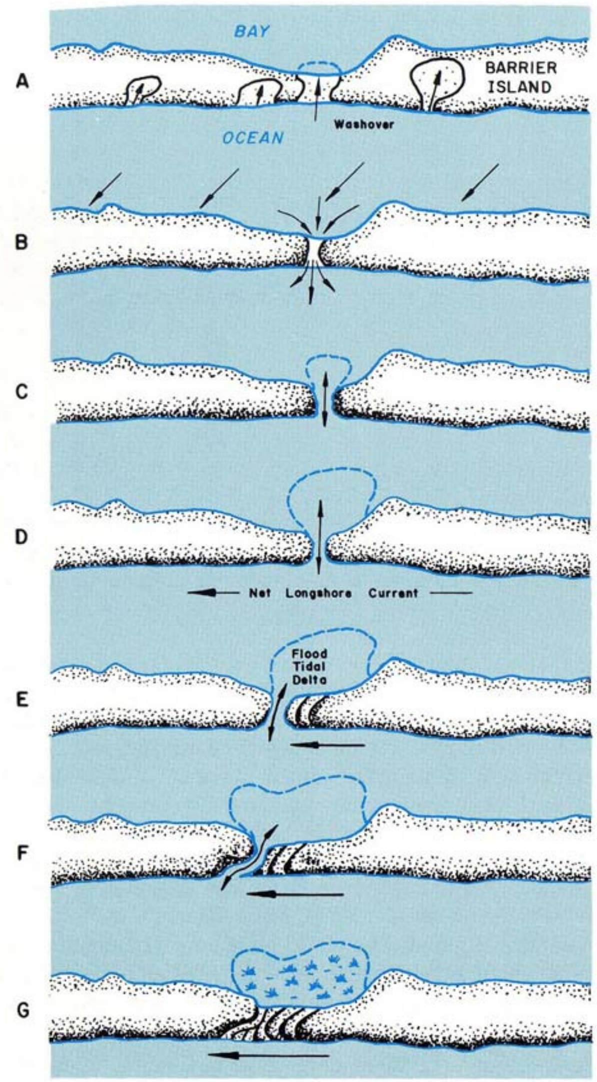

Figure 2: This diagram illustrates the processes of inlet breaching, migration, and closure as longshore sediment transport leads to flood-tidal delta creation and eventually fills the inlet with sediment. Credit: Stephen P. Leatherman.

downdrift end. The curved southern end of Assateague Island, known as Tom's Cove Hook, is an example of this process.

The waves moving perpendicular to the shore also affect the barriers' size and shape. At both Fenwick and Assateague Islands, high-energy waves remove sediment from the beach, occasionally pushing it over the top of the barrier into "overwash," which extends the spit or island to the landward side.[10] This process keeps Fenwick and Assateague continually moving westward by essentially rolling themselves over. Without doing so, these barriers would erode due to rising sea level, and eventually they would be submerged. Sea level rise averaged about one foot (0.3 m) per century over the last few hundred years, and on the gradually sloping Atlantic continental shelf, this level of rising water can cause inundation. Barriers must therefore keep retreating to stay above the escalating water.[11] Overwash is one key method of the migration process.

During storms, when wave energy is at its highest, the opening of an inlet can take place along with sediment overwash. Inlet dynamics are the second factor contributing to the continual migration of these features. When an inlet opens at a narrow point on a barrier, sediment from longshore currents accretes in the bay or lagoon to the landward side of the barrier, creating what is known as a flood-tidal delta. Continued littoral drift eventually closes these inlets by depositing sediment along the barrier coast, and, as Leatherman explained, "With inlet closure or migration, the flood-tidal delta becomes prime substrate for salt marsh development." These marshes are incorporated into the barrier as overwash extends it landward, and thus these former flood-tidal deltas become a migratory mechanism.[12]

The storms that lead to overwash and inlet breaching may be hurricanes that strike in late summer or fall, or extratropical winter storms known on the Atlantic coast as "northeasters." Therefore, storms, despite their apparent destructiveness, actually contribute to the growth and renewal of these barriers.[13] Any barrier feature in this region must coexist with storm activity because the shape of the continental shelf affects storm water just as it does rising sea level. Dr. Andrew Morang and Charles B. Chesnutt stated, "The importance of the wide shelf is that hurricanes and northeasters can generate large storm surges [over a wide, flat shelf]. During a major storm, damage caused by waves is magnified greatly because the waves are superimposed on an elevated water level."[14]

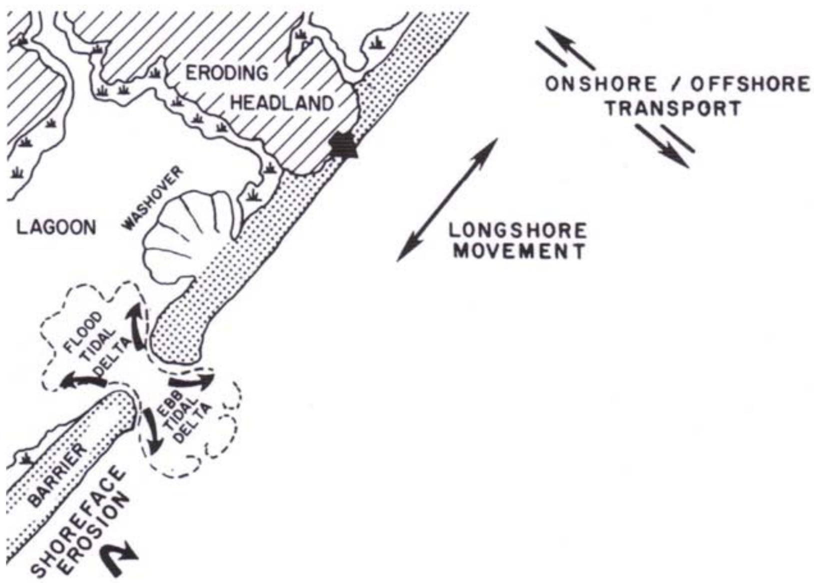

Figure 2-1: Shoreline geomorphic features. General sediment transport pathways shown. Modified from Kraft and others (1987).

Figure 3: Pictured here are a number of geomorphic features common to barrier shorelines. General sediment transport pathways are also shown; onshore/offshore transport takes place with seasonal wave action as well as storm activity. Source: USACE Baltimore District.

Barrier features have adjusted to the storm surges controlled by underlying geology and incorporated this oceanic process into their evolution. They have adjusted so well, in fact, that they rely on inlet dynamics and overwash for their continued existence.

Along with storm activity, seasonal wave action impacts erosion and accretion along barrier beaches. As William Amos explained in *A Barrier Island Natural History,* "In winter, with increased winds and forceful waves, a beach is cut away, narrowing the berm and even creating a small, steep cliff face, or scarp, up against the primary dune." This eroded sand is usually deposited in offshore bars, and the erosion is compensated for by the reconstructive action of low-energy waves that occur commonly in summer. These waves move the sediment back onto the beach, resulting in seasonal changes to the shoreline. Wave action thus changes the beach profile, a cross-sectional view of the beach from the dune to the nearshore. The rebuilding of the beach by low-energy waves pushing sand up the profile can take longer than erosion of the beach by high-energy waves moving sand down the profile. However, in a given year, there are many more days of low-energy waves than there are days of high-energy waves and storm activity, and this helps to balance the effects of erosion and accretion. Therefore, a barrier shoreline is impacted by seasonal changes as well as the long-term landward migration of the entire barrier from inlet dynamics and overwash.[15]

Diverse Shore Environments

Vibrant and unique ecosystems have evolved on barriers despite the constant movement of sand and the storms that batter them with wind and waves. The nearshore and beach comprise environments of a barrier that are, predictably, dominated by sand. The nearshore is the subaqueous zone directly adjacent to the beach, and it often contains

Figure 4: Assateague Island National Seashore Beach.
Photo: National Park Service

sand bars and troughs. This is where waves break before they run up onto the beach itself, which consists of the foreshore that is lapped by waves and the typically dry backshore.

The foreshore and backshore are also known as the subaerial, or visible, beach. This is the wind-swept, sun-drenched environment conjured by the word "beach," and it plays a very important role in the overall stability of the barrier. The National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center stated that, of all the areas of a barrier, the beach "in many respects is the most important because it affords protection from wave attack to the landward upland environments (where development is typically located)." [16] Although they are composed of unconsolidated material, beaches absorb wave energy and provide a buffer between developments and the open water. Because the beach is constantly being re-shaped by currents, wave energy, tides and sediment deposition, any development there exists on essentially impermanent land that will shift, grow and disappear around any structure.

Landward of the beach is the dune area where wind-blown sand gathers into hills and mounds. Fine-grained sand carried by wind collects against debris and vegetation, or even other ridges of sand, and the more stable a dune is, the more vegetation is able to gain a foothold, thereby encouraging the dune-building process.[17]

The most important vegetative species for dunes on Fenwick and Assateague Islands is American beach grass (*Ammophila breviligulata*), which can tolerate salt spray and accumulating sand. This sturdy plant continues growing through piled sand, thereby catching more wind-blown sediment and building the dune. But, as Leatherman assessed, “Dunes grow only to be knocked down and pushed back by the next overwash event on rapidly retreating barriers.”[18] The overwashed sediments form barrier flats, which extend the island landward and propel the natural rollover process. These thin layers of sediments, infiltrated with brackish bay water, comprise an important and delicate ecosystem, and on undeveloped barriers, such as Assateague Island, they host rare, and sometimes endangered, species of plants and animals, particularly birds.[19]

Farther inland are freshwater ponds where the underground water table reaches the surface. These areas are protected from salt spray by dunes, and they are important water sources for wildlife on a barrier. At the highest elevation is the zone that, on undeveloped barriers, evolves into the thicket or forest area. If protected from overwash and salt spray for long periods of time, this environment can evolve to support large trees, shrubs, and abundant wildlife. If a barrier is developed, such as Fenwick Island with the location of Ocean City, this is the region most conducive to supporting structures. On narrow features with persistent overwash, however, the forest environment is often replaced by barrier flats and sparse vegetation, leading to the wetlands that typically occupy the bay side of a barrier.[20]

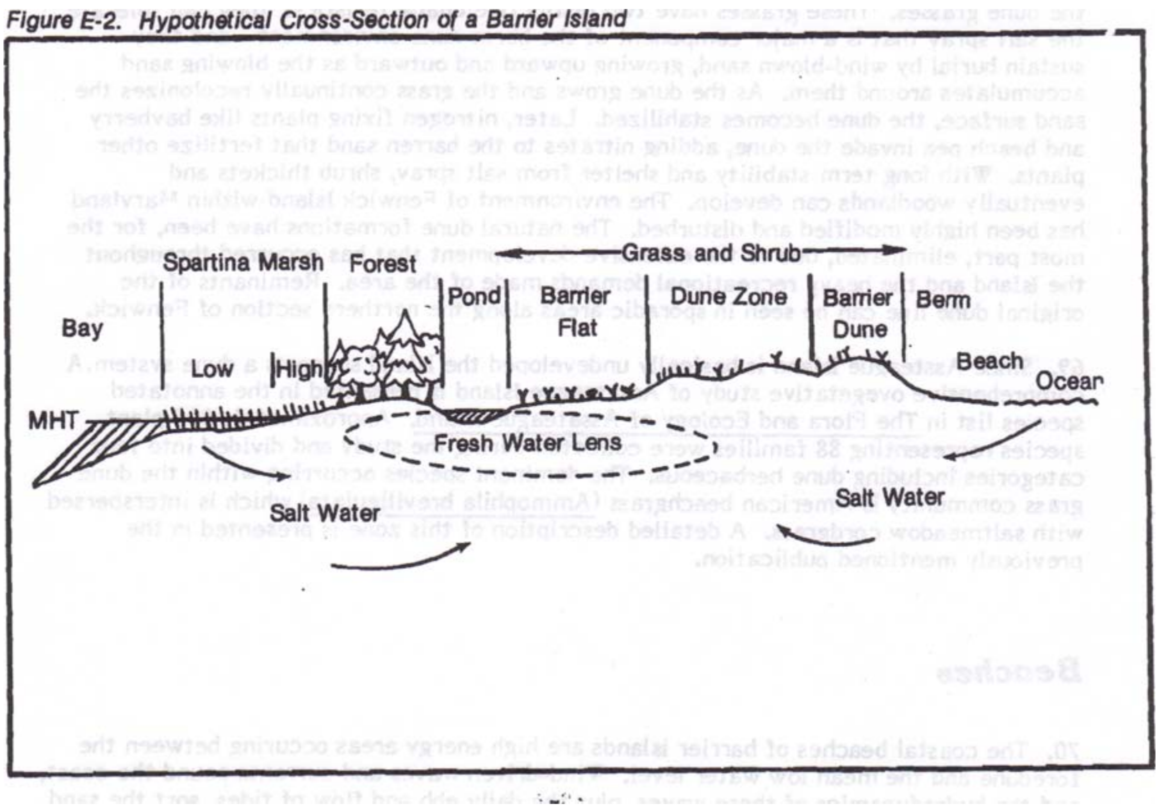

Figure 5: The various ecosystems typically found on an undeveloped barrier island. Source: USACE Baltimore District.

In northern latitudes, barrier wetlands take the form of salt marshes, and on Fenwick and Assateague these environments are dominated by salt-tolerant grasses and a proliferation of wildlife. The vigorous cordgrasses (genus *Spartina*) collect sediment from overwash during storms, stabilizing the bay shore and aiding a barrier's landward migration. Amos explained the process of salt marsh formation in overwash sediment and its role in the dynamics of a barrier island: "Once marsh plants are established, they trap sediment from the tides and add their own substance after seasonal decay in the quiet water. Gradually the sand fan turns dark with organic sediment, the bottom level rises, is exposed at high tide, and new land at last emerges: the island's progress has extended into the bay."[21] Two zones of salt marsh are common to barriers: high marsh is usually flooded only at high tide, and it serves as an important habitat for birds and other animals foraging for food. Low marsh is flooded most or all of the time, and consequently the most salt-tolerant plants thrive there, particularly salt cordgrass *(Spartina alterniflora)*.[22]

Salt marshes are dependent on sediments from the sea even though they are far from the ocean, thereby showing how a barrier's regions are interconnected. Likewise,

Figure 6: Salt Marsh on Toms Cove
Photo: National Park Service

the underwater flood-tidal deltas that began as separate entities eventually merge with the barrier and become salt marshes after natural inlet closure. Salt marshes exist midway between land and water—not stable enough to support buildings but not fluid enough for boat navigation. Any development, either land-based or maritime, must alter these conditions, which the barrier will continuously try to re-establish with storm overwash and the absorption of former flood-tidal deltas.

Each of the environments of a barrier feature is constantly adapting to the waves and winds that surround it. No region is static; all areas of a barrier evolve with the seasonal and storm-induced changes in topography and habitats. Rising and falling tides, gusting breezes, and surging waves all shape the sediments of a barrier, and consequently the life forms that occupy it, including humans. In this way, barrier features exemplify the ephemeral nature of all coasts, which are also subject to the whims and dictates of the air and water that meet at the land's edges. The people who interact with the coasts—such as those at Ocean City and on Assateague Island—have been and continue to be affected by those forces, just as they exert their own impact on the sands that are both fleeting and timeless.

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[5] Ibid., 4.
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[7] Mark Byrnes, discussion with author, December 3, 2008.
[8] Leatherman, *Barrier Island Handbook*, 10-12.
[9] Donald K. Stauble et al., *Beach Nourishment Project Response and Design Evaluation: Ocean City, Maryland, Report I 1988-1992*, Technical Report CERC-93-13 for the U.S. Army Corps of Engineers, August 1993, 9, 13. This source estimated the average amount of sediment to be 175,000 yd^3 per year but possibly reaching close to 300,000 yd^3; Leatherman, *Barrier Island Handbook*, 54.
[10] Byrnes, discussion with author 12/3/08.

[11] Leatherman, *Barrier Island Handbook*, 41-42.
[12] Ibid., 38, 55-63.
[13] Ibid., 46.
[14] Andrew Morang, Ph.D., and Charles B. Chesnutt, *Historical Origins and Demographic and Geologic Influences on Corps of Engineers Coastal Missions* IWR Report 04-NSMS-4, (Washington, D.C: U.S. Army Corps of Engineers, 2004), 4. http://www.nsms.iwr.usace.army.mil/docs/Coastal_Mission_IWR04-NSMS-4.pdf.
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[22] Ibid., 88.

1: Discovery and Early Settlement, 1524–1875

Fenwick Island

The narrow finger of land that would eventually be known as Fenwick Island to the north and Assateague Island to the south was a mostly wild, uninhabited place from its formation well into historical times. The first European believed to have explored Fenwick Island and its vicinity was Giovanni da Verrazano, who sailed along the Atlantic coast in 1524 for the kingdom of France.[1] There is some disagreement as to whether Verrazano was actually in the Delmarva area or possibly farther south, but he is generally credited with discovering the region.

Henry Norwood's account of abandonment on Assateague Island in 1650 is the first precise account of exploration, albeit involuntarily. Norwood and a party of colonists were marooned on the island en route to the Virginia colony. As Mary Corddry summarized in *City on the Sand: Ocean City, Maryland, and the People Who Built It,* "They suffered intense hardships before reaching their destination with the help of friendly Indians."[2] By the late seventeenth century, Fenwick Island and other barriers along the Eastern Shore served as grazing lands for livestock from the mainland. Farmers released their animals on the uninhabited barriers because those lands were exempt from fencing laws and fees.[3] It wasn't until after the Civil War that interest grew in settling and developing Fenwick Island.

Ocean City Founded

Ocean City, the town that occupies the Maryland portion of Fenwick Island, was first envisioned by Colonel Lemuel Showell III, who created the Atlantic Hotel Company Corporation in 1868 with four associates. The son of a former plantation owner, Showell built a cottage at the site of Ocean City in the 1860s and invested heavily in the Wicomico & Pocomoke Railroad, which was extending from Salisbury, Maryland, toward Sinepuxent Bay.[4] At the same time that Showell was organizing his hotel company, Mr. Stephen Taber bought vast tracts of land on Fenwick Island and the mainland, totaling around 600 acres (243 hectares). Upon their request, Taber granted Showell's group a ten-acre parcel on which to build a hotel at the future site of Ocean City. Taber's generosity most likely stemmed from his desire to see his properties surrounding the prospective hotel increase in value. On July 4, 1875, the Atlantic Hotel opened and Ocean City welcomed its first guests. Soon thereafter, Taber deeded another 50 ac (20 ha) to the group, with the location named as Ocean City for the first time. Development of the land began almost immediately.[5]

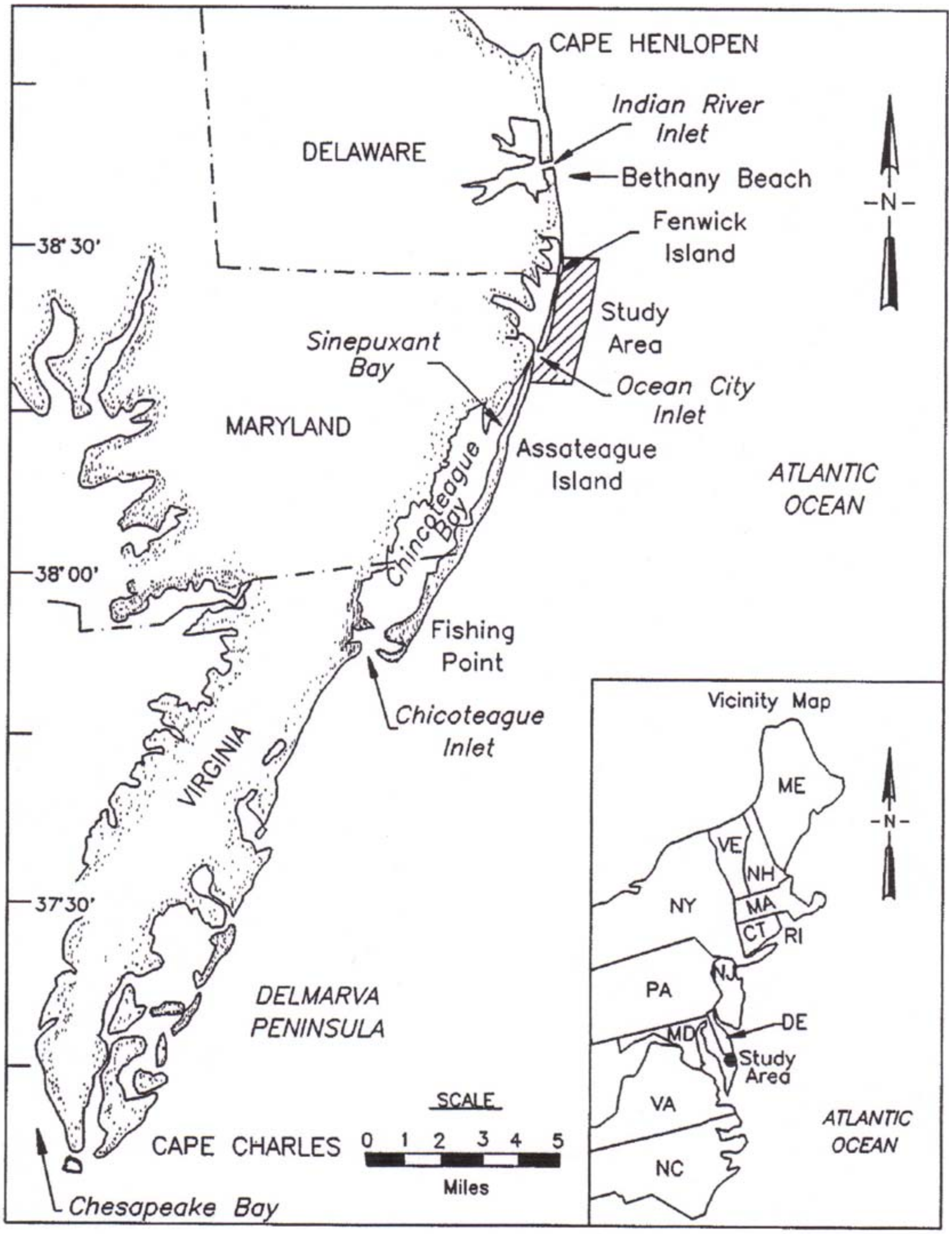
Since its inception, therefore, Ocean City, Maryland, was designed as a resort destination to be filled with structures and man-made developments. At the same time, natural processes continued along the coastline. Wave action opened inlets at various locations along Fenwick and Assateague Islands during the nineteenth century. Steven G. Underwood and Matteson W. Hiland, in their report on geologic developments at Ocean City Inlet, explained, "These inlets tended to be ephemeral in nature, originating during storm conditions and eventually closing due to a combination of natural coastal processes (i.e., incident wave conditions and longshore drift). Within three miles of Ocean City Inlet's present location were Beach Inlet and Inlet Shallows."[6] These temporary inlets show that Ocean City has been impacted by coastal processes from its beginning. Storms and their concomitant high-energy waves opened inlets, which then closed quickly due to littoral drift along the shoreline. The waves eroded sand from the beach then returned it, currents pushed sand into the inlet channels and flood-tidal deltas increased the salt marshes of the island's bay side—the same processes that had been going on since the spit's formation. These changes foreshadowed one that would alter Ocean City in a more permanent fashion in years to come.

Assateague Island

The Assateagues, a tribe of Algonquian Native Americans, are the people for whom the southern portion of the spit was named. "Assateague" has been translated to "swiftly moving water" and "place across," and from its formation the barrier was separated from the mainland by the waters of Sinepuxent Bay.[7] But the Assateague tribe didn't live solely on the island; archaeological research suggests that they only fished there seasonally. No evidence has been discovered of any widespread or permanent settlement. Pressures from the growing European population—including diseases and territorial disputes—caused the Native Americans to relinquish their lands along the Eastern Shore and flee into Delaware and areas farther westward by the eighteenth century.[8]

The colonies of Maryland and Virginia had divided Assateague between them in the late seventeenth century, with the northern portion falling under Maryland's jurisdiction and the southern portion under Virginia's. In 1677, Mr. Daniel Jennifer purchased 1,500 ac (607 ha) on Chincoteague Island directly to the south of Assateague, and he began using both places as grazing land. A local historian explained, "To avoid the cost of fencing, possible lawsuits and impending taxes, farmers moved their stock out to the barrier islands where no one lived, no one owned land, no one farmed, and grass and fresh water were available." The famed ponies of Chincoteague and Assateague

Figure 7: Location of the study area. Source: USACE Baltimore District.



Islands are feral descendents of these domestic horses that freely roamed the islands. A popular legend holds that the horses survived the wreck of a Spanish galleon and swam to shore, but experts believe they are the historical remnants of colonial grazing practices. In 1687 Jennifer officially received 3,500 ac (1,416 ha) on Assateague, and he subsequently settled a few employees on the island. [9] The early settlement was sparse, however, and Jennifer didn't put down lasting roots on Assateague. The island changed hands frequently, sometimes for barter payments including sacks of tobacco. "The property was bought and sold many times in the eighteenth and nineteenth centuries. Evidently not many farmers or stock men were successful because much of the island was returned to the state for non-payment of taxes," *The Piping Plover* reported.[10]

Many visitors arrived accidentally due to shipwrecks that occurred regularly along the Atlantic coast. Because of inlets opening and closing, and the barriers' continual landward migration, many former ebb-tidal deltas remained in the offshore waters near the Delmarva Peninsula. Ebb-tidal deltas are similar to flood-tidal deltas except they form on the seaward side on an inlet. They are "formed from the sand that moves through an inlet with the ebbing tide," and they become detached from the barrier when the inlet closes and the barrier migrates landward.[11] Left as underwater shoals, they frequently caused ships to run aground. Underwood and Hiland explained, "Fenwick and Assateague Islands have the largest number (63) and highest density of attached and detached sand ridges" in comparison to other barrier coastlines along the Atlantic coast of the United States.[12] By the time of the Revolutionary War, "salvaging" cargo from wrecked ships was a main source of income for the island's few residents, along with salt-making, which was crucial during the war when the British naval blockade cut off foreign salt supplies. Eventually, land was cleared for small-scale farming and continued husbandry of sheep, horses and a few cows. These activities, along with shellfishing, led to the growth of a small village on the Virginia portion of the island in the early nineteenth century.[13]

Assateague Village

The dangerous nature of the mid-Atlantic coast resulted in two important developments for Assateague Island in the nineteenth century: the building of Assateague Lighthouse and the opening of Life-Saving Stations. The U.S. Fish and Wildlife Service (USFWS) recounted, "In 1833, the first Assateague Lighthouse was constructed to warn ocean travelers of the dangerous shoals offshore. Plans to replace the lighthouse with a taller, more powerfully illuminating brick structure were delayed by the Civil War." Prior to the war, the Federal Government had determined that the lighthouse's power and range needed to be increased because the shoals extended for miles off the coast. Once the war ended, there was money and manpower for the improvements, and the original building was replaced in 1867 with the 142-feet-tall (43 m) landmark that remains today.[14] It required a number of keepers to continually maintain the oil-burning lamp, and these families increased the size of Assateague Village.

Figure 8: Historic photo of Assateague Island lighthouse. c. 1955. Photo: U.S. Fish & Wildlife Service

In 1871, Congress authorized the funding of the U.S. Life-Saving Service, with stations to be built along the Atlantic coast to aid survivors of shipwrecks. The first Life-Saving Stations on Assateague Island opened in 1875 at Green Run and Assateague

Beach. The frequent storms and shipwrecks kept a number of “surfmen” employed, and with the growth of its agricultural and fishing occupations, Assateague Island soon reached its historic peak in population and activity.[15]

Conclusion

Ocean City and Assateague Island had achieved a similar level of development by 1875, but their paths would soon diverge significantly. Both had small populations—just a couple hundred at most—and were heavily influenced by the natural environment, whether through storms and offshore shoals causing shipwrecks, inlets opening and closing or natural resources providing abundant grazing and fishing. But underneath those similarities lay different founding principles. Ocean City had been built as a vacation destination, a place where crowds could relax on the beach and in high-quality, even luxurious, accommodations. Assateague Island, conversely, contained a small village of residents and public servants that had slowly grown over time. Subsistence and safety functions were the inhabitants’ purposes.

These historical settlement patterns would affect coastal engineering decisions many years later because population and development levels are considerations that influence the purpose of projects and the analysis of alternative solutions by the U.S. Army Corps of Engineers when evaluating coastal projects. As Ocean City and Assateague Island changed, so would the Corps’ view of coastal engineering and intervention in both locations. Ocean City’s focus on development would increase pressure to maintain the beach and modify the coastline, while Assateague’s relative wildness and sparse settlement set a historical precedence for letting nature dominate along the island’s shores.

[1] Mary Corddry, *City on the Sand: Ocean City, Maryland, and the People Who Built It* (Centreville, MD: Tidewater Publishers, 1991), 11.
[2] Ibid., 12.
[3] Hayward, *State of the Parks*, 23 (see Prologue, n. 18).
[4] Corddry, *City on the Sand,* 15-20.
[5] Ibid., 17-21.
[6] Steven G. Underwood and Matteson W. Hiland, *Historical Development of Ocean City Inlet Ebb Shoal and Its Effect on Northern Assateague Island*, report prepared for the U.S. Army Engineers Waterways Experiment Station, Coastal Engineering Research Center, and the U.S. Department of the Interior, National Park Service, Mid-Atlantic Region and Assateague Island National Seashore, 1995, 48.
[7] Corddry, *City on the Sand,* 11; The Assateague Indians, http://www.virginiaindians.com.
[8] Corddry, *City on the Sand,* 10; Hayward, *State of the Parks*, 23; National Park Service, "Welcome to Assateague" in *Assateague Island National Seashore Handbook 106* (Washington, D.C: U.S. Department of the Interior, 1980), 13.
[9] Wilma Young, "Settlement on Assateague Island," *The Piping Plover,* Winter 1997-1998 http://www.assateague.org/plover/4-97-g.html; Hayward, *State of the Parks*, 15, 23; U.S. Fish and Wildlife Service (USFWS), "Chincoteague National Wildlife Refuge: History," http://www.fws.gov/northeast/chinco/history.htm.
[10] Young, "Settlement on Assateague Island."
[11] Leatherman, *Barrier Island Handbook*, 37; Underwood and Hiland, *Historical Development*, 12.
[12] Underwood and Hiland, *Historical Development*, 12.
[13] Ibid.; National Park Service, "Welcome to Assateague," 14, 22.
[14] USFWS, "Chincoteague National Wildlife Refuge: History."
[15] Bob Stevens, "A History of the U.S. Life-Saving Service," Ocean City Life-Saving Station Museum, http://www.ocmuseum.org/index.php/site/usls-serv_article/a_history_of_the_us_life_saving_service/.

2: Beginning of Divergence, 1876–1933

Ocean City

The Atlantic Hotel opened in 1875, but it was an event the following year that truly introduced Ocean City to the rest of the Eastern Shore: the construction of the railroad. By 1876, the Wicomico & Pocomoke Railroad had built a trestle across Sinepuxent Bay and passengers could travel from Salisbury, Maryland, to the Atlantic Hotel's door.[1] There was no direct rail line across Chesapeake Bay to Ocean City, however, and it remained an arduous journey between steamboats and various trains to reach the new resort from larger cities on the eastern seaboard. But the small town thrived nonetheless, so that "[b]y 1880 three major hotels, several cottages, the United States Life-Saving Station, a post office, two general stores, several churches, and a railroad station had been established in Ocean City."[2]

In 1890, the newly organized Sinepuxent Beach Company from Baltimore bought the Atlantic Hotel and thousands of acres on Fenwick Island, Assateague Island and the mainland—the land that had previously belonged to Stephen Taber. They platted and sold lots throughout the town and southward down to where Ocean City Inlet would eventually wash away the land. By century's end, new resorts had sprung up, along with the boardwalk and pound fishing camps at the southern end of town.[3]

Early Industry

Many of the original, grand hotels at Ocean City in the late nineteenth and early twentieth centuries were owned and operated by enterprising women known as the "Petticoat Regime." The Plimhimmon, which opened in 1893, was built and managed by Rosalie Tilghman Shreve, a southern belle who had been bankrupted by the Civil War and widowed with two children at age nineteen. The Hamilton, the Dennis and the Mayflower were only a few of the other large, Victorian-style hotels run by entrepreneurial women.[4] At the same time that women dominated the tourism business, the men of Ocean City worked in sea-related industries, including pound fishing. This particularly laborious form of fishing used large nets to catch entire schools of fish offshore that were then hauled onto boats and transported back to shore. Fishing camps crowded the area around the railroad station in the first decades of the twentieth century. By the 1930s, however, local stocks had been overfished and the industry was finished off by the opening of Ocean City Inlet, which destroyed most of the camps.[5]

The Life-Saving Service also employed surfmen at Ocean City starting in 1878. Corddry stated, “Surfmen and their families added to the population and community life of the tiny resort beginning to form on the beach and calling itself Ocean City. Some of its leading business and civic leaders and two mayors were to come from the ranks of the Service.”[6] The Life-Saving Service became the Coast Guard in 1915, but it remained an important component of the city that frequently experienced damaging storms and violent shipwrecks.

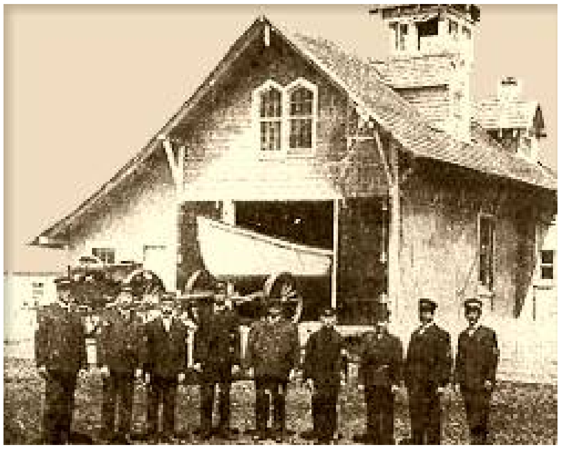


Figure 9: Coast Guard

Storm Activity

Natural events continued to impact Ocean City in the early twentieth century, even as tourism flourished and development increased. In the first two decades of the century, land development companies platted the town north to the Delaware state line and an automobile bridge was built from the mainland across Sinepuxent Bay, greatly increasing the number of vacationers.[7] In 1920, however, a powerful northeaster "opened an inlet approximately 4.8 km [3 mi] south of Ocean City. This inlet migrated laterally southward for about .8 km [.5 mi], and eventually was closed by a northeaster on May 9, 1928." The 1920 storm opened what was named Sinepuxent Inlet, and it also damaged a number of properties. "The reconstruction of these cottages, commercial properties, and [the] nearshore beach line initiated the local township's commitment to maintaining their beachfront through various engineering activities," Underwood and Hiland explained.[8]

Timber groins were built along the beach beginning in 1922, and in the decades to come many more groin fields were constructed. Groins are long, arm-like structures that are built perpendicular to the shore to trap sand on the beach, ideally to limit erosion and maintain a sand-filled beach. But by catching sediment on their updrift, side groins deprive downdrift areas of sediment that would naturally move down the beach. Quantitative data about these early groins' effectiveness is not extant. Underwood and Hiland reported that "visual accounts give testimony that the groin fields were a very effective littoral barrier. However, the net effect of the entire groin system on the shore has been negligible."[9]

Whatever effects the groins might have had, they couldn't prevent the opening of Ocean City Inlet in 1933, which significantly altered not only Ocean City but also Assateague Island and the surrounding waters. On August 23, 1933, after days of intense rainfall that filled Sinepuxent and Isle of Wight Bays to the west of Fenwick Island, the hurricane's winds shifted offshore. The change in winds to the offshore direction and the ebb tide sent the floodwaters rushing back out to sea, smashing through the narrowest part of Fenwick Island and creating a new inlet.[10] Only months earlier, a congressional committee had approved a plan to manually open an inlet near that location to boost the local fishing industry in the midst of the Depression. The project had first been discussed in 1927, and by the early 1930s, with pound fishing on the decline, the prospect of a harbor for larger fishing vessels was very attractive. But the bill hadn't been passed by the end of the congressional session. "It was at this point," Corddry summarized, "that Nature achieved what government had so far failed to bring about."[11]

Four days after the inlet opened, the first sport fishermen set sail from the new natural harbor—an activity that would revolutionize the tourism industry at Ocean City. Commercial fishing had been foremost in residents' minds when they requested to have an inlet created, but sport fishing would become the true economic boon of the waterway. Congress authorized the U.S. Army Corps of Engineers to stabilize the inlet for navigation purposes, essentially implementing the act that had stalled in the previous session. The Corps quickly set to work on the project.[12]

The hurricane in 1933 destroyed private properties, pound fishing camps and the railroad bridge that had first fueled the town's growth. But the inlet it created and the economic opportunities that would stem from that event soon outweighed any losses, as the next few years would prove. The railroad bridge that was swept away by the storm was not rebuilt; cars were the dominant form of transportation by this time. Ocean City was moving into the modern era and would turn increasingly to technology to maintain the beach and inlet—the engines of its continued prosperity.

Assateague Island

By the late 1870s, Assateague Island was home to a small but thriving village on the Virginia side. The Pope's Island Life-Saving Station opened on the island's southern portion in 1878, followed by the North Beach station on the Maryland side in 1884. A small settlement had also grown around the Green Run station in Maryland, including Scott's Ocean House, a bayside resort that was built in the 1870s. It reached its peak of popularity in the 1880s, but by the end of the century the vacationers dwindled. The Life-Saving Station at Green Run remained, however, with a small community based around it.[13] Of the many shipwrecks the Assateague stations responded to, perhaps the most famous was the presidential yacht, the *Dispatch*, which ran aground only 75 yards offshore from the Assateague Beach station. The Fish and Wildlife Service stated, "No deaths occurred, but what had once been the official yacht of Presidents Hayes, Garfield, Arthur, Cleveland, and Harrison was a total loss."[14]

In the early twentieth century, Assateague Village's population reached over 200. It had a school, multiple churches and a general store. Fishing along Tom's Cove Hook, at the southern end of the island, continued to be an important part of the village's economy. It became more industrialized over time. *The Piping Plover* explained, "The first fish factory was the Seaboard Fish Oil and Guano Company built in 1912. In 1919 the factory burned, but the Conant Brothers Fish Oil Company set up another company that same year. This operation lasted only ten years."[15] The silting of the cove prevented ships from docking there to pick up shipments of oil—yet another consequence of the coastal processes at Assateague Island.[16]

The waters near Assateague were the site of attacks by German U-boats in World War I. In May 1918, the submarine U-151 destroyed three ships, the *Hattie Dunn, Hauppauge* and *Edna,* off the coast near Assateague and held their crews captive for nearly a week. U-117 also sank a number of ships near Assateague in the summer of 1918. Fortunately, there were no casualties, and after that summer the U-boat threat ended. [17]

The Beginning of the End

Early in the twentieth century, Mr. Samuel B. Fields of Baltimore purchased most of Assateague Island, and in 1922 he installed a new overseer on his property named Mr. Oliphant, who refused to allow the villagers to cross the property en route to the southern fishing grounds. "With their access over the shell road to the cove closed, the villagers began to move off the island," according to Edwin C. Bearss, in his study of Assateague's history. "Their houses were jacked up, placed on skids, and taken to the waterfront. There they were placed on barges and floated across Assateague Channel to be relocated on Chincoteague Island." The last resident to leave was the general store's owner, Bill Scott, who moved away in 1932.[18]

The island's isolation was punctuated by the 1933 hurricane that separated Assateague Island from Fenwick Island. Underwood and Hiland stated, "At least 11 inlets have been cut through Assateague Island since the early 1800s, eight within its present boundaries."[19] But the natural process of littoral drift that closed the previous inlets would be interrupted by activities at Ocean City. Human settlement on Assateague was winding down by the 1930s, but the effects of man-made structures and engineering methods were only beginning.

Figure 10: Locations of historical inlets on Fenwick and Assateague Islands. Figure 29 on page 47 of Underwood & Hiland.

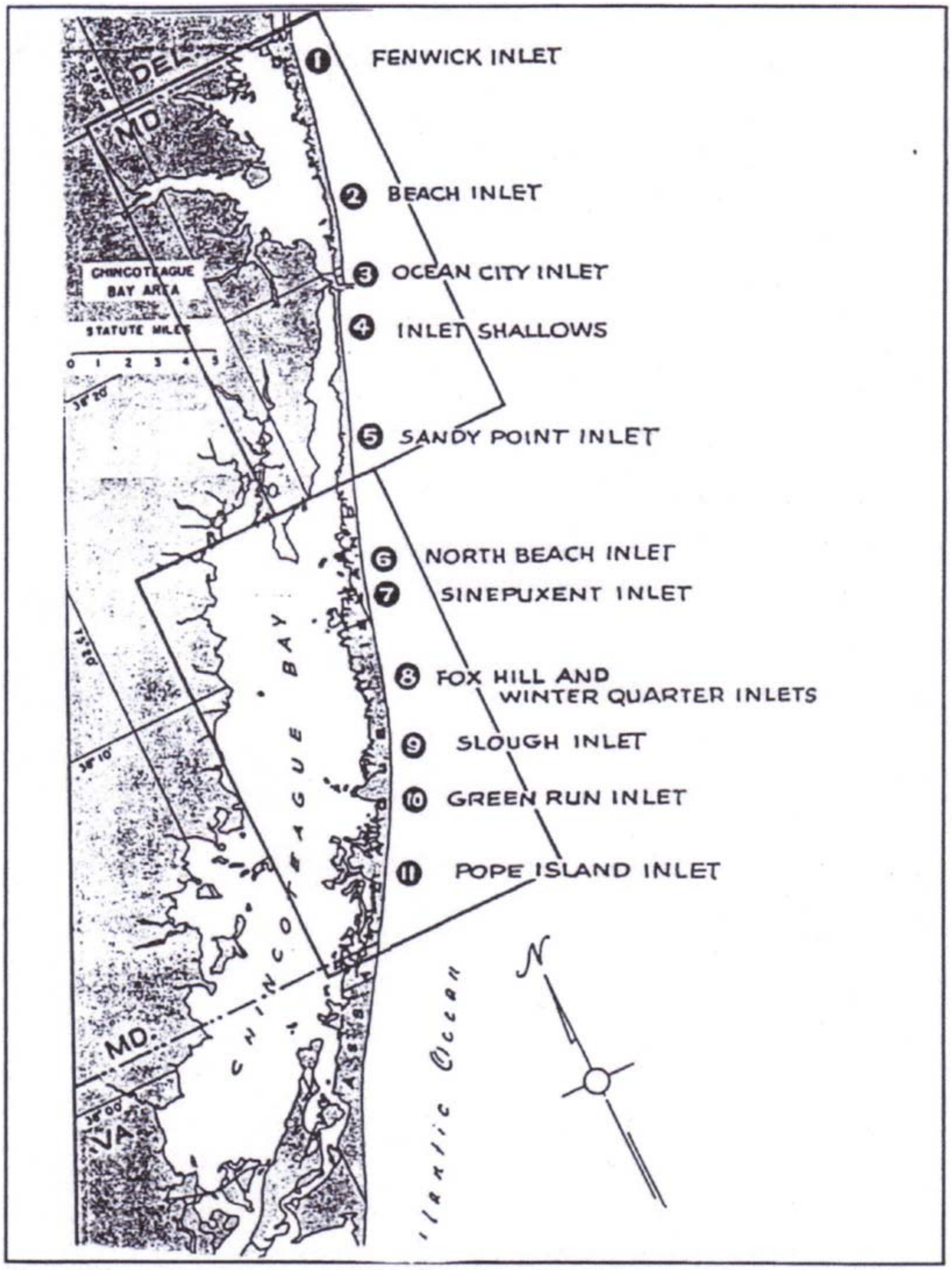


Figure 29. Various historical inlet locations along Fenwick and Assateague Islands (From Truitt 1967).

Conclusion

The late nineteenth and early twentieth centuries saw many changes at Ocean City and Assateague Island. The burgeoning tourism industry at Ocean City ushered in an era of opulent hotels catering to wealthy guests, while dwindling economic opportunities caused the gradual abandonment of Assateague Village. More and more structures—from hotels to the boardwalk to groin fields—were built along the beach at Ocean City, while an absentee landlord interrupted human activity on Assateague's beaches. These divergences were amplified by the physical separation of Assateague Island from Fenwick Island in 1933.

Immediately following the opening of Ocean City Inlet, the town of Ocean City turned to the U.S. Army Corps of Engineers for shoreline stabilization measures because the Corps' responsibilities had grown to include navigation-related engineering. The townspeople wanted to maintain the inlet to facilitate boat traffic; to do so, the inlet had to be kept free of sediment that could close the channel. Although the Corps focused on rivers and canals during much of the nineteenth century, they had also become involved in coastal harbor improvements, including at Baltimore, Maryland, and Charleston, South Carolina.[20] At this time, structures such as bulkheads, revetments and jetties were the measures used to modify shorelines, both for navigation and erosion control purposes.

The Corps responded to Ocean City's request by planning jetties to stabilize Ocean City Inlet and prevent its closure by littoral drift. The primary purpose of jetties is to facilitate safe navigation through the surf zone by blocking waves. Their secondary purpose is to prevent sand from being deposited in the channel, thereby maximizing the draft of vessels that can use the channel. Like groins, jetties are long structures built perpendicular to the shore. They extend out into the water and prevent sediment from clogging harbors or inlets. By doing so, they not only keep navigation channels open, but they also impact nearby beaches by stopping the movement of sand.[21]

While the Corps was increasing its role in navigation-related engineering, another coastal issue was developing. In the *Coastal Engineering Manual* Lockhart and Morang explained, "In the 20th century, a new social phenomena arose that resulted in an ever-increasing interest in the coastal zone: more and more Americans achieved the economic means and leisure time to enjoy the beach for recreational purposes."[22] Ocean City was exactly the type of place a more affluent and mobile public was seeking out for vacations, and this would lead to an expansion of the Corps' activities at Ocean City, from maintaining a navigation channel to preserving the sands and structures affected by the inlet itself.

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[1] Corddry, *City on the Sand,* 24.
[2] Town of Ocean City, Maryland, "Chapter 3: Land Use and Community Character" in *Planning and Zoning Comprehensive Plan* (2006). http://www.town.ocean-city.md.us/Planning%20and%20Zoning/DraftComprehensivePlan/index.html.
[3] Corddry, *City on the Sand,* 22-23, 31.
[4] Ibid., 61-72; "The Petticoat Regime of 1890-1926," Ocean City Life-Saving Station Museum, http://www.ocmuseum.org/index.php/site/oc-history_article/the_petticoat_regime_of_1890_1926/.
[5] Corddry, *City on the Sand,* 83-86.
[6] Ibid., 88.
[7] Town of Ocean City, "Chapter 3."
[8] Underwood and Hiland, *Historical Development,* 31, 33.
[9] NOAA Coastal Services Center, "Beach Nourishment,"; Underwood and Hiland, *Historical Development,* 33.
[10] Underwood and Hiland, *Historical Development,* 30, 42; Corddry, *City on the Sand,* 98-99.
[11] Corddry, *City on the Sand,* 101; Nicholas Kraus, discussion with author, December 12, 2008.
[12] Corddry, *City on the Sand,* 102; Kraus, discussion with author 12/12/08.
[13] Edwin C. Bearss, *General Background Study and Historical Base Map: Assateague Island National Seashore Maryland-Virginia,* report prepared for the Department of the Interior, National Park Service, 1968, 81-85.
[14] USFWS, "Chincoteague National Wildlife Refuge."
[15] Young, "Settlement on Assateague Island."
[16] Bearss, *General Background Study,* 95.
[17] Ibid., 60-74.
[18] Ibid., 87.

[19] Underwood and Hiland, *Historical Development*, 42.
[20] John H. Lockhart, Jr. and Andrew Morang, *History of Coastal Engineering* in *Coastal Engineering Manual Part I: CEM Introduction* EM-1110-2-1100, chair. Andrew Morang (Washington, D.C: U.S. Army Corps of Engineers, 2002), 1-3-11 – 1-3-12. http://chl.erdc.usace.army.mil/Media/1/7/6/CEM_Part-I_Chap-3.pdf.
[21] NOAA Coastal Services Center, "Beach Nourishment."
[22] Ibid., 1-3-12.

3: Ocean City Urbanizes while Assateague Reverts to Wilderness, 1934–1962

Ocean City

Just days after a hurricane breached Fenwick Island and created Ocean City Inlet, the first sport-fishing party set sail from the new waterway. A man and woman chartered Captain D. Frank Parsons to take them fishing in the Atlantic Ocean, and for the first time since Sinepuxent Inlet closed in 1928, the boat could be launched from the relatively calm waters of the inlet instead of directly through the surf, as had been previously necessary.[1] With the opening of this natural inlet, the plan to create one artificially became obsolete, and Congress instead authorized the stabilization of the natural inlet, which was undertaken by the U.S. Army Corps of Engineers.[2]

The following year two brothers, Jack and Paul Townsend from Selbyville, Delaware, chartered a boat to search for white marlin, a prized billfish known to frequent the warm Gulf Stream waters. They reportedly spotted one, but it was Captain John Mickle who actually landed the first white marlin offshore of Ocean City in 1934. The "Jack Spot," located about twenty miles offshore, became a haven for marlin seekers. "In 1936 there were 175 marlin landings reported. In 1937 there were 200 landings. In 1938 the figure leaped to 781 landings," Corddry reported.[3] Over 170 white marlin were caught at the Jack Spot in only one day in July 1939, and such astronomical numbers led to Ocean City's designation as the "White Marlin Capital of the World." At the same time, however, fishermen began to worry about depletion of marlin in the area, but that issue was quickly resolved with the outbreak of World War II and the suspension of sport-fishing from 1942 to 1944.[4]

Wartime Changes

In 1942 German U-boats began infiltrating the waters near Ocean City, as they had done near Assateague Island during World War I. This time, however, the results were much more deadly. A number of commercial ships were sunk, and many lives were lost, including 28 men from the *David Atwater* who were shelled while trying to escape their sinking ship in a lifeboat. To prevent ships from being silhouetted by the town's bright lights, "the Coast Guard ordered a dimout in Ocean City extending for three-quarters of a mile inland. Cars moving at night had to have only the parking lights on and be kept to 15 miles an hour," Corddry stated. The dimout was effective, and it was instituted again in 1943. By the end of that summer, the U-boat threat had dissipated, and soon after the war, Ocean City resumed its carefree and well-lit atmosphere.[5]

Post-War Growth

The Chesapeake Bay Bridge opened to traffic in 1952, and this event marked another turning point in Ocean City's growth. Reaching Ocean City had become easier over time with the extension of the coastal highway from the Delaware state line to the north end of town, but that highway could only be accessed by taking secondary roads from the mainland to the shores of Delaware. The Bay Bridge ended the need for a ferry trip across the Chesapeake Bay or a circuitous road journey through Delaware, and the easy access the bridge provided to Ocean City, along with the resumption of white marlin fishing and general post-war prosperity, resulted in a marked increase in tourism and development.[6]

The pressure on the physical landscape called for measures to protect the structures springing up in Ocean City. Beach erosion on the ocean side of Fenwick Island was an ongoing process because of coastal events. Storms had impacted the barrier since its settlement, just as they had since its formation. The storm surges and high-energy waves from hurricanes and northeasters continually eroded the beach. Tidal action also removed sediment, and sea-level rise constantly moved the shoreline landward, even as buildings and roads filled the narrow spit. This retreat of the town's eastern edge became problematic once a large number of hotels and other properties, including the boardwalk, became dependent on the beach's location and integrity.

Figure 11: The developed coastline of Ocean City prevented natural barrier rollover mechanisms from taking place, and they provided a fixed point of reference against which erosion was visible. Photo: Aerial view of the canal joining Little Assawoman Bay (bottom left) with Assawoman Bay (top right); Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

The natural barrier rollover mechanisms—by which waves moved sediment from the ocean side to the bay side—interfered with the objectives of Ocean City officials, residents and visitors who wanted the seaside beach to remain in place. At this time, the rollover process was not understood as a natural barrier response, and people felt it was necessary to maintain the beach in a stable position. By the 1990s, the conflict between rollover and development was better appreciated, and Fred J. Anders and Mark Hansen summarized, "On developed barriers, rollover is incompatible with man's activities, requiring either alteration of natural processes or man's adaptation to nature."[7] But in the mid-twentieth century, this understanding was not a standard part of coastal engineering practice, and overwash was known only for its damage to structures. Furthermore, inlet dynamics were prevented by the stabilization of the inlet and could not function as a method of barrier migration. Natural responses to beach erosion were not viable; rather, the Maryland State Roads Commission began implementing engineering measures to maintain the beaches and dunes in their contemporary location.

Groin-building had begun in 1922 to stabilize the beach and protect properties damaged by the 1920 storm that had opened Sinepuxent Inlet. These activities continued so that by 1961, "25 timber groins were constructed along the Maryland portion of Fenwick Island by the Maryland State Roads Commission with funds provided by Worcester County."[8] During the years 1954 and 1955, another 43 sand-asphalt groins were built along the beach. Despite these actions, the groins' usefulness at keeping sand on the beach was, at best, minimal. "The groins didn't hurt, but they didn't help much. There is just not much sand in the area in the first place," explained Don Stauble, research physical scientist at the Corps' Coastal and Hydraulics Laboratory.[9]

But hard structural methods weren't the only ones used in the 1940s and 1950s. Once the coastal highway was opened, "the State Roads Commission soon became aware that to protect the road, it had to keep the ocean from washing back and forth across it or breaking through the barrier [*sic*]. To do that, the Commission would have to maintain nature's own line of defense, the sand dunes washed up by wind and wave to form a natural barrier. Where the dune line was weak, the Commission, through the 1940s and 1950s, constructed sand fences to catch and hold the moving sand."[10] These actions showed how area officials were starting to appreciate the role of natural landforms in coastal processes, even though hard structures such as groins and jetties were still the primary means of maintaining shorelines.

This understanding, however, was not ubiquitous, and the State Roads Commission filed an injunction against a developer in 1960 to prevent him from bulldozing the dunes in North Ocean City. The developer, James B. Caine, would remain a contentious figure in the years of Ocean City's explosive growth, and in 1960 he leveled the beaches of the northern end of town to prepare the area for development. The State Roads Commission and Worcester County officials objected to these actions, arguing that dune removal endangered other properties. Caine eventually settled with the Commission and Worcester County. "He agreed to build sand fences and to plant beach vegetation to hold the dunes in place," according to Corddry.[11]

The Five-High Storm

Just when Ocean City residents and officials began to realize the importance of a wide, sand-filled beach to the safety of their structures, a catastrophic storm showed the town what it had to fear from the merciless waves. On Monday, March 5, 1962, a northeaster hit the region in the evening hours. "But two lows merged off the Maryland coast and coincided on Tuesday with the new moon, when tides are highest," explained Corddry. The storm stalled over the area for more than two days, leading to its nickname, the “Five-High Storm,” because it lasted for five high tides. “The storm reached its peak on Wednesday morning when the high tide rose to 9 feet 4 or 5 inches [3 m] above mean low water…The ocean surf pounded the town. As it receded, it undercut the foundations of buildings and washed so much sand from the beach that the front steps of oceanfront buildings were hanging in space higher than a man’s head,” Corddry recounted.[12]

Figure 12: Damage at Virginia Beach, Virginia following the Ash Wednesday Storm of 1962. Photo: U.S. Army Corps of Engineers.

Not only were structures damaged, but swathes of land were swept away as well. A temporary inlet was opened at 71st Street in the northern part of town, and the entire beach was severely eroded. “The Five-High Storm really damaged Ocean City,” said Jordan Loran, director of engineering and construction for the Maryland Department of Natural Resources. “It led to emergency action by the Corps, and it started the discussion of a major project,” he explained.[13]

Indeed, the Corps was called upon to implement emergency repairs to the entire beach. It was clear that hard structures could not replace the sand that was sorely lacking; therefore sand was taken from nearby sources and added onto the beach. Underwood and Hiland maintained, “Following the March 1962 storm, emergency beach nourishment operations were begun for Ocean City, by the U.S. Army Corps of Engineers, from 2nd Street north to the Maryland-Delaware state line. Approximately 798,000 m^3 [1.1 million yd^3] of sand were deposited along the beach for dune and berm reconstruction, accompanied by sand fencing along the constructed dune ridges. This sediment was borrowed from Isle of Wight and Assawoman Bays."[14]

These actions were very successful, and after cleaning up and repairing the buildings and beach, Ocean City returned to form and was thriving by the summer vacation season of 1962. But the town had been permanently affected by the Five-High Storm. The need for storm protection and erosion control measures was undeniable, and it was becoming increasingly clear that these objectives were intertwined. The next year, the Corps would begin a study of the Ocean City beach that would influence the shape of the shore for years to come.

Ocean City Inlet

Prior to 1933, boats at Ocean City had launched directly into the breaking waves in the surf zone, which was difficult and dangerous. Almost immediately after the creation of Ocean City Inlet, the Corps began to stabilize the waterway with structures called jetties, which block breaking waves and allow vessels to navigate safely through the surf zone. "A jetty is a shore-connected structure, generally built perpendicular to the shore, extending into a body of water to direct and confine a stream or tidal flow to a selected channel and to prevent or reduce shoaling of that channel," according to Dr. Edward F. Thompson et al.[15] A single jetty may be constructed to block waves and littoral drift coming from one direction, or a pair of jetties can be built at either side of the inlet channel, which was the configuration chosen at Ocean City Inlet. Underwood and Hiland summarized, "Typically, jetties are constructed of quarry stone, and flank both sides of the desired channel alignment, and extend from the shoreline to a depth usually governed by the desirable depth of the entrance channel. Jetties provide the following functions: (1) block entry of littoral drift into the navigation channel, (2) stabilize a migrating inlet, (3) serve as training walls for inlet tidal currents, and (4) increase velocity of tidal currents, flushing sediments from the channel."[16] The town of Ocean City wanted all these benefits for the inlet so that it could be used reliably for navigational purposes. Due to the coastal processes of the area—littoral drift choking inlets after a few years, as had most recently taken place at Sinepuxent Inlet—officials chose structural stabilization methods to maintain the inlet permanently.

Therefore, in September 1933, the Corps began construction of the north jetty at the tip of Ocean City. When it was completed in October 1934, it was 1,100 ft (335 m) long and had an elevation of +2.7 ft (0.8 m) National Geodetic Vertical Datum (NGVD), a sea-level elevation measurement established by the National Geodetic Survey in 1929.[17] That same month construction of the south jetty began at the northern tip of Assateague Island, and in May 1935 this angled structure was completed at a total length of 2,380 ft (725 m) and an elevation of +4.7 ft (1.4 m) NGVD. As explained in *Rehabilitation of the South Jetty, Ocean City, Maryland,* "The inshore section of the south jetty paralleled the north jetty for a distance of about

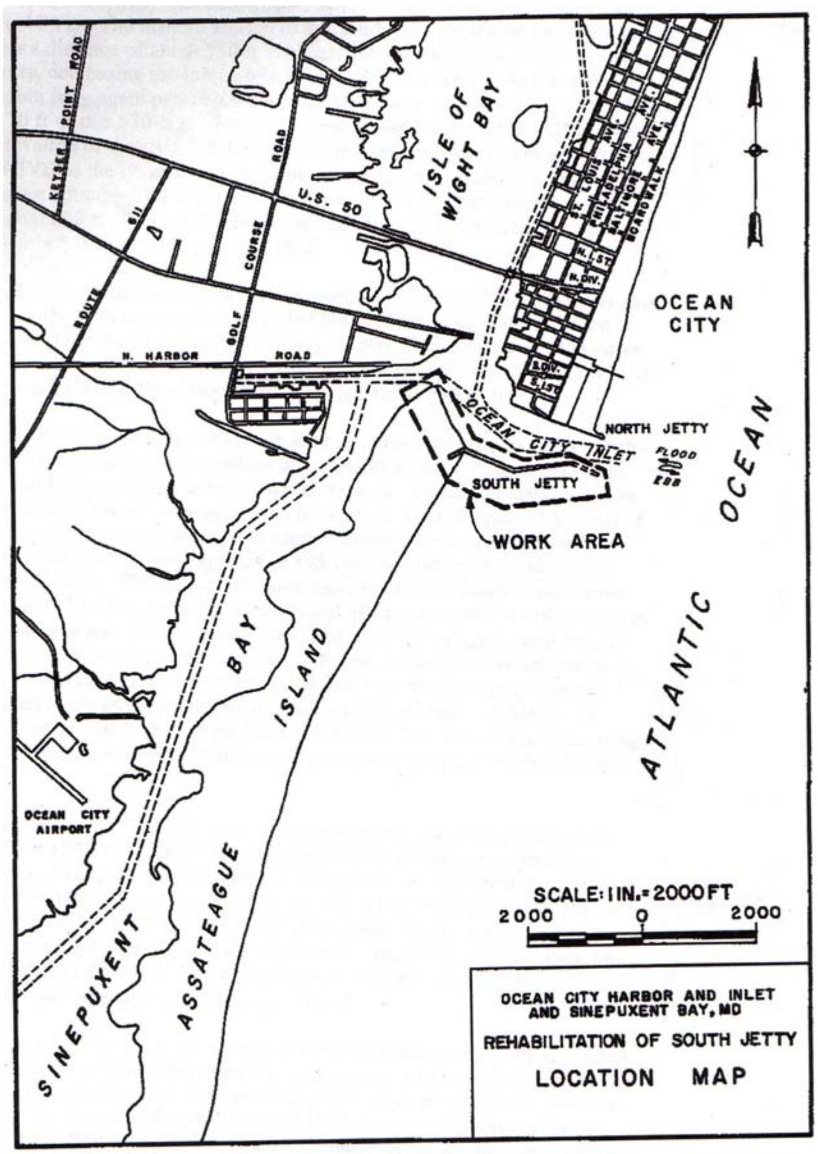
Figure 13: Aerial view of the Ocean City Inlet from Isle of Wight. Photo: Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

750 ft [229 m] at which point it trended towards the north jetty, decreasing the inlet width from 1,100 ft to 600 ft [335 m to 183 m]. At this point, the south jetty again paralleled the north jetty for a length of 530 ft [162 m]. The first 170 ft [52 m] of this 530-ft [162 m] section had a crest elevation of +4.7 ft [1.4 m] NGVD to the elevation of the 'apron' section which was 4 ft [1.2 m] above the existing bottom. This apron section continued at this elevation for an additional 200 ft [61 m]."[18]

To create a harbor where ships had room to dock and maneuver, the Corps dredged Ocean City Harbor and Sinepuxent Channel in 1935. The Harbor is located at the landward edge of northern Sinepuxent Bay, and the channel extends southward into the bay, 755 ft (230 m) northwest of Assateague Island. A tiny island named South Point Spoils was created at this time in Chincoteague Bay to the south of Sinepuxent Bay. "The island was formed by the Corps of Engineers in 1935 from dredged material side-casted from the newly created Sinepuxent Channel," explained the Corps Baltimore District.[19] Dredging of the inlet channel itself also took place in 1935 along the centerline of the inlet, which had an original depth of 8.5 ft (2.6 m) mean low water (MLW) and width of 200 ft (61 m).[20]

Once the north jetty was in place, it began impounding sand on its updrift side because it blocked longshore sediment transport. The entire length of the north jetty became filled with sand, which extended northward into a fillet, a flat section of land. As Corddry stated, "The beach at the south end of Ocean City became so deep, in fact, as to change the elevated Boardwalk to a ground-level promenade, and so wide as to contain a municipal parking lot as well as space for thousands of sunbathers."[21] But this impoundment caused problems for the navigation channel because by 1937 sand was spilling over the top of the north jetty into the channel, which created shoaling problems. In response, the Corps added more concrete to make the structure higher. The Baltimore District reported, "The jetty was raised by a means of a concrete superstructure which

Figure 14: The location of the south jetty that was completed in 1935. Source: U.S. Army Corps of Engineers.



was constructed to elevation +10.7 ft NGVD (+12.9 ft MLW), beginning at the boardwalk and extending 100 ft seaward, at which point it stepped down to +7.7 ft NGVD (+9.0 ft MLW) for 254 ft, where it again stepped down to +5.7 ft NGVD (+7.0 ft MLW)."[22]

The jetty's increased height, along with the structures' inherent effect of concentrating inlet currents, maintained flushing of Ocean City Inlet so that dredging activities were minimal. Initial maintenance dredging took place in 1947-1948 and removed 47,880 m^3 (63,000 yd^3) of sediment. In 1954-1955, another 57,000 m^3 (75,000 yd^3) were dredged, and 28,880 m^3 (38,000 yd^3) were removed in 1962-1963.[23]

Shoal Formation

Although the north jetty blocked a significant amount of sediment, it didn't remove all the littoral material from the inlet area. Sediment that passed around the north jetty was moved by tidal currents, which were themselves concentrated and sped up by the jetties. The tides moved water into the inlet and bays during flood tide and then back out to sea with the ebb tide. This volume of water is called the "tidal prism," which "is defined as the total amount of water (corresponding to spring range of tide) that flows into and out of an inlet with movement of the tide, excluding freshwater flow." Underwood and Hiland continued, "An increased tidal prism volume would amplify both ebb and flood inlet current velocities, allowing for greater sediment transport capabilities, as compared to an adjacent inlet with a smaller tidal prism."[24] They noted that even microtidal coasts, such as those along the Delmarva Peninsula, can have large tidal prisms at inlets, and "a large tidal prism exists for Ocean City Inlet." Consequently, the inlet's currents were enhanced by the large tidal prism and jetties in concert, and these strong currents moved and deposited significant amounts of sediment from the inlet's earliest days, resulting in the formation of subaqueous sand bodies, or shoals.[25]

The sediment carried by the tidal currents formed flood-tidal shoals in the bays and an ebb-tidal shoal at the seaward end of the inlet. This volume of sediment scoured the south jetty and damaged an 800-ft-long (244 m) section by the late 1930s. Bass et al. reported, "This damaged jetty was not rehabilitated immediately because the navigation channel was not significantly affected."[26] More serious was the effect of sand settling into the ebb-tidal shoal, the subaqueous sand body at the seaward edge of the inlet, instead of traveling farther downstream. "The formation of ebb-tidal delta sand bodies prevents littoral drift material from reaching the adjacent shoreline by acting as sediment sinks or traps, accumulating large reservoirs of sand. Sediment volumes found in these ebb shoals is very significant when evaluated in terms of erosion or deposition of adjacent barrier islands," stated Underwood and Hiland.[27] As a result, the northern end of Assateague Island was deprived of a large amount of sand as soon as the jetties were built. Sediment was removed from longshore currents by the north jetty, which directly impounded the sand to its updrift side, and by the shoals that grew as currents deposited more and more sediment in the formations. By 1962, the ebb shoal had grown to a width of 1.3 km (0.8 mi) and extended 1.1 km (0.7 mi) offshore.[28] Within only a few years of their construction, the jetties had significantly altered the coastal processes and adjacent landforms around Ocean City Inlet.

Shoreline Changes

The shorelines of Ocean City and Assateague Island were both changed by the jetties but in very different ways. Underwood and Hiland determined that the average rate of shoreline change at the southern end of Fenwick Island changed from -1.2 m/year in 1933, indicating erosive conditions, to +1.2 m/year in 1942 (-3.9 ft/year to +3.9 ft/year). "Since 1942, there was little if any significant change in shoreline advancement adjacent to the north jetty. One reason for this may be because the north fillet adjacent to the jetty is impounded to capacity," they stated. Alternately, at Assateague Island, "Between 1933-1942, an area of severe shoreline retreat developed just downdrift of the south jetty, indicating an interruption of longshore sediment transport processes." Average shoreline change rates in the northernmost 6.5 km (4 mi) of the island were calculated to have increased from -3.15 m/year to -6.37 m/year (-10.3 ft/year to -20.9 ft/year).[29]

The lack of sediment arriving with longshore currents led to erosion around the south jetty itself, so in 1956 the Corps added 845 tons of stone to the jetty to maintain its integrity with the receding shoreline. The north jetty was also repaired in 1956 with the section at +5.7 ft (1.8 m) NGVD raised to +7.7 ft (2 m) NGVD.[30] These activities maintained the structures, but they didn't change the coastal processes that the jetties were instigating, namely modification of currents, shoal formation and sand starvation of Assateague Island. From 1942 to 1962, Underwood and Hiland stated, the rate of shoreline retreat at the northern 6.5 km (4 mi) of Assateague Island reached -9.41 m/year (30.9 ft/year).[31]

When the Five-High Storm struck in March 1962, the eroded north end of Assateague Island breached in two places—directly along the south jetty and about 2,000 m (6,500 ft) downdrift. In response, the Corps placed an emergency beach fill southwest of the south jetty. "Using material dredged from the Inlet, a breach in the island at this location [southwest of jetty] was closed following the March 1962 storm. About

1,000,000 cubic yards [765,000 m^3] of material were placed in this area to close the breach," according to the Baltimore District.[32] Dunes were rebuilt to close the second breach as well. Despite the damage occurring to Assateague Island, only emergency repairs were done for the shoreline. The northern end continued to erode, but the Five-High Storm had important implications for the rest of the island as well.

Assateague Island

By 1934, Assateague Island had become increasingly undeveloped. Assateague Village on the southern portion of the island and the community at Green Run farther north had dissolved as the residents moved off the island. A small number of Coast Guard members remained at Green Run until the station was decommissioned in 1937.[33] Hunters sought prey on the island for sport, but there was no settlement after the villagers moved away. The National Park Service (NPS) of the Department of the Interior surveyed lands along the Atlantic and Gulf Coasts in 1934 to identify potential areas to become national seashores, the coastal versions of national parks. "Assateague Island and the adjacent mainland comprised one of 12 areas found to qualify for such status by virtue of their natural qualities, recreational values, and propinquity to major populations," according to *Assateague Island National Seashore: An Administrative History* by Barry Mackintosh.[34] Representative Schuyler Otis Bland of Virginia introduced a bill to authorize Federal acquisition of Assateague Island and much of the surrounding area in the 76th Congress in 1940. "Representative Bland introduced similar bills in the 77th, 78th, 79th, and 80th Congresses, but the House took no action and no companion bills were introduced in the Senate," Mackintosh stated. In the 81st Congress in 1949, Bland tried to introduce a more modest acquisition proposal, but that too failed, and his death in office in 1950 temporarily ended attempts at seashore legislation.[35]

Chincoteague National Wildlife Refuge

But the southern portion of Assateague Island was acquired by the Bureau of Sports Fisheries and Wildlife (which would later be named the U.S. Fish and Wildlife Service) in 1943. The descendents of Samuel B. Fields, whose overseer had chased away the Assateague villagers from the southern fishing grounds, sold the land to the government for use as a wildlife refuge.[36] On May 13, 1943, Chincoteague National Wildlife Refuge was established on the Virginia section of the island, along with 418 acres (170 ha) on the Maryland side and small parcels on nearby Morris and Chincoteague Islands. The refuge was meant to provide a habitat for migratory birds, particularly snow geese, whose population numbers had been plummeting. After the establishment of the reserve, snow goose numbers began to improve, and as a strategic location along the Atlantic Flyway, it became a key habitat for numerous bird species. Waterfowl such as geese and ducks; waterbirds including herons, egrets and ibis; and shorebirds such as terns, skimmers and piping plovers began to frequent the wildlife

Figure 15: Flock of waterfowl fly from wetland at Chincoteague. Photo: Steve Hillebrand, U.S. Fish & Wildlife Service.

refuge, which quickly became an important component of the National Wildlife Refuge System.[37]

Drive for Development

Meanwhile, farther north, Mr. Leon Ackerman and a group of investors from Baltimore and Washington, D.C., acquired 15 miles of ocean shoreline in the Maryland portion of Assateague Island. In 1950 the land was surveyed and platted for residential and commercial development. "Ackerman paved a road—'Baltimore Boulevard'—down the island, erected numbered street signs for un-built lateral streets, and inaugurated a major sales campaign with full-page advertisements in the metropolitan newspapers for his development, named Ocean Beach," Mackintosh maintained. The opening of the Chesapeake Bay Bridge in 1952 encouraged investment in the project. Mackintosh summarized, "Visions of seaside vacation retreats and expectations of speculative profits from resale led some 3,200 parties to acquire 5,850 lots at Ocean Beach by the early 1960s, although fewer than 30 dwellings were constructed."[38] Sparse though it was, this level of development prevented acquisition of the land; NPS conducted another survey of possible national seashore locations in the early 1950s, but the report deemed the Maryland portion of Assateague to be in the "advanced stages" of real-estate development and, therefore, unsuitable for a national seashore.

Attempts at development proceeded fitfully in the late 1950s and early 1960s. Ackerman donated 540 acres (219 ha) to the state of Maryland for the creation of a state park in 1956. His goal was to entice the state into building a bridge to the island, and the park was meant to justify the use of public funds. Dune-building was also implemented along the island to protect proposed developments. Another 1,740 lots were subdivided and marketed by Atlantic Ocean Estates Inc. in 1957, and although many were sold, none were built upon. The Maryland General Assembly authorized the building of a bridge to Assateague Island in 1961, and when it seemed that the island would be developed after all, the Five-High Storm wreaked near-total destruction on existing structures in 1962. Mackintosh reported, "The protective dunes were severed in many places, and high winds and water destroyed all but the sturdiest structures. Only about 16 cottages, 17 gun clubs, and a few other buildings remained in the Maryland portion, many of them older structures on the relatively sheltered bay side outside the Ocean Beach subdivision. The road down the island was variously washed out and buried. The suitability of the shifting barrier [*sic*] for private development, always a matter of doubt, was called much more widely into question."[39]

After the storm, dune-building continued as a means to repair the damage. "The storm leveled almost every dune," explained Tony Pratt, administrator of the Shoreline and Waterway Management Section of the state of Delaware. [40] The Corps reconstructed dunes at Tom's Cove Hook and northward along most of the island. Although these activities recognized the importance of natural features for storm protection, they were an artificial manipulation of the environment and ran counter to the direction in which Assateague Island was moving. The Five-High Storm created another opportunity for NPS to acquire the island as a national seashore, and it was becoming increasingly apparent that natural forces would dictate the condition of the island and any man-made developments existed there only at nature's fickle discretion.

Conclusion

The experiences of Ocean City and Assateague Island in the mid-twentieth century exemplified many of the issues present in coastal management. The maintenance of navigable ports and waterways is and has always been crucial to the economic vitality of the nation, and the need for a stable harbor for fishing vessels at Ocean City Inlet caused the town's officials to turn to the Corps for engineering measures. These actions can have consequences for other coastal processes and areas, as seen by the interruption of longshore sediment transport by the inlet's jetties and the erosion of northern Assateague Island. This man-made erosion, along with the naturally occurring erosion of Ocean City's beaches from storms and sea-level rise, became extremely problematic after a catastrophic storm event, the Five-High Storm of March 1962. Breaches along Fenwick and Assateague Islands, eviscerated beaches and shattered structures proved that storm protection needed to be a primary concern for coastal residents and officials.

The need for a coordinated response to storm-induced erosion was first noticed along the coasts of New York and New Jersey, where storms early in the twentieth century caused widespread erosion. Theodore M. Hillyer stated, "Millions of dollars were spent in these states on uncoordinated and often totally inappropriate erosion control structures that often produced results that were minimally effective, and in some cases, counterproductive. It was soon realized that the efforts of individual property owners were incapable of coping with the problem of coastal erosion and that a broader-based approach was necessary."[41] The Corps began studying beach erosion in the 1930s, particularly through the Beach Erosion Board (BEB), which was established in 1930.

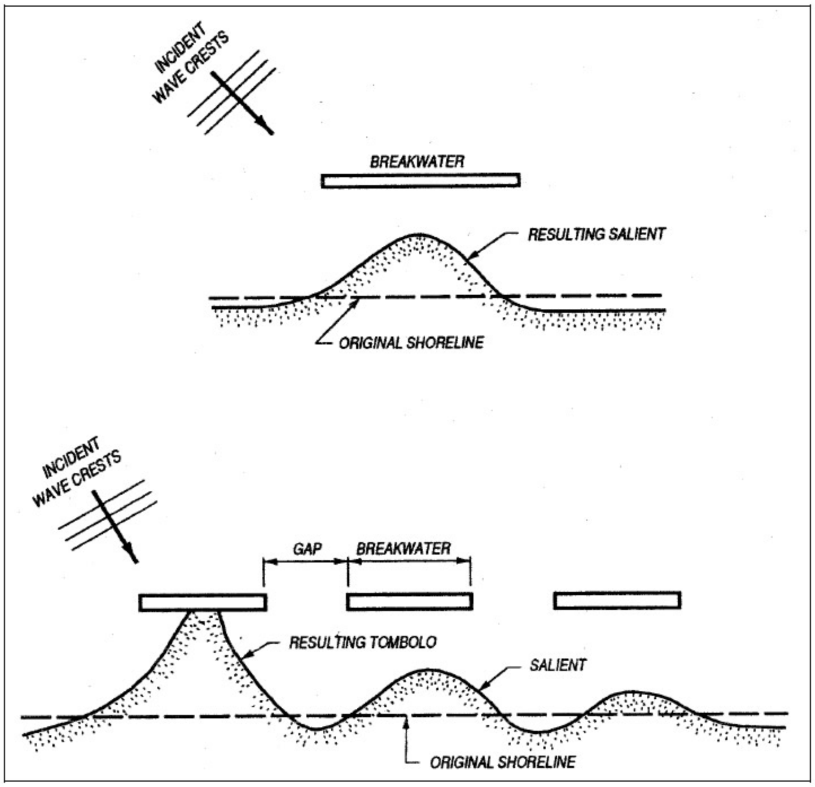


Figure 16: These diagrams illustrate how breakwaters can cause erosion and accretion, resulting in a scalloped shoreline. Source: U.S. Army Corps of Engineers.

Groins, breakwaters and jetties were the structures most often turned to for shoreline stabilization and protection at this time. As noted, groins and jetties are perpendicular structures built to stop the movement of sediment. Groins trap sand on the beach to maintain the shoreline and protect landward developments, and jetties block longshore sediment transport for inlet stabilization. Breakwaters are structures built parallel to the shore that can be connected to the shore or detached, and they "reflect or dissipate wave energy and thus prevent or reduce wave action in the protected area."[42] The protected region can include the beach and/or an inlet. Breakwaters shield the areas immediately behind them from waves, a process which allows sediment to accrete in those locations. The waves that pass between or around the breakwaters, however, erode the shoreline and create pockets of erosion next to areas of accretion, thus altering the shoreline and aggravating erosion in certain places.[43]

According to Hillyer, "In the late 1940s and early 1950s, the basic concept of shore protection evolved to a new approach. Rather than relying solely on the traditional coastal defense structures of the past, it was increasingly realized that, in many situations, results would be more cost-efficient and functionally successful if techniques were used which replicated the protective characteristics of natural beach and dune systems." In 1955 after a series of devastating hurricanes, Congress authorized Federal agencies to develop shore protection measures, and Public Law 84-826 in 1956 "provided for Federal assistance for periodic [beach] nourishment on the same bases as new construction, for a period to be specified by the Chief of Engineers, when it would be the most suitable and economical remedial measure."[44] These legislative activities officially recognized that storm protection had to take many forms, including nourishing the beaches that were critical to protecting the land behind them from waves and storm surges.

The experiences of New York and New Jersey, and the failure of their structural methods to stop erosion, had inspired the Corps to investigate non-structural measures for erosion control. According to Lockhart and Morang, "The resultant use of artificial beaches and stabilized dunes as an engineering approach was an economically viable and more environmentally friendly means for dissipating wave energy and protecting coastal developments. Artificial beaches also had more aesthetic and recreational value than structured shores."[45] Storms such as the Five-High Storm created erosion and shoreline protection problems that required long-term and comprehensive solutions. The success of emergency beach nourishment measures at Ocean City in 1962 helped shape engineers' thinking about the value of non-structural erosion control measures. These activities provided real-world examples of the ideas that had been developed over the preceding decades.

The evolution of the Corps' responses to erosion and the need for shoreline protection intertwined with the events at Ocean City and Assateague Island. By the early 1960s, the Corps began to recognize the importance of the interrelationship between erosion control and storm protection, with the Five-High Storm acting as a fundamental case study. Storm events, beach erosion and the need to maintain a navigable waterway continued to challenge the decision-making by the Corps and other agencies involved with the management of Ocean City Inlet and its surrounding landforms.

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[1] Corddry, *City on the Sand*, 102-103.
[2] Gregory P. Bass et al., *Rehabilitation of the South Jetty, Ocean City, Maryland*, technical report CERC-94-6 prepared for U.S. Army Corps of Engineers, March 1994, 1.
[3] Corddry, *City on the Sand*, 103-104.
[4] Ibid.; Scorchy Tawes, "The White Marlin Capital of the World," Ocean City Life-Saving Station Museum, http://www.ocmuseum.org/index.php/site/oc-history_article/white_marlin_capital_of_the_world/.
[5] Corddry, *City on the Sand*, 89-90.
[6] Ibid., 126; Town of Ocean City, Maryland, "Chapter 3: Land Use and Community Character" in *Planning and Zoning Comprehensive Plan* (2006). http://www.town.ocean-city.md.us/Planning%20and%20Zoning/DraftComprehensivePlan/index.html.
[7] Fred J. Anders and Mark Hansen, *Beach and Borrow Site Sediment Investigation for a Beach Nourishment at Ocean City, Maryland*, technical report CERC-90-5 prepared for the Department of the Army, May 1990, 8.
[8] Baltimore District Corps of Engineers, *History of Coastal Engineering Projects at Ocean City and Assateague Island, Maryland*, Department of the Army, February 1986, 6.
[9] Underwood and Hiland, *Historical Development*, 33; Don Stauble, discussion with author, January 7, 2009.
[10] Corddry, *City on the Sand*, 127.
[11] Ibid., 127-128.
[12] Ibid., 109 (both quotes and description of the storm).
[13] Jordan Loran, discussion with author, January 8, 2009.
[14] Underwood and Hiland, *Historical Development*, 35.
[15] Edward F. Thompson et al., *Navigation Projects* in *Coastal Engineering Manual Part V: Coastal Project Planning and Design* EM-1110-2-1100, chair. Donald L. Ward (Washington, D.C: U.S. Army Corps of Engineers, 2006), V-5-55. http://chl.erdc.usace.army.mil/Media/1/9/9/CEM_Part-V_Chap-5.pdf; Charles B. Chesnutt, discussion with author, May 26, 2009.
[16] Underwood and Hiland, *Historical Development*, 73.

[17] Bass et al., *Rehabilitation of the South Jetty*, 1; U.S. Army Engineer Research and Development Center (ERDC), Ocean City Inlet, Maryland, Construction and Rehabilitation History, Inlets Online, http://www.oceanscience.net/inletsonline/usa/inletsearch.php3?inlet=Ocean+City&state=Maryland&district=Baltimore.
[18] Bass et al., *Rehabilitation of the South Jetty*, 5.
[19] U.S. Army Corps of Engineers Baltimore District, *Ocean City, Maryland, and Vicinity Water Resources Study* Final *Integrated Feasibility Report and Environmental Impact Statement*, (Baltimore, MD: U.S. Army Corps of Engineers, 1998), 2-6.
[20] Underwood and Hiland, *Historical Development*, 35.
[21] Corddry, *City on the Sand*, 101-102.
[22] Baltimore District, *History of Coastal Engineering*, 1. The metric conversion of the NGVD measurements are as follows: 10.7 ft = 3 m; 100 ft = 30 m; 7.7 ft = 2 m; 254 ft = 77 m; 5.7 ft = 1.8 m.
[23] Underwood and Hiland, *Historical Development*, 36.
[24] Ibid., 51 (both quotes).
[25] Ibid.
[26] Bass et al., *Rehabilitation of the South Jetty*, 5.
[27] Underwood and Hiland, *Historical Development*, 53.
[28] Ibid., 99.
[29] Ibid., 87 (all quotes and figures).
[30] Bass et al., *Rehabilitation of the South Jetty*, 1; ERDC, Inlets Online.
[31] Underwood and Hiland, *Historical Development of Ocean City Inlet Ebb Shoal*, 87.
[32] Baltimore District, *History of Coastal Engineering*, 8.
[33] Bearss, *General Background Study*, 84.
[34] Barry Mackintosh, *Assateague Island National Seashore: An Administrative History* (Washington, D.C: Department of the Interior, 1982), http://www.nps.gov/archive/asis/adhi/adhi1.htm.
[35] Ibid.
[36] USFWS "Chincoteague National Wildlife Refuge: History," http://www.fws.gov/northeast/chinco/history.htm.
[37] Ibid.; Mackintosh, *Assateague Island National Seashore*, http://www.nps.gov/archive/asis/adhi/adhi1.htm.
[38] Ibid., (both quotes).
[39] Ibid.
[40] Tony Pratt, discussion with author, December 5, 2008.
[41] Theodore M. Hillyer, *The Corps of Engineers and Shore Protection: History, Projects, Costs* IWR Report 03-NSMS-1 for the U.S. Army Corps of Engineers, Washington, D.C., 2002, 3. http://www.nsms.iwr.usace.army.mil/docs/National_Shoreline_Study_IWR03-NSMS-1.pdf.
[42] Thompson et al., *Navigation Projects*, V-5-50.
[43] NOAA Coastal Services Center, "Beach Nourishment."
. [44] Hillyer, *History, Projects, Costs*, 5-6 (both quotes).
[45] Lockhart and Morang, *History of Coastal Engineering*, 1-3-21.

4: Different Trajectories, Similar Problems, 1963–1980

Ocean City

After recovering from the damage inflicted by the Five-High Storm of 1962, Ocean City continued to thrive as a popular summer destination for vacationers. Increasing numbers of Americans had the time and means to vacation at the beach, and Ocean City expanded its development to accommodate more homes and hotels at its northern end. In 1965 the town annexed more of North Ocean City and extended sewer and water lines. By the end of the decade, the town reached all the way to the Delaware/Maryland state line and its first high-rise was built. [1]

The growing number of buildings exceeded the amount of available land, so developers created more land by filling wetlands on the city's bay side. In the mid-1960s, this process was accelerated by developer James B. Caine. "In 1965, several big dredging and filling projects were in progress, and Mr. Caine was planning one that would have extended two-thirds of the way across Assawoman Bay," Corddry stated.[2] At properties named Caine Keys I and Caine Keys II, he continued the process of filling and destroying the bay-side marshes. "Artificial canals were dredged and bulkheaded (stabilized with wooden walls on each side) and the

Figure 17: Development on Ocean City beach. Photo: U.S. Army Corps of Engineers.

spoil spread behind the bulkheads to raise the wetland to building elevations, thereby creating 'waterfront' lots with adjacent boat docks," explained Corddry.[3]

The impacts of extensive development could no longer be ignored, and officials and residents alike began to question the viability of inexorable growth. The memory of the denuded beaches after the Five-High Storm and the sight of buildings atop what had formerly been marshes teeming with wildlife led to research, legislation and activism pertaining to environmental degradation and erosion problems.

Environmental Protection

Attitudes about the environment were shifting towards an emphasis on the preservation of natural areas and wildlife habitats in the 1960s. Rachel Carson's 1962 book, *Silent Spring*, had inspired an environmental ethic based on protecting land and living things from the negative effects of humanity's actions. Up until this time, however, marshes and wetlands had been viewed as worthless land precisely because they couldn't be built upon or farmed. Land owners were applauded for "improving" wetlands by filling and developing them. Throughout much of Ocean City's history that was certainly the case, and the tendency to destroy the marshes along the bay was amplified by a property boom that began in the late 1960s. Corddry summarized, "The value of 'unproductive' marshland was being doubled many times over by dredging, bulkheading, and filling land. The practice created rich profits for developers and investors and greatly enhanced the tax base for rural counties, which could use the money."[4]

But the broader ecological value of wetlands was starting to be recognized and development of marshland was antithetical to conservationists. In a report from 1971, the Corps stated that one of the coastal area's most important aspects was its natural habitat:

"With the associated marshes, embayments, and estuaries, the shoreline provides the most productive areas for marine life and varieties of fish and wildlife which derive their existence from the rich resources of the region. Conservation of the natural environment is of general concern."[5] Private individuals had already acted upon that belief, including Ilia and Joe Fehrer of Snow Hill, Maryland, who founded the Worcester Environmental Trust to protest and prevent the destruction of coastal wetlands.

They and other residents and officials decried the dredging and filling projects taking place in the mid-1960s, particularly after the press reported that Caine and a few other developers had acquired hundreds of acres of wetlands for little or no payment and without any public notice. A grand jury investigation exonerated the public officials involved, but Caine's project for the wetlands adjacent to Assawoman Bay prompted the attorney general, Thomas B. Finan, to decree that property owners required official approval before filling wetlands.[6] The Worcester County Shoreline Commission was also created in the late 1960s to approve dredge and fill operations. All these measures were superseded by the Maryland Wetlands Act of 1970. Corddry stated, "The Act established a legal definition for public and private wetlands, mandated a mapping system to identify them, and created a permit process for any activity that would alter them."[7]

Caine continued to fill and develop the bay-side areas of Ocean City into the 1970s, but state legislation remained a powerful force for environmental preservation. His massive project named Lighthouse Sound was stopped because it violated the 1970 act. At the Federal level, the Corps became involved in wetlands protection at this time as well. The Clean Water Act (CWA) of 1972 (Public Law 92-500) charged the Corps with providing permits for the disposal of dredged material. Section 404 authorized the Corps to deny disposal if “the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas.”[8] This law dovetailed with the National Environmental Policy Act (NEPA) of 1970 (Public Law 91-190), which mandates an evaluation of the environmental impact of Federally funded projects, such as construction, dredging or beach nourishment. NEPA requires agencies to inform the public about a project and solicit public opinion, develop a number of alternative plans and perform detailed assessments of the environmental impacts of each plan, and select the least environmentally damaging plan.[9] The results of an environmental impact statement (EIS) can help the Corps make informed decisions about the impact of dredging and filling upon coastal areas including wetlands. If the conclusions of an EIS violate Section 404 of the CWA, a permit cannot be issued. State and Federal laws passed in the early 1970s, therefore, reflected the growing importance of the environment—particularly wetlands—to the public and the Corps’ mission. The environmental quality of the coastal zone was becoming an area of emphasis for the Corps, but the issue of coastal erosion and how to manage it was looming even larger.

Confronting Beach Erosion

The storm damage at Ocean City in 1962 highlighted the importance of a wide beach and healthy dune system, as well as the risks an eroded beach presented to the landward developments during a storm. The town and the Corps turned to emergency beach replenishment and dune-building to mitigate the situation, with the goal of protecting the shoreline from the ocean’s waves with a natural, nonstructural approach. The beach not only protected the hotels and cottages that housed the town’s tourists, it also formed the lifeblood of the economy as the principal attraction for visitors. Thus, the townspeople wanted to ensure the beach's integrity for reasons of safety and economics.

The experience of the storm led local officials and residents to appeal to the Federal Government for a more lasting solution to the issues of erosion and storm protection beyond just the emergency repairs after the Five-High Storm. According to Stauble et al., "The Committee on Public Works of the House of Representatives, at the request of local interests made through their representatives in Congress, adopted a resolution on June 19, 1963, directing the Secretary of the Army to direct the Chief of Engineers [CE] to make a study of the shores of the Atlantic Ocean in Maryland. The CE was to ascertain the need for beach erosion control, hurricane protection, and related purposes."[10]

By this time, the Corps was realizing that hard structures couldn't maintain a beach entirely. Lockhart and Morang summarized, "In certain resort areas, structures had proliferated to such an extent that the protection actually impeded the recreational use of the beaches. Erosion of the sand continued, but the fixed back-beach line remained, resulting in a loss of beach area."[11] This harkened back to the failure of beach stabilization attempts in New York and New Jersey in earlier decades, and in the 1960s the percentage of federal funds spent on structural protection measures declined from 65% of the protection budget to 9%.[12]

The study of the Atlantic coast of Maryland coincided with a wider shift in Corps research and understanding of coastal processes. The BEB, which had studied coastal erosion since 1930 and pioneered the study of coastal engineering techniques, was replaced in 1963 by the Coastal Engineering Research Center (CERC) and an advisory board. According to Lockhart and Morang, "The Coastal Engineering Research Board (CERB) and CERC followed the lead of their predecessor, the BEB, in pursuing field measurements and basic coastal processes research. The argument was that more research would produce more data, provide for more sound coastal engineering approaches, and lead to greater savings. Spurred by both increasing development and environmental awareness, CERC planned programs to quantify phenomena that previously had been understood only qualitatively."[13] The Maryland study, which eventually encompassed Assateague Island as well as Ocean City, exemplified the increased focus on data collection and evaluation.

The first draft of the report was completed in May 1970. "This report was not made final because the city of Ocean City withdrew project support until the mid-1970s. The draft report recommended that a Federal project for beach erosion control and hurricane protection at Ocean City be adopted," stated Stauble et al. Immediately following this draft, the Corps released the results of a sweeping study of the nation's shorelines. The National Shoreline Study, completed in 1971, had been authorized by the River and Harbor Act of 1968, in which "the Congress gave to the Chief of Engineers special responsibilities for appraising, investigating, and studying the condition of the Nation's shorelines and for developing suitable means for protecting, restoring, and managing them so as to minimize erosion induced damages."[14]

This report acknowledged two critical ideas related to Ocean City: the importance of recreational beaches and the efficacy of beach nourishment. It stated, "The population expansion and increased leisure time cause rapidly increasing demands for beach areas. Because the quantity of beaches is limited, continued loss of beach areas will increase in importance and economic value." For confronting problems of erosion, the report judged, "When conditions permit, artificial fill with periodic nourishment to restore and preserve a beach is the preferred method; it is the natural method, is aesthetically pleasing, and permits a variety of recreational uses. In many areas vegetation may be used to reduce losses of sand from dunes, or zoning and land-use controls may be imposed to reduce or control damage attributable to erosion."[15]

Although the Atlantic coastal study in Maryland was still being revised in the early 1970s, the principles discussed in the National Shoreline Study and the techniques being developed by the Corps were incorporated into the evolving plan. The town of Ocean City, meanwhile, was enacting its own erosion control measures to preserve the beach while the Corps and other government agencies formulated more official plans.

Any Means Necessary

By the early years of the 1970s, Ocean City was experiencing yet another property-development boom, this time concentrated on high-rise condominiums. "Ocean City was wide open to big-time development. It had one of the last developable oceanfronts in the mid-Atlantic coastal region close to two major cities, Baltimore and Washington, and it was a town which, from the beginning, had existed as a seaside resort…Even so, the town was not prepared for the scale of activity that suddenly hit it," Corddry maintained.[16] Over 1,000 condominium units were under construction just in 1971, and within a few years the glutted market crashed, only to pick up again in the late 1970s. Despite the boom and bust cycle of the property market, people wanted to preserve the beach that was the lifeline of the tourism-based economy. Town officials, therefore, resorted to many erosion control measures, including unconventional and even impractical ones.

The Maryland Department of Natural Resources (DNR) began a groin-building program in 1972 that resulted in 11 timber groins, each extending for 200 feet, which added to the existing groin field.[17] The project was spearheaded by Ocean City's colorful and often controversial mayor, Harry Kelley, who took office in 1970. Mayor Kelley adamantly believed the groins would trap a significant amount of sand to nourish the beach, and he had rescinded the town's official support for the Corps' beach nourishment project in November 1971 to focus instead on the groin-building project. Officials with the Corps, City Council, Maryland Geological Survey and Maryland DNR convinced the mayor to reinstate support in 1972 and again in 1973, after he had repeatedly retracted support. According to the project's final environmental impact study, in 1973 "the study was reactivated and the Baltimore District initiated an update of the draft survey report and preparation of a new EIS since the previous draft was three years old."[18]

By 1977, the Corps had completed the updated study and recommendations. Mayor Kelley, however, rescinded the town's support for the project once more and advocated bulldozing sand from the nearshore onto the beach as an alternative. "Mayor Kelley asserted that beaches could be restored by bulldozing at a fraction of the cost of the beach restoration projects being studied by the Corps and supported by the Maryland Department of Natural Resources. Furthermore, they could do it on the spot without the long and cumbersome bureaucratic delays encountered when dealing with government agencies," according to Corddry.[19] Despite protests from scientists who argued that the damage to the nearshore area was unacceptable for the short-term benefits, his bulldozing program garnered community support as an immediate action to preserve the beach. "He was pretty adamant that he wouldn't let the beach disappear without a fight," said Loran, "but in the long run [bulldozing] didn't have a negative effect."[20] Mayor Kelley's actions—which included him personally pushing sand in a city bulldozer onto the beach in front of TV cameras—drew attention to the problem of beach erosion, but they didn't provide a sustainable solution for it.

A much more mundane act in 1975 by the Maryland State Legislature took a step towards a long-term answer to the erosion problem. March of that year saw the passage of a bill that established a building limit on the beach and an erosion control district from the dune to the surf zone.[21] These types of building regulations are a form of management that prevents buildings from being constructed in areas of high erosion, thereby negating the possibility of structural damage from storms or flooding. The *National Shoreline Study Shore Management Guidelines* explained, "Engineering techniques deal with the physical interaction of water and shore…Management techniques are employed to influence people in their use of the shore…Both engineering and management techniques can be employed for either preservation or enhancement."[22] The 1975 building restrictions and the Corps' long-studied plan would carry out this two-pronged recommendation.

The Corps study that had begun in 1963 reached a critical point 15 years later when it received official state support. According to the Baltimore District, "In a letter dated March 29, 1978, Secretary James Coulter of the Maryland Department of Natural Resources stated that the State of Maryland would provide necessary non-Federal assurances."[23] With state sponsorship and funding assistance, the Corps was able to coordinate with officials and the public to move forward with the project. The document containing the research and recommendations was titled *Atlantic Coast of Maryland and Assateague Island, Virginia, Feasibility Report and Final Environmental Impact Statement*. This study advocated a massive beach nourishment project, complete with dune-building and a steel bulkhead along the boardwalk. “The feasibility report recommended the construction of a beach and dune system along approximately 33,500 ft [10,200 m] of shoreline between 27th Street and the Maryland-Delaware state line…A sheet-pile bulkhead was recommended to be placed from 27th Street south to North Division Street (located south of 1st Street). The design height of the berm was +8.7 ft [2.7 m], the total beach width was recommended to be 200 ft [61 m], and the dune/bulkhead crest was recommended to be +16.0 ft [5 m].”[24]

The scope of the project was extensive because officials understood that the beach was the center of the area’s economy. The feasibility study determined that “the resort and travel-oriented industry is the only really significant industry in Ocean City.” Furthermore, the value of tourism extended beyond the town itself. In 1979-1980, Ocean City represented nearly 80% of Worcester County’s property tax revenues.[25] As an economic engine and tax source for the entire county, Ocean City’s beach was critical to the local population. The protection the beach provided to the town’s residents and visitors—as had been proven after the Five-High Storm—also bolstered support for the Corps’ beach nourishment effort. This project would therefore incorporate existing knowledge of erosion-control practices, including hard and soft structures, while complementing nonstructural methods such as the 1975 building limit ordinance. This approach envisioned the collaborative use of many methods between agencies to mitigate erosion.

Ocean City Inlet

Like the landforms surrounding it, Ocean City Inlet was also affected by the Five-High Storm. Erosion of northern Assateague Island had reached average rates of -9.41 m/yr (30 ft/yr) by the early 1960s, so when the storm struck, the land directly adjacent to the south jetty was exposed to the full brunt of the wind and waves. Consequently, more land was washed away and the storm-induced erosion severed the south jetty from the shore. Emergency repairs were undertaken in response. As a result of the storm damage, "in 1963, the inshore end of the jetty was extended landward in a southwest direction for a distance of 680 ft [207 m]. In addition, a 720-ft [219-m] section previously damaged due to foundational scouring was repaired, starting 1,300 ft [396 m] seaward from the original landward jetty end," according to Bass et al.[26]

The repairs re-established the jetty's shoreline integrity and filled the portion of the structure scoured by passing sediments. All these actions attempted to minimize the amount of sediment getting through or around the jetty and into the inlet. But the rehabilitated structures couldn't completely prevent sediment from settling in the inlet and shoals, and increasing amounts had to be dredged from the inlet over time. Between 1962 and 1963, 37,774 yd^3 (28,880 m^3) was dredged from the inlet channel. Dredging took place another eight times between 1969 and 1979.[27] Bass et al. summarized, "Dredging requirements increased from an average annual amount of 10,000 to 15,000 yd^3 [7,646 to 11, 468 m^3] per year in 1969-1970 to 50,000 yd^3 [38,228 m^3] per year in 1971-1973."[28] This increase in dredging activity and totals reflected the significant amount of littoral material in the area, although the inlet's flushing capacity remained relatively high.

Figure 18: Dimensions of structures at Ocean City Inlet with chronology of construction events (modified from Dean et. Al. 1979). Source: U.S. Army Corps of Engineers.

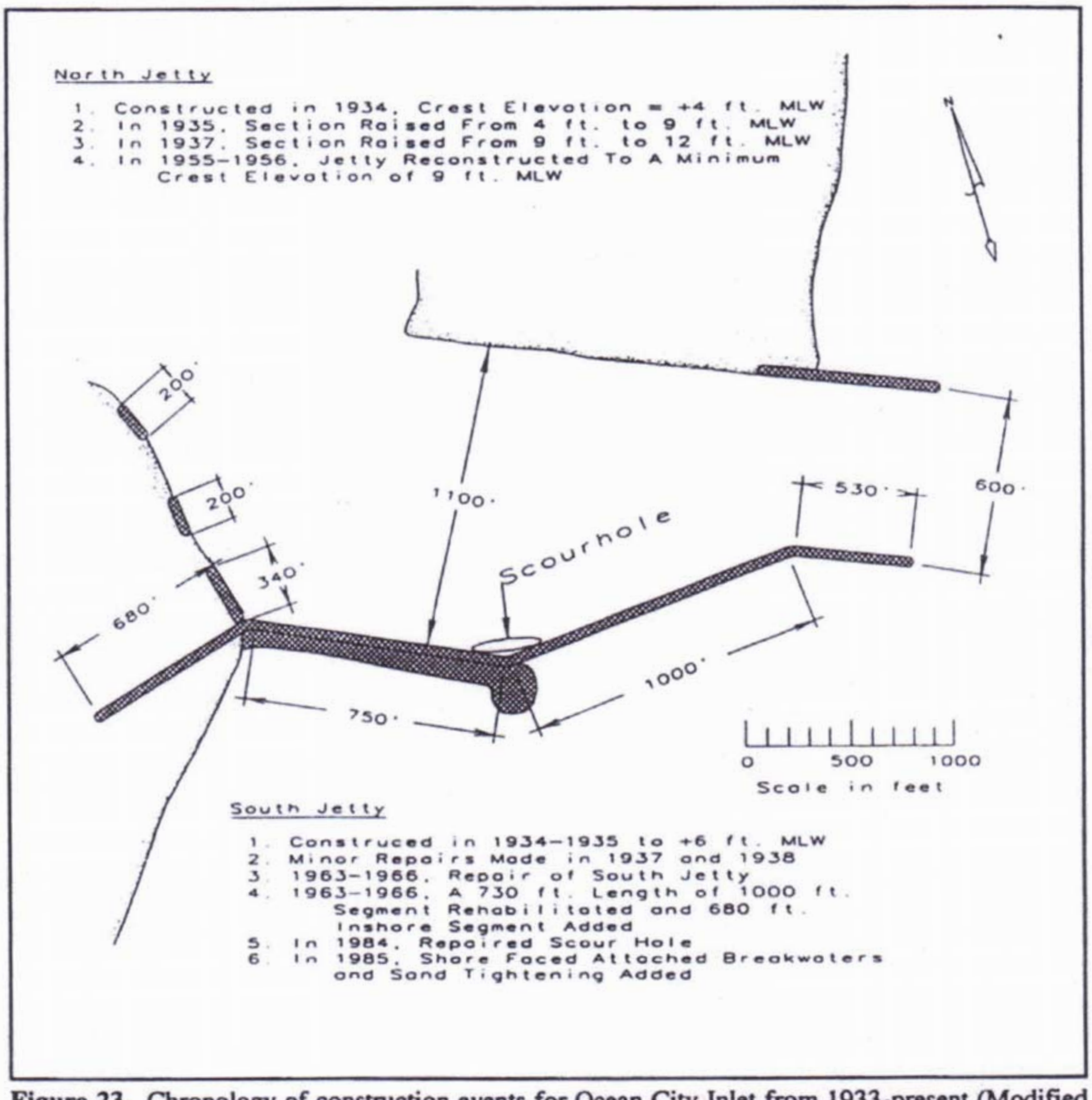

Figure 23. Chronology of construction events for Ocean City Inlet from 1933-present (Modified from Dean et al 1979).

Ebb Shoal Morphology

With the large tidal prism moving a substantial volume of water and the jetties focusing currents, Ocean City Inlet was able to transport sediment into the growing shoals, including the ebb-tidal shoal on the seaward side of the inlet. Underwood and Hiland stated that between 1962 and 1968, "the ebb shoal advanced seaward only 70 m [230 ft], while its width increased approximately 324 m [1063 ft]."[29] The morphology of this subaqueous sand body—its growth and movement—was due to coastal processes, including the Five-High Storm. When "storm waves break along the outer edge of the terminal lobe, they tend to place the bottom material into suspension, push the bar back towards and/or along the shore, and pile some of the material back on the ebb shoal platform. At the same time, some of this material is pushed sideways, flattening and elongating the face of the shoal where the predominant wave activity is focused," Underwood and Hiland explained. Northeasters, such as that in March 1962, struck from their eponymous direction and thereby began pushing the ebb shoal in a southwesterly direction towards Assateague Island. Between 1962 and 1978, Underwood and Hiland concluded, "This lateral movement of sediment was probably the initial stage before shoal attachment to Assateague Island." [30]

As the ebb shoal was expanding and moving, northern Assateague Island continued to erode. Sediment leaving the inlet with the ebb tide, as well as that which passed around the jetties, was still settling into the ebb shoal and not reaching the northern end of the island. When an ebb shoal reaches its optimal size, it can act as a bridge for sediment by transferring sand across itself to a downdrift beach. As waves and tidal currents push the shoal, a sand bar grows in the direction of the littoral drift, in this case to the south, and attaches to the downdrift shoreline. "At this stage, significant sand bypassing of the inlet can occur, re-establishing in great part the transport downdrift that existed prior to formation of the inlet," explained Kevin R. Bodge and Julie D. Rosati in the *Coastal Engineering Manual*.[31] This action was not yet taking place at Ocean City Inlet by the late 1970s, but the movement of the ebb shoal suggested equilibrium would be reached.

Figure 19: This aerial view captures the accelerated landward movement of Assateague Island compared to Fenwick Island. To the far right, waves break over the seaward edge of the ebb-tidal shoal. Photo: Inlets Online.

In the meantime, however, rates of erosion on the northern 6.5 km (4 mi) of the island slowed to approximately 4.42 m/yr (14.5 ft/yr) between 1962 and 1976. "This reduced shoreline change rate may be attributable to emergency USACE repairs to this stretch of shoreline," stated Underwood and Hiland.[32] The Corps placed dredged material on the shoreline immediately following the Five-High Storm to repair the breach near the south jetty. More material was added from inlet dredging operations. Pratt explained, "The inlet was dredged and [the spoil] was placed on the northern end of Assateague. It was a series of channel dredgings that just happened to be placed on Assateague."[33] Dredged material was not viewed as a particularly valuable resource and the channel spoil was disposed on Assateague Island for short-term expediency, but it had the ancillary benefit of easing the continual erosion.

Because the north end of the island was a mostly barren, overwashed landscape, there was no environmental issue with placing the dredged sediment once the Clean Water Act of 1972 was passed. Rather, laws in the early 1970s encouraged the use of coastal management plans that complemented or restored natural processes. The Coastal

Zone Management Act of 1972 (Public Law 92-583) "established policy to preserve, protect, and develop the coastal zone while restoring and enhancing coastal resources. It required states to develop and implement management programs to achieve wise use of the land and water resources in the coastal zone, giving full consideration to ecological, cultural, historic, and aesthetic values, as well as compatible economic development." Likewise, the Water Resources Development Act of 1976 (Public Law 94-587) authorized nourishment of adjacent beaches during dredging operations. "Section 156 of the law authorized the Corps to extend Federal aid in periodic beach nourishment up to 15 years (from the original 10) from the date of initiation of construction and contained several authorizations for shoreline studies and projects," according to Hillyer.[34] Thus, the placement of dredged material from Ocean City Inlet onto Assateague Island was complementary to the developing principles of beach nourishment, even though it began as a measure of convenience. The practice was not uniform or carefully designed, and therefore only partially effective, but it reflected the growing interconnectedness of the Corps' navigation and erosion-control missions.

By the late 1970s, shoreline change rates for northern Assateague Island had become increasingly erratic, which suggested that ebb-shoal morphology and beach fill operations—even on an ad hoc basis—were affecting the island. According to Underwood and Hiland, along the northernmost 3.85 km (2.4 mi) during the years 1976 to 1980, rates averaged from +15 m/yr to -10 m/yr (+49 ft/yr to -33 ft/yr).[35] Despite the ebb shoal's movements and changes, the erosion problem was still significantly damaging the island and the structures at Ocean City Inlet were experiencing continual pressure from the currents and scouring sediments. The inlet was changing, but not completely for the better.

Assateague Island

In 1963, the bridge that Leon Ackerman and other property owners on Assateague Island had so fervently desired was completed. It connected the island with Sandy Point on the mainland across Sinepuxent Bay. It became the second bridge to the island because a toll bridge built by the Chincoteague-Assateague Bridge and Beach Authority had opened in 1962 at the southern end of the island. The Authority leased the land for the bridge from the BSFW in the Chincoteague National Wildlife Refuge.[36] But there was no development to reach on Assateague Island after crossing those bridges. The Five-High Storm had destroyed nearly every building on the island, and by 1964 another 540 ac (219 ha) had officially become Assateague State Park.[37] The NPS was determined to establish a national seashore on the island. They began the legislative wrangling necessary to reach their goal,but the opposing aims of development and wilderness preservation would continue to conflict in the coming years.

Assateague Island National Seashore

Secretary of the Interior Stewart L. Udall viewed the Five-High Storm as an opportunity to pass legislation authorizing Assateague Island as a national seashore belonging to the National Parks system. This achievement had slipped away from the NPS in 1955 when the island had been deemed too developed for national seashore status. Udall initiated a study by the Bureau of Outdoor Recreation, another agency in the Interior Department, and the report advocated the solution he and the NPS were seeking. Mackintosh stated, “Issued in April 1963, the report recommended establishment of an

Assateague Island National Seashore under the Park Service, encompassing the entire island. To avert opposition from the Maryland Department of Forests and Parks and the Bureau of Sports Fisheries and Wildlife, Assateague State Park and Chincoteague National Wildlife Refuge would retain their individual identities under their separate administrations."[38] The plan envisioned recreational day-use of the park but no amenities such as restaurants or hotels.

Worcester County officials opposed the loss of a potential tax base from commercial and residential properties. They commissioned a separate study in 1963 that ended up confirming the Interior Department's assertions—namely, that real estate development would be extremely costly and environmentally damaging. According to Mackintosh, the report "found that 84% of the subdivided lands would require from one to seven or more feet of fill, totaling some 17 million yd^3 [13 million m^3], to bring them up to the minimum level recommended for permanent construction. Hydraulic filling from the floor of the bay, the most economical method, would deepen the shallows there with a probable adverse affect on water life."[39]

Individuals who had purchased the subdivided properties remained unconvinced, however, and were very hostile to the idea of the government taking over their land. Despite the ravages of the storm, their long-awaited bridge opened in 1963 and many still hoped to develop a seaside resort community. During a trip to Assateague Island in June 1963, one landowner named Philip King confronted Udall. King reportedly told the Secretary, "You, sir, are on our land and you're trying to use our money to take it away from us." King was the president of the Ocean Beach Club, which represented the 3,200 landowners whose properties would be acquired, and he was also a retired NPS employee. The *Washington Post* reported, “As he spoke, King’s feet were planted deep in sand that, over years, had nearly covered a street sign that stuck incongruously up into the barrenness, proclaiming a nonexistent ‘Baltimore Ave. and N. 135th St.’”[40]

In the fall of 1963, the state of Maryland gave its approval to the national seashore plans. Mackintosh explained, “Economic conditions played no small role in the state’s position: responsible officials contrasted the tourism income from a national seashore with the specter of major state investment to protect private property on Assateague.”[41] Maryland’s federal representatives and senators began introducing legislation in the 88th Congress in 1963, but it took many emendations until a plan acceptable to the NPS, the BSFW and the states of Maryland and Virginia was drafted. On June 15, 1965, the Senate Committee on Interior and Insular Affairs recommended an amended bill for passage.

The bill proposed a number of recreational developments on the island: a fishing area near the south jetty, Assateague State Park, a 600-acre (243-ha) concession area on the beach south of the state park, three picnicking and swimming areas, an administrative headquarters on the mainland and Chincoteague National Wildlife Refuge. It authorized the Secretary of the Interior to acquire the interests of the Chincoteague-Assateague Bridge and Beach Authority, and it decreed that private properties could only be acquired with landowners’ consent. Owners could also reserve rights of use for up to 25 years.[42]

It also decreed the “formulation of plans for beach erosion control and hurricane protection of the seashore; and any such protective works that are undertaken by the Chief of Engineers, Department of the Army, shall be carried out in accordance with a plan that is acceptable to the Secretary of the Interior and is consistent with the purposes of this Act.” Most controversially, the bill directed the construction of a road between the

Sandy Points Bridge at the northern part of the island and the bridge at Tom's Cove Hook that was owned by the Bridge and Beach Authority.[43] Udall was opposed to such a road, but he compromised over the vague wording in the actual bill that left the exact location of the road to the Secretary's discretion.

Concerning Worcester County officials and the Ocean Beach Club members, the stakeholders opposed to the legislation, the June 15th report stated, "The committee was very sympathetic to their position, particularly in view of the fact that in 1955, the Department of the Interior had apparently abandoned its original plans for Federal acquisition. Despite all this and in view of the very limited development that existed on the island it was the unanimous position of the members of the committee that the public interest could be best served by the creation of the national seashore."[44] On September 21, 1965, President Lyndon B. Johnson signed the bill into law as Public Law 89-185, officially designating Assateague Island National Seashore (ASIS).

Unlike Chincoteague National Wildlife Refuge, which was expressly designed to provide habitat for rare wildlife species, the national seashore was meant for recreational use by humans. The picnicking and swimming areas were to encourage visitation, and hunting and fishing were allowed in certain zones, except for the wildlife refuge. Concentrated recreational development, however, couldn't be compatible with habitat preservation, and Assateague was becoming an increasingly important home to many species.

Abundance of Wildlife

As human settlement on Assateague Island diminished over the twentieth century, plant and animal species expanded in the relatively pristine barrier ecosystems.

Descendents of the horses *(Equus caballus)* pastured on the island by seventeenth-century colonists had become feral and they developed into two herds. In 1968, the NPS acquired ownership of the Maryland herd, while the Chincoteague Volunteer Fire Company retained ownership of the Virginia herd. The two herds were separated by a fence on the state line. The Virginia herd was limited in size because of the annual "pony penning" that took place on Chincoteague Island where foals were, and still are, auctioned to the public to support the Volunteer Fire Company. The Maryland herd consisted of only 28 horses when the NPS took it over. Left to their own devices with no natural predators, the horses began overgrazing American beachgrass in the dune area and their population rose precipitously. Another non-native mammal species that was thriving on Assateague Island was the sika deer *(Cervus nippon)*, which was believed to have arrived in the 1920s with a Boy Scout troop. [45] The overgrazing caused by these animals would remain a concern in later years.

Figure 20: Ponies on Assateague Island. Photo: National Park Service.

Birds benefited significantly from the establishment of the national seashore. Chincoteague National Wildlife Refuge on the southern portion of the island was already an important habitat for many migratory birds because Assateague Island was the only undeveloped barrier between Cape Cod, MA, and Cape Hatteras, NC, even by the 1970s. Birds such as peregrine falcons *(Falco peregrinus)*, bald eagles *(Haliaectus leucocephalus)* and snowy owls *(Nyctea scandiaca)* soon appeared in central and northern Assateague. The barrier flats, the seemingly barren sands of overwash sediment, became particularly important for struggling bird species that required this rare habitat for nesting or feeding. The piping plover *(Charadrius melodus)* came to rely on Assateague Island as its numbers declined from hunting and habitat loss. The frequently overwashed northern end of the island was one of the few locations on the Eastern Seaboard that maintained the plovers' habitat. "The birds prefer to nest on the upper beach and sparsely vegetated overwash fans and inter-dune areas. They find the most productive forage along sound-side mudflats and low, moist sand flats in the island's interior—habitats created and maintained by storms," according to the National Parks Conservation Association.[46] The barrier flats and overwash areas would increase in importance as more birds were listed as threatened or endangered, making the habitat at Assateague Island more critical.

Figure 21: Piping Plover. Photo: Gene Nieminen, U.S. Fish & Wildlife Service.

Although they were thriving at Assateague, increasing development was adversely impacting bird populations across the United States, and many species were listed as federally endangered once the Endangered Species Act of 1973 (Public Law 93-205) was passed. Locally, other animal species were declining in the Maryland area in the 1960s. For example, hard clams *(Mercenaria mercenaria)* had lived in the coastal bays for centuries and were an important source of food and income for generations. But in 1967 "a regulation was enacted permitting the use of hydraulic escalator dredges and between 1967 and 1972, clam harvests averaged 352,000 pounds a year," according to the Fisheries Service of the Maryland DNR.[47] Within a few years, the clams had all but disappeared from the bays.

The growing flocks of rare birds at Assateague Island, as well as the number of species declining from eastern U.S. habitats, coincided with the rise of conservation principles. The original seashore legislation recognized that Assateague Island was unique for its wilderness along the heavily developed East Coast, but it had advocated extensive recreational use. The purpose of the national seashore began to change once its wilderness status became appreciated in a different way—as a place for wildlife to flourish without the intervention of people.

Conservation Trumps Development

In 1970, Judith Johnson and five others founded the Committee to Preserve Assateague, a conservation organization dedicated to maintaining the island's wilderness.[48] The Committee's main objection was to the road authorized by the seashore legislation in 1965, and they weren't alone in their opposition. Secretary Udall had spent years delaying the project or keeping it as a low priority in the planning process because, as he said in 1966, "It is my own feeling that it would be improvident to build a road until a successful dune stabilization program is well under way. There are other reasons why the road should have a low priority, but it seems to me that the absence of a protective barrier dune is a most compelling argument for the present."[49]

Various legislators, however, wanted the road to bring in more tourists, and after much factional infighting between various Interior agencies, a "one-sheet master plan" was written for the seashore in 1967. It envisioned not only the island-long road but also restaurants, motels, recreational facilities, hundreds of campsites and parking for thousands of cars. Immediately, the National Parks Association, other assorted conservation groups and Maryland's Senator Joseph D. Tydings vociferously opposed the plan and calls for the revision of the original legislation began to circulate. The 1965 law had decreed the developments as a way to achieve a compromise between the various stakeholders, so a major shift in the seashore's management would have to be codified in revised legislation.[50]

The tide was turning in the conservationists' direction. Senator A. Willis Robertson of Virginia, the road's most ardent supporter, was defeated in a 1966 primary election. And, Mackintosh continued, "By 1970 private visitor services in Chincoteague had so expanded that the local chamber of commerce sought assurance from Interior that competing concessions would not be established at Tom's Cove. It was assured that Park Service policy opposed in-park development as long as public needs were being met outside. The road proposal also encountered local opposition from businesses who feared it would siphon tourists off to the north."[51] At this time, the Committee to Preserve Assateague began investigating development plans at Assateague State Park, and federal environmental laws were also emphasizing and enforcing environmental protection.

The National Environmental Policy Act (NEPA) of 1970 required a detailed environmental impact statement for federally funded projects, such as the road on Assateague Island. Likewise, the Coastal Zone Management Act (CZMA) of 1972 declared it was officially national policy "to preserve, protect, develop, and, where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations," and that acceptable state coastal plans must provide for "the protection of natural resources, including wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat, within the coastal zone."[52]

Just as significant as the legislation and wilderness preservation movement was the growing realization that barrier islands were and always would be changing, evolving landforms. By the early 1970s, scientists started to advocate that preventing barrier islands from shifting was, at best, pointless and, at worst, detrimental. Mackintosh explained, "In a report prepared for the chief scientist of the National Park Service on Atlantic national seashores, Paul J. Godfrey of the University of Massachusetts characterized the barrier islands as inherently dynamic and unstable. Attempts to artificially stabilize them by dune building were not only doomed to failure but were ecologically harmful…To the extent that the dunes held and prevented periodic overwash, they impeded the natural formation of salt marsh on the bay side, again adversely affecting productivity."[53] This line of reasoning supported the removal of developments and the encouragement of wilderness and natural conditions, both for the health of the barrier and to prevent property losses that would happen eventually, regardless of the measures taken to protect them from the barrier's dynamics. The damages inflicted on properties after the Five-High Storm exemplified this viewpoint, and a political consensus for legislative changes developed.

By 1974, legislators from Maryland and Virginia introduced new legislation for Assateague Island National Seashore, which replaced the sections that authorized the concessions developments and road. Two years later, on October 21, 1976, President Ford signed the bill into law. It had undergone many revisions but ultimately it removed the provisions for the concessions area and, most critically, the road. Mackintosh summarized, "Thus it was that 11 years and one month after Assateague Island National Seashore was legally inaugurated, its planning and development mandates were so fundamentally transformed as to render it ‘born again.’ The change of direction long accepted in practice had become a matter of law, and the law now required the charting of a new course for the seashore.”[54] A management plan was drafted that limited developments and decreed not to stop overwash processes in most areas of the island, but it would be a few more years until the details were completely determined. With the publication of the beach nourishment plans for Ocean City, there were many other issues to consider by 1980 as well.

Conclusion

The years after the Five-High Storm of 1962 witnessed significant changes in both Ocean City and Assateague Island. The storm had wreaked terrible destruction in both places, but they responded in completely different ways. Ocean City experienced a building boom in the late 1960s and early 1970s that not only replaced the destroyed structures but far surpassed any level of development the town had previously seen. High-rises soared above the beach and homes filled the bay-side marshes, and after a brief recessionary period the development continued apace. Assateague, conversely, was authorized as a national seashore in 1965, and despite challenges from development-minded groups, its legislation was changed to keep it as free of human intervention as possible.

Despite the different trajectories, however, both Ocean City and Assateague Island were experiencing severe erosion. Ocean City’s concentrated development pattern exposed fixed buildings to a fluid shoreline that was naturally eroding with rising sea level. Assateague Island’s jetty-induced erosion was significantly, if erratically, affecting its northern end. The findings of the Corps’ National Shoreline Study in 1971 highlighted the widespread erosion across the coasts of the United States. The study surveyed 84,000 miles (135,185 km) of U.S. shorelines, including Alaska, and investigated areas of "critical" erosion, where the condition was so severe as to warrant action to halt it. The report found "critical erosion totals about 2,700 miles [4,300 km] of shore for the Nation. The major regions in which critical erosion is occurring are the North Atlantic region with 1,090 miles [1,750 km] and the South Atlantic-Gulf region with 980 miles [1,600 km]. The large amounts of critical shoreline in these regions are directly related to extensive development along the shores of these areas."[55] It deemed that 22 miles (35 km) on Assateague Island were experiencing critical erosion.

Through research and the experience of storm events, the Corps was recognizing that the beach itself was an important resource for storm protection, recreational use and environmental conservation. "Probably most significant and important with respect to erosion is the loss of beach recreation areas, a valuable natural resource," the *Report on the National Shoreline Study* stated. It also maintained, "The preservation of natural and scenic values is an equally important use of the shoreline. Beaches, marshes, and their adjacent nearshore areas provide some of the Nation's most productive areas for marine and other life forms. In many instances, the Nation's beaches and shores are directly related to the values of the adjacent estuaries or bays."[56] The shoreline management issues at Ocean City and Assateague Island exemplified these problems; erosion at these locations threatened recreation and habitats, as well as developments.

By the late 1970s, the peak number of tourists during the summer season at Ocean City reached 192,000 and the town's year-round population grew by 23% between 1970 and 1980.[57] Thus, increasing numbers of people relied on the beach for recreational opportunities and income. Developments proliferated along the beach as the town's seasonal and permanent population rose. The Corps estimated that if erosion continued at the historical rate of 2 ft (0.6 m) per year, the beach would lose 140 ft (43 m) by the year 2040, resulting in significant property loss.[58] Maintaining the beach was therefore growing in importance just as erosion was becoming a considerable problem. Likewise, the integrity of Assateague Island itself was threatened by sand starvation. If erosion continued unabated, the island would lose territory that was home to diverse species of unique and endangered wildlife. As the only undeveloped barrier along the East Coast, Assateague remained extremely valuable as a habitat.

During this time, the Corps was increasingly viewing its missions in the coastal zone as a connected web where management decisions needed to benefit, or at least not be detrimental to, its various duties, including navigation maintenance, shoreline protection and regulation. The *Report on the National Shoreline Study* encapsulated this evolving viewpoint: "Shore protection is most effective and economical when complete physiographic reaches are considered and proper attention is given to the effects of the protection on adjacent shores and on natural environment."[59]

Beach nourishment, which placed sand dredged from a suitable source or sources onto an eroding beach, could achieve this goal in a way structural methods could not. This method maintained a beach for humans, wildlife and wave-energy absorption while not interrupting coastal processes, such as longshore sediment transport, as the Ocean City jetties had done. It also appealed to the Corps because it could protect developed areas and it could replicate natural processes, such as seasonal erosion and accretion. In this way, beach nourishment approached coastal management by addressing the entire coastal system in a particular region. Accounting for the effects of management decisions on nearby areas and the interaction of different uses of the coastal zone became increasingly important as the Corps' missions grew to include sediment management, erosion control, environmental stewardship and storm protection.

These ideas were all exemplified by the *Atlantic Coast of Maryland and Assateague Island, Virginia, Feasibility Report and Final Environmental Impact Statement* of 1980, which advocated a major beach nourishment project at Ocean City and Assateague Island. It still called for a structural response—a steel bulkhead to be built along the boardwalk at Ocean City—but its main components were a beach fill, dune construction and periodic renourishment. These methods mimicked natural processes and actively sought to avoid negative consequences elsewhere, thereby considering the broader effects of shoreline engineering. The plan was based upon mathematical calculations and detailed data sets that estimated the amount of sand needed to maintain a beach that was a minimum of 200 ft (61 m) wide. To carry out the project, engineers required a "sediment budget," which is a calculation of the amount of sediment entering and leaving a particular coastal area.

The Coastal Services Center at NOAA explained, "If more sediment is transported into an area than transported out of an area, shoreline accretion results. Conversely, if more sediment is transported out of an area than is transported in, shoreline erosion results. Balancing the inflow and outflow of sand resources for a given region is important to maintaining stable beaches, and is used by coastal engineers and geologists to analyze and understand shoreline changes as well as to design beach nourishment projects and predict their future behavior."[60] To determine how much sediment was entering and exiting the area around Ocean City Inlet, engineers and researchers gathered information on how the shorelines had changed over time, the bathymetry of the region and the engineering history of the inlet. Calculating rates of sediment transport and the way that waves impacted the shores also figured into the sediment budget. The unpredictability of the inlet environment made the calculations educated guesses to a degree, and over time the figures would be modified based on further research. But the beach nourishment plan for Ocean City entailed extensive research and modeling, which became a cornerstone of the Corps' approach to shoreline management.

Rather than using only structures to modify dynamic coastal areas, engineers were learning about and working with the geomorphology of the area. Gathering scientific data was crucial to the development of a lasting, sustainable management plan. The use of computer models also followed the growing technological innovations taking place. Bodge and Rosati summarized, "Whether or not formally developed, the sediment budget concept is fundamental to coastal engineering and science, usually providing the backdrop by which processes and projects are evaluated and alternatives considered."[61] The data required to create a sediment budget and determine the other facets of a beach nourishment project would become better understood as this method became the focus of coastal management near Ocean City Inlet.

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[1] Corddry, *City on the Sand*, 128; Town of Ocean City, Maryland, "Chapter 3."
[2] Corddry, *City on the Sand*, 131.
[3] Ibid., 129.
[4] Ibid., 130.
[5] Department of the Army Corps of Engineers, *Report on the National Shoreline Study* (Washington, D.C: Department of the Army, 1971), 3.
[6] Corddry, *City on the Sand*, 131-134.
[7] Ibid., 134.

[8] *Federal Water Pollution Control Amendments of 1972*, 33 U.S.C. 1251 et seq., 92nd Cong. (1972), http://www.usace.army.mil/CECW/Documents/cecwo/reg/materials/cwa_sec404doc.pdf.
[9] NOAA Coastal Services Center, "Beach Nourishment."
[10] Stauble et al., *Beach Nourishment Project Response,* 6.
[11] Lockhart and Morang, *History of Coastal Engineering,* 1-3-21.
[12] Ibid., see figure 1-3-13 on page 1-3-22.
[13] Ibid.
[14] Department of the Army Corps of Engineers, *Report on the National Shoreline Study,* Abstract.
[15] Ibid., 13, 23.
[16] Corddry, *City on the Sand,* 143.
[17] Underwood and Hiland, *Historical Development,* 33; Baltimore District, *History of Coastal Engineering,* 6.
[18] U.S. Army Corps of Engineers Baltimore District, *Atlantic Coast of Maryland and Assateague Island, Virginia, Feasibility Report and Final Environmental Impact Statement* (Baltimore, MD: U.S. Army Corps of Engineers, 1980), 47–48.
[19] Corddry, *City on the Sand*, 155.
[20] Loran, discussion with author, 1/8/09.
[21] Corddry, *City on the Sand*,, 129.
[22] Department of the Army Corps of Engineers, *National Shoreline Study Shore Management Guidelines* (Washington, D.C: Department of the Army, 1971), 21.
[23] USACE Baltimore District, *Atlantic Coast of Maryland,* 48.
[24] Donald K. Stauble et al., *Beach Nourishment Project Response,* 6 (Both quotes).
[25] USACE Baltimore District, *Atlantic Coast of Maryland*, 10-11.
[26] Bass et al., *Rehabilitation of the South Jetty,* 5.
[27] Underwood and Hiland, *Historical Development,* 36.
[28] Bass et al., *Rehabilitation of the South Jetty,* 5.
[29] Underwood and Hiland, *Historical Development,* 99.
[30] Ibid., 113 (both quotes).
[31] Kevin R. Bodge and Julie D. Rosati, *Sediment Management at Inlets and Harbors* in *Coastal Engineering Manual Part V: Coastal Project Planning and Design* EM-1110-2-1100, chair. Donald L. Ward (Washington, D.C: U.S. Army Corps of Engineers, 2003), V-6-93. http://chl.erdc.usace.army.mil/Media/2/0/0/CEM_Part-V_Chap-6.pdf.
[32] Underwood and Hiland, *Historical Development*, 87.
[33] Pratt, discussion with author, 12/05/08.
[34] Theodore M. Hillyer, *History, Projects, Costs,* 8 (both quotes).
[35] Underwood and Hiland, *Historical Development*, 94.
[36] Senate Committee on Interior and Insular Affairs, *Authorizing the Assateague Island National Seashore,* 89th Cong., 1st sess., 1965, S. Rep. 331, 3.
[37] Hayward, *State of the Parks*, 24.
[38] Mackintosh, *Assateague Island National Seashore,* http://www.nps.gov/archive/asis/adhi/adhi1b.htm.
[39] Ibid.
[40] Richard L. Homan, "Turbulent Tides: A Story of Assateague Island," *Washington Post*, August 3, 2003.
[41] Mackintosh, *Assateague Island National Seashore,* http://www.nps.gov/archive/asis/adhi/adhi1b.htm.
[42] Senate Committee, *Authorizing the Assateague Island National Seashore,* S. Rep. 331, 7.
[43] Senate Committee on Interior and Insular Affairs, *Assateague Island National Seashore, Maryland and Virginia*, 89th Cong., 1st sess., 1965, H. Rep. 893, 3-4.
[44] Senate Committee, *Authorizing the Assateague Island National Seashore,* S. Rep. 331, 5.
[45] Hayward, *State of the Parks,* 13-15.
[46] Ibid., 11.
[47] Mark L. Homer et al., "A Survey of Molluscan Communities in Three Maryland Coastal Bay Areas Proposed for Island Creation and Restoration," page 1, in *Ocean City, Maryland, and Vicinity Water Resources Study* Final *Integrated Feasibility Report and Environmental Impact Statement* (Baltimore, MD: U.S. Army Corps of Engineers, 1998).
[48] Frederick N. Rasmussen, Obituary of Judith Johnson, *Baltimore Sun,* February 16, 2007.
[49] Mackintosh, *Assateague Island National Seashore,* http://www.nps.gov/archive/asis/adhi/adhi3.htm.

[50] Ibid.
[51] Ibid., http://www.nps.gov/archive/asis/adhi/adhi3b.htm.
[52] *Coastal Zone Management Act of 1972* 16 U.S.C. § 1451, National Oceanic and Atmospheric Association Ocean and Coastal Resource Management, http://www.coastalmanagement.noaa.gov/about/czma.html#top.
[53] Mackintosh, *Assateague Island National Seashore*, http://www.nps.gov/archive/asis/adhi/adhi7.htm.
[54] Mackintosh, *Assateague Island National Seashore*, http://www.nps.gov/archive/asis/adhi/adhi3d.htm.
[55] Department of the Army Corps of Engineers, *Report on the National Shoreline Study*, 17.
[56] Ibid., 13-14.
[57] Town of Ocean City, Maryland, "Chapter 1: Population Characteristics and Trends" in *Planning and Zoning Comprehensive Plan* (2006). http://www.town.ocean-city.md.us/Planning%20and%20Zoning/DraftComprehensivePlan/index.html.
[58] USACE Baltimore District, *Atlantic Coast of Maryland*, 14.
[59] Ibid., 23.
[60] NOAA Coastal Services Center, "Beach Nourishment."
[61] Bodge and Rosati, *Sediment Management at Inlets and Harbors*, V-6-66.

5: New Principles Enacted with a Systems Approach to Coastal Management, 1981–2007

Ocean City

Erosion at Ocean City had prompted numerous responses from officials responsible for the town and region, including the construction of groin fields on the beach and bulldozing sand from the nearshore onto the foreshore. In 1980, after an exhaustive study, the USACE Baltimore District recommended beach nourishment as a means to provide storm protection for the town of Ocean City. Engineers, officials and residents had come to realize that a sandy beach absorbed wave energy and protected landward developments better than most structures. Anders and Hansen summarized, "The main advantage over other engineering methods is that [beach nourishment] provides a wide beach which is aesthetically pleasing and not hazardous to users, wave energy is dissipated naturally across the beach, there are generally few related problems downdrift (an exception can be inlet filling), and cost can be low compared with alternative erosion control measures. Disadvantages are that construction guidelines are not well developed and periodic maintenance is generally required to provide project design specifications."[1] Indeed, the idea of a beach nourishment project at Ocean City sounded promising, but the implementation of such a plan posed a series of problems in terms of logistics and policy.

First, a large amount of technical data concerning the native beach and potential borrow sources was needed because, as Anders and Hansen noted, guidelines for beach nourishment in the mid-1980s were minimal. Second, the feasibility study that recommended the project included plans for replenishment every three years. And, lastly, the benefit-cost ratio wasn't high enough to initially justify the project.[2] The Baltimore District and Maryland DNR had agreed on the solution to Ocean City's erosion problem; next they had to make the plan acceptable to state and federal officials.

Phase I: The State Fill

In September 1981, the Chief of Engineers (CE) submitted the report recommending beach nourishment to the Assistant Secretary of the Army for Civil Works. "The Assistant Secretary, on May 27, 1983, requested that the Office of Management and Budget (OMB) review the Chief of Engineers' report. At that time OMB opposed authorization of the project because recreational benefits were a large part of the total benefits of the project," according to Stauble et al.[3] Benefits derived from recreational use weren't considered in Corps budgets in the early 1980s. The OMB judged that the scope and cost of the project weren't justified by storm protection benefits alone. Thus, the project almost fell apart before it had even begun. Loran explained, "Initially, the Corps' benefit-to-cost ratio was less than one because recreation benefits were not counted. To make the benefits-to-cost ratio higher, the state had to do Phase I to help recreation, and the Corps did shoreline protection."[4]

In 1984, Maryland Governor Harry Hughes raised concerns over OMB's decision not to authorize the project and reiterated the need for storm protection and erosion control at Ocean City. Stauble et al. recounted, "The Baltimore District Engineer responded that the project was recreation-oriented and that State and local governments or the private sector should provide for recreational opportunities. In April 1985, the Governor outlined the State of Maryland's ongoing efforts to stabilize the beach at Ocean City and requested that the District consider providing only the hurricane protection portion of the CE 1981 plan." Governor Hughes offered to have the state build more groins and provide a 24-ft-wide beach (7 m), but it was determined in 1985 that periodic renourishment would be more cost effective than the groins. "During that same year, the CE found that the State's plan would provide 10-year protection from storms and that the benefit-cost ratio on storm-protection benefits only, above the 10-year level, was estimated at 1.3 to 1. In August 1985, the USAED [U.S. Army Engineer District], Baltimore, furnished the Governor [with] a letter stating that the storm protection plan was economically justified if the State beach replenishment plan was in place."[5]

The state agreed to construct the recreational beach, abandon the planned groins and share the costs of the storm protection plan. Grosskopf and Stauble stated, "The Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project was authorized for construction by Section 501(a) of the Water Resources Development Act of 1986 (Public Law 99-662) 'at a total cost of $58,200,000, with an estimated first-Federal cost of $26,700,000 and an estimated first non-Federal cost of $31,500,000.'" The agreement obliged the State of Maryland to "construct a beach profile which exceeds minimum requirements essential for erosion control …"[6] In 1986, therefore, the Maryland DNR signed a Memorandum of Agreement (MOA) with the Coastal Engineering Research Center (CERC) to identify key characteristics of the native Ocean City beach and evaluate potential sand sources. The MOA specified that "CERC would collect and evaluate native beach sediment to determine grain sizes and collect sediment cores and geophysical information on potential borrow sites for determination of sediment size, thickness, and lateral extent. The CERC would identify suitable borrow sources, calculate their overfill ratios, make borrow site recommendations, and after consultation with

DNR, develop cross-section design templates for the actual beach fill."[7] This data would allow the Corps and Maryland DNR to understand specific details about the beach and potential borrow sands. Engineers required this information to develop the sediment budget—essentially determining how much sand was leaving the area and how much had to be added to achieve the project's design.

It was critical to the project's success that the correct fill material be used so that as much sand as possible would remain on the nourished beach while maintaining a texture acceptable for recreational use. Anders and Hansen, in their report on the borrow site research, explained the intricacies of proper fill sources:

> Coarser sediment placed on the beach will better withstand erosion. However, coarse sediment such as gravel is not as aesthetically pleasing as sand and is usually not preferred for recreational beaches. Coarse sand and gravel are not as common as fine sands and silts and therefore are difficult to locate and often more expensive to use. Fine sand is generally not resistant to erosive processes. Therefore, the goal is to find a borrow source which is as coarse or slightly coarser than the native beach, or a source which has a wide variety of grain sizes such that after sorting by waves the resultant beach is similar or slightly coarser than the original beach.[8]

From April to November 1986, grain samples and profile surveys of the Ocean City beach were gathered, and cores of sediment were taken from potential borrow sites and analyzed to find suitable matches. Profile surveys measure the volume of beach sediment along a continuous line, in this case from the landward side of the dune "to a point offshore where no notable change in bottom elevation occurs."[9] This point offshore is named the "closure depth." The surveys were conducted with a sled, which consisted of a platform and mast that was towed across the beach, and through the nearshore waters while attached to a boat, with prisms atop the mast. Instruments on a second apparatus used lasers to reach the prisms and measure the elevation of the sled as it moved. When

Figure 22: Pictured are the locations of the nine offshore shoals investigated as potential sediment borrow sources in the late 1980s. Source: U.S. Army Corps of Engineers.

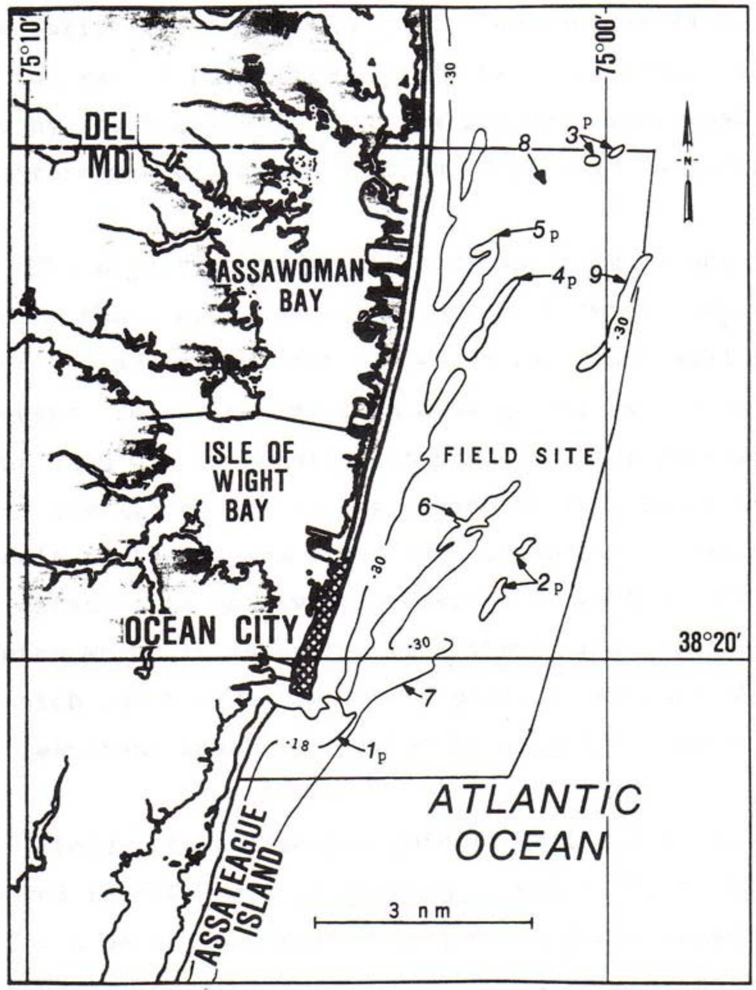

Figure 4. Location of shoals/potential borrow sites at Ocean City, MD; p = those designated later as primary sites

the elevation data was calculated, it provided a measurement of the beach's volume at points along the survey lines, which corresponded to the town's numbered streets.[10] For the pre-fill examination, polyvinyl chloride pipes were also used to collect cores of sediment from the beach, and underwater grab samples in the nearshore were gathered with a clamshell-shaped instrument.[11] A total of 396 grab samples were taken to ensure a thorough understanding of the grain sizes and types on the native beach.

The environmental impact statement from 1980 that first outlined the Ocean City beach nourishment project had excluded sediment from Isle of Wight and Assawoman Bays as a source for the project. These locations had been dredged for emergency beach repairs after the Five-High Storm in 1962, but by the 1980s the Corps determined that the potential damages to these sensitive environments outweighed the expediency of dredging from sources so close to the Ocean City beach. Instead, borrow site investigations focused on underwater shoals in the waters of the Atlantic. These were the same subaqueous features that caused shipwrecks earlier in the region's history. A number of theories had been posited about their formation, but by the mid-1980s it was generally accepted that, "once an irregularity develops in the nearshore zone, southerly littoral drift and barrier migration westward result in north-northeast to south-southwest elongation of the feature. Eventually a shoal detaches from the shoreface and becomes isolated on the shelf as the barrier migrates away." These features are likely former ebb-tidal deltas left behind from previous temporary inlets, and they have frequently been found to contain medium to fine-grain sand, which makes them suitable candidates for nourishment projects.[12]

In keeping with regulations established by the NEPA law of 1970 and its related laws and executive orders, scientists performed detailed environmental studies at the potential borrow sites and in the wider region before recommending the shoals for final consideration. According to Anders and Hansen, "[e]nvironmental assessments were completed over each site and surrounding areas to identify potential dredging impacts to flora and fauna. Archeological surveys were conducted to ensure dredging would not damage any historically valuable objects. Numerical wave refraction studies were conducted to examine potential erosional effects of borrow site mining on adjacent shorelines."[13] These actions took into account the regional effects of the beach nourishment project, both spatially, by examining the effects on ecosystems and nearby shores, and temporally, by evaluating the historical significance of the area. This process helped the Corps and other project stakeholders to implement the project with broader support and fewer negative consequences. Once the borrow sites had been deemed appropriate, more detailed sedimentological studies were initiated to find the best match.

CERC evaluated nine shoals north of Ocean City Inlet with an instrument called a vibracore, which was sunk into the shoals to retrieve samples of sediment. Machines sorted the sand grains from the beach and borrow sites, and, as Anders and Hansen explained, "[c]omposite grain size [was] determined by mathematically averaging individual size fractions of many samples to form one composite sample."[14] Composites allowed for a comprehensive analysis of the sediment in each source by creating an average figure. Rather than comparing all the various sizes of sand grains in one source to those in a different source, composite figures helped researchers to streamline the grain size information about the native beach and each potential source. It was determined that two particular shoals contained sediment that best corresponded in size and coarseness to that of the native beach.

Sediments similar to the beach were necessary because fine sediments are winnowed out of fill material by waves, so more initial fill material must be placed on the beach to account for what will be removed by wave action. If borrow sediment is significantly finer than the native beach, this "overfill" amount that has to be placed becomes too high to justify the project. Of the nine potential sources examined, "[r]enourishment factors together with overfill factors suggest[ed] that Borrow Site 3 has the best quality material and should be considered the primary site. Borrow Site 2 is next," stated Anders and Hansen.[15]

Borrow Site 2 is found offshore of southern Ocean City, while Borrow Site 3 is farther north, offshore near the Delaware-Maryland state line. In the summer of 1988, the State of Maryland dredged these two sources to create a widened beach across the whole of the Ocean City shoreline. Stauble and Kraus explained, "Using two dredges, fill material from the southern borrow site was placed between 3rd Street and 92nd Street, simultaneously with fill material from the northern borrow site between 92nd Street and the state line. Approximately 2.1 million m^3 [2.7 million yd^3] of total fill material were placed during this first State fill phase."[16] The sand was pumped onto the beach and then distributed by bulldozers. This fulfilled the state's agreement to build a recreational beach and it paved the way for the Corps' storm protection project to begin.

Before the Federal portion got underway, however, more data about the beach's response to the state fill was required. Since few beach nourishment projects had been studied extensively, the Ocean City project presented an opportunity to gather real-world evidence about the process. In September and October of 1988, sled surveys were taken along twelve profiles of the beach, located between 37th Street and 103rd Street. These post-fill surveys were taken again at quarterly intervals for a year after the first post-fill evaluation. Four storms impacted the area between February and March of 1989, which allowed engineers to measure storm-induced changes as well.[17]

In June 1990, surveys were again taken to gather data before the Federal fill. The results of these surveys found that erosion of the subaerial beach had indeed taken place, but most of the fill material remained in the nearshore area and thus stayed in the littoral system. Stauble et al. determined that at 37th Street, about two years after the initial nourishment, "monitoring of the State fill showed that 47.5% of the fill remained on the subaerial beach as waves moved material back onto the foreshore. The total active profile contained 74.1% of the State fill sand placed on this beach, with the bulk remaining in the nearshore zone."[18] Likewise, the survey at 66th Street found that sand eroded and accreted according to storm activity and wave energy, but overall the profile retained the fill: "The subaerial beach maintained a reasonably constant volume after fill placement, except for the erosion after the March storms. After the storms in March 1989, 60% of the fill was on the visible beach, and 198.7% of the State fill volume at initial placement was on the 900-ft length of the profile in April 1989." The gain in material was credited to longshore sediment transport moving sand from the northern end of the nourished beach to the profiles farther south, and more than 100% of the fill volume was found along the 66th Street profile after the June 1990 survey as well. [19]

Not all survey locations had the same results; at locations where shoals attached to the shoreface, erosion was found to be worse than in places without attached shoals.

"With a larger volume of fill placed at 81st Street," Stauble and Kraus explained, "the March 1989 storms removed all but 32% of the State fill above NGVD, but only 87% of the fill could be accounted for in the profile. By June 1990, only 35% of the fill remained on the subaerial beach, and the active profile contained 64% of the State fill volume placed at this location[.]"[20] It was becoming clear that erosion was occurring, sometimes erratically, but natural processes were taking over and moving sediment into the nearshore and back onto the beach. Even after a series of northeasters, the fill stayed in the system. Stauble et al. summarized, "The State fill two-year monitoring volume averages indicate[d] that a substantial amount of sand returned to the subaerial beach by June 1989. An average of 58.6%, or over half of the fill placed, was retained on the subaerial beach. The overall profile average State fill retention was 87.8% within the 3.7-mile [6 km] central portion of the fill limits."[21] The series of post-fill surveys showed that sand remained in the littoral system, which augured well for the Corps portion of the project.

Phase II: The Federal Fill

With the state fill in place, the Corps used a storm-erosion numerical simulation model to develop the design of the Federal portion. The model simulated storm damage to 37 profile locations using different beach-fill configurations to see which design would prevent the most damage. The storm data for these models (i.e., wave height and water level during storms) was taken from "hindcasts" of 18 previous storms in the area. Hindcast information is also drawn from computer models that tabulate historical wind and bathymetrical information and make an estimate of the wave height, storm surge and related aquatic data during past storms. The simulation model used to create the project design calculated water information for a 100-year storm striking the Ocean City beach. Grosskopf and Stauble stated, "These results were used to calculate inland property damage for each design configuration. The alternative that maximized the benefit-cost ratio was selected for final design and construction."[22]

The Federal fill commenced in the summer of 1990, and it consisted of a beach fill, dune construction and the building of a seawall along the boardwalk. Work was carried out from 3rd Street north to 100th Street between June and September of 1990. From 3rd Street to 27th Street, a 165-ft-wide (50 m) beach was added to the existing state fill, with a 100-ft-wide (30 m) berm at +8.5 ft (3 m) NGVD. "A concrete-capped steel sheetpile bulkhead was also built along the seaward edge of the boardwalk in this area with a crest at +14.5 ft (4.42 m) NGVD," stated Grosskopf and Stauble.[23] The seawall was a cost-effective protection method, considering the large project area. Pratt explained, "The Corps was looking for a level of protection that would be equal throughout the community. They wanted to transition from the boardwalk to the dune to protect up to the Delaware state line, and they needed a 100-ft-wide dune [30 m] and a 200-ft-wide [61 m] beach. This was more expensive than the seawall, so up to 27th Street there is a seawall attached to the boardwalk itself." Economics weren't the only considerations, however; the protection provided by the seawall justified the cost savings: "If that fronting beach goes away, the seawall is there. Because of [the beach's] low-lying nature, and the commercial nature of the boardwalk, a back-up with a structural approach gives a factor of safety," explained Grosskopf, one of the coastal engineers who assisted in the design and evaluation of the project.[24]

Figure 23: Diagram of the project area, including the location of the bulkhead, reconstructed dune line, and the selected offshore borrow sites. Source: U.S. Army Corps of Engineers.

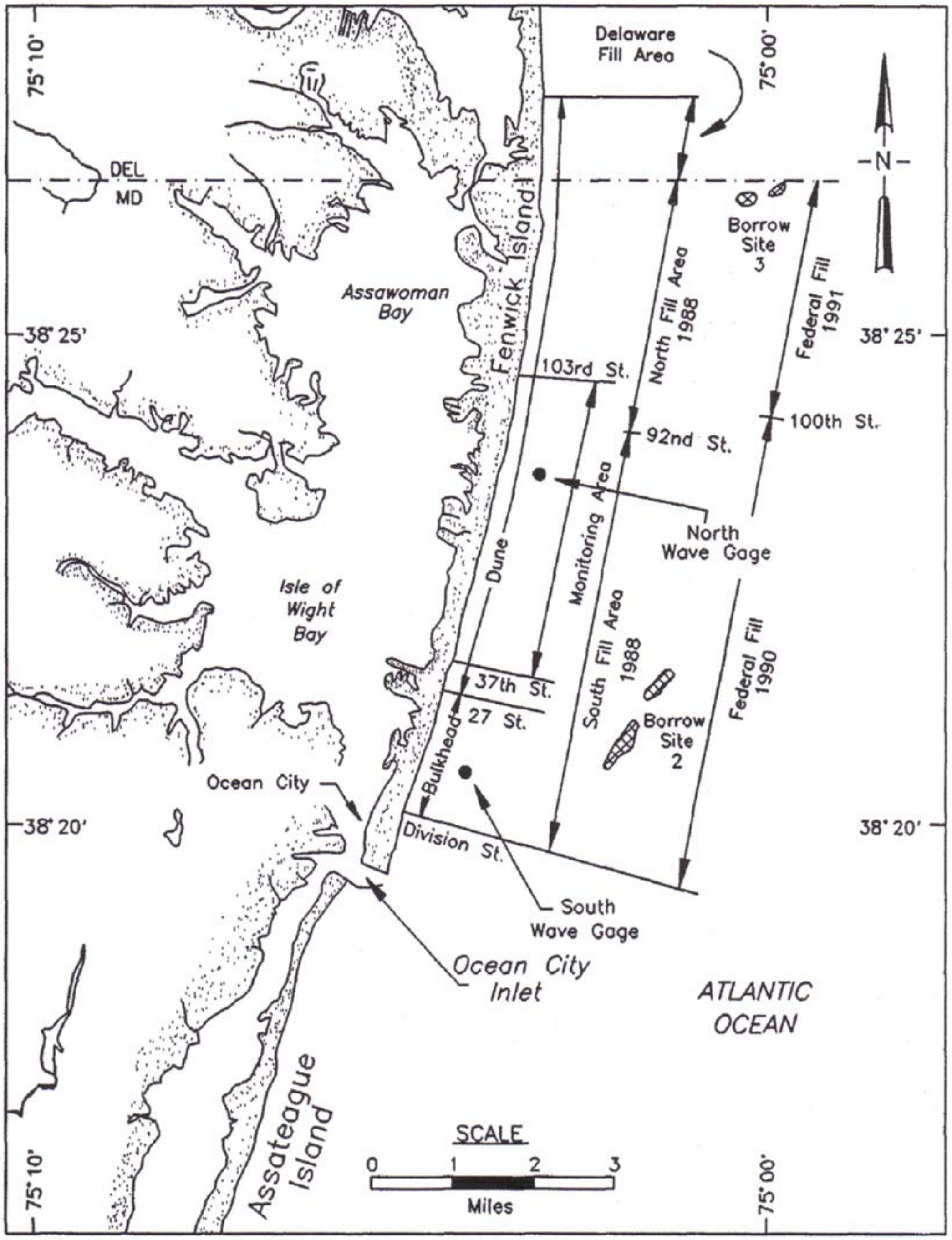

Figure 3. Beach nourishment project monitoring area

North of 27th Street, a dune and beach were constructed up to the Delaware state line. The dune was built with a 25-ft-wide (8 m) crest at +14.5 ft (4.4 m) NGVD, and the beach was a total of 100 feet wide (30 m), including a 35-ft-wide (11 m) berm at +8.5 ft (3 m) NGVD.[25] The project hadn't reached the state line by the end of the summer in 1990, so construction stopped because the fall and winter months, which coincide with hurricane season and increased extratropical storm activity, weren't ideal times for the construction work. The project resumed in June 1991 when the section from 100th Street to 146th Street was built. Borrow Sources 2 and 3 were used again for Phase II, which was considered finished by September 1991. Stauble and Bass stated, "A total of around 2.9 million m^3 [3.8 million yd^3] was placed during this phase."[26] To construct the beaches, sand was pumped onto the shore and moved with bulldozers, as in the state fill. "Following the construction of the beach and dune in the Federal project, sand fencing was manually emplaced followed by planting of dune grasses," according to Stauble et al.[27]

Extensive monitoring began in December 1990 and continued periodically for years. Two wave gauges were installed offshore in February 1990 to measure characteristics of waves striking the beach, which shed light on the ways storm surges and waves impacted the fill area. Profile surveys were made on land, along straight lines from the dune to an average of 900 ft (274 m) seaward, allowing engineers and scientists to compile detailed data sets for a thorough understanding of the fill's performance over time. In December 1990, three months after the first half of the Federal fill was completed, 22 profile survey lines "were surveyed to a depth of 25 ft (7.6 m), extending from 1,000 to 2,000 ft (305 to 610 m) from the baseline. Monitoring of the profile and sediment change continued along the twenty-two lines with a 6-month interval March/April and a 9-month interval June 1991 data set."[28]

Before the results were studied at length, however, a series of extremely severe northeasters struck the area in late 1991 and early 1992. The first took place from October 29-November 2, 1991, resulting in its name, the "Halloween Storm." "This extratropical storm impacted the project area for an extended 66-hour period, with surge valued of around +1.6 m [5.25 ft] NGVD," according to Stauble. The maximum recorded wave height was 10.2 ft (3.11 m). A second, less powerful, storm landed on November 7, 1991. A limited survey was taken after these storms at six locations, and results found that "average project erosion of -43 m^3/m [-56 yd^3] above NGVD was measured, with accretion in the nearshore of +31 m^3/m [+41 yd^3] out to the -6 m [-20 ft] depth contour."[29]

Just two months later, the worst storm since the Five-High Storm of 1962 struck Ocean City before the beach had time to recover naturally from the erosion caused by the previous two storms. From January 3-5, 1992, a fast-moving but intense storm battered the shore. According to Grosskopf and Stauble, the storm had a wave height "of 14.4 ft (4.39 m) and a maximum surge level of 6.6 ft (2.01 m) above NGVD as measured locally at wave gauges placed and maintained by the Coastal Engineering Research Center of the USAE [U.S. Army Engineer] Waterways Experiment Station."[30] Monitoring surveys started in January 1992. "Immediately following the January storm, a sled survey of the entire beach area was performed between the dune line and a water depth of -25 ft (-7.6 m) NGVD. The survey indicated that approximately 94% of the material placed for the project was present in the active beach profile."[31]

Figure 24: Location of beach profile survey lines used to measure beach fill response. Source: U.S. Army Corps of Engineers.

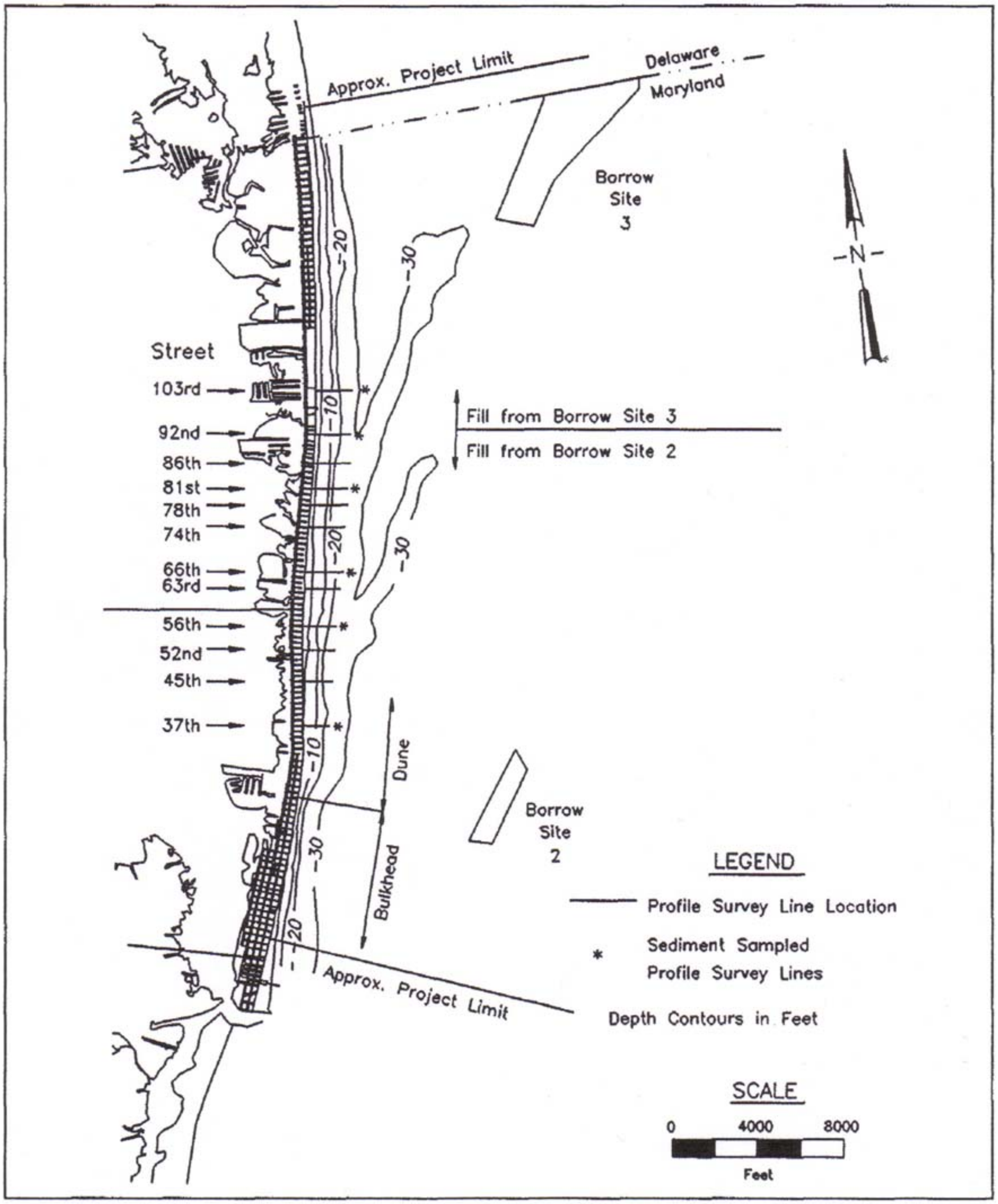

Figure 17. Survey line and sediment sample locations used in report for monitoring fill behavior and their relative positions to the shoreface-attached shoals

The remaining sediment was concentrated in the nearshore waters, not on the visible beach. Overwash along with extreme erosion of the subaerial beach and dune had taken place. However, sand still remained in the littoral system: "After the Halloween and January 4 northeasters, an average of 43.6% of the Federal fill remained above NGVD. The eroded material was again deposited in the nearshore region, and 96% of the fill material was still within the nearshore area of the 3.7-mile-long [6 km] fill monitoring area of the 7-mile-long project [11.3 km]," Stauble et al. reported.[32] Survey data also revealed that the erosion was not consistent across the project area. As in the post-state-fill surveys, places where shoals attached to the shoreface, specifically between 45th and 63rd Streets and 74th and 92nd Streets, exhibited greater-than-average erosion. These locations are known as erosion "hot spots." Conversely, "cold spots" of greater-than-average accretion were found at 37th Street and between 92nd and 103rd Streets.[33]

In response to the storm-induced erosion, an emergency beach fill took place in the summer of 1992. Over half of the fill material had been removed from the subaerial beach, so an "additional 1.2 million m^3 [1.6 million yd^3] of fill was placed along the project length from April to September 1992 (Fill #3) to mitigate the storm impacts," Stauble and Bass stated.[34] The beach nourishment project as a whole experienced severe erosion after the storms of 1991-1992, but as a storm protection endeavor, it achieved its designed goal. The sands absorbed the ocean's pounding waves and landward developments were largely spared from any damages. Grosskopf and Stauble recalled that "Mr. Dennis Dare, the Ocean City Manager, observed that the fill performed its intended function of preventing all property damage in the resort city. He also stated that without the beach nourishment project, the city would likely not have had a recreational

Figure 25: These photos demonstrate how the nourished beach at Ocean City responded to storm conditions in 1991-1992. Credit: William G. Grosskopf and Donald K. Stauble, Shore & Beach, *Journal of the American Shore & Beach Preservation Association.*

Fig. 3. Photograph of the 81st Street area (looking north) following construction of the Federal beach nourishment project in summer of 1991.

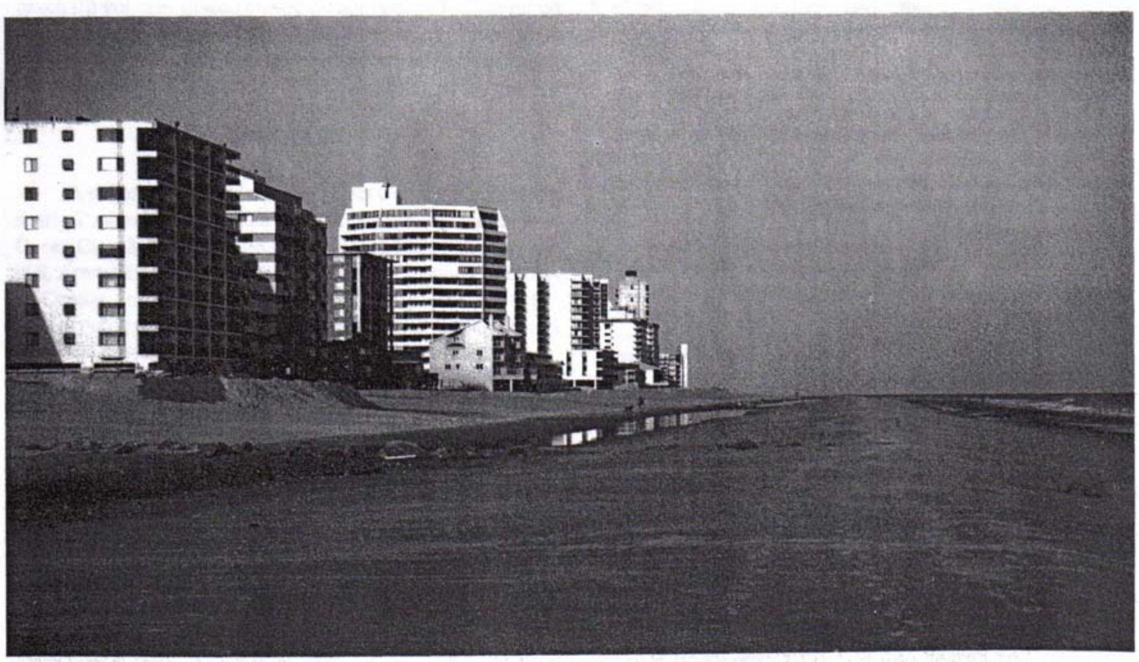

Fig. 4. Photograph of the 81st Street area (looking north) after the storm of January 1992.

season in 1992. The USAED Baltimore has estimated that approximately $93,000,000 in wave, flooding and erosion damages were prevented as a result of the fill project during the two storms. This value does not include the nearly $500,000,000 in revenues and the associated taxes realized by the salvaged 1992 summer recreational season."[35] Indeed, in 1992 the average summer weekend population in Ocean City reached nearly 277,000 people.[36] The thriving tourist season was sustained by the beach and recreational lodgings, which remained viable due to the absorption of wave energy by the nourished beach.

Numerous intense storms took place between late 1992 and early 1994. "Storm activity continued at a high frequency in the winters of 1992/93 (a weak El Niño) and 1993/94 (a moderate El Niño) requiring an additional 1.0 million m^3 [1.3 million yd^3] from April-May and September-October 1994 (Fill #4), to bring the fill profile back up to project design volume," explained Stauble and Bass. Fill #3 utilized sand from Borrow Source 3, while Fill #4 used sediment from Borrow Source 9, which was another of the offshore shoals identified in the borrow source investigations in the 1980s. Borrow Source 9 was chosen for the second emergency fill because Borrow Sources 2 and 3 were mostly exhausted by 1992.[37]

Monitoring of the third and fourth fills began in 1995 and proceeded through 1998. During this time, ten storms occurred between the winter of 1995 and the summer of 1996. Storm activity dropped off in 1996-1997, and eleven storms took place in the winter of 1997-1998. A total of 712 samples, which had been collected on the beach with hand scoops and grab samplers, were analyzed by mid-1998.[38]

Once again, machines sorted the grains and composite samples were calculated mathematically to facilitate the analysis of grain size. Results confirmed earlier surveys: sediment was removed from the subaerial beach during periods of storm activity and returned in calmer periods; hot spots near the shoreface-attached shoals experienced more erosion than other locations, while accretion was highest at the northern and southern ends of the survey area; and composite sediments were coarser by 1998 than they had been after the initial fills, as finer sediments were winnowed out by storms. "The project has placed a total of 7.2 million m^3 [9.4 million yd^3] of fill material mostly on the foreshore of the 14.7-km long project [9.1 miles]," Stauble and Bass summarized. "At the end of a ten year monitoring (after an intense storm sequence) there was still between 100 and 226 m^3/m [131 to 296 yd^3] of fill material on the foreshore area, which was coarser than the native beach. The nearshore was the recipient of between 150 to 402 m^3/m [196 to 526 yd^3] of fill material that was generally coarser than the native sediment," they concluded.[39]

Despite the intense storm sequence of the 1990s, Ocean City continued to thrive as a tourist destination and it saw an increase in visitation. In 1998, the average summer weekend population was over 278,000 people, and the average weekend population during other seasons rose as well. Furthermore, Terry McGean, city engineer for the Town of Ocean City, estimated that $238 million in damages were prevented throughout the 1990s by the beach nourishment project that protected the town from numerous severe storms.[40] For residents, officials and visitors, the Corps project protected lives and property, saved money, and supported the economic and recreational activities for thousands of people.

Continued Efforts

The Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project was designed as a 50-year agreement between the Corps, the State of Maryland, Worcester County and the Town of Ocean City to maintain a nourished beach. In 1994, after the last emergency fill (Fill #4), the state accepted Phase II as complete, and a four-year renourishment schedule was implemented to maintain the project's designed level of storm protection. This time period was one year longer than the initial feasibility study had advocated, but the extensive data gathered from surveys of the fill's performance helped engineers to calibrate the renourishment timeframe.

Project engineers were also able to concentrate renourishment placement at erosion hot spots where shoals attached to the shoreface. These features are believed to cause higher erosion because they modify waves in their vicinity. S. Jeffress Williams, coastal marine geologist with the United States Geological Survey (USGS), explained, "Because they rise up from the sea floor [shoals] affect waves. They can increase erosion by refocusing wave energy, especially during storms." Stauble concurred, "Shoals focus the waves on the beach just north of where the shoal attaches. Waves are funneled into the island, which has a tendency to cause a deficit of sand. It scours out a bar, and in those places that don't maintain a bar, the sand is moved north or south."[41] By gathering thorough data sets over an extended period of time, project engineers and designers learned the particular responses of different areas of the beach, and they could modify the sediment budget accordingly to avoid placing too much or too little sand during project maintenance events.

Renourishment took place in 1998, 2002 and 2006, with efforts focused on the erosion hot spots. The Baltimore District noted in a 2008 report on the project, "Nourishment sand is placed in several discontinuous reaches that include erosional hot spots located in the vicinity of 33rd, 81st, and 145th Streets. Sand accumulates along the southernmost mile of the beach and nourishment is not required there." In 1998, approximately 1.0 million m^3 (1.3 million yd^3) were added to the beach. In 2002 the Corps placed nearly 570,000 m^3 (745,000 yd^3), and in 2006 the beach received another 713,000 m^3 (932,000 yd^3).[42] Borrow Source 9 was used for these renourishments, while sediment in the coastal bays was again excluded as a possible source because of the environmental risks of dredging large quantities from these ecosystems.[43]

Condition surveys were frequently taken throughout the first decade of the twenty-first century. According to Bass, beach surveys were made annually between renourishment events, wave data was collected and economic analyses of storm damage were performed. This continued research allowed engineers and stakeholders to gain a better understanding of the workings of this project, as well as lessons to be applied to other beach nourishment efforts. In 2001, a General Reevaluation Study was initiated to identify additional sand sources to supply the project through the year 2044, when the current authorization expires. Engineers estimated that Borrow Source 9 would be exhausted by 2010, and they began the General Reevaluation Study to prepare the sediment budget in advance of that date.[44]

The Ocean City project also benefited from a regional coastal management effort called the Long-Term Sand Management project. This project began in 2004 as a means to mitigate erosion damage at Assateague Island, but its scope included the broader coastal area near Assateague and issues relating to navigation and environmental restoration. As will be seen, the nourishment efforts at Assateague provided an opportunity to supplement the Ocean City project, and since 2004 approximately 25,000 m^3 (32,000 yd^3) have been placed at Ocean City as part of the Long-Term Sand Management effort.[45]

Despite its growing popularity as a coastal management technique, beach nourishment was not without controversy. Continuously pumping dredged material onto a beach only to have it swept offshore was challenged by some scientists who believed it was not a cost-effective and sustainable management technique. In *The Corps and the Shore,* Orrin H. Pilkey and Katharine L. Dixon specifically questioned the wisdom of the Ocean City project and its renourishment events: "The Corps' Baltimore District declared the projects a success because the artificial beach protected beachfront buildings from direct wave attack. This was great news for a privileged few oceanfront property owners and city officials. But from another viewpoint, that of Congress and the American people, the projects were financial disasters. Within just three years, *one-third* of the amount of sand originally projected to be needed over *fifty years* was gone."[46]

They also criticized the Corps' methods of project planning: "Not surprisingly, storm occurrence is *the* major factor determining durability of replenished beaches. But uncertainties about the frequency and magnitudes of storms are not considered by the Corps. No matter how solid the engineering, the uncertainty inherent in the coastal environment, particularly prediction of storm frequency and strength, must be reflected in planning and design documents as well as in congressional debate."[47] But, in fact, while engineers can predict the probability of a given size of a storm, meteorologists cannot predict when such a storm will occur.

The intense storm activity that occurred at Ocean City almost immediately after the project began (winter of 1989 through 1998) indeed proved that storms are unpredictable. But however imperfect the initial beach fill process might have been, the Ocean City beach nourishment project did achieve its stated goals and reflect a flexibility of Corps principles. The project was, first and foremost, centered on recreation and storm protection, both of which the nourished beach provided. The summer vacation season in 1992 showed that sunbathers and buildings would remain in Ocean City if the beach was there. Area residents, seasonal employees and property owners alike benefited from the beach's preservation of hotels and cottages, which brought in vacationers for the summer and continued to do so throughout the 1990s. The alternative of not maintaining the beach could have resulted in extremely negative consequences. Dare stated, "Without this project and the Corps as a partner with the state and county, Ocean City would have become a footnote in history by now."[48]

Also, it was acknowledged at the project's beginning that continuing construction was an integral part of an economical solution. The projects are designed to be built in stages. The emergency fills in 1992 and 1994 certainly required more sediment than what had initially been projected for the construction phases, but detailed surveys allowed engineers to focus later renourishments only at erosion hot spots. In these instances, research allowed the Corps' plans to be adjusted based upon conditions on the ground. The ephemeral nature of the beach itself was never in doubt. Loran summarized, "All these beach projects in effect are sacrificial. Sand is put there to mimic natural processes and provide storm protection."[49]

Lastly, although storms can never be predicted with total certainty, the expectation of a severe storm figured prominently in the planning. The Water Resources Development Act of 1986 that authorized the project stated that it was to "provide beach erosion control and to protect the Town of Ocean City from a 100-year storm on the Atlantic Ocean."[50] The precise wind, wave and water level conditions of a 100-year storm may be debatable, and its timing certainly unknowable, but the project engineers designed this project to withstand such an event, and indeed the project performed as designed.

The Ocean City beach nourishment project reflected the growing integration of the Corps' objectives for sediment management in the latter part of the twentieth century. Erosion control and storm protection were seen as complementary, and environmental protection became an important factor as well. The environmental impact statements and benefit-cost ratios used to plan the project showed that numerous considerations figured into the project, not simply what was the quickest or least expensive option. By focusing on beach fills and dune restoration, this project also demonstrated how Corps methods began to work with natural processes more than in the past, when structures were built without serious regard for their regional effects. Supplying sand to the littoral system and allowing sediment transport to work naturally led to the beach absorbing wave energy and even healing itself to a significant degree after storm activity. Most importantly, downdrift areas were not starved of sediment. Rather, the efforts at Ocean City influenced similar ones farther south at Assateague Island, which would eventually complement the Ocean City project in a truly regional approach to coastal management.

Ocean City Inlet

By the early 1980s, 20 years had passed since the structures at Ocean City Inlet had been updated or repaired. In that time, dredging requirements also increased substantially so that between 1973 and 1985 the annual dredging amounts averaged 30,000 yd^3 (23,000 m^3). As shown by the dredging requirements, sediment settling in the navigation channel had become increasingly problematic. The ebb shoal at the seaward edge of the inlet continued to grow and a shoal inside the channel itself, near the northwestern corner of Assateague Island, was causing additional issues for boats navigating through the inlet. The south jetty was also suffering damage from the constant scouring of sediments at the base of the jetty. "Due to the frequent maintenance dredging requirements, the restricted navigation conditions between dredging events, and the continued scouring at the foundation of the outer end of the south jetty," Bass et al. explained, "a study was conducted by Dean and Perlin (1977) for the U.S. Army Engineer District (USAED), Baltimore, to determine the source of the shoaling problem and potential solutions for both the shoaling and scour problems."[51]

Figure 26: The rehabilitated south jetty and breakwaters constructed at northern Assateague Island, shown in an aerial photo from 1986. Photo: Inlets Online.

This study found that sediment was moving through and over the south jetty and into the navigation channel. The physical features at Ocean City Inlet—the structures and ebb-tidal shoal—modified currents at the inlet's mouth, thereby affecting sediment transport. The dominant direction of littoral transport was to the south, to be sure, but when longshore currents encountered the inlet's mouth, they were interrupted and their flow was modified, which moved sediment in locations other than to the south, as seen by the erosion of northern Assateague Island. It was found that sediment was moving through and over the south jetty and being deposited temporarily as a shoal at the northwestern edge of Assateague. "From there, ebb-tidal currents from Sinepuxent Bay transported the sand *northward* (emphasis added) towards the navigation channel where the stronger southerly moving ebb-tidal currents from the Isle of Wight Bay were encountered and caused the sand to be transported and deposited in the problem shoal area. The localized northerly sand transport was determined to be a result of the sheltering effect of the north and south jetties and the wave transformation effects from the offshore ebb-tidal shoal," Bass et al. summarized.[52]

Sand-Tightening and Breakwaters

To remedy the situation, an extensive rehabilitation of the south jetty began in 1984 to prevent sediment from crossing over and through the structure. This project consisted of three separate actions: filling a large scour hole at the base of the south jetty, building a new section of the jetty and installing breakwaters to protect northern Assateague Island from increased erosion. These activities took place between 1984 and 1985, and the project was monitored extensively from 1986 to 1989.

Repair of the scour hole began early in 1984. A numerical model analysis was performed on the inlet hydraulics and shoaling patterns, and while this study found that the outer section of the south jetty wasn't directly contributing to the shoaling problem in the channel, the scour hole was damaging the structure's stability. Serious damage to, or even collapse of, the south jetty would clearly disrupt navigation in the area, so the scour hole was filled with sand dredged from the problem shoal just northwest of Assateague Island. The fill was made “to elevation -30.0 ft [-9.1 m] NGVD and then armored with a protective blanket composed of several layers of 50- to 200-lb [22.7 to 90.7 kg] stone…In addition, an armored stability berm was placed on the inlet side of the jetty[.]”[53]

In 1985, a new section of the south jetty was constructed for the purpose of preventing sediment from entering the inlet and causing shoaling problems. According to the Corps Baltimore District, the new jetty section was “offset 30 ft [9.1 m] southward of the existing jetty centerline. The existing jetty was left intact. The rehabilitated section was constructed at +7.5 ft [2.3 m] NGVD and consisted of successive layers of bedding material, corestone, intermediate stone, one layer of capstone, and pre-cast concrete units along the centerline to form a core that would be impermeable to sand transport.”[54] Enhancing the structure and its sediment-blocking capabilities was beneficial to the navigation channel and the boats using it. But it also kept sand from reaching northern Assateague Island, which was already suffering severe erosion due to the jetties and ebb shoal. The “sand-tightening” of the south jetty deprived the island of yet more sediment, and the Corps undertook measures to offset this increase in erosion that was anticipated with the repairs to the jetty.

Severe erosion at northern Assateague had the potential to interfere with navigation in the channel, just as the sediment moving through the south jetty had done. Bass et al. explained, “Shoreline recession could have eventually reached the inshore tie-out of the jetty and resulted in a breach which would allow significant quantities of sand to be transported into the navigation channel.” They continued, “To stabilize this shoreline area, three headland breakwaters were constructed. Each of these breakwaters was constructed by placing successive layers of bedding materials, corestone, intermediate stone and capstone to an elevation of +6.0 ft [1.8 m] NGVD[.]" The first breakwater connected to the south jetty and was 340 ft (104 m) long, while the second and third breakwaters were built 300 ft (91 m) apart from each other and both were 200 ft (61 m) long.[55]

The breakwaters were installed to dissipate wave and current energy, thereby protecting the northern end of Assateague Island from eroding further once the supply of sediment through the south jetty was cut off. But breakwaters create uneven shoreline responses; the spaces between them are impacted by waves and currents and consequently become eroded. The result is usually a crenulated, or scalloped-looking, shoreline with areas of accretion directly behind the breakwaters and pockets of erosion between them.[56] Indeed, this took place at Assateague Island, but by the end of the decade the embayments in the shoreline were behaving reasonably similar to the mathematical models developed at the start of the project. The areas between the breakwaters eroded and accreted from year to year, but the shoreline was considered to be in "dynamic equilibrium," meaning that it changed over time, but not to an extreme degree. The areas behind the breakwaters maintained their position, so that by the end of the monitoring period, Bass et al. determined, "Overall, the headland breakwaters appear to be effectively stabilizing the northern shoreline of Assateague Island[.]"[57]

The South Jetty Monitoring Program, which gathered data on the project up to 1989, formed part of the Monitoring Completed Coastal Projects (MCCP) program, a larger effort to evaluate the performance of coastal engineering projects. The South Jetty

Monitoring Program was selected as part of the MCCP to contribute to the advancement of coastal engineering technology, and it used a variety of methods to understand the response of the inlet and island to the construction and maintenance project. "The primary activities comprising the effort were beach and offshore profile surveys, aerial and ground photography of the inlet and adjacent shorelines, hydrographic surveys of the inlet, continuous nondirectional wave gauging, and side scan sonar surveys of the scour protection area," according to Bass et al.[58]

The latter was carried out to measure the integrity of the filled scour hole. Two inspections were made; the first was in August 1984 and the second in June 1990, and both determined that there was no subsequent damage to the structure. Numerous wave gauges were deployed in the offshore waters, and despite frequent technical difficulties and equipment replacements, readings were taken successfully through 1987, which contributed to an understanding of the longshore sediment transport distribution in the area.[59] Hydrographic surveys of the volume and movement of water in the inlet, sled surveys of 15 beach profiles and aerial photographs were taken at various times throughout 1986, 1987 and 1989. Digital analyses of the research allowed engineers to develop shoreline change maps and study the response of the beaches around the inlet.[60]

Researchers found that the sand-tightened jetty performed exceptionally well as a littoral barrier. During the monitoring period, 4,000 ft (1,200 m) of shoreline from the jetty southward accreted and extended toward the ocean by an average of 100 ft (30 m), with seasonal variations. The total estimated accretion along this portion of the beach was 558,000 yd^3 (427,000 m^3) between August 1986 and March 1990, which equaled about 160,000 yd^3 (122, 000 m^3) per year. The rate of sediment being transported through and over the south jetty had been estimated at 100,000 to 200,000 yd^3 per year (77,000 to 153,000 m^3 per year). In light of the shoreline growth south of the jetty, Bass et al. concluded, "This would indicate that a very high percentage of the northward drift was trapped as a result of the jetty sand tightening."[61]

In addition to the growing shoreline, the jetty's effectiveness was ironically proven by the increased erosion between the headland breakwaters at northern Assateague Island. Sand was removed from the shore as waves struck the areas that weren't protected by the breakwaters. Had sediment been entering the inlet over and through the jetty, it was assumed that these areas would have been constantly replenished with sand. But with little sand reaching the northern shoreline, erosion between the breakwaters became more pronounced. Researchers determined that "the embayments between the breakwaters on Assateague Island are characteristic of the condition of minimal or no longshore sediment transport."[62] The rehabilitated jetty thus mitigated erosion in one area (directly south of the jetty) while enhancing it in another (between the breakwaters). The breakwaters themselves, however, maintained most of Assateague's northern shoreline by protecting it from wave energy, and shoaling problems in the inlet were reduced by the impermeable structure.

"These actions didn't stop the island from changing; it just changed in different ways," stated Carl Zimmerman, chief of the Division of Resource Management at Assateague Island National Seashore. He continued, "The sand tightening had a pretty big effect on the ebb-tidal shoal. Prior to that action, there was a circular gyre motion of sand going back into the inlet and through the jetty, which was effectively halted by the sand tightening. It started a period of dramatic growth of the ebb shoal and led to it merging [with Assateague Island].”[63] The changes to the ebb shoal impacted the rest of the inlet area and Assateague Island itself, in the short and long term.

Ebb Shoal Equilibrium

With large amounts of sediment kept out of the inlet due to the sand-tightened jetty, the ebb shoal began growing significantly after a period of mild enlargement in the 1970s. Sediment that would have entered Ocean City Inlet and possibly settled into shoals in the channel or bays was instead funneled to the ebb shoal and downdrift shoreline by currents and waves. “From 1978-1990, the ebb shoal advanced seaward approximately 100 m [328 ft] offshore and increased 240 m [787 ft] in width,” according

Figure 27: This diagram illustrates offshore bar bypassing across the ebb-tidal shoal and the creation of swash-bar complexes through tidal movements. These are the processes by which natural sand bypassing is achieved. Source: U.S. Army Corps of Engineers.

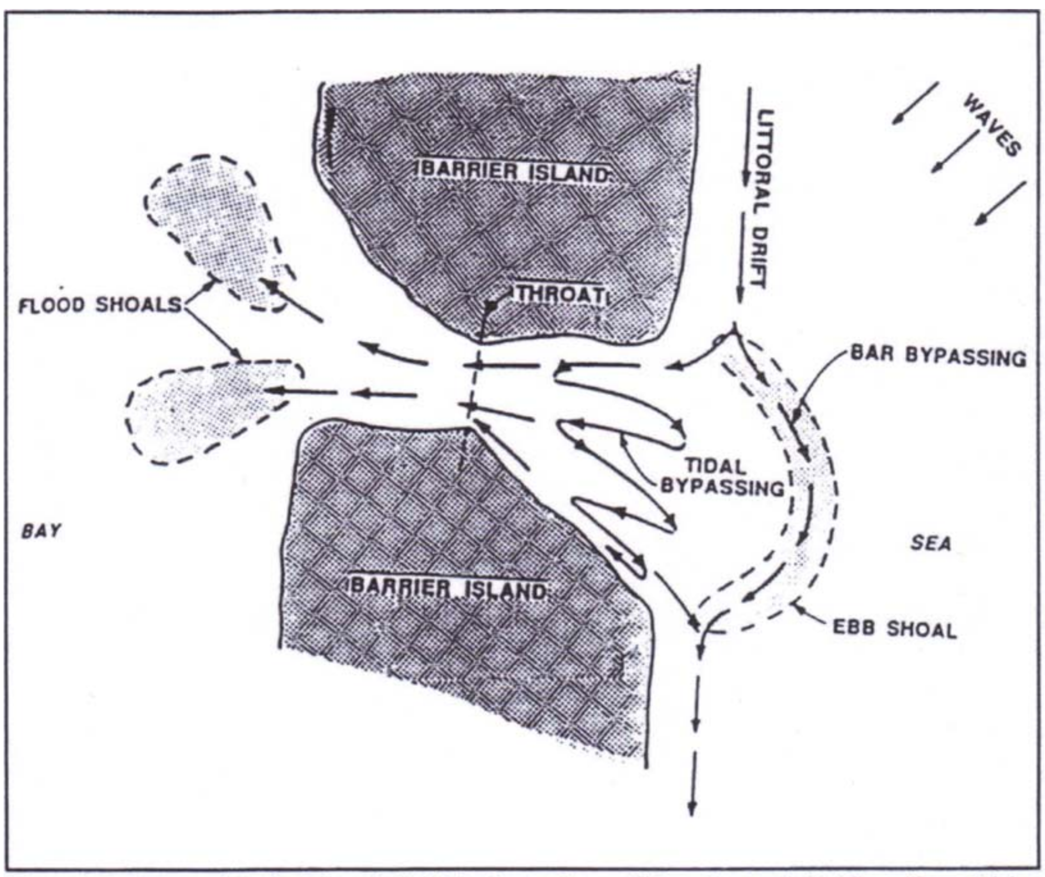

Figure 38. Two main principles of tidal inlet bypassing - offshore bar and tidal flow (From Mehta et al 1989).

to Underwood and Hiland. After 1978 the ebb shoal's volume grew by approximately 150,000 m^3 (196,000 yd^3) per year, so that by 1990 it consisted of an estimated 8.0 million m^3 (10.5 million yd^3). Bathymetric maps from 1990 showed that it had reached 1.3 km (0.8 mi) offshore and was 1.9 km (1.18 mi) wide, and it was attached to the northern end of Assateague Island about 600 m (2,000 ft) south of the south jetty.[64] Storm activity had contributed to the attachment of the shoal because increased wave energy helped push the underwater feature closer to the island over time. Once it attached, the ebb shoal ceased to be a sediment sink and became a sediment source for the eroded northern end of Assateague.

By the early 1990s, the ebb shoal essentially became a "sand bridge" to the island, which allowed natural bypassing of sediment around the inlet to the downdrift shoreline. Underwood and Hiland explained, "The sediment bypassing mechanism may have involved a two-stage process; initially through ebb flows pushing sediment offshore, and then bar-bypassing processes of formation, and landward migration of swash-bar complexes, via wave-induced sediment transport across and along the shoal platform to northern Assateague."[65] Offshore bar-bypassing occurs when sediment is transported by waves and currents across the shoal, basically moving along the sand bridge until arriving at the shoreline. Swash-bar complexes are created by sediment that is moved through the inlet and eventually deposited in bars outside of the inlet, which are then pushed against the shoreline by waves. An attachment bar formed between the ebb shoal and Assateague, thereby supplying sand to the island's shore along with the sediment passed across the shoal itself.[66]

The rehabilitated south jetty, the attached ebb shoal and the sand introduced to the littoral system from the Ocean City beach nourishment project jointly impacted Assateague Island. The influx of sand from the north meant there was more sediment moving in the longshore currents. With the jetty keeping northward-moving sand out of the inlet and the ebb shoal growing and attaching to the northern end of the island, there was a larger volume of sand remaining near Assateague. Consequently, the rate of shoreline retreat along the northern 6.5 km (4 mi) slowed to approximately -6.30 m/yr (21 ft/yr) by the early 1990s.[67] Although a reduced rate of erosion was observed, there continued to be net erosion at the north end of the island, even with the jetty rehabilitation and increased sediment volume in the area.

The erosion of Assateague Island was a commonly known problem, but a lack of widespread stakeholder support resulted in the abandonment of a beach fill project in the 1980s. Responsibility for carrying out such a project was left to NPS in the 1980 feasibility study. But recreation and storm protection goals, such as those that motivated the Ocean City project, had little resonance at Assateague because there weren't large-scale beach developments that necessitated such maintenance. Pratt explained, "There was no economic imperative to save houses on Assateague. The value was the natural resource." Until the mid-1990s, the disappearance of the natural resource itself—the island, its habitats and wildlife, the national and state parks—was not recognized as a serious issue outside of the immediate stakeholders. Zimmerman stated, "NPS wanted to move forward with restoration and mitigation, but the issue wasn't well-supported by the public, the Corps, and Congress."[68]

Even if emergency measures were taken, akin to Ocean City's bulldozing efforts or the beach fills after the Five-High Storm, the closest sand source was considered off limits to dredging. Since the ebb shoal was acting as a sand bridge, removing large portions of it would create holes or depressions in the feature that would fill once more, thereby keeping sand from transferring across the shoal and onto the beach at Assateague. The Committee on Coastal Erosion Zone Management et al. identified ebb-tidal shoals as key parts of the "sand-sharing system" near inlets and stated, "If a portion of this ebb-tidal shoal is lowered by dredging, a sand sink is created and the remainder of the system responds by providing sand from the beach to attempt to re-establish equilibrium."[69] Likewise, in 1995 Underwood and Hiland reported, "Removal of even a small amount of sand from this shoal could potentially result in serious shoreline erosion of northern Assateague…This shoal will continue to shield northern Assateague from maximum storm wave energies, and at the same time re-establish and provide for longshore littoral drift movement downdrift from the inlet, and towards the inlet (through wave refraction)."[70] By the middle of the 1990s, however, it was acknowledged that this natural bypassing process would not be enough to protect the island from continued severe erosion and a possible breach. The hands-off approach to Assateague Island, and the ebb shoal, required re-evaluation.

New Solutions

In 2002, the Corps Baltimore District made repairs to the south jetty for the first time since 1984. The work was designed to "restore approximately 1,100 ft [335 m] of the outer leg of the south jetty to preserve its hydraulic function of protecting the federally maintained channel in the Ocean City Inlet."[71] The work finished in January

2003, and as in past repairs, the goal was to ensure the soundness of the jetty so that currents would be intensified and sediment kept out of the inlet. The inlet had sustained considerable flushing capacity, and it was dredged every few years on an as-needed basis. In 1997, 14,000 m^3 (18,000 yd^3) were removed, and in August 2003 a channel in Isle of Wight Bay was dredged, removing approximately 23,000 yd^3 (approx. 17,600 m^3).[72]

Management decisions had been evolving since the 1990s, and by the early years of the twenty-first century the Corps and regional stakeholders had planned to integrate the maintenance of the inlet with sediment management activities at Ocean City and Assateague Island. Regular dredging of the inlet and its flood and ebb shoals began as part of the Long-Term Sand Management project, which started in 2004 as an effort to restore northern Assateague Island and contribute sediment to the Ocean City project. Diverse funding mechanisms were established to carry out the different components of the project. The Long-Term Sand Management (LTSM) project as a whole was designed to be funded with Construction General funds, and the back-passing of sediment to Ocean City was included on the dredging contract for Assateague Island. Funding for the channel maintenance was covered by the Continuing Authorities Program with 10% paid by the non-federal sponsor, the Maryland DNR.

According to the Corps Baltimore District, "Following implementation of the LTSM project in 2004, inlet dredging has been effectively accomplished under the auspices of the LTSM project. Since that time, 2,000 to 3,000 yd^3 [1,500 to 2,300 m^3] of material have been dredged from the inlet area twice yearly."[73] The dredged sediment from the navigation channel has been used to nourish Assateague Island and Ocean City. Combining activities has been beneficial for the channel and surrounding beaches because navigation conditions are improved and sand is available for nourishment. The landforms around Ocean City Inlet have been intricately linked to the waterway since its formation. By the early twenty-first century, management practices acknowledged these links and planned accordingly to address the entire inlet system.

Assateague Island

The feasibility study that proposed the Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project in 1980 also advocated replenishment at Assateague Island. The plan envisioned bringing dredged material from borrow sources to the island's eroding north end. "This proposed exception to the general hands-off policy was justified on the grounds that the recession was man-caused (from the Ocean City Inlet jetties impeding the littoral drift) and therefore required human remediation," explained Mackintosh.[74] But the Corps left jurisdiction of this project to NPS, which didn't have the necessary stakeholder support to implement the recommended action. There were no developed properties to protect on Assateague, and even recreational use of the beach was sparse in comparison to Ocean City. The emphasis on letting nature take its course, enhanced by the reauthorization of the seashore legislation in 1976, along with the low density of developments on the island led many officials to believe that storms posed no pertinent threat to Assateague, at least not one that necessitated a large-scale response.

The NPS began to focus on the comprehensive plan for the national seashore that was developed in the late 1970s and early 1980s. This plan addressed maintenance of the land and visitor facilities, and it generally advocated a middle road between development and wilderness preservation. Mackintosh detailed the plan's provisions for the national seashore:

> In the NPS lands, most existing recreational uses would be maintained with minor expansion of some facilities. Overwash would not be prevented except in areas zoned for recreational development, where short-term protection of existing facilities could be achieved by artificial dune maintenance. More bay access would be provided along the causeway west of the day-use area at North Beach. The Park Service would not support local plans for sewage effluent pipelines crossing Assateague, and it would not assume responsibility for correcting the westward migration of the north end of the island.[75]

Assateague State Park planned an increased number of campsites and parking spots, and Chincoteague National Wildlife Refuge was largely left as a "primitive" area.

As the plan worked its way through various government agencies and legislative reviews, a provision was added that authorized off-road vehicles on the bay side of the island, not just the seaside beach. This provision was strongly opposed by the Committee to Preserve Assateague, but the plan was seen as a compromise for all stakeholders and it was implemented in the summer of 1982.[76]

The General Management Plan of 1982 decreed that the NPS wouldn't try to stop the migration of the island, but the Corps held jurisdiction over Ocean City Inlet, and they proceeded with rehabilitation and construction activities at northern Assateague in the mid-1980s. As mentioned previously, shoreline recession rates along the northern end of the island slowed after the south jetty was sand-tightened, but significant erosion was still taking place. The island showed its vulnerability to storms in the early 1990s when the powerful northeasters of 1991-1992 leveled the dunes that had been artificially maintained after the Five-High Storm of 1962. These dune-building activities had mostly ceased by the early 1980s except for those authorized by the General Management Plan, but, as Zimmerman explained, "The dune system remained largely intact until the Halloween Storm and January 4 storm, which eliminated about 80% of the artificial dune line in the Maryland portion."[77] With only a few scattered recreational facilities to protect, the loss of the dunes themselves wasn't immediately catastrophic and the landscape responded to their removal in important, and even beneficial, ways.

Ecological Responses

By preventing overwash, the artificially maintained dunes affected the ecosystems and habitats on Assateague Island. Woody plant communities flourished because the trees and shrubs were protected from salt water and salt spray by the dunes. The Halloween Storm of 1991 and the intense northeaster in January 1992 changed the island's environments when they decimated the dunes. After the storms, "there was an expansion of the herbaceous community because the woody plants were subjected to salt water intrusion from overwash now that the dunes were gone," stated Zimmerman. Herbaceous plants have little or no woody material, as shrubs and trees do. They include annual and perennial plants, which grow faster than woody plants and hence re-establish themselves quickly after overwash events. On Assateague, these plants include beach heath (*Hudsonia tomentosa*), broom sedge (*Andropogon virginicus*) and seabeach orach (*Atriplex arenaria*).[78]

These changes affected animals as well. The barren overwash fans and sand flats provide habitat for piping plovers, which were listed as a federally threatened species in 1986. After the storms of 1991-1992, their population numbers on the island began to increase, correlating with the expansion of

Figure 28: Least tern. Photo: U.S. Fish & Wildlife Service.

their nesting and foraging habitats. Other rare birds, such as the least tern (*Sterna antillarum*), black skimmer (*Rhynchops niger*) and American oystercatcher (*Haematopus palliates*), also depend on barren flats, and, consequently, they benefited from the removal of the dunes and expansion of overwash zones.[79]

The population growth of these species coincided with an important distinction for Assateague. In 1990, the island was designated an International Shorebird Reserve because of its importance as a stop on the Atlantic Flyway and its habitats for rare birds.[80] The storm activity in the early 1990s, and the subsequent flourishing of plant and animal communities that relied on early-successional habitats (those that form shortly after destructive events), confirmed that natural processes would carry on and keep the barrier island dynamic.

Plan of Action

The only problem with letting nature take its course, however, was that nature had to contend with the effects of humanity's actions. The intensity of the storms in the early 1990s raised the prospect of a breach on Assateague Island since the dunes were destroyed. A breach had the highest probability of taking place along the north end that was sand starved because of jetty-induced erosion. Such an event would expose the mainland communities west of Assateague to harsher ocean conditions and increased storm damage. After the January northeaster in 1992, in fact, four communities landward of Sinepuxent Bay incurred $3.2 million in damages, a figure that likely would have been even higher if Assateague Island had breached.[81] These storms of the early 1990s highlighted the risk of wider regional damage due to the jetty-induced erosion.

Because of officials' and residents' growing awareness of the risk of storm damage, a reconnaissance study was carried out after the storms of 1991-1992. During this study, the Corps, other government agencies and the public identified problems with water resources in the region, including erosion at Assateague Island. It was also acknowledged that Ocean City Inlet needed to be deepened to accommodate larger vessels, which were having problems navigating around the growing shoals, and that agriculture, development and erosion had significantly damaged wetlands and wildlife habitats throughout the coastal bays watershed. Although Assateague had been preserved as a place where nature acted unimpeded, the consequences of peoples' actions from earlier decades required evaluation and solutions.[82]

After the reconnaissance study, a feasibility study began in 1995 with the goal of tackling the interrelated issues of erosion, channel shoaling and environmental degradation. The intention was to find a long-term solution, similar to that undertaken at Ocean City, that would confront the regional nature of the problems. The Baltimore District, in the study's final environmental impact statement, maintained,

> Since their construction, the jetties have rerouted a large portion of the sand that would have otherwise reached Assateague. This disruption in the natural longshore transport of sediment between Ocean City and Assateague Island has caused adverse physical, biological, and economic impacts to the area, particularly to the northern 11 km (6.8 mi) of the island. The island overwashes frequently, and the shoreline has eroded back towards the mainland at an accelerated rate. The disruption in sediment transport has also caused the loss of salt marshes and subtidal habitat on the bay side of the island, the infilling and reduction in size of Sinepuxent Bay, and a decrease of habitat diversity on the island. It has contributed to navigation difficulties through the inlet and back bays and has increased the vulnerability of mainland communities to storm damage.[83]

These connected dilemmas required a coordinated response that considered many stakeholders throughout the entire region, such as mainland residents, the fishing industry and environmental groups, to name only a few. The regional nature of the issues at Assateague was the factor that finally prompted a response. Measures weren't taken "until the Assateague problem was correctly characterized as a regional problem," Zimmerman stated.[84]

Figure 29: Looking southward in 1993, this view shows the dramatic landward movement of Assateague Island in comparison to Fenwick Island resultant from sand starvation by the Ocean City Inlet jetties, which disrupted longshore sediment transport to Assateague Island.Photo: Inlets Online.

The Water Resources Development Act (WRDA) of 1996 (PL 104-303) authorized the Corps to implement the restoration of Assateague Island, pursuant to Section 111 of the River and Harbor Act of 1968, which authorized projects to mitigate damages from other Federal navigation works.[85] Assateague Island clearly fell under this provision because the Ocean City Inlet jetties were Federal navigation projects that caused damages elsewhere. For the restoration of the island, a two-pronged approach was advocated by the feasibility study, which was completed following the WRDA authorization of 1996.

The first step proposed by the study was the placement of a one-time, large-scale beach fill to immediately protect the island from a potential breach. The report stated, "This recommended short-term plan involves placing approximately 1.4 million m^3 (1.8 million yd^3) of sand on Assateague Island. The borrow area to be used is Great Gull

Bank, an offshore shoal. The area designated to receive the material is between 2.5 km (1.6 mi) and 11.3 km (7 mi) south of the inlet. Also, the plan includes a low storm berm to be constructed to an elevation of 3.3 m (10.8 ft) NGVD (averaging 0.8 m in height) in the portion of the beach between 3 km and 10 km (2 mi and 6.2 mi) south of the inlet."[86] Great Gull Bank was chosen as the sediment source because it had a suitable, but not inexhaustible, amount of sand that closely matched grain sizes on the native Assateague beach. This short-term repair was just that—a relatively quick solution that could prevent a breach but not address the larger problem. The Baltimore District stated, "Even if material is placed on Assateague Island for a short-term solution, the jetties will continue to disrupt the longshore transport, and Assateague will continue to erode at an accelerated rate."[87]

Therefore, the feasibility study also recommended the implementation of a long-term sand bypassing project to continually supply Assateague Island with sediment and mitigate the interruption of longshore transport by the jetties. Sand bypassing is a process that "restores the natural flow of sand to the downdrift shorelines and reduces the need for channel dredging."[88] It involves physically taking sediment from one location and releasing it in another where currents and waves will move it along the shore. This project at Assateague, named Long-Term Sand Management, was focused on the island and also the broader region at the same time. Its goal was "[t]o evolve towards the most efficient, sustainable long-term sand management program that over time will follow the natural process and not adversely impact the water system. By preventing the movement of sediment through the inlet, the plan should help reduce the shoaling problems in the coastal bays and on the ebb shoal. The plan should also consider the sediment supply needs of the Ocean City beach."[89] Numerous alternatives were evaluated to determine which solution met the criteria of efficiency and sustainability while achieving multiple management objectives.

The selected plan advocated the deposition of dredged material in the nearshore waters of northern Assateague where it would be distributed by the natural longshore transport process. This replicated the actions that would take place if the Ocean City Inlet jetties weren't depriving the area of sand and modifying currents. The Corps supported utilizing a mobile dredge to extract sediment from sources and bring it to Assateague Island because using a shallow dredge vessel owned by the Wilmington District was more cost effective than other options. Additionally, by avoiding the use of a fixed dredging plant and trucks, piping plover habitats wouldn't be disturbed. The Corps used sediment transport rate measurements and mathematical computations to develop a sediment budget that advocated placing approximately 145,000 m³ (189,000 yd³) of sediment per year at Assateague Island to mitigate the erosion from the jetties and the sediment being diverted to the ebb shoal and inlet channel. [90]

Figure 30: Waves breaking over the edge of the ebb-tidal shoal reveal how large this underwater feature had grown by the end of the 20th century. Photo: Inlets Online.

The Corps and the project's other sponsors, the NPS, State of Maryland, Worcester County and the Town of Ocean City agreed to dredge multiple sources two times a year to supply sand to Assateague Island for the 25-year duration of the Long-Term Sand Management project. Benefit-cost analyses of the various alternatives, which included assessments of environmental impacts, determined this to be the most effective plan. The Baltimore District stated,

> [M]ining 145,000 m^3/yr (189,000 yd^3/yr) from a variety of sand sources each year: 40,000 m^3 (52,000 yd^3/yr) from the updrift fillet, 85,000 m^3 (111,000 yd^3/yr) from the ebb shoal, and 20,000 m^3/yr (26,000 yd^3/yr) from the navigation channel and flood shoals produces the greatest level of benefits. This plan replaces the annual amount of sand lost at Assateague Island with minimal impacts to sources due to the use of multiple sources. In addition, this plan approximates the natural longshore sand transport process and is extremely flexible. Specifically, if a bypassing source does not infill at the anticipated rate, then use of a different source or different quantity is possible. This plan in time will create a sustainable, cyclical, long-term sand bypassing approach.[91]

By placing sand in the nearshore twice a year, this project would more closely resemble natural sediment transport processes than a single, annual, large-scale deposit. This plan also considered the viability of the sediment sources; dredging from multiple sources lessened the impact on each one. "A concern of all sponsors including the District was not to negatively impact any bypassing material sources. Taking too much material could result in affecting the hydrodynamics or material recharge not occurring," the Baltimore District maintained. "The greater the [amount of] material from individual sources, the greater the opposition."[92]

The inclusion of the ebb shoal in the sediment budget was controversial because removing large amounts of sand was expected to upset the shoal's equilibrium. Such an event would make the ebb shoal a sand sink once more, as passing sediments filled in any holes, rather than traveling to Assateague in the natural sand bridging process. The Corps determined, however, that "based on best professional judgment, it is expected that since the proposed yearly dredging would remove such a small percentage of the overall volume in the ebb shoal (approximately 0.7%), that removing this material will not cause any adverse impacts to the inlet system." In practice, this required careful dredging and close monitoring. Use of the updrift fillet was acceptable provided that material was dredged from immediately adjacent to the north jetty. The Corps agreed with the Town of Ocean City that even after dredging the fillet, the beach should remain 200 ft (61 m) wide to provide adequate storm protection. The flood shoals and navigation channel were deemed safe choices because the channel was already being dredged regularly, and the computer models made during the planning process showed that the removal of small amounts of the flood shoals would have negligible effects on the hydrodynamics of the bays.[93]

The plan also considered the renourishment efforts at Ocean City and aimed to complement them. Although the need for different dredging vessels prevented the Corps from combining Long-Term Sand Management with the Atlantic Coast of Maryland (Ocean City) project, the Long-Term Sand Management study determined that an additional amount of sand, approximately 15,000 m^3 (20,000 yd^3) could be dredged and released at Ocean City during renourishment events for Assateague. The Corps stated that, "It was determined that placing this volume of material annually in areas of increased erosion along Ocean City would provide short-term benefits to that area, would provide longer-term benefits to other project areas as it naturally migrates through the system and would decrease the cost of the four-year renourishment. Furthermore, if the sand is back-passed in spring or early summer, the wave conditions would tend to be more favorable for onshore transport of sand, where it is most beneficial to the Project."[94] This facet of the plan exemplified the regional scope of the Long-Term Sand Management project because it accounted for regional erosion and transport of sand, while lowering costs of the Shoreline Protection Project by contributing sediment to Ocean City.

In addition to mitigating erosion, the Long-Term Sand Management plan addressed continual shoaling problems in Ocean City Inlet. Despite jetty repairs and sand tightening, shoaling remained an issue for boats. Commercial fishing vessels were particularly impacted by shoaling in the channel and harbor, which were both 10 ft (3 m) deep. The Corps' recommended plan was to dredge Ocean City Harbor to a depth of 14 ft (4.3 m) and the inlet to 16 ft (4.9 m). The channel width was to be maintained at 200 ft (61 m). The dredged material was designated for use in the Long-Term Sand Management project, both for sediment bypassing and to create wildlife habitats for the environmental restoration component of the project.[95] Combining the channel dredging with other sediment management activities was a sensible solution to the water resource issues in the region. "Our goal was to develop the most efficient solutions because the inlet affects both Assateague Island and Ocean City, so you have to look at everything," explained Scott Johnson, senior construction manager at the Aberdeen Integrated Program Office and former project manager for Ocean City and Assateague Island.[96]

Interagency and public meetings had identified a number of problems in the coastal bays area, including the erosion and navigational issues, and also the historic and recent destruction of thousands of acres of marshland for agriculture and development, and the resulting loss of wildlife habitat. To satisfy the project component of restoring fish and wildlife habitats and ecosystem functions in the watershed, the Corps and other stakeholders identified an individual project for replacing lost salt marshes and creating nesting habitats for colonial waterbirds. Four specific sites were chosen: Isle of Wight, Ocean Pines, South Point Spoils and Dog Island.

The Isle of Wight restoration site is located on the shore of a 90-hectare (223 acre) island in Isle of Wight Bay, which is traversed by Route 90 to Ocean City. The plan recommended the creation of salt marshes along the shoreline, and parking areas, trails and a pier were proposed for recreational use of the site. At Ocean Pines, two parcels near a residential development on the mainland adjacent to Isle of Wight Bay were chosen for salt marsh restoration by lowering the ground's elevation and planting salt marsh grasses. South Point Spoils is an artificial island of dredged material that had been created in 1934 in Chincoteague Bay. The restoration plan advocated stabilizing the 0.1-hectare (2.3 ac) island with geotextile tubes and creating a second island, both of which would be used by waterbirds. Dog Island, which is actually an exposed shoal in Isle of Wight Bay, was selected as a habitat creation and salt marsh restoration site to be stabilized and filled with dredged material. These sites were chosen for inclusion in the final plan after detailed benefit-cost analyses accounted for factors such as affordability, proximity to dredging locations and, of course, the potential for positive impact on wildlife habitats.[97] But deciding on an overall sediment management plan was only the first step to mitigating the shoreline issues in the region, and nature, unpredictable as ever, impacted the implementation of the plan just when consensus had been reached.

Emergency Measures

As had so often happened in the past, storm activity changed the trajectory of management at Assateague Island. In January and February of 1998, two northeasters struck the island, causing heavy damages to the landscape. According to Zimmerman, "They scoured up to about 6 feet [1.8 m] of sand and almost breached the island in the area that had experienced the highest rate of erosion, which was about 5 miles [8 km] down from the inlet."[98] The risk of a breach had initiated the Assateague restoration feasibility study earlier in the decade, and the seemingly imminent opening of a new inlet led to emergency actions before the study's recommendations could be implemented. The Corps anticipated that it would fill a breach so that mainland properties would be protected and the hydrodynamics of Ocean City Inlet would remain unaffected. "The NPS found itself in a bad position," explained Zimmerman, "because a newly opened inlet would complicate the coming restoration process, so emergency repairs were made as a hold-over to the bigger project."[99]

Between August and September of 1998, "USACE dredged approximately 134,000 yd^3 [102,000 m^3] of sand from Great Gull Bank and placed it on northern Assateague along an 8,400-ft-long [2,560 m] reach of the island located from 3.2 to 4.8 mi [5 to 8 km] south of the inlet within the National Seashore," according to the Baltimore District. The Corps also built an emergency berm on the beach to a height of approximately 11 ft (3 m). [100] This berm, unfortunately, resulted in two negative consequences.

First, the presence of the berm ostensibly solved the erosion problem by preventing a breach. In reality, as the Corps' feasibility study had outlined, a long-term solution was needed to mitigate the jetty-induced erosion. But there were no funds appropriated for the short- and long-term restoration phases, and Long-Term Sand Management project stalled temporarily after the berm was in place. Second, the berm worked too well in preventing overwash. Consequently, barren substrate on the north end became re-vegetated once salt water was kept to the seaward side of the berm, and piping plover habitat decreased as a result. By the early years of the twenty-first century, however, funding was secured for restoration work to begin, and the projects got underway to alleviate the damages to Assateague, including the emergency berm.[101]

Restoration Projects at Assateague Island

In July 2002, construction began on the short-term phase of the Assateague restoration project. As planned, approximately 1.4 million m^3 (1.8 million yd^3) of sediment were pumped from Great Gull Bank onto the beach at northern Assateague in the area between 1.6 mi and 7.2 mi (2.6 to 11.6 km) south of the south jetty. This portion was completed in December 2002.[102] In the course of the short-term project, the Maryland DNR also renourished the beach at Assateague State Park. The agency used 73,000 m^3 (95,000 yd^3) of sediment from Great Gull Bank to enlarge the beach and build a dune along the stretch of land belonging to the state park. The dune was finished in 2003 and, when complete, it contained newly planted dune grasses and electric fencing to keep the island's horses from grazing on the grasses, which could interfere with their dune-building abilities. The state welcomed the chance to nourish the stretch of beach managed under their jurisdiction, and the joint effort made sense environmentally and economically since sediment was already being placed just north of the state park.[103]

The long-term phase of the project started in January 2004 as a collaborative effort between the Corps, NPS, Maryland DNR, the Maryland Geological Survey and the Town of Ocean City. To carry out the dredge and placement operations, the Corps used the *Currituck,* the shallow dredge belonging to the Wilmington District, which has a capacity of 230 m^3 (300 yd^3). The ebb shoal and navigation channel provided the sediment, with 95% being released in the nearshore waters at Assateague and 5% released farther north where currents would take it to Ocean City. Approximately 145,000 m³ (189,000 yd³) were released between the winter and summer nourishments.[104]

Figure 31: The Currituck dredges sediment from offshore sources for release in the nearshore waters at Assateague Island. Photo courtesy of Nicholas C. Kraus.

The problematic berm from 1998 was also reconfigured in 2004, with notches added to allow spaces for overwash to get through. "Until reconfiguration, the habitats became unsuitable for rare and endangered species," Zimmerman stated. Habitat monitoring after the repairs produced mixed results. A total of 66 breeding pairs of piping plover were found on Assateague in 2006, which was a marked increase from the 14 pairs that were found in 1990, but the delicate balance of storm protection and overwash habitat preservation remained challenging.[105]

Since 2004, these biannual sand bypassing operations have continued with the same vessel and dredging guidelines. Semi-annual meetings have been held between representatives of the Corps, NPS, Maryland DNR, Worcester County, the Town of Ocean City and the FWS, whose jurisdiction over Chincoteague National Wildlife Refuge made them a stakeholder in the health of the northern portion of the island. "This was a collective effort between many parties, which shows [the project's] regional nature," said Zimmerman. "It's a good example of groups working together toward the common good. Collaboration made it happen."[106]

Extensive multi-agency monitoring began once the project was implemented. The appropriations for the short-term phase included funds for five years of monitoring to gauge the effects of the large-scale beach fill. The personnel at ASIS had been taking elevation and GPS surveys of the beach since the early 1990s, and they continued to gather data on the long-term phase of the project by performing those types of surveys, as well as evaluating aerial photography and Lidar topography surveys. Lidar is a form of radar that uses light lasers to measure beach elevation. These monitoring efforts complemented the ongoing biological studies of plovers and other endangered species. The Corps also took sled surveys and sediment samples from the beach, and engineers examined the flood and ebb shoals with underwater surveys of the bathymetry to monitor the shoals' responses to dredging.[107]

Figure 32: Seagrass on the western side of Isle of Wight Bay. Photo: Jane Thomas, IAN Image Library (www.ian.umces.edu/imagelibrary/)

The biannual dredging also maintained the deepened navigation channel. The environmental restoration component has since proceeded, albeit with a reduced scope due to funding and competing resource management objectives. To date, ecosystem restoration has taken place at Isle of Wight and Ocean Pines. Restoration activities began at Isle of Wight in 2002. The first phase of the work consisted of removing a failing steel bulkhead along the island's eastern side and replacing it with a stone revetment. An access road and parking spaces were constructed. Between February and July 2003, concrete rubble shoreline materials were removed, stone breakwaters and sills were built to protect the new marshes from waves, and an interpretive walkway/pier was built for recreational purposes. In August 2003, approximately 28,000 m^3 (36,000 yd^3) of material from the maintenance dredging at Isle of Wight channel were pumped onto the island, graded and planted with *Spartina alterniflora* and *S. patens.* In the spring of 2004, small-scale replanting of *S. alterniflora* took place in areas where the ground had settled to a lower elevation. The project was completed by August 2004, resulting in approximately 3 ha (8 ac) of new salt marsh.[108]

At Ocean Pines, construction of low and high salt marshes began in 2001 on a 2.4 ha (6 ac) site and a 1 ha (2.5 ac) site. According to the Baltimore District, construction was finished ahead of schedule in October 2001.[109] In contrast to the Isle of Wight restoration site, Ocean Pines has no breakwaters or related structures; it consists solely of replanted marshes. Kevin Smith, chief of restoration services with the Maryland DNR stated, “The project is performing exceptionally. It has contact with the daily tides and little structural component.” The projects at South Point Spoils and Dog Island, however, were not completed to their specifications in the feasibility study. At South Point Spoils, large beds of submerged aquatic vegetation (SAV) colonized the area. Stakeholders didn’t want to destroy these important aquatic environments by adding dredged fill, which highlighted the variety of sensitive environments in the bays.

Figure 33: The large ebb-tidal shoal currently provides sediment to Assateague Island through natural sand bypassing and by functioning as a source for erosion mitigation activities. Source: Inlets Online.

Because of these competing environmental resource objectives, the project did not proceed. Dog Island was not made into a bird habitat because of lack of funds. Despite these setbacks, the new marshes at Isle of Wight and Ocean Pines continued to thrive, thereby increasing the environmental quality of the bays.[110]

In 2002, ASIS developed a long-range plan for improving interpretive services at the park, the first comprehensive planning initiative since the 1982 General Management Plan. By the time the long-range plan was published, ASIS was receiving more than 2 million visitors each year, mostly in the summer months. The 2002 proposal emphasized the need to educate visitors about Assateague's unique environments and place within the larger global water system. Maintaining the sediment supply to the island is critical to preserving the island for its visitors, while managing sensitive ecosystems for endangered and rare species will help the park to achieve its goals and remain a vibrant, dynamic barrier enjoyed by humans and wildlife alike.[111]

Conclusion

The events at Ocean City and Assateague Island in the last decades of the twentieth century and the first years of the twenty-first exemplified the evolution of human priorities and land uses in this region as well as Corps planning and engineering principles during this time. Maintenance of a navigational waterway remained a primary focus for the Corps, as shown by the dredging activities and jetty rehabilitations at Ocean City Inlet. But an increased understanding of the interconnectedness of coastal processes and events inspired the Corps to modify the ways in which it carried out its other missions related to coastal issues, such as coastal storm damage reduction and environmental restoration. Moreover, an emphasis on regional solutions became central to coastal management projects in action and in legislation.

By authorizing the Corps to carry out projects that compensated for damages from previous navigation works, the River and Harbor Act of 1968 had cleared the way for the Corps to address problems like jetty-induced erosion. Likewise, NEPA and the CWA brought environmental considerations to the fore of water resource management projects, which was a critical step in coastal areas where wetlands and fragile marine ecosystems met with navigation and concentrated development. Furthermore, a comprehensive understanding of the way coastal processes function—and how they are connected throughout regional areas—played an important role in the Corps' decision-making process at Ocean City and Assateague Island. Viewing coastal areas, such as beaches, bays and inlets, not as isolated locations but as part of a connected physical and ecological system impacted the way in which the Corps managed those areas.

Along the Atlantic coast of Maryland, where jetties and groins had been used to stop longshore sediment transport and hold ephemeral barrier features in place, this understanding translated to projects that mitigated the structures' damages and accounted for future impacts to the wider coastal region. Nourishing beaches, acquiring sand from a variety of sources and mimicking natural processes embodied a sustainable approach to coastal management. The Corps also emphasized the related nature of its missions. Mitigating erosion at Assateague not only preserved the environmental integrity of the island, it also protected landward communities from storm damage. Worcester County's population nearly doubled between 1970 and 2000, from over 24,000 to almost 47,000 residents. Thus protection of communities increased in importance as more people resided in the area.[112]

Dredging the navigation channel and providing sediment to eroded areas are complementary activities; therefore, combining them improved efficiency. “It makes sense because it’s a system, not individual processes, so you have to look at it holistically,” Johnson explained. This systems-based approach recognized that sediment, including dredged material, is a valuable resource that can mitigate erosion and restore habitats. These principles—sustainable methods, related solutions, reduced expenditures—formed the basis of regional sediment management, the Corps’ strategy for sediment.[113]

The restoration projects at Ocean City and Assateague Island also emphasized collaboration between people, not just missions. Because regional actions involved a number of stakeholders, the Corps took into account the objectives and contributions of many government agencies, private organizations and the public. Before dredging Great Gull Bank for the short-term Assateague restoration, the Corps and FWS gave a joint presentation to the American Fisheries Society to explain the process and methods of avoiding habitat damage. Sediment sources for the Long-Term Sand Management project considered the objections of agencies such as the NPS and Town of Ocean City. And public meetings throughout the planning process encouraged interaction between agencies and the public to develop solutions acceptable to all stakeholders. For example, public meetings and workshops during the reconnaissance phase of the Assateague restoration project resulted in a list of water resource issues from which the components of the Assateague project were drawn.[114]

By working with natural processes and various stakeholders, the Corps was able to effect significant changes to the management of the coastal region in Maryland. “This cooperative effort with the Park Service, state agencies, and Ocean City managers has been going on for many years. It’s an archetype for these projects, and there’s been an establishment of trust and a sense of cooperation,” Kraus explained.[115] With extensive field data and collaborative relationships in place, the Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project and the Long-Term Sand Management Program have moved from being new innovations to standard management practices that remain flexible, and therefore viable, for years to come.

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[1] Anders and Hansen, *Beach and Borrow Site Sediment Investigation,* 13.
[2] Ibid., 14; Stauble et al., *Beach Nourishment Project Response,* 6.
[3] Stauble et al., *Beach Nourishment Project Response,* 6.
[4] Loran, discussion with author, 01/08/09.
[5] Stauble et al., *Beach Nourishment Project Response*, 6-8 (both quotes).
[6] William G. Grosskopf, and Donald K. Stauble, “Atlantic Coast of Maryland (Ocean City) Shoreline-Protection Project,” *Shore & Beach* 61, no. 1 (1993): 5.
[7] Anders and Hansen, *Beach and Borrow Site Sediment Investigation,* 6.
[8] Ibid., 14.
[9] Stauble et al., *Beach Nourishment Project Response,* 52.
[10] Gregory P. Bass, discussion with author, March 6, 2009.
[11] For a detailed discussion of sled survey equipment and processes, see Stauble et al., *Beach Nourishment Project Response,* 40-42, and Anders and Hansen, *Beach and Borrow Site Sediment Investigation,* 17-21.
[12] Anders and Hansen, *Beach and Borrow Site Sediment Investigation,* 12.
[13] Ibid., 27.
[14] Ibid., 15.
[15] Ibid., 66-67, 73.
[16] Donald K. Stauble and Nicholas C. Kraus, “Project Performance: Ocean City, Maryland, Beach Nourishment,” in *Beach Nourishment Engineering and Management Considerations,* ed. Donald K. Stauble and Nicholas C. Kraus (New York: American Society of Civil Engineers, 1993), 2.
[17] Stauble et al., *Beach Nourishment Project Response,* 49.
[18] Ibid., 76.
[19] Ibid., 98.
[20] Stauble and Kraus, “Project Performance: Ocean City,” 8.
[21] Stauble et al., *Beach Nourishment Project Response*, 187.
[22] Grosskopf and Stauble, “Atlantic Coast of Maryland (Ocean City),” 4.
[23] Ibid,.
[24] Pratt, discussion with author, 12/05/08; William G. Grosskopf, discussion with author, January 12, 2009.
[25] Grosskopf and Stauble, “Atlantic Coast of Maryland (Ocean City),” 4.
[26] Donald K. Stauble and Gregory P. Bass, “Sediment Dynamics and Profile Interactions of a Beach Nourishment Project,” in *Coastal Sediments ’99* 3, ed. Nicholas C. Kraus and William G. McDougal (Reston, VA: American Society of Civil Engineers, 1999), 2567.
[27] Stauble et al., *Beach Nourishment Project Response,* 17.

[28] Donald K. Stauble and William G. Grosskopf, "Monitoring Project Response to Storms: Ocean City, Maryland, Beach Fill," in *Shore & Beach* 61, no. 1 (1993): 24.
[29] Donald K. Stauble, "The Impact of Storms on Beach Nourishment Projects," in *The State of the Art of Beach Nourishment*, comp. Lawrence S. Tait (Tallahassee, FL: The Florida Shore & Beach Preservation Association, 1993): 57 (both quotes).
[30] Grosskopf and Stauble, "Atlantic Coast of Maryland (Ocean City), 5.
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Chapter 6: Next Steps, 2008 and Onward

Ocean City

The nation's shorelines have continually grown in importance as locations for shipping, fishing, immigration and, more recently, recreation. Approximately 40% of the population lives in a coastal county that could be affected by coastal hazards. In the North Atlantic region, Worcester County, Maryland, the site of Ocean City, is expected to continue growing as an aging population seeks retirement homes near the sea. In 2000, persons over the age of 55 comprised 40% of Ocean City's population. The town stated, "From 1995 to 2020, the population age 55 and over is projected to increase by over 100% while the general population will likely increase by only 40%."[1] This demographic change will impact the town's infrastructure and emergency services, thereby making storm protection for the beach increasingly important.

Furthermore, Ocean City has become indispensable economically to the State of Maryland and the region. According to City Engineer Terry McGean, in Fiscal Year 2007 Ocean City provided $121 million in tax revenues to the Federal Government, $184 million to the state, and $92.5 million to Worcester County. "Schools and social services across Maryland come from revenues from Ocean City," added McGean, and without the beach drawing tourists, critical funding and services would be lost.[2] For these reasons, it is imperative that the beach nourishment project maintains a healthy coastal system to accommodate residents and visitors and provide storm protection.

As the first decade of the twenty-first century draws to a close, stakeholders in the Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project are anticipating future needs and circumstances. The project is reaching the halfway point of its economic lifespan, and planners and engineers are developing ways to maintain the project's viability in the coming decades. A cost-sharing plan has been established between the State of Maryland, the official local sponsor of the project and the Corps for renourishment events. The state pays 47% of the costs and the Corps is responsible for the other 53%. The state then divides the cost of the 47% between itself and the Town of Ocean City and Worcester County.[3]

Borrow Sources 2, 3 and 9, the offshore shoals that have provided fill material for the project since 1988, are expected to be exhausted by 2010. The General Reevaluation Study that began in 2001 was completed in 2008. It outlined the results of borrow source investigations and a tentative plan for renourishment events. Currently, the next renourishment is scheduled to take place in 2010. Accordingly, new borrow sources needed to be identified for renourishment through the year 2044, when the current authorization for the project is scheduled to end. First, a suitable quantity of required fill material had to be established. Approximately 800,000 yd^3 (612,000 m^3) have been placed on the Ocean City beach every four years since 1998. Using that amount, the Corps estimated the need for at least 6.8 million yd^3 (5.2 million m^3) to last from 2010 until 2044, with renourishments scheduled every four years.

The Corps also considered, however, that severe storms could impact the project in the future, just as they did in the early 1990s at the start of the project. Should storm activity cause increased erosion, then the project would need higher-than-average renourishment amounts. The supplemental environmental impact statement for the study concluded, "Accordingly, to account for this possibility, it was considered appropriate to identify up to 15 million yd^3 [11.5 million m^3] of sand to meet Ocean City's sand needs through the end of the project's economic life in 2044."[4]

Regional Considerations

Working with research provided by the Minerals Management Service (MMS) and Maryland Geological Survey (MGS), the Corps identified nine offshore shoals as potential borrow sources. The coastal bays were excluded as possible sites because of the risk of environmental damage from dredging large amounts in those locations. The General Reevaluation Study recommended three shoals as the best potential sand sources: Weaver Shoal, Isle of Wight Shoal and Shoal A. The Ocean City Inlet ebb shoal and another offshore location, Shoal B, were named as potential sites to be examined again before impending renourishment events.[5]

The other candidate shoals were excluded after environmental impact assessments and grain size analyses. For example, Little Gull Bank was not chosen because it's an important fishing ground, and Shoal E has dissimilar grain sizes compared to the Ocean City beach. Great Gull Bank was also eliminated because of its use in the Long-Term Sand Management project for Assateague Island, and engineers did not want to dredge even more material from this shoal and permanently damage it.[6] Sediment samples from vibracores showed that Weaver Shoal, Isle of Wight Shoal and Shoal A have large sections with suitable amounts of sand similar in size to that at Ocean City and, at the time of the General Reevaluation Study, they were not key fishing areas or high-value marine habitats. But the Corps recognizes that offshore shoals are nonrenewable resources that can become important habitats at various times. Therefore, it was

Figure 34: The locations of offshore shoal fields near Ocean City. Exhausted borrow areas are denoted BA. Source: USACE Baltimore District.

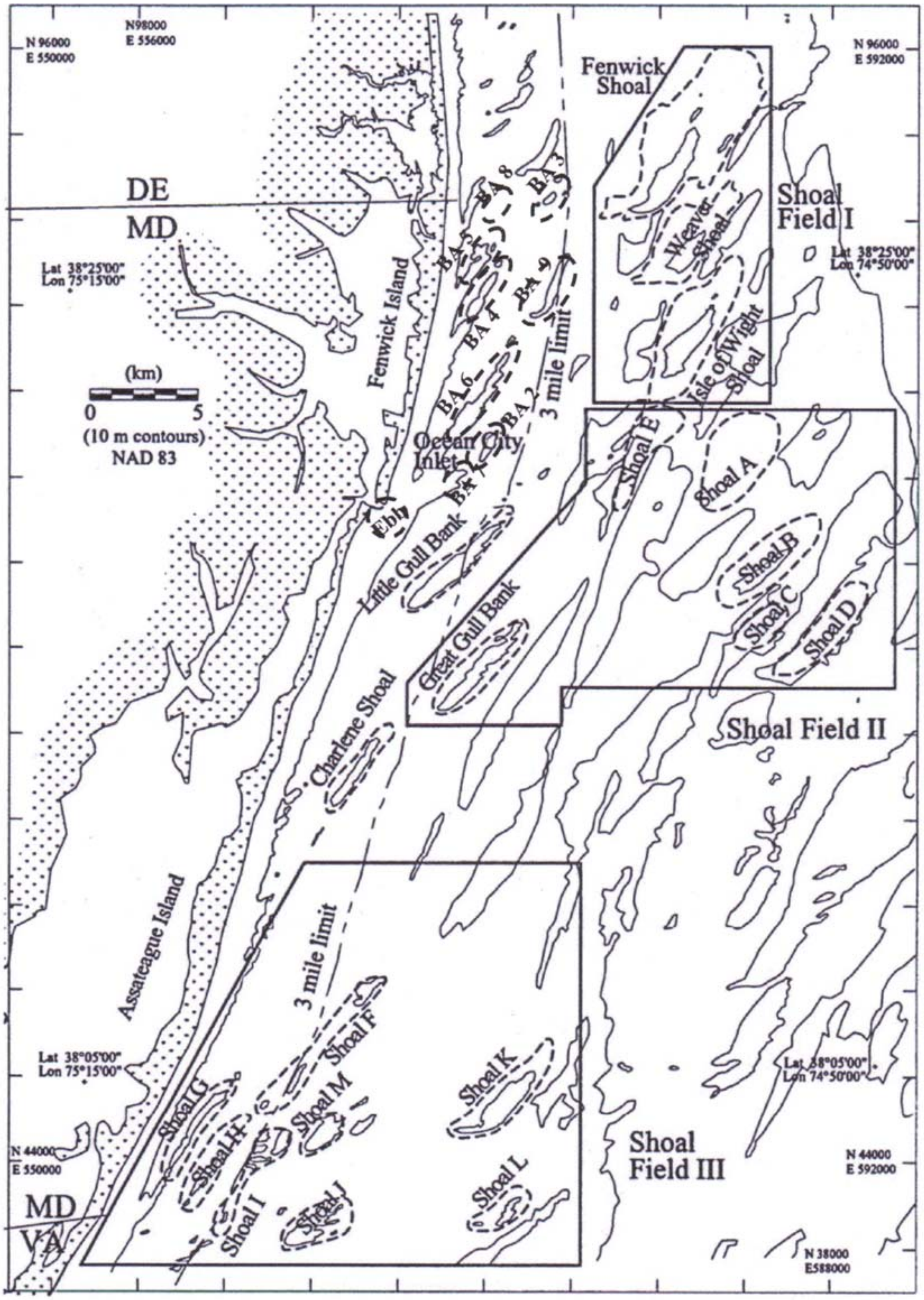

Figure 2-4: Offshore shoals off Fenwick Island (modified from an MGS source figure) BA=Borrow Area.

necessary to develop a maintenance plan for the shoals that accounts for changing environmental and economic concerns.[7]

Earlier in the project's history, dredging was carried out only with the intention of procuring sediment for the beach fill. "Past borrow actions to obtain sand for Ocean City altered the geomorphic character of Borrow Areas 2, 3 and 9; measures to minimize impacts of dredging on the shoals as habitat were not specifically considered in advance," the Baltimore District explained. By the early twenty-first century, however, the Corps had learned that "offshore shoals are believed to be important features to which migrating finfish and mobile benthos orient for navigational purposes or stage upon at various times (daily or perhaps seasonally)."[8] The Corps collaborated with the FWS and local fishermen to evaluate the importance of the candidate shoals as habitats, and, as of 2008, they determined that Shoal B would be excluded temporarily because it supports artificial reefs and important fishing activity. Its status as a fishing ground will be re-evaluated in the future, and if it is no longer ecologically and economically vital, it can be dredged for fill material. Likewise, Weaver Shoal, Isle of Wight Shoal and Shoal A will be re-evaluated periodically, and if one becomes a valuable fishing location, dredging activities will shift to another borrow source to preserve the marine habitats and fishing industry at any high-value location.[9]

The Corps plans to minimize the environmental impacts associated with dredging the shoals. Preserving the geomorphic integrity of the shoals is paramount because shoals' relief off the sea floor is important for the fish that congregate near them, and birds frequently forage in the shallow waters above the shoals' crests. Based on this biological research, "the study team determined that it would be prudent to minimize impacts to shoal maximum relief and shallow areas along the crest since shoal relief recovery time following dredging is unknown, and these areas likely have particular importance as habitat features." After consulting with sea floor experts, the Corps adopted a dredging plan that stipulates four guidelines: avoid the crest, dredge from accreting or eroding sides, dredge a thin and uniform thickness from a large area, and do not dredge below the sea floor. This plan will impact a number of shoals by dredging multiple sources, but it will prevent significant damage to any one shoal by preserving the overall size and integrity of each.[10]

The impact of dredging activities on the surrounding shorelines was also considered during the development of the borrow source plan. "Offshore shoals are very attractive from a sand-mining standpoint because they contain large amounts of high-quality sand. But disturbing areas close to the shore can alter wave energy and increase erosion," explained Williams from USGS.[11] Since shoals cause waves to break before reaching the beach, they are important mechanisms for dissipating wave energy. Consequently, their removal could damage the very shores that their sand is going to nourish.

The Corps therefore consulted studies performed by the MMS to analyze the effects of dredging these candidate shoals. The computer models created by MMS researchers showed that by dredging multiple shoals 10 ft (3 m) deep across an area of 170 ac (69 ha) that "no significant impacts to shoreline erosion rates would occur."[12] This calculation underscores the importance of dredging in the least damaging manner possible and maintaining the geomorphic integrity of the sand sources. If shoals are used in a way that causes negative impacts to the Ocean City beach, then the project would be counterproductive. Thoroughly evaluating the effects of dredging offshore shoals is an important step towards avoiding unintended consequences.

The monetary costs of dredging the final three candidate shoals were evaluated to find the most cost-efficient option. While use of Weaver Shoal would be the least expensive in terms of mining and sand transport because it is closest to Ocean City, it isn't large enough to supply the necessary quantity of sand without damaging the shoal. Weaver and Isle of Wight Shoals are in close proximity, approximately 8 mi (13 km) offshore of Ocean City, and Shoal A is about 9.5 mi (15 km) offshore. The small distances between these shoals bring the dredging costs for each to a very similar rate. "The cost differences in dollars and percent difference in cost between dredging either Weaver or Isle of Wight Shoal individually is measured in only tens of thousands of dollars; the percent difference in cost is well below 1%. The difference in cost between dredging Shoal A versus either Weaver or Isle of Wight Shoal individually is more substantial at 5.75%, but still well within the contingency estimate," stated the Baltimore District.[13]

Based on the negligible cost differences and the need to dredge multiple shoals to minimize impacts to each one, the Corps and associated stakeholders concluded, "Accordingly, it is recommended that Weaver, Isle of Wight, and Shoal A all be utilized as borrow sources for Ocean City for the remainder of the project life[.]" Furthermore, to avoid damaging the shoals, the plan recommended that the borrow areas on the shoals be dredged in progression so that each dredged area will have a significant amount of time to recover.[14] These guidelines will help the project to be cost effective while still mining the sand sources in a sustainable manner.

Long-Term Planning

The recommended plan also keeps Shoal B as a potential source, depending on restrictions because of its value as a fish habitat and fishing location. The plan also designates the ebb shoal as a possible source but with the prerequisite that more research be gathered on the potential impacts to Assateague Island. The ebb shoal is a prime source of sand because it's not a valuable fishing ground, but it's already a source for the Long-Term Sand Management (LTSM) bypassing project for Assateague Island. It is being carefully dredged and monitored for that project, and engineers believe that removing increased sand amounts could damage the shoal and the surrounding area. The Corps identified a number of important concerns regarding the ebb shoal as a source: "1) Impacts to northern Assateague Island environmental character and stability from increased wave energy and potential reduction in sediment delivered via natural bypassing. 2) Altered wave energies and bathymetries in the vicinity of the inlet and potential impacts to navigation. 3) Following placement of finer-grained sand dredged from the ebb shoal on the Ocean City beach, increased deposition of finer-grained sand could detrimentally impact the environment of [the] inlet vicinity, with the coastal bays being of greatest concern."[15]

Because of the potential for negative impacts and the fact that the ebb shoal's sand is finer than that on the Ocean City beach, the Corps decided to compile more data about the effects of dredging on the ebb shoal. "A substantial portion of the information that would ultimately be required to determine whether increased volumes of sand could be dredged from the ebb shoal for Ocean City is already being collected under the LTSM monitoring program," the Baltimore District stated.[16] As the data from these investigations become available and conclusions are drawn, the sediment budget for Ocean City will be re-evaluated. With increased knowledge of its morphology, the Corps will be able to more accurately determine the ebb shoal's suitability as a source in the future.

The components of the plan for the Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project focus on flexibility, sustainability and considering the project's effects on stakeholders and the larger region. This plan anticipates a changing sediment budget based on storm activity, and it recommends periodic re-evaluations of shoals' value as habitats and economic engines for the Maryland coastal area. It advocates dredging sources in a manner that preserves them as nonrenewable resources, thereby maintaining the shoals for long periods of time and for other uses. The plan also considers the views of private industry, environmental organizations, other government agencies and the surrounding communities. The Corps collaborated with MMS and FWS for research and data, addressed the American Fisheries Society with the FWS in joint presentation in 2002, consulted the Maryland DNR and Town of Ocean City for planning and decision-making assistance, published public notices of the environmental impact assessment process and held a public meeting to discuss the conclusions of the study.[17]

This approach to coastal management considers the environmental and economic impacts of activities in the region over time. It identifies the most viable and widely acceptable plan for mitigating erosion while not adversely affecting other activities and locations. In essence, it is a systems-based approach, which is the cornerstone of regional sediment management, an approach to shoreline stewardship that the Corps began to conceive and implement over the late twentieth and early twenty-first centuries. Using this approach allowed the Corps to create a comprehensive and flexible management plan for Ocean City that is based on current scientific data and sensitive to other coastal needs in the region. The Corps will be able to use this plan and update it as needed to sustainably manage the shoreline at Ocean City and beyond.

Ocean City Inlet

Ocean City Inlet continues to function as an important pathway to the sea for the commercial and recreational boats along Maryland's Atlantic coast. Accordingly, a number of navigation-related businesses rely on the boat traffic through the inlet as well. Commercial fishermen frequent the area, as seen by the negotiations over using Shoal B as a sand source for Ocean City. Sport fishing is also an important economic engine for the town because it remains a popular tourist activity. For example, in 2004 the White Marlin Open, an annual, week-long sport fishing tournament, generated approximately $20 million in revenue for Ocean City.[18] Decades after their initial sighting in the area, white marlin continue to draw tourists to the waters off Ocean City. Maintaining the waterway therefore remains a central concern for the town and the Corps, as it has been since the 1930s.

The Long-Term Sand Management project anticipates that channel maintenance dredging will occur twice yearly to reduce channel shoaling and contribute sediment for bypassing at Assateague Island through the year 2029. Since the last repairs in 2002, the south jetty has been performing well, and the other structures at the inlet are not yet scheduled for more maintenance. Along with maintaining the inlet's capacity for boat traffic, the most important shoreline management activity currently taking place at Ocean City Inlet is the use of the ebb shoal as a sand source for the Long-Term Sand

Management project. Until the late 1990s, the ebb shoal was considered unsuitable for dredging because upsetting its equilibrium would deprive Assateague Island of sediment from natural bypassing. But engineers chose to re-examine it as a source because of improvements in computer modeling and the shoal's continued impediment to navigation.

"We've been pretty innovative about when and where we take material from that shoal," states Grosskopf, who is currently assisting the Baltimore District in developing the sediment budget for Assateague Island. "Different parts of the shoal pass sand in different directions. The north part grows toward Ocean City and the sand disrupts the navigation channel, so that's a source that's been used over the last five years. In areas that are far offshore in deeper water, [the sand] is sliding off the seaward edge of the shoal," he continues. Indeed, these areas have been dredged because they aren't leaving holes near the crest, where infilling sediment would deprive the downdrift beach at Assateague of natural sand bypassing. "We're shaving off the outer edge and moving it onto the beach," explains Stauble.[19]

The Corps and private contractors are continually monitoring the ebb shoal with numerical modeling tools and multi-beam surveys, which provide nearly photographic views of the sea floor. Data gathered at the inlet since the start of the Long-Term Sand Management project is being analyzed, and the sediment budgets for both Ocean City and Assateague Island will consider the condition of the ebb shoal when the results are compiled.[20]

The flood-tidal shoals, the subaqueous sand bodies on the landward side of the inlet, are viewed as viable sources for the Long-Term Sand Management project because the sediment accreting in the coastal bays isn't part of the amount being bypassed naturally by the ebb shoal. But environmental and hydrological considerations will continue to impact dredging in those areas. "For the Atlantic coast of Maryland, the sand region is from Cape Henlopen, Delaware, to Chincoteague, Virginia, and it includes the inlet and the coastal bays. All the modeling we do accounts for those areas and sinks of material," Grosskopf maintains. Extensive research and continual monitoring are crucial to the computer modeling efforts that inform the management plans. Observing and measuring the geomorphology, hydrology and biology of the area allows designers and engineers to understand the regional long-term effects of potential plans. "This is one of the best-studied inlet systems in the United States," explains Julie Rosati, a research hydraulic engineer at the Engineering Research and Development Center's Coastal and Hydraulics Laboratory.[21] With thorough information now and in the future, the Corps will be able to develop management plans that satisfy multiple objectives and stakeholders. This well-informed, integrated approach to dredging, bypassing and environmental preservation is the hallmark of regional sediment management, which helps guide management decisions in and around Ocean City Inlet.

Assateague Island

As one of the only undeveloped barriers along the East Coast, and the recipient of millions of visitors each year, Assateague Island is valuable to humans as well as wildlife. It is within a day's drive of tens of millions of residents in the Washington, DC, and Baltimore metropolitan areas; therefore, it furnishes unique educational and recreational activities for a large, urban population. According to the NPS, the national seashore provides opportunities for "hiking, camping, nature study, beach combing, fishing, hunting, shellfishing, swimming, birding, biking, picnicking, recreational ORV use, as well as many other leisure activities."[22] As host to rare and some endangered species, the island's ecological value is crucial to the environmental diversity of the Atlantic coast. For these reasons, the Corps, NPS and other stakeholders want to ensure the basic geological integrity of the island so that humans and wildlife can enjoy it in the future.

The biannual sand bypassing at northern Assateague appears to be stabilizing the island, although exact results are currently being compiled. Personnel from the National Seashore have been collecting GPS shoreline surveys, beach profiles and Lidar elevation surveys, and the Corps has been taking beach profile surveys, wave and current measurements, aerial photography and sediment samples.[23] When analyzed, this data will inform project managers about the responses of the shoreline and the project's effects on erosion.

The goal, however, is not to stop all erosion or extend the island seaward to its former position. "What's happened since 2002 is impact mitigation," Zimmerman explains. "It's to mitigate the impacts of the Ocean City Inlet system."[24] Consequently, managers will focus on creating conditions that would be present if the Ocean City Inlet and its jetties didn't exist. Even in that hypothetical situation, Assateague Island would still be a dynamic, changing barrier island, and that status is not to be altered through the Long-Term Sand Management project. Rather, stakeholders are trying to strike a balance between compensating for jetty-induced damages and retaining the island's evolving character.

Biological monitoring of piping plover population numbers and distribution continues, along with studies of the vegetation types throughout northern Assateague. Seabeach amaranth *(Amaranthus pumilus)*, an endangered plant that thrives in the same overwash fans as plovers, is being monitored as an indicator of habitat prevalence along the northern end. Since 2005, these plants have been protected from off-road vehicles and horse and deer grazing with cages built around them on the beach sands.[25] The numbers of these endangered animal and plant species help park personnel to understand how much overwash is taking place and how the environment is responding to erosion mitigation. The surrounding salt marsh restoration projects will also be monitored for their biological diversity. The environmental restoration project at Isle of Wight, for example, might be modified to remove structural elements and increase the marshes' contact with daily tides.[26]

Figure 35: Seabeach amaranth is a federally threatened plant growing on Assateague Island. Cages protect young plants from grazing horses and over-sand vehicles. Photo: State of the Parks.

The geological and biological data compiled from extensive research will facilitate the creation of a sediment budget that compensates for the jetties' effects, ideally without impacting the island in other ways. Overwash fans that provide barren substrate habitat and material for salt marsh creation are still crucial to the island's health, so National Seashore personnel want to ensure that overwash still takes place. For this reason, the emergency berm built in 1998 and any extensive dune growth remain as concerns. Since 1998, Assateague Island has experienced a relatively calm period in terms of storm activity. The project will have to be re-evaluated if and when storms increase in frequency and severity. Factors to be examined include the amount of sand that remains in the littoral system, the shoreline's response to storms, the quality and quantity of overwash habitat, and the island's function as protection for the mainland coastline.

By working collaboratively and examining the extensive data collected, the Corps and NPS can develop a responsive management plan that balances multiple objectives. Understanding the project's effects to date is a key step towards maintaining an appropriate plan. Combining missions, such as navigation maintenance and erosion mitigation, will help the Long-Term Sand Management project remain viable, and the Corps' systems-based approach can achieve that goal.

Conclusion

The stakeholders in the shoreline management projects along Maryland's Atlantic coast are gathering a wealth of data and analyzing the appropriate next steps for the region. Geological and biological information about the surrounding seabed have informed sediment budgets for Ocean City and Assateague Island, and as more data is compiled and studied, the projects will be better equipped to mitigate erosion, facilitate navigation and preserve wildlife habitats.

The systems-based approach and regional sediment management principles facilitated the General Reevaluation Study that identified sand sources for the remainder of the Ocean City project, and they will impact the revisions made to the sediment budget for Assateague Island as well. By evaluating the regional impact of dredging and beach nourishment methods, the Corps will be able to minimize negative consequences and increase efficiencies. Concentrating renourishment at erosion hot spots at Ocean City and combining channel maintenance with sand bypassing at Assateague Island have already furthered these goals, and the Corps looks to build upon these actions to keep these projects viable and successful in the coming years.

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[25] Hayward, *State of the Parks*, 12.
[26] Smith, discussion with author, 03/09/09.

Epilogue: Looking to Future Challenges

The coasts at Fenwick and Assateague Islands will always be evolving and responding to the relentless wind, waves and currents in the coastal zone. Humans and wildlife will continue to value the ocean and the unique environments where land and water interact. Only by considering the characteristics, values and needs of the varied communities and processes along the coasts can the Corps effectively manage Maryland's Atlantic coast and shores nationwide.

Coastal area and shoreline management at Ocean City and Assateague Island has changed significantly over time. Management approaches began with structures, namely groins and jetties, to stabilize the beach and inlet. As erosion became an issue, beach nourishment was adopted as a main component of management plans, and this method itself has been refined. The experiences at Ocean City, Ocean City Inlet and Assateague Island resulted in important discoveries and improvements in the development of sediment management strategies and the implementation of beach nourishment.

Advancements Made

At Ocean City, recognition of the value of the bay environments encouraged the use of offshore shoals instead of the bays as sediment sources. Dredging sediment from Isle of Wight and Assawoman Bays after the Five-High Storm in 1962 was quick and relatively inexpensive, but the environmental costs to the bay habitats precluded this as a continuing practice. Therefore, evaluation and use of offshore shoals became the norm for the Atlantic Coast of Maryland (Ocean City) Shoreline Protection Project. The Corps also examined the potential impact of dredging one source significantly versus the benefit of dredging multiple sources lightly. Understanding the importance of underwater shoals as marine habitats and wave energy absorbers helped the Corps modify its dredging methods. The project's initial borrow sources were exhausted from repeated dredging events, but in the future sediment sources will be dredged minimally so as to preserve their geomorphic character for marine life and shoreline protection.

The sand bypassing project at Assateague Island shows how mimicking natural processes such as longshore sediment transport can be less damaging than many structural responses to erosion. Rather than building groins on the beach, which could aggravate erosion downdrift, or even placing sand directly onto the foreshore, where wildlife could be adversely affected, the Corps releases sediment into the nearshore waters so that currents and waves can distribute the sediment naturally and with as little impact to the environment as possible. Replicating natural processes and remaining sensitive to local conditions is important for keeping projects viable at varied locations. At Assateague, this approach considers the value of the beach environment for endangered species and plans accordingly to supply the needed sediment to the coastal system while protecting habitats.

The sediment budget and management plan for the Assateague Island project also considers the effects of dredging the ebb-tidal shoal, an important sand body at the inlet system. Rather than damage the shoal and make it a sand sink once again, the Corps is utilizing cutting-edge technology to take advantage of this plentiful sand source yet maintain it as a sand bridge and wave absorber.

The key to these scientific innovations is data collection, and the extensive monitoring efforts that have taken place throughout this region demonstrate the importance of this aspect of coastal management. The characteristics of sediments from the native beaches and offshore shoals, the response of the beach to renourishment and the value of onshore and offshore habitats have all been evaluated after years of monitoring. The conclusions drawn from this data have helped refine sediment budget analysis and management strategies. For example, renourishment at Ocean City has been concentrated at erosion hot spots that were discovered through profile surveys. If the hot spots can be managed effectively, it could be possible to extend the renourishment period beyond the current four years. Monitoring has also allowed the ebb-tidal shoal to become a sediment source because engineers have a better understanding of how to preserve its geomorphic character, thereby opening up an extensive and nearby sediment source for the bypassing at Assateague Island.[1]

Monitoring and improved practices have reinforced each other. The Ocean City Inlet system has provided large amounts of data for computer modeling efforts taking place at the Engineering Research and Development Center (ERDC) and ERDC personnel have produced models that have been useful to the projects in the Ocean City area as well as other inlet systems. The detailed profile surveys taken at Ocean City from the start of the shoreline protection project and the South Jetty Monitoring Program have been valuable sources of information about the effects of soft and hard structural responses to erosion. Because of the importance of regular monitoring, data collection efforts continue in this region. The authorization of the short-term restoration at Assateague Island included funding for five years of data collection. Additionally, the Corps and NPS collaboratively fund and implement annual monitoring of the long-term phase. The data gathered from these efforts is currently being used to update and refine the management plans for the island.[2]

Furthermore, these projects prove that efficiency can be increased by combining actions, such as channel maintenance and erosion mitigation. The biannual dredging of Ocean City Inlet maintains this regionally crucial waterway, but it also supplies sediment for Assateague Island. Likewise, back-passing sand to Ocean City during bypassing events at Assateague complements the Ocean City project by adding sediment while nourishment is already taking place at a nearby location. This integrated management considers the long-range implications of coastal management decisions and aims to benefit the entire system, not simply one individual location, and it illustrates the regional sediment management approach.

Understanding the regional scope of a sediment system—barriers, inlets, bays, shoals, mainland—was instrumental to management developments on Maryland's Atlantic coast. By viewing the components of the geological and hydrological systems as interconnected, the Corps has refined its projects to function as mechanisms for maintaining the natural system of sediment movement. This approach can support economic activities and environmental preservation while providing storm protection because sediment, whether on beaches or in shoals, is valued as a resource and is carefully managed to provide wave energy absorption, space for recreation and habitats. It is also sustainably managed so that the system will have significant amounts of sediment for years to come.

The Ocean City and Assateague Island shoreline management projects also demonstrate the importance of stakeholder collaboration. Research conducted by multiple agencies informed the sediment budgets and management plans for these projects, and collaborative monitoring efforts continue to provide critical project data. The interests of private industry and government agencies helped drive management objectives and continue to do so. These beach nourishment projects were initiated only when there was a general consensus among stakeholders that action was necessary to preserve coastal resources. Hence, the Corps realizes that the management objectives of other government and non-government agencies are relevant to the sediment system and must be incorporated into management plans. By considering the views and interests of multiple parties, the projects can remain viable and responsive to changing conditions.

Tomorrow's Questions

Flexibility will be important for addressing climate change, both in the present and the future. A changing climate can impact a dynamic barrier in a number of ways. Increased storm activity is one possible consequence, with the resultant erosion, overwash and/or breaching. If storm activity increases and/or sea level rise accelerates, the shoreline at Ocean City and the structures built there will be at increased risk for flooding and damage. A recent study advocated the advancement of "sea level rise planning principles, such as designating non-structural and structural shore protection areas, natural shore erosion areas, areas where erosion-based setbacks should be implemented, and areas to target for land conservation and acquisition."[3] Additionally, the sediment management plan may need to be altered to ensure the system has enough sand to cope with rising sea level. "We can handle small, incremental changes," Loran explains, "and for incremental changes you put in more sand."[4] Thus, updating the sediment budget and management plan in the coming years and decades will be a key part of the Corps' climate change strategy.

At Ocean City Inlet, the ebb shoal and flood shoals may increase in importance as sand sources depending upon the development of alternative energy technologies in the area. It is possible that offshore shoals could be sites for wind turbines or wave-powered generators, which would preclude their use as beach fill sources. These varied objectives could be managed if a thorough planning process takes place, according to Rosati. "Sources of sand for bypassing are local and the ebb shoal could still be used, as long as [alternative energy sites] are included in the planning," she explains. "It probably wouldn't be a deal-breaker."[5]

Climate change will also impact Assateague Island and the Long-Term Sand Management project. Even without increased storm activity, Assateague Island will be affected by climate-induced changes to sea level. A recent study by the USGS determined that 30% of Assateague's shoreline is highly vulnerable to the effects of sea level rise, and nearly 80% of the total shoreline is ranked between very high to moderate risk.[6] The coastal vulnerability index (CVI) measured geomorphology, historical shoreline change rate, regional coastal slope, relative sea-level change, mean significant wave height and mean tidal range. Data from photographs, bathymetric surveys, and tidal and wave gauges were analyzed in mathematical equations to evaluate the island's risk of flooding from rising seas. The areas at the highest risk for inundation and salt-water intrusion are the northern and central parts of the island, which have the lowest elevation and have experienced higher rates of erosion than the southern end. The southern portion of the island is ranked at low to moderate risk.

A potential breach of the island from a severe storm is also a consideration for future management plans. "Another breach would disrupt Ocean City Inlet," explains

Stauble, and it would expose mainland communities to increased damages. Therefore, the Corps would likely advocate filling any breach. At the National Seashore, however, a breach is seen as a marsh-creating mechanism and part of the island's natural migration, so filling one artificially would not be desirable. These differing management objectives will be addressed as circumstances evolve, but they will remain important questions for the future.[7]

This issue also exemplifies why multiple stakeholders must be included in management decisions. The objectives of navigation maintenance, shoreline protection and environmental restoration are all present in the issue of filling a breach; therefore, the groups with interests in those objectives must collaborate to find an acceptable solution to a coastal issue. By working with other government agencies, such as the NPS, and private interest groups, the Corps can carry out its duties and successfully manage differing, and even competing, aims.

The Way Forward

The future of shoreline management will focus on maintaining these projects' flexibility and regional context. The systems-based approach will continue to be applied to integrate the management of the navigation, erosion control and environmental restoration projects along Maryland's Atlantic coast. Through this approach, sediment can be conserved and used beneficially, economic opportunities will be enhanced and rare ecosystems can coexist with humanity's activities. Significantly, this approach is not an end in itself; it facilitates projects remaining relevant and responsive to changing conditions. As alterations are constantly taking place in the dynamic coastal region, the

Corps aims to adapt its practices to those changes. With a broad, regional perspective, benefits can be achieved in many locations over the years and decades to come.

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[1] Johnson, discussion with author, 05/28/09; Grosskopf, discussion with author, 01/12/09.
[2] USACE Baltimore District, *Appendix D: Restoration of Assateague Island*, 6-20; Scott Johnson, e-mail correspondence with author, June 1, 2009.
[3] Zoë Pfahl Johnson, *A Sea Level Rise Response Strategy for the State of Maryland*, report prepared for the Maryland Department of Natural Resources Coastal Zone Management Division, Annapolis, MD, 2000, 38. http://dnrweb.dnr.state.md.us/download/bays/sea_level_strategy.pdf.
[4] Loran, discussion with author, 01/08/09.
[5] Rosati, discussion with author, 12/12/08.
[6] Elizabeth A. Pendleton, S. Jeffress Williams, and E. Robert Thieler, *Coastal Vulnerability Assessment of Assateague Island National Seashore (ASIS) to Sea-Level Rise*, U.S. Geological Survey open-file report 2004-1020, 2004, 9.
[7] Stauble, discussion with author, 01/07/09; Zimmerman, discussion with author, February 3, 2009.

Abbreviations

ASIS: Assateague Island National Seashore

BEB: Beach Erosion Board

BSFW: Bureau of Sports Fisheries and Wildlife (precursor to U.S. Fish and Wildlife Service)

CE: Chief of Engineers

CERC: Coastal Engineering Research Center

CWA: Clean Water Act

DNR: Department of Natural Resources

EIS: Environmental Impact Statement

ERDC: Engineer Research & Development Center

FWS: U.S. Fish and Wildlife Service

LTSM: Long-Term Sand Management

MGS: Maryland Geological Survey

MMS: Minerals Management Service

MOA: Memorandum of Agreement

NEPA: National Environmental Policy Act

NGVD: National Geodetic Vertical Datum

NPS: National Park Service

RSM: Regional Sediment Management

USACE: U.S. Army Corps of Engineers

USAED: U.S. Army Engineer District

USGS: U.S. Geological Survey

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