Guide's Guide
Coastal Processes and Their Effects

Outer Cape Salt Marshes

A salt marsh, such as the Nauset Marsh, is a vast expanse of land and dominant swaths of hearty grasses criss-crossed by meandering streams and tidal creeks of seawater which flows in and out with twice daily flooding and draining by tides. The Nauset Marsh is among the most productive in the world.

Cape Cod salt marshes began developing extensively when rising sea level caused the creation of barrier beaches and spits and shallow, protected embayments. Salt marsh grasses thrive in such habitats, and build proportionately along with elevating sea levels. Thus, new marsh layers build upon the base provided by former generations.

The two main salt marsh grasses on Cape Cod belong to the genus *spartina*. *Spartina alternaflora*, known locally as salt marsh cord grass, is the taller of the two species. Cord grass grows in the deeper portions of the salt marsh margins and in the center of tidal flats. It can survive having its roots and base submerged by salt water twice daily, and the entire plant can withstand being completely inundated for several days at a time during extremely high course tides and storms. The plant has a means for exuding excess salt from its system, which is also why it can survive in an otherwise hostile environ-ment with only limited competition. *Spartina patens*, or salt marsh hay, has similar qualities, but is finer and softer to the touch than its robust cousin, and can withstand only the twice monthly emersions of salt water which it routinely receives.

Hence, salt marsh hay is found on the higher edges of the salt marsh community directly adjacent to the upland transition known as the “wrack line.”

Surprisingly, extensive salt marsh communities on the Outer Cape are relatively new. Most of the conditions favoring their formation have only recently come into being, in geologic time. One evidence of this is the chart of Nauset Marsh drawn up by Samuel De Champlain in 1604, which shows relatively little salt marsh and much open water. We know that Champlain could not have been mistaken about this matter because his company’s ship actually sailed into the open bay that existed then.

Gradually rising sea levels force the salt marsh community to grow ever upward, but the pace is matched by new plant life growing upon the remains of older growth. The mixture of organic plant materials, along with silt and mud, creates an extensive and durable base of peat upon which the salt marsh not only grows but thrives. Decomposing materials within this layer provide additional food for crustaceans, mollusks, and fish. Smaller creatures, in turn, become food sources for larger ones, including a multitude of wading birds, such as yellowlegs and herons.

The daily inward and outward tidal flow also helps the salt marsh to thrive. New nutrients are brought in, and wastes are flushed out. But the inward and outward flow also connects the salt marsh to the greater ocean ecosystem in a significant way. Many species of fish and shellfish use the salt marsh environment as a nursery. It has beenfound that one of the key developmental stages of the American lobster often takes place in the salt marsh environment
.

The salt marsh uplands have an equally rich significance. In the early days of settlement on Cape Cod, residents harvested salt marsh hay extensively. While shellfish resources were used by Native American people as a key supplement to their diet, shell midden remains have shown that at various times they also did so on a year-round basis. Pilgrim settlers were particularly impressed with the quality of Cape Cod oysters, especially in the vicinity of Wellfleet bay. But, surprisingly, mid 19th-century Cape Cod mariners sought out Cape Cod clams not for eating, but for baiting their cod fish hand lines. Today, the rich visual qualities of Outer Cape salt marshes, with brilliant greens in spring and margins crowned by subtitle violet sea side lavender in the fall, serve as inspiration to all who view it.

Coastal Processes and Their Effects
The Sandy Shore and Dunes Environment

A sandy beach, at first glance, may seem to be barren of animal life. *Herring gulls* stand quietly at the water's edge until someone walks nearby. *Terns* swoop back and forth and suddenly plunge down to catch a gleaming *silver side minnow*. *Sandpipers*, large and small, run across the wet sand, stopping to probe with their long bills, always staying just ahead of the waves.

The remaining animals adapted to these open beach conditions are harder to find. Some are sand-colored, blending beautifully with their background; many dig into the sand; still others are so small that they can live in between sand grains.

Along the tideline, shells and other dried sealife give clues to animals and plants living in the sandy bottom. Most of these animals are burrowers and so keep from being carried away by waves and currents.

A Desert Environment

In the dune area, high above the tideline, live an amazing number of plants and animals adapting to surviving in what amounts to a desert environment. The sandy soil does not hold rainwater for long, and the air is often full of salt spray, drawing out the fresh water already in the plants. Plants that have thick, waxy leaves, much like desert cacti; those equipped with long tap roots (up to thirty feet) which descend into the water table; and beach grass whose roots spread over a great surface area, are adapted to the dry conditions.

Another necessary adaptation living things make is to the tremendous heat. During the hot daylight hours, many animals dig into the sand. If you do the same, you can feel that it is many degrees cooler just under the surface. No animal can stay more than a few seconds on the hot sand. Leaves of many plants droop or curl, thus reducing evaporation.

Because there is little natural cover for animals to hide from predators, color adaptation is protective. The common large *dune grasshopper* and *wolf spider* have dull gray speckled bodies, hard to see against sand. The young *sanderlings* are pictures of protective coloration. When potential danger approaches, they freeze in place and seem to vanish from sight.

Beach Grass

B*each grass* is the creator and guardian of our sandy beaches and dunes. It is a perennial, tough, native grass that can withstand some flooding, salt spray, drought, strong winds and accumulating sand. It is the first plant to be seen growing on a forming sand dune. Bits of broken rhizome from the beach grass root system will start growing with little moisture. This is why beach grass grows back so quickly after a storm has torn it topieces or buried it completely. When a healthy stand of grass develops, the stems break the force of winds and blowing sand. Grains of sand come to rest at the base of the stem and a good stand of grass can accumulate up to four feet of sand in a year's time.

This natural system is more effective than artificial methods for dune building and rebuilding. When the root system of the grass is exposed, one can see clearly that the clumps of grass are connected to each other by underground horizontal stems, the rhizomes. These horizontal rhizomes have enlargements from which grow tough wiry roots that spread out into the sand. As the grass is buried and grows up, decaying parts of the grass create humus so other beach plants can take hold and grow.

It is best not to walk on the grass with shoes, and not slide down or climb up a dune face. Wherever beach grass is destroyed, the dune begins to disintegrate and blow away.

Coastal Processes and Their Effects
Tides

A hundred years ago, lives of the people of Cape Cod were inseparably connected to the sea. They relied on the ocean-going vessels for their food, travel and trade, making an understanding of the tides essential for their survival. In an age of mass transporta-tion, our link to the ocean and our knowledge of its cycles has weakened with time.

Visiting a bayside beach during a low tide may cause some inconvenience to a summer vacationer. All in all, most people have little cause to think about the ebb and flow of the ocean's tide. Playing a small part in modern life, the tides are the driving force behind life on the coast.

Gravitational Pull

Newton provided the first detailed explanation of tidal action when he introduced the theory of gravitation in 1687. He proposed that objects exert a force upon each other which pulls them towards each other. This force, known as gravity, keeps the speeding planets in orbit around the sun and the moon spinning around the earth. Larger objects, such as planets, produce a stronger pull on each other compared to smaller objects. In addition, the force of gravity between objects will decrease as the distance between them increases.

As the earth and moon spin around a central axis, the moon's gravitational force pulls up on the earth's surface. The force isn't strong enough to change the shape of the inflexible land masses. However, as the moon passes over the earth's oceans, a mound of water is created. As the earth spins, the bulge of water travels across the planet's surface. This mound results in an increase in the water level, thus creating the tide. The whole ocean undergoes the regular tidal changes. They are easier to perceive near shore.

Centrifugal Effect

Newton described a second effect which is necessary for the explanation of why we have two tides per day, even though we have only one moon. Centrifugal effects tend to throw objects away from spinning bodies. On the side of the earth away from the moon, this action counteracts the gravitational pull, and creates a second, smaller mound of water on the earth's surface. We experience the second tide as the earth turns beneath it.

Cape Cod, like most places on the coast, experiences semidurnal tides, meaning two high and two low tides occur daily. Each tide, controlled by lunar movement, takes place fifty minutes later than the previous day. The moon completes a full circle around the earth every 24 hours and fifty minutes, causing the variation of tidal timing from day to day.

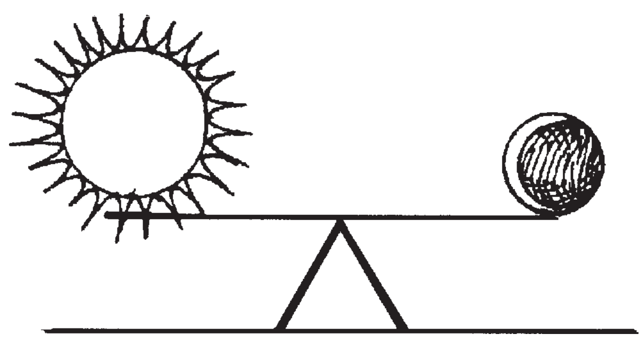
Spring and Neap Tides

The sun's gravitational pull on the earth, though 81 times weaker than the moon's pull, still affects the tides despite its immense distance from us. During each lunar month,two higher than normal tides and two lower than normal tides occur. Corresponding to the full and new moon when the sun, earth, and moon align with each other, this phenomenon is called a spring tide. The name originated from an old Saxon word meaning rising or rolling of water and has nothing to do with the spring season. The sun's gravitational force is added to the moon's pull. This extra pull creates an extra large mound of water, resulting in extreme high and low tides.

The sun's pull creates another interesting tidal variation called "neap tide." Occurring on the first and third quarters of the moon cycle, the moon, earth and sun are positioned in a 90-degree angle. The force of the sun and moon work against each other, counter-acting their effects on the ocean. A smaller mound of water is formed, producing a less significant change in the water level between high and low tide.

Local factors, such as coastal geography, add an interesting twist to the already complicated story of the tides. Most areas have semidurnal tides (two high and two low). However, the Gulf of Mexico experiences diurnal tides, having only one high and one low tide a day. Tidal height is another factor which is produced by local differences. For example, New York City normally has a five-foot difference between the high and low tide marks; whereas, Rockport, Maine sees a change of ten feet between tides, and the Bay of Fundy has an incredible thirty-foot change in water level.

The tides are an essential life regulating force in and around the ocean. Bays, estuaries and marshes rely on the huge amount of water which is forced into these areas churning and distributing organic matter in its wake. Nutrients produced in the estuaries are then flushed into deeper water as the tides recede, fueling the food chains of the open ocean. The tides set the rhythm of life for the plants and animals of the ocean's edge. Horseshoe crabs and small fish called grunion are stimulated to mate by the change in tides.



Coastal Processes and Their Effects

The Changing Cape Cod Coast

If one were to draw a map of North America as it looked, or probably looked, 70,000 years ago, Cape Cod would not be visible. The area was part of the mainland with low hills and flat stretches that reached far out into the Atlantic Ocean. But if you were to drill five hundred feet down into the ground of the Upper Cape today, you would find the same bedrock of granite that underlies the rest of New England.

How Cape Cod Became a Cape

The geography of New England was changed by ice. The weather in the north became so cold that snow didn't melt in summer, but instead, piled deeper and deeper and formed sheets of ice or glaciers that were thousands of feet thick. Gradually dragging along everything they met in their path, these huge sheets of ice spread south.

In the course of millions of years, there were a series of Ice Ages. It was during the last one about 20,000 years ago that Cape Cod was formed. Covering what is now Cape Cod, Martha's Vineyard, and Nantucket, the ice sheet (or glacier) sometimes up to two miles high, crept south. And then it stopped. For a long time it stayed there; then as the weather warmed, it receded to form a new line that ran along the north side of Cape Cod. Again it stopped until the weather warmed up about 18,000 years ago. This time the weather stayed warm enough for the ice finally to melt altogether in what is now the New England area. Eventually so much ice melted that the ocean level rose four hundred feet. Miles of land that had been at the edge of the continent, were now under water. Only the highest parts were above water.

The hills along the northern coast of the Cape (beside the mid Cape highway east of the Canal) are made up of the debris which the glacier gathered in its long journey from the north and dumped here.

The ice didn't melt evenly. When the ice sheet retreated, it left behind great blocks of ice. When these blocks finally melted, they left great hollows in the ground. Some were simply depressions in the ground; some later became cranberry bogs; some filled up with fresh water and have become freshwater ponds; some are connected by channels with the sea and have become salt ponds.

There are hundreds of these ice-block lakes (or kettles) on Cape Cod. Round Pond, north of Wellfleet, is an example of a deep freshwater kettle. The first Visitor Center at the National Seashore has been named for the salt pond (or kettle) beside it.

Other reminders of the Ice Age can be seen on Cape Cod. Every large boulder originally came from some place farther north. It was picked up by the glacier, dragged down to the Cape, and left here.

Doane Rock, off the road that leads from the Salt Pond Visitor Center to Coast Guard Beach, is the largest glacial boulder known on the Outer Cape.

Many pebbles, stones, and rocks have scratch marks on their surfaces. These were made as the glacier, rolling and scraping the rocks against each other, moved south.

The Changing Cape

Not only ice has shaped the Cape, but wind and waves are constantly taking land away from one place and adding it to another. Thousands of years ago, the southern and eastern shores of the Cape were not only rough and ragged, they also extended several miles farther into the ocean. Gradually, however, waves and winter storms have smoothed out the coastline and have dragged sand away from the cliffs of the Outer Cape. An average of three feet of Atlantic shoreline disappears every year. But not all the sand has left the shore forever. Much of it is returned farther north in an ever-length-ening beach. First the sand forms a sandbar underwater, and as more sand is added, the sandbar is exposed and becomes what is known as a sandspit, new land that is a contin-uation of the old.

All of the Province Lands is new land. Glacial deposits end at High Head in Truro. From there the sand has built up in ridges or dunes that may be seen from the observation platform at Province Lands Visitor Center on Race Point Road.

North Beach in Chatham and Nauset Spit in Eastham are also prime examples of sandspits.

On the Cape Cod Bay shore in Wellfleet and South Truro, there were once four islands. Now there is one long beach known as Great Island. Sand has filled in between the islands, and linked the islands, including Great Island (which stood alone as recently as 1831), to the mainland.

On the other hand, Billingsgate Island, which once was the home of many families, has eroded to the point where only a sandbar is seen at low tide.

Cape Cod loses more land than it gains. While the ocean side of the Lower Cape loses five acres a year, it gains only two new acres. In other words, the Cape loses three feet of shoreline a year. The planting of beach grass on bare dunes has helped them to be more able to resist storms and waves than before. If people respect these fragile areas, the beach will have a better chance to survive, although the Cape will continue to be re-formed by wind and water, as it always has.

Coastal Processes and Their Effects

Erosion on Outer Cape Cod

Erosion is a natural thing on Cape Cod. In fact, much of what we enjoy about the Cape is a result of this natural process. The wide sandy beaches we walk on are made from sand that falls down from the glacial cliffs, or scarps, behind the beach. Waves, currents and wind then move much of this sand to other parts of Cape Cod. All of the Province Lands area, as well as Nauset Spit, and much of Great Island were created by the movement and relocation of sand. If erosion of the outer beach cliffs were somehow stopped, these formations would eventually disappear.

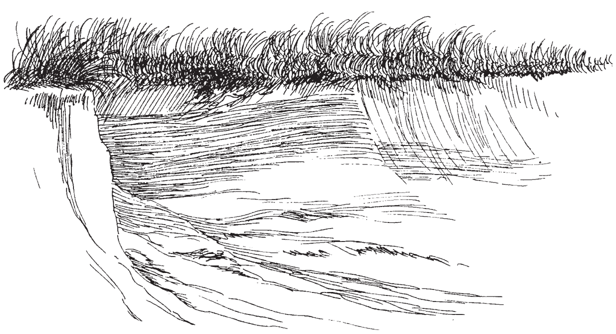
Human construction such as buildings and parking lots, often suffer severe-ly from coastal erosion. The Highland and Nauset Lighthouses are in danger of falling over the cliff as a result of shoreline retreat. In 1977, the Old Harbor Life Saving Station had to be moved from North Beach in Chatham to Race Point Beach in Provincetown in order to save it. In the following year, a 300-car parking lot located at Coast Guard Beach in Eastham was completely demolished by the Great Storm of 1978. More recently, private home sites in Chatham have fallen into the ocean as a result of coastal erosion. We have now learned that it is better to build further away from the shoreline, and to plan for regular replacement of buildings and features that need to be located close to the water's edge.

Nature Prevails

We have also found that natural "systems" are often better at slowing and controlling erosion than human "solutions" (such as building sea walls, jetties, or placing boulders along the beach). Scientists have found that the natural movement and placement of sand (both up and down the coast, as well as on and off the shoreline) slows the erosion effect of waves. You can test this on your own. Try running on a sandy beach for a certain distance. Time yourself. Then try running for the same distance on a parking lot. Time yourself again. The sand on the beach will have slowed you down considerably. Likewise, the soft sandy beach slows down the power of storm waves much better than solid concrete barriers can.

Beach grass planting in the Province Lands dunes is another way in which natural restoration activities can help correct unnatural erosion rates. Beach grass traps the sand blown by the wind, and is actually responsible for forming all of the dunes that you see on Outer Cape Cod. When people or animals trample beach grass and kill it, the dunes in turn begin to fall apart. Before the Pilgrims arrived on Cape Cod, the beach grass in the Province Lands did such a good job of holding the dunes together that once a complete forest grew on top of them. Sometimes you can still see the remains of old trees poking through the sand!

The average natural erosion rate on the ocean side of Cape Cod has been calculated by scientists at three feet a year. This means that there may be no erosion for several years, and more than three feet other years. Thus, the Cape is gradually narrowing. Its natural life span still gives the Cape several thousand more years.



Human activities that increase erosion can upset the natural "give and take." While natural processes narrow the Cape, they also build it up in other areas. All of the Province Lands was created by sand being transferred from other parts of the Cape. The same is true of Nauset Spit, Monomoy, and Sandy Neck. These sandy stretches can also grow upwards, due to windblown sand deposits forming into dunes, which in turn are stabilized further by native vegetation. Cuts in these features by trails created by humans can cause accelerated, unnatural rates of erosion. This is why it is important for people to learn not to take shortcuts through the dunes to get to the beaches. Beach grass can withstand the most powerful winds, but can die if stepped on more than twice. Erosion is a natural process that has shaped much of Cape Cod as we see it today. It is important that this process be kept natural and not be upset by human interference.

Coastal Processes and Their Effects
Dune Stabilization

Erosion and dune stabilization along the eastern shore of Cape Cod have been a concern for many years, with winds and waves damaging beaches and dunes the entire length of the Seashore.

Erosion is the primary factor altering this unique area, yet the processes of erosion consist of various agents acting, at times, independently of each other to create and shape a changing land form. Erosion of the coastline continually results in a vertical removal of shoreline sediments, principally by marine agents. Visitors to the Seashore, seeking to understand the geologic features of a changing coast, encounter a marine scarp, beaches, migrating sand spits and inlets, all vital components of a dynamic, moving coastline. Generally, erosion problems involving these elements occur as a combination of natural forces and, to a lesser extent, human-induced activities. The major problems related to shoreline erosion are associated with erosion of the scarp, recession of the shoreline, and landward migration of the barrier beaches. Stabilization efforts directed to these areas are futile; sea erosion along the Great Beach occurs at an average of three feet per year. Coastal retreat is inevitable, a natural, on-going process of shoreline recession. The changing shoreline is a result of severe storms, winds and waves, a rising sea level and the careless habits of man.

A Story of Change

The history of the Outer Cape is a story of change. It is a story of how nature formed the land and how man has since changed it. Several hundred years ago the Province Lands was completely forested. European settlement changed the face of this area and damaged the forest ecosystem. Cutting of timber, creation of open grazing land, and sporadic wildfires broke the vegetative cover and caused massive blowouts which finally released the dunes. Early settlers attempted to control sand movement by plant-ing vegetation; their efforts achieved only limited success. Despite measures to still the sand over a period of years, human impacts have caused dune migration to persist.

The Province Lands is an area with a variety of attractions that entice many people and their vehicles. Continued human activities have allowed these spectacular resources to deteriorate. Uncontrolled pedestrian traffic and indiscriminate off-road vehicle use eroded the natural and scenic quality of prime seashore resources. Each winter prevailing winds drive the massive dunes across the landscape. Some of the sand dunes move fifteen to twenty feet per year. Today, these spectacular dunes are eroding and losing height while threatening other unique resources with burial. In the past, erosion of the dunes was man-induced. For the moment, it is man’s activities in conjunction with natural forces that adversely impact eight square miles of dunes within the National Seashore.

The National Seashore was set aside as an area for public use to be preserved and used by present and future generations. As Such, the National Park Service has an overridingresponsibility to protect significant Park resources. This mandate prompted the Service to implement restrictive types and levels of use with respect to deteriorating resources. It studied the feasibility of stabilizing the migrating dunes. Scientific research now furnishes the data that is used to direct the course of action the Seashore is pursuing to preserve the high dunes in the Province Lands.

Lessons in the Sand

We are slowly learning that it is a mistake to stabilize a sandy shoreline; as long as the sea level continues to rise the coastline will erode. But the problem of erosion in the dunes is not the same problem as coastal erosion. While the sea is responsible for rearranging the coastal scene, the wind and the handiwork of man are the primary forces that alter the unique land forms in the Province Lands. Research shows that planting the bare areas of sand can stabilize and give life back to the high dunes. Following recommendations from scientific studies, the Park has acted to revegetate portions of active dune fields in anticipation of stabilizing critical areas. Since 1985 beach grass planting activities have been completed by private contract, Park volunteers and Seashore personnel who together have helped stabilize nearly 153 acres of barren sand.

In order to continue to provide for visitor use as well as resource protection, the Seashore has set guidelines for more discriminate use and dune access by both people and oversand vehicles. The long term goal of the National Park Service is to restore a portion of the dune vegetation and thereby restore the stability of dunes which today continue to encroach upon significant and critical resources within the National Seashore. The Service will continue to regulate human activities, to minimize man-made erosion problems, and protect this unique area without damaging its infinite beauty.