Basic Dune Physical Characteristics

New Jersey's Beach and Dune Characteristics

Dunes in New Jersey are mainly confined to a narrow strip of land between the beach berm and upland development. While there are a few locations in which the sand supply and beach width are adequate for dunes to reach their full form (Island Beach State Park, for example) most dunes are limited in height and width by the sand available from the beach berm area and the infrastructure landward of the beach. As a result, on most New Jersey beaches only a single line of dunes exists.

The shape of the beach on any given day is the result of a complex set of interactions between the air, the land, and the sea. Some of the more important factors include the:

- wave heights and water levels experienced at site during the recent past
- present wave and water level conditions
- characteristics of the sand
- underlying geologic conditions at the site
- presence of any artificial structures.

Throughout much of New Jersey and the Mid-Atlantic, present-day dune heights reach 8 to 15 feet above the flat part of the beach known as the berm (Hamer et al. 1992; Psuty and Ofiara 2002). This height has been found to be related to the limit of the ability of the wind to move sand higher on the dune and deposit it on the back or lee side of the dune (Hamer et al. 1992). Dunes have the potential under ideal conditions to grow in height up to 4 feet per year, although growth rates of less than 2 feet per year are more typical.

In a typical beach configuration, known as a *beach profile* (Figure 2), the dune is located along the back part of the sandy beach. The line of dunes closest to the water is called the *foredune* or *primary dune*. These primary dunes are particularly susceptible to erosion, overwash, and breaching during extreme storms. Dunes located landward of the foredune are numbered consecutively and are referred to as the *secondary dune*, the *tertiary dune*, and so on. Along developed coasts, the natural dunes are sometimes enlarged with artificially placed sand or replaced altogether with a structure such as a seawall, bulkhead, or revetment.

Seaward of the dune is the *beach berm*, which is the flat, dry section of the beach that is normally used by recreational beach users and by several species of wildlife and plants. Some of these include rare, threatened, and endangered species. Beyond the berm is a sloped area known as the *foreshore* which leads into the water. This foreshore is exposed to constant wave action and generally shifts shape and slope between seasons and storm events in response to changes in wave action.

The beach profile continues under water. The area closest to the dry sand is called the *nearshore*. Like the foreshore, the nearshore is constantly affected by the energy of the breaking waves. The nearshore generally takes one of two shapes. During calm periods, the beach slopes off uniformly into deep water and generally takes on a characteristic shape known as an *equilibrium beach profile* (Dean 1977). During stormy periods, however, sand eroded from the dry beach collects in nearshore sand bars which form near the point at which the majority of the waves are breaking. The part of the beach between the breakpoint and the area that is constantly dry is sometimes referred to as the *surfzone*. The area beyond the breakers is generally referred to as the *offshore portion* of the beach profile.

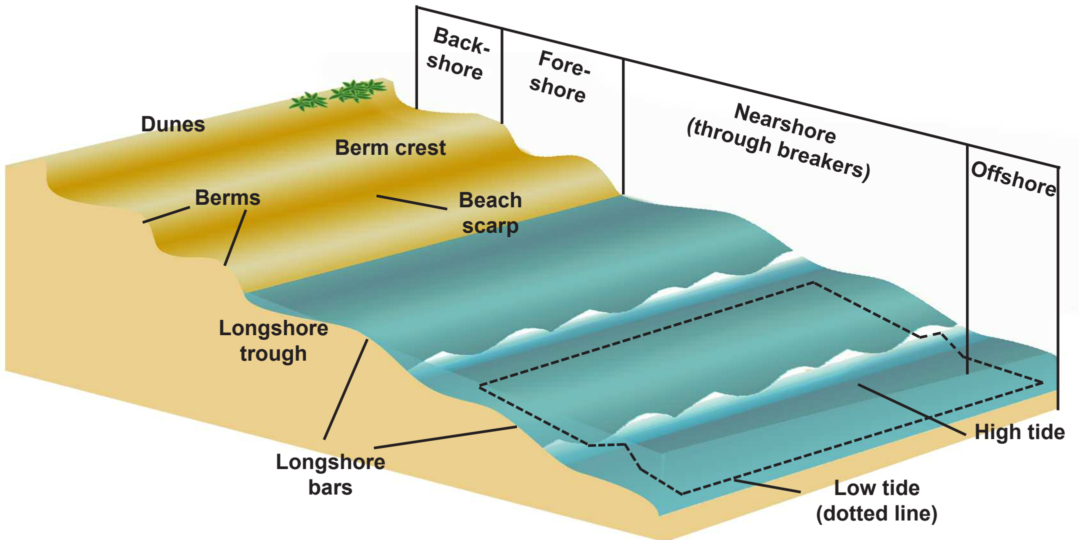

Figure 2. Example of a typical beach profile.

Dunes are constantly changing in response to both short- and long-term environmental processes at a given location. Dunes are sometimes referred to as reservoirs of sand. Their size fluctuates in response to the amount of available sand on the beach berm, the strength and duration of the wind, and the storm surge and wave action. Dunes can either be erosional or depositional depending on the interaction between these processes. Sand loss from wind- and wave-generated erosion can impact the dune directly or indirectly by decreasing the supply of sand available to build the dune. During large storms, high water levels may allow waves to erode the base of the dune and create a vertical cut or scarp (Figure 5A, B). Typically, the sand eroded from the dune gets swept into the surfzone, where it becomes a part of the active littoral transport system until it is deposited offshore in a bar or on a downdrift beach.

Winds play an important role as well, with offshore winds blowing sand from the dune onto the beach, and onshore winds blowing the sand back into the dune. Vegetation plays a critical role both in trapping sand blown towards the dune and in limiting the sand blown off the dune. These dynamic environmental conditions cause dunes to shift between erosive and accretional phases. On many beaches, the dune shifts landward during the winter in response to erosive conditions and seaward in the summer in response to accretional conditions (Figure 3). On a stable coast, the forces building the dune are balanced out by the forces acting to erode the dune.

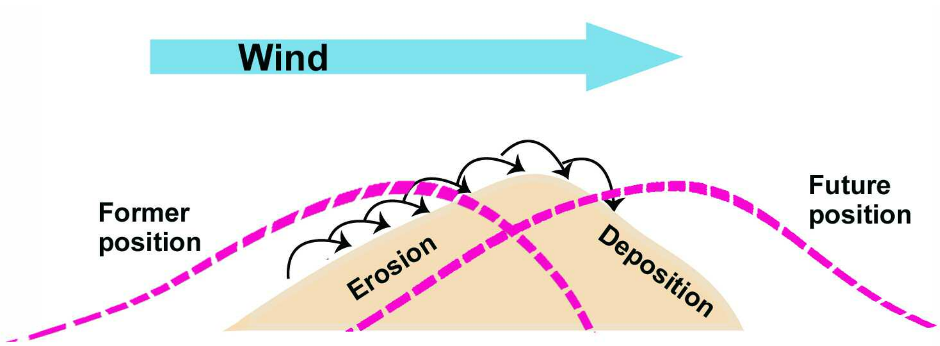

Figure 3. Dune migration due to sand movement from wind.

Long-Term Dune Evolution

Historically, sea level rise has had the greatest impact on the shape of our coastlines. At the end of the last glacial period (approximately 20,000 years ago), sea level was about 450 feet lower than it is today, and the shoreline was located approximately 100 miles seaward of its present-day position (Psuty and Ofiara 2002). As the earth's temperature increased and the glaciers began to melt, sea level rose rapidly and continued to do so until about 2,500 years ago, when it slowed significantly. Geologists generally agree that the barrier island shoreline of New Jersey at this time was low and narrow, with poorly developed beaches and dunes that were frequently overwashed during large storms (Psuty and Ofiara 2002). During this time the coastal landscape was extremely dynamic. As the rate of sea level rise decreased to approximately its current rate, the waves and currents began to move the sediments that were originally flooded during the period of rapid sea level rise onto New Jersey's barrier islands. The rate of sand transfer was sufficient to accumulate large quantities of sediment, increasing the width and height of the barrier islands (Psuty and Ofiara 2002). As the barrier islands became more stable, vegetation began to grow and coastal dunes began to develop landward of the beach berm (Figure 4). Within the last 500 years or so, New Jersey's barrier islands entered a new phase in their evolutionary development as the once bountiful supply of offshore sand dwindled, causing a transition from a period of relative stability to one of gradual loss (Psuty and Ofiara 2002). As surges and large waves associated with coastal storms began to inundate the beaches on a more regular basis, the dunes began to erode and migrate landward. More recently, human alterations to the environment, such as shoreline armoring, have further reduced the natural supply of sediment to the coast. Without a natural source of sediment and to compensate for sand removed from the system during storms, beaches and dunes struggle to survive.

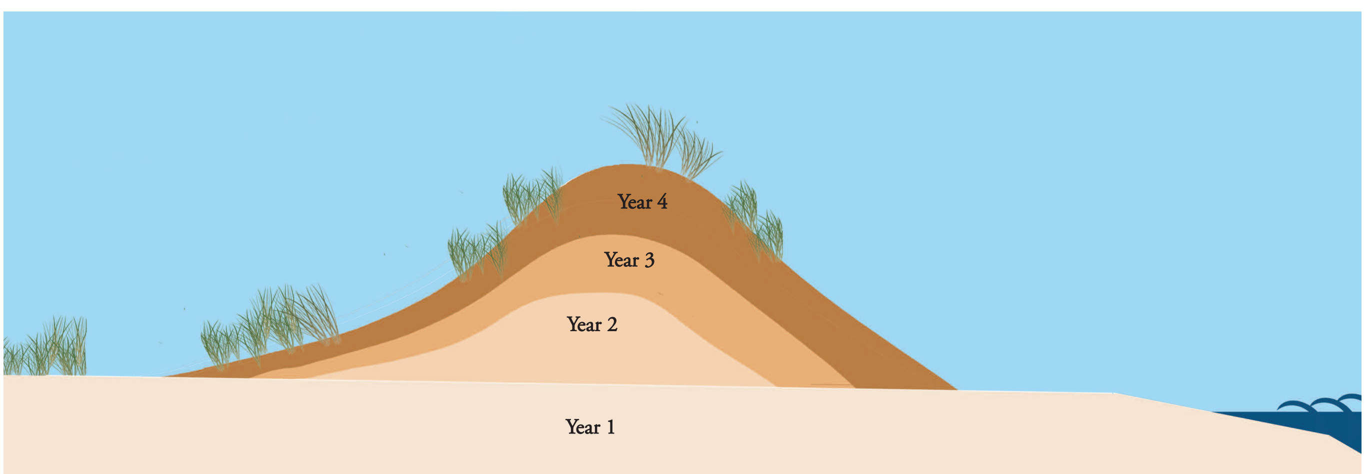

Figure 4. Dune width and height increase over time and migrate in a seaward direction (Rogers and Nash 2003).

On eroding coastlines, dunes respond by shifting landward as the beach erodes. The existence of dunes along eroding shorelines is an indication that sand is intermittently being transported into the dunes. On natural dunes, as sand is lost on the seaward side, it is typically deposited on the crest and landward side of the dune (Psuty and Ofiara 2002) during overwash. Along developed coastlines, however, there is typically limited space for the dunes to shift inland, which exposes the dunes to increased wave attack and scarping (vertical erosion) that threatens to destroy the dune system (Figures 5A, B).

Figure 5A. Dunes eroded by Hurricane Ida in New Jersey. Figure 5B. Eroded dune base resulting from strong wave action during a severe storm.

Short-Term Evolution

Sediment Deposition for Dune Growth

Wind is the main force responsible for the establishment, growth, and maintenance of coastal dunes. When a strong wind blows across a sandy beach, it picks up grains of sand which then move by sliding, rolling, or even hopping past one another. Lighter grains of sand are capable of being moved more easily and can travel farther, while the heavier grains are left behind. Natural and artificial obstructions on the beach cause the wind to slow down, which results in depositional areas in select locations. On a natural beach, vegetation is the most common obstruction, while on developed beaches, snow fencing or sand fencing is frequently installed to mimic the effect of vegetation and accelerate dune growth (Figure 1). The rate at which the wind can supply sand to a dune depends on the strength of the wind and the availability of a sand source. A beach with a wide berm typically provides an adequate sand source and will allow the dune to grow; however, if the beach is narrow, there may be an insufficient sand supply, which limits dune growth. On naturally narrow beaches, beach nourishment projects represent an opportunity to encourage dune growth that might not occur otherwise.

As a dune grows, it becomes asymmetrical in shape, with a steep seaward face and a mildly sloping landward tail. As the dune becomes taller and the vegetation becomes denser, the backdune is sheltered from the wind. Under these conditions, growth landward of the crest is reduced, while seaward of the crest, growth remains steady. On wide, depositional coastlines, it is possible for several distinct dune features to develop. If more than one line of dunes exist, the landward line must be established first.

Otherwise the line closest to the shoreline will trap sand, preventing it from reaching the original dune. Generally, the seaward-most dune will continue to grow seaward until the toe of the dune reaches the landward limit of seasonal beach fluctuations. If the toe of the dune reaches the mean high water line, beach use for both humans as well as rare, threatened, and endangered species can be inhibited. Healthy beach and dune systems require both a dune and a fronting beach, which may require periodic beach nourishment projects in areas where natural sediment sources have been compromised.

Sand Grain Size

The size of sand grains on a beach influences the rate of sand transport and dune growth. On a natural beach, a given sample of sand will contain particles of varying sizes, each of which respond differently to a given set of wind and wave conditions. Fine-grain sands will move more easily, remain in motion longer, and therefore travel farther than coarse-grain sands. The result is a tendency for wind and waves to sort beach sediment. Fine-grain sand is more easily removed from the beach face and is commonly found in dunes and offshore in deeper water. Once the initial layer of fine sand is removed from the beach, the remaining larger grains armor the ground surface, making it more difficult to transport additional sand. Higher wind speeds or larger waves are then required to continue the transport process after the fine surface materials have been removed. On most beaches, the sand found at the bottom of the foreshore slope, near the location of most intense wave action, is typically the coarsest sand.

Vegetation

Vegetation is an important part of the evolution of dunes, as it serves multiple ecological and physical purposes. Vegetation slows the wind, causing some of the trapped wind-blown sand to settle to the ground. The heavy grains fall out first, as more energy is required to keep them suspended. As the wind deposits the sand, it accumulates around the vegetation, initiating the creation of a new dune or contributing to the growth of an existing one. The accumulating sand promotes the growth of vegetation uniquely adapted to dune environments. Both the vegetation and the dune grow in elevation simultaneously as the roots of the vegetation strengthen and help reinforce the base of the dune. While barriers such as sand fences can recreate the trapping efficiency of vegetation, they cannot grow with the dunes like vegetation and therefore require maintenance over time.

The most effective dune systems in both promoting habitat and providing storm protection are those in which the appropriate vegetation is encouraged in each

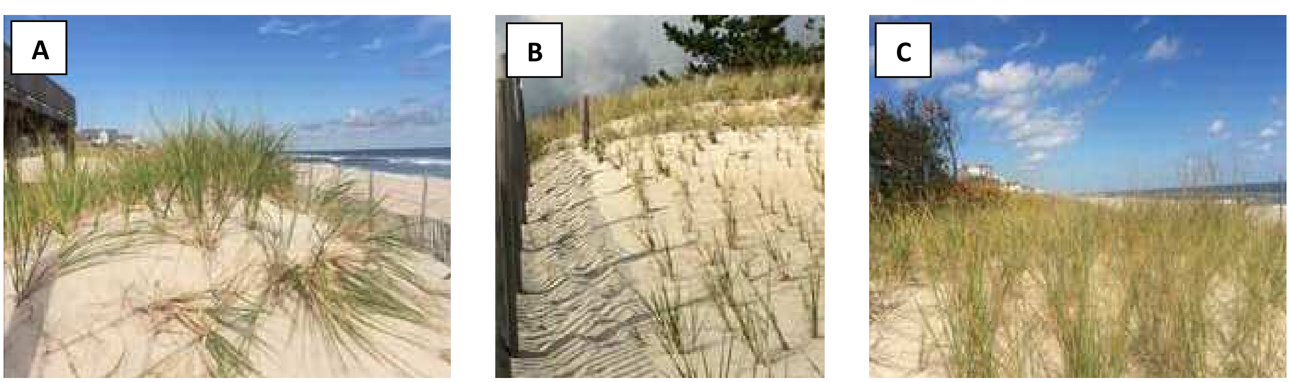

Figure 6A, B, C. American beachgrass on dunes on Long Beach Island, New Jersey.

Figure 7A, B. Multiple species of dune plants that colonize along the landward side of an established dune.

zone. 'Cape' American beachgrass *(Ammophila breviligulata)* is the primary plant species found on foredunes (or pioneer zone) in New Jersey (for more information, see the dune planting section of this guide) (Figure 6A-C). American beachgrass thrives on windblown sand deposits and collects sparse nutrients from the incoming sand, stimulating growth and reproduction. American beachgrass establishes quickly and spreads rapidly, making it a favorite among communities undertaking dune restoration projects. Trapping rates of 2 to 4 feet per season have been observed along densely cultivated dunes.

In natural dune systems, as growth progresses, multiple species of plants will begin to colonize areas landward of the foredune. In New Jersey, typical species are rugosa rose (*Rugosa rosa*), bayberry (*Morella pensylvanica*), and goldenrod (*Solidago sp*.) (Figure 7A, B). Species diversity is important for dune stabilization because each plant type has a different capacity to retain sand through its roots and above-ground vegetation. One of the most common mistakes communities make when undertaking a dune restoration project is planting a single species (most often American beachgrass) everywhere within the dune complex. Within the dune system, dense and diverse native herbaceous plants in the appropriate zones can provide habitat to pollinators and other wildlife. In the beach berm zone, the appropriate vegetation is native, herbaceous, and very sparse (<10% cover). More information on the type of vegetation appropriate for each zone is covered in subsequent chapters; however, dune planting should always be consistent with a community's beach management plan and should be coordinated with the ENSP to ensure that habitat provisioning is not compromised.

Sand Fencing

Sand fencing or snow fencing is often used as a means of accelerating or controlling the growth of dunes. Sand fencing performs a role similar to the stems of the vegetation on a natural beach. By slowing the wind to a point below that which is required to keep sand grains entrained, deposition is encouraged. Sand accumulates around the base of the sand fence, similar to the way snow accumulates around a snow fence in colder climates. Fencings of various materials and densities have been utilized. However, experiments have found that the typical wire-bound, wood-slat fencing with a width roughly equal to the spacing between slats (50% porosity) traps about as much sand as other, more costly materials (Manohar and Bruun 1970) (Figure 8A, B). Due to the relative cost effectiveness of this type of fencing, it is the type most frequently used in New Jersey.

In terms of effectiveness, it has been found that sand will accumulate and eventually reach a level about three-fourths of the exposed height of the sand fence (Hamer et al. 1992), depending on factors such as limitation of space and sediment supply. In Dover Township (now Toms River Township), New Jersey, a 4-foot-tall sand fence placed in a straight line parallel to the ocean was observed to trap concave sand

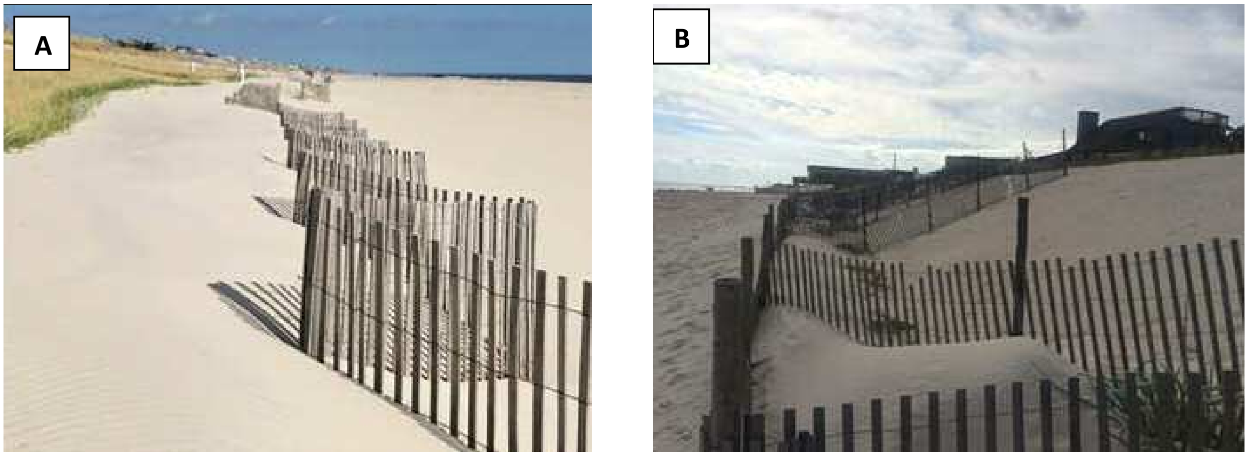

Figure 8A, B. Examples of dune fences with sand accumulation.

deposits 40 feet wide and 3.5 feet high (Herrington 2004). Although there are some subtle differences in sand-trapping ability, the most important factor is the total length of fence in a given area. Studies have shown that where windblown sand is abundant, installing twice as much fence (one row about 40 feet behind the first) traps about twice as much sand, regardless of fence alignment (Hamer et al. 1992).

Sand fencing is also commonly used for several other activities related to dune building in New Jersey. Several coastal communities deploy sand fencing seasonally to reduce the amount of wind-blown sand deposited in the street and/or on private property during the winter months. Typically, this material is redistributed on the berm during the spring. Some communities also try to use sand fencing to create desired dune geometries. By strategically placing fencing, dune characteristics such as height, width, and uniformity can be controlled. Although these practices are not advocated, if they are conducted they should be included in a community's beach maintenance plan and should be coordinated with the NJDEP to ensure that the beach/dune system (including habitat provisioning) is not compromised during the process.

Seasonal Variability

On stable or eroding coastlines, the seasonal fluctuation in the beach profile limits the seaward extent of the coastal dune system. Pioneer dune grasses typically encroach on the berm during the summer, advancing the dune seaward. During the winter, this summer growth is subsequently cut back by storms that erode the berm and cut into the dune toe. Where fully established dune systems exist, the berm will typically be eroded back to the seaward line of dune vegetation. This seasonal process gives rise to the relatively clear, straight vegetation lines found on many natural beaches (Rogers and Nash 2003) which represent the landward limit of wave-induced erosion during the last several storm seasons.

In New Jersey, seasonal weather patterns cause dynamic changes in the beach profile. During periods of high wave energy, the foreshore slope is flattened as sand erodes from the berm and moves offshore. Typically, much of the sand is stored relatively close to shore in underwater sandbars. If the storms are severe enough, the erosion may extend all the way across the beach berm and impact the base of the dunes. This causes an avalanching processes known as *beach scarping,* which can result in large vertical cuts in the seaward dune face. During periods of reduced wave energy, the New Jersey coast is exposed to smaller, less frequent storms and long-period ocean swell that transports sand from offshore back onto the dry beach. During this process, the foreshore region is steepened and the widest beaches of the season (typically during the late summer/early fall) are formed. Overall, these seasonal fluctuations can add up to 75 to 100 feet of horizontal and 2 to 5 feet of vertical change.

Storms and Recovery

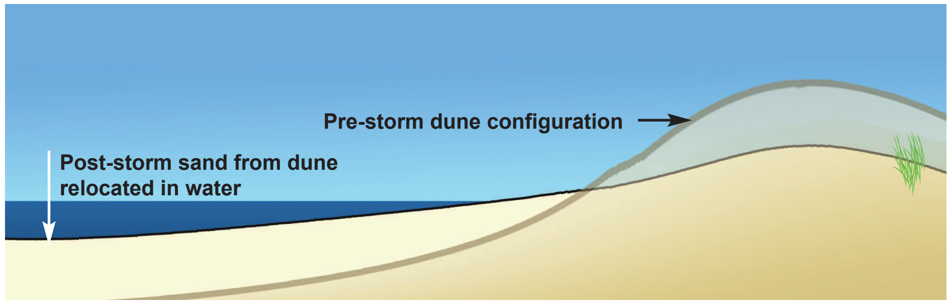

Figure 9. Relocation of sand after a storm.

Small storms typically only impact the beach/berm system and leave the dunes intact. The pre-storm beach width, elevation, and presence/absence of vegetation will affect the severity of the erosion experienced during a storm. In addition, if the beach has been left vulnerable by previous storms, increased erosion is likely. In fact, the cumulative effects of two closely spaced minor storms can often exceed the impact of a single severe storm.

Dune recession typically only occurs during larger, more infrequent storm events. During these strong storm events, the berm erodes first, which exposes the foredune to direct wave impact. As the waves erode the base of the dune, the front face eventually becomes unstable and collapses. During routine storms, most of the eroded sand is temporarily stored offshore in sandbars that migrate onshore during calm weather. The beach berm can recover to its pre-storm width and elevation in a matter of months. Depending on the extent of the erosion, post-storm dune recovery can take much longer. While the dune begins to recover almost immediately, it typically takes several growing seasons for the beach, dune, and vegetation to return to pre-storm conditions. In some cases, it has been found that full recovery from the most extreme storms can take up to a decade (Rogers and Nash 2003). In the wake of severe storms, emergency beach nourishments are often utilized as a way to rebuild the beach and accelerate dune recovery.

Breaches

Storms like Sandy that generate extreme water levels and intense wave action can generate breaches in undersized sand dune systems. Breaches can occur either from the land side or the bay side, depending on the relative elevation of the water. On undeveloped coastlines, breaches and overwash are natural processes that contribute to barrier island migration and refresh important habitats. On developed barrier islands, however, breaches represent one of the most destructive short-term erosion hazards as swift currents can create deep channels capable of carrying away anything in their paths. During Superstorm Sandy, multiple breaches were formed in the Borough of Mantoloking, resulting in extensive damage to the community (Walling 2015). When they occur in developed areas such as Mantoloking, breaches are typically closed manually through sand placement or structural means; however, when they occur on natural coastlines, breaches may be left to evolve naturally.