# Coastal Habitats
# 2. Beach Nourishment

## DEFINITION

*Beach nourishment* is the addition of sediment, usually sand, directly on or adjacent to an eroding beach (USACE n.d.a). Beach nourishment involves transporting large quantities of sand to the eroding beach to help stabilize it. The additional sand is then redistributed across the intertidal zone by natural processes such as incoming wave energy and managed erosion (USACE 2007). Sand can either be transported overland from inland sources or dredged from nearby areas offshore. Beach nourishment falls under the category of *soft* or *green* shoreline defenses because, while significant human alterations to the shoreline are involved, beach nourishment uses natural processes of sediment deposition, whereas gray infrastructure does not. Beach nourishment is increasingly necessary as natural sediment deposition processes are disrupted by anthropogenic activities like urban development, damming rivers, and dredging channels (Staudt et al. 2021). The impacts of climate change, especially sea level rise and increased storm severity, require more frequent beach nourishment (Stive et al. 1991).

## TECHNICAL APPROACH

Implementing a beach nourishment project requires moving large amounts of sand into the correct position on the beach. The process varies considerably depending on the source of the sand (Haney et. al. 2007). When choosing which source to use, managers must consider the compatibility of the new sand with naturally occurring sand at the beach. Sand sources must have similar composition, texture, and color to natural sand in order for the project to be successful (Parkinson and Ogurcak 2018). There are several sand source options:

- **Sand from offshore sources:** Dredging sand directly offshore from the recipient beach is the most common technique of beach nourishment (Figure 1). A hopper or pipeline dredge sucks sediment up from the bottom of the ocean and then pumps it onto the beach via a long tube (NPS 2019). While this method reduces the logistical complexities of transporting sand, it can have detrimental impacts on bottom-dwelling and migratory species (NRC 1995).
- **Sand from inlet sources:** The dredging process is similar to extracting sand from offshore sources, except that the dredge is usually smaller. Sand from a nearby inlet, sound, or waterway is dredged onto the beach. The advantage of this approach is that the sediment source is more frequently replenished from depositions of inland rivers (Qiu et al. 2020).
- **Sand from upland sources:** Retrieving sand from upland sources and transporting it to the beach has been an increasingly popular method of beach nourishment because of lower mobilization costs and greater quality control. Inland sand mines harvest the

sand, which is then loaded on trucks that transport it to the beach. The downsides of this approach are that it takes thousands of truckloads to complete large projects and the trucks need access to the beach (Brenner 2016).

- **Sand from previously planned dredging projects:** Sediment is frequently dredged for other purposes besides beach nourishment, usually to deepen shipping channels around commercial ports. Using the sediment gathered during these projects for beach nourishment helps limit the cost of dredging sand. It also lessens the environmental impact of dredging and reduces the amount of dredged material that ends up in landfills (USACE n.d.b).

Sometimes, sand is not placed on the subaerial (above water) portion of the beach because of ecological or financial constraints (NPS n.d.). Alternative strategies involve depositing the sediment closer to the dredge site, reducing transportation costs. These techniques rely on natural currents to transport the sediment to the target beach (Dean 2002). Ecologically, these techniques are often selected because benthic communities further offshore can recover more quickly after nourishment than those in the intertidal zone (Essink et. al. 1997). Therefore, the following alternative beach nourishment strategies are often used:

- **Subaqueous nourishment:** *Subaqueous nourishment* involves dredging sediment and depositing it offshore of the beach in berms. Over time, wave action will help the sand migrate shoreward and gradually replenish the beach (Atkinson and Baldock 2020).

### Figure 2.1 Nourishment of Ocean View Beach in Virginia via dredging and sand redistribution

Photo courtesy US Army Corps of Engineers

- **Sediment bypassing:** *Sediment bypassing* is where the dredged material is dumped downdrift of the desired nourishment location. Sediment bypassing is often paired with the dredging of an armored inlet, replacing the lost source of sediment associated with hard armoring (NPS n.d.). The sediment is then carried by the current to the desired location (Dean 2002).

### Small Island Creation

*Small island creation* is a particular type of beach nourishment where a previously submerged island is rebuilt via dredged sediment. The process of small island creation is similar to both beach nourishment and thin layer placement in coastal marsh restoration. However, a major difference is that the recipient area has already been submerged, complicating the process of depositing dredged sediment at the site (USACE n.d.a.).

Small island creation is primarily used to create barrier islands or restore salt marshes that have previously been submerged. Barrier islands have many benefits, including storm protection and recreational value (Morton 2008). Barrier islands are naturally ephemeral geomorphic features, with inlet formation and sediment transport constantly changing. However, hardened shorelines have hastened the decline of sediment transport, resulting in the need for island nourishment and small island creation (Feagin et al. 2010).

In the context of salt marshes, small island creation is viewed as alternative to assisted marsh migration. Within the resist-adapt-direct framework of ecosystem management, assisted marsh migration would be under the *direct* phase while small island creation would be considered *resisting* (Schuurman et al. 2020). Small island creation is used in scenarios where the upland habitat is not suitable for marsh migration, but managers still want to preserve it. Small islands are created within the inundated marsh using dredged material. Marsh vegetation will then migrate to or be planted on the island, preventing the marsh from being submerged (Myszewski and Alber 2017).

The sustainability of small island creation projects has often been questioned because of the rapid pace of sea level rise. Even if the island can remain above sea level for a few more years, subsequent nourishment events will be needed to combat tidal erosion. Modeling sea level rise at the site is important to understand the longevity of the project's benefits (Stive et al. 1991).

## OPERATIONS AND MAINTENANCE

After beach nourishment, it is necessary to plow the sand to prevent compaction. Beach access points must also be maintained as sand shifts following nourishment. Because beach nourishment does not address the cause of sand erosion that threatens beaches, it must be repeated every 2 to 10 years to maintain the beach width (Staudt et al. 2021).

## FACTORS INFLUENCING SITE SUITABILITY

- ✓ **Gently sloping beaches with minor upland erosion:** Steep cliffs and severe erosion make it difficult to complete beach nourishment (VIMS 2023).

- ✓ **Proximity to already-planned channel dredging projects:** Beneficial use of dredged material agreements are much easier to facilitate when the dredging location is close to the beach nourishment project. Dredged sediment is very heavy and difficult to transport (VIMS 2023).
- ✓ **Established groin fields with sand present:** Adding onto an already existing beach is much easier than recreating a beach after all the sand has already eroded (VIMS 2023).
- ✓ **Beach that receives significant recreational use:** Recreation is one of the major drivers of beach nourishment. Beach nourishment widens the beach, increasing its ability to handle more beachgoers.
- ✓ **Upland infrastructure at risk of flooding directly behind the beach:** Beach nourishment provides additional space between the ocean and development, protecting property from sea level rise and storm surges (TGLO n.d).
- ✗ **Presence of submerged aquatic vegetation or mangroves:** Beach nourishment can significantly degrade these ecosystems, reducing their coastal protection capacity (Nunez et al. 2022).
- ✗ **Special geomorphic features, such as sand spits:** Sand spits and other special geomorphic features are highly ephemeral. It is not worth investing in beach nourishment for an area that will naturally disappear (Nunez et al. 2022).
- ✗ **Area where sand migration will inhibit boat navigation or surrounding land uses:** In small waterways, beach nourishment will take over a significant portion of the channel with sand. This will compromise the navigability of the waterway (VIMS 2023).
- ✗ **Bank height greater than 9 meters:** Erosion on banks greater than 9 m is generally not caused by tidal erosion, which beach nourishment is meant to address. Beach nourishment is unable to mitigate other drivers of erosion such as overland runoff, upland development, and vegetation management (Nunez et al. 2022).
- ✗ **Directly in front of a seawall:** Seawalls are drivers of erosion. Investing in beach nourishment in areas that are experiencing accelerated erosion from anthropogenic factors is not a viable strategy (Thibodaux 2018).

## TOOLS, TRAINING, AND RESOURCES FOR PLANNING AND IMPLEMENTATION

| Name and Link | Resource Type | Year | Authors/ Authoring Organization | Geography | Description | Resource Includes: Design/Construction Guidance? | Site Selection? | Monitoring Guidance? | Example Projects? |
|---|---|---|---|---|---|---|---|---|---|
| Handbook of Coastal Processes and Erosion, Chapter 11: Principles of Beach Nourishment | Book chapter | 2017 | Paul D. Iomar | National | This guide gives a framework for designing beach nourishment projects and weighing the trade-offs between different sediment sources. Other topics include estimating the life expectancy and slope adjustment for a project. | ✓ | — | — | ✓ |
| Beach Nourishment: Theory and Practice | Guidebook | 2002 | World Scientific | National | Developed to be used by project designers, this book contains information relating to designing and executing a successful beach nourishment project. Accounting for differences in sediment sizes, bathymetry, and beach profiles are all covered. | ✓ | — | — | ✓ |
| Beach Nourishment Resiliency Design Guide | Guidebook | n.d. | Texas Government Lands Office | Designed for Texas but most of the information is more broadly applicable | This easy-to-read guide covers all the main elements of beach nourishment, from analyzing the site characteristics to monitoring. Included is a helpful infographic that lays out the entire spectrum of green to gray shoreline defense techniques. | ✓ | — | ✓ | — |
| State, Territory and Commonwealth Beach Nourishment Programs | Guidebook | 2000 | National Oceanic and Atmospheric Administration (NOAA) | National | NOAA provides an overview of the beach nourishment programs and projects across the United States. Additional topics covered include funding sources for projects, alternative strategies for managing beach erosion, and issues regarding beach nourishment. | — | — | — | ✓ |

| Name and Link | Resource Type | Year | Authors/ Authoring Organization | Geography | Description | Resource Includes: Design/Construction Guidance? | Site Selection? | Monitoring Guidance? | Example Projects? |
|---|---|---|---|---|---|---|---|---|---|
| Beach Nourishment and Protection | Guidebook | 1995 | National Research Council | National | This guide covers beach nourishment design, predicting future erosion, and the role of federal agencies in the process. The authors also outline the monitoring process and economic feasibility of projects. | ✓ | ✓ | ✓ | — |
| Beach Nourishment | Guidebook | 2007 | Massachusetts Department of Environmental Protection | Designed for Massachusetts but most of the information is more broadly applicable | Beach stability determinations, information about permit requirements, and monitoring plans are just some of the information presented in this practical guide. The authors provide a helpful six-step plan for beach nourishment and address the problem of getting source sediment to match the sediment of the receiving beach. | ✓ | ✓ | ✓ | — |
| Shoreline Protection Assessment: How Beach Nourishment Projects Work | Document | 2007 | USACE | National | The authors describe the value of beach nourishment projects as well as the engineering considerations that go into them. Additional topics covered include the environmental implications of beach nourishment and how projects respond to storms. | ✓ | — | — | ✓ |
| National Beach Nourishment Database | Database | 2023 | American Shore & Beach Preservation Association, APTIM | National | This resource is a compilation of every beach nourishment project in the United States. Equipped with a map to help navigate the projects, the database includes the cost of beach nourishment projects as well as how many nourishment events have been completed. | — | — | — | ✓ |

## GRAY INFRASTRUCTURE ALTERNATIVES

Beach nourishment can be an alternative to several gray infrastructure approaches that reduce the effects of beach erosion and preserve beach width: bulkheads, riprap/revetments, seawalls, groins, and artificial breakwaters. The ability of a beach nourishment project to replace or supplement one of these gray infrastructure types strongly depends on the project's location and whether it is designed to create the necessary outcomes. Certain environmental conditions may require gray infrastructure rather than beach nourishment. See the gray infrastructure alternative tables in Section 1 for a comparison of beach nourishment to these alternatives.

## LIKELY BENEFITS AND OUTCOMES

Primary objectives for each strategy are highlighted.

### Climate Threat Reduction

- **Storm protection:** Beach nourishment is highly effective at reducing impacts from severe storms, averting millions in property damage. However, the storm may significantly degrade the beach itself, requiring another round of nourishment to extend the benefits into the future (Pompe and Rinehart 1995).
- **Reduced flooding:** Beach nourishment serves as a vital defense against storm surges. Waves must travel over longer distances of a nourished beach during a storm surge, resulting in communities with beach nourishment avoiding significant flood damage (Jones and Mangun 2001).
- **Sea level rise adaptation and resilience:** Beach nourishment has been shown to lessen the impacts of sea level rise. Beach nourishment provides a greater buffer zone in between the ocean and developments, allowing for the coastline to absorb rising sea levels. Nourishing the underwater portion of the shore is also important to allow the shore to accrete (Stive et al. 1991).

### Social and Economic

- **Tourism:** Tourism is often the economic engine of coastal resort towns, with beach access being the primary draw for visitors. Therefore, preserving a wide and accessible beach is a paramount concern for many communities. Studies have shown that even expensive beach nourishment projects usually pay for themselves in tourism revenues (Jones and Mangun 2001).
- **Reduced or avoided costs:** Beach nourishment has reduced the cost of flood insurance in many properties surrounding the project (Leatherman 2018).
- **Increased property values:** Beach nourishment has been shown to increase the value of nearby properties. This results from the storm protection that wider beaches provide as well as the increase in recreational and tourism opportunities (Edwards and Gable 1991).
- **Cultural values:** Beaches are highly valued in American culture and are a vital source of recreation for millions of people each year (Wolch and Zhang 2017).

- **Mental health and well-being:** Beach nourishment helps restore public shorelines, boosting mental health and psychological well-being.
- **Jobs:** Contractors will need to be hired to operate the extensive machinery required for a beach nourishment project, contributing to the local economy.
- **Reduced erosion:** While coastal erosion has increased globally as sea level rise and severe storms degrade coastlines, areas with beach nourishment have had an increase in accretion of sediments as opposed to erosion. This has been seen along the Atlantic Coast of the United States, where there has been a long-term shift toward accretion resulting from the prevalence of beach nourishment (Armstrong and Lazarus 2019). While beach nourishment does not temper the drivers of erosion, it is still able to mask the effects. On the other hand, gray infrastructure such as seawalls accelerates erosion, significantly degrading intertidal habitat (Pilkey and Wright 1988).

### Ecological

- **Supports wildlife:** Unlike gray infrastructure, which eliminates intertidal habitat, beach nourishment increases the amount of intertidal habitat available for use by wildlife species. While this habitat may be temporarily disrupted during nourishment events, it helps protect the ecosystem in the long term (Speybroeck et. al. 2006). Downdrift and upland habitats adjacent to beach nourishment projects reap the benefits of beach nourishment projects as well. Erosion of sediment from the beach to downdrift undeveloped habitats helps restore the role of developed areas as sediment sources. Beach nourishment also buffers upland dune and marsh habitats by dissipating most of the wave energy (Nordstrom 2005). Sea turtles are one species of high conservation value that benefit from beach nourishment. Beach nourishment helps increase sea turtle breeding grounds that have suffered from sand deficits as a result of hard armoring. While nourishment events can disrupt sea turtles' nests, these can be strategically timed to avoid conflicts (Montague 2008).
- **Increased biodiversity:** While beach nourishment can have deleterious effects on the ecosystem in the short run, the disruption caused by beach nourishment can create a greater diversity of habitats within the cycle of succession. Beach nourishment helps address the lack of early succession communities in coastal habitats, creating a diversity of habitats that favors a wide variety of species. Furthermore, beach nourishment protects coastal habitats against sea level rise and erosion, enhancing their long-term sustainability (Kindeberg et al. 2023).

## BARRIERS AND SOLUTIONS FOR PRACTITIONERS

### Common Barriers

Several barriers are common across many of the nature-based solutions strategies; these are described in more detail in Section 1 of the Roadmap. Additional notes about the barriers specific to beach nourishment are included here.

- **Expense:** Beach nourishment is expensive because of the large amount of equipment needed to complete a project. Mobilization costs for dredges alone range from $100,000 to over $1 million (TGLO n.d.). These high mobilization costs make transporting sand from upland mines more economical for smaller projects. However, for large projects, dredges make more sense as the large volume of sediment deposited pays for the high upfront cost (Dobkowski 1998). In recent years, the cost of beach nourishment has been rising, with the average increasing $10 per cubic meter. Beach nourishment projects are known to overrun cost estimates because of delays, storms, and logistical challenges (Parkinson and Ogurcak 2018).

- **Capacity**
- **Public opinion**
- **Conflict with other land uses**
- **Regulation**
- **Lack of effectiveness data**

## Economic

- **Required repetition:** Beach nourishment is not a permanent fix to eroding shorelines and must be redone periodically to restore the beach. Facing the prospect that an investment of millions of dollars may only result in two years of protection makes beach nourishment infeasible for many communities (Smith et al. 2009).
- **Need for tourism to recoup the cost:** Most beach nourishment projects are undertaken by local municipalities who justify the high cost by pointing to increases in property values and tourism, both vital sources of tax revenue. However, projects on federal lands do not reap these same benefits because there is no private property to tax and most units do not charge entrance fees. Thus, it may be more difficult to secure funding for federal land managers than local municipalities (NRC 1995).

## Community

- **Heavy truck traffic:** For projects that use upland sources of sediment, a large number of trucks will be needed to transport the sand to the nourishment site. Many coastal communities have limited highway access and the truck trips for the project may plunge the entire community into gridlock. Trucks used for the Sandy Hook beach nourishment project in New Jersey caused the destruction of beach dunes, snarled local roads, and closed the beach to recreational users (Nordstrom et al. 1978). Most trucks can only carry 12 to 18 $y^3$ of sediment (Smith 2013). For example, an average-sized beach nourishment project of 5,400 $y^3$ would require 360 truck trips (Cipriani et al. 1999)
- **Positive feedback loop of development:** Beach nourishment gives communities a greater sense of security despite the grave risks of sea level rise, erosion, and severe storms associated with living along the coast. After a beach nourishment event, more developments are built behind the nourished beach. While this may be advantageous to individual developers, increased urbanization along the coast lessens resiliency to climate change in the long term (Armstrong et al. 2016).

- **Temporary lack of beach access:** During a nourishment event, beaches must be temporarily closed to the public to ensure safety while the heavy equipment works on the beach. Beach nourishment must be performed under ideal weather conditions, which coincides with the main tourism season. Coastal communities may lose portions of a lucrative tourism season if the beach is closed (Smith 2013).

## Ecological

- **Death of sessile animals:** Sessile animals, those that cannot move on their own, are prevalent along intertidal zones. During beach nourishment, these animals are either smothered or buried, causing immediate death from the impact of the sediment or subsequent mortality from lack of food. The mass die-off of these organisms after beach nourishment causes a trophic cascade as animals higher up the food chain struggle to find enough prey (Miselis et al. 2021).
- **Increase in water turbidity:** Beach nourishment can cause turbidity both at the mine site and the target beach. When sediment is mined, it disrupts the surrounding water and causes large amounts of sediment to become suspended in the water, increasing turbidity. At the target beach, turbidity increases when wave energy hits the sediments as they are being deposited, carrying excess sediment out with the current (Greene 2002).
- **Degradation of sediment source habitats:** When sediment is dredged from offshore or inlet sources, it can have detrimental impacts to the benthic communities that inhabit the dredging sites. Dredging causes mass mortality and decreased diversity as a result of the lack of sediments (Miselis et al. 2021). Inland sand mining has negative environmental impacts as well, reducing habitat, increasing sediment transport, and adding to carbon emissions by requiring thousands of truck trips (Dobkowski 1998).

## EXAMPLE PROJECTS

| Name and Link | Location | Leading Organizations | Techniques Used | Size, mi | Cost, $ | Duration | Project Description | Climate Threats Targeted | Lessons Learned or Adaptive Management |
|---|---|---|---|---|---|---|---|---|---|
| Buxton Beach Nourishment Project | Cape Hatteras National Seashore, Buxton, NC | **National Park Service (NPS);** Dare County, NC | Sediment dredging from offshore sources | 2.9 | 18,106,674 | 6 weeks | Contractor Great Lakes Dredge & Dock Co. used the dredger *Ellis Island* to deposit 1.2 million $y^3$ of sediment along the beach. | Sea level rise, coastal flooding, increasingly severe storms | Project was paused as the *Ellis Island* suffered mechanical issues and had to be repaired. |
| North End Restoration Project | Assateague Island National Seashore, MD | **NPS;** Maryland Department of Natural Resources; Worchester County, MD | Sediment dredging from offshore sources | 5.9 | 12,653,540 | 18 years (spans 4 nourishment events) | The north end of Assateague Island was at risk of disappearing from the urbanization of nearby Ocean City, MD, and the construction of a jetty that blocked sediment transport. Beach nourishment has helped restore the island and protect endangered species habitat. | Sea level rise, coastal flooding, increasingly severe storms | After severe storms in 1998, officials placed an emergency storm berm along the shore to protect the island until beach nourishment could occur. |
| Ocean Beach Nourishment Project | Golden Gate National Recreation Area, San Francisco, CA | **NPS,** USACE, City of San Francisco | Reusing sediment dredged to increase channel navigability | 0.57 | 13,370,000 | Not provided | Contractors constructed dunes and placed sediment onto the beach using a hopper dredge. | Sea level rise, coastal flooding | Crews worked on the project 24/7 because the source of the sediment, dredging to deepen the San Francisco ship channel, never stopped. |

| Name and Link | Location | Leading Organizations | Techniques Used | Size, mi | Cost, $ | Duration | Project Description | Climate Threats Targeted | Lessons Learned or Adaptive Management |
|---|---|---|---|---|---|---|---|---|---|
| South Padre Island Beach Nourishment Project | South Padre Island, TX | **US Geological Survey**, Coastal Texas Program, Town of South Padre Island, Texas General Land Office, USACE | Reusing dredged sediment, transporting sediment via trucks | 2.9 | 27,365,044 | 24 years (spans 13 nourishment events) | Sediment reused from dredging nearby shipping lanes was deposited on the beach. Additionally, sediment that blocked a local highway was removed and transported to the beach. | Sea level rise, coastal flooding, increasingly severe storms | Because of frequent storms and high rates of erosion, renourishment has occurred at an extremely quick interval. |
| Sandy Hook Beach Nourishment Project | Gateway National Recreation Area, NJ | **NPS;** USACE; Monmouth County, NJ | Sediment dredging from offshore sources | 21 | 414,028,787 | 59 years (spans 16 nourishment events) | The latest nourishment cycle, which costs $26 million, involves dredging sand to the eroding beach in the largest beach nourishment project ever undertaken. | Sea level rise, coastal flooding, increasingly severe storms | Every batch of sediment must be inspected for unexploded munitions, given that this area was once an army training ground. |
| Dade County Beach Erosion and Hurricane Protection Project, Miami Beach Renourishment | Miami Beach, FL | USACE, City of Miami Beach | Trucking in sediment from an upland sand mine | 9.3 | 87,889,481 | 40 years (spans 37 nourishment events) | To restore one of America's most well-known beaches, contractors have trucked in around 17 million $y^3$ of sand over the course of 40 years to help sustain the beach. | Sea level rise, coastal flooding, increasingly severe storms | Sea turtle nests were relocated to protect them from the impacts of the project. |

**Bolding** indicates DOI affiliates.

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