Sea Grant
WOODS HOLE OCEANOGRAPHIC INSTITUTION

WHOI Sea Grant · Cape Cod Cooperative Extension · Spring 2023

MARINE EXTENSION BULLETIN

Beach Nourishment Guide for Homeowners

By Greg Berman, Coastal Processes Specialist

INTRODUCTION

Coastal beaches have natural beauty and intrinsic value, but they also provide storm damage prevention and protect wildlife habitat. Human-built structures, like revetments and sea walls, alter the natural movement of sediment, reducing the supply of sand to adjacent and nearby beaches and can create a "sand-starved" system. These stabilization projects, also referred to as shoreline armor, are designed to protect the upland upon which a house is located, but erosion is often shifted to other coastal resources seaward of these structures.

To make up for the reduction in the sediment supply caused by these projects, compensatory nourishment is almost always required during the permitting process for a proposed new Coastal Engineering Structure (CES) as well as for the reconstruction or repair of existing structures. These projects must comply with a variety of state and local regulations that can be complex and nuanced.

RATIONALE FOR COMPENSATORY NOURISHMENT

Beaches and dunes are comprised of sand that comes from the erosion of coastal banks. Coastal beaches provide storm damage prevention by allowing wave energy to dissipate along their gentle slope. When sand is lost from a beach its elevation is lowered enabling larger waves to reach the shoreline, which increases the vulnerability of nearby habitats and coastal houses. This loss of sand can impact many species of animals (e.g., birds, turtles, shellfish, etc.) that depend upon a beach habitat of a specific elevation. If the beach height drops due to lack of sediment supply, it may no longer be suitable for these species.

This bulletin is intended for conservation commissions, property owners, their consultants, and others involved in using sand as mitigation. Its goal is to consolidate and synthesize the many regulatory and guidance documents on this topic to assist in navigating these projects.

There are three reasons why a stabilization project might be required to provide sediment on an ongoing basis:

1. To mitigate for the elimination of a sediment source for a downdrift beach

- State regulations require that the form and volume of beaches are not adversely affected.
- If the form and volume of the beach is reduced there will no longer be the same level of storm damage protection and wildlife habitat.
- Many recreational areas and public access sites would be eliminated without a constant supply of sand.

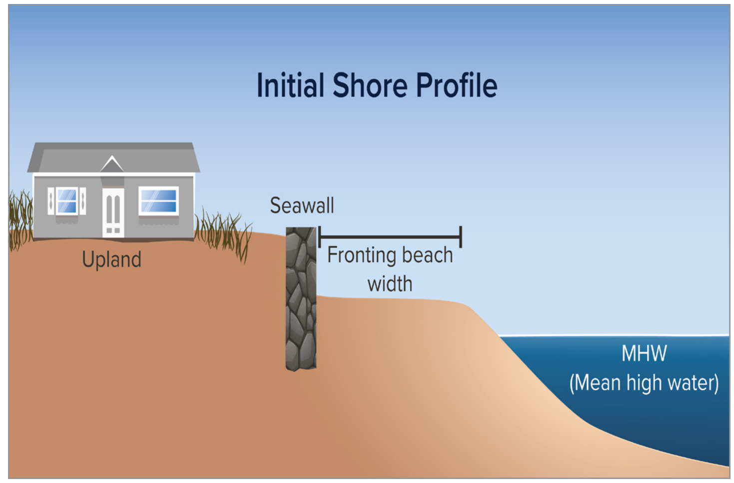
2. To reduce wave energy, mitigating for the structure's impact to the adjacent beach

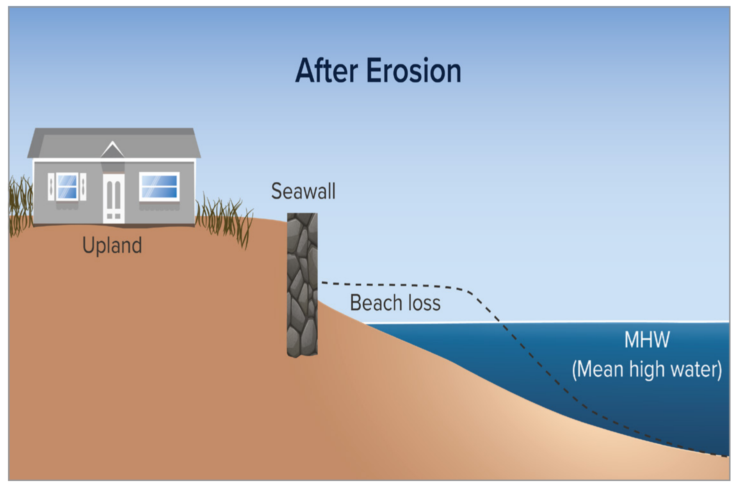
- Wave reflection off the hard structure of a CES can reduce the elevation of the adjacent beach, also jeopardizing the base of the CES.
- Reduce terminal (aka end scour) which can flank the CES. See image below.
- Keeping the adjacent beach to proper elevation will also help maintain the beach volume in front of the structure, increasing CES longevity and reducing the frequency of maintenance with its associated short term beach impacts.

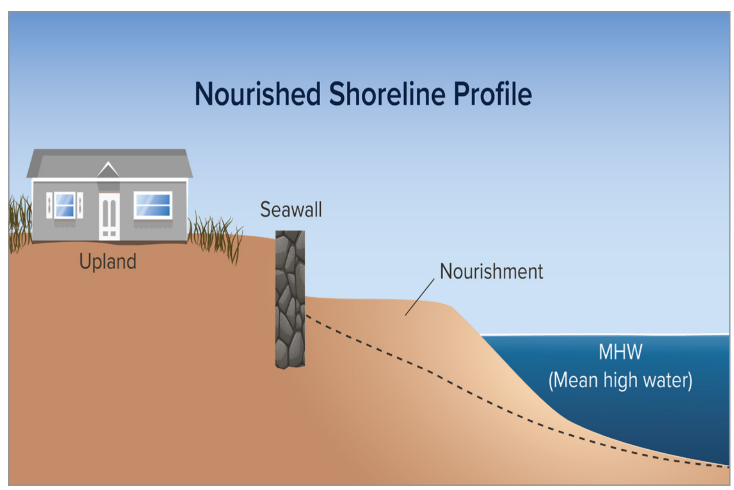
3. To protect biodegradable components

- Some projects use biodegradable components such as coir, which breaks down much more quickly when exposed to sunlight. Keeping the coir covered with sand will protect it and greatly increase the longevity of the material.
- Coir at the end of a CES can transition into an unarmored bank. Nourishment on, and at the end of, the coir can further reduce impacts from the end of a stabilization project.

An example of scour at the end of a bulkhead. Waves refract around the terminus of the CES exacerbating the erosion and compromising the structure.







Beach loss typically occurs in front of a seawall for a beach experiencing net longterm retreat. This beach loss can be mitigated through nourishment. (Figure adapted from Natural Hazard Considerations for Purchasing Coastal Real Estate in Hawaii - A Practical Guide of Common Questions and Answers, by University of Hawaii Sea Grant College Program, 2006.)

HOW TO CALCULATE NOURISHMENT REQUIREMENTS

The standard equation for calculating compensatory nourishment requirements is as follows:

Erosion Rate (ft/yr) x CES Length (ft) x Bank Height (ft)

= Compensatory Nourishment (ft^3/yr)

Erosion Rate

Often the CZM (Coastal Zone Management) Massachusetts Coastal Erosion Viewer is used if there is no finer scale information. If long-term and short-term rates indicate accretion (or minimal change), it is unlikely a CES would be needed at this location. At a minimum the long-term rate of erosion should be used; however, if the short-term rate shows faster erosion it may better represent current conditions. In any estimate of shoreline change, there is a "best professional guess" followed by a potential uncertainty in the analysis. For example, if the historical erosion rate is 1 ft/yr (+/- 0.5 ft/yr) then the actual erosion rate is somewhere between 0.5-1.5 ft/yr. While the "best guess" is typically used, in some sensitive areas the full erosion range (0.5-1.5 ft/yr) might be considered. Besides the uncertainty inherent in the analysis, these rates also look at the past and not the present or future. All reasonable future estimates of sea level include some degree of acceleration, which would consequently speed erosion rates. Mitigation volumes can be adjusted over time to account for this, however a new erosion rate is not easily calculated at a site that has had a CES installed and has received regular nourishment. A comparable, unarmored site might need to be used.

CES Length

The length of the Coastal Engineering Structure that is preventing the coastal bank from eroding is a relatively easy parameter to determine from the site plans.

Bank Height

Regardless of its proposed height, a CES is typically designed to stop erosion of the entire bank. The total height of the bank, and not just the height of a seawall or vegetated area, should be used to calculate the volume.

Compensatory Nourishment

The output of the equation is the required annual volume in cubic feet per year. To convert to cubic yards (CY) per year, divide by 27. If this turns out to be a relatively small amount, it may make more sense to nourish less frequently but with the same overall volume. For example, if the appropriate annual compensatory nourishment was 10 CY then it might be reasonable to place 30 CY every three years.

Additional Considerations

The annual compensatory nourishment requirement described above is mitigation to make up for the reduction of sediment supply to downdrift beaches. This may, or may not, help preserve the volume of the beach adjacent to the CES. If regulators determine there is a need to maintain the fronting beach, then a triggered nourishment requirement (aka trigger) might be compulsory, either instead of, or in addition to the annual requirement. To make use of a trigger, a secure visible marker(s) is typically installed on the CES during construction. When the beach drops below the elevation-based marker for a designated period of time, nourishment would be brought in to bring the beach back up to design elevation. This type of nourishment strategy would benefit from a monitoring plan that includes, at a minimum, yearly assessments of the beach elevation made at the same time of year to lessen the influence of seasonal fluctuations. Monitoring should also include examination of downdrift impacts and special conditions may be needed that allow the permitting authority to adjust nourishment volumes.

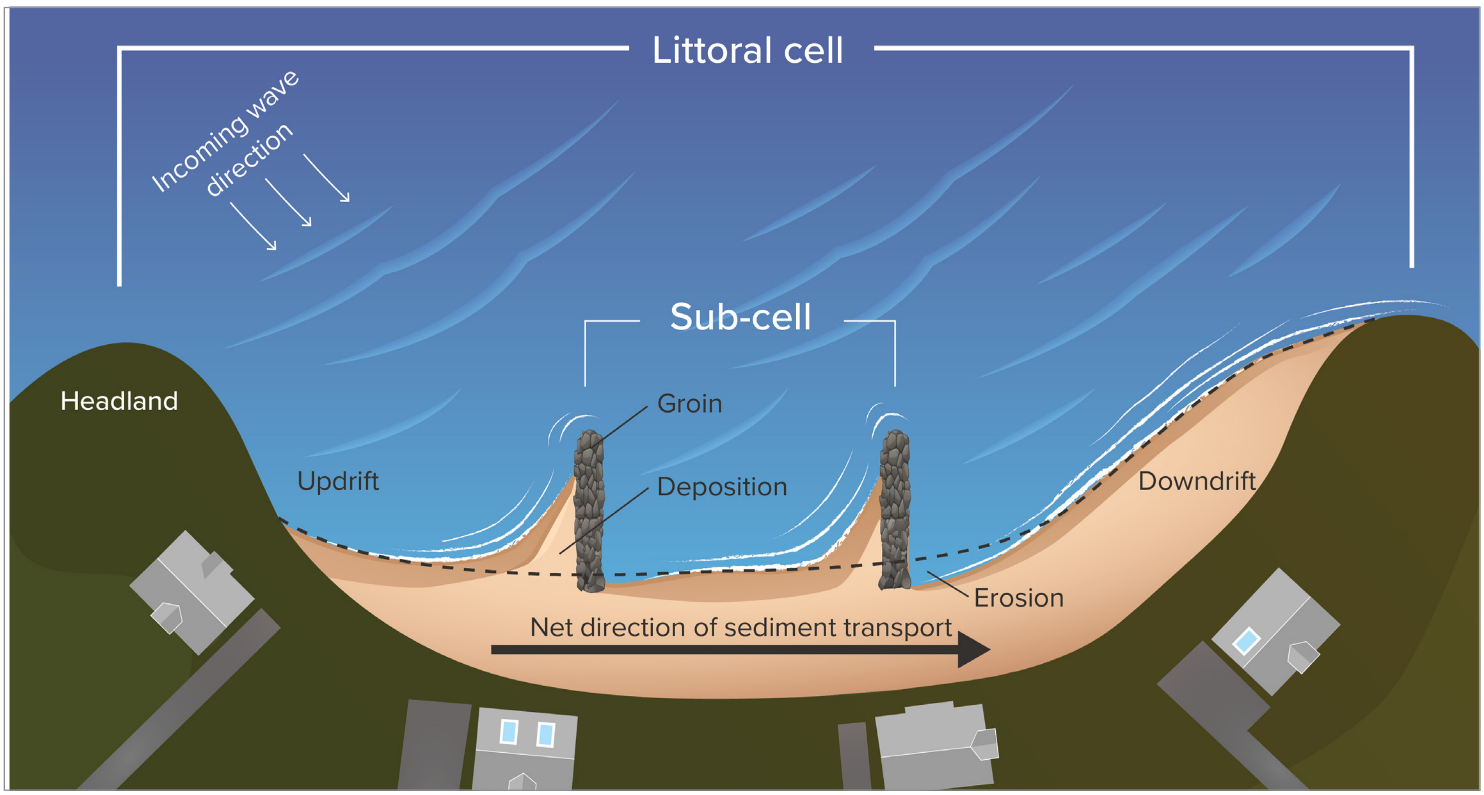
Triggers can also be required for stabilization arrays that are not considered a CES. Typically, non-CES arrays, such as coir, do not have the associated compensatory

If a biodegradable stabilization method does not maintain proper sand cover it will deteriorate much more quickly than the design life of the array.

nourishment required to make up for the reduction in sediment supply, as the systems are designed to degrade over time and allow vegetation to naturally stabilize the toe of the landform. It is important to note that for these biodegradable alternatives to not be considered a CES, they cannot be maintained permanently in a static location and failure is a part of their lifecycle. However, if sand cover is not maintained over coir products, the array will break down more quickly than the designed lifespan. Therefore, erosion will trigger the need for additional sand cover, which is typically required to be continuously maintained over a biodegradable array, with fresh sand brought in as soon as reasonable after a storm erodes the sand cover. If a biodegradable stabilization method "fails" due to lack of maintenance, then that would not "prove" that a CES is required to protect a house from storm damage. Additionally, if a fully biodegradable array is abandoned by the property owner it can be allowed to "rot in place," and the landform will return to its previously eroding state.

DETERMINING THE TYPE OF SAND

This document uses the term sand, as this is the grain size most frequently utilized for beach nourishment. However, sand is only one class of grain size for sediment. Depending on what is most compatible with the beach,



Littoral cells are, in the most basic sense, a way to divide sections of coastline that contains common sediment sources, transport paths, and sinks. Littoral cell boundaries are highly dependent on project scale, a cell for a typical parcel level beach nourishment project may be a smaller sub-cell within a larger cell. Cells are bounded by inhibitors, typically inlets, large groins, or headlands, which prevent transport in most wind/wave conditions. Some inhibitors can be bypassed during larger storm events. For example, during a large storm event sediment can be transported through an inlet or overtop a groin. Proposed nourishment projects need to examine how the project, as well as cumulative impacts, have an effect on cell and subcell sediment exchange. For example, if an inlet's jetty is at capacity then adding more sand updrift may flow into a navigational channel.

gravel or even cobbles might be included in nourishment. Generally nourishment sediment is the same, or coarser, than the receiving beach, with less than 10% fines. Fine grained sediment can mobilize quickly and potentially smother nearby shellfish and eelgrass beds. The priority is that clean sediment of an appropriate grain size, shape, color, and texture is used. The state's 32-page guidance document, Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts (along with the 20 pages of technical attachments), describes the steps for sampling beach sediments and comparing them to offsite source material.

Example of a site that is not appropriate for the placement of nourishment.

WHERE TO PUT NOURISHMENT

Often, in an effort to simplify permitting, some projects add too much sediment above the mean high water (MHW) line, creating an overly steep profile. In these cases, the sediment then erodes more rapidly than in a natural gently sloping beach profile. As the system adjusts back to stable slope, the sand is quickly mobilized and may be deposited in sensitive areas in volumes that are typically only experienced during larger storm events. If there is not enough horizontal distance between MHW and the toe of the CES to place sediment, then alternative locations should be explored. Instead of adding sand at the toe of the revetment, it can be placed on or above the revetment. In this way the sand would be removed by larger storm waves, which is when most erosion would occur naturally. Also, if there is terminal scour at an end of the CES, required nourishment could be focused in this area to reduce the potential for erosion reaching behind the structure and causing additional damage to coastal resource areas. In some locations sand could be applied directly on top of existing vegetation. If applied correctly, our studies at the Cooperative Extension farm have shown that up to two feet of beach-compatible sand can be placed on top of established beachgrass with minimal long term impact to the vegetation. At some sites there is simply no room to place compensatory nourishment without negatively impacting sensitive coastal resources (e.g. salt marsh, shellfish beds, eelgrass, etc.). For these properties, homeowners may be required to provide nourishment off site of their property but still within the same littoral cell.

TOO MUCH OF A GOOD THING

Sometimes attempts to make up for the deprivation of sand to the system can have unintended consequences. Unconsolidated nourishment often erodes more quickly than a glacially derived coastal bank. This means more material is mobilized in weaker wave events (e.g., a years' worth of sand is eroded in a single small storm, instead of over many months of small storms). Too much sediment too quickly can negatively impact navigation, vegetation, and animals.

Navigation

The natural flow of sand past a natural inlet may temporarily close it, leading to anoxic events, fish kills, etc. Jetties are installed at some inlets to reduce these closures, however when the jetty reaches capacity to hold sand, it can be overtopped or bypassed, which then requires dredging to maintain the inlet. Navigational channels and marinas also require occasional maintenance dredging to allow safe passage of vessels. If too much sand is placed at a nearby stabilization project, or if it mobilizes too quickly, there is the potential to "plug" inlets, channels, marinas, private docks, etc.

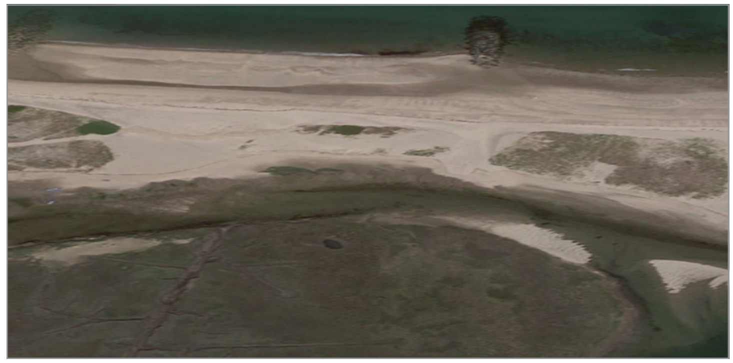
Example of a dock that has been impacted by sediment.

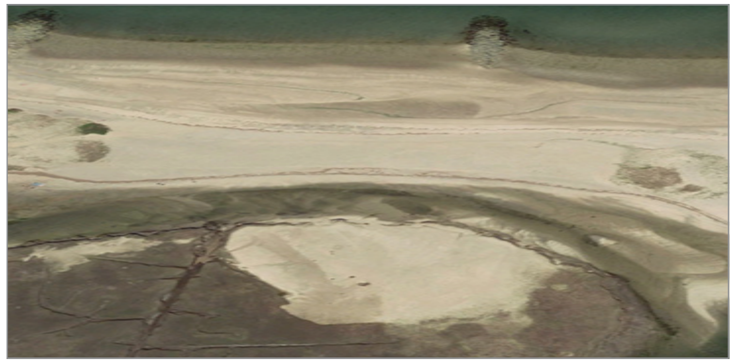
Vegetation

Coastal vegetation is dependent on an ongoing sediment supply to maintain a relatively narrow band of elevation in which native species have adapted to thrive. If too much sand is placed on a site, or if it mobilizes too quickly, there is the potential to smother some types of vegetation. While beachgrass has evolved to survive (and even thrive) being buried by over two feet of sand, sites with marsh grass can be damaged for many years by less than a foot of burial (see images at right). Eelgrass and marsh grasses are adapted to estuarine areas, with less wave energy and corresponding less sand transport. Subaqueous eelgrass may be even more sensitive to burial, with as little to 2-4 cm causing 70-90% mortality (2008, Cabaço, S. et al). Until new vegetation eventually colonizes the site, it will be more vulnerable to erosion and the new vegetation may be of a different species.

Animals

A plethora of animal species depend on the beaches and dunes of Massachusetts to feed, breed, and rest. Many rare species such as beach nesting birds, plants, insects, etc., have specific coastal habitat requirements (e.g., gentle slopes, grain size, overwash areas, etc.). Compensatory nourishment contributes sediment to the littoral system which often supports the habitat of state-listed and common species. While the proper amount of nourishment can be beneficial, specific design requirements may be needed to regulate the best volume, grain size, and beach geometry so as to not negatively affect the habitats of State-listed and other rare species, which is prohibited by the Massachusetts Endangered Species Act.





Example of vegetation that has been impacted by sediment. (GoogleEarth images from top: 2014, 2015, and 2021)

An example of an aquaculture planting of clams under protective netting which was mounded over with sand in a dynamic area.

Shellfish can also potentially be negatively affected. Though not endangered or threatened, shellfish are an important part of the food web, culture and economics of our region. While some wild shellfish, like species of clams, may be able to move up and down in the sediment making them capable of "digging out," other species incapable of movement, like oysters and mussels, may be smothered. Shellfish aquaculture sites that include any bottom planted shellfish are particularly susceptible to potential smothering. The planting of oysters on the bottom or clams under netting provides a disruption of flow where sand tends to accumulate if entering the plot in suspension (See picture at left). Shellfish aquaculture sites may be intertidal or subtidal and increases in sand may result in increases in the elevation. Increases in tidal elevation often reduce the time that a location is not covered by water potentially reducing viability of that location for shellfish farming.

RECOMMENDATIONS

Compensatory and/or trigger sand requirements, while beneficial for dunes and beaches, can negatively impact important living resources. If these resources exist nearby, and the sediment nourishment may feasibly affect them, a simplified sediment budget may be used to identify and reduce potential impacts. While only larger projects may require quantitative analysis, even parcel level projects could examine the qualitative aspects of a sediment budget. At a minimum, a parcel level sediment budget should discuss the net direction of sediment moving past the site. It would also be useful to identify factors that currently affect the sediment volume moving towards the site, the volume moving past the site, and how the proposed nourishment will affect these volumes and rates of transport. The larger littoral cell should also be examined to determine effects to the broader system as well as cumulative effects.

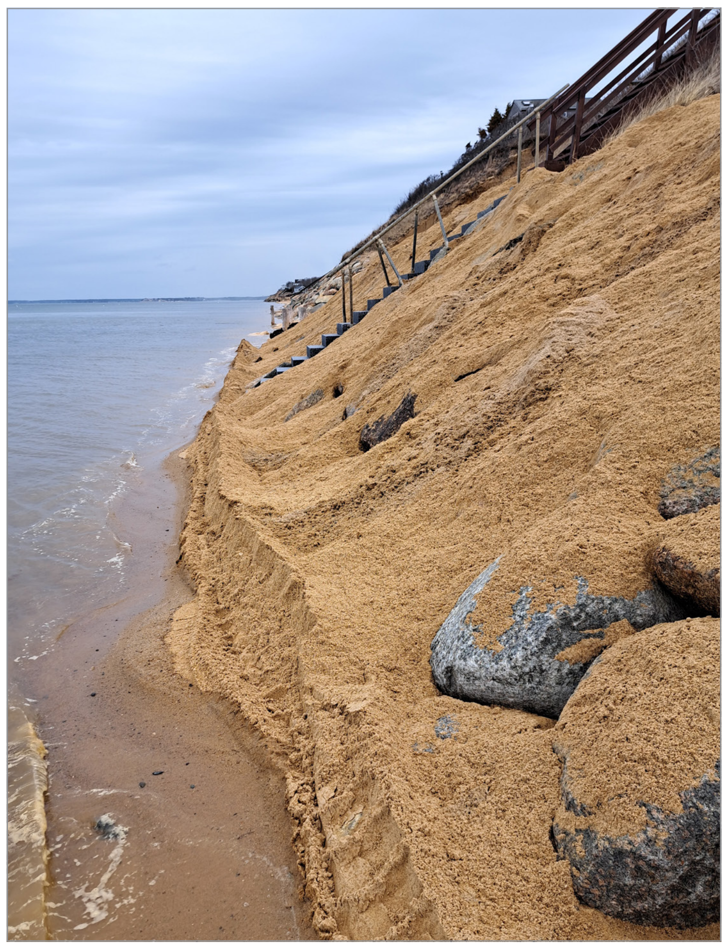
When beach nourishment is required, the conditions should be noted on the Conservation Commission's Order of Conditions (OOC) and be extended to the Certificate of Compliance as conditions in perpetuity. However, the exact volume requirement should be regularly re-visited. It is often helpful to make this note on the site plan and identify the monitoring plan in the OOC.

A project can be conditioned with both a trigger and an annual requirement, or may only need one of these depending on the location. Some years the volume needed to maintain the trigger will be more than the annual requirement, so no additional material would need to be placed. In years where the volume required by the trigger is less than the annual requirement, additional material would be needed. Depending on site conditions, and if the difference is a small amount, then it may be reasonable to average the difference across a few years.

In areas with sensitive resources (such as eelgrass and shellfish), correct sediment grain size becomes even more important. Sand that is coarser than the receiving beach, and containing no fines, may reduce the potential for the sediment to move quickly into eelgrass and shellfish beds, as well as aquaculture sites. It is also important that these beaches do not become over steepened, as this will also lead to more rapid mobilization of the sediment.

Annual compensatory nourishment is typically considered as "sacrificial" in that it is not required to be planted since it is intended to erode within the year and provide sediment for downdrift resource areas. Sand required due to a trigger – that is, to maintain the beach frontage – can be planted in the hopes of vegetation's roots aiding in the stabilization of the resource area on the site.

Compensatory nourishment is almost always required for a proposed new CES. Reconstruction of existing CES should include design improvements based on the best available techniques to reduce impacts, improve structure longevity, and minimize maintenance costs. Even if an existing stabilization project doesn't have a nourishment requirement, it is reasonable to add this requirement during the permitting process for reconstruction or repair.



A shoreline with many rock revetments has been recently nourished to make up for reduction in sand supply to the beach. Photo courtesy of Keith Johnson, Town of Eastham.

Monitoring Plan

A monitoring plan should be part of any project that includes nourishment. Such a plan would address:

How frequent is the monitoring?

- Typically once per year and right after storms
- Same time of year to reduce seasonal variations

Who does the monitoring?

- Can the homeowner just submit pictures or does this need to be professionally surveyed?

Who gets the reports?

- Typically submitted by a certain date to the Conservation Commission agent

How to measure the beach elevation?

- Typically with fixed markers but some may require regular topographic surveys
- Examples of fixed markers are grooves cut into revetment stones or how much a sand fence is exposed

How to determine if a trigger is reached?

- Make sure it's well defined and easily determined at the site.
- How much of an array has to be uncovered to require nourishment sand? (ex. xx% of total, or xx' exposed)
- How much sand must be put down if the trigger is reached? (ex. cover to xx" over entire array, or refill up to xx CY to design elevation)

What was the volume and grain size of the sediment?

- Receipts showing the volume and when it was placed
- A grain size analysis provided to the ConCom agent before placement.

What are the indicators for changing the required volumes?

- Additional sediment may be needed to mitigate for erosion
- Sediment may be need to be reduced if impacting navigation, vegetation, or animals.

References

This bulletin depended heavily on the following state guidance documents:

2017. Applying the Massachusetts Coastal Wetlands Regulations: A Practical Manual for Conservation Commissions to Protect the Storm Damage Prevention and Flood Control Functions of Coastal Resource Areas (aka Coastal Manual). 330pp. Prepared by MassCZM and MassDEP.

2013 (updates in 2018). StormSmart Properties Fact Sheet 7: Repair and Reconstruction of Seawalls and Revetments. 12 pp. Prepared by MassCZM.

2008. The impact of sediment burial and erosion on seagrasses: A review. Estuarine, Coastal and Shelf Science 79(3):354-366. Cabaço, S. et al.

2007. Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts. 32pp. Prepared by MassDEP.

2007. Technical Attachments to Beach Nourishment: MassDEP's Guide to Best Management Practices for Projects in Massachusetts. 20pp. Prepared by MassDEP.

Further reading

You may also want to read these for more information on how sand moves:

2015. The Effect of Sea Level Rise on the Barrier Beaches of Cape Cod, Martha's Vineyard, and Nantucket. Prepared by Greg Berman.

2011. Longshore Sediment Transport, Cape Cod, Massachusetts. Prepared by Greg Berman.

ACKNOWLEDGEMENTS

The author greatly appreciates the involvement and detailed comments from the technical review team: Rebecca Haney (Massachusetts Coastal Zone Management), Nate Corcoran (MassDEP Wetlands & Waterways Program), and Amy Hoenig (Massachusetts Natural Heritage & Endangered Species Program). Comments from Conservation Commission Agents in Orleans (John Jannell) and Wellfleet (Hillary Greenberg-Lemos) were also very beneficial. Joshua Reitsma, (WHOI Sea Grant Program and Cape Cod Cooperative Extension) contributed effective text, images, and comments to the shellfish portion of this bulletin. Finally, a big thanks to Stephanie Murphy (WHOI Sea Grant Program) for superior editing and layout support!

This publication was prepared by G. Berman under NOAA Grant NA18OAR4170104 and NA22OAR4170122 through NOAA's National Sea Grant College Program, U.S. Dept. of Commerce; and was supported in part by Barnstable County's Cape Cod Cooperative Extension. The statements, findings, conclusions, and recommendations are those of the author and do not necessarily reflect the views of the aforementioned organizations. All photos except where noted are courtesy of WHOI Sea Grant and Cape Cod Cooperative Extension.

Instead of adding sand across the full length of the revetment, it can be placed at the end to reduce the potential for erosion reaching behind the structure and causing additional damage to coastal resource areas.