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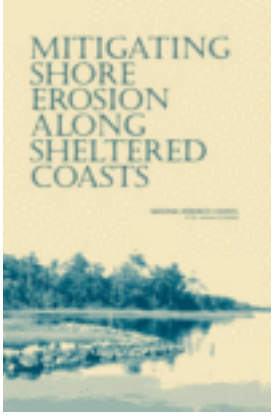

Mitigating Shore Erosion along Sheltered Coasts

Committee on Mitigating Shore Erosion along Sheltered Coasts, National Research Council

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Sheltered coastal areas, such as those along bays and estuaries, experience land loss from erosion and sea level rise much like ocean beaches. Owners of property along sheltered coasts often reinforce their shoreline with bulkheads and other structures to prevent erosion. However, this construction alters the coastal ecosystem, causing changes that threaten landscapes, public access, recreational opportunities, natural habitats, and fish populations. At the request of the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), and the Cooperative Institute for Coastal and Estuarine Environmental Technology, this report examines the impacts of shoreline management on sheltered coasts. The report calls for a regional management approach that considers the environmental impacts that could accumulate if hard structures are permitted on a site by site basis. In addition the report recommends changing the current permitting system to remove the default preference for bulkheads and similar structures and allow more flexibility to encourage use of more ecologically beneficial erosion-control methods, such as planting of marshes.

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Summary

Erosion is a natural phenomenon that threatens the growing number of properties built on coastal shores. Although open coasts have been the focus of most studies on erosion and technologies for stabilizing the shoreline, sheltered coastal areas,[1] such as those found in bays and estuaries, also suffer land loss from erosion and high waters. For example, the Maryland Geological Survey estimated that Maryland lost more than 20 acres of land on the western shore of Chesapeake Bay in the wake of Tropical Storm Isabel, causing $84,000,000 in damages to shoreline structures (Maryland Department of Planning, 2004, Baltimore, MD. 29 pp. *Lessons learned from Tropical Storm Isabel)*.

Landowners frequently respond to the threat of erosion by armoring the shoreline with bulkheads, revetments, and other structures. Although the armoring of a few properties has little impact, the proliferation of structures along a shoreline can inadvertently change the coastal environment and the ecosystem services that these areas provide. Managers and decision-makers have been challenged to balance the trade-offs between protection of property and potential loss of landscapes, public access, recreational opportunities, natural habitats, and reduced populations of fish and other living marine resources that depend on these habitats.

At the request of the Environmental Protection Agency, the Army Corps of Engineers, and the Cooperative Institute for Coastal and Estuarine Environmental Technology, this report examines the impacts of shoreline management on sheltered coastal environments and strategies to minimize potential negative

[1]A glossary of terms used in this report can be found in Appendix E.

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impacts to adjacent or nearby coastal resources (see Box S-1). The report suggests the development of a new shoreline management framework that would help decision makers evaluate the spectrum of available approaches to shoreline erosion problems in the context of the environmental setting, including the physical properties and ecological services of sheltered coasts and the potential for cumulative impacts.

SHELTERED COASTS AND EROSION

Sheltered coasts are shorelines that face smaller bodies of water in comparison to the beaches found facing the open ocean. Similarly, lagoons formed by fringing coral reefs or sand bars, which experience reduced wave energy, have relatively protected shorelines. Many of the processes that govern erosion on the open coast also apply to sheltered coasts, but compared to the typically long linear nature of open coasts, sheltered shorelines exhibit a more irregular configuration and often display very distinct geomorphic compartments containing a complex mix of resources that may vary from compartment to compartment. The lower energy conditions found on sheltered coasts create unique environments that foster habitats and ecological communities, such as marshes and mudflats, typically not found on open coasts. The differences between the shore dynamics and habitats on sheltered versus open coasts affect the potential technological approaches and the consequences of actions taken to stem erosion and land loss from sea-level rise.

Erosion is a natural phenomenon caused by winds, waves, currents, and tides that pick up and transport shoreline sediments; and weathering processes that destabilize landforms such as dunes and bluffs. Although natural processes contribute to erosion, the rate may be accelerated by human activities such as construction of dams upstream of estuaries or rivers that trap sediments, or installation of groins and seawalls that alter the magnitude and direction of sediment transport. Similarly, inundation may increase if land subsides due to natural compaction of sediments or due to withdrawal of subsurface resources, such as groundwater and petroleum. Other human activities that increase erosion include dredge and fill operations, wetland drainage, boat traffic, and channel dredging.

Superimposed on the impacts of erosion and subsidence, the effects of rising sea level will exacerbate the loss of waterfront property and increase vulnerability to inundation hazards. Sea level rise changes the location of the coastline, moving it landward along low lying contours and exposing new areas and landforms to erosion. Additionally, sea-level rise is chronic and progressive, requiring a response that is correspondingly progressive. Attempts to follow a "hold the line" mitigation[2] strategy against erosion and sea-level rise by coastal armoring

[2]In this report, "erosion mitigation" is used to describe efforts to reduce or lessen the severity of erosion and should not be confused with mitigation of environmental damages.

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BOX S-1
Statement of Task

The study will examine the impacts of shoreline management on sheltered coastal environments (e.g., estuaries, bays, lagoons, mudflats, deltaic coasts) and identify conventional and alternative strategies to minimize potential negative impacts to adjacent or nearby coastal resources. These impacts include: loss of intertidal and shallow water ecosystems, effects on species, and loss of public trust uses. The study will provide a framework for collaboration between different levels of government, conservancies, and property owners to aid in making decisions regarding the most appropriate alternatives for shoreline protection.

In particular, the committee will address the following questions:

- What engineering techniques, technologies, and land management/planning measures are available to protect sheltered coastlines from erosion or inundation resulting from either natural or anthropogenically forced processes? When does the design and implementation of these measures require a distinction between natural and anthropogenic causes and how can this be achieved?
- What information is needed to determine where and when these measures are reliable and effective both from an engineering and a habitat perspective? What are the likely individual and cumulative impacts of shoreline protection practices or no action on sheltered coastal habitats including public and private property, and public access along the shore, locally and regionally?
- Over what time frame are monitoring data needed to document the effectiveness of protective coastal measures? What data are needed to predict when design criteria may be exceeded?
- Given current trends in erosion and inundation rates and a possible acceleration of relative sea-level rise, how can design criteria, the mix of technologies employed, and land use plans be implemented for the protection of the environment and property over the long term?

will result in a steady escalation in both the costs of maintenance and the consequences of failure.

CURRENT APPROACHES TO MITIGATE EROSION

The pressure to develop and stabilize shorelines in sheltered coastal areas is increasing; more people desire waterfront homes, raising coastal property values and creating strong incentives to protect high-priced real estate. There are several types of mitigation measures to stabilize shorelines, including structural hardening (e.g., seawalls, bulkheads, revetments) and alternatives, such as constructed marsh fringes, that are designed to preserve a more natural shoreline. The selec-

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tion of the type of response to prevent or offset land loss depends on understanding local causes of erosion or inundation.

The most common response to erosion of sheltered shorelines has been a "hold the line" strategy that relies on technologies that harden the shoreline. A shift away from this approach has been slow, in part because there is a greater familiarity with these methods than with alternative approaches such as constructing a marsh fringe or using vegetation to stabilize a bluff. Contractors are more likely to recommend structures such as bulkheads because they have experience with the technology and know the design specifications and expected performance. Landowners expect that a hard, barrier-type structure will be required to prevent loss of property and protect buildings. In many regions, the regulatory system may unintentionally encourage shoreline armoring because it is simpler and faster to obtain the required permit(s).

However, there are indirect costs associated with mitigation options that armor the shoreline, including loss of ecosystem services at the site and in surrounding waters and shorelines. Many of these costs are borne by the public rather than the landowner. For example, installation of a seawall can result in loss of the fronting beach with attendant loss of public access and scenic amenities. Seawalls and bulkheads may also lead to loss of the intertidal zone and an exchange of habitat types from soft to hard substrates with subsequent changes in the plants and animals that inhabit these areas. When marshes are lost as the result of an installation, a highly diverse and productive plant and animal community is lost with attendant loss of vital ecosystem services such as nursery areas for important fish stocks, removal of excess nutrients from land runoff, feeding areas for migratory birds, and sediment stabilization. Some types of armoring may affect erosion patterns in nearby areas through scouring at the edges of structures or through disrupting the transport of sediment to downstream areas.

A NEW SHORELINE MANAGEMENT FRAMEWORK

Changing the current practice of armoring sheltered coasts will require a change in the shoreline management framework. Decision-makers should appreciate the costs and benefits of the spectrum of potential solutions to shoreline erosion problems, including potential cumulative impacts on shoreline features, habitats, and other amenities. The management framework should encourage approaches that minimize habitat loss and enhance natural habitats in environments where such methods offer effective stabilization.

Overcoming the obstacles associated with the existing management framework will require a number of societal and institutional changes that include:

- better understanding of sheltered shoreline processes and ecological services,

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- improved awareness of the choices available for erosion mitigation,
- documentation of individual and cumulative consequences of erosion mitigation approaches,
- shoreline management planning that takes into consideration the unique ecological and physical processes of sheltered coasts, and
- a permitting system with incentives that support the goals of the shoreline management plan.

The study's main findings and recommendations on these points are summarized below.

Understanding Sheltered Shoreline Processes and Ecological Services

Overall, less is known about physical process of sheltered coastal systems than of open coasts. Basic information, such as resource characterization, shoreline change analysis, sediment transport patterns, habitat function, and ecological services, is available for only a portion of the nation's sheltered shorelines and few programs address these knowledge gaps. States generally lack sufficient resources to conduct the type of comprehensive assessment of shorelines required for effective regional planning. However, decision-makers need adequate information about the physical and biological systems that will be affected to make well-informed choices about erosion mitigation along sheltered coasts.

FINDING: In most areas, the scope and accessibility of information regarding the causes of erosion at specific sites and the overall patterns of erosion, accretion, and inundation in the broader region (estuary, lagoon, littoral cell) is insufficient to support the development of an integrated plan for managing shore erosion.

RECOMMENDATIONS:

- **Federal agencies (e.g., USACE, EPA, USGS, and NOAA), state agencies, and coastal counties and communities should support targeted studies of sheltered coast dynamics to provide an informed basis for selecting erosion mitigation options that consider the characteristics of the broader coastal system rather than simply addressing immediate problems at individual sites. These studies should:**

  — Identify trade-offs in ecosystem services associated with various mitigation measures,
  — Quantify the costs and benefits of nonstructural erosion control techniques,
  — Document system-wide process and hazard information, including mapping of erosion zones and rates. This information needs to be

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presented in non-technical formats such as summary maps that can be readily understood by decision-makers, and

— Develop models to predict the evolution of coastal features under various scenarios.

• State and federal agencies should ensure that the information obtained from these studies is readily available to the public and decision makers at all levels of government.

Improved Awareness of the Choices Available for Addressing Erosion

One barrier to changing the trend towards increased shoreline armoring is a general lack of knowledge and experience among decision-makers, particularly property owners, regarding alternative options for shoreline erosion response, the relative level of erosion mitigation afforded by the alternative approaches and their expected lifetime, and the nature of the associated impacts and benefits. This unfamiliarity with alternative engineering approaches has resulted in disinterest, concern, or disagreement among regulators regarding the ecological consequences of alternative shoreline stabilization measures.

FINDING: Many decision-makers, particularly homeowners but also some state and federal regulators, are not sufficiently informed about the mitigation options available to them or the short and long term impacts of their choices. Decision-makers need assessments of new techniques and materials designed to mitigate shore erosion. Because of the comparatively low energy environments on sheltered coasts, special techniques have been developed to address erosion in these areas. Some techniques, such as the combination of a planted marsh fringe with a sill, have been tested and proven effective under well-characterized physical settings. However, new techniques (or structural materials) are periodically introduced that require a rigorous process of testing and evaluation to determine their effectiveness in controlling erosion and to evaluate their impacts on the environment.

RECOMMENDATIONS:

• The major federal agencies involved in permitting activities (EPA, USACE, and NOAA) should initiate a national policy dialogue on erosion mitigation for sheltered coasts to bring together state and federal decision-makers and share information on the potential application and value of different mitigation approaches.

• The national dialogue should be used to develop guidelines for mitigating erosion on sheltered coasts that give deference to ecologically beneficial measures and ensure consistency of decision-making across regions.

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• As part of the national dialogue, the permitting agencies should develop publications that contain objective information about erosion mitigation techniques, including descriptions of the conditions under which each option would be effective. These publications (either print or electronic) should be actively distributed to state and local planning and permitting staff, professional associations of environmental consultants, engineers, zoning officials, planners, and building inspectors; and extension agents; and made readily available to property owners and community groups.

• Professional societies and conferences should be utilized as a venue for transferring information to decision-makers such as regulators, engineers, and consultants.

Cumulative Consequences of Erosion Mitigation Approaches

Cumulative impacts[3] encompass the combined effects on legal, social, ecological, and physical systems. From a legal or regulatory perspective, issuance of a permit may establish a precedent, potentially facilitating the approval process for future requests for similarly situated structures. Another aspect of cumulative impact is the erosion enhancing effect of structures such as bulkheads on adjoining properties. Flanking property owners are likely to respond by constructing their own bulkheads, with a domino-type effect up and down the shoreline. It is difficult to identify the point at which individual projects accumulate to an extent that threatens the valued properties of the shoreline.

FINDINGS:

• Although loss of small parcels of shoreline habitat from hardening may not have a large impact on the ecosystem, the cumulative impact of the loss of many small parcels will at some point alter the properties, composition, and values of the ecosystem. In addition, the economic, recreational, and aesthetic properties of the shoreline will be altered, with potential loss of public use, access, and scenic values.

• Cumulative effects of shoreline hardening projects are rarely assessed and hence are generally unknown. However, an appreciation of the potential cumulative effects will be necessary to prevent an underestimation of the impacts of individual projects.

[3]Cumulative impacts are defined as "the impacts on the environment, which result from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7 and 1508.8).

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RECOMMENDATIONS:

- **Cumulative effects should be considered in shoreline management plans, both for the values invested by the affected communities in non-hardened shorelines and the value of ecosystem properties that stand to be lost with shoreline hardening. Although it may not be possible to identify the threshold beyond which cumulative impacts become unacceptable or irreversible, anticipation of the problem allows prioritization of projects in areas unsuited to nonstructural alternatives or sites where structures are predicted to have less impact.**
- **In the absence of a comprehensive assessment of the cumulative impacts of erosion mitigation measures, a precautionary approach should be used to prevent the unintentional loss of shoreline features and significant alteration of the coastal ecosystem.**

Permitting System

FINDINGS:

- **The current permitting system fosters a reactive response to the problem of erosion on sheltered coasts. Decision-making is usually parcel-by-parcel and based on little or no physical or ecological information. The path of least resistance drives choices through a rigid decision-making process, with inadequate attention to the cumulative effects of individual decisions.**
- **The current regulatory framework for sheltered coasts contains disincentives to the development and implementation of erosion control measures that preserve more of the natural features of shorelines, mainly as a result of the combined lack of knowledge, vision, and planning.**

RECOMMENDATIONS:

- **State and federal agencies (EPA, USACE, and NOAA) need to convene a working group to evaluate the decision-making process used for issuing permits for erosion mitigation structures to revise the criteria for sheltered coasts, including consideration of potential cumulative impacts.**
- **The regulatory preference for permitting bulkheads and similar structures should be changed to favor more ecologically beneficial solutions that still help stabilize the shore.**
- **State and federal regulatory programs (or other programs as appropriate) should establish a technical assistance function to provide advice on permitting issues and information on types of erosion mitigation approaches and their effectiveness under various site conditions.**

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Shoreline Management Planning

Creating a more proactive "regional approach" to shoreline management could address the unintended consequences of reactive permit decisions. The term "regional" is used in this report to reflect an area of shoreline that is defined by functional physical or ecological parameters such as littoral cells, or the scale of processes that affect sediment transport. Several examples of regional planning already exist for shorelines: the USACE Regional Sediment Management (RSM) approach, the EPA National Estuary Program, and some special area management plans approved by state coastal management programs.

FINDINGS:

- **The RSM approach provides a model and framework that could be adapted to address sheltered shoreline erosion problems within a regional context. Many factors in addition to sediment budgets must be considered in the development of regional shoreline management plans. These factors include socioeconomic considerations (e.g., ownership of the shoreline, waterfront property values, beach access for recreational boating and fishing) as well as a broad range of habitat and other ecological issues.**
- **Regional plans facilitate the assessment of cumulative impacts but require credible monitoring of project performance within and without the region of interest. Regional shoreline management plans could be created under the auspices of the Federal Coastal Zone Management Act (CZMA), Section 309 - Special Area Management Plans, thereby providing an opportunity to employ the federal consistency provisions of the CZMA to ensure that federal permitting actions are consistent with the plan.**

RECOMMENDATIONS:

- **Proactive erosion mitigation plans should be implemented to avoid unintended consequences when hardened shorelines reduce the recreational, aesthetic, economic, and ecological value of sheltered coastal areas.**
- **The essential elements of a regional shoreline management plan should include: (1) a shared vision for the future shoreline of the water body through stakeholder collaboration, (2) analysis of regional sediment budgets and the cumulative effects of existing shoreline management activities, (3) the mechanism for turning the vision into reality through consistent permitting provisions, (4) implementation, and (5) performance evaluation and monitoring requirements.**
- **Plans should be considered "living documents" and updated every 5 to 10 years as new information (e.g., monitoring data, research results) becomes available.**
- **Each regional shoreline management plan should describe the physical and hydrodynamic settings, including the location and type of existing**

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shoreline structures in a Global Information System (GIS) format. The plan should describe the available mitigation options and discuss the applicability, relative cost and benefit, and effectiveness of each option.

- **Monitoring should include both a preconstruction baseline and more detailed assessments after project implementation, both at the individual project level and for the entire region covered by the plan. Individual monitoring should be the responsibility of project proponents while regional monitoring should be the responsibility of the management plan authority.**
- **Regional shoreline management plans (based on estuary, bay, or littoral cell as appropriate) should be developed by local, state, and federal partners to address erosion on sheltered shorelines in a comprehensive, proactive manner.**
- **Information obtained from monitoring programs should be incorporated in subsequent planning activities to support adaptive management as a mechanism to consistently evaluate and refine regional plans.**

CONCLUSION

Until the regulatory framework addresses the regional scale of the processes controlling sediment transport, stabilization of individual sites will often include structures that damage adjacent areas and create a domino-type effect of coastal armoring. Therefore, the dimensions of the regulatory framework should match the scale of the processes that contribute to shore erosion.

Currently there is no national mandate to document erosion processes on sheltered coasts or to develop regional scale plans. No federal agency has been assigned to provide that scale of planning, although some states have become more proactive in shoreline management. Hence, implementation of a regional plan will require a new commitment for coordination among local, state, and federal programs, including a regional general permit.

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Preface

Sheltered coasts, and the bodies of water they surround, are increasingly popular places for people to live, work, and recreate. This is partially due to a preference for a serene setting that is afforded some protection from the full fury of coastal storms. The same sheltered nature of these areas also creates some of the most biologically productive and ecologically valuable resources of the coastal region. But sheltered coasts are indeed subject to erosion and sea level rise, and suffer chronic land loss as a result. The common response by landowners to the loss of their increasingly valuable land has been to "harden" the shoreline by construction of fixed structures such as bulkheads, revetments, or groins. This response can easily create a "bathtub" effect and fundamentally change the character of the coastal environment; in some cases actually worsening the erosion and inundation, and in most cases causing a loss or shift in ecological values. As a better understanding is gained of the physical and ecological impacts of hardening the shoreline, new approaches are being developed for managing eroding sheltered shorelines. This report reviews options available to mitigate erosion of sheltered coasts; explores why certain decisions are made regarding the choice of erosion mitigation options; provides critical information about the consequences or altering sheltered shorelines; and, provides recommendations about how to better inform decisions in the future.

Integrating broad societal and ecological considerations into erosion mitigation strategies is a continuing challenge. Practitioners are slowly moving in that direction and are encouraged to continue on that course. We suggest that more focused research on sheltered coasts, and long-term regional planning early in the process, are key solutions to this chronic issue.

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We hope that the conclusions and recommendations of this report provide meaningful advice to state and federal agencies, local communities, and landowners to guide a new management approach in the planning, design, and construction of erosion mitigation strategies for sheltered coasts.

Jeffrey R. Benoit, *Chair*

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by **Norbert Psuty**, Rutgers University. Appointed by the National Research Council, the reviewers were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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