The North Carolina Estuarine Biological and Physical Processes Work Group's

Recommendations for Appropriate Shoreline Stabilization Methods for the Different North Carolina Estuarine Shoreline Types

North Carolina Division of Coastal Management

August 2006

RECOMMENDATIONS FOR APPROPRIATE SHORELINE STABILIZATION METHODS FOR THE DIFFERENT NORTH CAROLINA ESTUARINE SHORELINE TYPES

August 2006

Prepared by:

North Carolina Estuarine Biological and
Physical Processes Work Group

and

North Carolina Division of Coastal Management

Prepared for:

North Carolina Coastal Resources Commission
Estuarine Shoreline Stabilization Subcommittee

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Executive Summary

Estuarine shorelines are dynamic features that experience continued erosion by short-term (boat wakes, storms, tides, etc.) and long-term (sea level rise) processes. As coastal populations encroach on estuarine shorelines, coastal states have begun to formulate new policies and management plans to deal with estuarine shoreline erosion. These plans try to strike a balance between the need to provide protection to the public from coastal hazards with the need to maintain the integrity of the natural system. The North Carolina Division of Coastal Management (DCM) has concluded that more research and discussion is needed between managers and researchers to effectively address and understand the impact of shoreline stabilization methods on the habitats and productivity of estuarine systems. This conclusion was the main motivation for the formation of the Estuarine Biological and Physical Processes Work Group. The Work Group consists of experts in the field of estuarine system processes.

The Work Group was charged with the task of developing recommendations to guide the development of new estuarine shoreline stabilization rules. The Work Group did not conduct any research, but merely utilized prior research and best scientific judgment in developing this report. Beyond classification and measurement of shoreline recession rates, there has been little research that applies directly to shoreline stabilization methods in North Carolina. In spite of this shortcoming, this report includes recommendations that take into account the dynamic nature of the estuarine system and considers the benefits and impacts of various shoreline stabilization methods on the biological communities and physical processes.

The Work Group evaluated the ecological functions and values of the different North Carolina shoreline types and the habitat changes due to the physical impacts associated with each shoreline stabilization structure or method. The recommendations of shoreline stabilization methods are based upon the Work Group's stated goal of maintaining the current shoreline type and continuation of the current ecological functions and values. Based on these criteria, the lists of stabilization measures for each shoreline type represent a ranking of options, from the option with the least potential adverse impact to the existing system (ranking of 1), to the option with the greatest potential adverse impact to the system (maximum ranking of 8).

In summary, the recommendations for each of the shoreline types are typically different with a few similarities. The number one recommendation for all estuarine shoreline types is land planning (i.e. leave the land in its natural state). Typically, the number two recommendation is to use vegetation control because vegetation is a natural and environmentally beneficial stabilization method. In many cases, beach fill is a recommended action to maintain the current shoreline type due to its non-structural, non-hardening attributes. When shoreline hardening stabilization methods are proposed, the Work Group rank sills as the most preferred option since it is a small structure that is constructed to support wetland plantings, or the conservation of existing wetland vegetation. Groins, breakwaters, sloped structures, and vertical structures vary in ranking and were determined to be shoreline type and site specific.

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1. INTRODUCTION

1.1 Background

Estuarine shorelines are dynamic features that experience continued erosion. Land is lost by short-term processes, such as, erosion by storms, boat wakes, and tidal currents within the long-term process of rising sea level. Rising sea level by itself does not cause loss of land, rather it changes the relationship between sea level and land elevation, and is effective in moving the shoreline only where land elevations are quite low. As coastal populations encroach on estuarine shorelines, coastal states have begun to formulate new policies and management plans to deal with estuarine shoreline erosion. These plans try to strike a balance between the need to provide protection to the public from coastal hazards with the need to maintain the integrity of the natural system. Various estuarine shoreline-armoring strategies have been examined by coastal states, culminating in the revision or drafting of new estuarine shoreline stabilization regulations and permitting guidelines.

Estuarine erosion management in North Carolina has allowed people to protect their property from erosion, while attempting to minimize the impacts of erosion control structures. These efforts include limiting encroachment and fill into the estuarine waters and limiting structures and fill on, or waterward of the coastal wetlands. The current management strategies need stronger consideration of the estuarine habitats, impact of the erosion control structures and migration of wetlands in response to rising sea level.

To protect coastal property, North Carolina has allowed homeowners to armor the waterward boundary of their property hardened structures such as vertical and sloped structures. These methods are effective, but due to the shoreline type specific habitats and structure impacts, it is becoming apparent that some stabilization methods are not necessarily appropriate for all shoreline types and the shore zone as a whole.

The North Carolina Division of Coastal Management (DCM) has concluded that more research and discussion is needed between managers and researchers to more fully address and understand the impact of shoreline stabilization methods on the habitats and productivity of estuarine systems. This conclusion was the main motivation for the formation of the Estuarine Biological and Physical Processes Work Group. The Work Group is a science-based panel specifically charged with the task of developing recommendations to guide the development of new shoreline stabilization rules. The Work Group did not conduct any research, but merely utilized prior research and best scientific judgment in developing the report. Beyond classification and measurement of shoreline recession rates, there has been little research that applies directly to shoreline stabilization methods in North Carolina. In spite of this shortcoming, this report includes recommendations that take into account the dynamic nature of the estuarine system and consider the benefits and impacts of various shoreline stabilization methods on the biological communities and physical processes.

1.2 Chronology of Estuarine Shoreline Management Efforts

In 1998, the Coastal Resources Commission (CRC) directed DCM staff to begin developing comprehensive rules that address appropriate uses and protection of the estuarine shoreline. During that process, establishment of an estuarine shoreline buffer zone and revision of current hard stabilization practices were undertaken. However, in January 1999, DCM staff were directed by the CRC to work on shoreline stabilization rules separately from other shoreline protection measures being considered (shoreline buffer rule). In August 2002, a 30-foot vegetated buffer zone was adopted by the CRC in an attempt to protect coastal water quality.

Discussion continued on shoreline stabilization practices. DCM staff met several times with coastal citizens to explore new concepts and principles that could be used in the development of shoreline stabilization rules and to discuss proposed draft rule language. Staff also met with contractors and other interested parties to solicit ideas and concerns with implementation and effectiveness of the existing rules. Comments from the various interested parties were used as a foundation for the development of draft shoreline stabilization rules.

The proposed draft rules represented a work in progress that needed considerable discussion and input by the Implementation & Standards Committee (standing committee of the CRC) before being sent to public hearing by the CRC. This initial attempt at addressing shoreline stabilization practices lacked a firm scientific foundation to support significant modifications in the current rules. Since the initial drafting of the proposed rules, an Estuarine Shoreline Stabilization Subcommittee was established by the CRC to help review the issues associated with the estuarine shoreline rule development process. In November 2000, the Subcommittee developed a set of principles and concepts to guide further development of any shoreline stabilization rule changes (Figure 1-1). These concepts and principles represent the basis for discussion by the Estuarine Biological and Physical Processes Work Group and have provided a frame of reference for the informational needs to be addressed by the Work Group.

However, the departure of key DCM staff in 2003 delayed further development of the rules by the Estuarine Biological and Physical Processes Work Group, as well as the Estuarine Shoreline Stabilization Subcommittee. In 2005, the Coastal Habitat Protection Plan (CHPP) Implementation Plan was approved by the CRC. One of the implementation actions included establishing a Shoreline Stabilization Committee, and encouraging alternatives to vertical shoreline stabilization methods. In November 2005, the CRC re-established an Estuarine Shoreline Stabilization Subcommittee and began working on alternatives to vertical shoreline stabilization methods. The Subcommittee updated the original "Coastal Resources Commission Concepts/Principles for Estuarine Shoreline Stabilization Policy Assessment and Development" and requested that the Estuarine Biological and Physical Processes Work Group be reestablished to advise the committee on the science of the estuarine systems. In March 2006, the Estuarine Biological and Physical Processes Work Group began developing recommendations on appropriate shoreline stabilization methods for the different North Carolina shoreline types. The Work Group used portions of the research done in 2002 as the foundation for their recommendations.

Coastal Resources Commission Concepts/Principles for Estuarine Shoreline Stabilization Policy Assessment and Development (updated 2006)

1. The State of North Carolina has the authority under CAMA and the Dredge and Fill Law to regulate placement and installation of shoreline stabilization measures.

2. Stabilization techniques should be appropriate for site and erosion forces present.

3. Measures with the least adverse environmental effects are preferred.

4. The goals of establishing standards for estuarine and public trust shorelines are:
    a. To safeguard and perpetuate the natural productivity and biological, economic and aesthetic values of natural ecological conditions of the estuarine system (Protection of Habitat and Water Quality).
    b. To insure that the development or preservation of the land and water resources of the coastal area proceed in a manner consistent with the capability of the land and water for development, use, and preservation based on ecological considerations (Appropriate Development For Site).
    c. To insure the orderly and balanced use and preservation of our coastal resources on behalf of the people of North Carolina and the nation (Protection of Public Trust and Private Property Rights).

5. CRC will create development standards for stabilization technique/measures.
    a. Soft Measures
        i. Beachfill
        ii. Vegetation Planting
    b. Hard Measures
        i. Bulkheads
        ii. Groins
        iii. Breakwaters
        iv. Sills
        v. Revetments
        vi. Wave-boards (wooden breakwaters)
    c. Combinations

6. Stabilization measures shall be located as far landward as feasible.

7. CRC will set standards for existing stabilization projects:
    a. Allowing for tying with existing stabilization projects and adjoining lots
    b. Allowing for vertical structures on constructed canals and basins
    c. Allowing in kind/in place repair
    d. Allowing for in kind/in place replacement

8. CRC will attempt to keep criteria and standards simple to understand and implement.

9. CRC will gather public input on the above principles and provide guidance on the concepts prior to DCM developing draft rule text.

10. Most shorelines erode. Erosion rates vary greatly due to shoreline type and their location.

Figure 1-1: Coastal Resources Commission Concepts/Principles for Estuarine Shoreline Stabilization Policy Assessment and Development (updated 2006)

1.3 Objectives

The Estuarine Shoreline Stabilization Subcommittee charged the Estuarine Biological and Physical Processes Work Group with developing recommendations of appropriate shoreline stabilization methods associated with different North Carolina shoreline types. This information will provide the Estuarine Shoreline Stabilization Subcommittee with the necessary information to make informed recommendations regarding rules and regulations to the North Carolina Coastal Resources Commission.

2. ESTUARINE BIOLOGICAL AND PHYSICAL PROCESSES WORK GROUP

The North Carolina Estuarine Biological and Physical Processes Work Group was assembled to provide science based recommendations to the CRC's Estuarine Shoreline Stabilization Subcommittee. The Work Group is a science-based panel specifically charged with the task of developing recommendations for an existing array of shoreline stabilization methods for different shoreline types. The members were selected based on research experience and knowledge of the estuarine system (Table 2-1).

Table 2-1: Estuarine Biological and Physical Processes Work Group Members

Members	Affiliation	Experience/Specialty
Mark Brinson	East Carolina University	Wetland Ecology/Sea Level Rise
Martin Posey	University of North Carolina-Wilmington	Benthic Ecology
Tracy Skrabal	NC Coastal Federation	Erosion Control
Spencer Rogers	NC Sea Grant	Erosion Control
Stan Riggs	East Carolina University	Geology/NC Estuarine Physical Processes
Anne Deaton	NC Division of Marine Fisheries	Fisheries Biologist
David Moye	NC Division of Coastal Management	DCM Field Staff/NC Rules & Permitting
Bonnie Divito	NC Division of Coastal Management	Coastal Engineer/Work Group Coordinator

Discussion of appropriate shoreline stabilization options for estuarine shorelines has occurred through a series of meetings held in 2002 and 2006. The conclusions and recommendations agreed upon by the members are compiled in the following Sections of this document. This document represents a significant step in addressing policy needs to better manage estuarine shorelines. The Division of Coastal Management, along with the Estuarine Shoreline Stabilization Subcommittee, will utilize this document to guide the development and implementation of practical and sound estuarine shoreline management erosion strategies.

3. REGULATORY FRAMEWORK

Areas of Environmental Concern (AECs) are the foundation of the Coastal Resources Commission's permitting program for coastal development. The Coastal Resources Commission designates areas as AECs to protect them from uncontrolled development, which may cause irreversible damage to property, public health or the environment, thereby diminishing their value to the entire state. The CRC has adopted four categories of AECs:

- The Estuarine and Ocean System
- The Ocean Hazard System
- Public Water Supplies
- Natural and Cultural Resource Areas

The North Carolina estuarine system as it applies to this report falls under The Estuarine and Ocean System AEC.

3.1 The Estuarine and Ocean System AEC

The estuarine and ocean system is the coast's broad network of brackish sounds, marshes and surrounding shores. Normally found where rivers and streams meet the ocean, an estuary is a unique and important part of coastal life – a transitional area where fresh and salt water mix. From broad, shallow sounds like the Albemarle and Pamlico, to narrow bodies of water such as Core and Masonboro sounds, North Carolina has 2.2 million acres of estuarine waters. Cradled behind the state's long string of barrier islands, these shallow sounds, rivers and creeks make up one of the largest estuarine systems in the United States. The Division of Coastal Management issues permits for development in this system.

3.1.1 Public Trust Areas

Public Trust Areas are the waters and submerged lands that all citizens have the right to use for activities such as boating, swimming or fishing. These areas often overlap with estuarine waters, but they also include many inland fishing waters. The following lands and waters are considered public trust areas:

- all waters of the Atlantic Ocean and the lands underneath, from the normal high water mark on shore to the state's official boundary three miles offshore;
- all navigable natural water bodies and the lands underneath, to the normal high watermark on shore (a body of water is considered navigable if you can float a canoe in it). This does not include privately owned lakes where the public does not have access rights;
- all water in artificially created water bodies that have significant public fishing resources and are accessible to the public from other waters; and
- all waters in artificially created water bodies where the public has acquired rights by prescription, custom, usage, dedication or any other means.

3.1.2 Estuarine Waters

Estuarine Waters are the state's oceans, sounds, tidal rivers and their tributaries, which stretch across coastal North Carolina and link to the other parts of the estuarine system: public trust areas, coastal wetlands and coastal shorelines. The boundaries between inland and coastal fishing waters are set forth in an agreement adopted by the Wildlife Resources Commission and the Department of Environment and Natural Resources and in the most current revision of the North Carolina Marine Fisheries Regulations for Coastal Waters..

3.1.3 Coastal Shorelines

Coastal Shorelines, which include public trust areas (Section 3.1.1) and estuarine waters (Section 3.1.2), are all lands within 75 feet of the normal high water level or normal water level of estuarine waters. This definition also includes lands within 30 feet of the normal high water level or normal water level of public trust waters located inland of the dividing line between coastal fishing waters and inland fishing waters. Along Outstanding Resource Waters, this definition includes lands within 575 feet of the normal high water level.

For the purposes of this report, the discussion of estuarine shorelines is assumed to encompass "Coastal Shorelines" as described in Section 3.1.3 under the jurisdiction of the CRC.

4. ESTUARINE SHORELINE TYPES

Shorelines in general can be delineated as to where the water meets the surface topography of the land. Shorelines are highly variable in the estuarine system and range from gently sloping land colonized by hydrophytic vegetation to steeply incised cliffs composed of older sedimentary and rock material (Riggs 2001). The waterline (line of intersection on the land) is not constant and changes due to astronomical and wind tides, creating a shore zone. A major function of the shore zone is to absorb the energy of the water at the land and water interface. Depending on the composition of land along this shore zone and the environmental conditions, the erosion rates of the shoreline can be quite variable (Bellis et al. 1975, Riggs 2001, and Riggs and Ames 2003). Due to the variability in slope, energy climate, sediment composition and other physical characteristics, a unique suite of organisms have adapted to live and utilize the resources of the various shoreline types. For this reason, it is important to investigate the impact and benefit of shoreline stabilization methods for each shoreline type.

The first task of the Work Group was to determine a framework to begin discussing the impacts and benefits of shoreline stabilization on the estuarine system. The Work Group found that the estuarine shoreline is composed of a diverse array of shoreline types, ranging from organic and sediment bank shorelines to combination shorelines. Combination shorelines, which are a composite of two or more shoreline types, are representative of most of the estuarine shorelines. This diversity in shoreline types led the Work Group to conclude that a “one rule fits all” strategy is not appropriate. The Work Group decided to approach discussions of impacts/benefits through a list of representative shoreline types according to the classification scheme developed by Riggs (2001). Using Riggs’ shoreline classification as a guide, a list of shoreline types was developed to assist in discussion and recommendations. In all, eleven shorelines were selected.

1. Swamp Forest
2. Marsh
3. Marsh with Oysters
4. Marsh with Mud Flats
5. Low Sediment Bank with Marsh
6. Low Sediment Bank with Swamp Forest
7. Low Sediment Bank with Oysters /SAV
8. Low Sediment Bank with Woody Debris
9. Low Sediment Bank with Sand
10. High Sediment Bank
11. Overwash Barrier/Inlet Areas

4.1 Swamp Forest

Swamp forests are very poorly drained forested wetlands or shrub/scrub communities that are regularly, occasionally, seasonally, or semi-permanently flooded by lunar tides, wind tides, and/or overbank flow. In the estuarine system, swamp forests occur along the margins of freshwater and brackish sounds and along the lower reaches of coastal rivers and streams. Swamp forests can occur directly on the estuarine shoreline or grade down slope to marsh. This shoreline type is an expansive swamp forest with no sediment bank behind or with one landward enough that the regular, non-storm event waves dissipate before reaching the bank. A common example of swamp forest is tidal cypress gum swamp.

Figure 4-1: Typical photographs of swamp forest.

4.2 Marsh

Coastal marshes are low-lying meadows of herbaceous plants that occur along the margins of estuaries and along the shorelines of coastal rivers and streams. Most marshes along the estuarine shoreline are subject to regular or irregular flooding by lunar tides and/or wind generated water level fluctuations. Some riverine flooding may be the most important source of hydrology in areas not subject to tidal flooding. Marsh plant species composition is highly dependent on salinity, with distinctly different marsh communities occurring within freshwater, brackish, and saline zones and within the regularly and irregularly flooded areas within each zone. Common coastal marsh species include: Cord Grass (Spartina alterniflora), Black Needlerush (Juncus roemerianus), Glasswort (Salicornia spp.), Salt Grass (Distichlis spicata), Sea Lavender (Limonium spp.), Bulrush (Scirpus spp.), Saw Grass (Cladium jamaicense), Cat-tail (Typha spp.), Salt Meadow Grass (Spartina patens), Reed Grass (Spartina cynosuroides).

During the natural formation of a coastline, a marsh develops when sediment deposition exceeds sediment removal by waves. Three critical conditions are required for marsh formation: abundant sediment supply, low wave energy, and a low surface gradient. Once sediment accumulation reaches a critical height, the mud flats are colonized by halophytic plants that aid in trapping sediment when flooding occurs and that add organic material to the substrate (Morang et al. 2002). This shoreline type is an expansive marsh with no sediment bank behind or with one landward enough that the regular, non-storm event waves dissipate before reaching the bank.

Figure 4-2: Typical photographs of the expansive marsh shorelines.

4.2.1 Marsh with Oysters

Marsh with oysters shorelines include marsh as described in Section 4.2 and oysters or oyster reefs adjacent to the marsh shoreline. An oyster reef can be defined as a structure created by oysters growing on a firm substrate such as shell or rock, while subsequent generations attach to the older oysters, often forming clusters.

Figure 4-3: Close up views of the abundant oyster reefs that occur on the mudflats and extend into the lower portions of the marsh.

4.2.2 Marsh with Mudflats

Marsh with mudflats shorelines include marsh as described in Section 4.2 and adjacent mud flats. Mudflats are relatively flat, muddy regions found in inter-tidal areas that are exposed during times of low tide.

Figure 4-4: Close up (left) and overall (right) view of exposed mudflats in a tidal creek.

4.3 Low Sediment Bank

Low sediment bank shorelines, which are less than 5 feet of vertical height, are dominant in the eastern portions of the estuaries and consist of unconsolidated sediment on top of a clay bed, which usually occurs at or slightly below sea level. Clay beds usually occur just below the thin surface sands in the offshore area and control the bottom slope and water depths. Low sediment bank shorelines consist of a gently seaward sloping, wave-cut platform below water level, and an associated steeply sloping, wave-cut scarp on the landward side of the beach. (Riggs 2001)

4.3.1 Low Sediment Bank with Marsh

Low sediment bank with marsh shorelines include a combination of low sediment bank as described in Section 4.3 and marsh as described in Section 4.2 waterward of the sediment bank. This shoreline is designated for shorelines with non-expansive marshes that occur as narrow zones of marsh on the waterward side of the sediment bank. Non-expansive marshes can be identified by wave dissipation that occurs throughout the marsh and extends landward to the sediment bank. If the marsh is determined to be extensive then it shall fall under the classification of marsh from Section 4.2.


Figure 4-5: Marsh growing along very low (left) and low (right) sediment bank shorelines.

4.3.2 Low Sediment Bank with Swamp Forest

Low sediment bank with swamp forest shorelines include a combination of low sediment bank as described in Section 4.3 and swamp forest as described in Section 4.1 waterward of the sediment bank. This shoreline is designated for shorelines with non-expansive swamp forests. Non-expansive swamp forests can be identified by wave dissipation that occurs throughout the swamp forest and extends landward to the sediment bank. If the swamp forest is determined to be extensive then it shall fall under the classification of swamp forest from Section 4.1.


Figure 4-6: Swamp forest along sediment bank shorelines.

4.3.3 Low Sediment Bank with Sand

Low sediment bank with sand shorelines include a combination of high or low sediment bank as described in Section 4.3 and a sandy bottom/beach waterward of the sediment bank. Sandy beaches are typically broad and shallow shorelines. This shoreline type is to be considered such if it is widespread rather than a small patch of sandy shoreline among other more dominant shoreline types.

Figure 4-7: Sandy beach in front of vegetated low sediment bank.

4.3.4 Low Sediment Bank with Woody Debris

Low sediment bank with woody debris shorelines include a combination of low sediment bank as described in Section 4.3 and woody debris waterward of the sediment bank. Woody debris is characterized by naturally occurring drowned trees, logs, and brush.

Figure 4-8: Low sediment bank shoreline with the remnants of a drowned forest.

4.3.5 Low Sediment Bank with Oysters/SAV

Low sediment bank with oysters or submerged aquatic vegetation (SAV) shorelines include a combination of low sediment bank as described in Section 4.3 with oysters, oyster reefs or SAV beds waterward of the sediment bank. An oyster reef can be defined as a structure created by oysters growing on a firm substrate such as shell or rock, while subsequent generations attach to the older oysters, often forming clusters. SAV is vegetation rooted in the substrate of a body of water (usually no deeper than 10 feet) that does not characteristically extend above the water surface and usually grows in beds.

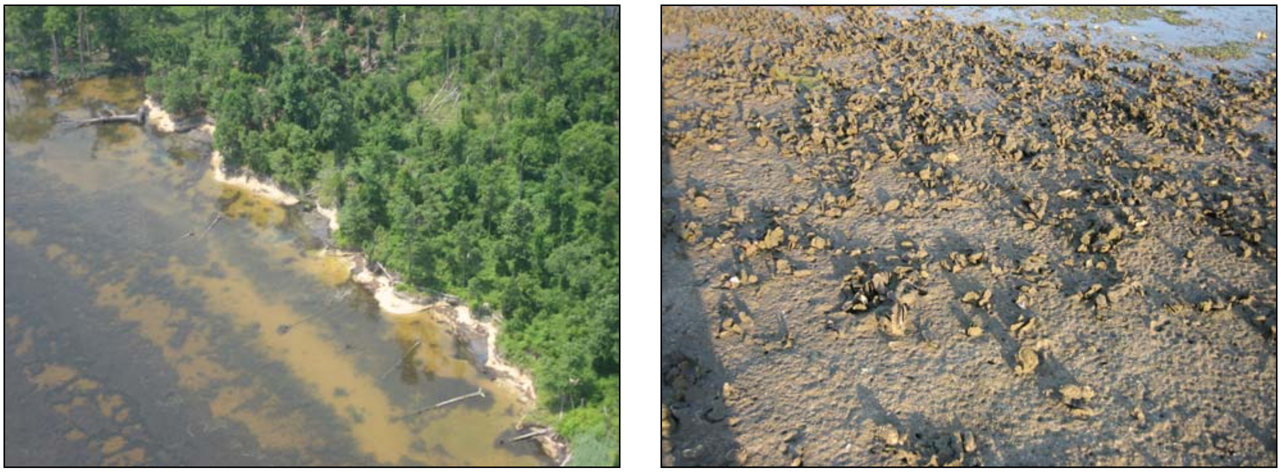

Figure 4-9: SAV (left) and oysters (right) along a sediment bank shoreline.

4.4 High Sediment Bank

High sediment bank shorelines consist of a gently seaward sloping, wave-cut platform below water level, and an associated steeply sloping, wave-cut scarp on the landward side of the beach. High sediment bank shorelines are defined as over 5 feet of vertical height above the high tide line. The high sediment bank shorelines are dominant in the westernmost portion of the estuarine system and consist of tight clay and moderately to tightly cemented sandstone near their base with unconsolidated water-bearing sands and clayey sand above. Depending on the bank composition, most high sediment bank shorelines have well-developed sand beaches. (Riggs 2001)

Figure 4-10: High sediment bank shorelines.

4.5 Overwash Barrier/Inlet Areas

Overwash barrier/inlet areas shorelines include areas subject to active overwashing or inlet influence. These shorelines experience sediment transport landward of the active beach by storm events and/or extreme waves leaving overwash fans. This shoreline can also include remnants of old inlet flood tide deltas, which now extend into the estuary. Sand deposits from over-wash and inlet deltas form shallow sand platforms become important sites for the growth of vast salt marshes and submerged marine grass beds. (Riggs 2001)

Figure 4-11: Sandy beach from adjacent inlet influence (left) and area of a barrier island overwashed during a recent storm event (right).

5. ESTUARINE SHORELINE STABILIZATION METHODS

Below is a table of the shoreline stabilization methods in which the Work Group considered. Each of the methods can be constructed using an array of possible materials with the most common materials listed.

Table 5-1: Estuarine shoreline stabilization structures summary and quick reference

Structure Type	Aliases	Typical Construction Materials	Characteristics	Erosion Control Purpose
Land Planning			Live with/plan around existing conditions	Leave the land in its natural state.
Vegetation Control	Wetland or Upland Plantings	Wetland or upland vegetation	Planting, replanting, or conserving existing vegetation	Creates a buffer to dissipate wave energy.
Beach Fill	Beach Nourishment	Sediment/sand similar to the native beach	Placing sand on the shoreline	Acts as a sacrificial erosive barrier.
Sills	Marsh Sill, Wooden Breakwater, Wave Board	Timber, rock, concrete pieces, vinyl	Parallel and close to shore, low elevation, associated with wetland vegetation	Reduces wave energy on the shoreline. Traps sediment landward to rebuild/protect wetlands.
Groins	Jetties	Timber, rock, concrete, vinyl	Perpendicular to shore	Trap sand on the updrift side to build out the upland.
Breakwaters	Wave Attenuator	Timber, concrete, rock	Shore parallel, larger and further offshore than sills	Reduces wave energy on the shoreline. Trap sand between the shore and breakwater.
Sloped Structures	Riprap, Revetment Sloped seawall	Concrete, rock	Watertight or porous, sloped against a bank	Protect land from erosion and absorb wave energy without reflecting waves.
Vertical Structures	Bulkhead, Seawall, Gravity Wall	Timber, steel, vinyl, rock, concrete	Watertight, vertical, parallel to shore	Hold back land.

5.1 Land Planning

Land planning is designing your property around existing conditions and possible erosion. This includes utilizing the land as it exists without construction of shoreline stabilization methods. The most common practices associated with land planning include setbacks, buffers, and no action.

5.2 Vegetation Control

Vegetation control is the use of wetland (marsh or swamp) vegetation (new plantings or preserving existing wetland vegetation) to prevent further erosion. The vegetation provides a buffer that helps dissipate the wave energy in a natural non-structural form. Vegetation may be planted or allowed to colonize naturally. Vegetation control can also include bioengineering as erosion control measures. Bioengineering includes organic or biologic components, which are usually designed in combination with re-grading of the banks, and plantings of wetlands or native plants. Live saplings wrapped in biodegradable coverings, downed trees, tree stumps, and cut brush are examples of bioengineering types of vegetation control. Plantings may take place on the existing slope or filling may be used to create the proper water depths for the colonizing to occur.

Figure 5-1: Vegetation Control in the form of marsh planting (left) and its growth after 1 year (right). (Barnard and Hardaway)

5.3 Beach Fill

Beach fill is a process in which sand or sediments that are lost by erosion and longshore drift is added to or replaced on the native beach. Material, from an outside source, of the same grain size and density as the natural beach material is placed on the eroded part of the beach to compensate for the lack of natural beach material. Beach fill is used for prevention of shoreline erosion by eroding the newly added sand in lieu of the natural shoreline. Beach fill can be maintained indefinitely by periodically adding additional sand equal to the erosion losses.

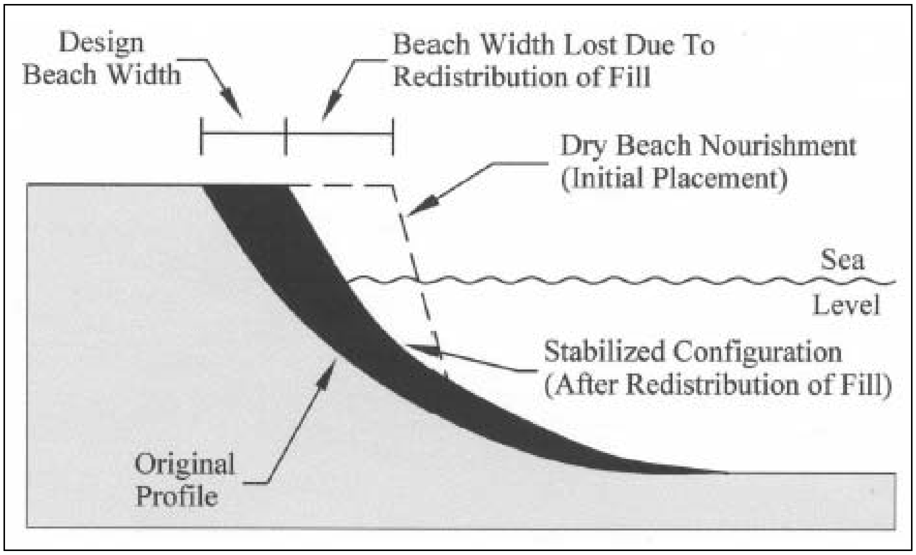

Figure 5-2: Beach fill project design profile. (California Department of Boating and Waterways and State Coastal Conservancy 2002)

Figure 5-3: The view of a beach before beach fill (left) and after its completion (right).

5.4 Sills

A sill is a coast-parallel, long or short submerged structure built with the objective of reducing the wave action on the beach by forcing wave breaking over the sill. A sill is a smaller version of a reef breakwater (Section 5.6) built nearshore and used to retard offshore sand movements by introducing a structural barrier on the beach profile (Burcharth and Hughes 2002). The sloped or vertical face of the sill holds the sand on the landward side at a higher elevation than on the seaward side, creating a perched beach that extends the shoreline seaward. To prevent the sand from leaking seaward, sills are continuous (not segmented/detached). Submerged sills are also used to retain beach material artificially placed on the beach profile behind the sill. Sills are usually built as rock-armored, rubble-mound structures or timber sheet pile structures, although can be constructed from commercially available prefabricated units or oyster shell bags. Sills are often used in conjunction with vegetation control (plantings of marsh grass) or existing wetland vegetation landward of the sill.

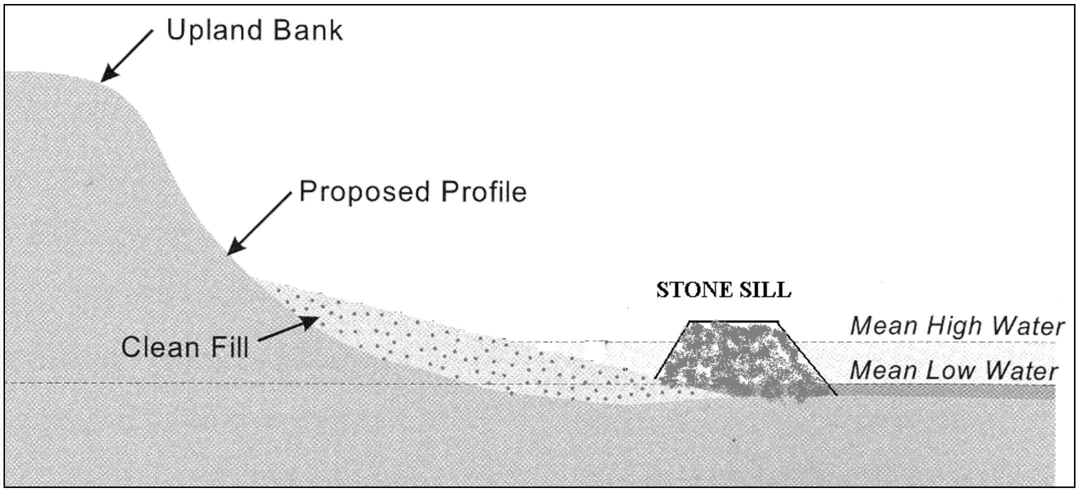

Figure 5-4: Cross-section of a stone sill (Barnard and Hardaway)

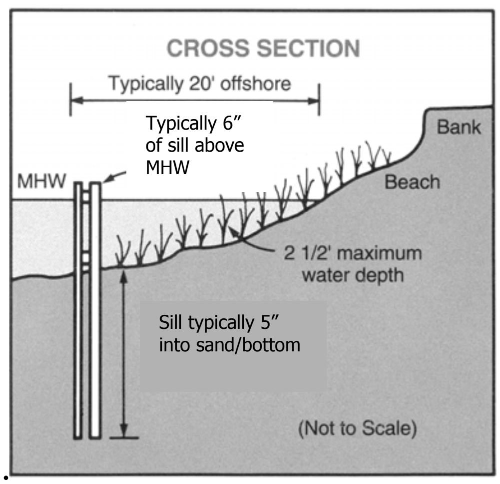

Figure 5-5: Cross-section of a timber sheet pile sill. (Rogers et al. 1992)

In the North Carolina estuarine system, although somewhat variable, sill heights are typically less than 1 foot above normal high water level and may be constructed with stone or as a freestanding vertical wall. The most common type of marsh vegetation to combine with sills is smooth cordgrass, which prefers a tidal range from mid-tide to the normal high water level. The sills are thus located slightly waterward of mid-tide to properly accommodate the cordgrass. In North Carolina, sills and reef breakwaters (Section 5.6) are very similar with sills closer to shore, not detached, and of smaller construction. The main difference between a sill and a breakwater is that sills in North Carolina are always associated with wetland vegetation in some way whether it be protecting existing or the planting of new vegetation. DCM permits the timber sheet pile sills as "marsh enhancement breakwaters."

Figure 5-6: View of a rubble mound (rock) sill (left) and a timber sheet pile sill (right).

5.5 Groins

Groins are narrow structures, usually straight and perpendicular to the pre-project shoreline. Groins are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. Groins function only when longshore transport occurs. The anticipated effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side; both effects extend some distance from the structure. Consequently, a groin system (series of groins) results in a saw-tooth-shaped shoreline within the groin field and a differential in beach level on either side of the groins. (Burcharth and Hughes 2002)

Groins are also used to hold artificially nourished beach material, protect newly planted marsh plantings, and to prevent sedimentation or accretion in a downdrift area (e.g., at an inlet) by acting as a barrier to longshore transport. Groins can also be used to deflect strong tidal currents away from the shoreline. The orientation, length, height, permeability, and spacing of the groins determine, under given natural conditions, the actual change in the shoreline and the beach level. Groins are occasionally constructed non-perpendicular to the shoreline, can be curved, have fishtails, or have a shore-parallel T-head at their seaward end. (Burcharth and Hughes 2002)

Groins are often mistakenly called jetties, which are larger structures designed for stabilization of navigation channels at river mouths and tidal inlets. Jetties are shore-connected structures generally built on either one or both sides of the navigation channel perpendicular to the shore and extending waterward. (Burcharth and Hughes 2002)

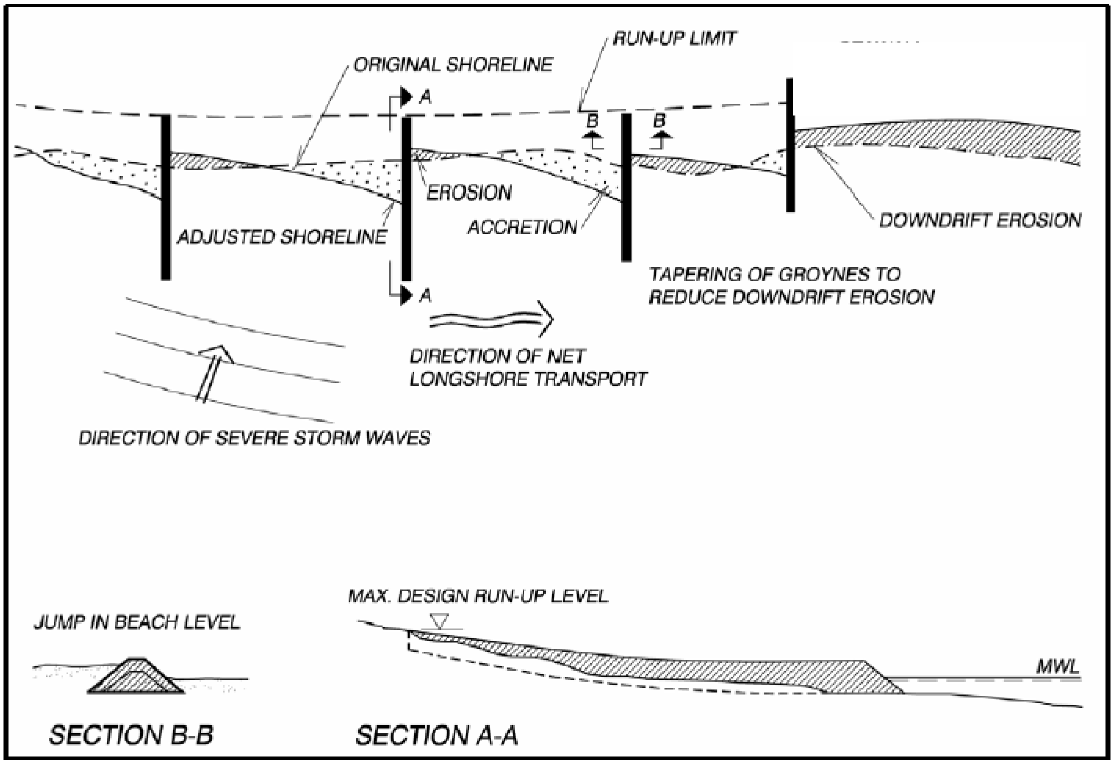

Figure 5-7: Typical configuration of a series of groins. (Burcharth and Hughes 2002)

In the North Carolina estuarine system, groins are typically constructed with stone or as a freestanding vertical wall and either in a series or individually. These groins are typically constructed to act as a sand trap and build out the upland.

Figure 5-8: A groin series and its resultant saw-toothed shaped post construction beach (left) and a single groin (right).

5.6 Breakwaters

Breakwaters (including detached, reef and floating breakwaters) are built to reduce wave action in an area in the lee of the structure. Wave action is reduced through a combination of reflection and dissipation of incoming wave energy. When used for shore protection, breakwaters are built in nearshore waters and usually oriented parallel to the shore. Breakwaters can be classified into two main types: sloping-front and vertical-front structures. Sloping-front structures are in most cases rubble-mound structures armored with rock or concrete armor units. Vertical-front structures in lower wave climates are constructed of sheet piling filled with soil, or rock. (Burcharth and Hughes 2002)

Detached breakwaters are small, relatively short, nonshore-connected nearshore breakwaters with the principal function of reducing erosion. They are built parallel to the shore just seaward of the shoreline in shallow water depths. Multiple detached breakwaters spaced along the shoreline can provide protection to substantial lengths of shoreline frontages. The gaps between the breakwaters are in most cases on the same order of magnitude as the length of one individual structure. Each breakwater reflects and dissipates some of the incoming wave energy, thus reducing wave heights in the lee of the structure and reducing shore erosion. Beach material transported along the beach moves into the sheltered area behind the breakwater where it is deposited in the lower wave energy region. The nearshore wave pattern, which is strongly influenced by diffraction at the heads of the structures, will cause salients and sometimes tombolos to be formed, thus making the coastline similar to a series of pocket beaches. Once formed, the pockets will cause wave refraction, which helps to stabilize the pocket-shaped coastline. Detached breakwaters are normally built as rubble-mound structures with fairly low crest levels that allow significant overtopping during storms at high water. The low-crested structures are less visible and help promote a more even distribution of littoral material along the coastline. Submerged detached breakwaters are used in some cases because they do not spoil the view. (Burcharth and Hughes 2002)

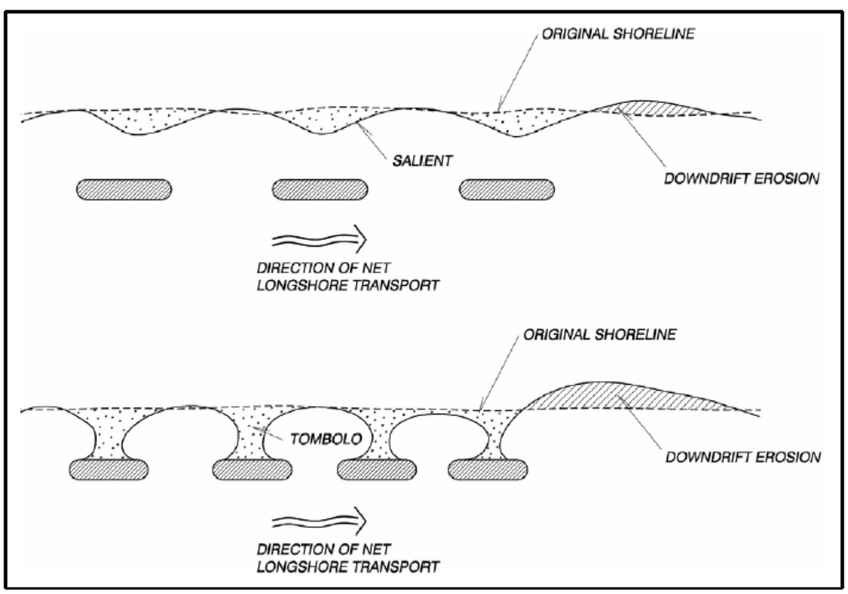

Figure 5-9: Typical configuration of detached breakwaters. (Burcharth and Hughes 2002)

Reef breakwaters are coast-parallel, long or short submerged structures built with the objective of reducing the wave action on the beach by forcing wave breaking over the reef. Reef breakwaters are normally rubble-mound structures constructed as a homogeneous pile of stone or concrete armor units. Besides triggering wave breaking and subsequent energy dissipation, reef breakwaters can be used to regulate wave action by refraction and diffraction. (Burcharth and Hughes 2002)

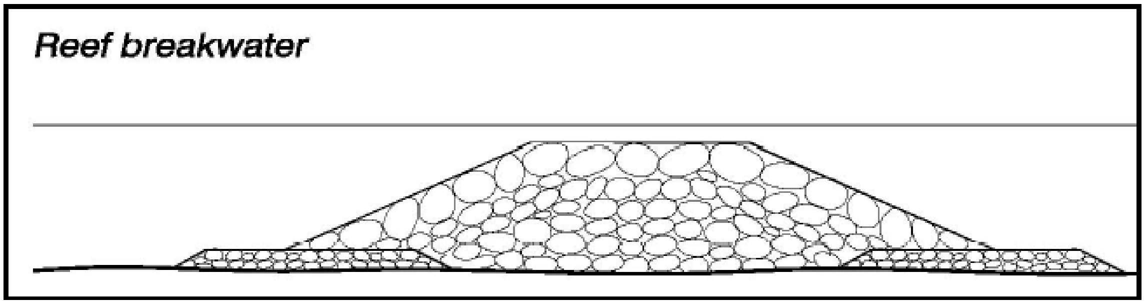

Figure 5-10: Cross-section of a reef breakwater. (Burcharth and Hughes 2002)

Floating breakwaters are coast-parallel, long or short, floating structures anchored offshore with the intention of dissipating wave energy before the wave attenuates to the shoreline. Floating breakwaters are used in protected regions that experience mild wave climates with very short-period waves. (Burcharth and Hughes 2002)

In the North Carolina estuarine system, breakwaters are typically constructed from stone and may extend several feet above the normal high water level for protection of storm waves. Detached breakwaters are constructed the most frequently. Smaller reef breakwaters when used to protect wetland vegetation can have the same design as a typical sill. In North Carolina, sills and breakwaters are very similar, but typical breakwaters are of the detached breakwater construction, which is further from shore, gapped or detached, and of larger construction. Breakwaters are not typically associated with vegetation control and are designed most usually as sand trapping structures.

Figure 5-11: A single (left) and multiple (right) detached rock breakwaters and their resultant tombolos.

5.7 Sloped Structures

Sloped structures are shore parallel, watertight or porous structures constructed against a bank with the principal function of protecting the shoreline from erosion while absorbing wave energy. Sloped structures armor sloping natural shoreline profiles and typically consist of a placed rock or riprap (randomly placed and sized stone, concrete, or asphalt pieces), but can be constructed from oyster shell bags as well. (Burcharth and Hughes 2002)

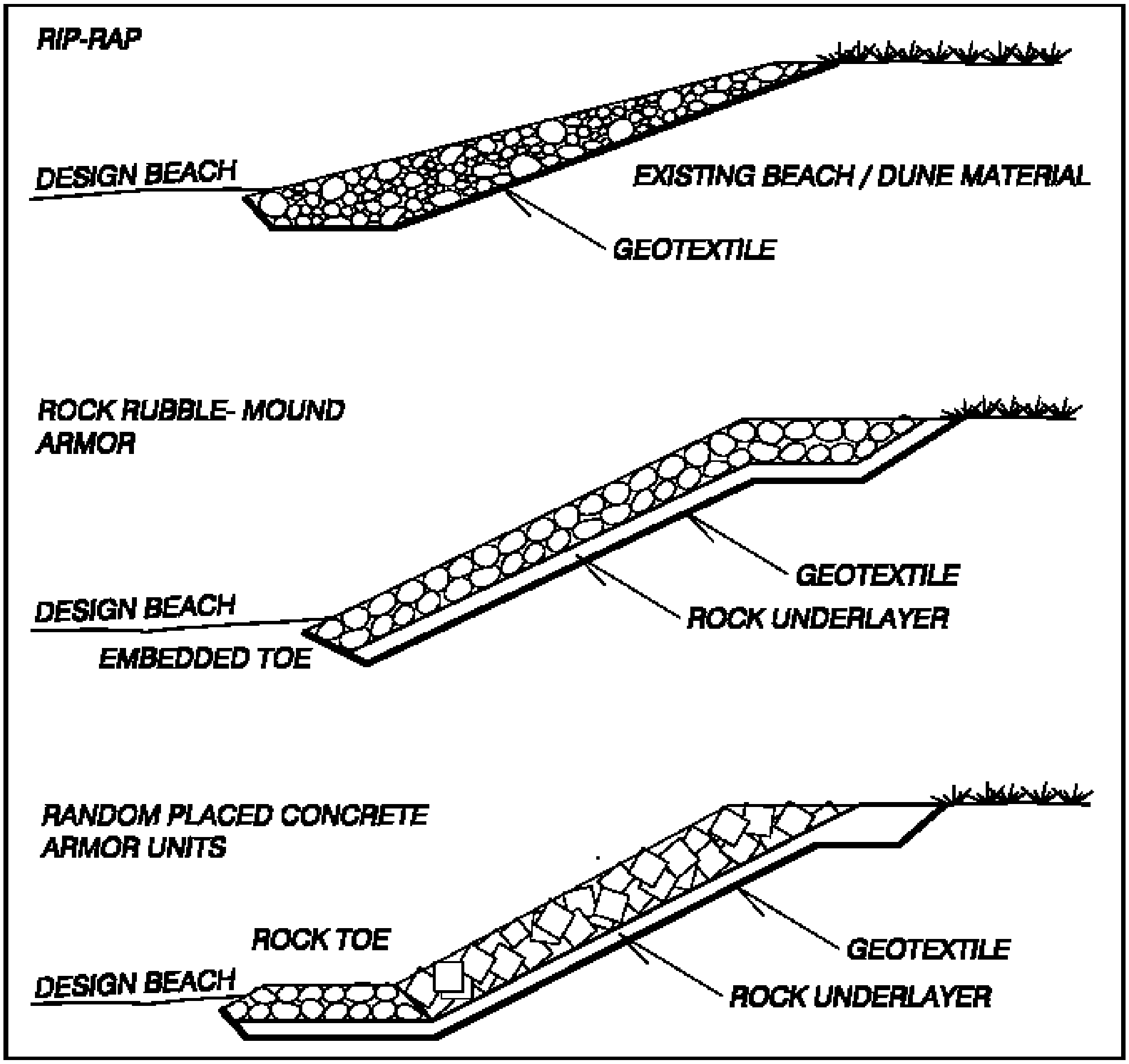

Figure 5-12: Cross-sections of sloping structures with different construction material. (Burcharth and Hughes 2002)

Sloped structures can also be used as toe protection along wetlands. Sloping structures for toe protection are generally smaller, sloping stone or riprap structures used to protect the marsh or wetland roots from undermining. Typically marsh toe sloping structures may extend up to 6 inches above the elevation of the marsh wetland.

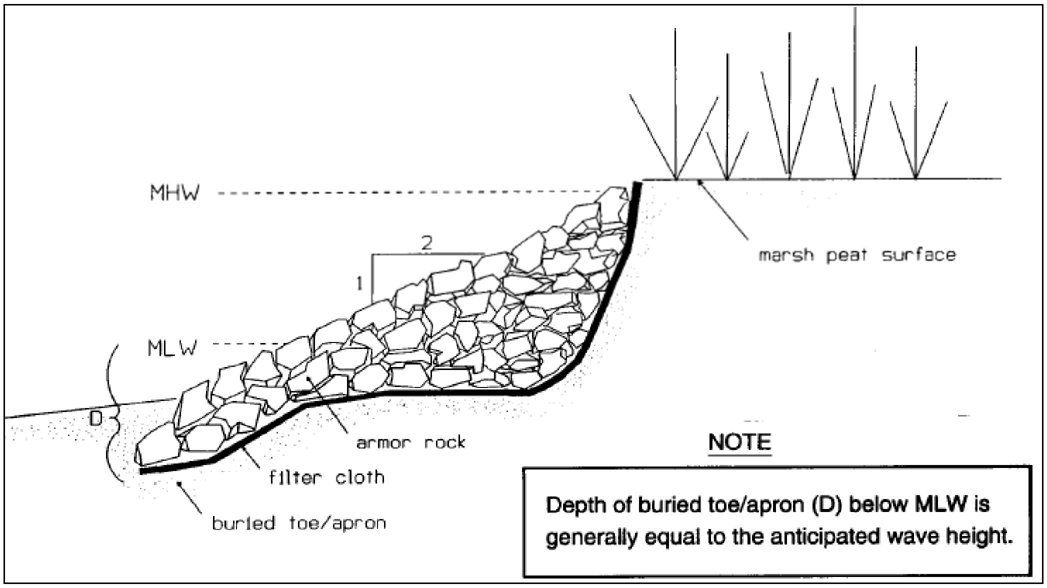

Figure 5-13: Cross-section of a sloping structure for toe protection. (Barnard)

In North Carolina estuarine systems, sloped structures typically consist of several layers of stone and less commonly with continuously cast concrete, interconnected armor units. Sloped structures are typically built on a 1:1.5 (vertical to horizontal) or flatter slope.

Figure 5-14: Sloped structures constructed from rock (left) and watertight cast concrete (right).

5.8 Vertical Structures

Vertical structures typically include seawalls and bulkheads, although some reference literature does not make a distinction between them.

Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves. Seawalls are built parallel to the shoreline as a reinforcement of a part of the coastal profile. Seawalls range from vertical face structures such as massive gravity concrete walls, tied walls using steel or concrete piling, and stone-filled cribwork with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble. (Burcharth and Hughes 2002)

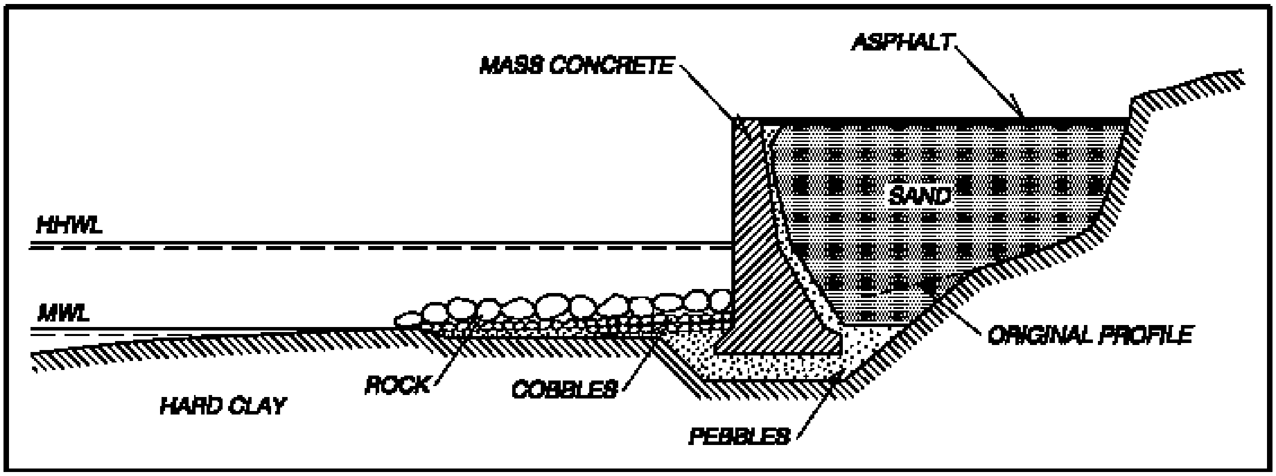

Figure 5-15: Typical concrete seawall (vertical structure) cross-section. (Burcharth and Hughes 2002)

Bulkhead is the term for structures primarily intended to retain or prevent sliding of the land, whereas protecting the hinterland against flooding and wave action is of secondary importance. Bulkheads are built as soil retaining structures, and in most cases as a vertical wall anchored with tie rods. (Burcharth and Hughes 2002)

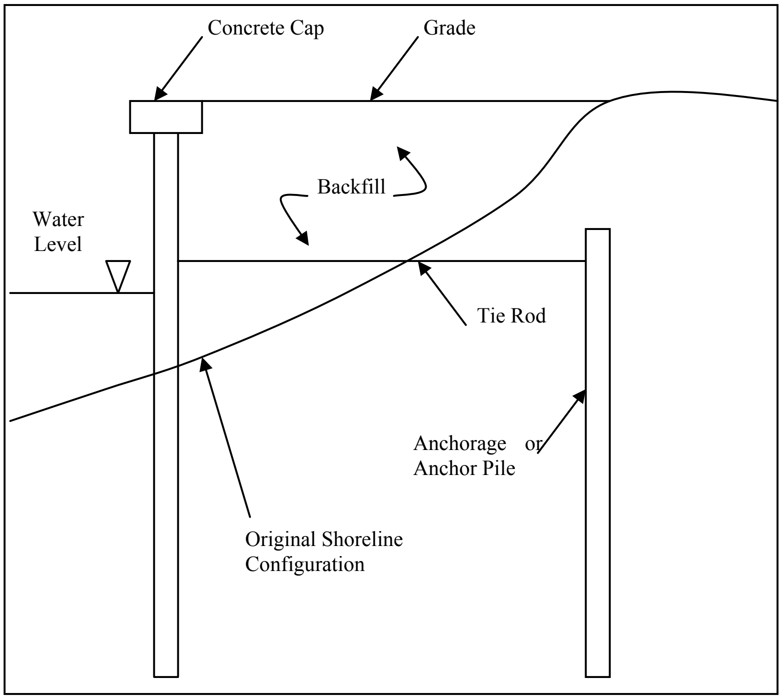

Figure 5-16: Typical bulkhead (vertical structure) cross-section.

In North Carolina, vertical structures are generically known as bulkheads on the estuarine shoreline and seawalls on the oceanfront shoreline, but seawalls can be found throughout the estuarine system. Vertical structures are typically constructed as timber sheet pile structures with tie backs.

Figure 5-17: Typical CCA treated timber bulkhead (left) and stone seawall (left).

6. ECOLOGICAL ASSESSMENT OF ESTUARINE SHORELINES

Each unique shoreline type differs somewhat in the beneficial ecological functions that it provides. To assist in the evaluation of the impacts/benefits of the implementation of shoreline management options to the shoreline's ecological functions, a functional assessment of each shoreline type was completed. This exercise provided a baseline for understanding the importance of individual shoreline types to the estuarine system. Given that a list of functions was not available specifically for estuarine shores, the Work Group drew on the functions of riverine wetlands (Brinson et al. 1995) as a starting point for the list. The descriptions have been modified to apply to estuarine shorelines and shore zones of North Carolina.

6.1 Function Descriptions

6.1.1 Hydrologic Functions

Hydrologic functions deal with the properties, distribution, and circulation of water on and below the estuarine shoreline surface. (Brinson et al. 1995)

- **Surface Water Storage -** Surface water storage is the capacity to hold water above the surface of the soil or sediment. By storing runoff, alterations to the natural hydrology of the system are reduced and the amount of sediment and pollutants entering open waters is reduced. Shorelines freely exchange water during tidal and wave activity. Without water, shoreline processes such as erosion and accretion, biogeochemical cycling, and aquatic habitat maintenance cannot occur. Surface water storage is reduced by filling-in existing shoreline components that once held water. Storage is increased by excavating or eroding shoreline components that consisted of soil and sediment. Without surface water storage, none of the functions listed above can take place. (Brinson et al. 1995)

- **Storm/Buffer Energy Dissipation -** Storm/buffer energy dissipation is the allocation of the energy of water, usually from tidal currents and waves, to other forms as it moves through, into, or out of the shoreline as a result of roughness associated with vegetation structure, micro- and macrotopography, and other obstructions. The dissipation of energy at the shoreline protects nearshore environments by reducing physically stressful environmental conditions both toward the land and toward the water. It increases deposition of suspended material and chemical transformation and processing due to longer residence times. Generally, biological processes and diversity are reduced with increasing levels of physical stressors. Dissipation of energy is increased and more broadly distributed by "softer" shorelines typically consisting of roots and stems of vegetation. Shoreline hardening reverses this effect such that less energy is dissipated at the shoreline and more is dissipated elsewhere. The net result is that the hardening of shorelines may result in greater levels of water turbulence and erosion. Reflecting waves from bulkheads, for example, are commonly observed to scour and deepen nearshore environments. (Brinson et al. 1995)

- **Filtration of Particulates/Baffling -** Filtration of particulates/baffling is the capacity of a shoreline to reduce current velocities and increase sedimentation rates of organic and inorganic particulates. Vegetation that reduces current velocities may result in the settling-out of suspended particulates, including bed load. Compared with shorelines that lack vegetation, vegetated shorelines have a greater tendency to accrete rather than erode, although erosion is nevertheless prevalent throughout North Carolina estuaries. The root zone of vegetation contributes to this function by stabilizing soil so that plants can become established to produce the baffling effect. Removal of vegetation eliminates this baffling effect on shorelines. Removal can have a cascading effect of destabilizing the root mat and making the shoreline more vulnerable to erosion. (Brinson et al. 1995)

- **Groundwater Storage -** Groundwater storage is the capacity of a shoreline bank to store subsurface water. Storage capacity becomes available when periodic drawdown of the water table occurs, making soil pores available for storage of water. Bank storage is a common function of streams that consists of infiltration of channel water during high stream stages and release of water during low stages. The influence of bank storage is proportionately greater on smaller streams than on larger streams. Consequently, hydrologic effects on estuaries would be minimal because of the high ratio of water volume to shoreline length. However, groundwater storage locally influences biogeochemical processes in soil, and retains water for the establishment and maintenance of biotic communities. Removal of sediment by erosion and other means eliminates this function. Excessive detention of groundwater due to flow restrictions may result in more anoxic conditions. (Brinson et al. 1995)

6.1.2 Biogeochemical Functions

Biogeochemical functions relate to the partitioning and cycling of chemical elements and compounds between the living and nonliving parts of the estuarine shoreline ecosystem. (Brinson et al. 1995)

- **Nutrient Retention/Cycling -** Nutrient retention and cycling are abiotic and biotic processes that convert nutrients and other elements from one form to another. Retention occurs when more is taken up than is released. Shorelines have a limited capacity to retain and cycle nutrients, in part because they are environments undergoing erosion. Retention is more likely in lower energy shoreline environments where plant growth and sediment accretion occur, at least seasonally. Replacement of vegetation by non-living structures reduces the capacity for retention and cycling when accompanied by accelerated erosion. In some cases, nutrient retention can be increased especially when shorelines are stabilized. However, the balance will depend on the details of storm/buffer energy dissipation. (Brinson et al. 1995)

- **Biotic Productivity -** Productivity is the capacity of a shoreline to support primary production and food webs. Shorelines consist of a complex of aquatic, wetland, and terrestrial environments, usually in very close proximity. Most primary production is converted to detritus, which is the basis for fueling most food webs. Plankton production contributes to the support of benthic organisms, as does algal production on vascular plants, sediment, and other surfaces. Most shoreline alterations modify the type of primary production and food web support. (Brinson et al. 1995)

- **Detrital Export/Retention -** Detrital export/retention is the capacity of a shoreline to produce organic matter for detrital production, export, and retention. Detritus is commonly the major contributor to secondary production, in contrast to direct grazing by herbivores. Shorelines occupied by vascular plants, and especially marshes, have a high capacity for both export and retention. Consequently, both the shoreline itself and nearshore environments benefit from these sources of organic matter. An increase in hydraulic energy of the shoreline will alter the capacity for detrital export and retention. Alterations that increase the intensity of currents and waves may increase export at the expense of retention and vice versa. (Brinson et al. 1995)

6.1.3 Plant and Animal Community Functions

Plant and Animal Community Functions consist of the interrelationship of organisms with one another and the estuarine shoreline ecosystem.

- **Biodiversity/Community Structure -** Biodiversity refers to diversity of species supported by a habitat type (fully recognizing that few species are maintained within a single isolated habitat). Community structure was included to recognize associated aspects of community complexity, which may transcend simple measures of species richness and include aspects of trophic structure, stability, population dynamics, etc. Physical destruction of habitat is considered to be the most pervasive cause of biodiversity loss (Heywood 1995, Norse and Watling 1999).

- **Habitat Structure/Refuge -** Physical structure of habitats, such as vegetation or shells, can be important to providing refuge habitat for residents of certain life stages of transient species. As such, the provision of such refuge can be critical for population levels of some taxa. However, the importance of this refuge function may depend on the location of the habitats (e.g. high intertidal vs. subtidal), type, size and density of structure, and predictable association of other structural types. Biotic structure occurring in shallow water along the shoreline, whether it is wetland plants, submerged grasses, oysters, or worm tubes, provides refuge and an abundant food source for small juvenile fish and invertebrates (nursery habitat). The structure also slows currents, improving conditions for successful recruitment, particularly for anadromous species such as river herring (O'rear 1983). Some small resident wetland fish species, such as mummichog and grass shrimp, spawn in the shoreline marsh. This function recognizes the structural and potential refuge function of certain shoreline habitats.

- **Filtering -** Removal of particulates and certain other materials is used to distinguish filtering conducted actively by organisms (e.g. filtration by oysters, clams and mussels; uptake of nutrients by plants) as opposed to deposition of particles resulting from baffling of current flow or waves (included as a separate category under hydrologic function in Section 6.1.1).

- **Foraging/Nursery –** Shorelines and shore zones produce food sources for an array of species. Some species are absolutely dependent upon estuarine habitats in general, of which the shore is one component. Primary nursery areas identified by the NC Division of Marine Fisheries (DMF) often have a high ratio of shoreline length to water surface area (Street et al. 2004). Juvenile fish and invertebrates feed on the high organic content of the detrital material, the benthic macroalgae, and the infauna (worms, clams, crustaceans) in the shallow sediment (Peterson and Peterson 1979). The amount of productivity on soft bottom is controlled by temperature, light availability, sediment grain size and community biomass (Pinckney and Zingmard 1993). In North Carolina, most primary nursery areas consist of a shallow muddy bottom, usually adjacent to wetlands. These areas support a high abundance of juvenile fish composed of relatively few, but important fishery species, including summer and southern flounder, spot, croaker, and penaeid shrimp (Ross and Epperly 1985).

- **Habitat Diversity/Connectivity –** Certain habitats may not support high diversity or have critical nursery functions in isolation; but they may be important parts of the landscape-providing habitat for selected species during certain parts of their life histories, interacting with other habitats to increase certain functions, or serving a corridor function for migratory species. These ephemeral, linkage, and interactive aspects of habitat functions are recognized in this category. The shallow nearshore waters allow for safe corridor for juvenile fishes and invertebrates migrating through the estuary that is in accessible to larger predators.

- **Unique Habitat -** This category recognizes that certain habitats may be essential for specific species of concern or may have very limited yet important roles in the estuarine system. Examples include banks that serve as nesting areas for swallows (which might otherwise have low estuarine habitat function) or barrier island shores that are nesting areas for certain shorebirds and seabirds of concern.

6.2 Ecological Assessment of Natural Shoreline Types

The Work Group evaluated each of the shoreline categories with regard to the foregoing descriptions. The resulting matrices (Tables 6-1, 6-2, and 6-3) were scored using three discrete values. The three values ranged from minimal to exceptional functional importance to the estuarine ecosystems. It should be recognized that scores only reflect natural functions and do not imply ecologically superior or inferior conditions. Conditions altered by human activities are treated as impacts in Section 7.0. The Work Group applied best scientific judgment without specific reference to the published research literature. The matrix scores include:

- **Minimal Function (0)** = Shoreline type having nominal to slight functional importance.

- **Moderate Function (1) =** Shoreline type having average functional importance.

- **Exceptional Function (2) =** Shoreline type having superior functional importance.

Table 6-1: Hydrologic functions of natural shoreline types.

Shoreline Type	Surface Water Storage	Storm Buffer/ Energy Dissipation	Filtration of Particulates/ Baffling	Groundwater Storage
High Sediment Bank	0	2	0	2
Swamp Forest	2	2	2	0
Marsh	2	2	2	0
Marsh with Oysters	2	2	2	0
Low Sediment Bank with Swamp	2	2	2	0
Low Sediment Bank with Marsh	2	2	2	0
Low Sediment Bank with Oyster/SAV	0	1	1 - Oyster / 2 - SAV	0
Low Sediment Bank with Woody Debris	0	1	1	0
Low Sediment Bank with Sand	0	1	0	0
Marsh with Mudflats	0	1	1	0
Overwash Barrier/Inlet Areas	0	1	0	0

Table 6-2: Biogeochemical functions of natural shoreline types.

Shoreline Type	Nutrient Retention/ Cycling	Biotic Productivity (in situ)	Detrital Export/ Retention
High Sediment Bank	1	0	0
Swamp Forest	2	2	2
Marsh	2	2	2
Marsh with Oysters	2	2	2
Low Sediment Bank with Swamp	2	2	2
Low Sediment Bank with Marsh	2	2	2
Low Sediment Bank with Oyster/SAV	2	2	2
Low Sediment Bank with Woody Debris	1	1	1
Low Sediment Bank with Sand	1	1	0
Marsh with Mudflats	2	2	1
Overwash Barrier/Inlet Areas	1	1	0

Table 6-3: Plant and animal community functions of natural shoreline types.

Shoreline Type	Biodiversity/ Community Structure	Habitat Structure/ Refuge	Filtering (active)	Foraging/ Nursery	Habitat Diversity/ Connectivity	Unique Habitat
High Sediment Bank	0	0	0	1	1	2 (swallows)
Swamp Forest	2	2	1	2	2	0
Marsh	2	2	2	2	2	0
Marsh with Oysters	2	2	2	2	2	0
Low Sediment Bank with Swamp	2	2	1	2	2	0
Low Sediment Bank with Marsh	2	2	1	2	2	0
Low Sediment Bank with Oyster/SAV	2	2	2	2	2	0
Low Sediment Bank with Woody Debris	2	2	0	2	2	0
Low Sediment Bank with Sand	1	0	0	1	1	0
Marsh with Mudflats	2	1	1	2	1	0
Overwash Barrier/Inlet Areas	1	0	0	1	1	2 (shorebirds)

7. PHYSICAL ASSESSMENT OF SHORELINE STABILIZATION

The impact assessment is intended to demonstrate likely results of modifying and altering natural shorelines and shore zones. The Work Group constructed a table (Table 7-1) consisting of the impacts of the different shoreline stabilization structures. After an initial assessment, it was determined that the majority of the impacts are consistent for the different shoreline types. This process helped lead to a ranking of the severity of impacts relative to the condition of maintaining the natural shoreline types.

Table 7-1: Possible habitat changes resulting from specific shoreline stabilization methods

Land Planning	Vegetation Control	Beachfill	Sills	Groins	Breakwaters	Sloped Structure	Vertical Structure
Continued erosion with loss of upland	Reduces sediment and nutrient input into estuary	Changes from estuarine/sandy bottom to upland	Reduces sediment and nutrient input into estuary	Reduces sediment and nutrient input into estuary	Reduces sediment and nutrient input into estuary	Reduces sediment and nutrient input into estuary	Reduces sediment and nutrient input into estuary
	Reduces erosion landward	Reduces erosion landward	Reduces erosion landward	Reduces local erosion landward	Reduces erosion landward	Reduces erosion landward	Reduces erosion landward
		Could change sediment size distribution	Creates hard structure for non-mobile marine life	Creates hard structure for non-mobile marine life	Creates hard structure for non-mobile marine life	Creates hard structure for non-mobile marine life	Creates hard structure for non-mobile marine life
		Buries local shoreline type with sand	Fill resulting in wetland or upland	Sand trap or fill results in wetland or upland	Sand trap or fill results in wetland or upland	Could eliminate intertidal habitat or environment	Could eliminate intertidal habitat or environment
			Creates a new, lower energy environment	Increased erosion downdrift	Creates a new, lower energy environment	Reduces sediment to depositional areas downdrift	Reduces sediment to depositional areas downdrift
			Fragments habitat	Starves sediment depositional areas	Fragments habitat	Deepens water	Deepens water
			Increases habitat complexity	Increases habitat complexity	Increases habitat complexity	Increases habitat complexity	Concentrates turbulence
						Concentrates turbulence	

8. ESTUARINE SHORELINE RANKING OF STABILIZATION METHODS

The following rankings are based upon the Work Group's stated goal of maintaining the current shoreline type and continuation of the current ecological functions and values. Sediment input as a pollutant to water quality was not a primary consideration in the rankings and could change the rankings slightly if considered to have a higher priority. Based on these criteria, the lists of stabilization measures for each shoreline type represent a ranking of options, from the option with the least potential adverse impact to the existing system (minimum ranking of 1), to the option with the greatest potential adverse impact to the system (maximum ranking of 8).

Although the following rankings were compiled by the Work Group, there was a consensus that the location of the stabilization method was more important than the actual structure type. For example, the sloped and vertical structures will have less impact if they are is located further away from the normal high water line. The rankings were based upon ideal site circumstances and so the design of the structures is very important because not all structures will perform as it is intended on every site.

Table 8-1: Summary of ranking of stabilization methods.

	Swamp Forest	Marsh	Marsh with Oysters	Marsh with Mudflats	Low Sediment Bank with Marsh	Low Sed. Bank with Swamp Forest
Land Planning	1	1	1	1	1	1
Vegetation Control	2	2	2	2	2	2
Beach Fill	3	3	NR	NR	NR	NR
Sills	4	4	3	3	3	3
Groins	5	5	4	4	4	4
Breakwaters	6	6	NR	NR	4	4
Sloped Structures	4-toe only NR-other	4-toe only NR-other	3-toe only NR-other	3-toe only NR-other	3-toe only 4-other	3-toe only 4-other
Vertical Structures	NR	NR	NR	NR	4	4

NR = Not Recommended

Table 8-2: Summary of ranking of stabilization methods continued.

	Low Sediment Bank with Sand	Low Sediment Bank with Woody Debris	Low Sediment Bank with Oysters/SAV	High Sediment Bank	Overwash Barrier/Inlet Areas
Land Planning	1	1	1	1	1
Vegetation Control	3	2	2	3	2
Beach Fill	2	NR	NR	2	2
Sills	5	3	3	5	4
Groins	4	NR	NR	4	3
Breakwaters	6	NR	NR	6	5
Sloped Structures	7	4	4	7	6
Vertical Structures	8	5	5	8	7

NR = Not Recommended

8.1 Swamp Forest

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** - Land planning should always be evaluated as the first option.
2. **Vegetation Control** - Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Beach Fill** - Beach fill should only be used on this shoreline type if a sandy beach is already present waterward of the swamp forest. Beach fill will maintain the current shoreline type and associated functions and values. Beach fill is used to create a buffer of intertidal or supratidal sandy beach to protect the shoreline from further erosion. The sandy buffer helps to dissipate wave action before it impacts the swamp forest landward of the sandy beach. Although beach fill is a temporary measure, it does help to control the erosion and continues to contribute sediment into the system.
4. **Sills, Sloped Structures (for toe protection only)** - Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. These structures can only be used as toe protection on this shoreline since there is not a sediment bank to construct a larger sloped structure against. Sills should be constructed waterward of the swamp forest to provide protection against erosion by forcing wave breaking prior to reaching the trees and other woody vegetation. Since sills are usually constructed in conjunction with vegetation control, they should not only slow the erosion of the swamp forest, but also increase wetland vegetation. Fill should only be used when it will improve conditions or the function of the shoreline.
5. **Groins** - Groins are typically constructed as sand traps, but can also be designed to dissipate wave energy. Groins cause erosion downdrift of the structure that can result in a loss of marsh and block juvenile fish passage. Fill should only be utilized to improve the conditions or the function of the shoreline type.
6. **Breakwaters** - Breakwaters are typically constructed as a sand trap, and they are designed to dissipate and alter the incoming wave energy, to create a stable sandy embayment. Breakwaters may create supratidal beaches or high ground/upland, resulting in a loss of soft bottom habitat and/or swamp forest. The resulting sandy beach will act as a buffer to dissipate wave energy, but would alter the shoreline type. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. Breakwaters typically have a large footprint, which would cover the soft bottom habitat.
7. **Vertical Structures** - Vertical structures are not recommended waterward of the swamp forest, as it would be associated with fill that would cover/alter the swamp forest. If the vertical structure is not associated with fill, is low in elevation, and located waterward of the swamp forest, it should be considered a sill.

8.2 Marsh

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control** - Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Beach Fill** – Beach fill should only be used on this shoreline type if a sandy beach is already present waterward of the marsh. Beach fill will maintain the current shoreline type and associated functions and values. Beach fill is used to create a buffer of intertidal or supratidal sandy beach to protect the shoreline from further erosion. The sandy buffer helps to dissipate wave action before it impacts the marsh landward of the sandy beach. Although beach fill is a temporary measure, it does help to control the erosion and continues to contribute sediment into the system.
4. **Sills, Sloped Structures (for toe protection only)** - Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. These structures can only be used as toe protection on this shoreline since there is not a sediment bank to construct a larger sloped structure against. Sills should be constructed waterward of the marsh to provide protection against erosion by forcing wave breaking prior to reaching the marsh. Since sills are usually constructed in conjunction with vegetation control, they may not only slow the erosion of the marsh, but may also increase wetland vegetation. Fill should only be used when it will improve conditions or the function of the shoreline.
5. **Groins** - Groins are typically constructed as sand traps, but can also be designed to dissipate wave energy. Groins cause erosion downdrift of the structure that can result in a loss of marsh and block juvenile fish passage. Fill should only be utilized to improve the conditions or the function of the shoreline type.
6. **Breakwaters** – Breakwaters are typically constructed as a sand trap, and they are designed to dissipate and alter the incoming wave energy, to create a stable sandy embayment. Breakwaters may create supratidal beaches or high ground/upland, resulting in a loss of soft bottom habitat and/or marsh. The resulting sandy beach will act as a buffer to dissipate wave energy, but would alter the shoreline type. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. Breakwaters typically have a large footprint, which would cover the soft bottom habitat.
7. **Vertical Structures** - Vertical structures are not recommended waterward of the marsh as it would be associated with fill that would cover/alter the marsh. If the vertical structure is not associated with fill and is low in elevation waterward of the marsh, it should be considered a sill.

8.3 Marsh with Oysters

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** - Land planning should always be evaluated as the first option.
2. **Vegetation Control** - Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sills, Sloped Structures (for toe protection only)** - Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. These structures can only be used as toe protection on this shoreline since there is not a sediment bank to construct a larger sloped structure against. Sills should be constructed waterward of the marsh to provide protection against erosion by forcing wave breaking prior to reaching the marsh. Since sills are usually constructed in conjunction with vegetation control, they may not only slow the erosion of the marsh, but may also increase wetland vegetation. Both methods should avoid disruption to adjacent oyster reefs. Fill should only be used when it will improve conditions or the function of the shoreline. When feasible, oyster shells/oyster shell bags should be used as the construction material for the sills and sloped structures because they provide a superior substrate for recruitment of new oysters.
4. **Groins** - Groins are typically constructed as sand traps, but can also be designed to dissipate wave energy. Groins cause erosion downdrift of the structure that can result in a loss of marsh and oyster habitat as well as block juvenile fish passage. Fill should only be utilized to improve the conditions or the function of the shoreline type.
5. **Breakwater** – Breakwaters are not recommended on this shoreline type because they are typically constructed to be a sand trap. Breakwaters may create supratidal beaches or high ground/upland, resulting in a loss of soft bottom habitat, oyster habitat, and/or marsh. The resulting sandy beach will act as a buffer to dissipate wave energy, but would alter the shoreline type. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. Breakwaters typically have a large footprint, which would cover the soft bottom habitat.
6. **Vertical Structures** – Vertical structures are not recommended waterward of the oyster/oyster beds or marsh, as it would be associated with fill that would cover/alter the habitat. If the vertical structure is not associated with fill, is low in elevation, and located waterward of the marsh, it should be considered a sill.
7. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover/alter the existing oyster or marsh habitat, altering its function.

8.4 Marsh with Mudflats

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** - Land planning should always be evaluated as the first option.
2. **Vegetation Control** - Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sills, Sloped Structures (for toe protection only)** - Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. These structures can only be used as toe protection on this shoreline since there is not a sediment bank to construct a larger sloped structure against. Sills should be constructed waterward of the marsh to provide protection against erosion by forcing wave breaking prior to reaching the marsh. Since sills are usually constructed in conjunction with vegetation control, they may not only slow the erosion of the marsh, but may also increase wetland vegetation. Fill should only be used when it will improve conditions or the function of the shoreline.
4. **Groins** - Groins are typically constructed as sand traps, but can also be designed to dissipate wave energy. Groins cause erosion downdrift of the structure that can result in a loss of marsh, change mudflat characteristics, and block juvenile fish passage. Fill should only be utilized to improve the conditions or the function of the shoreline type.
5. **Breakwater** – Breakwaters are not recommended on this shoreline type because they are typically constructed to be a sand trap. Breakwaters may create supratidal beaches or high ground/upland, resulting in a loss of soft bottom habitat, mudflats, and/or marsh. The resulting sandy beach will act as a buffer to dissipate wave energy, but would alter the shoreline type. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. Breakwaters typically have a large footprint, which would cover the soft bottom habitat.
6. **Vertical Structures** – Vertical structures are not recommended waterward of the mudflats or marsh, as it would be associated with fill that would cover/alter the habitat. If the vertical structure is not associated with fill, is low in elevation, and is located waterward of the marsh, it should be considered a sill.
7. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover/alter the existing mudflat or marsh habitat, altering its function.

8.5 Low Sediment Bank with Marsh

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control** – Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sills, Sloped Structure (for toe protection only)** – Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. Sills can be constructed waterward of the marsh to provide protection against erosion of the sediment bank by forcing wave-breaking waterward of the sediment bank and marsh vegetation. Since sills are usually constructed in conjunction with vegetation control, they may not only slow the erosion of the non-expansive marsh, but may also increase wetland vegetation. The vegetation control can add an additional buffer for wave energy dissipation. Fill should only be used when it will improve conditions or the function of the shoreline. Sloped structures are placed waterward and at the toe of the marsh to protect it from additional erosion. For both the sill and sloped structure (for toe protection only), fill should only be used when it will improve conditions or the function of the shoreline.
4. **Sloped Structures, Vertical Structures, Groins, Breakwaters** – Sloped Structures, Vertical Structures, Groins, and Breakwaters are ranked similarly for this shoreline type because each of these structures can be seen as the “better” option at different locations. This ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated against the impacts it will have on the shoreline. Sloped and vertical structures are only to be located landward of the existing marsh vegetation (with location to be as landward as possible) because when located in the wave dissipation zone these structures could eliminate the intertidal zone, halt marsh migration, and cause scour. Groins and breakwaters are typically used as sand traps in areas with high wave energy and in sediment rich water bodies; therefore, these structures should only be used to protect against erosion under these conditions. Groins and breakwaters may cause the following: create a loss of soft bottom habitat by sand trapping and through structure footprints; create a loss of marsh though sand accretion through the vegetation; accelerate downstream erosion; and block juvenile fish passage. The Work Group had considerable debate regarding the potential use of these structures on this ranking level. Some members argued that, while these structures may be an equal option in some situations this option would not be preferred in a majority of situations along the general coastal region. None of these shoreline stabilization methods would maintain the marsh on the shoreline for the long-term.
5. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover the habitat, altering its function and convert the shoreline type to sediment bank with sand shoreline.

8.6 Low Sediment Bank with Swamp Forest

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control** – Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sills, Sloped Structure (for toe protection only)** – Sills and sloped structures are ranked similarly since the ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated based on the impacts it will have on the shoreline, the incident forces of erosion, and the potential functions and impact of each structure. Sills can be constructed waterward of the swamp forest to provide protection against erosion of the sediment bank by forcing wave-breaking waterward of the sediment bank and swamp forest vegetation. Since sills are usually constructed in conjunction with vegetation control, they may not only slow the erosion of the non-expansive swamp forest, but may also increase wetland vegetation. The vegetation control can add an additional buffer for wave energy dissipation. Fill should only be used when it will improve conditions or the function of the shoreline. Sloped structures are placed waterward and at the toe of the swamp forest to protect it from additional erosion. For both the sill and sloped structure (for toe protection only), fill should only be used when it will improve conditions or the function of the shoreline.
4. **Sloped Structures, Vertical Structures, Groins, Breakwaters** – Sloped Structures, Vertical Structures, Groins, and Breakwaters are ranked similarly for this shoreline type because each of these structures can be seen as the "better" option at different locations. This ranking level is site specific and dependant on the site conditions and water body attributes. Each structure should be evaluated against the impacts on which it will have on the shoreline. Sloped and vertical structures are only to be located landward of the existing swamp forest vegetation (with location to be as landward as possible). When located in the wave dissipation zone these structures could eliminate the intertidal zone, halt swamp forest migration, and cause scour. Groins and Breakwaters are typically used as sand traps in areas with high wave energy and in sediment rich water bodies; therefore, these structures should only be used to protect against erosion under these conditions. Groins and breakwaters may cause the following: create a loss of soft bottom habitat by sand trapping and through structure footprints; create a loss of swamp forest though sand accretion through the vegetation; accelerate downstream erosion; and block juvenile fish passage. The Work Group had considerable debate regarding the potential use of these structures on this ranking level. Some members argued that, while these structures may be an equal option in some situations this option would not be preferred in a majority of situations along the general coastal region. None of these shoreline stabilization methods would maintain the swamp forest on the shoreline for the long-term.
5. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover the habitat, altering its function and convert the shoreline type to sediment bank with sand shoreline.

8.7 Low Sediment Bank with Sand

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Beach Fill** – Beach fill will maintain the current shoreline type, and function with a non-structural means. Beach fill is used to create a buffer of high ground (sandy beach) to protect the shoreline from further erosion. The buffer helps to dissipate wave action prior to reaching the sediment bank landward of the sandy beach. Although beach fill is a temporary measure, it does help to control the erosion and continues to provide sediment into the system.
3. **Vegetation Control** – Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Vegetation control will change the shoreline type to a sediment bank with marsh or other vegetated shoreline.
4. **Groins –** Groins are typically constructed to trap sand. This will create a larger sandy beach waterward of the sediment bank, which will act as a buffer to dissipate wave energy, but will cause erosion downdrift and block juvenile fish passage.
5. **Sills** – Sills are constructed with the objective of reducing the wave action on the sediment bank by forcing wave breaking over the sill. A sill will protect the sediment bank from additional erosion but can also be used in conjunction with vegetation control. The vegetation control can add an additional buffer for wave energy dissipation, but could change the shoreline type to a sediment bank with marsh shoreline. Fill should only be used when it will improve conditions or the function of the shoreline.
6. **Breakwaters** – A breakwater is typically constructed to trap sand. This will create a larger sandy beach waterward of the sediment bank, which will act as a buffer to dissipate wave energy. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. However, the large footprints of some breakwater designs may impact subtidal habitat.
7. **Sloped Structures** – A sloped structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduces the sediment and nutrient input into the estuary. The sloped structure should be constructed as far landward as possible.
8. **Vertical Structures** – A vertical structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The vertical structure should be constructed as far landward as possible to lessen the impact to the intertidal zone.

8.8 Low Sediment Bank with Woody Debris

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control** – Vegetation control, which includes the use of living or dead vegetation, is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sill** – Sills are constructed with the objective of reducing the wave action on the sediment bank by forcing wave breaking over the sill. A sill will protect the sediment bank from additional erosion but can also be used in conjunction with vegetation control. The vegetation control can add an additional buffer for wave energy dissipation, but could change the shoreline type to a sediment bank with marsh shoreline. Fill should only be used when it will improve conditions or the function of the shoreline.
4. **Sloped Structures** – A sloped structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The sloped structure should be constructed as far landward as possible to avoid being placed on the habitat of this shoreline.
5. **Vertical Structures** – A vertical structure will reduce erosion of the sediment bank but when located in the wave dissipation zone, could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The vertical structure should be constructed as far landward as possible to lessen the impact to the intertidal zone.
6. **Groins** – Groins are not recommended on this shoreline. Groins would not only have a drastic impact on the shoreline function, but it would change the shoreline type to a sediment bank with sand shoreline. Groins are constructed to trap sand updrift of the groin's location. This will create a sandy beach waterward of the shoreline, which will act as a buffer to dissipate wave energy, but will inherently cause erosion downdrift and block juvenile fish passage.
7. **Breakwater** – Breakwaters are not recommended on this shoreline type because they are typically constructed to be a sand trap. Sand traps will create a sandy beach between the breakwater and sediment bank, which will cover the habitat. The deposited sand will act as a buffer to dissipate wave energy, but would change the shoreline type to a sediment bank with sand. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline.
8. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover the habitat, altering its function and convert the shoreline type to sediment bank with sand shoreline.

8.9 Low Sediment Bank with Oysters/SAV

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control** – Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Vegetation control will change the shoreline type to a sediment bank with marsh shoreline. Fill should only be utilized to establish a suitable grade necessary to support the growth of the plantings, which will preserve or improve the conditions or the function of the shoreline type.
3. **Sills** – Sills are constructed with the objective of reducing the wave action on the sediment bank by forcing wave breaking over the sill. A sill will protect the sediment bank from additional erosion but can also be used in conjunction with vegetation control. The vegetation control can add an additional buffer for wave energy dissipation, but could change the shoreline type to a sediment bank with marsh shoreline. Fill should only be used when it will improve conditions or the function of the shoreline. Caution should be taken on design and placement of the structure as to minimize the footprint atop the oysters and/or SAV.
4. **Sloped Structures** – A sloped structure will reduce erosion of the sediment bank but when located in the wave dissipation zone, could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The sloped structure should be constructed as far landward as possible to avoid being placed on the habitat of this shoreline.
5. **Vertical Structures** – A vertical structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The vertical structure should be constructed as far landward as possible to lessen the impact to the intertidal zone.
6. **Groins** – Groins are not recommended on this shoreline. Groins would not only have a drastic impact on the shoreline function, but it would change the shoreline type to a sediment bank with sand shoreline. Groins are constructed to trap sand updrift of the groin's location. This will create a sandy beach waterward of the shoreline, which will act as a buffer to dissipate wave energy, but will inherently cause erosion downdrift and block juvenile fish passage.
7. **Breakwaters** – Breakwaters are not recommended on this shoreline type because they are typically constructed to be a sand trap. Sand traps will create a sandy beach between the breakwater and sediment bank, which will cover the oysters/SAV. The deposited sand will act as a buffer to dissipate wave energy, but would change the shoreline type to a sediment bank with sand. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline.
8. **Beach Fill** – Beach fill is not recommended on this shoreline type. Beach fill will cover the habitat, altering its function and convert the shoreline type to sediment bank with sand shoreline.

8.10 High Sediment Bank

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Beach Fill** – Beach fill will maintain the current shoreline type, and function with a non-structural means. Beach fill is used to create a buffer of high ground (sandy beach) to protect the shoreline from further erosion. The buffer helps to dissipate wave action prior to reaching the sediment bank landward of the sandy beach. Although beach fill is a temporary measure, it does help to control the erosion and continues to provide sediment into the system.
3. **Vegetation Control** – Vegetation control is a non-structural method of stabilizing the shoreline by creating a wave dissipation buffer. Vegetation control will change the shoreline type to a sediment bank with marsh or other vegetated shoreline. Because high sediment bank shorelines are typically located along water bodies with high wave energy, vegetation control is not usually a feasible option. Areas of low wave energy should be evaluated for vegetation control as a shoreline stabilization method.
4. **Groins –** Groins are typically constructed to trap sand. This will create a larger sandy beach waterward of the sediment bank, which will act as a buffer to dissipate wave energy, but will cause erosion downdrift and block juvenile fish passage.
5. **Sills** – Sills are constructed with the objective of reducing the wave action on the sediment bank by forcing wave breaking over the sill. A sill will protect the sediment bank from additional erosion but can also be used in conjunction with vegetation control. The vegetation control can add an additional buffer for wave energy dissipation, but could change the shoreline type to a sediment bank with marsh shoreline. Fill should only be used when it will improve conditions or the function of the shoreline.
6. **Breakwaters** – A breakwater is typically constructed to trap sand. This will create a larger sandy beach waterward of the sediment bank, which will act as a buffer to dissipate wave energy. The breakwater itself is designed to reduce wave action by forcing wave breaking prior to reaching the shoreline. However, the large footprints of some breakwater designs may impact subtidal habitat.
7. **Sloped Structures** – A sloped structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduces the sediment and nutrient input into the estuary. The sloped structure should be constructed as far landward as possible.
8. **Vertical Structures** – A vertical structure will reduce erosion of the sediment bank but when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The vertical structure should be constructed as far landward as possible to lessen the impact to the intertidal zone.

8.11 Overwash Barrier/Inlet Areas

Recommendations of Shoreline Stabilization Methods in Ranked Order:

1. **Land Planning** – Land planning should always be evaluated as the first option.
2. **Vegetation Control, Beach Fill** – Vegetation Control and beach fill are non-structural methods of erosion control. Each of these methods can be seen as the "better" option at different locations. This ranking level is site specific and dependant on the site conditions. If a sandy beach shoreline exists in the active overwash or inlet area without any marsh vegetation, beach fill is the optimal choice. If marsh is actively growing and thriving on the active overwash or inlet area, then vegetation control is the optimal choice.
3. **Groins** – Groins are constructed to trap sand updrift of the groin's location. This will create a sandy beach waterward of the shoreline, which will act as a buffer to dissipate wave energy. Groins inherently cause erosion downdrift and block juvenile fish passage.
4. **Sill** – Sills are constructed with the objective of reducing the wave action on the sediment bank by forcing wave breaking over the sill. A sill will protect the sediment bank from additional erosion but can also be used in conjunction with vegetation control, which can add an additional buffer for wave energy dissipation. Vegetation control should only be used in conjunction with the sill if a marsh currently exists on the site.
5. **Breakwater** – A breakwater is typically constructed to trap sand. This will create a larger sandy beach waterward of the sediment bank, which will act as a buffer to dissipate wave energy. The breakwater itself is also designed to reduce wave action by forcing wave breaking prior to reaching the shoreline.
6. **Sloped Structures** – A sloped structure will reduce erosion of the sediment bank by armoring the shoreline. A sloped structure should not be used to raise the land up, but only to protect their land from erosive forces (i.e. the sloped structures should be constructed only to the height of the current shoreline elevation). When a structure raises the land up, it could interfere with the active overwashing process that occurs during storm events. Sloped structures, when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The sloped structure should be constructed as far landward as possible.
7. **Vertical Structures** – A vertical structure will reduce erosion of the sediment bank by armoring the shoreline. A vertical structure should not be used to raise the land up, but only to protect the land from erosive forces (i.e. the vertical structures should be constructed only to the height of the current shoreline elevation). When a structure raises the land up, it could interfere with the active overwashing process that occurs during storm events. Vertical structures, when located in the wave dissipation zone could eliminate the intertidal zone, cause scour, and reduce the sediment and nutrient input into the estuary. The vertical structure should be constructed as far landward as possible.

9. CONCLUSIONS

The recommendations for each of the shoreline types are different with a few consistent similarities. The number one recommendation for all estuarine shoreline types is land planning (i.e. leave the land in its natural state). The typical number two recommendation is to use vegetation control because where it may alter the shoreline type, vegetation is a natural and environmentally beneficial stabilization method. Beach fill is usually the third recommended action because of its non-structural, non-hardening features, but only when it maintains the current shoreline type. Generally speaking, when shoreline hardening stabilization methods are proposed, the Work Group rank sills as the most preferred option. In North Carolina, sills are small structures that are always constructed to support wetland plantings, or the conservation of existing wetland vegetation. Groins, breakwaters, sloped structures, and vertical structures vary in ranking and were determined to be shoreline type and site specific. On some shoreline types, groins, breakwaters, sloped structures and vertical structures are not recommended at all because their adverse impacts are too great.

APPENDIX A

FUTURE ESTUARINE WORK GROUP TOPICS

Future Estuarine Work Group Topics To Discuss

There has been a general consensus from the Work Group members that they should continue to meet as a group and discuss estuarine shoreline related topics. The Work Group has compiled a list of topics in which may be useful to the Estuarine Shoreline Stabilization Subcommittee.

- Location of shoreline stabilization structures on the estuarine shoreline profile
- Buffer measurement/movement associated with structure location
- Long term response to sea level rise
- Methodology for inventorying the hardened structures along the estuarine shoreline
- Cumulative impacts involved with shoreline hardening and its unit of measure
- Refining the estuarine shoreline characterization
- Estuarine erosion rates
- Water quality impacts of stopping erosion

APPENDIX B

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