NC COASTAL RESOURCES COMMISSION
TERMINAL GROIN STUDY
RECOMMENDATIONS

The NC General Assembly of North Carolina enacted Session Law 2009-479 (House Bill 709) to direct the Coastal Resources Commission (CRC) in consultation with the Division of Coastal Management (DCM), the Division of Land Resources, and the Coastal Resources Advisory Commission (CRAC) to study the feasibility and advisability of the use of a terminal groin as an erosion control device. The Session Law also mandated that the CRC develop recommendations to be presented to the Environmental Review Commission and the General Assembly by April 1, 2010.

Specifically, the CRC was directed to consider six focus areas:

(1) Scientific data regarding the effectiveness of terminal groins constructed in North Carolina and other states in controlling erosion. Such data will include consideration of the effect of terminal groins on adjacent areas of the coastline.
(2) Scientific data regarding the impact of terminal groins on the environment and natural wildlife habitats.
(3) Information regarding the engineering techniques used to construct terminal groins, including technological advances and techniques that minimize the impact on adjacent shorelines.
(4) Information regarding the current and projected economic impact to the State, local governments, and the private sector from erosion caused by shifting inlets, including loss of property, public infrastructure, and tax base.
(5) Information regarding the public and private monetary costs of the construction and maintenance of terminal groins.
(6) Whether the potential use of terminal groins should be limited to navigable, dredged inlet channels.

The DENR has contracted with engineering firm Moffatt & Nichol to complete the study for the CRC at a cost of $287,420. The project team members were:

- Moffatt & Nichol -Project Lead/ Coastal Engineering Analyses/Construction/Costs/Locations
- Dial Cordy and Associates, Inc.- Environmental Resource Assessment
- Dr. Duncan M. FitzGerald, Boston University - Coastal Geology
- Dr. Chris Dumas, UNC Wilmington - Socio-Economics

STUDY PROCESS

The Project Team was provided guidance by a Terminal Groin Study Steering Subcommittee comprised of CRC/CRAC members:

Bob Emory - CRC	Dara Royal – CRAC
Jim Leutze - CRC	Spencer Rogers - CRAC

Melvin Shepard - CRC	Anne Deaton - CRAC
Veronica Carter - CRC	Tracy Skrabal - CRAC
Charles “Boots” Elam - CRC	Bill Morrison – CRAC

The CRC also utilized the CRC’s Science Panel on Coastal Hazards to provide guidance on the proposed scope of work, the methodologies to be used for the various aspects of the study as well as the selection of study sites.

While House Bill 709 required the CRC to hold only three public hearings on the issues, the Commission, held five public hearings including three at meetings of the full Commission. In addition to the public hearings, written comments could be submitted to the executive secretary of the CRC. The five meetings of the Science Panel were also publicized and the public was allowed to attend and hear the discussions, although public comment was not taken at those meetings. All meeting minutes, presentations and public comments have been posted on the Division of Coastal Management website (www.nccoastalmanagement.net/CRC/tgs/terminal%20groin%20study.html).

SELECTION OF INLETS

In consultation with the Science Panel, five sites were selected to be included in the study. These sites were selected based on three main criteria developed by the Science Panel. First, whether the structure at the site fit the definition of a terminal groin; second, whether the site had similarity to potential North Carolina scenarios; and third, whether there was a reasonable expectation that a suitable quality and quantity of data was available for the location. For the purposes of this study, a terminal groin was defined as a structure built with the primary purpose to retain sand and not for navigation (jetty). Therefore, a terminal groin is defined as a narrow, roughly shore- normal structure that generally extends only a short distance offshore.

Additionally, the sites were chosen to reflect a variety of structures, inlet size and characteristics. Most sites contain a single terminal groin, that is, a terminal groin not part of a groin field located adjacent to a tidal inlet. The general consensus and direction given by the Science Panel was to study only terminal groins adjacent to inlets. The House Bill had defined the study to include “the feasibility and advisability of the use of a terminal groin as an erosion control device at the end of a littoral cell or the side of an inlet” and defined a littoral cell is as “any section of coastline that has its own sediment sources and is isolated from adjacent coastal reaches in terms of sediment movement.” The decision as to where a littoral cell begins or ends along a barrier island is extremely difficult to pinpoint and can shift. An inlet provides a clearly defined location and is generally the location of a terminal groin.

The five sites selected for the study are the terminal groins at Oregon Inlet and Beaufort Inlets (Fort Macon) in North Carolina, and at Amelia Island, Captiva Island and John’s Pass in Florida.

SUMMARY OF HARDENED STRUCTURES BAN IN NC

- June 1, 1979 – CRC limits the use of permanent erosion control methods to protect structures existing as of this date.
- 1984 - Outer Banks Erosion Task Force recommends prohibiting hardened structures unless strict criteria can be met.
- January 1985 - CRC bans hardened structures regardless of construction date.
- December 1989 - CRC amends rule to allow for the protection of the Bonner Bridge.
- August 1992 – Amendments to allow for the protection of nationally significant historic sites and existing commercial navigation channels.
- March 1995 – CRC grants a variance to allow a sand filled tube groin field on Bald Head Island.
- July 2003 – CAMA amended to prohibit permanent erosion control structures with limited exceptions.

FINDINGS

As with any study of this nature that has schedule and budgetary constraints, there are limitations that should be noted with respect to the quantity and quality of available data and analysis procedures. No new data collection efforts were undertaken for this study. Rather, available data (shoreline changes, nourishment and dredging activities, natural resources, etc.) were collected from as many sources as possible. Additionally, most of the data originally were collected for purposes other than determining the potential impact of a terminal groin.

The analysis procedures undertaken recognize the uncertainties associated with the underlying data, but detailed statistical analyses of the uncertainties were not performed. However, conclusions can still be drawn from the data and analyses as long as uncertainties are recognized. One cannot simply state in all cases that no conclusions can be made just because of underlying uncertainty (although in some cases this may be appropriate) as uncertainty will always exist in the analysis of coastal processes.

FOCUS AREAS

(*1) Scientific data regarding the effectiveness of terminal groins constructed in North Carolina and other states in controlling erosion. Such data will include consideration of the effect of terminal groins on adjacent areas of the coastline.*

- The most substantial (longer, higher and / or less permeable) terminal groins were typically found where the greatest amount of dredging activity occurs. While this may seem obvious, it is worth stating that the more significant the dredging activities, the potentially greater the impacts on adjacent shorelines, and the greater the potential need for more nourishment and/or additional substantial stabilization structures. Impacts from dredging activities may greatly outweigh or

mask any potential long-term shoreline changes resulting from the construction of a terminal groin.

- With respect to locating a terminal groin on the updrift or downdrift side of an inlet, it should be noted that both sides were represented among the five structures selected for this study. While an initial thought might be that a terminal groin should be located on the updrift side of an inlet in order to capture sediment, it must be noted that sediment typically moves in both directions along an inlet shoreline depending upon the incident wave activity, and significant reversals in sediment transport direction often occur near an inlet due to the presence of the ebb shoals and other inlet features which transform the waves as they approach the shoreline.
- Locating a terminal groin on the "net" downdrift side of inlet may have the additional impact of "stabilizing" the location of a migrating inlet, such as the case at Oregon Inlet where this impact has also resulted in changes to the inlet cross-section – a general narrowing and deepening of the main ebb channel over time since terminal groin construction. Great care should be exercised when siting a terminal groin in this setting as the channel may shift and potential undermining of the groin may become a concern.
- Based on the existing sites and the literature review completed, the impacts of terminal groins on adjacent shorelines are difficult to identify if located adjacent to a highly managed, deeper-draft navigable inlets.
- The relative impact of these structures on adjacent areas is likely increased when sited next to natural or minimally managed shallow-draft inlets. For these locations, additional care and study (geologic setting, sediment budgets, etc.) is warranted to be sure that the terminal groin's impact(s) is/are acceptable or can be mitigated through minimal human activities (dredging and nourishment).

(2) Scientific data regarding the impact of terminal groins on the environment and natural wildlife habitats.

- The environmental effects of a terminal groin structure alone could not be assessed for the sites without considering the associated beach nourishment activity.
- Potential effects of terminal groins in conjunction with shoreline management (i.e. beach nourishment) on natural resources vary according to the type of construction equipment used, the nature and location of sediment discharges (dredged material placement), the time period of construction and maintenance in relation to life cycles of organisms that could potentially be affected, and the nature of the interaction of a particular species.
- The construction of a terminal groin, in addition to beach nourishment and dune construction prevent overwash and inlet migration thereby contributing to a loss of habitat for breeding and non-breeding shorebirds and waterbirds, including the federally listed piping plover.
- Terminal groins are typically used in combination with a long-term shoreline protection program (beach fill), in areas where pre-project shoreline conditions are generally degraded with limited potential for sea turtle nesting activity.

- Based upon the historical nature of the terminal groins at Beaufort Inlet (Fort Macon), John's Pass (northern groin), and Redfish Pass; discernible trends of the effects of these terminal groins on the natural resources are somewhat limited. Lacking preconstruction data makes an empirical determination of post-construction effects at these sites difficult if not impossible.
- While the use of control and/or regional sites strengthens the ability of a study to infer an impact from a detected change, one cannot infer an impact if there is no statistical evidence for a change (Mapstone 1995); and due to the lack of complete datasets and high levels of confidence in the quality of the data, statistical analysis was precluded.
- The current development and use of some of the selected sites precludes unrestricted utilization by the site's natural resources. Sea turtles, avian species, and marine species, however, continue to make use of these managed sites, albeit sometimes on a limited basis.
- The terminal groins at Oregon Inlet and Amelia Island are more recent construction projects, and pre- and post-construction natural resource data readily available were evaluated (sea turtle and shorebird nesting data). The more recent data collected since construction indicates an increase in public interest/participation, and funding for monitoring of these resources.
- Although shorebirds and sea turtles utilize both locations, neither significant trends nor adverse effects were discernable from the available data. The resources present at both the Amelia Island and Beaufort Inlet (Fort Macon) terminal groin locations were compared to undisturbed neighboring barrier islands where data indicated resources were more prevalent, as expected.
- Anchoring the end of an island may curtail an inlet's natural migration patterns thereby minimizing the formation of sand flats.
- Sediment material placed in the fillet of a terminal groin should be compatible with native beach sediment to minimize effects on benthic infauna recovery and upper trophic levels;
- Resources continue to use locations where terminal groins exist, however, if habitat succession occurs, species suitability may be affected.

(3) Information regarding the engineering techniques used to construct terminal groins, including technological advances and techniques that minimize the impact on adjacent shorelines.

- The five study sites all consist of rubble mound (rock) groins.
- Terminal groin design is very site-specific. The length, height, and permeability of the groin will determine how effective the groin is at trapping sediment updrift of the groin and the overall impact of the groin on sediment transport.
- Long groins that are built above the seasonal high water level or are completely impermeable will most effectively block sediment. However, short groins with high permeability may not block enough sediment to be effective. Terminal groins should be just long enough to retain the required beach width, without causing an undue reduction in sediment transport downdrift.

- Ideally, the groin height should be limited to just above beach level. Adjustable heights to nourishment volumes and design berm heights are also beneficial. The design groin height should also account for wave overtopping and the desired amount of sediment transmission over the structure.
- Rock is generally the most widely used building material since it is readily available and highly durable. Concrete and steel are suitable building materials for shorter, mid to shallow-water groins; however, these materials tend to be cost prohibitive.
- Timber and geotextile groins are less expensive alternatives and can be adapted to a variety of beach conditions, but also have limited applicability to shorter, shallow-water conditions.
- Concrete, steel, and timber structures have the advantage of being adjustable with the beach profile without having to rebuild or remodel the groin.
- Groin notching is an emerging technique that allows for adaptive management. Notching allows for sediment to bypass the groin where it would normally be trapped. This may prove to be a cost-effective alternative to groin removal.
- It appears that for shorter groins, the interruption to littoral transport is smaller compared to the overall magnitude of sediment transport and the muted impacts seen both updrift and downdrift of the inlet.
- There also seems to be a threshold that appears with both length and height to be crossed where adjacent impacts become more pronounced. While it is possible that dredging impacts may be responsible for this threshold crossing, it underlies the importance to considering the overall length of the structure in relation to the exterior man-made and natural processes that also drive sediment transport so that the structure's relative effects are minimized or eliminated.
- The permeability of a terminal groin has a significant impact on adjacent shorelines. The Amelia Island structure has allowed material to bypass the structures to limit effects on downdrift shorelines and volumes. However, the structure has also had a limited impact on the updrift shoreline (mainly within the first 0.5 miles). The other structures have impermeable cores and appear to hold more sand for a greater distance updrift of the structure.

(4) Information regarding the current and projected economic impact to the State, local governments, and the private sector from erosion caused by shifting inlets, including loss of property, public infrastructure, and tax base.

- The economic value at risk within the 30 year risk areas for developed shorelines varies greatly from about $27 million at Ocean Isle to over $320 million at Bald Head Island. It must be noted, though, that not all of these properties can be protected by a terminal groin.
- The economic value at current or imminent risk (as defined by the presence of sandbags for temporary protection) for developed shorelines varies from just under $3 million at North Topsail Beach to about $26 million at the north end of Figure Eight Island.

- Barrier island municipality tax bases range from $409 million for Caswell Beach to over $4.2 billion for Emerald Isle. The countywide tax bases range from $3.8 billion for Pender County to $29.1 billion for New Hanover County.
- The full value of residential property may not be lost in the event that the properties themselves are lost to shifting inlets, as some of the property value associated with oceanfront or soundfront location may transfer to nearby properties.

(5) Information regarding the public and private monetary costs of the construction and maintenance of terminal groins.

- Construction costs of terminal groins can vary greatly depending upon construction materials, length and beach profile.
- The construction costs (in 2009 dollars) of the five terminal groins analyzed range from less than $1 million for John's Pass and Captiva Island to about $24 million for Oregon Inlet.
    - Four cost scenarios were developed:
        - Short, smaller cross-section groin (450 feet) on a flat-sloped beach
        - Short, smaller cross-section groin (450 feet) on a steep-sloped beach
        - Long, larger cross-section groin (1500 feet) on a flat-sloped beach
        - Long, larger cross-section groin (1500 feet) on a steep-sloped beach

- Rubble-mound terminal groins could range from about $1,230 per linear foot to $5,180 per linear foot.
- Geotextile Tube terminal groins could range from about $350 per linear foot to $660 per linear foot (short groin only; not recommended for longer groin)
- Steel or Concrete Sheet Pile or Timber terminal groins could range from about $4,000 per linear foot to $4,800 per linear foot. (Timber only recommended for short groin scenarios)
- Initial project costs including construction of the terminal groin, initial beach nourishment and permitting and design fees may range from about $3.5 million for a shorter groin to over $10 million for a larger one.
- Annual project costs including structure maintenance / repair, annual beach nourishment, and monitoring could be in the range of $0.7 million to over $2 million.
- Terminal groins are typically constructed as part of a broader beach management plan and may make nourishment adjacent to inlets feasible, but they do not eliminate the need for ongoing beach nourishment.
- These costs could vary substantially based on site conditions and design parameters.

(6) Whether the potential use of terminal groins should be limited to navigable, dredged inlet channels.

- The vast majority of the structures considered for this study were located at inlets with most of these adjacent to navigable, dredged channels.

- No terminal groins were identified as being located at the end of a non-inlet littoral cell.
- The most substantial (longer, higher and / or less permeable) terminal groins were typically found where the greatest amount of dredging activity occurs. While this may seem obvious, it is worth stating that the more significant the dredging activities, the potentially greater the impacts on adjacent shorelines; the greater the potential need for more nourishment and / or more substantial stabilization structures. The impacts from these dredging activities may greatly outweigh any potential long-term shoreline changes resulting from the construction of a terminal groin.

SUMMARY OF FINDINGS

In the CRC's discussion of the findings of the study, specific issues stand out in considering the siting of terminal groins in NC. Some of the issues are clear, such as it being expensive to remove one of these structures. Other issues, including the most relevant ones regarding the effects of such structures are less clear, making it difficult to draw definitive conclusions. The Commission has found that the general effects of the groins studies tend to be lost in the "noise" of other inlet management activities. The most substantial (longer, higher and / or less permeable) terminal groins were typically found in areas where the greatest amount of dredging activity occurs. It was found that the more significant the dredging activities, the potentially greater the impacts on adjacent shorelines. The impacts from these dredging activities may greatly outweigh any potential long-term shoreline changes resulting from the construction of a terminal groin.

While the groins do appear to hold the tip of the island in place, stabilizing the "net" downdrift side of inlet, there can be other resultant impacts such as changes to the inlet cross-section – a general narrowing and deepening over time which may cause the channel to shift and potentially undermine the groin. The permeability of the structure was found to have a significant impact on adjacent shorelines. The Amelia Island structure has allowed material to bypass the structures to limit effects on downdrift shorelines and volumes. However, the structure has also had a limited impact on the updrift shoreline (mainly within the first 0.5 miles). The other structures have impermeable cores and appear to hold more sand for a greater distance updrift of the structure.

Again the "noise" of other inlet management activities make identification of structure impacts on adjacent shorelines difficult to discern if they exist at all if located adjacent to a highly managed, deeper-draft navigable inlet. The relative impact of these structures on adjacent areas is likely increased when sited next to natural or minimally managed shallow-draft inlets. Should a structure be located in these locations, additional care and study (geologic setting, sediment budgets, etc.) is warranted to be sure that the terminal groin's impacts are acceptable or can be mitigated through minimal human activities (dredging and nourishment).

Dredging and nourishment were common and necessary activities associated with these structures. Terminal groins are typically constructed as part of a broader beach management plan and may make nourishment adjacent to inlets feasible, but they do not eliminate the need for ongoing beach nourishment. Initial project costs including construction of the terminal groin, initial beach nourishment and permitting and design fees may range from about $3.5 million for a shorter groin to over $10 million for a larger one. Annual project costs including structure maintenance / repair, annual beach nourishment, and monitoring could be in the range of $0.7 million to over $2 million. With sea level rise, it is prudent to assume that these costs will increase over the life span of an individual project.

With regard to the effects of a terminal groin on wildlife and the environment, the study found that the environmental effects of a terminal groin structure alone could not be isolated from the effects of the associated beach nourishment activity. The potential effects of terminal groins in conjunction with shoreline management (i.e. beach nourishment) on natural resources vary according to the type of construction equipment used, the nature and location of sediment discharges, the time period of construction and maintenance in relation to life cycles of organisms that could be potentially affected, and the nature of the interaction of a particular species.

While the study indicated that the construction of a terminal groin, along with beach nourishment and dune construction prevents overwash and inlet migration thereby contributing to a loss of habitat for breeding and non-breeding shorebirds, groins are typically used in combination with a long-term shoreline protection program (beach fill), in areas where pre-project shoreline conditions are generally degraded and offer only limited potential for sea turtle nesting activity.

Due to a lack of historic natural resource data, it is difficult to draw conclusions on the effects of the construction and operation of the terminal groin on natural resources. Based upon the historical nature of the terminal groins at Beaufort Inlet (Fort Macon), John's Pass (northern groin), and Redfish Pass; discernible trends of the effects of these terminal groins on the natural resources are somewhat limited. The lack of preconstruction data makes an empirical determination of post-construction effects at these sites difficult if not impossible.

The study found that the economic values within the 30 year risk areas for developed shorelines varies from about $27 million at Ocean Isle to over $320 million at Bald Head Island. However, it must be noted that not all of these properties can be protected by a terminal groin. The study further refined the economic value at current or imminent risk (as defined by the presence of sandbags for temporary protection) for developed shorelines from just under $3 million at North Topsail Beach to about $26 million at the north end of Figure Eight Island.

It was difficult to draw conclusions on the effects associated with a terminal groin on an unmanaged inlet since the majority of the structures considered for this study were located at inlets adjacent to navigable, dredged channels. It can be said that the

structure will alter the natural inlet processes of a specific inlet. In what manner and to what degree can only be determined through specific study of the geologic setting, sediment budgets and hydrodynamics of the individual inlet.

RECOMMENDATIONS

Under Article 14, Section 5 of the North Carolina Constitution, it is the policy of the State to conserve and protect its lands and waters for the benefit of all its citizenry, and to preserve as a part of the common heritage of this State its forests, wetlands, estuaries, beaches, historical sites, open lands, and places of beauty. In G.S. 113A-102(b), the General Assembly identified one of the goals of the Coastal Area Management Act as follows:

> (1) To provide a management system capable of preserving and managing the natural ecological conditions of the estuarine system, the barrier dune system, and the beaches, so as to safeguard and perpetuate their natural productivity and their biological, economic and esthetic values.

CAMA also specifically directed the Commission to develop standards capable of protecting the natural resources of the coastal area, including fish and wildlife, and maintaining public trust rights. CAMA recognized that the Commission would also need to consider economic development and impacts to private property.

As permanent erosion control structures may cause significant adverse impacts on the value and enjoyment of adjacent properties, the Commission has relied on AEC rules, land use planning and land classification, establishment of building setbacks, building relocation, subdivision regulations, management of vegetation, and beach nourishment to address coastal hazards. The use of sand trapping devices, such as terminal groins, has not been allowed on ocean and inlet shorelines except in extraordinary circumstances (i.e., protection of important public infrastructure). Even then, the projects were required to incorporate measures to minimize adverse impacts on adjoining properties and on public access to and use of the beach. It is imperative that activities in the coastal area reflect an awareness of the natural dynamics of the oceanfront. Government policies should not only address existing erosion problems, but should aim toward mitigating the public cost of erosion response. Actions required to deal with erosion problems are expensive and the direct costs of erosion abatement measures and other costs such as maintenance of projects, disaster relief and infrastructure repair will be borne by the public sector. Responses to erosion should be designed to limit these public costs.

The Commission found that the study was not definitive in its findings. Based on the results, the Commission can not make a determination that terminal groins would or would not cause adverse impacts on the environment or adjacent properties. The individuality of inlets necessitates case specific study and even then it may be difficult to accurately predict the impacts of a terminal groin in a particular location; the cost of

maintaining the structure; and the effectiveness of measures necessary to minimize its impacts. It is within this context that the following recommendations are made.

The Commission has adopted rules that give preference to non-structural responses to erosion including relocation of threatened structures, beach nourishment, inlet relocation and the temporary use of sandbags for short-term shoreline stabilization. The Commission has recently amended its rules on the use of sandbags in Inlet Hazard Areas to allow the extended use of these structures as well as the repetitive use of sandbags in conjunction with channel realignment projects. This preference toward non-structural responses to erosion should be maintained.

The current ban on the use of hardened structures for erosion control should be maintained.

However, if it is the desire of the Legislature to direct the Commission to consider the construction of terminal groins, the Commission could be given the authority to allow the construction of a terminal groin by variance if the Commission finds that the terminal groin will be located and constructed to avoid the interruption of natural sand movement to downdrift beaches; all other non-structural erosion control responses, including relocation of threatened structures, are inadequate; and specific criteria for issuance of a variance are met:

1. **An application for a permit to construct a terminal groin under this subsection shall be accompanied by an environmental impact statement that meets the requirements of G.S. 113A-4.**
2. **In addition to the notice required under G.S. 113A-119, the applicant for a permit to construct a terminal groin shall provide notice of the permit application by certified mail to each person who owns property located in the area potentially affected by the terminal groin. For purposes of this section, an area is potentially affected by a terminal groin if the environmental impact statement required under this section has identified direct or indirect impacts to the area as a result of construction of the terminal groin, maintenance and mitigation activities associated with the terminal groin, or potential post-construction effects of the terminal groin. The notice shall include a description of the project, including its proposed location and shall direct the property owner to the nearest location where a copy of the permit application and environmental impact statement can be inspected. If ownership of any property within the area potentially affected by the terminal groin changes before the Commission has made a final decision on the variance petition, the applicant shall provide notice pursuant to this section to the new property owner.**
3. **The variance may be granted only if the Commission finds that all of the variance criteria set out in G.S. 113A-120.1 have been met. For purposes of**

this subsection, G.S. 113A-120.1(a)(4) shall be interpreted to require the Commission to find that:

a. Construction of a terminal groin is the least environmentally damaging alternative for addressing shoreline changes that threaten existing structures, and;

b. The terminal groin will not directly or indirectly result in adverse impacts to other property, including impacts resulting from increased erosion.

4. A permit issued for a terminal groin pursuant to this section shall require:

a. A permittee other than a State agency, federal agency or unit of local government to provide financial assurance, in the form of a bond, insurance policy, escrow account or other financial instrument, that is adequate to cover the cost of:

i) Removal of the terminal groin and restoration of the beach if the Commission determines that the groin has an adverse impact on the environment or on other properties, and;

ii) Long-term maintenance of the terminal groin, including the cost of any required mitigation measures, and compliance with all conditions imposed on the variance.

b. The applicant shall submit evidence of a large-scale beach fill project as pursuant to 15A NCAC 7H .0305 including plans and related materials including reports, maps, tables and diagrams for the design and construction of the large- scale beach fill project, subsequent maintenance, and planned maintenance needed to achieve a design life providing no less than 25 years of shore protection. The plans and related materials shall be designed and prepared by the U.S. Army Corps of Engineers or persons meeting applicable State occupational licensing requirements for said work.

c. Documentation, including maps, geophysical, and geological data, to delineate the planned location and volume of compatible sediment as defined in 15A NCAC 07H .0312 necessary to construct and maintain the large-scale beach fill project over its design life. This documentation shall be designed and prepared by the U.S. Army Corps of Engineers or persons meeting applicable State occupational licensing requirements for said work.

d. Identification of the financial resources or funding sources necessary to fund the large-scale beach fill project over its design life.

e. Third party monitoring of the impact of the terminal groin on coastal resources and on adjoining or downdrift properties.

5. The Commission may impose reasonable and appropriate conditions on any variance issued under G.S. 113A-120.1 and shall include conditions

requiring monitoring of the impact of the terminal groin on coastal resources and on adjoining or downdrift properties.