VI. Initial Construction and Maintenance Costs

This section documents the state of knowledge regarding the initial and maintenance costs associated with terminal groin structures. As part of the cost study, a literature review of the existing five (5) study sites was completed to estimate their initial construction and maintenance costs. The selected terminal groins' plan sheets were used to determine a cost per linear foot of groin. Unit costs were estimated by knowledge of existing nearby projects in the Southeast (VA, NC, and GA) with similar water depths and constructability issues in shallower water, as well as estimates within *RS Means*. These unit costs were used with the structure lengths and dimensions to develop opinions of probable costs for the five (5) study sites. These estimates were checked against their reported construction costs (when known) escalated to 2009 dollars. These unit costs were then used to estimate a potential range of costs for potential terminal groins in North Carolina with varying lengths and slopes.

A. Overview of Costs and Key Factors

Groins are simple coastal structures that often require minor maintenance once the initial construction is complete. Initial construction and maintenance costs are mainly dependent on structure dimensions and type of material. Other factors such as availability of selected materials, transport, labor, and equipment costs also factor in the costs.

B. Development of Terminal Groin Unit Costs

A number of different building materials can be used in the construction of terminal groins as well as allowing for the need for adjustments and potential removal. Materials used in construction will vary with the intended purpose of the groin. As previously mentioned, unit costs for each material were estimated using nearby projects as well as estimates within *RS Means*. The unit costs were used with varying structure lengths and dimensions to develop a range of probable linear foot costs for each type of material. Figure VI-1 and Figure VI-2 show the range of structure depths which may be experienced along North Carolina shorelines and lead to the various unit costs per linear foot that were developed.

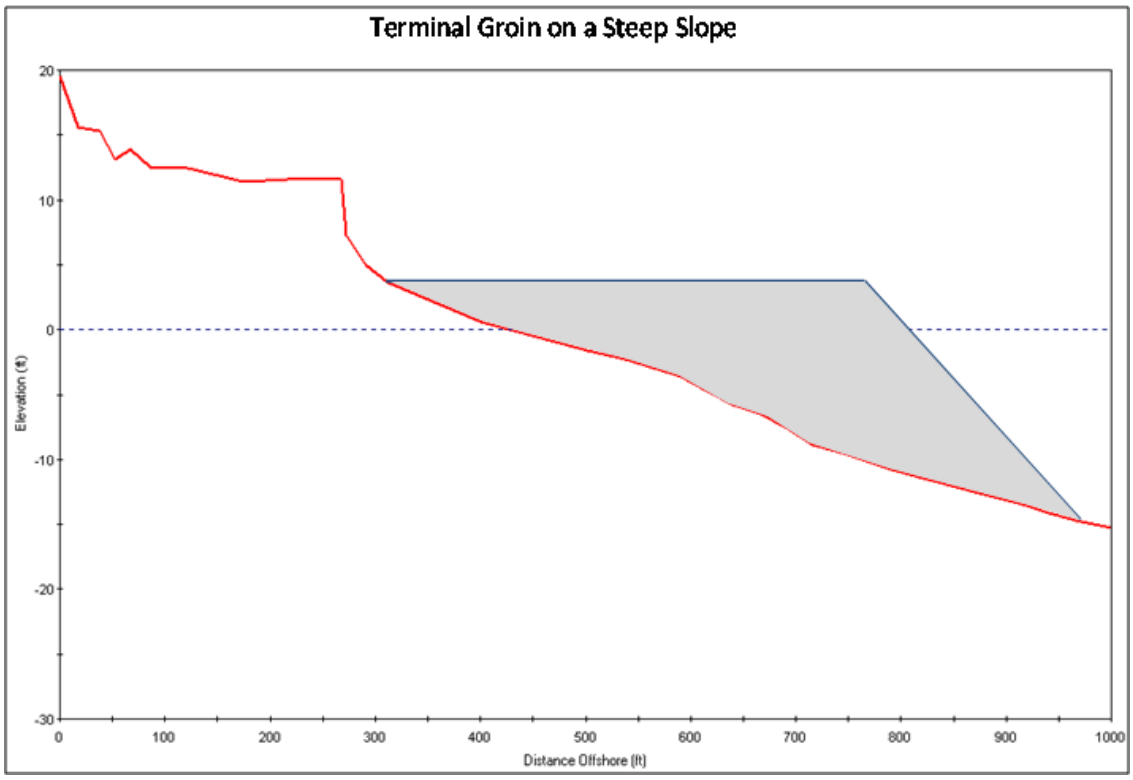


Figure VI-1. Terminal Groin Length along a Steep Slope

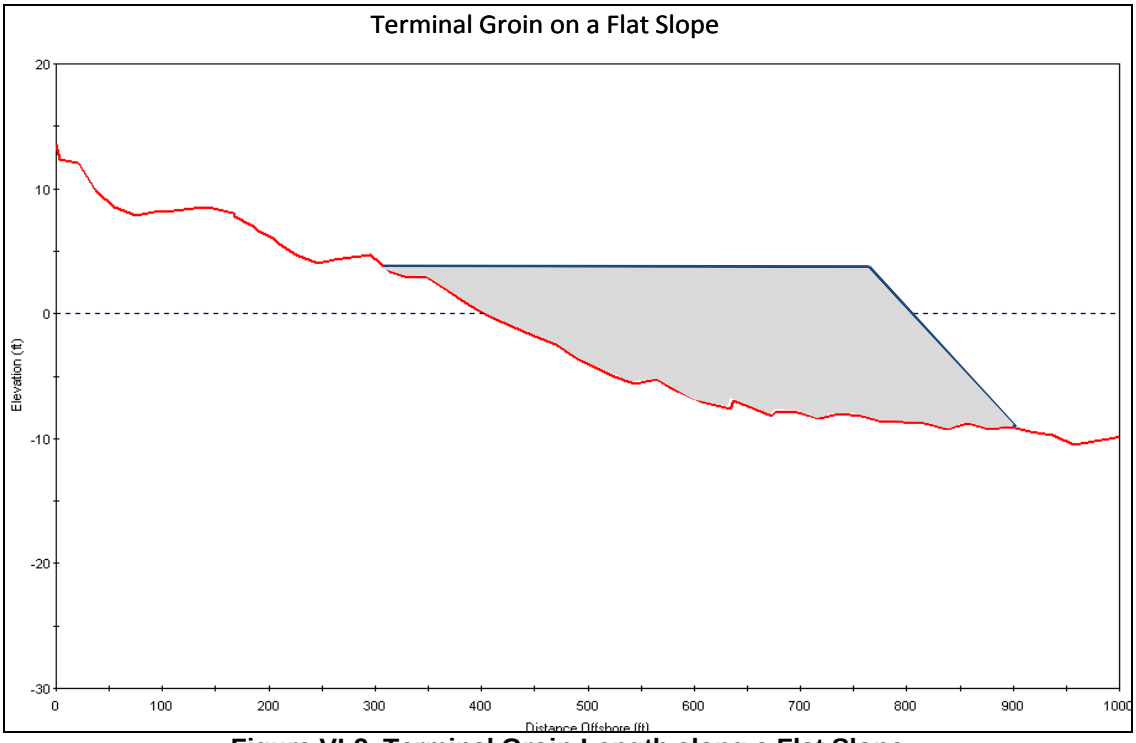


Figure VI-2. Terminal Groin Length along a Flat Slope

1. Rock

Generally, the most common type of material used for terminal groin structures is rock. Rock (or rubble mound) groins usually have a core of smaller, graded stone with an armor layer of larger stones overlying the core. The cost of stone varies with size. Generally, the material cost for a rubble mound groin may vary between $1,200 (for a small-stone groin that is 8-foot high with a 20-foot wide crest and 2:1 side slopes) and $6,500 per linear foot (for a large-stone groin that is 22-feet high with a 30-foot wide crest and 2:1 side slopes). Figure VI-3 shows an example of a typical cross-section for rubble mound groins. It should be noted that permeable groins may be designed without a core layer or a core layer built to a certain elevation to allow sand to pass through the structure.

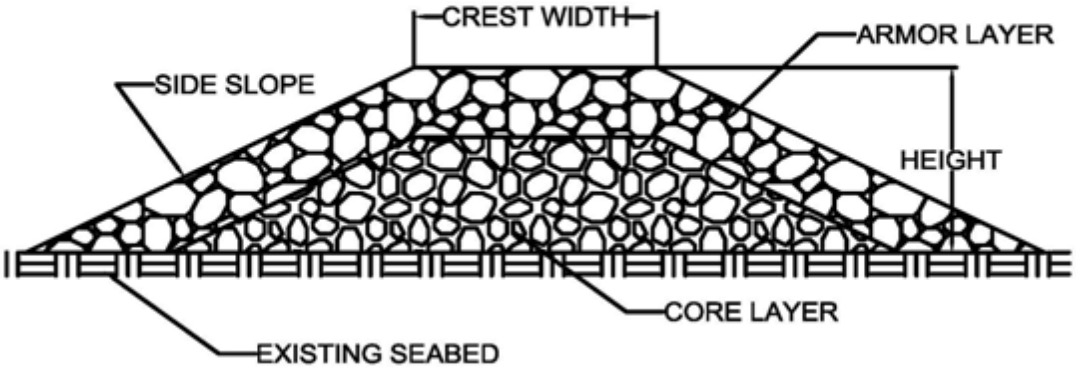


Figure VI-3. Rubble Mound Construction

2. Concrete and Steel

Concrete and steel sheet piles are more expensive options that may also be utilized. Concrete groins can also be constructed of precast blocks, fillable cells, or interlocking shapes (concrete armor units). Concrete armor unit costs vary greatly depending on the manufacturer.

For a concrete sheet pile groin, the unit cost is approximately $4,000 - $5,000 per linear foot up to a height of 16 feet (maximum water depth ~10 ft.). Typically, concrete groins would not be used for greater heights. Figure VI-4 illustrates an example of concrete sheet piles.

Figure VI-4. Example of Concrete Sheet Piles

Steel groins may be as simple as a line of sheet piling, or a combination of H-piling, waling, and sheeting. Steel groins with sheeting can be adjusted in the field by removing or adding panels to optimize the groin performance. Steel groins usually must be coated with epoxy finish to prevent deterioration from salt water and/or built with a concrete cap or fascia. A steel groin with concrete fascia and cap is approximately $4,000 - $5,000 per linear foot for groins up to 15 - 20 feet in height. Steel groins can be reinforced for use in greater depths of water; however, this is typically cost prohibitive to use for depths greater than 20 feet. Figure VI-5 illustrates an example of a steel sheet pile groin.

Figure VI-5. Example of Steel Sheet Pile Terminal Groins

3. Timber

Timber is another viable option for construction material. Generally, timber groins have pilings in single or multiple rows. Timber groins can also have planks between the pilings which may be adjusted depending on the required height for the groin. However, timber cannot withstand the same loads that rock, steel, or concrete groins can; therefore it should not be used for longer groins in deeper water. Typically, a timber groin would only be considered for water depths less than 6-8 feet. A timber pile groin's cost could range from approximately $3,000 to $4,000 per linear foot. Figure VI-6 illustrates an example of a timber groin with planks and pilings (taken from the Federal Highway Administration website).

Figure VI-6. Example of a Timber Groin

4. Geotextile

Geotextile tubes are an inexpensive alternative to some of the other building materials. There are numerous types of bags and tubes that can be filled with sand and stacked on top of one another to construct the groin. These types of structures have been utilized in the past at Bald Head Island and other locations. The geotextile tubes should not be utilized for longer groins in deeper water due to wave loading and scour concerns. Generally, a geotextile groin is approximately $250 (~5-6 ft in height) to $1,000 (~12-15 ft in height) per linear foot.

C. Cost Evaluation of Five (5) Selected Study Sites

An evaluation of the five selected existing terminal groins was performed to estimate the construction cost of the groins if they were built in 2009. The material unit prices were taken from previous estimates for nearby projects within the past year and *RS Means*.

1. Fort Macon

The Fort Macon terminal groin was constructed between 1961 and 1970. The final length is 1,530 feet long and the crest elevation is 6 feet (MLW). At the deepest portion, the groin is estimated to be approximately 14 feet above the sea floor. The crest width is 10 feet wide; while the base ranges from 58 to 66 feet wide. The groin utilizes 4 types of stone ranging from 1-foot stones for the bedding and core layers to 12.5-ton stone for the armor layer. Figure VI-7 shows the typical cross section for the Fort Macon terminal groin. Table VI-1 shows a summary of the estimated cost information for the Fort Macon terminal groin. No initial construction cost information was available for the terminal groin itself. However, using the typical cross section in the plans, the unit cost is determined to be $1,900 per linear foot, and the opinion of probable cost in 2009 dollars for the terminal groin is $2.9 million.

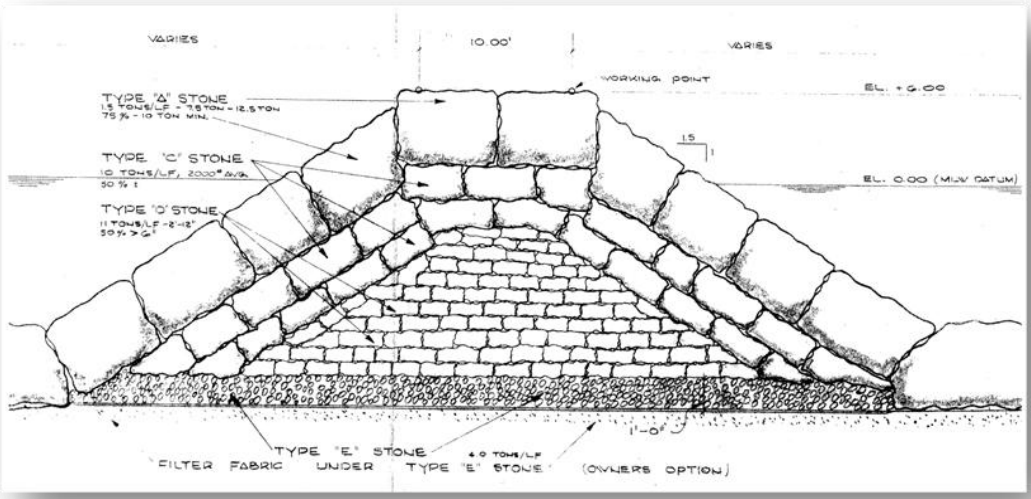


Figure VI-7. Typical Cross Section for Fort Macon Terminal Groin

Table VI-1. Fort Macon Terminal Groin Estimated Costs

Length	1,530 ft
Height	Up to 14 ft
Unit Cost	$1,900/LF
Total Estimated Cost	**$2.9M**

2. Oregon Inlet

The terminal groin and revetment at Oregon Inlet was completed in 1991. At the time, the construction cost for the groin was $13.4 million. The groin extends from the bulkhead in a northwest direction, curving 90 degrees towards the northeast, and straightening out to be perpendicular with the natural inlet shoreline. The total length of the groin is 3,125 feet. The crest elevation ranges from 8 to 9.5 feet (MSL). At its deepest portion, the groin is estimated to be 25.5 feet high. The crest width ranges from 15 to 39 feet wide; the base width ranges from 110 to 228 feet wide. The groin has toe protection on both sides, with lengths varying from 10.5 to 43 feet. The groin utilizes five different sizes of stone. The foundation stone ranges from 0.5 to 110 lbs. The underlayer stone ranges from 500 to 2000 lbs. The armor layer stone ranges from 2.5 to 10 tons. Figure VI-8 illustrates a typical cross-section for the Oregon Inlet terminal groin. Using the cross sections given in the plans, the unit cost is determined to be $8,410 per linear foot. The total estimated cost for the terminal groin alone is $26.3 million, which compares well with the escalated actual initial construction cost of $28.2 million (albeit this includes the revetment cost). Table VI-2 shows theses estimated costs for the Oregon Inlet terminal groin.

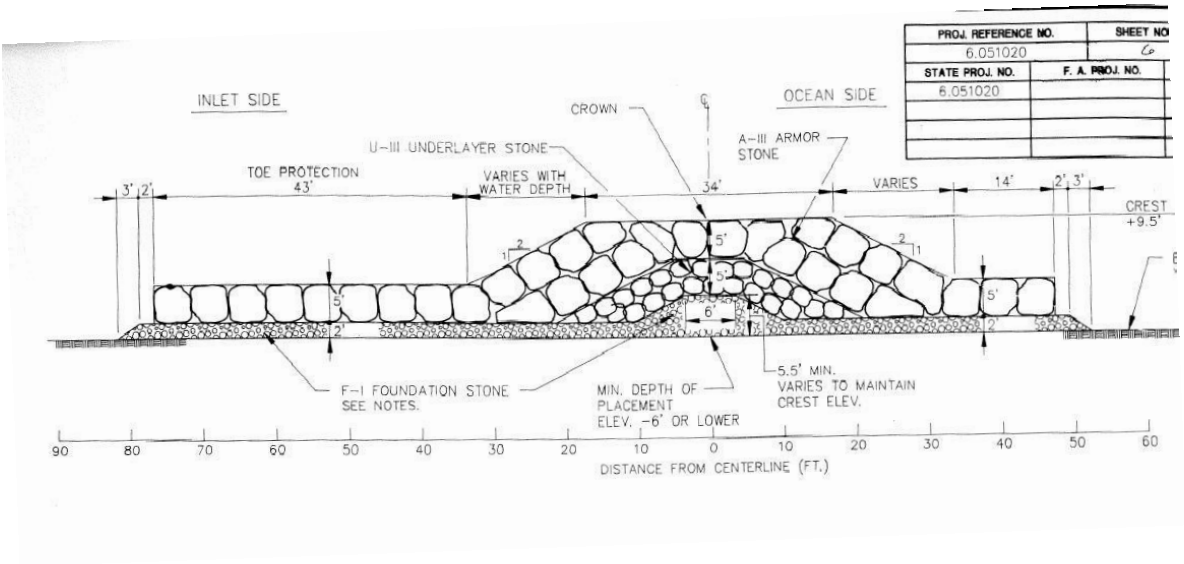


Figure VI-8. Oregon Inlet Typical Cross-Section

Table VI-2. Oregon Inlet Terminal Groin Estimated Costs

Length	3,125 ft
Height	14 – 25.5 ft
Unit Cost	$8,410/LF
Total Estimated Cost	**$26.3M**
1989 Construction Costs (includes revetment)*	$13.4
2009 Construction Costs (includes revetment)**	$24.2M

*reported by USACE
**assumes annual escalation of 3%

3. Amelia Island

The terminal groin at Amelia Island was constructed between 2004 and 2005 on the southern end of Amelia Island. Due to environmental concerns, the groin was designed and built utilizing only armor stone to maximize permeability. The approximate cost to build the groin was $3 million, in 2006 dollars. The groin length is approximately 1,500 feet long, and the crest elevation is 5.2 feet (NGVD). At the deepest portion, the groin height is estimated to be 15.2 feet high. The crest width ranges from 6 to 15 feet. The armor stone ranges from 0.4 to 7 tons. Figure VI-9 shows the cross-sections for the Amelia Island terminal groin. Table VI-3 summarizes the cost information for the Amelia Island terminal groin. Using the typical cross sections provided in the plans, the unit cost is determined to be $2,260 per linear foot. The total estimated cost for Amelia Island terminal groin is $3.4 million, which compares well with the actual escalated construction cost of $3.3 million.

Table VI-3. Amelia Island Terminal Groin Estimated Costs

Length	1,500 ft
Height	7.2 - 15.2 ft
Unit Cost	$2,260/LF
Total Estimated Cost	**$3.4M**
2006 Construction Costs	$3.0M
2009 Construction Costs*	$3.3M

*assumes annual escalation of 3%

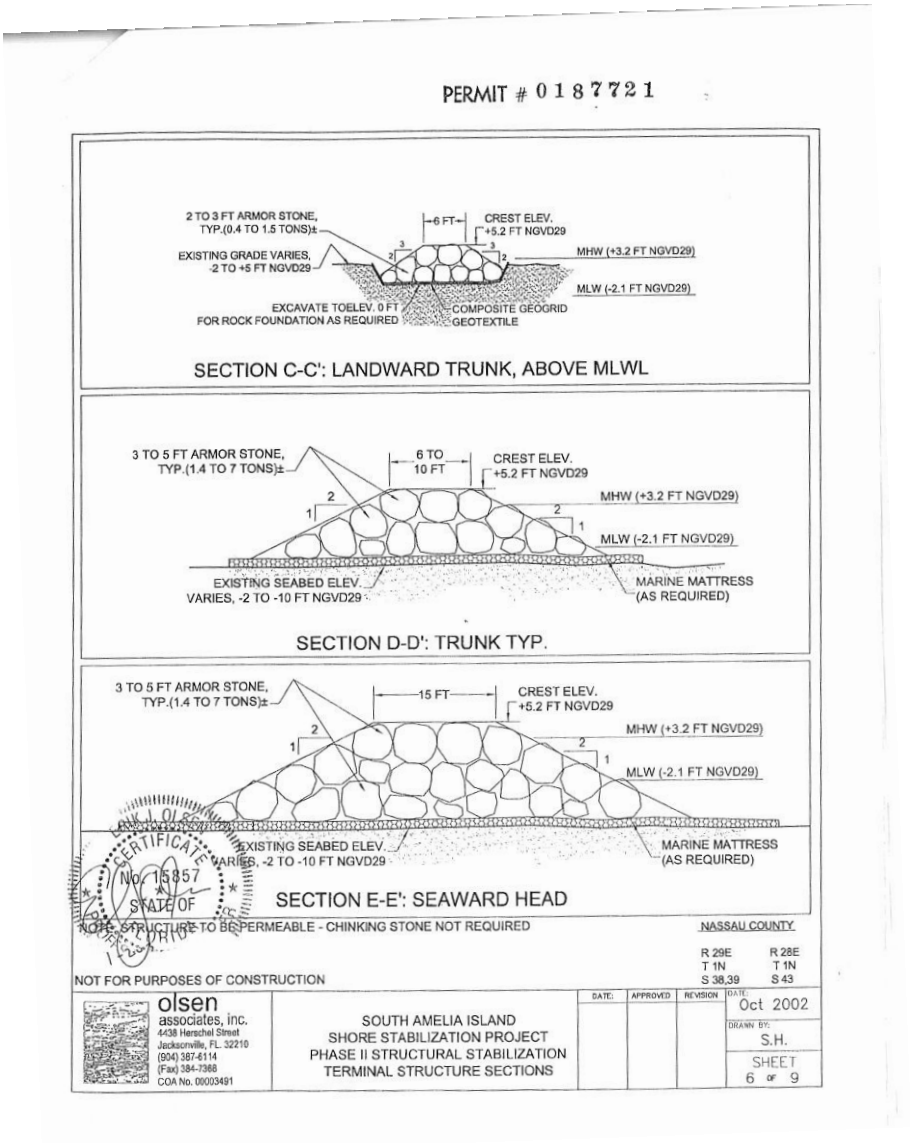


Figure VI-9. Amelia Island Terminal Groin Typical Cross-Section

4. John's Pass

A terminal groin was constructed at the south end of Madeira Beach at John's Pass in 1961. The groin extends 460 feet, and the crest elevation ranges from 3.2 to 5.7 feet (NGVD). At the deepest portion, the groin is estimated to be 15 feet above the sea floor. The crest width ranges from 12 to 22 feet. The groin utilizes three different types of stone. The bedding stone ranges from 15 to 50 lbs. The core stone averages 0.1 tons; and the armor stone averages 1 ton. No detailed initial construction cost information was available (reported to be less than $300k). However, utilizing the typical cross sections provided in the plans, the estimated unit cost is $1,925 per linear foot. The total estimated 2009 cost for John's Pass is $890,000.

Table VI-4 shows the cost information for the northern John's Pass terminal groin. This per linear foot cost matches well with the terminal groin constructed in 2000 along the opposite side of the inlet. The cost for this 760 ft long structure was $1.4 million (2000 dollars) which equates to $1,840 per linear foot.

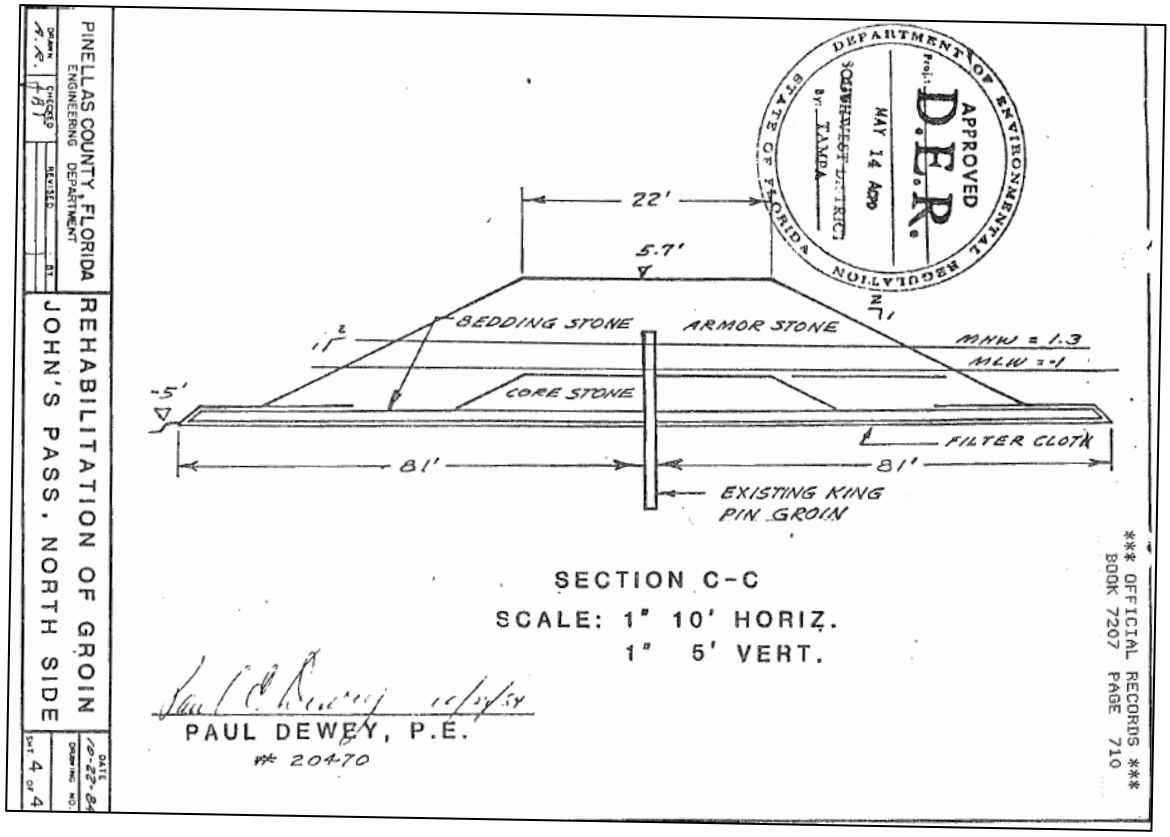


Figure VI-10. Typical Cross-Section for John's Pass Terminal Groin

Table VI-4. John's Pass Terminal Groin Estimated Costs

Length	460 ft
Height	Up to15 ft (~10 ft avg)
Unit Cost	$1,925/LF
Total Estimated Cost	**$890K**

5. Captiva Island

A rock groin was constructed in 1977 at the north end of Captiva Island at Redfish Pass. The terminal groin is 350 feet long. Typical cross sections could not be located for this groin, nor any initial construction cost data. For the estimated cost analysis, a typical cross section similar to John's Pass was used. The unit cost is assumed to be the same as John's Pass of $1,925 per linear foot, and the total 2009 estimated cost for the groin is $670,000. Table VI-5 summarizes the cost information for Captiva Island terminal groin.

Table VI-5. Captiva Island Terminal Groin Estimated Costs

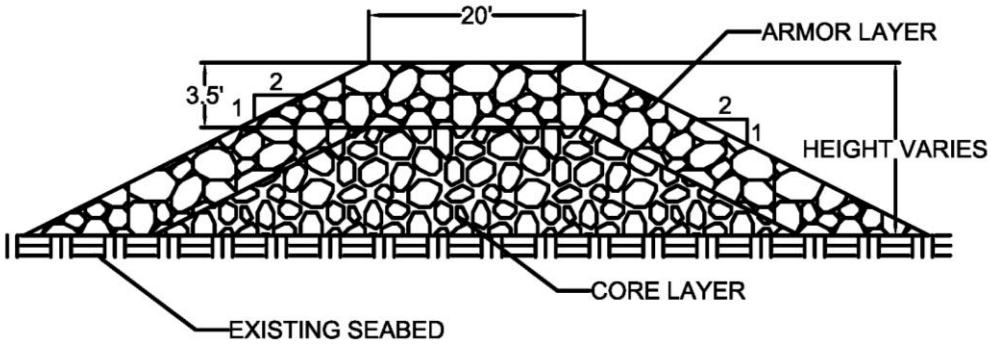
Length	350 ft
Height	Up to 15 ft* (~10 ft avg)
Unit Cost	$1,925/LF*
Total Estimated Cost	**$670K**

* Assumed same cross-sectional area as John's Pass

D. Potential Range of Initial Construction Costs for North Carolina Terminal Groins

Two scenarios were analyzed using these unit costs. A relatively short trapezoidal groin (450 feet long) was placed along typical North Carolina shoreline slopes. A crest elevation was set to 4.0 feet (MLW), with a crest width of 20 feet. The average groin height ranged from 8 to 12 feet. Side slopes were set to 2:1. Figure VI-11 illustrates the typical cross section for this scenario.

Figure VI-12 and Figure VI-13 show some typical beach slopes for this scenario. **Error! Reference source not found.** shows the ranges of anticipated unit and total costs for the above scenarios. Based on these scenarios, a typical short rock terminal groin initial construction cost may range from $550,000 - $1 million, while a short timber, steel or concrete groin initial construction cost may range from $1.8 – 2.2 million. A short geotextile groin may cost less than $300,000, but please note that these types of structures would have limited applicability given their likelihood of failure in deeper water and active swash zones.



Short Groin Scenario

Figure VI-11. Typical Cross Section for Short Groin Scenario

Table VI-6. Short Groin Scenario Unit Costs

	Flat-Sloped Beach	Steep-Sloped Beach
Length	450	450
Average Height	8	12
Rubble Mound (small stone)		
Unit Cost	$1230/LF	$1930/LF
Total Cost	$554K	$869K
Rubble Mound (large stone)		
Unit Cost	$1440/LF	$2260/LF
Total Cost	$648K	$1.0M
Geotextile Tubes		
Unit Cost	$350/LF	$660/LF
Total Cost	$160K	$300K
Steel Sheet Piles w/ concrete fascia & cap		
Unit Cost	$4000/LF	$4300/LF
Total Cost	$1.8M	$1.9M
Concrete sheet piles		
Unit Cost	$4600/LF	$4800/LF
Total Cost	$2.1M	$2.2M
Timber piles		
Unit Cost	$4000/LF	N/A*
Total Cost	$1.8M	N/A*

*Reaching upper limit of allowable use

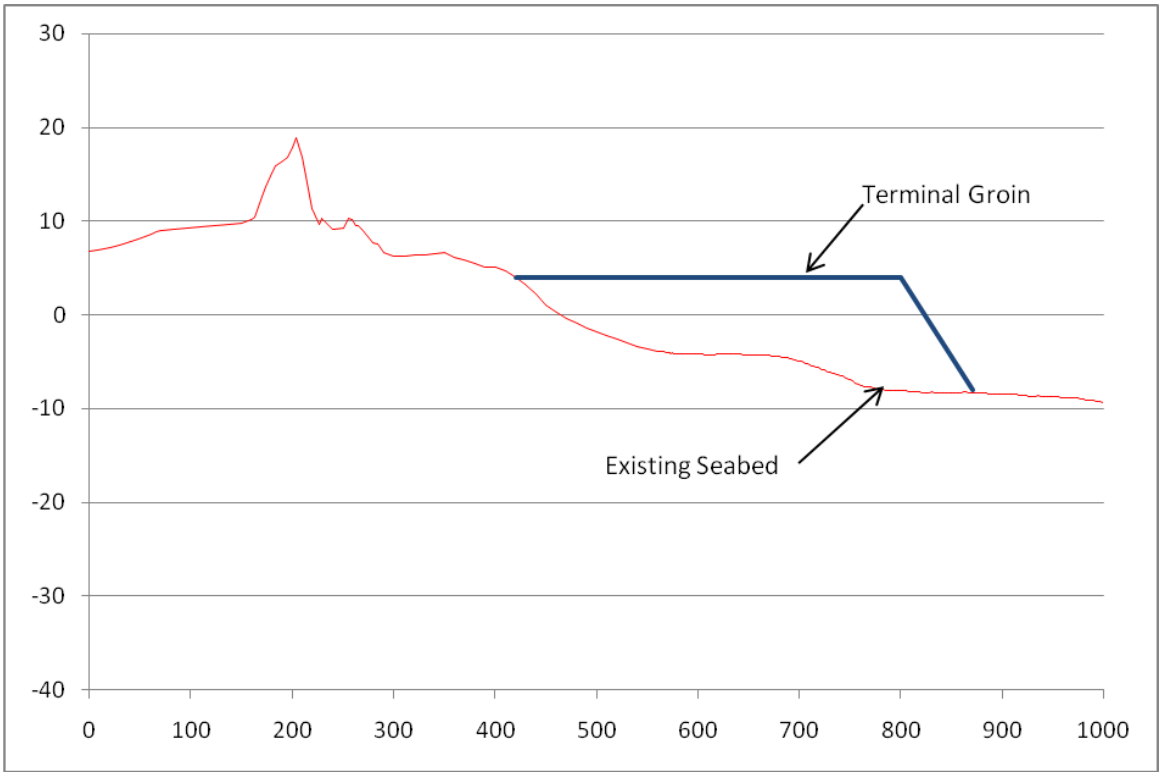


Figure VI-12. Short Groin along a Flat-Sloped Beach

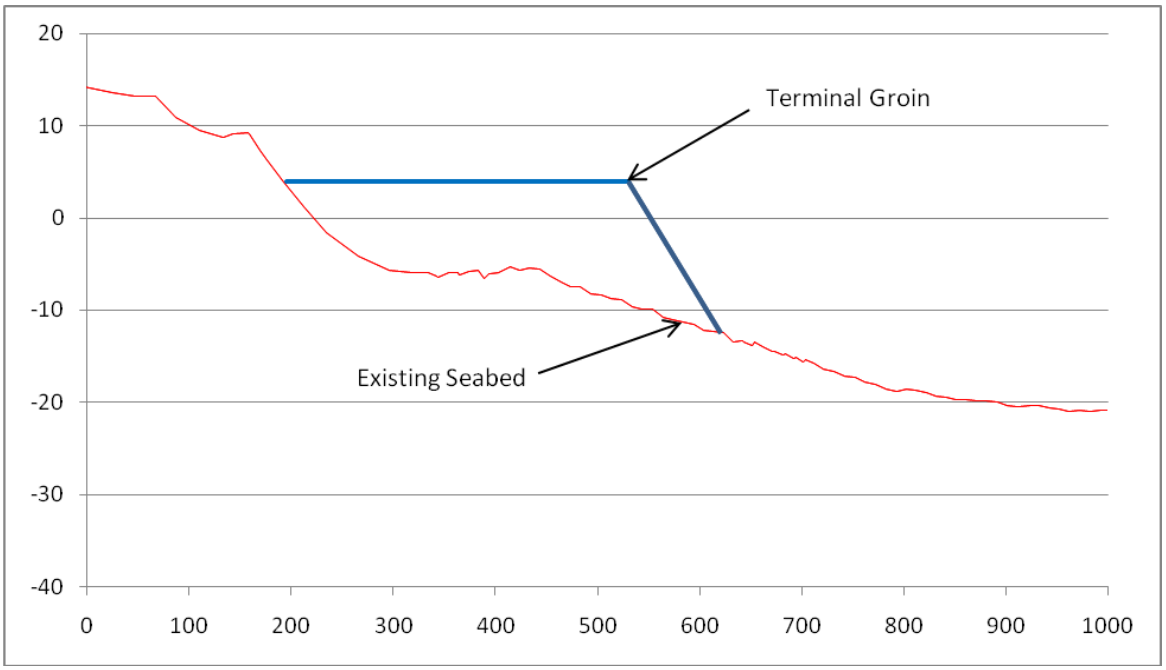


Figure VI-13. Short Groin along a Steep-Sloped Beach

The second scenario analyzed a longer groin (1,500 feet) placed on typical North Carolina slopes. The crest elevation remained set at 4 feet (MLW); however the width was widened to 30 feet due to the increased exposure to wave energy. The average groin height ranges from 12 to 19 feet; and the side slopes are set to 2:1. Figure VI-14 illustrates the typical cross-section for the long groin scenario. Figure VI-15 and Figure VI-16 show examples of this groin along various North Carolina beaches.

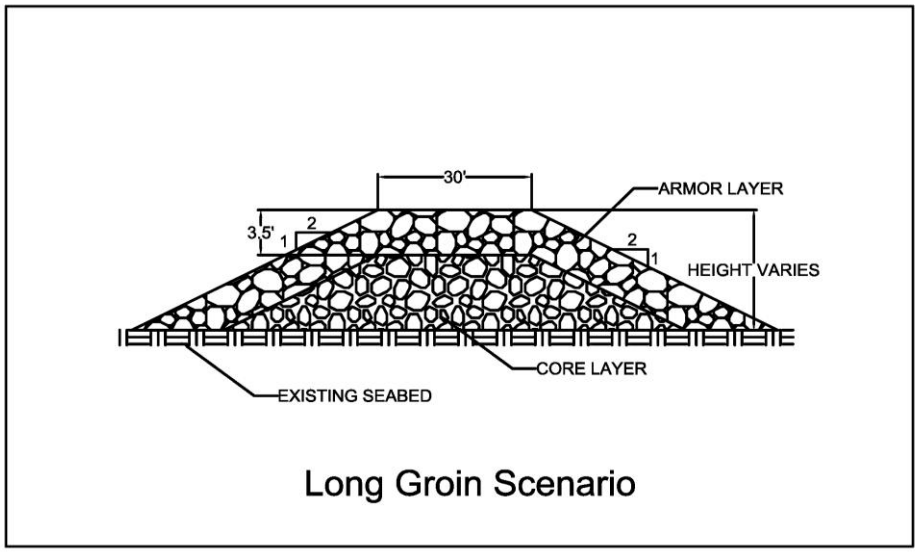


Figure VI-14. Typical Long Groin Scenario Cross Section

Table VI-7 shows the ranges of anticipated unit and total costs for the above scenarios. Based on the scenario, a typical long terminal groin initial construction cost may range from $4 - $8 million**.**

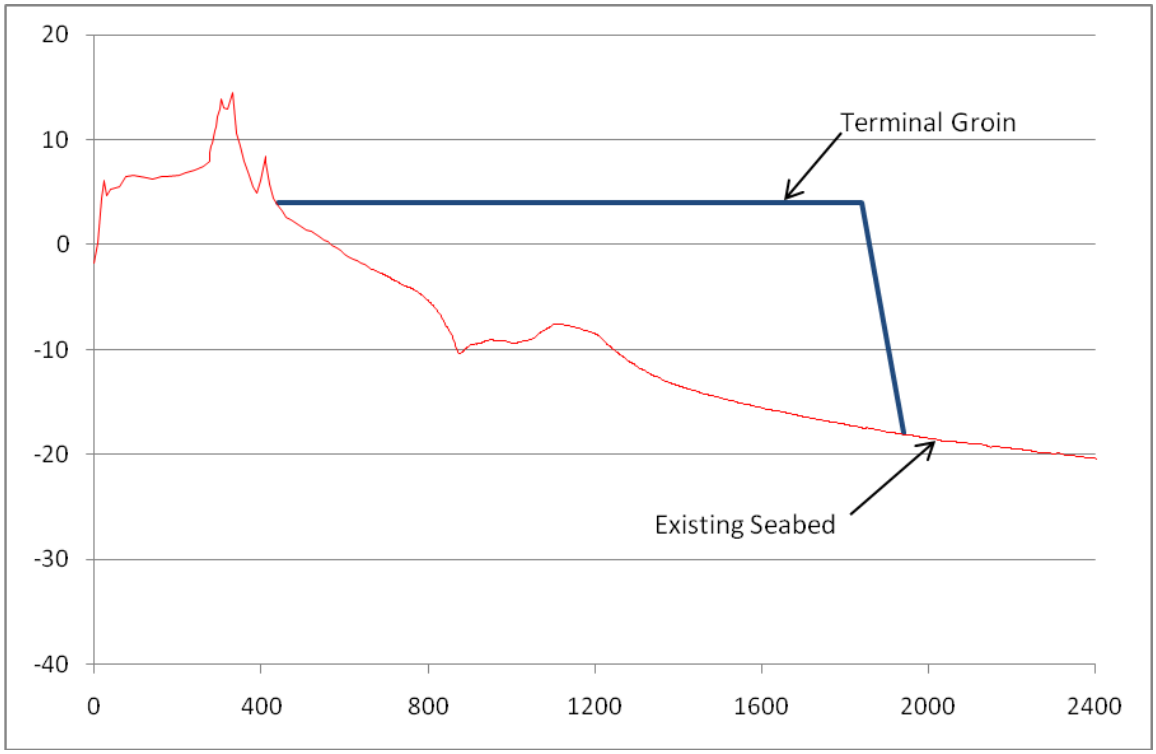


Figure VI-15. Long Groin Cross Section on a Flat-Sloped Beach

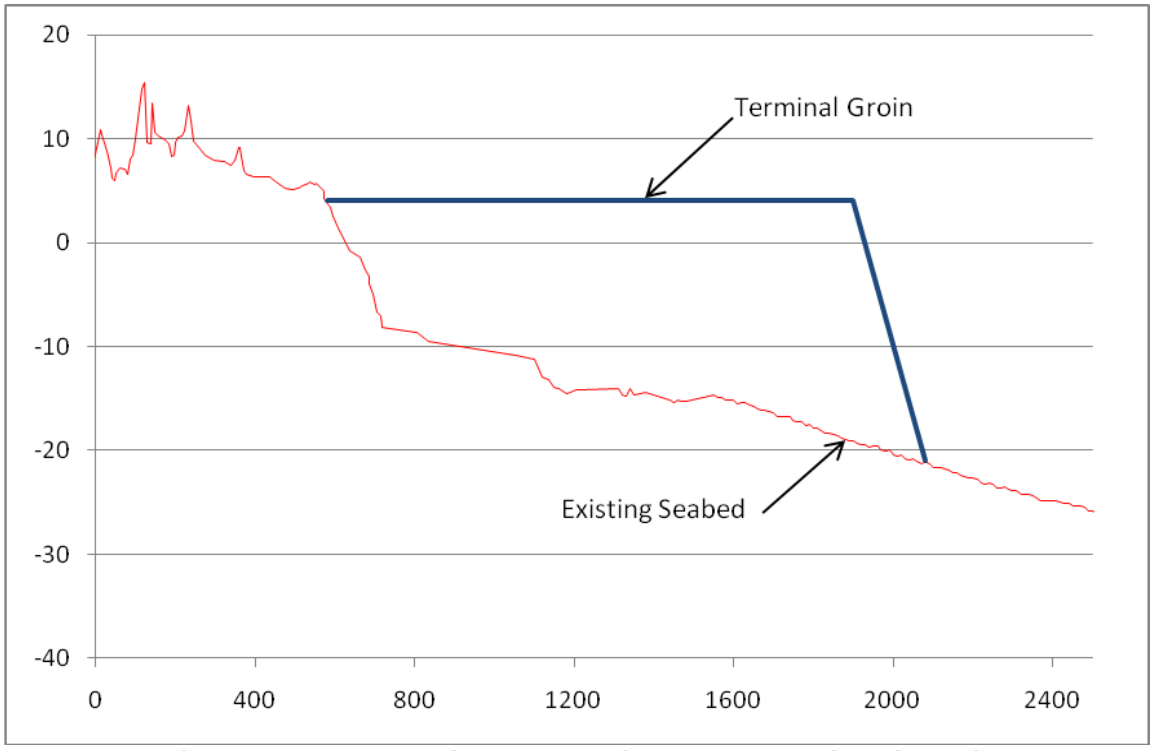


Figure VI-16. Long Groin Cross Section on a Steep-Sloped Beach

Table VI-7. Long Groin Scenario Unit Costs

	Flat-Sloped Beach	Steep-Sloped Beach
Length	1500 ft	1500 ft
Average Height	12 ft	19 ft
Rubble Mound (small stone)		
Unit Cost	$2,640/LF	$4,460/LF
Total Cost	$4.0M	$6.7M
Rubble Mound (large stone)		
Unit Cost	$3,090/LF	$5,180/LF
Total Cost	$4.6M	$7.8M
Geotextile Tubes*		
Unit Cost	N/A	N/A
Total Cost	N/A	N/A
Steel Sheet Piles w/ concrete fascia & cap		
Unit Cost	$4,300/LF	$4,500/LF
Total Cost	$6.5M	$6.8M
Concrete sheet piles**		
Unit Cost	$4,800/LF	N/A
Total Cost	$7.2M	N/A
Timber piles*		
Unit Cost	N/A	N/A
Total Cost	N/A	N/A

*Should not be used for longer groins
**Should not be used for water depths greater than 15 feet

E. Potential Range of Maintenance Costs for North Carolina Terminal Groins

1. Structure Maintenance Costs

As an estimate of maintenance costs, it was observed that a couple of the older structures in Florida have required rehabilitation after a 15 – 20 year time period, and the costs appeared to be roughly equivalent to the initial construction costs based on the tonnage reported. This would equate to a 5-10% annual maintenance cost (please note that maintenance costs for Oregon Inlet and Fort Macon have been negligible so this is likely a conservative estimate). With increased storminess and the possibility of accelerated sea level rise, the annualized maintenance costs (at a planning level) should be in the range of 10-15%, based on typical North Carolina offshore slopes.

2. Beach Nourishment Costs

Since initial beach nourishment will also be likely required for these structures, these costs should be included. Based on a rough estimate of the initial fillet that may be required for various structure lengths, an estimated 100,000 cubic yds of fill would be required for a short groin (0.5 x 450 ft wide x 3000 ft long x 4 ft deep) and 300,000 cubic yds of fill for a long groin (0.5 x 1500 ft wide x 3000 ft long x 4 ft deep). Using a cost of $12/cy, the initial beach nourishment costs would range between $1.2 and $3.6 million. A review of the results tables in Section II shows that for the five sites that an average cumulative volume loss along the groin side over the first 2 miles would be around 25,000 cy/yr for the shorter groins (~450') while the longer groins (~1,500') would average around 100,000 cy/yr. It should be noted that these volume losses are less than the pre-structure values (short groin average loss = ~100,000 cy/yr, long groin average loss = ~225,000 cy/yr), but the presence of a structure will not eliminate the need for beach nourishment but rather will lessen it. Nonetheless, ongoing nourishment costs should be included in the annual maintenance costs (since the terminal groin is specifically used to retain sand as part of a sand management plan) and may range from $300,000 /yr for the smaller groin to $1.2 million /yr for the larger groin. Detailed studies should be completed during the planning process to be sure that an adequate sand source exists to meet this ongoing need.

3. Other Costs

There are additional costs not included in the above estimates, including: permitting, design, monitoring, and possible removal of the groin. Permitting and engineering design costs are estimated to be between 15 – 25% of the initial construction costs for a larger groin project. Given the level of scrutiny that the first terminal groin project would receive, it is likely the that the permitting and engineering design costs would be similar for a small groin as well. Therefore, it is expected that permitting and design costs would likely be between $1 – 1.5 million. Monitoring costs would likely range from $100,000 (2 surveys/year) to $500,000 (multiple surveys and environmental monitoring) per year for a few years, depending on agency requirements. Given the State's longstanding ban on structures, it is expected that if this were to change the monitoring requirements during the first few years before and after terminal groin construction would be substantial.

Should unexpected negative impacts to existing marine environments occur, groin removal may be necessary. For structural members like steel, concrete piles, timber, or geotextile groins an average cost for removal is $250 (timber); $500 (steel); $750 (concrete sheets) per linear foot. For rock or concrete armor groins, the cost of removal is approximately $500 - $1500 per linear foot (depending on section). The rock structures would also provide the complicating factor that 100% removal of the structure would be difficult given the marine environment and substrate conditions.

F. Overall Findings and Summary

An estimate for initial construction and maintenance costs of the existing five (5) study sites was completed. The selected terminal groin plan sheets (when available) were utilized to develop costs per linear foot of groin. Table V-8 summarizes the estimated costs for each of the five selected sites.

Table VI-8. Summary of Estimated Costs for 5 Selected Sites

Site Location	
Fort Macon	
Unit Cost	$1,900/LF
Total Cost	$2.9M
Oregon Inlet	
Unit Cost	$8,410/LF
Total Cost	$26.3M
Amelia Island	
Unit Cost	$2,260/LF
Total Cost	$3.4M
John's Pass	
Unit Cost	$1,925/LF
Total Cost	$890K
Captiva Island	
Unit Cost	$1,925/LF
Total Cost	$670K

The unit costs developed were used to estimate a range of costs for varying lengths and slopes for potential terminal groins along the North Carolina coast. The two scenarios developed utilized a short groin (450 feet long) and a long groin (1500 feet long) placed on typical North Carolina shoreline slopes. Table VI-9 summarizes the range of anticipated costs for the developed scenarios.

Table VI-9. Estimated Costs for Potential North Carolina Groins

	Flat-Sloped Beach	Steep-Sloped Beach	Flat-Sloped Beach	Steep-Sloped Beach
Length	450 ft	450 ft	1500 ft	1500 ft
Average Height	8 ft	12 ft	12 ft	19 ft
Rubble Mound (small stone)				
Unit Cost	$1,230/LF	$1,930/LF	$2,640/LF	$4,460/LF
Total Cost	$554K	$869K	$4.0M	$6.7M
Rubble Mound (large stone)				
Unit Cost	$1,440/LF	$2,260/LF	$3,090/LF	$5,180/LF
Total Cost	$648K	$1.0M	$4.6M	$7.8M
Geotextile Tubes*				
Unit Cost	$350/LF	$660/LF	N/A	N/A
Total Cost	$160K	$300K	N/A	N/A
Steel Sheet Piles w/ concrete fascia & cap				
Unit Cost	$4,000/LF	$4,300/LF	$4,300/LF	$4,500/LF
Total Cost	$1.8M	$2.2M	$6.5M	$6.8M
Concrete sheet piles (tied back)**				
Unit Cost	$4,600/LF	$4,800/LF	$4,800/LF	N/A
Total Cost	$2.1M	$2.2M	$7.2M	N/A
Timber Piles*				
Unit Cost	$4,000/LF	N/A	N/A	N/A
Total Cost	$1.8M	N/A	N/A	N/A

*Should not be used for longer groins
**Likely not used for water depths greater than 15 feet

Based on the average initial construction costs reported above for the short and long terminal groin scenarios the total costs for the structures including maintenance are shown in Table V-10. Note that the results in the table are averages and that the actual initial and maintenance costs can vary substantially based on site conditions and the return period storm used in the design (higher return period = higher initial costs/lesser maintenance/repair costs).

Site specific analyses would be required for a potential site to determine if the initial and maintenance costs are outweighed by the infrastructure and property protection as well as reduced nourishment volumes benefits. Sand source investigations should also be completed to verify that a sustainable, adequate source is available (offshore, inlet crossings, etc.)

Table VI-10. Total Project Costs

Initial Costs	Cost	Short (450')	Long (1500')
Initial Cost (LS)	--	$1,000,000	$6,000,000
Initial Beach Nourishment (LS)	--	$1,200,000	$3,600,000
Permitting and Design	LS	$1,250,000	$1,250,000
Total Initial Costs	**Total**	**$3,450,000**	**$10,850,000**

Removal ($/LF)	$1,000	$450,000	$1,500,000

Annual Costs			
Annual Structure Maintenance ($/yr)	12.5%	$125,000	$750,000
Annual Beach Nourishment ($/yr)	LS	$300,000	$1,200,000
Annual Monitoring ($/yr)	LS	$300,000	$300,000
Total Annual Maintenance Costs	**Total**	**$725,000**	**$2,250,000**