

Construction and performance of six template groins at Hunting Island, South Carolina

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ABSTRACT

Hunting Island, South Carolina, a four-mile-long barrier-island state park, has one of the highest erosion rates in the United States, averaging over 20 ft/yr for the past ~50 years. After six federal and state nourishment projects (1968 to 2004) failed to keep pace with erosion, officials at the South Carolina Department of Parks, Recreation and Tourism (SCPRT) approved a beach stabilization project involving groins plus nourishment. The final plan called for construction of six groins in three clusters at strategic beach access locations along the largely undeveloped oceanfront. Nourishment was an integral and required part of the plan, because it provided a platform for land-based construction of the groins and a source of sand to accommodate sand trapping. In this mesotidal, moderate wave energy setting, the completed structures had to be ~450 ft long to provide a profile encompassing the design berm width and

wet-sand beach to low water. Groin spacing in clusters was ~1,200 ft. The template profile followed design guidance by ASCE (1994) and is likely one of the first groin installations in the United States attempting this recommended configuration. The groins were constructed using ASTM A690 steel sheet pile with steel caps. Toe protection was limited to broad, armor-stone mats at the heads of each groin. The structures were designed for low reveal along their lengths. Post-project monitoring confirms that erosion rates have lessened within each groin cluster. However, excess nourishment sand has been lost mainly to the north spit (the principal transport direction in this setting). Downcoast areas have continued to receive sand during the first two years following construction. The quantities of sand retained by the structures are dwarfed by the volumes of sand in the adjacent ebb-tidal deltas.

Hunting Island, in Beaufort County, SC, is a roughly four-mile-long barrier island bounded by Johnson Creek Inlet and Harbor Island at the northern end, and Fripp Inlet and Fripp Island at the southern end (Figure 1). St. Helena Sound (to the north) and its ebb-tidal delta encircle the offshore area of Hunting Island, complicating wave and tidal current patterns along the island. The result has been rapid erosion and loss of sand for over a century with shoreline changes exceeding 20 feet per year (ft/yr) (Hubbard *et al.* 1977, Anders *et al.* 1990). Depending on the time period, Hunting Island has lost 200,000-300,000 cubic yards per year (cy/yr) since the 1850s (CSE 1990). The erosion losses between 1998 and 2004 were ~100,000 cy/yr (CSE 2005).

Studies by numerous research groups have demonstrated that most of the sand

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eroded from Hunting Island shifts north into Johnson Creek Inlet and St. Helena Sound (e.g. Sill *et al.* 1981, Stapor and May 1981, McCreesh 1982). Average longshore transport rates in the past 20 years have ranged from 100,000 cy/yr to 160,000 cy/yr to the north at the northern end of Hunting Island based on comparative surveys. Net transport rates at the southern end of the island have ranged from ~10,000 cy/yr to 30,000 cy/yr over the past 15 years (CSE 2005).

Net longshore transport is negligible in a zone along the south-central reach of the island. Erosion is rapid for several reasons including: (1) the direction waves break along the shoreline; (2) the strength of flood tidal currents directed toward St. Helena Island; (3) the shape of Hunting Island which is not in equilibrium with waves; and (4) the large imbalance between storm waves or waves at high tide compared with fair-weather waves during much of the tidal cycle. The latter effect is due to sheltering of the shoreline by the outer shoals of St. Helena Sound.

Six nourishment projects totaling ~4.5 million cubic yards were constructed at Hunting Island between 1968 and 2004 (Table 1). Erosion of the nourishment sand was consistently rapid, threatening infrastructure and reducing recreational area within a few years of each project. One of the island's attractions is the

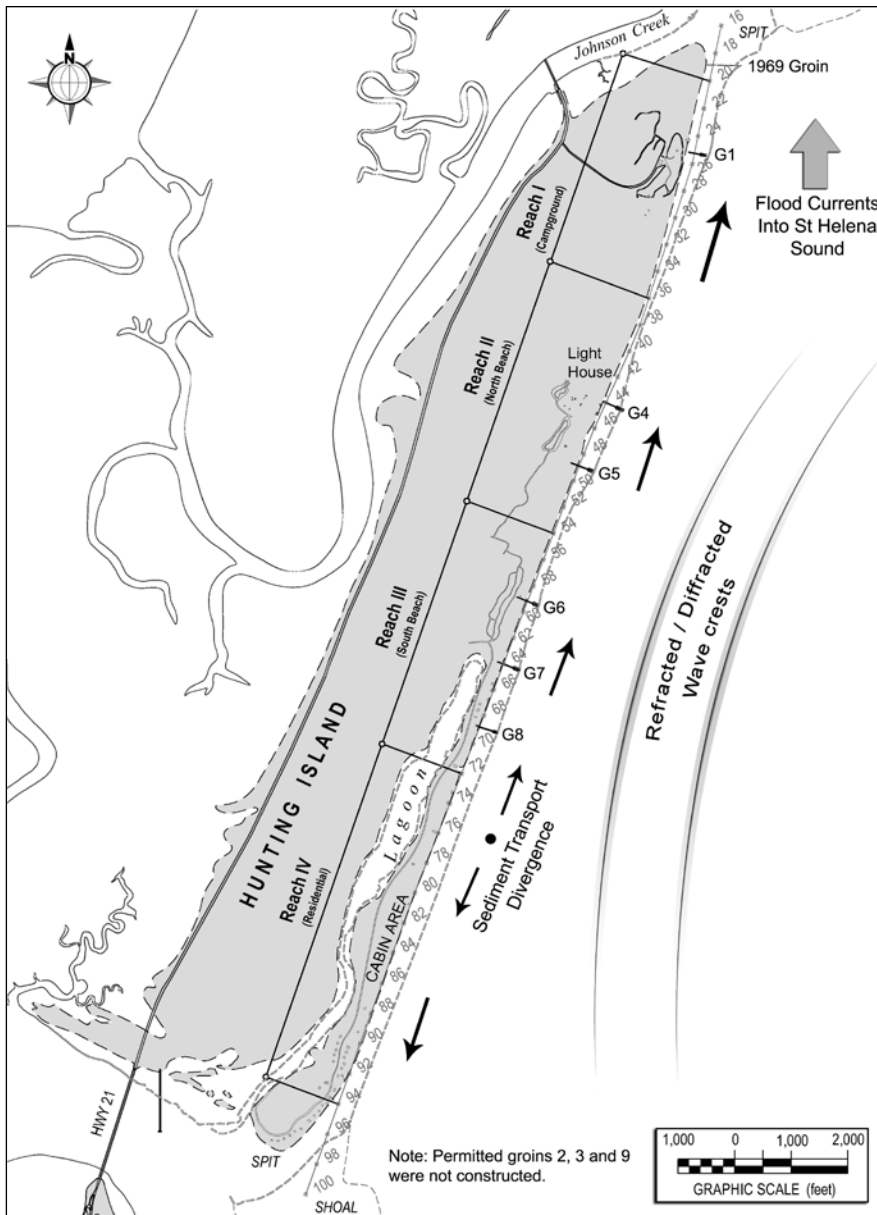


Figure 1. Map of Hunting Island showing principal wave and current directions, sediment transport patterns due to wave refraction and diffraction around offshore shoals, and profile locations. Net longshore transport splits and drives sand toward the ends of the island, accounting for high sand loss rates over the past century. Reaches referenced in this map do not coincide with the project limits, but are used for summarizing changes over larger portions of the island. Stations are referenced in the text and figures later in this paper.

mass of driftwood left on the beach as erosion encroaches maritime forest. Such driftwood, however, was a safety hazard along beach access points where visitors congregate. With little permanent development along most of the oceanfront, large sections of Hunting Island may be left in a natural state. Clusters of groins were proposed for areas referred to as North Beach and South Beach, where the main beach accesses are located. The restoration plan was designed to provide

safe recreational beach access while preserving the natural erosional character of the beach. The groin clusters satisfied this by stabilizing swimming areas, and allowing natural erosion between the groin cells.

A draft environmental assessment for a potential federal plan consisting of nourishment and construction of six groins along the northern half of the island concluded that “the proposed action (nourishment with groins) does

not constitute a major federal action significantly affecting the quality of the human environment (USACE 2004).” Federal funds were unavailable for the federal project; therefore, SCPRT opted for a modified version of the federal plan and a plan (Figure 2) by Coastal Science & Engineering (CSE).

ANALYSIS OF DOWNDRIFT IMPACTS

A detailed analysis of potential down-drift impacts was performed prior to the project as a prerequisite for permitting under South Carolina’s Beach Management Act (CSE 2005). The initial plan by CSE called for installation of nine groins in three clusters with nourishment satisfying trapping capacity of the groins. Due to budget limitations, the scope was reduced to construction of six groins and nourishment. The analysis was based on the reduced project and assumed the following:

- Groin 1 would be placed near the northern end of Hunting Island (Campground reach).
- Groins 2 and 3 and 9 are optional future groins.
- Groins 4 and 5 would be placed 1,200 ft apart along “North Beach” (lighthouse area).
- Groins 6, 7, and 8 would be placed 1,200 ft apart along the “South Beach” recreational area.

The analysis showed that these six groins, when combined with the existing terminal groin (Figure 3), have the potential to trap up to 690,000 cy over the applicable reaches (Figure 4). Excess sand would be placed to facilitate construction of the groins and would naturally feed downcoast areas after construction.

Post-project sediment budgets projected there would be little change in net longshore transport at the ends of Hunting Island during Years 0-2 after completion. Net longshore transport was expected to be of the order 150,000 cy/yr into Johnson Creek Inlet and 15,000 cy/yr into Fripp Inlet. During Years 2–10, erosion along Hunting Island was projected to decline to one-half the 1998-2004 rate in the presence of the structures. Future renourishment was anticipated as part of the long-term plan, but at a lower rate and frequency compared with prior projects.

Impacts of the project on Fripp Inlet (to the south) were projected to be indis-

tinguishable from normal inlet processes. The rates of net longshore transport at the southern end of Hunting Island with or without the project are dwarfed by volumes in the Fripp Inlet ebb-tidal delta. It was found that total trapping by the groins (worst-case scenario) would result in no measurable change along the northern shoal of Fripp Inlet. Net longshore transport inputs over the past decade represent less than 2 percent of the northern shoal volume. Also, the dominant net transport direction in the project area is to the north, which reduces the impact of groins to Fripp Island.

Because of uncertainties of the effect of the project, yearly surveys were made a condition of the permits for construction. Annual monitoring includes controlled vertical photography, beach and inshore profiling, and calculation of sand volume changes from reach to reach along Hunting Island.

PROJECT IMPLEMENTATION

State and federal permits and a 401 water-quality certification were required prior to construction. Nourishment, using an offshore sand source, began in late April 2006 and was designed to add at least 550,000 cy in three reaches. Before and after dredging surveys by the contractor, Great Lakes Dredge & Dock Company, showed ~644,000 cy were actually placed.

Because groin design was conditioned on the volume of nourishment sand placed, final design of the groins was completed after nourishment. Plans and specifications for groins were completed by CSE (J.W. Forman Jr., P.E.) in July 2006.

The final plan called for construction of six steel sheet-pile groins at the locations shown in Figure 2. Groin 1 was positioned ~1,200 ft south (updrift) of the 1969 terminal groin. Spacing within the North Beach and South Beach clusters was also set at 1,200 ft. The basic configuration of each groin is shown in Figure 5. Table 2 lists the final dimensions of each groin section. Each groin profile consisted of three sections: berm, beach face, and low-tide terrace – following design guidance in ASCE (1994) and Basco and Pope (2004). The lengths of each section were established based on the design berm width and natural beach slope after nourishment and profile adjustment (CSE 2005). Sheet piles for Groins 1, 6,

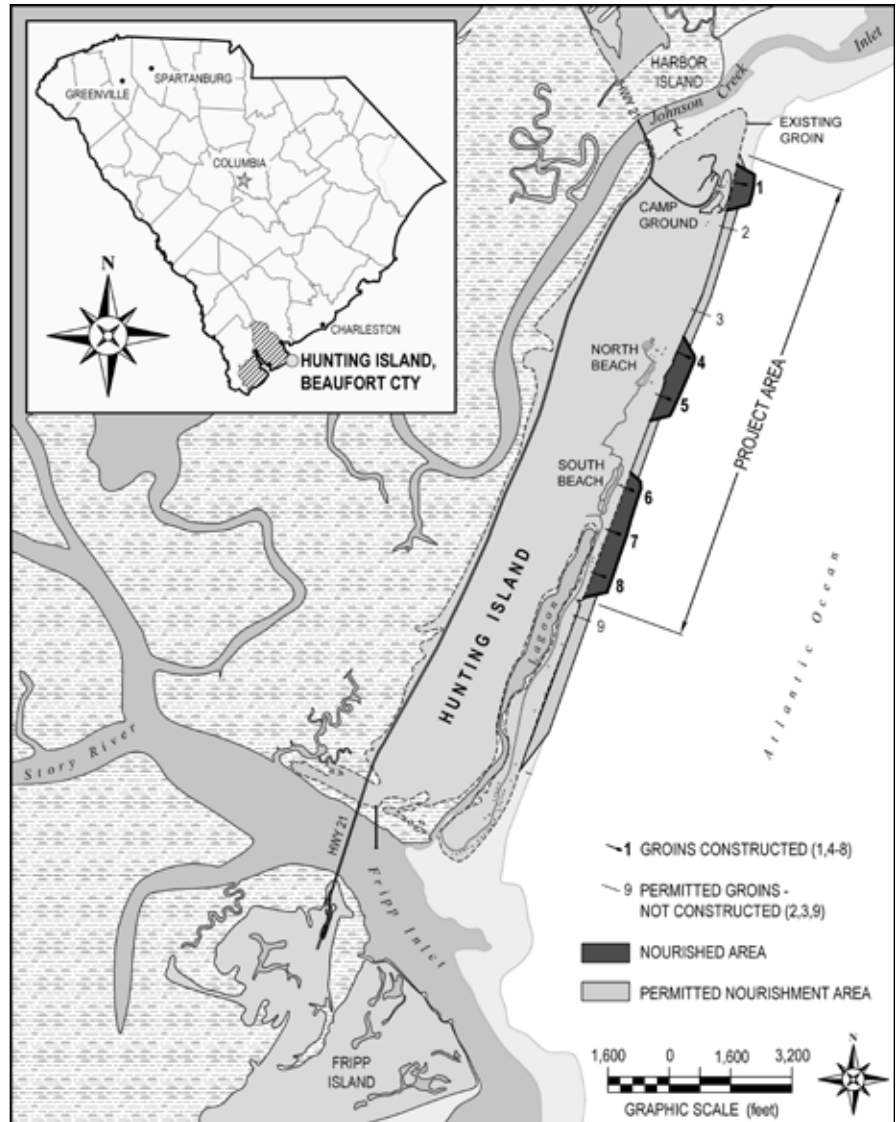


Figure 2. Project plan for nourishment and construction of six groins at Hunting Island, SC. The project was budget-limited; therefore, the final design omitted three of the permitted groins and reduced the nourishment volume to a smaller scale than the permitted plans. The principal beach access and recreational areas are the Campground, North Beach, and South Beach. (From CSE 2007.)

7, and 8 were in place in January 2007, followed by Groins 4 and 5 in February 2007. Quarry-stone toe protection at the heads and sheet-pile caps were completed in subsequent months.

The berm sections ranged from 150 ft to 205 ft long with the crest of the sheet pile set between +7.0 ft NGVD at the landward end and +6.0 ft NGVD at the seaward end. The beach-face sections ranged from 225 ft to 231 ft long, sloping at approximately 1:30 to a seaward elevation of -1.5 ft NGVD. The low-tide terrace (LTT) section ranged from 34 ft to 75 ft long set at -1.5 ft NGVD. This latter crest elevation was established based on the local, mean lower low

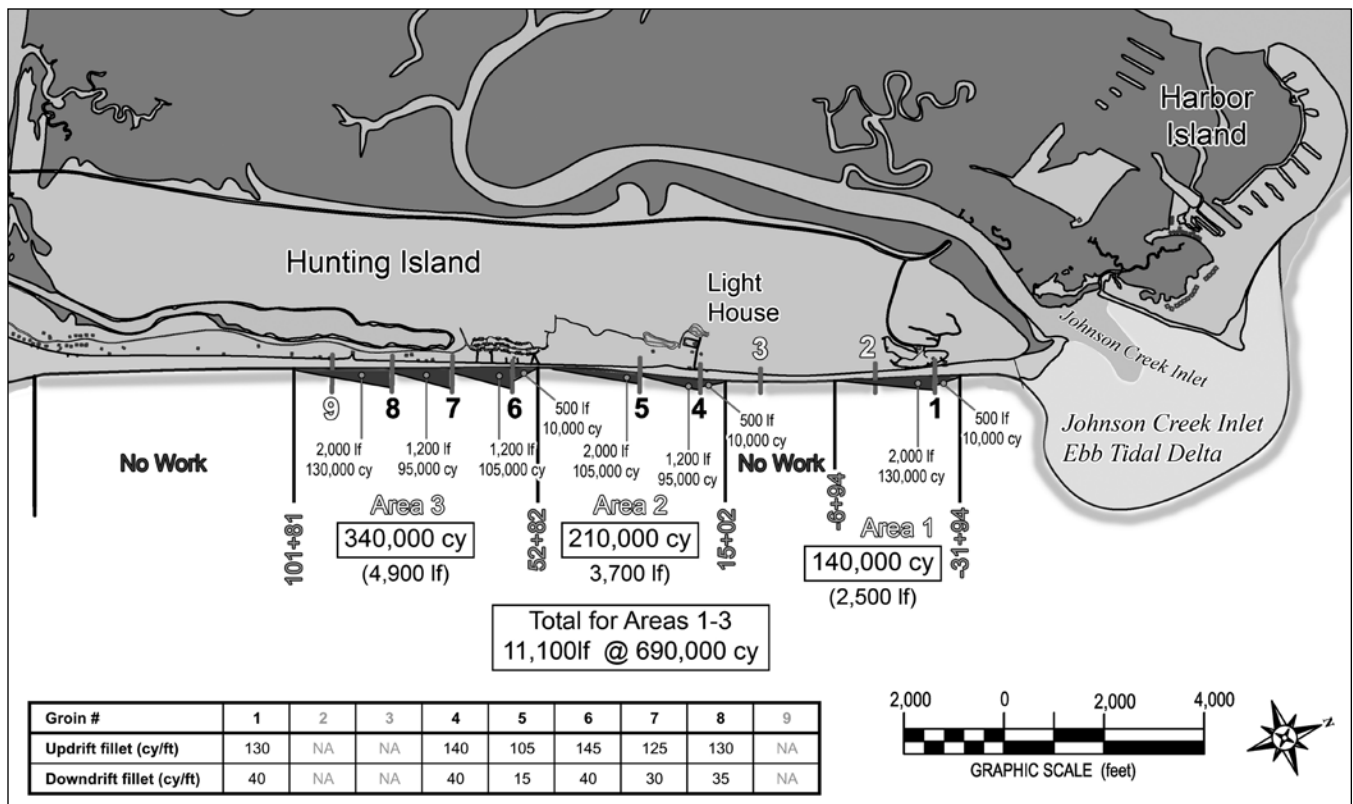
water elevation of -2.65 ft NGVD so as to allow the contractor to drive piles and attach caps in the seaward section at low tide without the aid of a coffer dam. The Industrial Company (TIC–Savannah, GA) worked closely with CSE’s project engineer to develop a practical construction plan which used the local tide range and hard-packed sands of the intertidal zone to advantage.

To the best of our knowledge, these are the first groins ever constructed along the open coast of the U.S. east coast or gulf coast which attempt to follow the natural profile to low water in accordance with design guidance in ASCE (1994). Sometimes referred to as “template”



Figure 3. Oblique aerial photo at low tide on 10 February 2006, showing the exposed shoals of the Johnson Creek ebb-tidal delta which is estimated to contain ~20 million cubic yards. The northern spit of Hunting Island is at the lower left. A terminal groin was constructed at the end of the spit in 1969.

Figure 4. Analysis of downdrift impacts showed that six groins, constructed to permitted lengths, could trap up to 690,000 cy of sand. Impacts to Harbor Island, the “downcoast” beach, were predicted to be small or indistinguishable from changes associated with the ebb-tidal delta of Johnson Creek Inlet (see Figure 3). (From CSE 2005.)



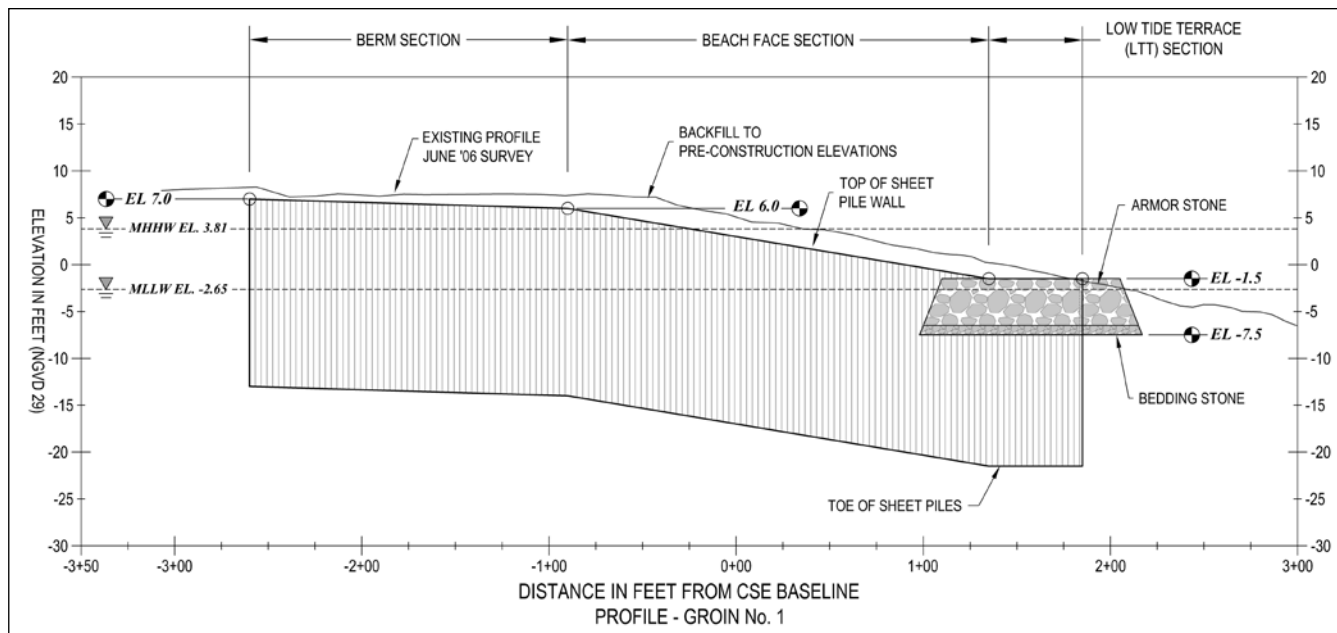


Figure 5. Construction plan for the sheet-pile Groin #1 in the Campground Reach. The berm and beach face sections are sloped to match the native profile of the beach. The low-tide terrace section is set at the local MLW elevation. Final design for each groin was completed after nourishment, as design depended on the condition of the beach after the fill was placed. (Courtesy: CSE unpublished construction documents.)

groins (Kana *et al.* 2004), a primary goal of such profiles is to reduce the exposure of the structure (i.e. the reveal above the sand level). Timber groins constructed by the SC Highway Department in the 1950s and 1960s typically sloped at ~1:50 from the base of the foredune (starting at +7 ft to +9 ft NGVD) to mean high water or higher. Their lengths were typically ~250 ft, terminating landward of the low-tide beach. Because their crests did not follow the natural profile of the beach, the head sections of the structure were more exposed (Kana *et al.* 2004).

The bid documents for the Hunting Island groins allowed for alternate bids utilizing steel (ASTM A-690 – a steel alloy with higher corrosion resistance) or aluminum sheet pile. The armor stone specified was SCDOT Class F (1,000-4,000 pounds, minimum specific gravity 165 pounds/cubic foot). The low base bid was \$2,113,385 for six 400-ft-long groins (average ~\$352,200 per groin, ~\$880 per linear foot). Other bids ranged from ~\$2.9 million to ~\$5.7 million.

Table 1.

Beach nourishment projects along Hunting Island (1968-2003). (Sources: USACE 1977, London *et al.* 1981, CSE 1991b, USACE unpublished data 2004.) Note: *USACE stations run north and south from the vicinity of the lighthouse (e.g. 50+00N is 5,000 ft north of the lighthouse; 97+00S is 9,700 ft south of the lighthouse). Total length of Hunting Island is about 21,000 ft (~4 miles), ranging from ~70+00N to ~140+00S. Costs do not include engineering and permitting.

Project	Construction Dates	Volume (cy)	Limits of Placement	Net Unit Cost (\$/cy)	Total Cost (\$)
1968	Feb.- Dec.	750,000	*50+00N to 50+00S	0.58	435,178
1971	May-Dec.	761,324	50+00N to 50+00S	0.70	534,000
1975	Apr.-June	612,974	60+00N to 30+00S	1.58	971,540
1980	Jan.-May	1,412,692	24+60N to 97+00S	1.60	2,267,201
1991	Feb.-Apr.	757,644	~20+00N to 55+00S	3.80	2,876,250
2003	Jan.-Mar.	230,181	~45+00S to 70+00S	10.78	~2,480,250
TOTALS		4,506,634		~2.11/cy	~9,564,419

Table 2.

Hunting Island groins constructed between December 2006 and July 2007. Note: Groin numbers reference the nine permitted groins, of which only six were constructed. (*Includes armor-stone toe protection at heads of each structure. Typical armor stone covered the outer ~80 ft of sheet pile plus ~20 ft seaward of the sheet-pile ends.)

Reach	Permitted Groin Number	Constructed Groin Number	Original Length (ft)	Landward End Distance from CSE BL (ft)	Final Design Sections (ft)			Final Length (ft)
					Berm Section	Beach Face	Low Tide*	
1	1	1	400	-260	150	225	70	445
1	2				Not Built			
2	3				Not Built			
2	4	2	400	-140	150	225	75	450
2	5	3	400	-200	175	231	44	450
3	6	4	400	-240	150	225	50	425
3	7	5	400	-170	170	231	59	460
3	8	6	400	-145	205	231	34	470
3	9				Not Built			

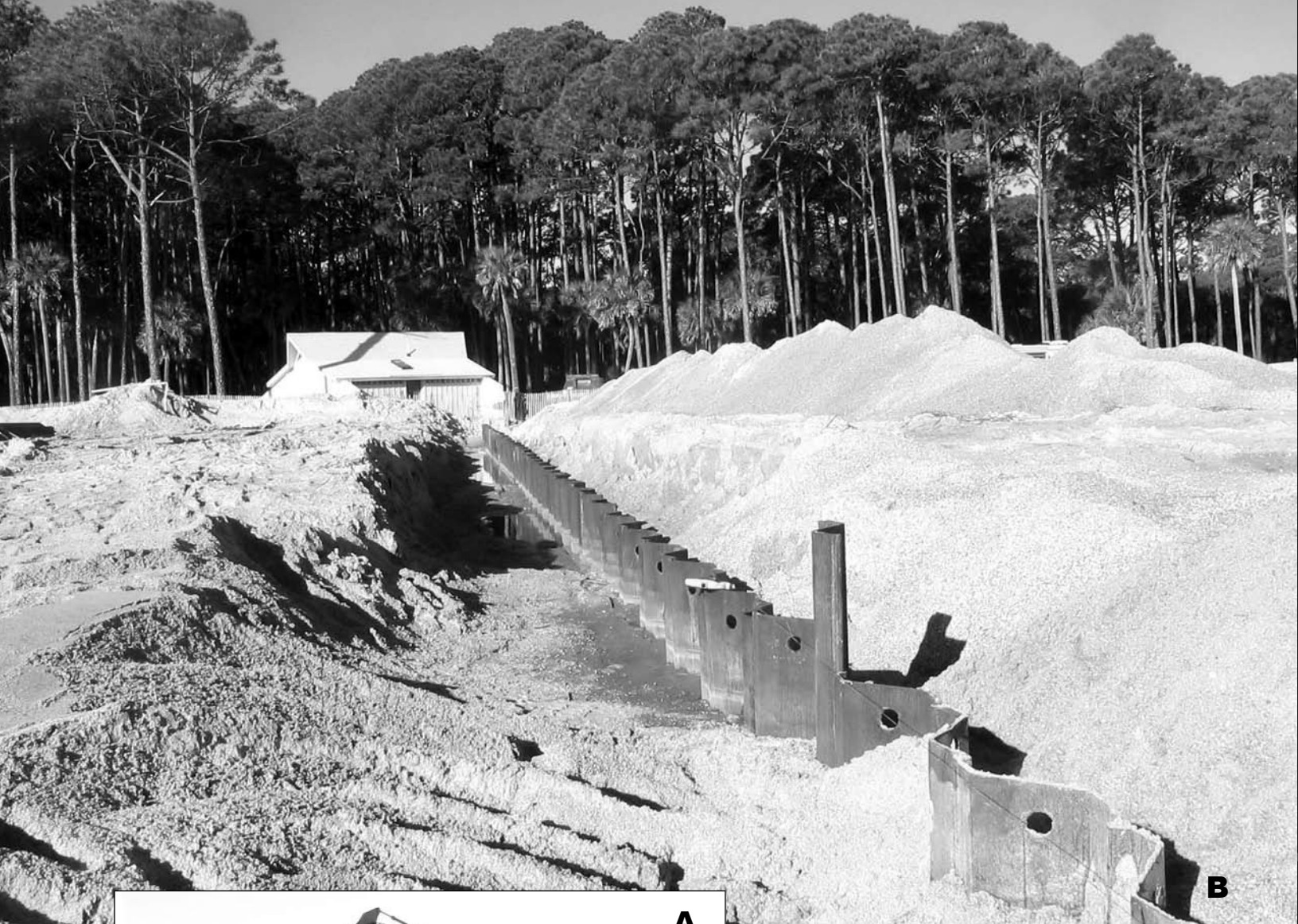


Figure 6. Construction photos of the groin installation project in January-February 2007. Steel sheet piles (20-ft long) were driven into the sand, following the natural profile of the beach (A and B). Armor stone was used for toe protection (C). Groin 2 at low tide in March 2007 (D).

Figure 6 presents representative photos of the construction. Minor modifications were made to the cap (steel channel) at the end of construction to improve its attachment. A combination of through-bolts, welded brackets, and spot-welding was used in the cap attachment. The project included signage and buoys marking the heads of the structures. Before and after aerial images are shown in Figure 7.

POST-PROJECT MONITORING AND PERFORMANCE

CSE performed comprehensive surveys of Hunting Island from Johnson Creek Inlet to Fripp Inlet in January 2008, January 2009, and January 2010. Profiles were spaced at ~500-ft intervals (c.f. Figure 1), and the outer limit for volume calculations was set typically at -12 ft NAVD and was cut off about 600 ft from the project baseline where the inshore zone flattened. Cross-sectional area differences were extrapolated to the next profile using the average-end-area method.

C



D





Figure 7. Before (looking north at low tide on 10 February 2006, left) and at present (28 April 2010, below, looking south) aerial images of the 2006-2007 nourishment and groin construction project at Hunting Island (SC). (Photos by CSE.)



Volume changes were computed for each profile section and project area.

The alongshore limits of project areas used for monitoring differ somewhat from actual project limits so as to place boundaries at CSE survey lines. The limits for the project areas are defined as follows:

- Area 1 — Campground: Lines 22 to 30 (2,002 ft)
- Area 2 — North Beach: Lines 42 to 52 (2,503 ft)
- Area 3 — South Beach: Lines 56 to 72 (4,068 ft)

(See Figure 1 for the location of profile lines.)

The nourishment occurred between the November 2005 and July 2006 surveys; therefore, the volume change between these two surveys accounts for the cumulative effects of the nourishment and natural sand volume changes between these two dates. Unit volumes for the project areas are shown in Figure 8.

• **Area 1 (Campground)** lost ~9,600 cy (4.8 cy/ft) between April 2007 and January 2010. As of January 2010, the area retained ~96.3 percent of the ~152,000 cy gained from November 2005 to July 2006 (approximate nourishment volume).

• **Area 2 (North Beach)** lost ~32,900 cy (13.2 cy/ft) between April 2007 and January 2010. As of January 2010, Area 2 retained ~86.0 percent of the ~162,000 cy gained between the 2005 and 2006.

• **Area 3 (South Beach)** showed the greatest erosion, losing ~90,900 cy (22.3 cy/ft) from April 2007 to January 2010. As of January 2010, Area 3 retained ~51.1 percent of the volume gained from 2005 to 2006.

When compared to sections of Hunting Island not protected by groins, the project areas show reduced erosion (Figure 9). Between April 2007 and January 2010, protected areas (updrift of groins) eroded an average of 13.1 cy/ft, while unprotected areas between project reaches eroded an average of 67.6 cy/ft. Overall, the northern two-thirds of Hunting Island (stations 16-72) has lost ~134,000 cy/yr since groin construction, which agrees well with the 150,000 cy/yr estimate presented in the downdrift impact analysis (CSE 2005).

To further highlight the effect groins have of reducing erosion compared to

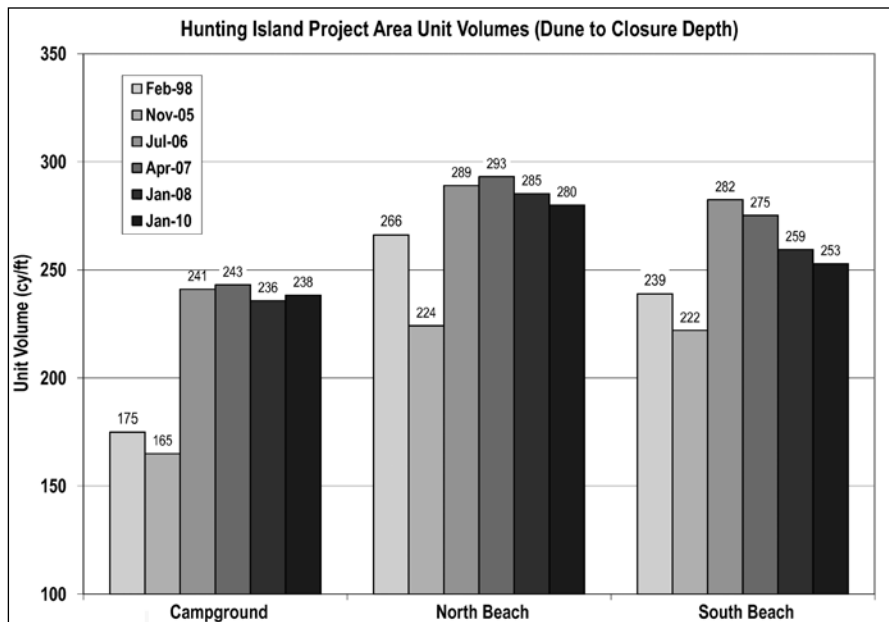
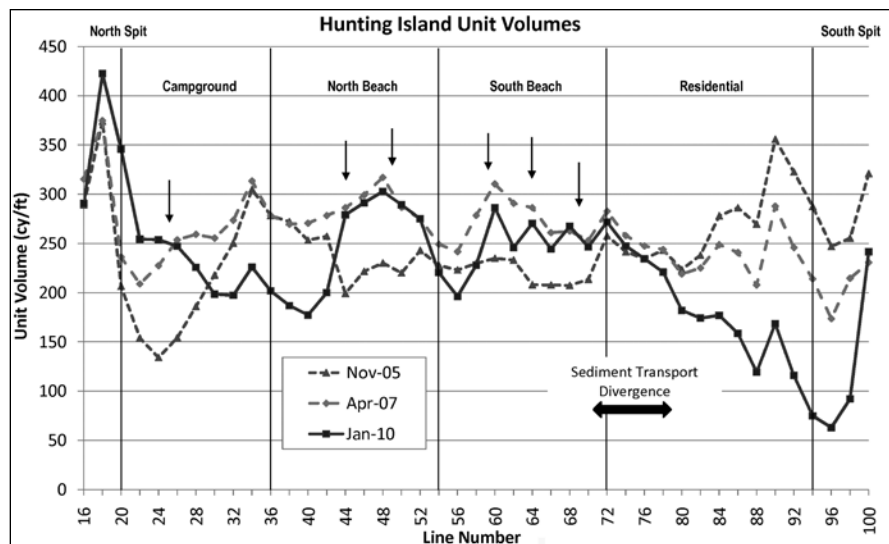


Figure 8. Project area unit volumes (cy/ft) since 1998. Nourishment occurred in spring 2006, and groin construction in January-February 2007. All project areas contain more sand than the 1998 condition. The South Beach reach shows the greatest erosion since groin construction, likely due to a lack of sediment supply as it is the updrift nourishment area.

Figure 9. Unit volume change for monitoring stations along Hunting Island. Stations are spaced ~500 ft apart and are oriented perpendicular to the beach. Groin locations are indicated by the arrows. Note how the area between the Campground and North Beach showed erosion of up to 100 cy/ft following groin installation, whereas areas in the influence of groins showed much less erosion. Net northerly transport dominates along most of the island, reversing to the south around Stations 72 to 80.



unprotected areas, profiles from North Beach (Station 48), South Beach (Station 68), and the unprotected area between North Beach and South Beach (Station 56) are shown in Figure 10. From April 2007 to January 2010, the two stations protected by groins (stations 48 and 68) showed relatively little volume change (-14.2 and +4.8 cy/ft, respectively) and ~25 ft of reduction in beach width (at

the +5 ft NAVD contour). Station 56 (not protected by groins) showed much more erosion over the same period, losing 45.4 cy/ft and ~55 ft of dry beach width (at the +5 ft NAVD contour). Station 56 has eroded 16.4 cy/ft/yr following groin construction, compared to 9.6 cy/ft/yr between 1998 and 2004. This increase may be due to sediment trapping of the updrift groin field; however, island-wide

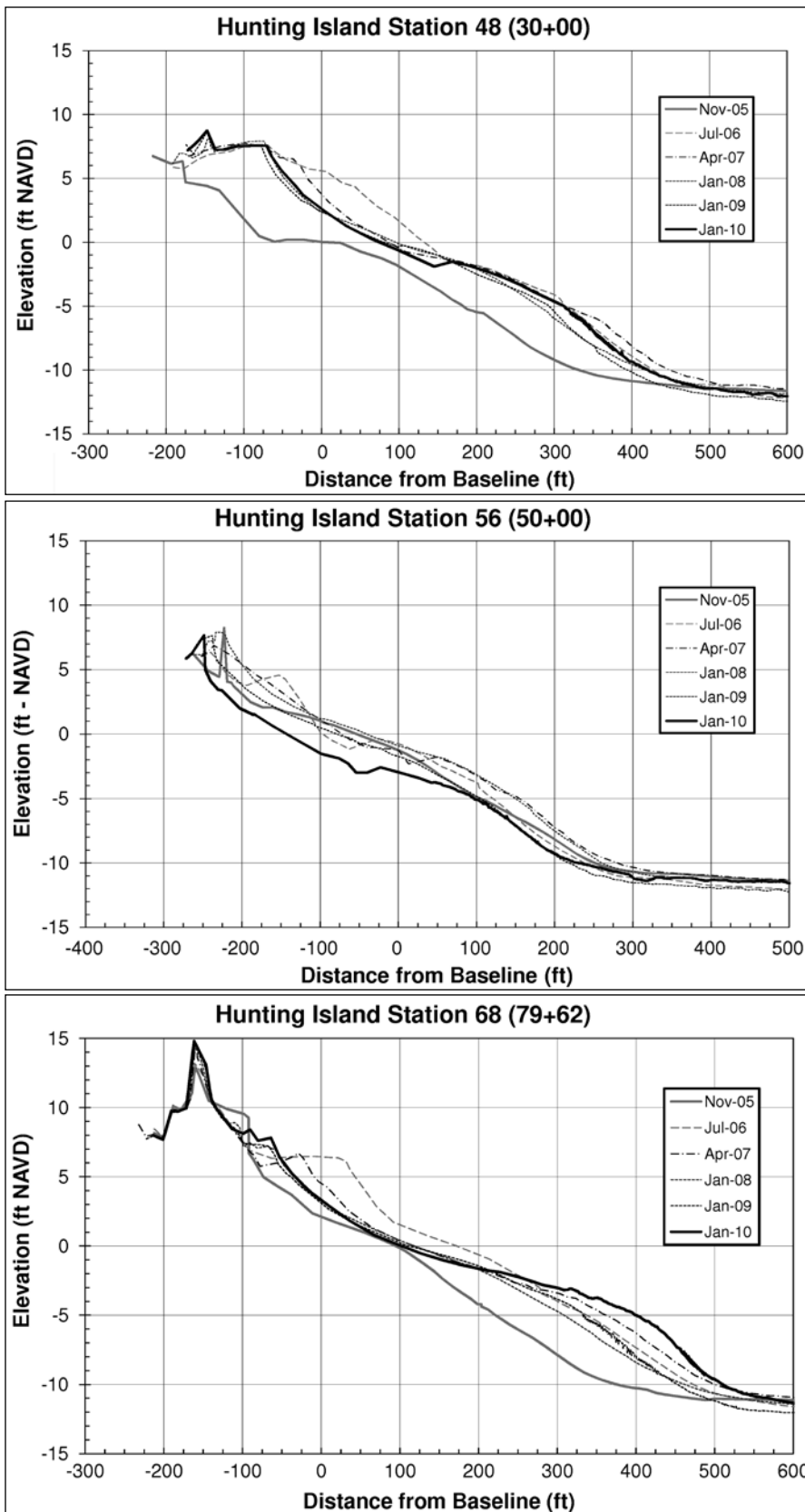


Figure 10. Profiles from Stations 48, 56, and 68. Stations 48 and 68 are in the North Beach and South Beach groin fields, respectively. Station 56 lies between the two groin fields. Note the relatively small change between the January 2008 and 2009 surveys at the protected stations, compared to the large change at Station 56, which is unprotected by groins. Nourishment occurred in spring 2006, followed by groin construction in January-February 2007.

erosion rates have also been higher during recent years.

One important aspect of the data shown in Figure 10 is that profiles in the influence of the groins are maintaining the lower beach profile (below mean low water [MLW]), which serves as a foundation to the visible beach (above MLW). As long as the lower portion of the profile remains stable, the exposures of the groins will be reduced, because the remainder of the visible beach necessarily maintains certain limiting slopes. This is also expected to improve aesthetics (Gomez-Pina 2004) and leave the upper beach better protected from erosion during storm events.

The groins showed relatively low reveal along their profiles after three years (Figure 11). The maximum exposure (~3.5 ft) was found along the north side of Groin 8. (Note the south side showed up to ~3 ft of reveal.) The degree of reveal diminished to the north with most of Groin 1 being buried in January 2009.

The newly installed groins act to slow northerly transport of sand along the northern two-thirds of Hunting Island. They are likely to become increasingly effective as sediment traps after more of each groin is exposed. The northern reaches benefit from the sand lost in the South Beach reach as reflected in the reduced erosion rates.

The post-project monitoring surveys suggest the groins have not had a measurable adverse impact on “downcoast” areas. While no quantitative data exists for the shoals on either side of the island, visual observations from vertical aerial photographs at the north end show spit growth, suggesting sand is moving from the project area in the principal downdrift direction.

Following groin construction, Hunting Island has continued to erode at a higher rate overall compared to other South Carolina beaches (CSE-Baird 1998, CSE 2005). However, the visible beach within the groin field remains more stable compared to the rest of the island. It is likely that high erosion rates the first two years following the project are mainly related to the perturbations in the shoreline produced by the segmented nourishment plan (c.f. Figure 2). Furthermore, the volumes placed significantly exceeded the sand-trapping capacity of the groins.



Figure 11. Post-project (April 2007) and January 2009 images of Groin 4 (upper) and Groin 7 (lower). All groins maintain a relatively low exposure (less than 4 ft), which was one of the goals of the project. “Template” groins, which slope to match the natural profile of the beach, are thought to maintain a lower reveal and offer better performance in the lower beach profile compared to most groins constructed in earlier decades, which often had little slope and terminated landward of the low-tide line.

CONCLUSIONS

Six groins were installed at Hunting Island (SC) in January-February 2007 as part of a nourishment project designed to slow erosion at the most used areas of the state park. The groins were designed to match the natural contour of the beach, following design guidance by ASCE (1994) and Basco and Pope (2004). After construction, areas protected by groins show reduced erosion rates on the visible beach compared to other areas of the island. Groins show relatively little exposure and no measurable adverse impacts to neighboring islands.

The discussion presented in this paper outlines the design, construction, and performance of one of the first installations of groins along the South Carolina coast in the past 25 years. Unlike traditional fields of groins built in the 1950s and 1960s, the Hunting Island groins were clustered at three localities with the intent of holding the dry beach at those places (for purposes of recreation) and allowing the undeveloped shoreline in between to erode to equilibrium. They also were designed to follow the natural profile of the beach, with discrete berm, slope, and low-tide terrace sections. Groin installation was combined with nourishment, which is now widely accepted as a critical component of any groin project (Galgano 2004). Groins should generally not be considered the most appropriate method of shore protection along beaches with low or moderate erosion rates. They were permitted only after six nourishment projects (1968 to 2004) confirmed that Hunting Island has one of the highest erosion rates along the U.S. coast.

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