Experimental Beach Landscape
12 Year Study Results

The Evolution of a Model Landscape Design and Management Plan for the Manmade Beach in Harrison County, Mississippi

By Pete Melby, ASLA, Landscape Architect
Thomas Cathcart, Biological Engineer

25 June,11:44, 26, 29, 1 July, 17, 25, 26 August 2007 6pm, 3 Sept, 16, 30 Sept, 1,2, 6,7,8,10,11 Oct 2007

Thesis Wind and rain along with sand beach management practices erode the manmade beach in Harrison County, Mississippi necessitating replacement four times since it was built in 1950. Sifting the sand to remove debris, and grading the beach to keep a flat profile is destructive to beach stabilization. Through the establishment of native plants in the lower and upper beach, along with less destructive beach management practices, the beach landscape can become stronger and provide a higher level of protection to the coastal edge.

Outline

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Study Overview The original 19th century natural beach and salt marsh landscape of the Mississippi coastal edge was replaced with a concrete seawall in the 1920's to better protect the mainland from storms. A sand beach pumped in from offshore was added in the 1950's to buffer the seawall from storm damage. A significant problem of the 26 mile long seawall-manmade beach system is the periodic requirement for beach replenishment caused by wind and water erosion due to beach management procedures and the absence of beach plants. Southerly winds blow sand disturbed by beach management activities north onto the adjacent four lane highway requiring frequent removal by sand sweepers and dump trucks. Sand also washes into the Mississippi Sound during rain events leaving a beach full of gullies. This loss of sand reduces the size of the beach to the extent that it has needed renourishment four times since it was built.

The experimental beach landscape study was begun in 1995 on three acres ()in order to determine how to move mainland water runoff to the Mississippi Sound in ways other than through the large concrete pipes that extend across the beach. The study also focused on retaining sand on the beach, reducing beach management efforts, reducing beach replacement costs, and eliminating the environmental impact of pumping sand from offshore for renourishment. This 12 year study revealed a plan for optimum coastal edge landscape development and management for the 26 mile long manmade beach landscape in Harrison County, Mississippi.

The 19th Century Natural Coastal Edge

The early Mississippi Gulf Coast edge in Harrison County was an intermittent sand beach and salt marsh landscape. In an 1893 newspaper account writers F. Graves and B. Scott with the New Orleans Picayune Newspaper reported a low-lying marsh east of President Jefferson Davis's home Beauvoir.. A resident at Beauvoir, Mortimer Dahlgren, wrote in April 1877 that …."waves….rolled majestically up the gently sloping beach which stretches out like a magnificent carpet of silver sand….". Late 19th century paintings by regional artists William Woodward and his brother Ellsworth depict through their artwork open, sandy beaches stretching from the waters edge, to an upper beach landscape with trees, shrubs and grasses. Beyond the sparse growth in the upper beach are closely spaced groves of live oak trees (*Quercus palustrus*).

In its 19th century natural condition the coastal edge probably consisted of a series of ecological zones that began at water's edge with either an open sand beach or a combination of beach and marsh grasses. Where there existed an open, sandy beach the lower 10-15 meters was totally devoid of plant material. In other areas such as where a bayou emptied into the Mississippi Sound, or that faced west, a grass zone existed composed of *Spartina alterniflora*, *Juncus romerianus* and *Spartina patens*. The supple *Spartina alterniflora* was predominately located along the flowing bayou and at areas of high wave energy, while the rigid *Juncus romerianus* was located higher in elevation but still in the zone subject to regular tidal innundation. The wiry *Spartina patens* was located above the high tide line, just behind the *Juncus*. The grass zone stretched from below the mean low tide line to beyond the high tide levels. It is reasonable to expect there were also areas without *Juncus romerianus* and composed of dense stands of *Spartina alterniflora* with *Spartina patens* above the high tide line.

Above the open sandy beach and the emergent grass marsh was the upper beach which was dominated by sea oats (*Uniola paniculata*) and host to greater than 50 other grasses and forbs (Table 1). The upper beach was also habitat for shrubs and trees listed in Table 2. Beyond this upper beach was the maritime forest composed of live oaks and longleaf pines located on higher and drier ground.

Table 1: Native Grasses and Forbs that are Indigenous to the Beach

Scientific Name	**Common Name**
Batis Maritima	Saltwort
Briza minor	Quaking Grass
Cakile edentula	Sea-rocket
Cassia aspera	Partridge-pea
Cassia fasciculate	Partridge-pea
Cenchrus incertus	Coastal Sandbur
Centrosema virginianum	Climbing Butterfly-pea
Clitoria mariana	Butterfly-pea
Croton glandulosus	Croton

Croton punctatus	Silver-leaf Croton
Cyperus esculentus	Yellow Nutgrass
Cyperus haspen	Leafless Sedge
Diodia teres	Rough Buttonweed
Distichlis spicata	Saltgrass
Erigeron vernus	Robin's-plantain
Eustachys petraea	Fingergrass
Gaillardia pulchella	Gaillardia or Firewheel
Helenium autumnale	Sneezeweed
Helianthemum corymbosum	Rock-rose, Sun-rose
Heterotheca subaxillaris	Camphorweed
Hydrocotyle umbellate	Marsh Pennywort
Ipomoea brasiliensis	Railroad-vine
Ipomoea stolonifera	Fiddle-leaf morning-glory
Lantana camara	Shrub-verbena, Lantana
Odontonychia corymbosa	Whitlow-wort
Oenothera laciniata	Cut-leaved Oenthera
Opuntia humifusa	Eastern Prickly-pear
Panicum amarum	Bitter Panic Grass
Paspalum notatum	Bahia Grass
Phlox drummondii	Annual phlox
Richardia brasiliensis Gomez	Mexican-Clover
Rhynochosia minima	Climbing Rhynchosia
Rotala ramosior	Toothcup
Rubrus argutus	Blackberry
Scripus americanus	Swordgrass
Sesbania vesicaria	Bladder-pod
Sesuvium portulacastrum	Sea-purslane
Soldage Canadensis	Tall Goldenrod
Solidage sempervirens	Seaside Goldenrod
Spartina alterniflora	Smooth Cordgrass
Spartina patens	Marsh Hay, Salt Hay
Strophostyles helvola	Wild Bean
Triplasis purpurea	Purple Sandgrass
Uniola paniculata	Sea Oats
Vicia angustifolia	Narrow-leaved Vetch
Vigna luteola	Vigna or Savi

Table 2: Native Shrubs and Trees that are Indigenous to the Beach

Scientific Name	**Common Name**
Aralia spinosa	Devil's Walking Stick
Baccharis halimifolia	Groundsel Bush
Carya glabra	Pignut Hickory
Ceratiola ericoidesI	Rosemary
Diospyros virginicus	Persimmon
Ilex glabra	Inkberry, Bitter Gallberry
Ilex vomitoria	Yaupon Holly
Iva frutescensi	Marsh Elder
Juniperus virginiana	Easter Red Cedar
Lantana camara	Shrub Verbena
Magnolia grandiflora	Southern Magnolia
Morus rubra	Red Mulberry
Myrica cerifera	Wax Myrtle
Pinus elliottii	Slash Pine

Pinus palustrus	Longleaf Pine
Quercus falcate	Southern Red Oak
Quercus virginicus	Live Oak
Rhus copallina	Winged Sumac
Sabal minor	Dwarf Palmetto
Sabal palmetto	Cabbage Palm
Sabel Palmetto "Louisiana"	Louisiana Palmetto
Serona repens	Saw Palmetto
Taxodium distichum	Common Bald Cypress

The Manmade Coastal Edge   In 1915 a major hurricane destroyed nearly every structure along the coastal edge. A 26 mile long concrete seawall (Figure 1) was finished in 1928 to provide for coastal edge storm defense.

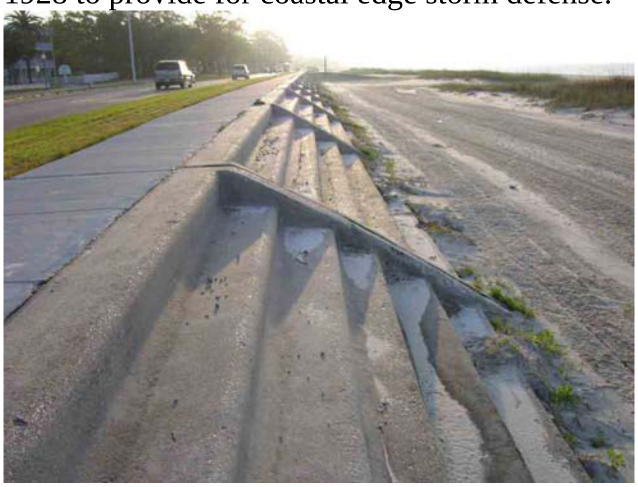

Figure 1. Seawall and the manmade beach

A massive hurricane in 1947 destroyed the 19 year old seawall in several locations prompting consideration of the need for a beach in front of the seawall as a storm defense mechanism. By 1953 a 300 foot (100 meter) wide beach, pumped in from offshore, was completed. At the same time a 4 lane coastal highway adjacent to the seawall was also completed. The manmade coastal edge combination of sand beach and highway became the coast's most significant tourist attraction. While the 79 year old seawall and the 54 year old highway exist today as they were initially constructed, wind and rain along with beach management processes have eroded the manmade beach and necessitated replacement four times through massive beach renourishment efforts.

The U.S. Highway 90 coastal roadway has been both useful and a problem. Many people use the coastal edge highway and traffic volumes are very high. Concrete barriers extend for miles down the middle of the roadway in some areas denying pedestrian access across the highway to the beach. The speed limit is 45 mph, creating dangerous pedestrian crossing conditions. Prevailing southeasterly winds blow sand from the beaches onto the highway as shown in Figure 2 creating vehicle traction problems, and requiring trucks and street sweepers for sand removal along the 26 mile long beach and roadway.

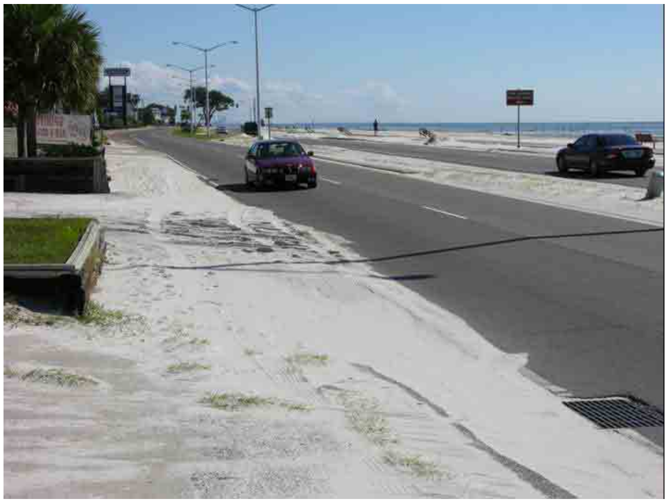

Figure 2. Wind blown beach sand on Highway 90.

There exists an occasional single line of sand dunes on the upper beach planted in the 1970’s, but mostly the beach is open and devoid of dunes and grasses. The natural establishment of beach grasses is prevented due to landscape management practices. Building of the seawall severed natural mainland drainage of water into the Mississippi Sound. Runoff water from roadways, parking lots, and commercial and residential development was rerouted through large pipes below ground and beneath the bottom of the seawall to the edge of the beach where they extend above ground to drain into the Sound. The 200 concrete drain pipes that cross the 26 miles of manmade beach in Harrison County vary in size from 30 – 36 inches in diameter. They are visually prominent and unattractive as shown in Figure 3. Many beach users think the pipes carry sanitary sewage water into the Mississippi Sound. When the seawall was built, bayous that drained into the Sound were placed into straight, concrete lined canals that extended out from the shoreline. The 26 miles of beach varies in width from 50-100 meters wide.

Figure 3. Storm drain for mainland water runoff. This was taken after Hurricane Katrina and depicts shoreline erosion.

Natural Conditions Affecting the Sand Beach

The Mississippi coastal edge is a very dynamic landscape under constant change due to wind, tides, and tropical storms. Because of the extreme conditions of sun, temperature, rainfall and drought, and occasional inundation of brackish water the harsh environment is host to a limited array of plants adaptable to those conditions.

Littoral drift along the Mississippi Sound is from east to west and sand transport follows this pattern. Littoral drift and the sand sharing system are the major contributors to change in the beach landscape as waves deposit sand in a linear berm along the tide line. As the sand dries out it is blown up beach by the prevailing southeasterly winds. This natural sand sharing cycle is what provides the sand for the ever-changing form of the beach, and is responsible for the building of sand dunes and the increase of sand reserves on the beach.

Sand dunes are sacrificial structures that serve to reduce the energy from storm waves and tropical storm surges. As the primary dune grass *Uniola paniculata* becomes established it spreads by rhizomes. Its vertical leaf structure will slow wind blown sand causing the sand to drop out, eventually creating a mound or dune. As the dune and beach gets higher and wider, it becomes a substantial structure for moderating storm wave energy. Dunes flattened by storm surges will grow back because the root stock of the dune grasses that formed the sand mound extend all the way down to the beach elevation when the dune was first created.

Besides damaging plant material and causing erosion, hurricanes and tropical storms can also affect the beach in a positive way. Beach grasses, shrubs, dunes, and trees slow wind and waves causing their sand loads to drop out and pile up from 1-5 feet deep on the upper beach. Plant roots eventually stabilize the additional sand by holding it together. Many beach plants will survive being buried and grow upward through the new sand deposit, thereby creating a taller and stronger beach structure that is bioengineered with roots at a greater depth than when first established. Organic matter washed up during the storms adds to the beach detritus cache. This organic matter, upon microbial degradation, becomes nutrients for beach plants. Washed up grass clumps such as *Spartina species* and *Juncus romerianus* can take root and add to the natural system for reestablishing a healthy and stabilized beach landscape.

Sea level rise is also impacting the manmade beach. Analysis of tidal records from 1891-1991 show that sea level in Biloxi, Mississippi has increased 0.6 feet (20 cm). Rise in sea level is projected to increase due to global warming.

Landscape Management Practices Affecting the Sand Beach

The Harrison County Sand Beach Department maintains the 26 miles of manmade sand beach. Beach management practices are carried out through the use of tractors towing sand sifters to clean debris from beach sand, and motor graders that are used to remove gullies caused by rainfall runoff and to maintain a flat beach. Large front end loaders are used for various beach management tasks including to pull sand away from the stepped, concrete seawall, to dig up and replace drainage pipes, and to pull sand away from clogged concrete outfall lines in the Mississippi Sound. Use of sand sifters during the summer recreation season loosen sand to a depth of 6-8 inches, making it susceptible to wind and runoff erosion. Prevailing winds from the south and southeast blow disturbed sand from the sifted layer up beach and onto U.S. Highway 90 and its right of way.

The establishment of beach grasses is prevented due to regular beach grooming with sand sifters to remove debris from the white sand, and motor graders that reshape the beach to flatten sand that becomes mounded on the northern part of the beach by wind and wave action.

The combined use of the tractors and sand sifters, motor graders, and front end loaders compact the sand and create a fragipan just below the sifted layer of loose sand. The dense fragipan restricts the movement of water drainage down into the sand and causes water to runoff horizontally down beach toward the Mississippi Sound carrying with it loose sand from the sifted sand layer. Beach landscape management practices are having a significant deleterious effect causing the beach to lose sand and become narrower.

The Natural Beach Landscape Study The initial goal of the study was to determine alternatives to move mainland water to the Mississippi Sound in ways other than across the sand beach in large concrete pipes. Additionally, the study identified other questions to be answered including could the appearance of the beach landscape be more attractive than it currently is, and could mainland runoff water emptying into the Sound be cleaned through the use of emergent grasses along the coastal edge? Ultimately, is there a way to reverse the loss of sand and grow a bigger and less fragile beach landscape? And finally, how can management of the 26 miles of manmade beach work to help achieve the answers to these questions?

As part of a Tourism Design Plan developed for the Harrison County, Mississippi coastal area in 1991, Mississippi State University Landscape Architecture students proposed developing alternative ways to replace unsightly concrete drain pipes used for draining mainland water runoff into the Mississippi Sound. A drain pipe replacement and natural beach landscape design for a 3 acre beach site was created and implemented in 1995. The 12 year long study of the beach site ensued and forms the basis for proposed landscape design and management plans in this study. While seeking a viable drain pipe replacement alternative, numerous other significant findings evolved that contributed to beach landscape design and management.

Elimination of the Concrete Drain Pipe In 1995, with the goal of demonstrating a way to eliminate the concrete drain pipes, landscape architecture and biological engineering students from the College of Agriculture and Life Sciences at Mississippi State University implemented a plan with the Harrison County Sand Beach Department on a 3 acre beach site. The plan included breaking a concrete drain pipe about 5 meters above the mean high tide line and creating a tidal basin on the sand beach (Figure 4).

Figure 4. Tidal basin created in April 1995.

This would allow mainland runoff water to drain into the Mississippi Sound through a tidal pool lined with marsh grasses. The 10 meter diameter tidal pool was sculpted from the point of the severed outfall pipe to the Mississippi Sound and planted with *Spartina* alterniflora at the lowest elevation and *Juncus romerianus* just above the *Spartina*. *Spartina patens* was planted above the *Juncus* and above the mean high tide line. A series of plantings to create sand dunes were laid out in the upper beach zone. *Uniola paniculata* was planted along with *Panicum amarum..*   Shrubs *Myrica cerifera, Sabal minor,* and *Ilex vomitoria,* and trees *Sabal palmetto 'Louisiana'* and *pinus palustrus* were planted as well.

Figure 5. Tidal stream from storm drain flowing westward

The natural forces of the wind, tide, and sand movement changed the physical form of the small salt marsh within a month. The tidal basin filled in with sand that washed down from up beach during heavy rains. Sand deposited at the beach edge by the sand sharing system blocked the Mississippi Sound opening of the experimental tidal pool. The large open mouth of the basin shrank to a very small tidal stream that intermittently flowed westward along the beach, before emptying into the Mississippi Sound (Figure 5).

Restriction of Beach Landscape Management on the Experimental Beach Site As the experimental storm drainage system struggled against the forces of nature, the dune plantings thrived creating a greater interest in the upper beach landscape. With newly planted vigorous beach grasses conflicting with the weekly beach management tasks of sand sifting and periodic grading of the beach after rain events to maintain the flat beach form, it was decided to restrict all mechanical grooming from the experimental beach site. A row of wharf sized posts placed along the east and west borders of the site defined the experimental beach boundaries and deterred access by beach management equipment.

Management Practices and Beach Sand Compaction and Infiltration After a year without regular mechanical beach cleaning both in the upper beach and along the tide line of the experimental beach site, it was noted that rainfall drained into the sand without creating standing pools of water. On the regularly managed control beach site large, shallow pools formed and surface drainage created gullies carried sand and as it flowed into the Mississippi Sound. This phenomenon was investigated to determine why water did not drain through the sand on the regularly maintained site and why it did drain into the sand on the experimental beach site. Figure 6 illustrates rainfall drainage on the experimental and control site during Hurricane Lily.

Figure 6. Rainfall draining through the sand on the experimental site and creating surface pools on the control site

Compaction. With the advice of plant and soil scientists a cone soil penetrometer (Spectrum, SCF-900) was used on both the control and experimental sites to survey sand compaction. The control site was the regularly maintained beach on the west side of the experimental beach site. The survey was carried out on 6 transects with a spacing of 12 meters apart and data collection stations at 6 m apart. This survey was conducted following an extended dry period on the beach.

Data illustrated in Figure 7 shows that control site compaction pressures were 1500 to 2000 KPa greater than the compaction pressures in the experimental beach. More specifically, at 10 cm depth the control site was 40% more compacted than the experimental site, and at 20 cm depth the control site was 60% more compacted than on the experimental site. This data indicates the presence of a fragipan where dense sand particles were impeding water infiltration. The reason for the difference is that heavy equipment used for beach grooming also compacted sand on the control site. Recall that rainfall runoff gullies on the control site are graded and flattened after rainfall events, and the open beach is sifted by tractors pulling sand cleaners on a weekly basis during the summer recreation season (Memorial Day through Labor Day). It has been shown by Adams, 1998 and DeJong-Hughes et al., 2001 that heavy equipment used in logging and agriculture compacts soil and decreases its soil permeability levels.

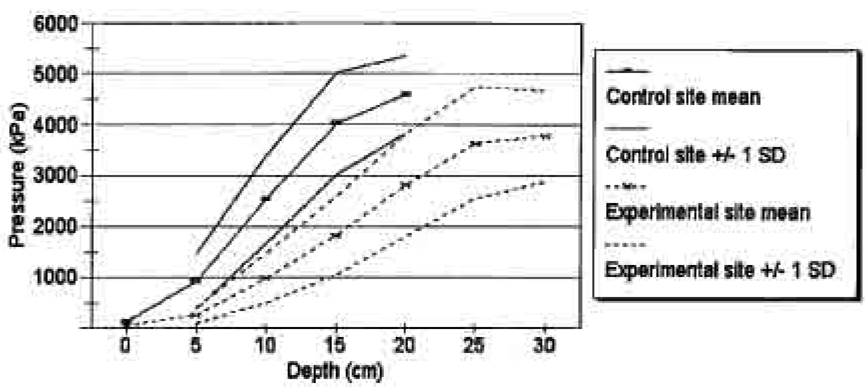

Figure 7. Mean Compaction values on the experimental and control sites.

Water Infiltration. Sand compaction measurements suggest water infiltration will be greater on the experimental site than on the control site. For further definition of the sand's infiltration rate Melby and Cathcart used a double ring infiltrometer (Turf-Tec International). Multiple samplings were made at the same location on the control and experimental sites. The samplings were located on the south side of the upper beach dune line, mid way from the water's edge to the top of the upper beach, and just north of the sand berm created by the sand sharing system (approximately at the high tide line). These three locations were selected because they had exposure to different beach management processes on the control site. South of the upper beach dune line on the control site sand is generally undisturbed by heavy equipment. At mid beach sand is most vulnerable to the compacting effects of heavy equipment, and sand near the sand sharing system berm line is most often reworked by wave action and cleaned by beach management equipment.

Table 3 illustrates the infiltration rates in centimeters per second (cm/s) measured on the experimental and control sites. At the sampling south of the upper beach dune the average water infiltration rate on the experimental site was 2.5 times greater than the rate of the control site. At the mid beach location the infiltration rate for the experimental site was 6 times the control site rate. At the sand sharing system beach berm location the infiltration rate on the experimental site was almost 9 times that of the control site.

The infiltration rates near the dunes in the experimental site were 5.7 cm/s greater than the control site. At the mid beach location the infiltration rates for the experimental site were 6.9 cm/s greater than the control site. At the sand sharing system beach berm location the infiltration rates for the experimental site were 11.9 cm/s greater than the control site.

	Location on beach	Mean Infiltration Rate (cm/s)	Standard Deviation (cm/s)	Number of Observations
Experimental Site	Upper	9.6	1.4	3
	Middle	8.3	2.0	8
	Lower	13.4	4.8	3
Control Site	Upper	3.9	1.4	5
	Middle	1.4	Range = 0.2 – 3.8[1]	8
	Lower	1.5	0.4	6

[1] Non-normal distribution (6 observations less than 1.25 cm/s; 2 observations 2.55-3.80 cm/s)

Table 3. Infiltration rate measurements. Upper = upper beach near the dune line. Middle = middle beach midway between the tide line and dune line. Lower = just north of the tide line.

The differences between both compaction and water infiltration rates on the control and experimental sites support the conclusion that beach management equipment affects sand compaction and infiltration rates. The biggest difference between the two sites is that beach management equipment does not enter the experimental site. Additionally, beach patrol vehicles, both trucks and four wheelers drive along the sand sharing system beach berm at the water's edge on the control site on a daily basis, contributing to sand compaction. The comparison of compaction and infiltration measurements show that more rainfall will infiltrate the beach on the experimental site thereby reducing runoff water erosion of the beach into the Mississippi Sound. This confirms the observations of standing pools of water during rainfall events on the control site and no pools of standing water on the experimental site as shown in Figure 6.

Beach Sand Dynamics   The sand sharing system on the beachfront provides a constant reservoir of sand for beach and dune creation. As the small berm of sand brought to the shore edge by wave action dries out, it is blown up beach by prevailing south southeast winds contributing to sand accretion and the dune building process. As dune grasses become established they send out runners and roots, expanding both the area they cover and the above ground mass of their stems. Their below ground biomass is greater than their above ground biomass thereby helping to hold sand in place. Without disturbance from beach maintenance equipment on the experimental beach site *Uniola* growth was unrestricted and wind blown sand began to accrete in the dune areas. Small dunes formed, some greater than 2 feet () in elevation within a 12 month period.   Additionally, the entire beach began to grow in elevation.

Two major factors allowed for the building of sand reserves on the experimental beach site. First, dune grasses were planted and allowed to grow unmolested by beach management equipment. Second, beach equipment including motor graders, was not being used to flatten the beach and spread out accumulating sand. Without the interruptions of these two natural dune building processes, sand from the naturally occurring sand sharing system accreted on the beach through plant and dune establishment.

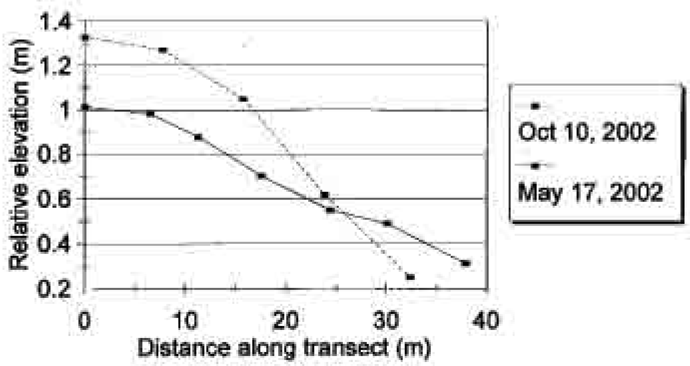

Figure 8. Experimental Site mean profiles before and after Tropical Storm Isidore and Hurricane Lily.

See the beach profiles in Figures 8 and 9 which show the elevation changes on the experimental and the control site in May 2002 and then in October 2002. Tropical Storm Isidore and Hurricane Lily occurred in October about a week apart. Note in the experimental beach profiles in Figure 8, there is some foreshortening of the beach and growth in elevation after the two tropical storms. The control beach site which is constantly flattened through beach management activities in order to keep the beach as wide as possible also experienced foreshortening and growth in elevation after the two tropical storms as shown in Figure 9. In fact there was a greater change in the beach profile on the control site as the October profile closely resembled the experimental beach site after the tropical storms. It is noteworthy that the vegetated experimental beach site gained more elevation than the control site. Storm tides bring large quantities of sand onto the site over short periods of time. Wave laden sand drops out as its velocity is slowed when it meets the dunes and beach plant materials.

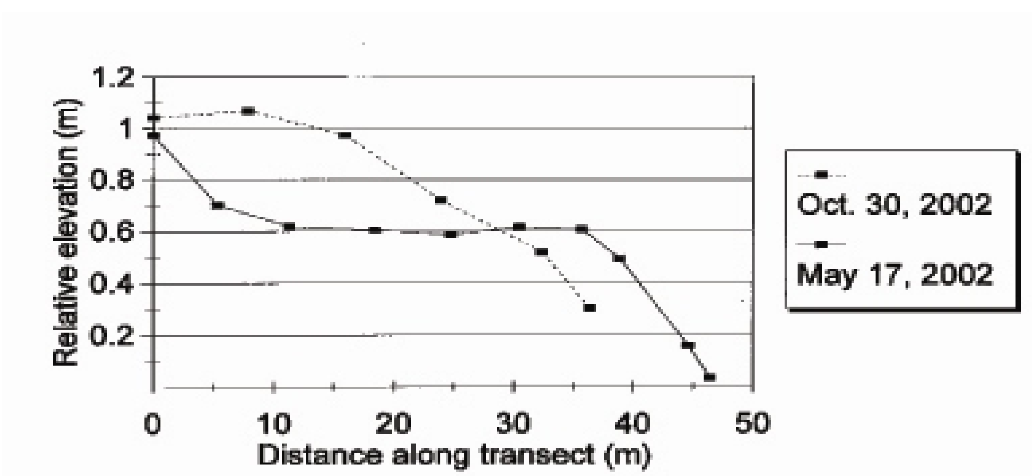

Figure 9. Control Site mean profiles before and after Tropical Storm Isidore and Hurricane Lily.

Beach Management and Windblown Sand. Blowing sand is a major part of erosion on the manmade beach. Once the experimental beach site was established with native plantings, it was observed that during periods of high wind there was very little sand being blown through the site. On the traditionally maintained site so much sand would be blowing that it would sting bare legs and make recreational use of the beach impossible. A major contributor to blowing sand is the regular sifting of the sand with a tractor and sifting trailer (Cherrington Model 740) that removes all matter larger than sand particles. The sand sifting machine extends 6 inches into the sand and separates sand from debris. Sifting to clean the beach occurs weekly along the beach during the summer tourism season which extends from May through September. The regular sifting precludes normal settling and interlocking of sand grains and creates ideal conditions for the loosened layer of sand to be either blown or washed away. When it rains, water drains through the top 6 inches () of loose sand and then drains horizontally as it meets the more compacted sand level, causing gullies and channels as sand is carried into the Mississippi Sound.

Through the use of Leatherman tubes (Leatherman 1978), an established way of measuring blowing sand, sand movement was measured on both the experimental and the control site. Six tubes were located at 15 m intervals at the upper beach of the experimental and control sites. The tubes were placed with 1 cm of tube exposed above the sand surface to ensure collected sand was from wind transport. Tubes were sampled from period durations of from 1 day to 2 weeks during the months of May and June 2002. Sand samples were air dried after collection and measured using a laboratory balance. See Table 4 for blowing sand measurements on the control and experimental sites.

	Sampling Date	Mean Sample Mass (g)	Range (max/min, g)	Number of Observations
Experimental Site	5/22/02	0.272	0.076 – 0.776	6
	5/31/02	1.851	1.432 – 2.567	6
	6/06/02	0.459	0.009 – 1.700	6
	6/09/02	1.519	0.238 – 4.909	6
	6/10/02	0.754	0.520 – 1.220	6
Control Site	5/22/02	7.863	2.11 – 14.99	3
	5/31/02	201.28	13.15 – 578.30	4
	6/06/02	127.45	53.86 – 197.75	5
	6/09/02	320.88	18.10 – 488.70	5
	6/10/02	54.58	20.95 – 95.35	6

Table 4. Leatherman tube measurements on the experimental and control sites.

A particularly good example of sand transport occurred on June 9 and 10 when there was a strong wind – 17 to 30 km/hr – from the southeast. Sand transport during this period on the control site was 70 times greater than the amount on the experimental site. On May 22 sand transport on the control site was 28 times more than on the experimental site. On May 31 sand transport on the control site was 108 times more than on the experimental site. On June 6 sand transport on the control site was 277 times more than on the experimental site. On June 10 sand transport on the control site was 72 times more than on the experimental site. Figure 9 depicts the sand captured by Leatherman tubes on the experimental and control sites over the 15 hour period on June 9 and 10 when there was a 17-30 km/hr southeast wind.

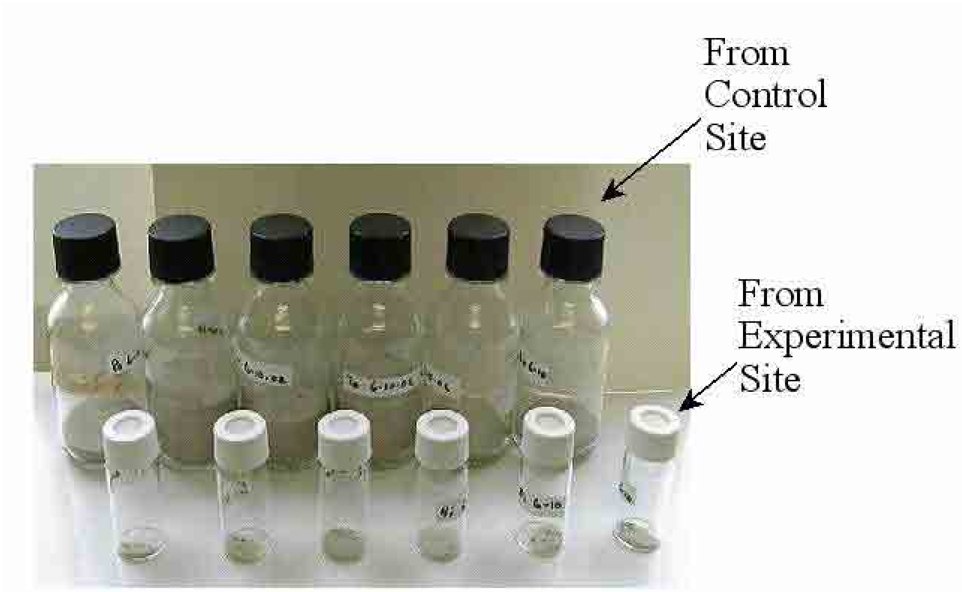

Figure 10. Sand captured in Leatherman Tubes on the experimental site (small bottles) and the control site (large bottles) over a 15 hour period.

The experimental site had established grasses, shrubs, and trees and the site was undisturbed from beach management equipment for over 2 years. The control site had only one line of dunes along the north border of the site and the beach was regularly disturbed by beach management equipment carrying out regular beach management tasks.

The dramatic reduction of sand movement on the experimental beach is due to two factors. The sand dunes and grass plantings stabilize sand from the sand sharing system that blows up beach, and the lack of site disturbance by beach management equipment keeps beach sand intact, allowing sand particles to interlock naturally creating a sand crust in the top 3-5 cm of sand. The result is the site is less susceptible to sand movement by wind. Without the beach management equipment, there is no sand compaction and creation of a fragipan. This condition allows rainwater to drain through the sand without creating standing pools and running off the site into the Mississippi Sound (Figures 11, 12).

Figure 11. Plants stop windblown sand and plant roots hold on to the sand. View from the experimental site to the control site.

Figure 12. View to the lower sand beach zone of the experimental site. This picture was taken in January after Hurricane Katrina.

A Plan for Optimum Beach Landscape Design and Management

The 12 year study revealed how the manmade beach is regularly affected by natural cycles and processes, and how those cycles influence beach size and form. It also revealed how land management practices of sifting the sand and grading the beach is destructive to beach stabilization. As a result of this insight optimum coastal edge landscape design and management plans have evolved for the 26 mile long manmade beach landscape in Harrison County, Mississippi.

The beach clearly cannot exist without human intervention because it is too narrow to accommodate the natural movement of sand during storm tides and surges. As a result, regular evaluation of beach conditions, and coordination with beach management strategies will create as strong a beach as possible to aid in protecting the highly developed coastal edge. For example, when plantings are damaged or destroyed, they will need to be replaced until they are reestablished and able to stop and hold blowing sand provided by the sand sharing system. Replacement of plants will always be necessary but there will probably be periods of stability where the infusion of energy and materials for beach stabilization will be reduced. The following design and management plan works with natural cycles and processes and will enhance the resistance of the beach to erosion, and better protect the mainland from storm impacts.

Work with Natural Cycles and Processes Naturally occurring cycles and processes include the sand sharing system, dune building, storm surges and sand accretion, and the evolution of marshes into dry beach. In addition to predictable, seasonal cycles the beach site was impacted by four hurricanes and two tropical storms during the study period. The combination of the seasonal cycles and the storms cause the beach to erode along the southern edge and accrete large deposits of sand on the upper beach. Storm surges spread sand onto the upper beach and beyond onto the adjacent highway. Beach edge erosion during Hurricane Katrina was up to 4 meters in width and the sand deposition on the upper beach and beyond onto U.S. Highway 90 was 5-6 feet deep. Sand deposition beyond the extent of the upper beach occurs because the beach is too narrow and greater width is needed in order to store the sand brought in from storms. Beach edge erosion occurs because the beach edge is devoid of emergent marsh grasses for protection. Larger dunes and greater sand reserves beyond the existing extent of the beach would provide additional protection to the mainland. The extra sand would be dispersed on the beach through the forces of wind, rainfall, and waves.

Continuously Evaluate the Sand Beach and Native Plantings Continuous human management is required in order for the relatively narrow sand beach to work with the natural cycles and processes that continuously affect it. Periodic replanting of emergent marsh grasses is needed along the water’s edge to reduce erosion. Replanting of upper beach grasses is required to make up for losses that occur during level 3 and greater hurricanes when beach grasses might be uprooted by storm tides.

Landscape Design Models for Establishment Stabilize the manmade beach through creating the types of plant communities that would establish themselves there naturally if given enough time. The following beach natural landscape design models will provide maximum protection for the coastal edge.

Where a bayou or creek empties into the Mississippi Sound develop a classic salt marsh plant community composed of emergent and beach grasses. Use *Spartina alterniflora* nearest the flowing water and *Juncus romerianus* behind it at a slightly higher elevation. The *Spartina alterniflora* is supple and it's leaves move with the waves and flowing water while the *Juncus romerianus* is very stiff and ridged. Just beyond the mean high tide line the wiry *Spartina patens* can be established. With 90% of their biomass located below the sand surface level, the combination of these plants is best for stabilizing the soil in a flowing water situation.

For open beach areas where swimming and sunning is to be accommodated, avoid emergent marsh grass plantings. Instead, the 10-15 meter wide open, sandy beach should extend to the upper beach landscape where there are dune grasses, shrubs, and trees planted up to the top most limits of the beach. Because open sandy beach areas are vulnerable to edge erosion, limit the number of these areas.

Water from rain events that flows through beach storm drain pipes contains runoff pollutants from yards, parking lots, and roadways. The outfall area around the storm drain pipes would best be planted as a *Spartina alterniflora* and *Spartina patens* marsh. *Juncus romerianus* is difficult to establish and its stiff leaf structure can cause injury to people. It is best to use this plant only in areas where human use is limited. Once established in a dense planting, runoff will flow through marsh plants, sediment drop out will occur, and water quality will be enhanced. Bacteria located on plant leaves, stems, root systems and on the sand and mud bottom will help to remove organic matter within the runoff. Additionally, the marsh will protect from beach edge erosion, provide habitat for aquatic life, and ultimately become dry beach as the marsh grows southward (Figure 13).

Figure 13. Marsh plants protect shore line from erosion and build beach southward. View to lower beach at experimental site.

In the upper beach establish native grasses, shrubs, and trees to stop blowing sand and build larger dunes for coastal edge protection. Develop *Uniola paniculata* plantings in curved lines of from 1-3 rows of grasses spaced 1 ½ meters apart. Make the overall rows about 75-150 feet long with 15-20 foot spacing between the end of one dune planting and the next. This space allows storm surges to move up beach between the dunes instead of the dunes acting as a dam. Where there is a dune opening, plant another linear line of *Uniola paniculata* behind it 30-45 feet away. The dune planting behind the opening will stop sand being blown up beach. The building of a dune system will evolve quickly with proper layout and planting. A dense line of deeply planted beach grasses can build dunes 2 feet high and higher within a 12 month period. Through planting 4 inch pots of *Uniola paniculata* 8-12 inches () below the beach surface allows for plant roots to be at the natural sand beach moisture level.

Throughout the upper beach, introduce shrubs and trees along the edges and between the dunes so that their roots will provide greater bioengineering of the sand, increase sand accretion, and create an appearance that reflects the natural model. Shrubs we used successfully on the experimental beach include *Myrica cerifera, Sabal minor, Iva frutescens*, and *Ilex vomitoria*. Trees used were *Quercus virginiana, Pinus palustrus, Sabal palmetto "Louisiana", Carya Ovata, Juniperus virginiana*, and *Morus rubra*. They can be planted individually and grouped in clumps of twos and threes, seeking to reflect the natural model. Increase the number of trees and shrubs at the topmost part of the beach including north of the seawall and adjacent to Highway 90. Establish shrubs and trees with either drip irrigation or through deep planting them where adequate soil moisture is available. Deeply planted trees (planted 3-4 feet deep) take advantage of the freshwater soil moisture level that is often available on beaches.

Landscape Management Model Through understanding how the beach is affected by natural cycles and processes, and tailoring management to these impacts will result in effective landscape management that is in harmony with nature, and in a stronger beach landscape that resists erosion. The following management proposals illustrate this approach.

Sand sifting equipment should be used only in high use, open beach areas and only if hand removal of debris is ineffective. Hand policing the beach will preserve the interlocking sand structure and eliminate the fragipan caused by heavy machinery.

Encourage the growth of native beach plants. Do not use heavy equipment in the vicinity where dunes are expected to establish. Leave the upper beach area untouched by mechanical equipment and pick up litter by hand. Once regular disturbance of the beach management equipment stops, a large variety of grasses will establish by the end of the first year to the extent the beach will appear to be fully covered with grass. There will be fewer grasses during the second growing season, and by the third season, the beach landscape will be mostly open, sandy areas with predominantly *Uniola* covered dunes. The evolution of grass growth on the beach is similar to a field where no till farming is practiced. In addition to the *Uniola* a host of approximately 50 other native grasses and forbs (Table 1.) will naturally establish themselves on the beach and within the dunes. In all areas except where intense beach sun bathing and active water recreation use is planned, allow the natural form of the beach to evolve rather than flattening the beach.

A 5 meter wide trough to catch wind blown sand at the top most part of the beach at the seawall will allow for collection of sand not trapped and stabilized on the beach by dunes and grasses. Sand collected in the trough can be moved by machine down to the beach edge where it will be washed back up on the beach and redistributed as part of the natural littoral drift and sand sharing system. This trough can also serve as a beach management equipment access route along the edge of the seawall (Figure 14).

Figure 14. Sand trough on the north side of the Experimental beach site to catch sand that blows over the beach.

As natural materials wash up on the shore, where possible, allow them to remain on the beach where they will eventually be blown or washed up beach by tides to serve as nutrients for beach plantings. Pick up manmade materials by hand and remove off site.

Regular evaluation of beach conditions and development of plans for beach stabilization is essential. This will provide the maximum, long term protection for the coastal edge and maintenance of the manmade beach.

Conclusion

There once was a natural beach shoreline along the coastal edge in Harrison County, Mississippi. Then human development was established in locations along the coastal edge vulnerable to storm damage. The seawall and manmade beach was built to enhance protection for development along the coastal edge.

Sand beach management processes have evolved over many years to create a wide and flat beach free from washed up debris and natural beach grasses, forbs, shrubs, and trees. It was found in the 12 year Experimental Beach Study that landscape management activities disturb the natural condition of the sand thereby making it vulnerable to movement by wind, rainfall, and storm surges. As a result, beach management activities along with the general absence of natural grasses, forbs, shrubs, and trees has caused the 26 mile long beach to wash away, necessitating replacement 4 times since it was built in the 1950's. The 2007 beach renourishment pumped in 1.5 million cubic yards of sand at a cost of $8,000,000.

A beach landscape design based on natural ecosystem models will help stabilize the sand, enlarge the sand reserves on the beach, and increase the elevation of the beach. Modification of beach landscape management procedures to minimize disturbance of the sand will reduce wind and water erosion and build sand reserves.

Because the manmade beach is not wide enough to accommodate the dynamic form of a natural beach, implementation of a sand trough at the back of the beach parallel to the seawall will provide a catchment area for blowing sand. The sand trough will collect sand that has blown across the beach so that it can be moved back down to the water's edge where it will wash along the shore and become part of the sand sharing system, eventually contributing to the sand beach reserves.

The combination of creating a beach landscape to stabilize the sand and grow a larger beach, along with a modified beach landscape management plan that will not disturb the natural interlocking of sand particles and drainage through the sand, will offer significantly enhanced protection to the sand beach landscape and coastal edge in Harrison County, Mississippi.

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