Most stretches of the American shoreline are eroding. Erosion; Underlying and reinforcing all causes of shoreline erosion is the sea level rise. Evidence from the continental shelf developed by Swift (1975) and Duane and Field (1976) indicates that barrier islands fronting all of the American coastal plain coasts probably formed at the shelf edge. After formation the islands migrated to their present position in response to the Holocene sea level rise. During their period of cross shelf migration the barrier islands must have been skinny (Table 1), judging from the fact that barrier islands today that are migrating rapidly are very skinny (e.g., Cape Island, South Carolina). It does not follow, however, that all skinny islands are migrating rapidly.

As the sea level rise slowed down, 4 to 5,000 years ago, many barrier islands began to fatten or grow seaward, e.g., Bogue Banks, North Carolina; Galveston Island, Texas. Fattening occurred on islands with large sand supplies. With few exceptions, the fattening of American barriers halted a few
hundred years ago to be replaced by frontside retreat, probably in response to
an increased rate of sea level rise once again.

Tide gauge studies by Hicks (1972) indicate that 50 or so years ago sea
level rise rate took a major leap. It is now eustatically rising at a rate of close to
one foot per century. Whether this sea level rise is a momentary "blip" on the
sea level curve or the start of a major long-continued rise is unknown. Even the
cause of the 50-year jump in rise rate remains a mystery; is the ice melting, is
the melting due to the greenhouse effect or is a mid ocean ridge bulging?

The net result of the recent sea level rise is to cause erosion on both sides
of many American islands. From a broad viewpoint this erosion can be seen
as a "slimming down" of the islands, preparatory to continued landward mi-
gration, assuming that the sea level rise continues unabated. Rapidly migrating
islands must widen themselves on their backsides over a broad front (Leather-
man, 1979). The only way to do this is to allow complete cross-island overwash
along a broad front; hence the need to slim down.

The evidence (other than tide gauge records) of a eustatic sea level rise is
best seen on barrier islands. The most pertinent evidence is the fact that almost
eroads into the best seen on barrier islands. The most pertinent evidence is the fact that almost
Jersey, marsh mud containing cow hooves and colonial implements appeared

at least one island width since a colonist dumped his garbage in the salt marsh.
In North Carolina widespread killing of certain tree species with low salt toler-
ance along the fringes of Pamlico and Albemarle Sounds reflects flooding by a
rising sea.

Because of all the factors involved, it is difficult to directly relate sea level
rise with shoreline erosion rate over a time span of a few years. However, Rosen
(1978) states that the sea level rise accounts for all shore retreat in the Virginia
Chesapeake Bay shoreline. Morton (1979) finds a very general correspondence
between Texas shoreline movement and sea level change.

Two additional important points must be made regarding the relationship
between the sea level rise and shoreline erosion. First of all, the rate of retreat
should be roughly a function of the slope of the land surface over which the
sea is flooding. Steep slopes produce slow migration rates; gentle coastal plain
surfaces should produce a shoreline retreat 100 to 1000 times the sea level rise
(Fig. 1). A one foot rise should cause a retreat of 100 to 1000 feet. The second
point is that the retreat of a beach is not just a surf zone retreat. Instead the
entire shoreface probably moves landward as suggested in Swift's model of
continental shelf evolution. Bruun (1962) proposed that a beach moves up and
back and retains its same surf zone profile as the sea level rises. This is not in
conflict with Swift's ideas. Swift has simply looked at shoreline movement on a
larger scale (Fig. 2).

### TABLE 1

<table>
<thead>
<tr>
<th>Phase</th>
<th>Age</th>
<th>Location</th>
<th>Migration Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>15,000 years ago</td>
<td>Islands formed at shelf edge.</td>
<td>Island migration</td>
</tr>
<tr>
<td>Skinny island</td>
<td>15,000-4,000 years ago</td>
<td>Islands migrated or hopped across the shelf in response to the Holocene sea level rise.</td>
<td>Island migration</td>
</tr>
<tr>
<td>Fat island</td>
<td>4,000-300 years ago</td>
<td>Many islands grew seaward in response to the slowdown in the sea level rise.</td>
<td>Island migration</td>
</tr>
<tr>
<td>Slimming down</td>
<td>300 years ago to present</td>
<td>Islands are slimming down in response to a sea level rise. The rise has accelerated within the last 50 years. Slimming prepares islands to migrate once more.</td>
<td>Island migration</td>
</tr>
</tbody>
</table>

### WHAT ENGINEERS DO

To begin with, engineers respond to a perceived public need. They respond to
a public outcry to "save the beach" or "save our cottages." Frequently the for-
mer phrase is used when the latter is really meant. In the long run abundant
evidence indicates that engineering destroys open ocean beaches. However,
Comparison of the Bruin Rule and the Swift Model of Shoreface Response Elements to the Sea Level Rise

Sea Level Rise Response Elements

TABLE 2
The Truths of the Shoreline

I. There is no shoreline erosion problem until someone builds something on the beach to measure it by.
II. Construction on the beach reduces flexibility and in itself causes erosion.
III. The interests of beach property owners should not be confused with the national interest.
IV. Once you start stabilization, you can't stop.
V. The cost of saving beach property is, in the long run, greater than the value of the property to be saved.
VI. In order to save the beach, you destroy it.

Source: Pilkey et al., 1980.

If short run preservation of beach front buildings is deemed the purpose of shoreline engineering, then engineers are much more successful.

It is important to point out that not all shoreline engineering structures that one sees on beaches were placed there by trained engineers. However, on the open ocean, high energy shoreline, few structures have been built without some expert design help. It is also important to note that sometimes engineers are forced for economic and political reasons to carry out projects that they know full well will cause serious environmental damage.

Table 2 is a summary of the truths of the shoreline; a set of carefully researched, incontrovertible, unassailable, precise generalizations. What engineers basically do to the shoreline in order to stabilize it is shown in Table 3. None of these approaches in any way addresses the sea level rise.

The gentlest thing that can be done by an engineer to a beach is replenishment. Replenished sands disappear faster than natural beaches as a rule for two reasons. The most obvious problem is that, for good economic reasons, sand is only pumped onto the upper shoreface. Thus the beach is steepened and in order to come to a natural equilibrium the sand is soon scattered across the shoreface, most of which is below the tide line. Perhaps a more fundamental problem is that because of the sea level rise the "equilibrium island" or equilibrium profile should continue to be displaced landward of the stabilized shoreline and each successive replenished beach should be more unstable (and disappear more quickly). The replenished beach at Wrightsville Beach, North Carolina, disappeared 10 times faster than the natural erosion rate. It remains to be seen how rapidly the second replenishment project (1980) disappears.

Since replenishment is a relatively gentle thing to do to a beach, it is not reasonable to ask, "Why replenish all of our problem areas?" The first and most obvious reason is cost. Fifteen miles of Miami Beach were replenished at a cost of 65 million dollars. A second factor is the effect of replenishment on development. The initial replenishment often takes place when development is relatively light. The new beach, however, adds time which is used by developers to increase density of development. The increased density and building size provides an increasing political power base which fosters additional replenishment projects but ultimately (in 50 years?) eliminates all alternatives to shoreline management except the inevitable sea wall.

Groins and jetties and other structures emplaced perpendicular to the beach hold sand in place by reducing longshore currents. Breakwaters work in the same way. The problem here is that the long range and long distance effect of sand trapping is impossible to predict. Morton (1979) estimates that sand trapping structures on the relatively undeveloped Texas shoreline have already tied up 50 percent of the longshore drift sand supply from eroding headlands. One would suspect that every grain of sand has been trapped on the much more heavily developed and heavily engineered New Jersey shore. Seasonal effects are often poorly understood. Engineers have proposed to place groins off Ocean City, Maryland. Statements have been made to the effect that no damage accrues to the Delaware shoreline since it is "upstream" and net sand movement is to the south, away from Delaware. However, during the winter large amounts of sand travel north from Maryland to Delaware and hence...

TABLE 3
What Engineers Do to Beaches

| I | Replace sand | replenishment |
| II | Trap sand | groins, jetties |
| III | Block wave energy | breakwaters, sea walls, bulkheads, revetments |

Note: I is a nonstructural "solution." II and III are structural "solutions."
the groins are likely to cause damage to Delaware beaches by cutting off their
winter supply.

Designing groins and evaluating their potential effects on the basis of
known net transportation rates is a common engineering error. Consider, for
example, the part played in the shoreline longshore drift equilibrium picture
by the 5 year, 10 year, 20 year, etc. storm. Storms that move sand in strange
directions and quantities can't be plugged into formulas and hence are consid-
ered to be natural disasters by engineers. Geologists consider storms to be part
of the system to be worked with even if we can't predict their role. Paul Ko-
mar (pers. comm.) points out that jetties caused severe beach erosion and loss
of the town of Bay Ocean, Oregon, even though there is no net transport of
sand on Tillamook Spit. The jetties caused the inner shell to change shape, the
changed shape refracted waves, refracted waves caused erosion, and buildings
fell in.

The worst thing that can be done to a natural shoreline system is construc-
tion of a sea wall. As pointed out in the Corps' Shoreline Protection Manual
(Corps of Engineers, 1975), wave reflection and other effects eventually remove
beaches from the foot of sea walls.

Discussing the effect of sea walls is a good time to bring in the concept of
New Jerseyization, the end point of the walled open ocean shoreline in a rising
sea level. New Jerseyization, a 50 to 150 year phenomenon, can be viewed in any
number of "old" New Jersey islands or shore communities such as Sea Bright,
Monmouth Beach, Long Branch, Cape May, and many others. New Jerseyiza-
tion is a phenomenon not restricted to New Jersey, however. Other American
beach communities such as Ocean City, Maryland; Wrightsville Beach, North
Carolina; Folly Beach, South Carolina; much of south Florida; Holly Beach,
Lowndes; and South Padre Island, Texas (to name a few) are well on their
way.

The classical New Jerseyized beach is no longer a beach except perhaps at
low tide. The upper foreshore is scattered with debris from destroyed sea
walls and groins of an earlier generation. Swimming is dangerous, but fishing
is probably improved because of the multitude of habitats. The present sea wall
is a massive and impressive structure. However, winds of 25 mph are capable
of producing sea wall topping waves and during genuine storms, the volume of
water pouring over and through the wall is impressive. The problem is that the
shoreline has steepened considerably and all waves, big or small, break directly
on the wall. By the time a developed shoreline has matured to the point of New
Jerseyization, the equilibrium profile (where the beach wants to be) is 10's or
hundreds of meters landward, the shoreline has steepened to the point where
replenishment is no longer an economically viable alternative, and the island or
beach has become a fortress. All the community can do hereafter is build bigger
and better seawalls.

In spite of the massive evidence that New Jerseyization is the long range
inevitable endpoint of open beach stabilization, sea walls are sprouting like
dandelions. In 1979 David gathered new ones on at least three islands in Geor-
gia. The attitude of the cottage owner is: I can't just let my house fall in, can I?
But it is shortsighted in the extreme to respond to the few individuals whose
homes are endangered when one considers that the long range effect will be to
destroy a resource that is used by a much larger public.

The greatest sea wall in America's Atlantic or Gulf Coasts is the massive
Galveston wall. It was built in response to the Hurricane of 1900 that killed 6,000
people in Galveston. Since the flooding that killed most of the people probably
came from the backside, the structure was built on the front side. Over the years
what was once a wide beach in front of the wall has largely disappeared. At the
base of one end of the wall, a row of boulder rip rap was placed to protect the
wall from undermining. A while later a second row of rip rap was emplaced to
protect the first row of rip rap. Now a third row of rip rap is placed to protect
the second row of rip rap, which was placed to protect the first row of rip rap
which protects the base of the sea wall. The sequence of rip rapping is a vivid
demonstration of the shoreface steepening effect of a stabilized shoreline in a
rising sea level...

The Final Word: Open ocean shoreline stabilization in the long range re-
sults in loss of the taxpayer's beach in order to protect the property of a very
few at a cost in taxpayers' dollars greater than the property is worth and, of
course, the very few whose property is being saved cause the problem to begin
with just by being there!

DO ENGINEERS EVER DO ANYTHING USEFUL?

Thousands of houses along miles and miles of stabilized American shorelines
owe their very existence to engineering structures. The rising sea level and the
migration of the shoreline would have long since caught up with them had it not
been for the sea walls and revetments fronting the beach. On the other hand
many of these communities have been New Jerseyized; all that's left of their
original raison d'être is the sea breeze.

What would have happened if the shorelines had not been stabilized or
engineered? The answer is that the front row or two of houses would no longer
exist; third avenue would now be front street, and a thriving beach and beauti-
ful sea view would be there for all to enjoy. No private or public funds would
have been wasted on engineering schemes and the future would not require a
heavy tax burden to build bigger and better seawalls. Big storms striking non-
engineered beach communities will destroy houses, but the same storm on an
engineered beach will also destroy houses.

What are we to do with the beaches of New York City such as Coney
Island? Should we allow them to respond to the sea level rise and watch as
ferris wheels, roller coasters, and apartment buildings fall in? Of course not.
Costly beach preservation procedures are fully justifiable to preserve and
even enhance these critical natural resources. The question is, where does one
draw the tax money line between 10,000 swimmers a day on Coney Is-
land, New York, and 100 beach cottage owners on Wrightsville Beach, North
Carolina?
The Corps of Engineers carries out demonstration projects along "quiet" water shorelines to experiment with new ideas on shoreline stabilization. Although conceived by some of the best brains in shoreline engineering and in spite of the fact that a great deal of ingenuity is exhibited in increasing effectiveness at lower costs, the structures still block wave energy, replace sand, or trap sand (Table 3). No one seems to sit back and ask the perfectly logical question: "How can we respond to the sea level rise?"

One unique approach that would take into account the rising sea was conceived by some National Park Service bureaucrats from Fire Island National Seashore. They have suggested that instead of pumping sand on the front side of the island, in the future it should be pumped on the backside. The sand would come from maintenance dredging of the intracoastal waterway. This would migrate the island artificially. There are, of course, some political problems with this. Home owners on front sides will be required to be good sports as their houses fall in, but their sportsmanship will be greatly aided by tax-supported federal flood insurance which will pay for their lost houses. Engineers have proposed alternative schemes for Fire Island management involving, you guessed it, sea walls, groins, and beach replenishment at a great cost to the taxpayers.

What other approaches can be taken as alternatives to stabilization? How about moving houses back as the shoreline retreats? The wrecking ball may have to be used on big structures, an approach actually suggested by some New Jersey officials. How about declaring front row conservation easements after the next hurricane; i.e., don't allow reconstruction next to the beach? How about establishing minimum construction standards for seawalls and groins (an idea given to me by engineer Jay Lang[elder])? This would allow people to stabilize their beach with structures that would withstand the 5-year storm but not the 10-year storm. The homeowner thus will gamble on when the 10-year storm will occur while hopefully such temporary stabilization will not wipe out the beach. Care must be taken not to allow the temporary structures simply to be replaced. Stabilization schemes billed as temporary or stop gap have a consistent history of not only becoming permanent but also "bigger and better."

Best of all, why not do nothing? Is this really an unreasonable or irrational or irresponsible approach in view of the long range costs and effect of non-do-nothing engineering? The National Park Service came to the do-nothing alternative after long study. On Cape Cod National Seashore parking lots are being designed to be constructed with beach gravel so that when (not if) they fall in, no one except a harried bureaucrat will know.

Table 4 summarizes the good and bad points of the major approaches to shoreline management including doing nothing.

### Table 4

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Preserves the beach?</th>
<th>Preserves houses?</th>
<th>Responds to Sea Level Rise?</th>
<th>Cost to Taxpayers?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Migration</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum construction standards</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Seawalls, groins</td>
<td>Temporarily</td>
<td>Temporarily</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Do-Nothing</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Beach replenishment</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

"The subject of sea level hardly warrants a comment. [Problems caused by rising sea level] will be solved by future generations."

The first part of the quote probably represents a minority view among coastal engineers. Most believe that the sea level rise is an important cause of erosion. It is my opinion, however, that a good portion of the "old guard" of coastal engineering still does not accept a widespread sea level rise or even
TABLE 5
The Differences Between Coastal Engineers and Geologists

<table>
<thead>
<tr>
<th>Reason for shoreline study</th>
<th>Engineers</th>
<th>Geologists</th>
</tr>
</thead>
<tbody>
<tr>
<td>stabilization</td>
<td>Stabilization</td>
<td>Stabilization; understanding of depositional-erosional processes; ancient environmental interpretation</td>
</tr>
<tr>
<td>People versus environment</td>
<td>On the side of people</td>
<td>On the side of the environment</td>
</tr>
<tr>
<td>How quantitative?</td>
<td>Highly quantitative</td>
<td>Arm wavers</td>
</tr>
<tr>
<td>Belief in beach &quot;numbers&quot;</td>
<td>Highly confident</td>
<td>Totally skeptical</td>
</tr>
<tr>
<td>View of the beach</td>
<td>A beach is a beach</td>
<td>A beach is a component of the continental shelf and of a barrier island chain, etc.</td>
</tr>
<tr>
<td>View of nature</td>
<td>Something to be defeated</td>
<td>Something to be lived with</td>
</tr>
<tr>
<td>Time viewpoint</td>
<td>Very short</td>
<td>Very long</td>
</tr>
<tr>
<td>Confidence in ultimate success of shoreline stabilization</td>
<td>Over confident</td>
<td>Totally skeptical</td>
</tr>
</tbody>
</table>

The evidence of ubiquitous erosion. Solving erosion on a crisis by crisis basis without recognition of the overall problem can only result in a disaster for the American shoreline. The second part of the quote regarding future generations is the very essence of engineering mentality! Future technology will come to the rescue so damn the torpedoes! However, for miles and miles and miles of New Jerseyized shoreline there is no economically feasible solution. The future is here! We are the future generation and now what?

There is no question that given enough money an engineer would be able to solve any shoreline problem. If money were no object, even a geologist could solve the problems. With replenishment costs running at 1 to 5 million dollars per mile and climbing at a rate similar to the rate of shoreline development, the point of no return has been reached. Short sighted approaches to the open ocean shoreline continue to abound. Recently the Corps announced a permanent solution to Ocean City's severe erosion problem in the form of a massive steel bulkhead accompanied by replenishment. If a decade or two is "permanent," then the statement is not misleading. But citizens of Ocean City should have been told that the solution would mean they will be New Jerseyized at great cost to themselves. Engineers on Folly Beach, South Carolina, have proposed a small beach replenishment project by taking sand from the lower beach and putting it on the upper beach. This will very likely increase the erosion rate.

Another quotation from an engineer shown below illustrates another point of difference between geologists and engineers:

"This project (the new Miami Beach) should last indefinitely providing a major storm doesn't come by."  
—Miami District Corps of Engineers Official

To a geologist the storm is a perfectly predictable and essential part of the natural system. Engineers know about storms too. But when they come, all bets are off on design life because of this tragic act of nature that's gone and messed things up.

Geologists also feel that most engineers have a narrow view of the shoreline system. A beach is a beach, an inlet is an inlet, and they are not perceived to be part of a large and complex barrier island-continental shelf system. This results in a practice best described as "bandaid engineering." That is, the immediate problem is "solved" with minimum regard or understanding of the impact on other beaches, islands, lagoons, inlets, etc.

THE BOTTOM LINE

The time has come to bite the bullet and either do nothing at the shoreline or at least respond to what's causing the problem—the sea level rise. Suggestions to do nothing usually elicit comments such as this:

"This do-nothing philosophy may have suited the times of King Canute in the 11th century when population was limited and few people had time or inclination to visit the coast, but it is unacceptable to the general public in 20th century America where the federal government has taken the responsibility to provide for the general public welfare."

—Corps of Engineers (CERC) geologist

The do-nothing suggestion made to a beach cottage owner elicits far more colorful comments with even longer sentences.

Nonetheless, a strong case can be made that shoreline stabilization does not provide for the general public welfare. In fact, it has been a massive long-range failure on American open ocean shorelines. The American public must be told what the long range costs and effects of stabilization will be. The net result of such education almost surely will be to keep the engineer off and away from the open ocean shoreline.

REFERENCES


PART TWO

Energy

Chapter 5  Energy and Ecosystems  105
Chapter 6  Renewable and Nonrenewable Energy  119