Coastal Structures: Types, Functions and Applications

US Army Corps of Engineers
Presentation to Shoreline Erosion Task Force
August 15, 2012
Hartford, CT

Session Objectives

Coastal Structure Types & Functions:
Understand fundamental concepts of coastal structures and how they provide protection.

SOFT v.s. HARD

(Erodable v.s. Nonerodable)

Beachfill

Dunes

Marshes

Bioengineered

Seawalls

Revetments

Breakwaters

Jetties

Groins

Bulkheads

geotubes are in between

What Do Coastal Structures Do?

1. Stop water
   - 1a. Stop flooding
   - 1b. Stop impact
2. Hold soil
   - 2a. Hold upland soil
   - 2b. Slow down sand transport

- **Protect infrastructure** from flooding due to high water levels, erosion, and impact from waves and currents
- **Protect boat traffic** by reducing waves and wave impact
- **Stabilize navigation channels** by reducing sedimentation, inlet migration
- **Reduce erosion** by stabilizing shorelines/beaches
- **Enhance recreation, beauty**

Advantages of Hard Structures v.s. Soft

- Withstand larger forces
- Resist erosion - consider hard structures if erosion > 3 ft/yr
- Less footprint area
- Reduce renourishment needs/costs
  - Help extend available sand resources
- Function in deep water
- Transition to existing shore over short distances
- Tend to last longer

Coastal Structures Functional Areas

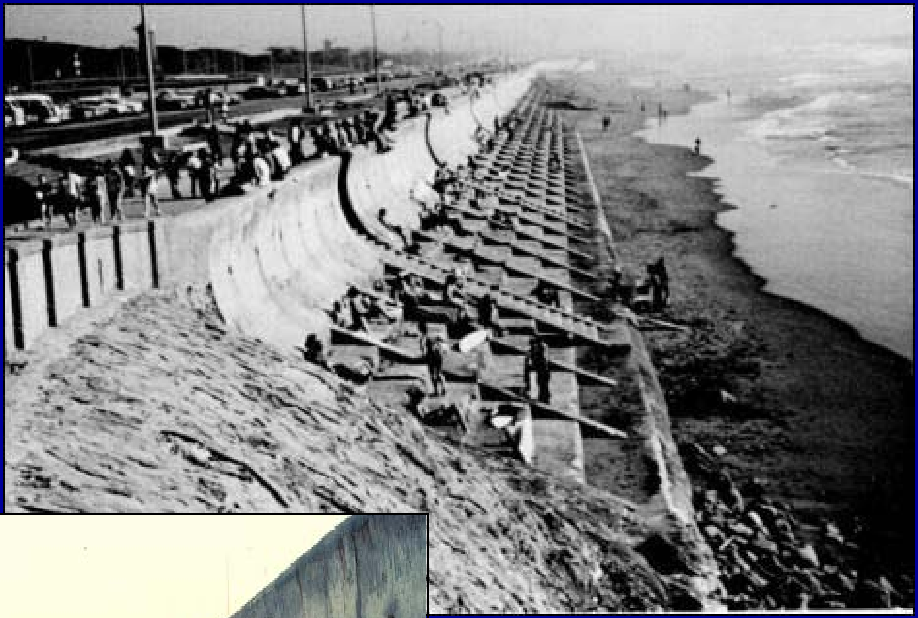
1. Coastal armoring structures resist waves, scour, overtopping
2. Beach or soil stabilization structures hold upland sediment, retard alongshore transport
3. Navigation structures resist waves, currents, sedimentation

1. Coastal Armoring Structures

More is more

- Seawalls — Largest
- Revetments — Medium
- Bulkheads — Smallest

Seawalls



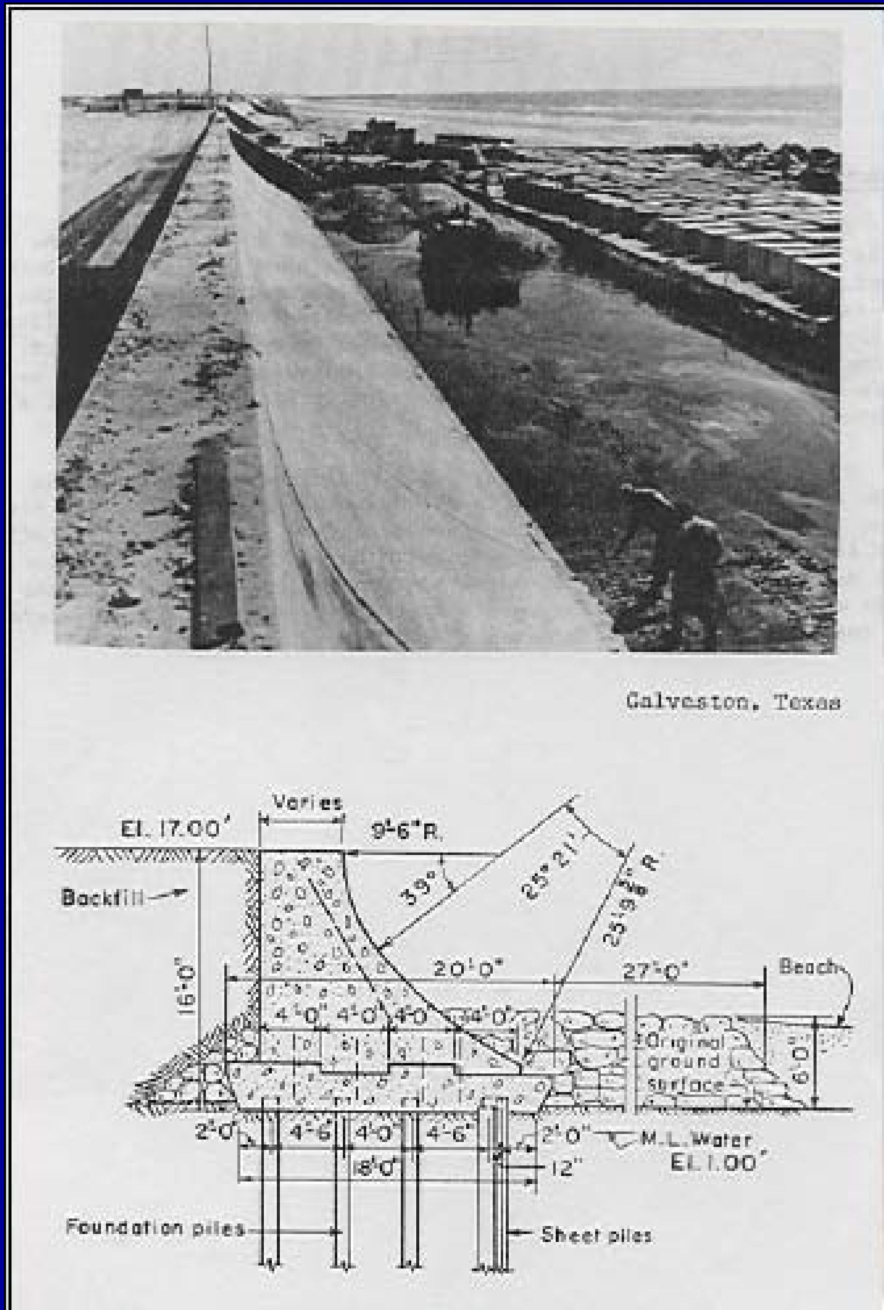
O'Shaughnessy

Seawall,

San Francisco, CA

- **Prime objective is to protect upland infrastructure from flooding, wave impact and overtopping**
- **Secondary function is to hold fill (bluff, shoreline) in place**
- **Generally massive. Often high. Often long.**
- **High wave energy application**

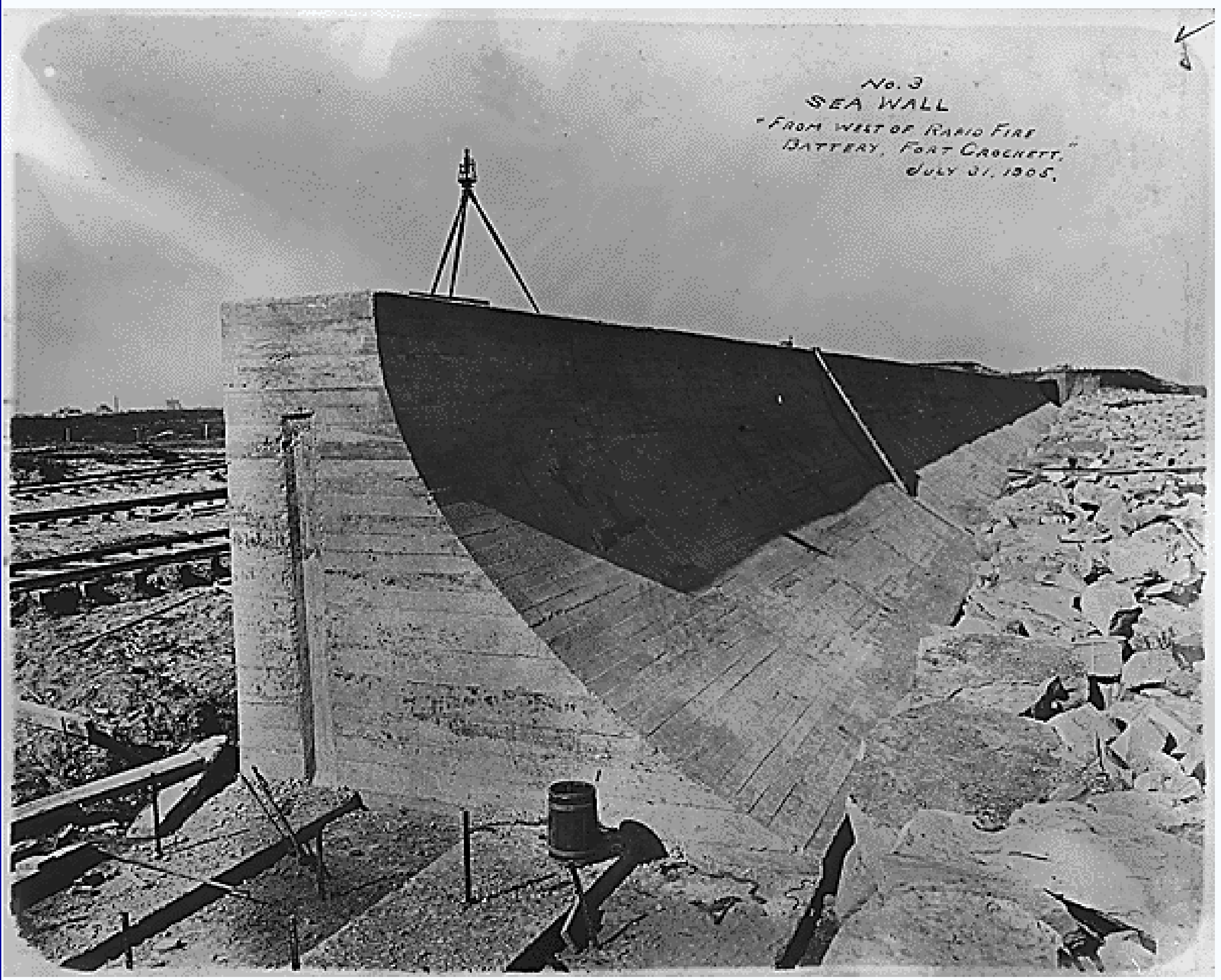
Seawalls



- Often concrete
- May be rubblemound or other materials
- Tend to be free-standing with backfill, gravity or pile supported
- Scour protection integral

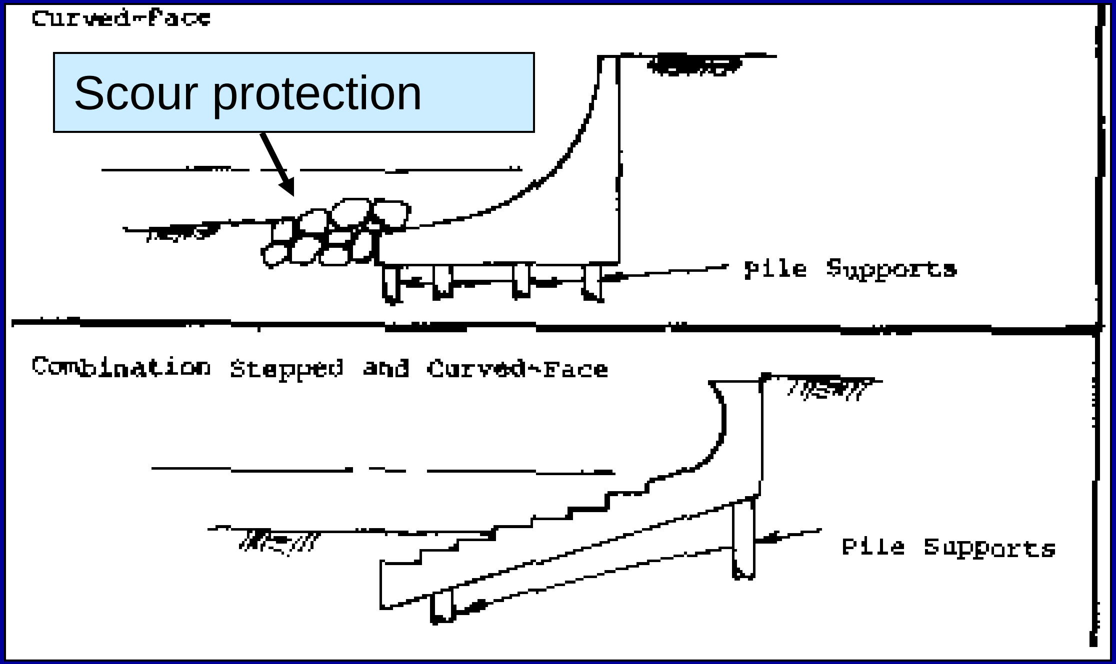
Galveston seawall, TX

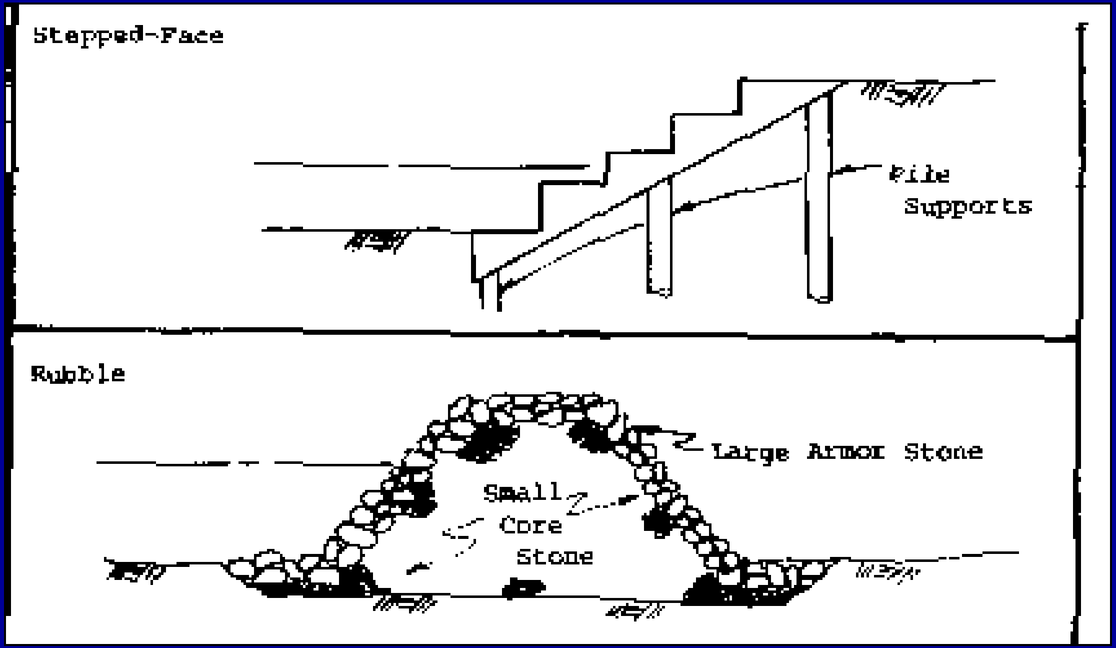
Galveston Seawall during construction, 1905. Built following Galveston Hurricane of 1900. (image from Wikipedia)



Seawalls

Typical cross-sections (EM1110-2-1614)





Seawalls

Waves breaking over Sea Bright NJ seawall

Curved concrete seawall La Jolla, CA

Curve directs waves away from infrastructure

Seawall

Hereford Inlet, NJ

Wall added for overtopping protection

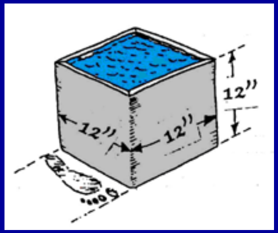
Seawalls

When would you want major armoring?

- Very valuable upland infrastructure
- Harsh wave conditions, high surge
- Cannot provide protection further offshore, for example with an offshore breakwater

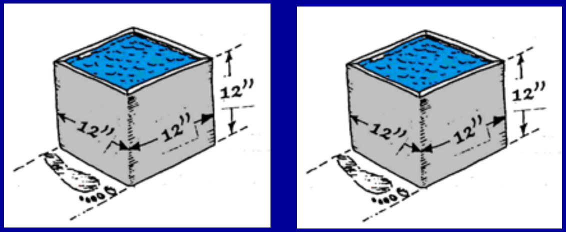
People understand flooding, but what exactly is "wave attack"?

Wave attack is impact from waves. Water is heavy, plus waves have forward velocity. To illustrate:



1 cubic foot = 7.48 gallons

1 cubic foot = 64 pounds



2 cubic feet = 128 pounds

Rule of Thumb

Repeated impact from 3-ft waves during a storm can destroy a small house.

Heavier seawall materials can withstand wave impact

Concrete	1 cubic foot = 145 pounds (more than me)
Rock	1 cubic foot = 165 pounds
Steel	1 cubic foot = 490 pounds

Sand (dry)	1 cubic foot = 100 pounds

Wave Impact on the Structure

- Waves impact the face of structure
- Overtopping also impacts the top & back of the structure
- Scour impacts the toe

What is overtopping?

Overtopping is water that splashes above and landward of the line of protection.

Lajes, Azores Breakwater (image from Jeff Melby)

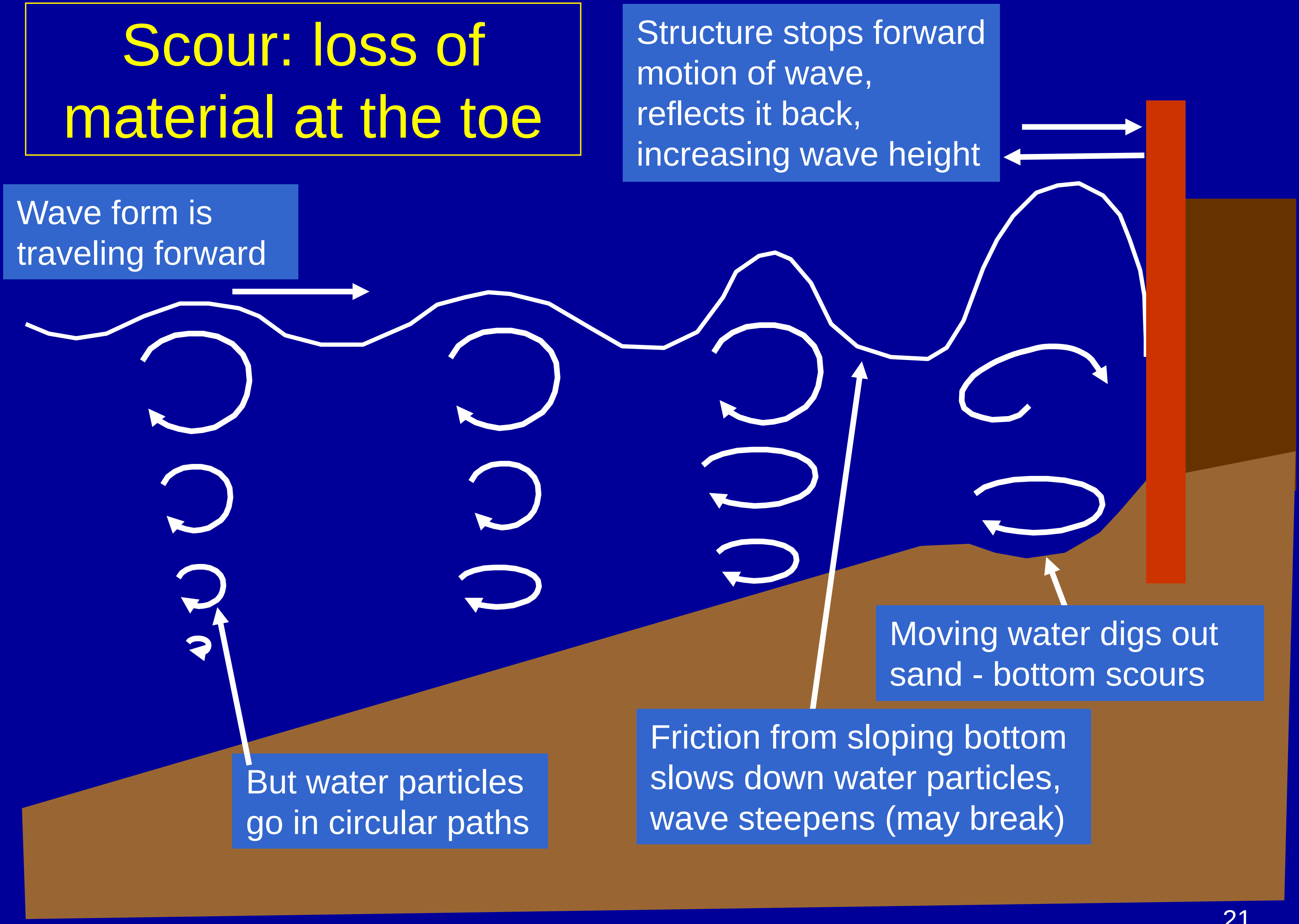
What does overtopping do?

Impact from overtopping water can cause direct damage to upland infrastructure, and can remove material from behind structures, causing structure failure. Overtopped water floods behind line of protection.

Removes unprotected soil from behind structure, fails structure

Damage reaches to far side of roadway

Scour: loss of material at the toe

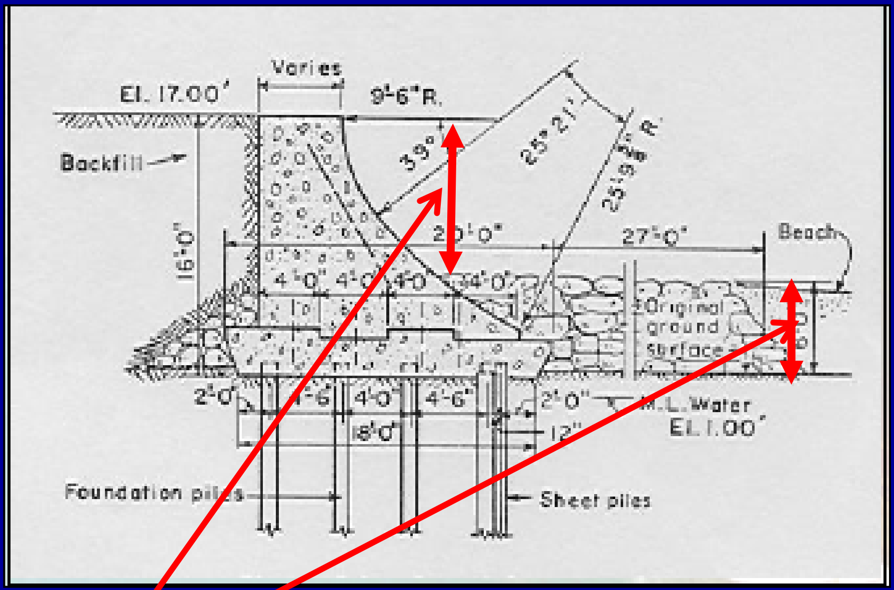


Scour

- Common experience of scour – standing still at waters edge, waves dig out around your feet, you sink.

Rule of Thumb:

Scour depth will equal reflected wave height



Scour protection likely to be comparable in size to upper part of seawall

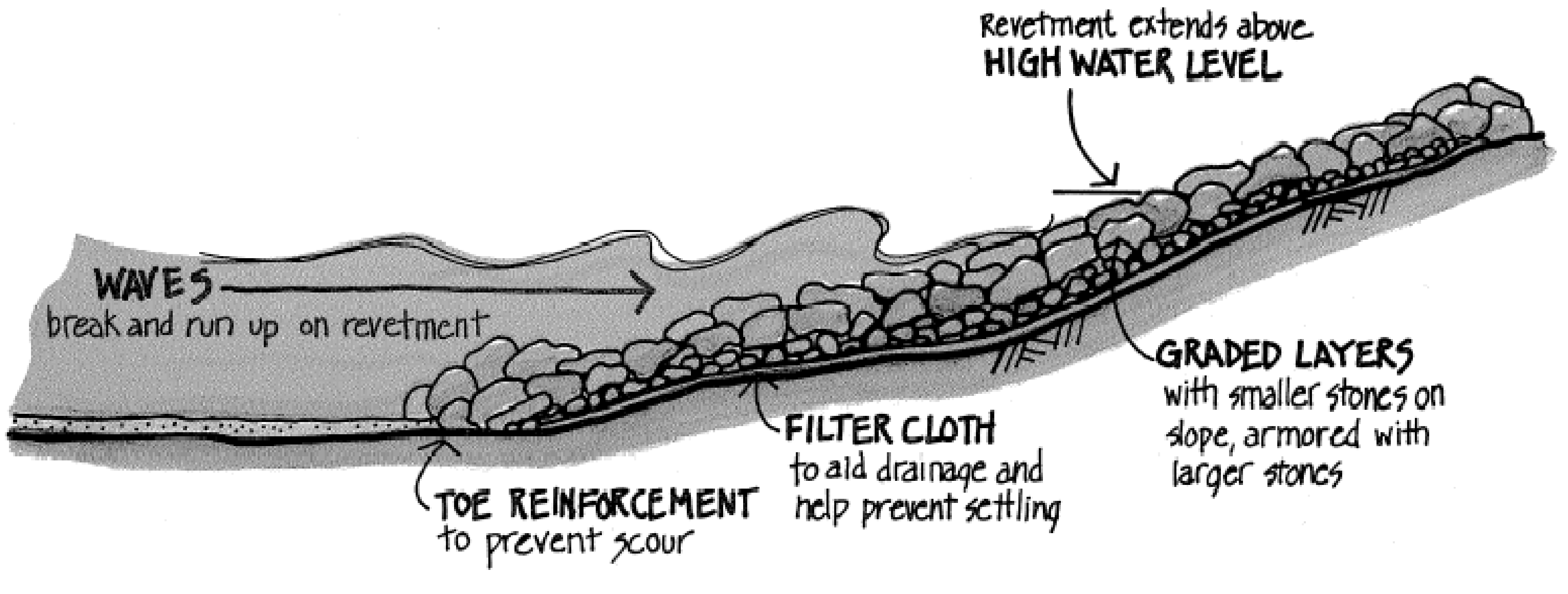
Coastal Armoring: Revetments

Barnegat North

- **Purpose is to protect the shoreline against erosion**
- **Function by reinforcing of part of the beach profile**
- **“Medium” cross-section size. Can be long.**
- **Generally built on existing slope**
- **Often rubblemound**

Revetments

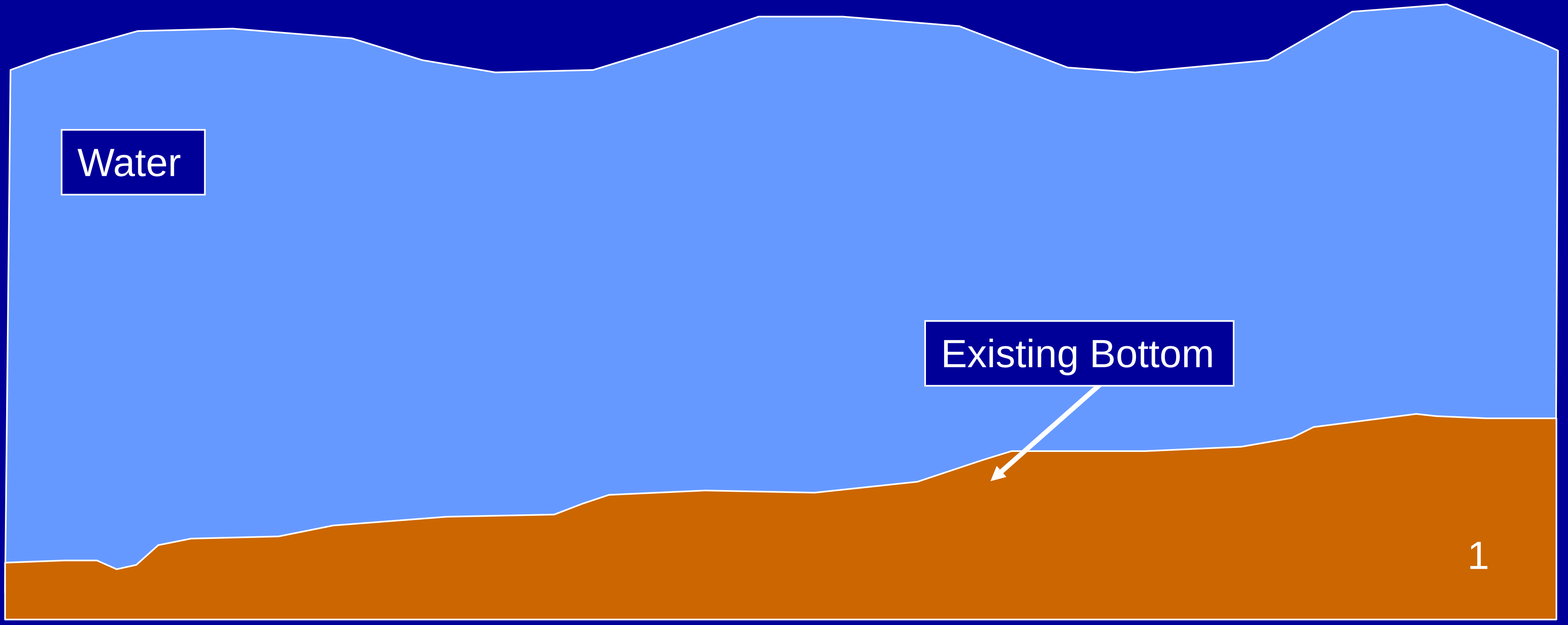
Materials: Rock, concrete



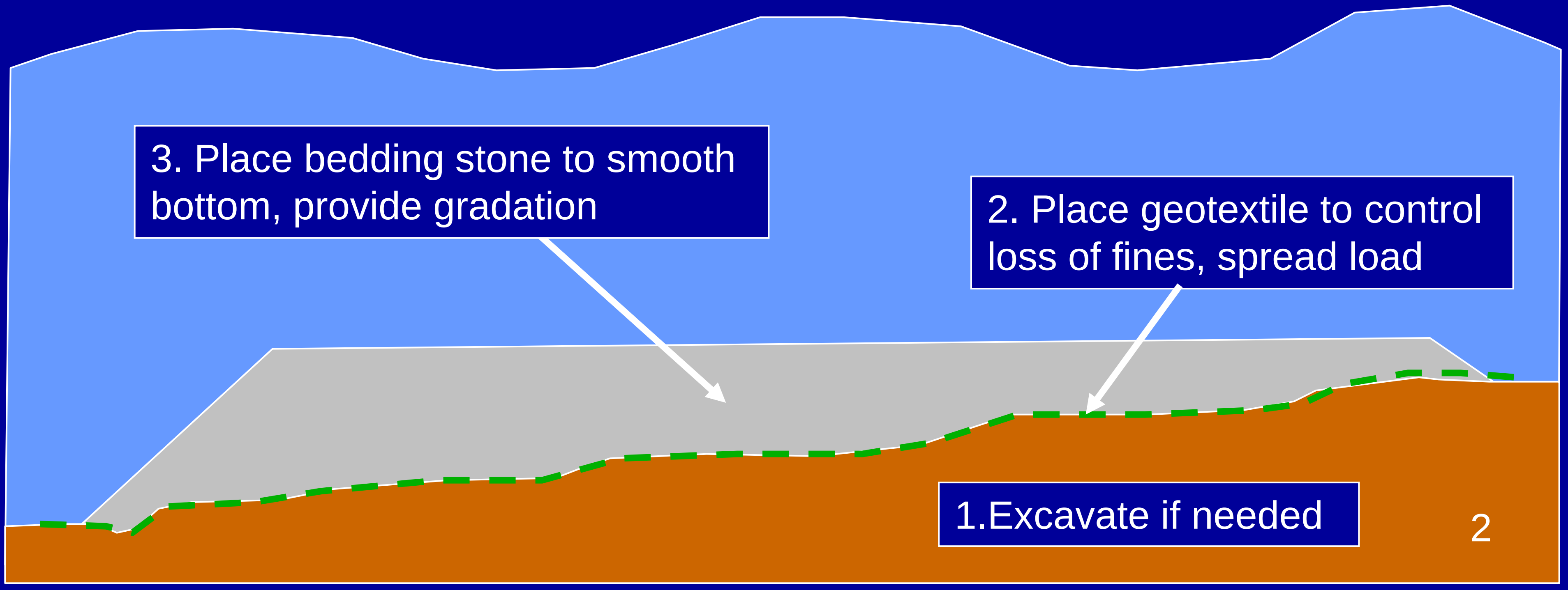
Layered on existing slope

Digression #2:

How to Build a Rubblemound Structure



How to Build a Rubblemound Structure



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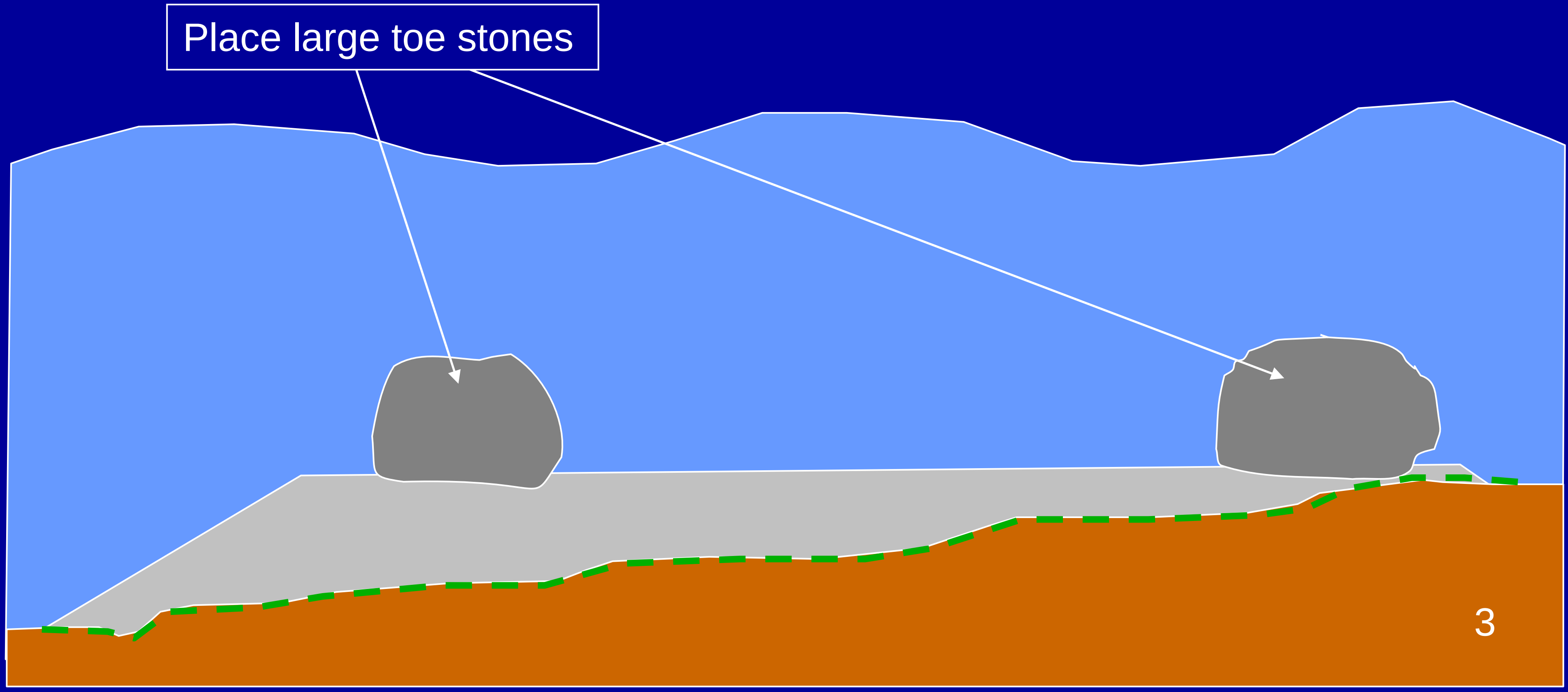
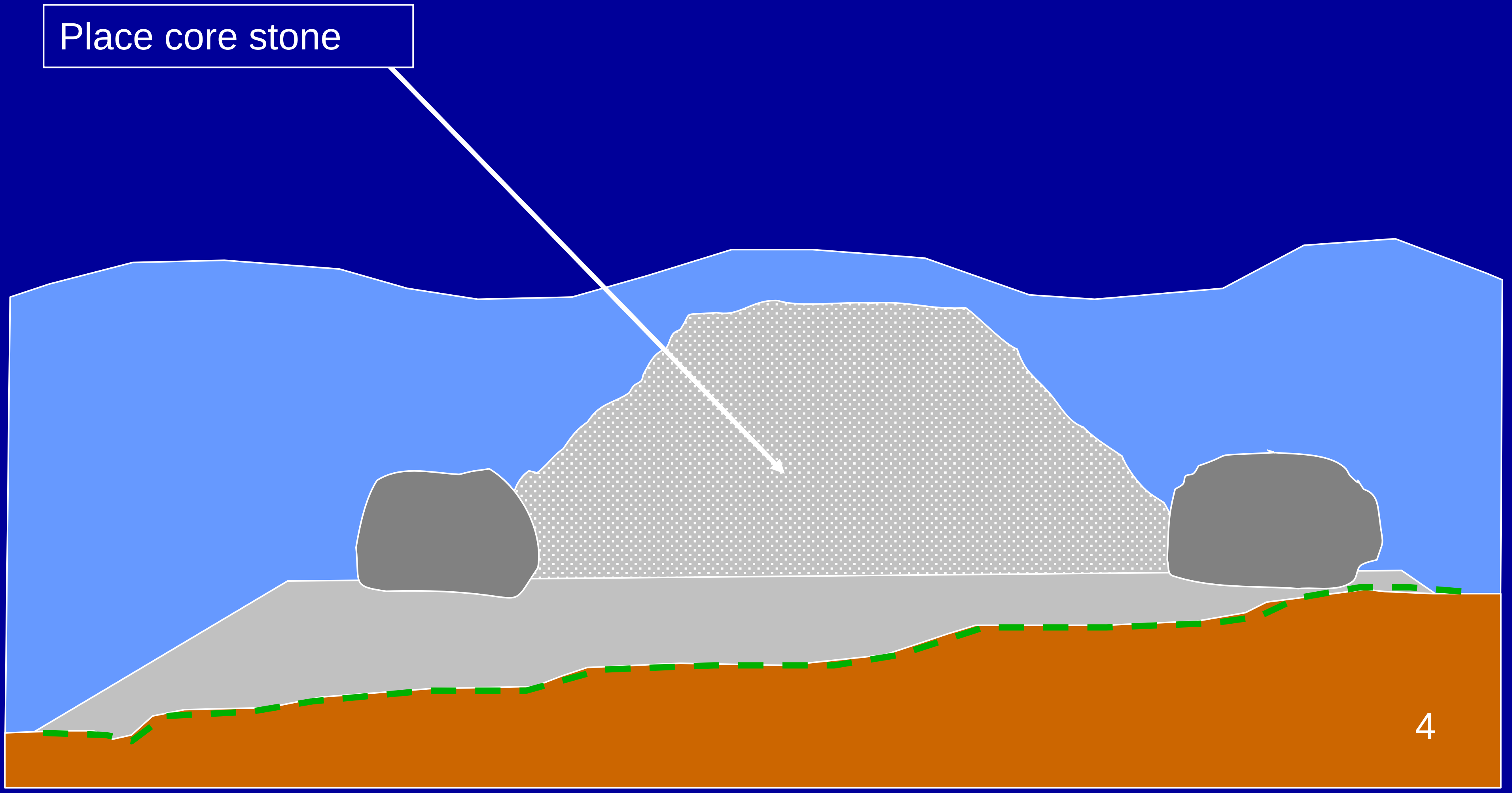
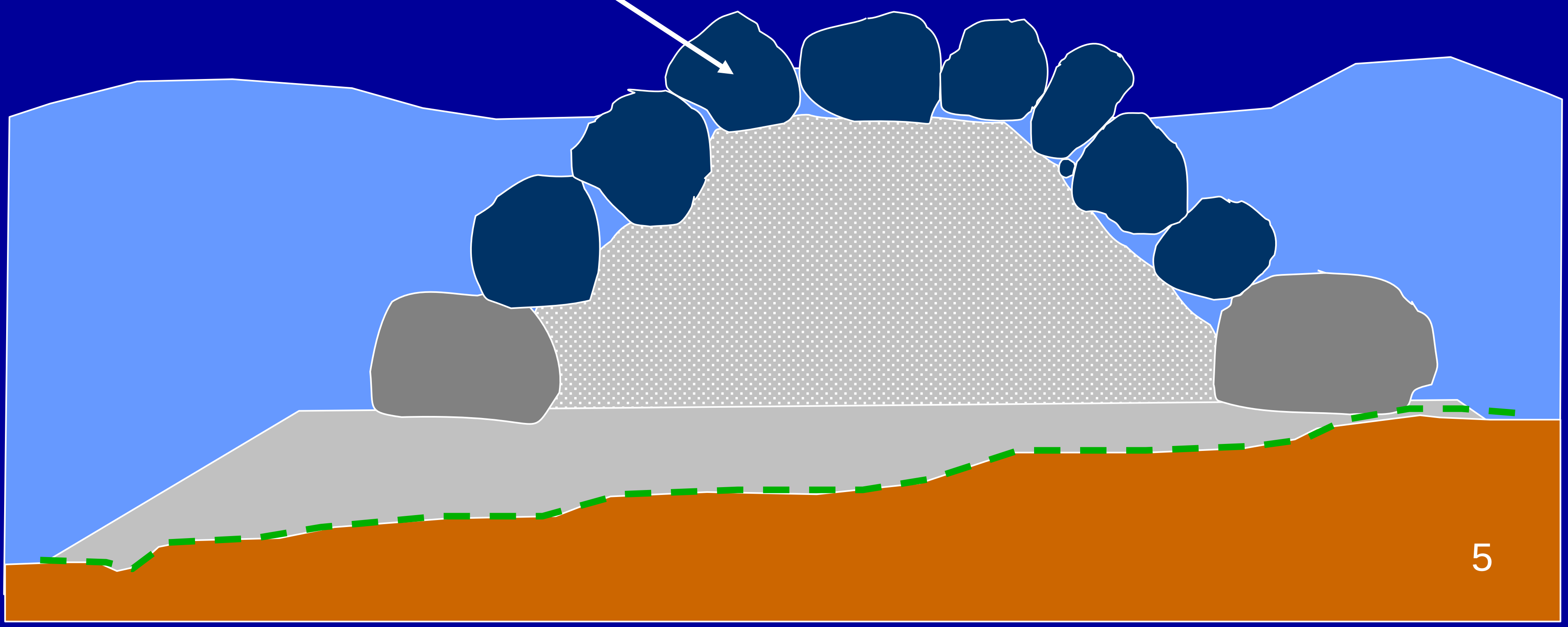


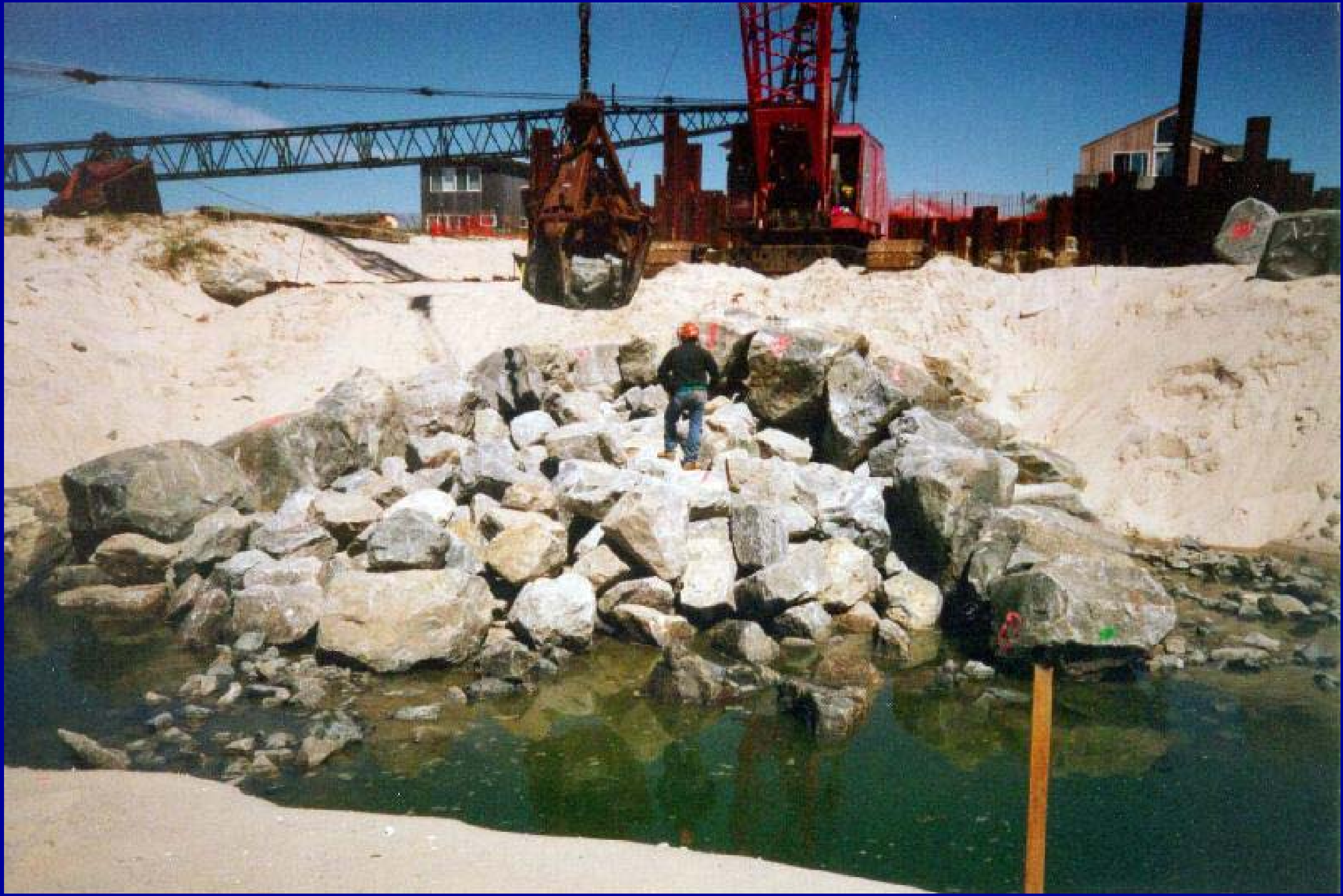
How to Build a Rubblemound Structure



How to Build a Rubblemound Structure

Place armor stone





Revetments
Materials: Other

Gabion Revetment
Cape May Pt, NJ

Geotube® revetment

Revetments

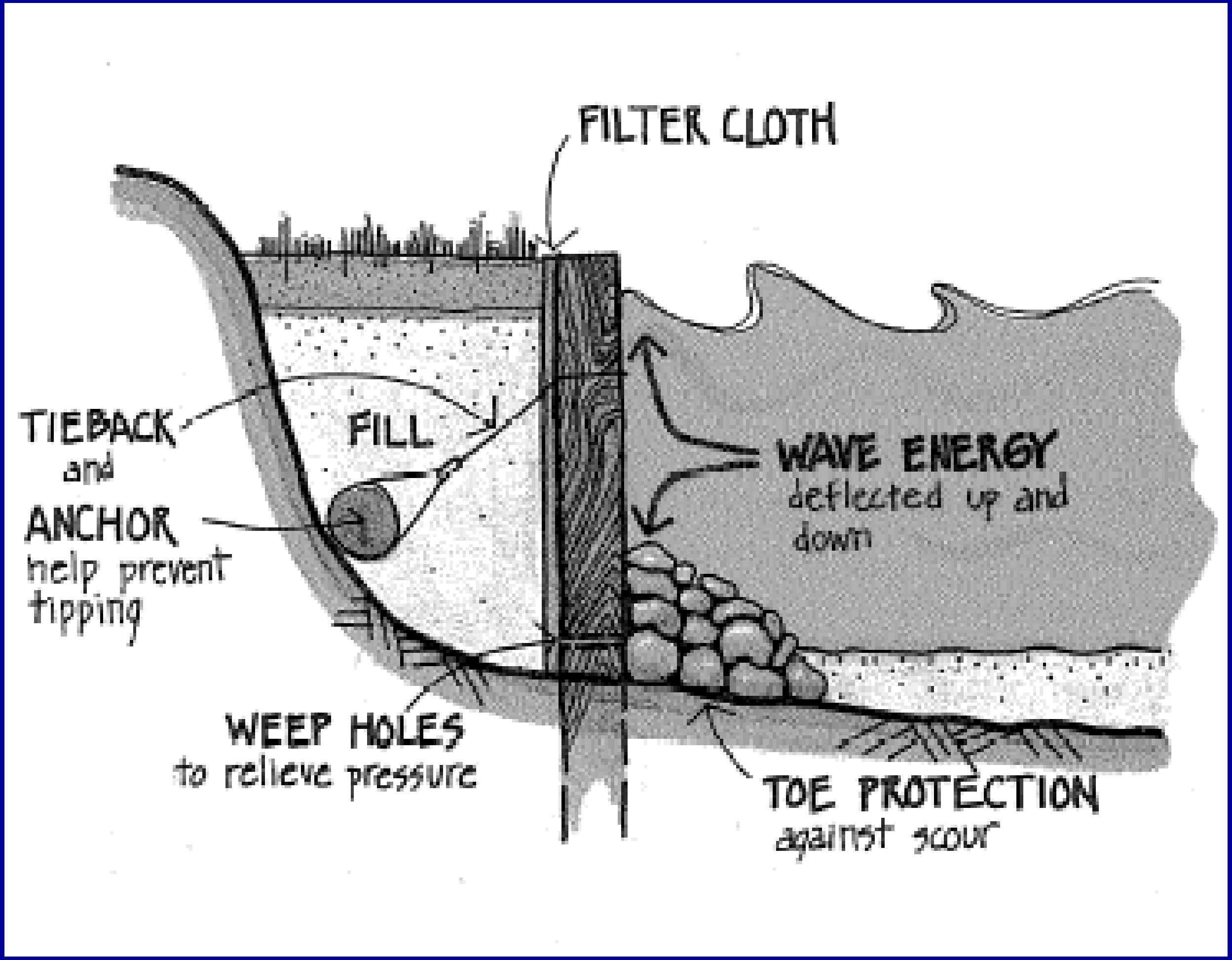
Fort Fisher, NC before

Fort Fisher, NC after

Road protection

Photos: Williams Dennis SAW

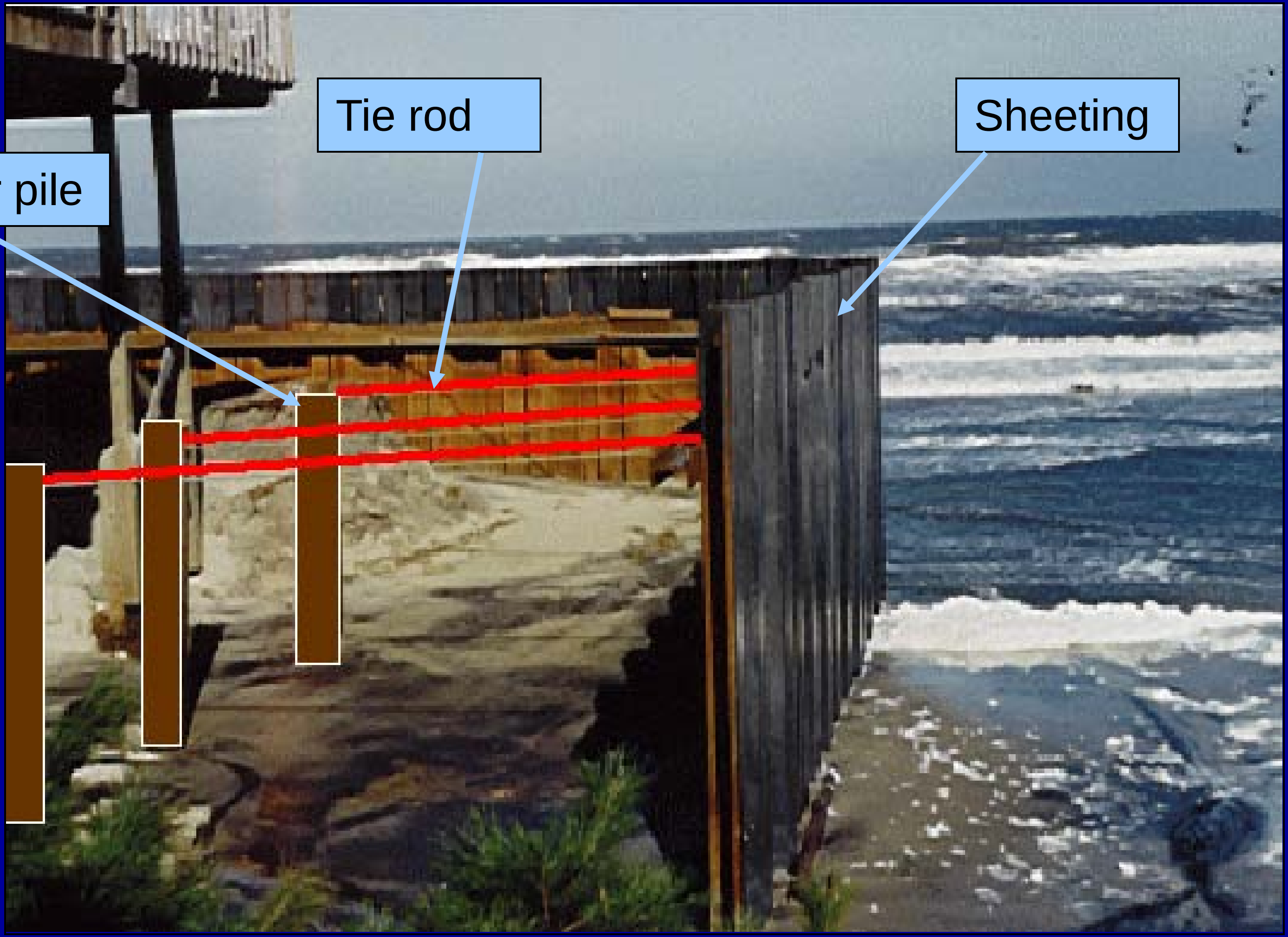
Bulkheads

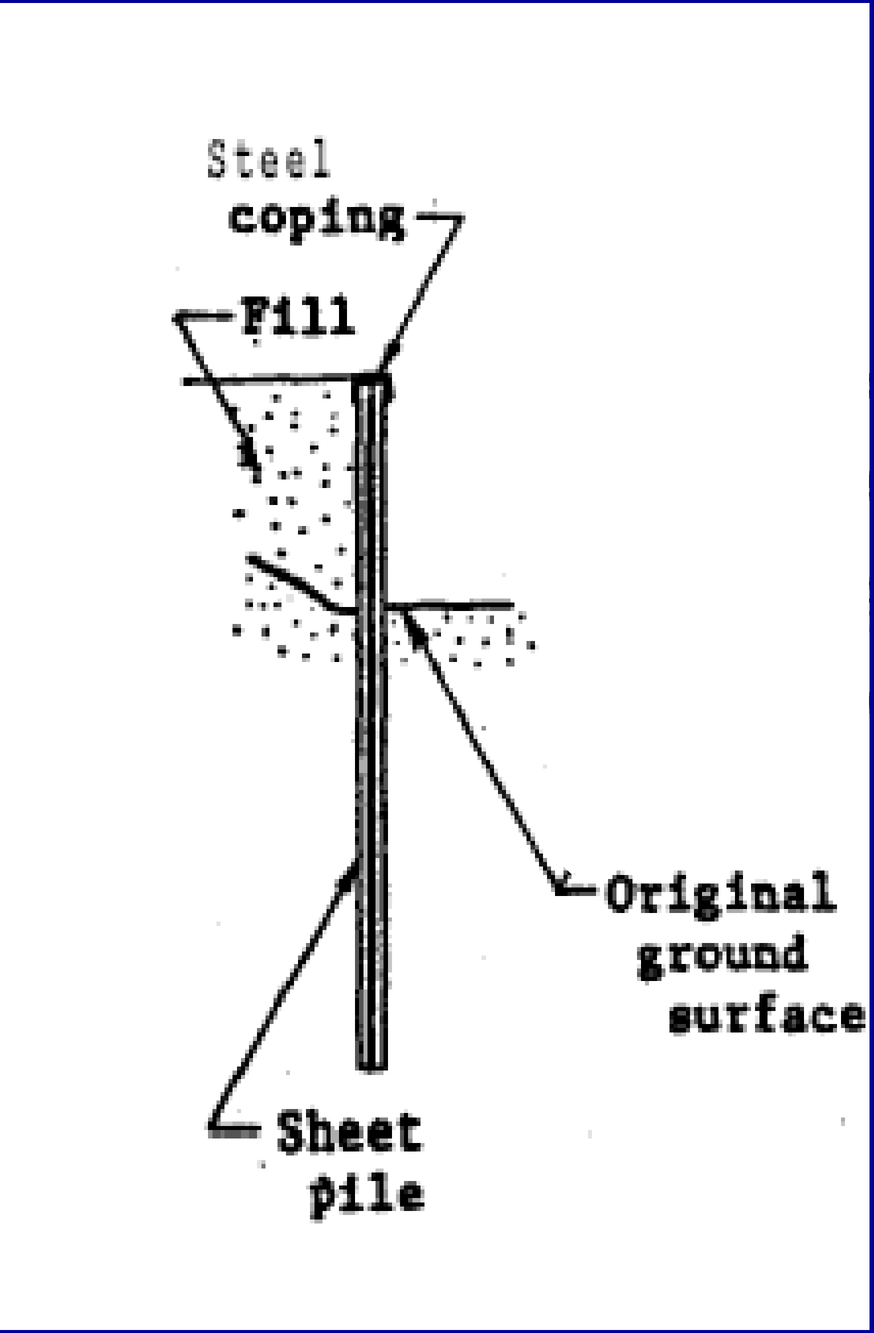


- **Objective is to retain upland soil**
- **Function is reinforcement of the soil bank**
- **Steel, concrete, timber, vinyl, composite**
- **"small"**

Bulkheads

Anchored





Bulkheads

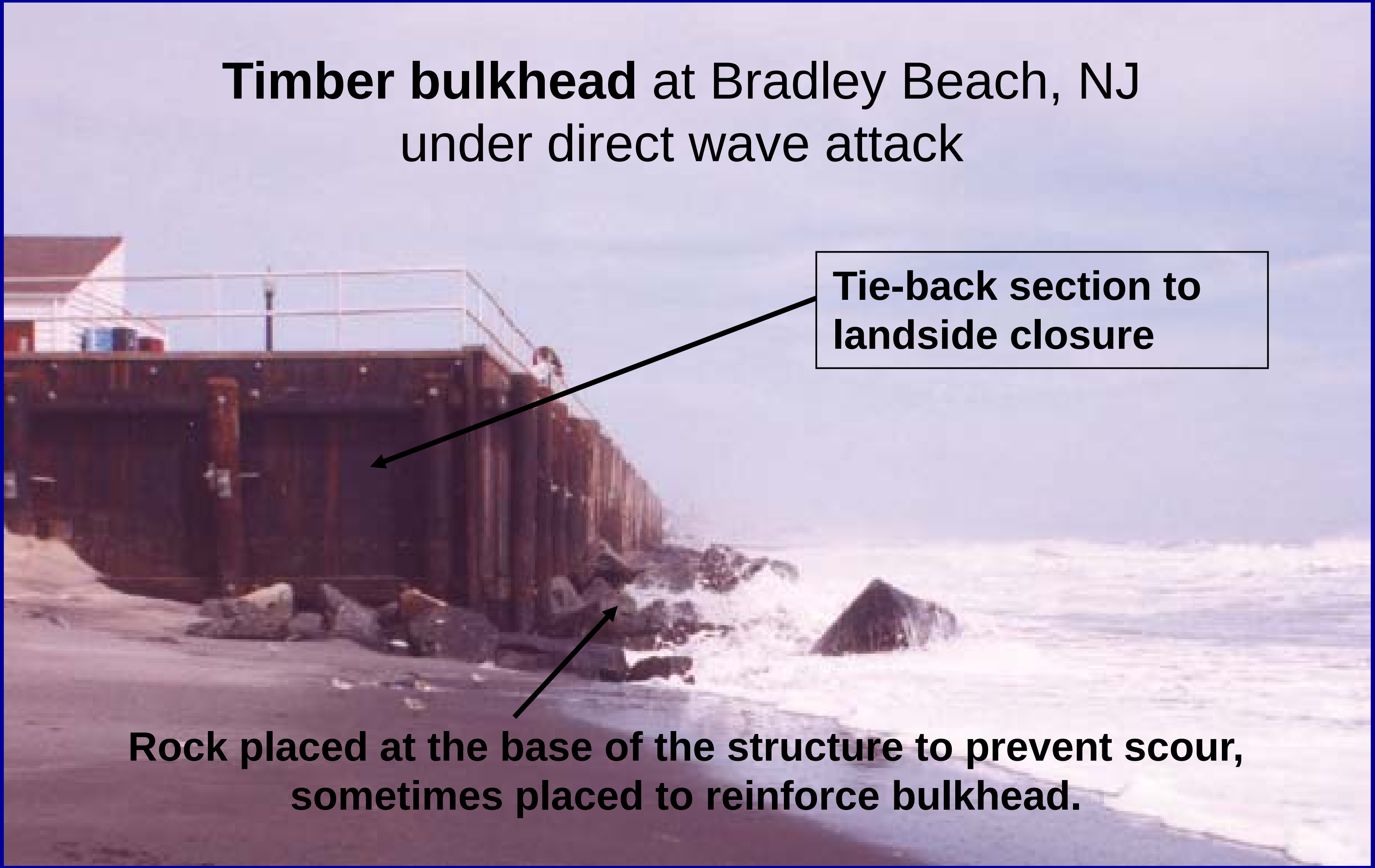
Cantilever

Bulkheads

Bulkheads: “Every homeowner for himself!”

Coney Island, 1990

Bulkheads


Timber bulkhead at Bradley Beach, NJ
under direct wave attack
Tie-back section to landside closure
Rock placed at the base of the structure to prevent scour, sometimes placed to reinforce bulkhead.

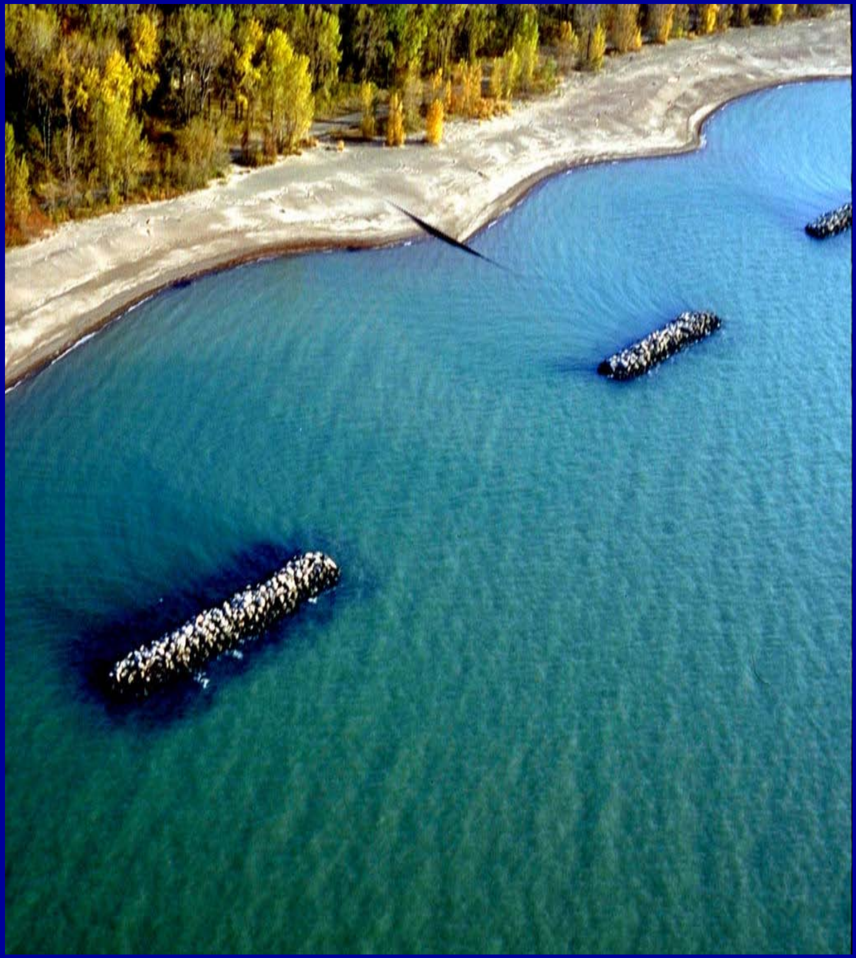
Types of Coastal Structures

1. Coastal armoring structures
2. **Beach or soil stabilization structures**
3. Navigation structures

Beach or Soil Stabilization Structures

- Nearshore breakwaters
- Groins
- Reefs and sills (“perched beach”)
- Containment dikes

Nearshore (Detached) Breakwaters



- Purpose is to prevent shoreline erosion
- Function is reduction of wave energy in lee and reduction of longshore transport
- Parallel to shoreline
- Allow some alongshore transport

Nearshore (Detached) Breakwaters
Presque Isle, PA

Nearshore Breakwaters
Maumee Bay State Park

Lake Erie

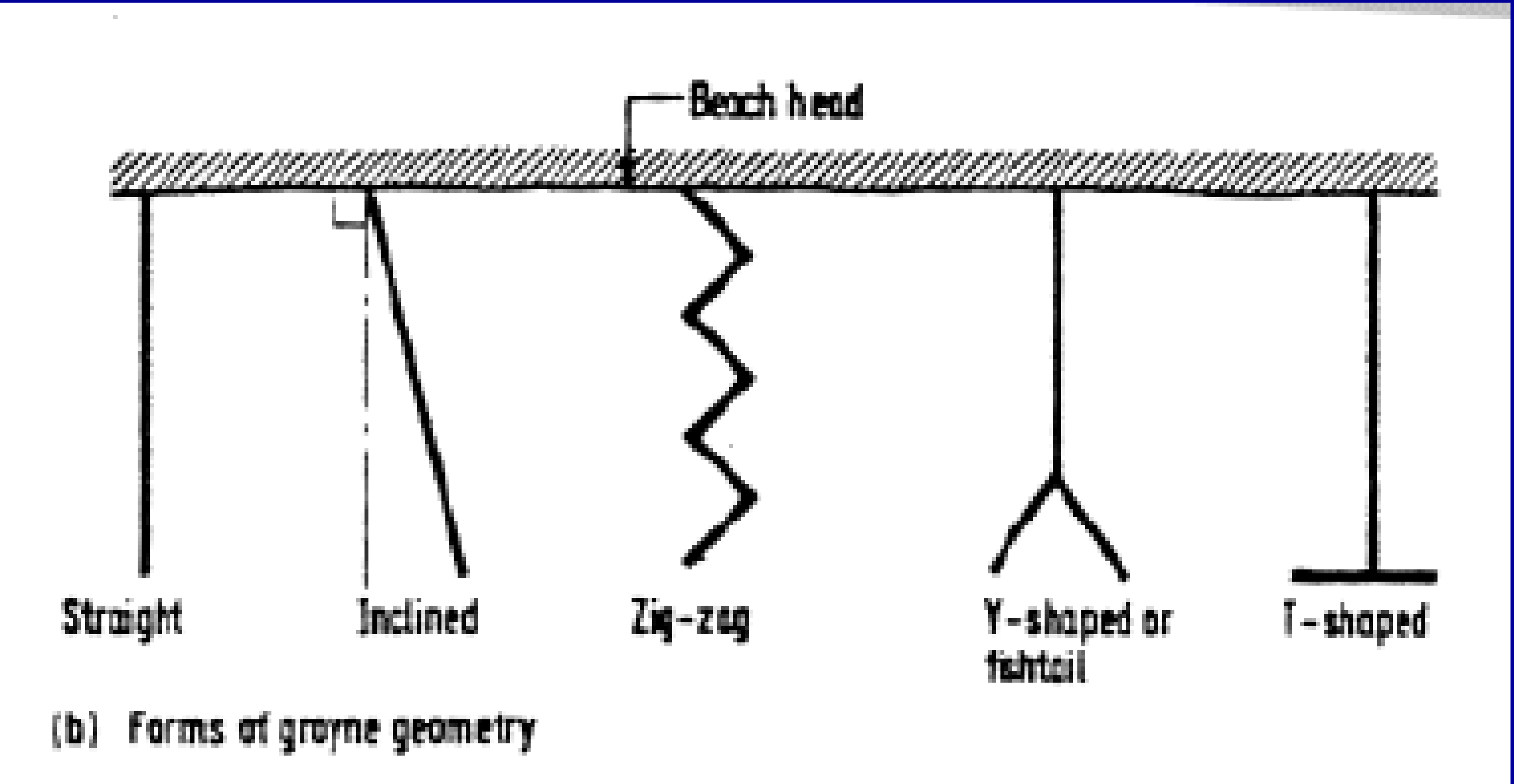
Groins

- Purpose is to reduce beach erosion, or terminate a beach fill
- Function by trapping or slowing down longshore transport.
- Generally perpendicular to shoreline
- Designed to both hold back sand and allow transport, to reduce downdrift impacts

Groins

- Not jetties!
- Trap % of longshore transport, if transport exists
- Most effective when combined with beach fill
- Usually constructed in groups or groin fields
- Terminal groins anchor beach or limit sand into navigation channel
- Types include notched, permeable, adjustable, T/L/Y shaped
- Varied types of construction materials

Groin Geometries



(Figure: CHL Website)

Groins

Overhead view of a rock **groin** showing the underwater extent of the structure

Groin Field

Long Branch and Deal, NJ 1987

Allenhurst, Loch Arbour, Asbury Park, NJ 1987

Groins

Coney Island terminal groin (w/beach)

Digression #3:

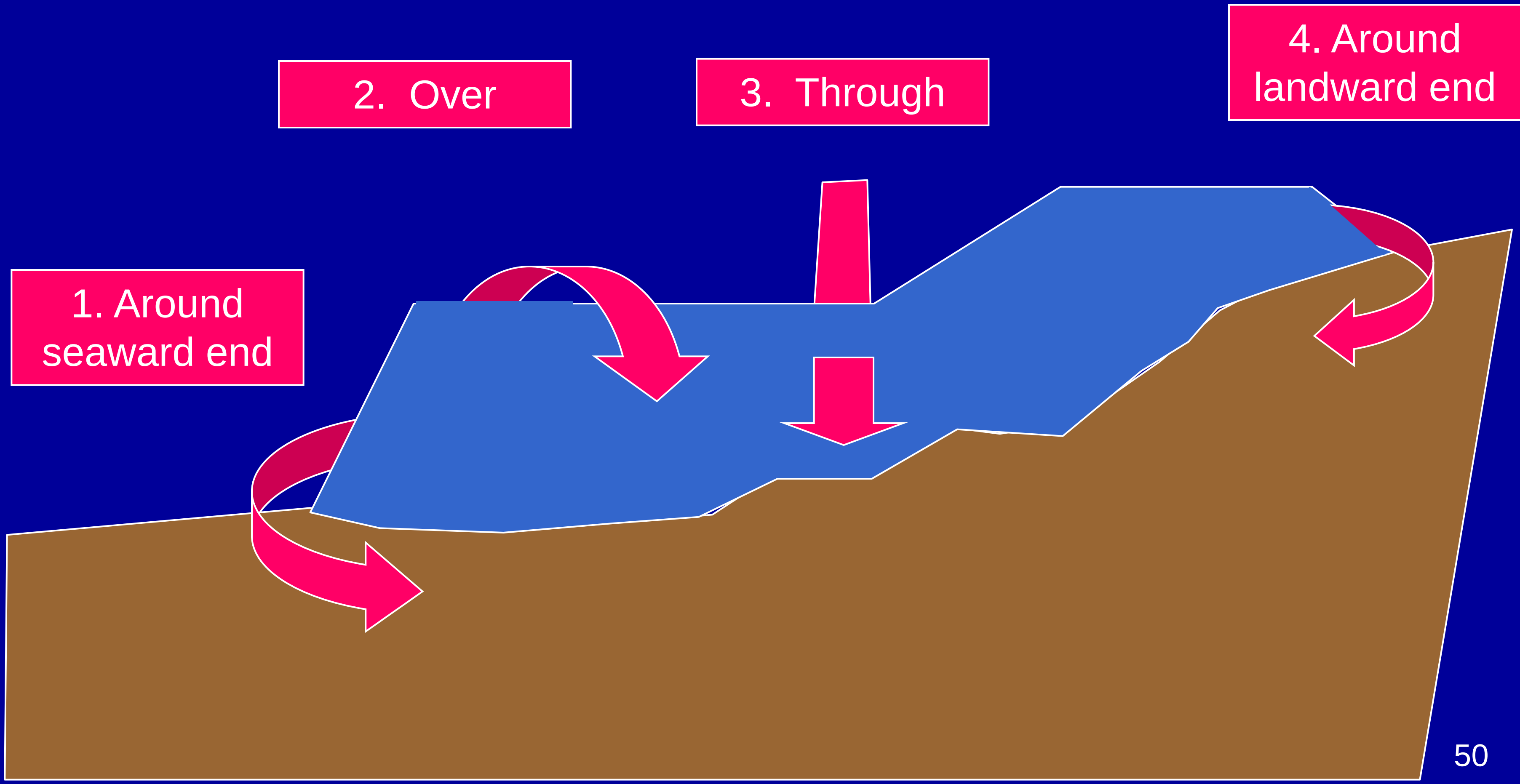
How does sand travel in water?

- Rolling along the bottom (bed load)
- Floating in the water column (suspended)
- Saltation, or hopping

Sand travels mostly between depth of closure and landward limit of flow

How does sand move past a groin?

Sand can only travel where the water flows



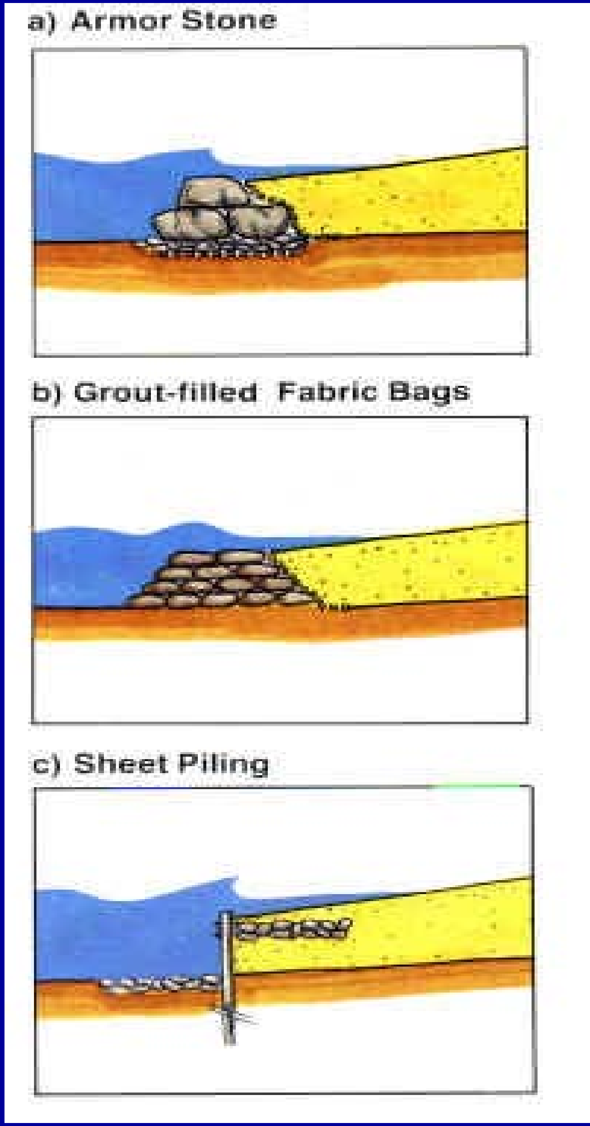
To add permeability to a groin:

- Lower the crest
- Shorten seaward extent
- Shorten landward extend
- Use material with voids

To reduce permeability:

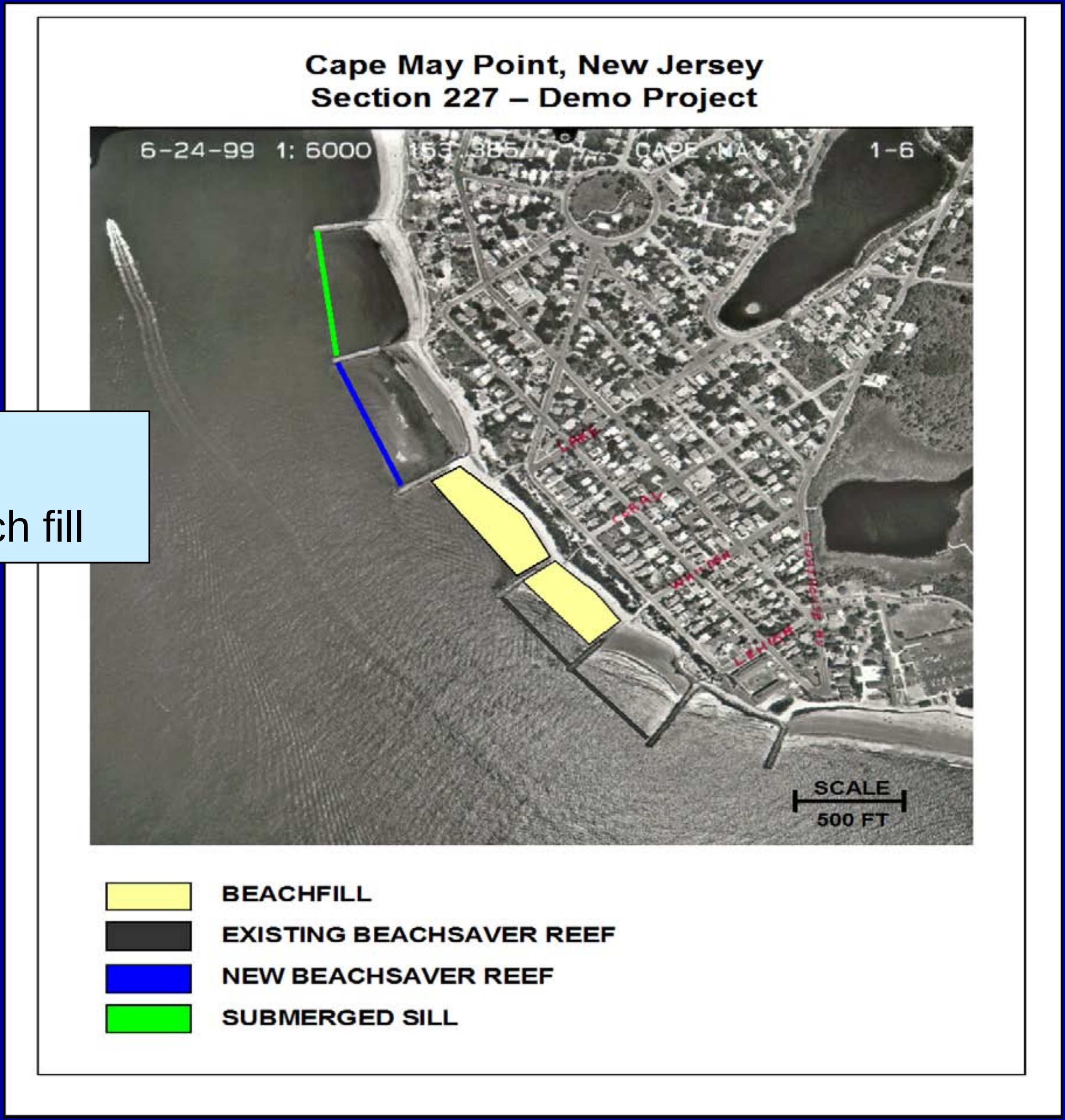
- Raise the crest
- Lengthen seaward extent
- Lengthen landward extend
- Eliminate voids

Reefs and Sills



- Purpose is to limit beach erosion
- Reef breakwaters function by reducing waves at the fill toe
- Submerged sills are used to slow offshore movement of sand, shorten fill profile
- Often used inside groin compartments

Reefs and Sills



Used with or

Without beach fill

Double-T Units & Scour Apron

Placement of Double T Unit

“Beachsaver” Units

Patented shape®

Other Technologies

- Holmberg Beach Technologies
- Sand Rx, Sand Castle Technologies
- Beach/Dune Dewatering

Containment Dikes

- Stabilize perimeters of marshes, disposal islands

Branch Box Breakwaters

Types of Coastal Structures

- Coastal armoring structures
- Beach stabilization structures
- **Navigation structures**

Navigation Structures

- Breakwaters
- Jetties

Repair of North Jetty Yaquina, Oregon (2000)

-Smaller vessels are more affected by waves

-Larger vessels are more affected by currents

-Faster moving vessels are less at risk than slower moving vessels

-Vessels generally have to slow down and turn to enter channels

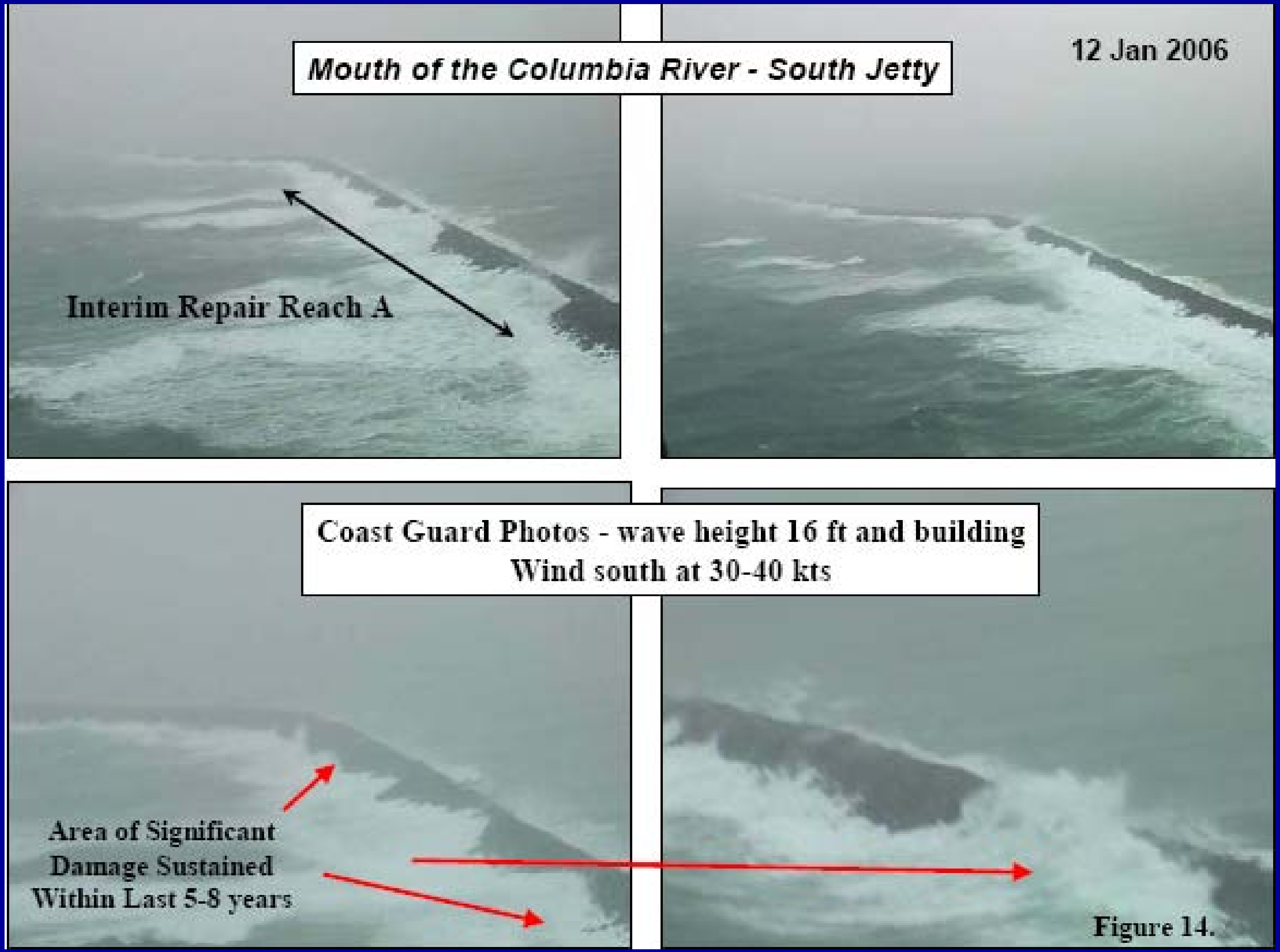
Navigation Breakwaters

Marina del Rey, CA

- Purpose is to shelter harbor basins and entrances against waves and currents primarily for boat traffic
- Function by dissipating and reflecting wave energy

Jetties

Acting as breakwaters



Source: Heidi Moritz, Portland District

Breakwaters and Jetties
Ventura Harbor, CA

Jetties

Barnegat Inlet, NJ (new south jetty)

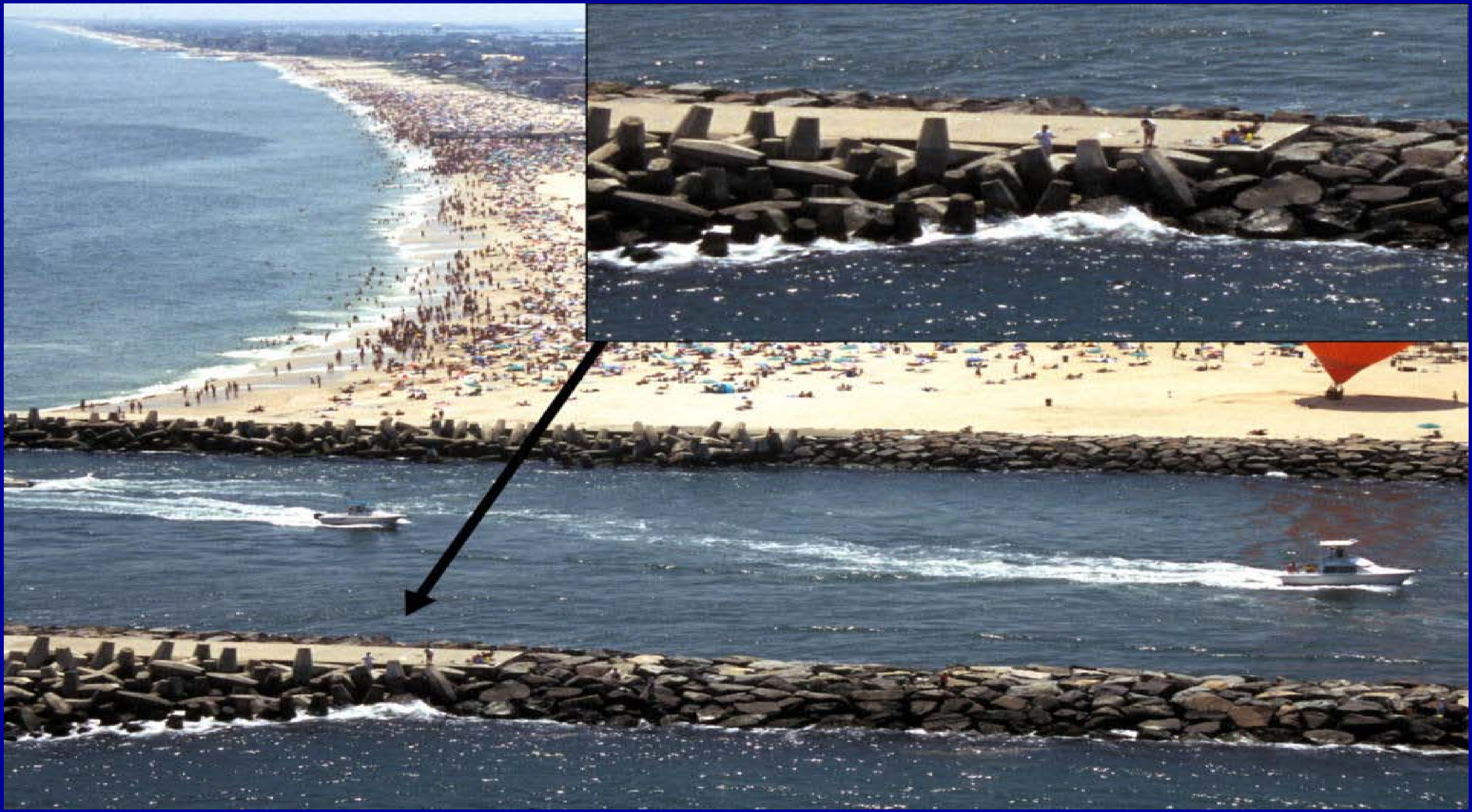
- Purpose is to reduce sedimentation of channels
- Shelter harbor basins and entrances against waves and currents
- Limit inlet migration

Jetties

As with groins, geometry can vary

Spur Jetties Siuslaw River, OR

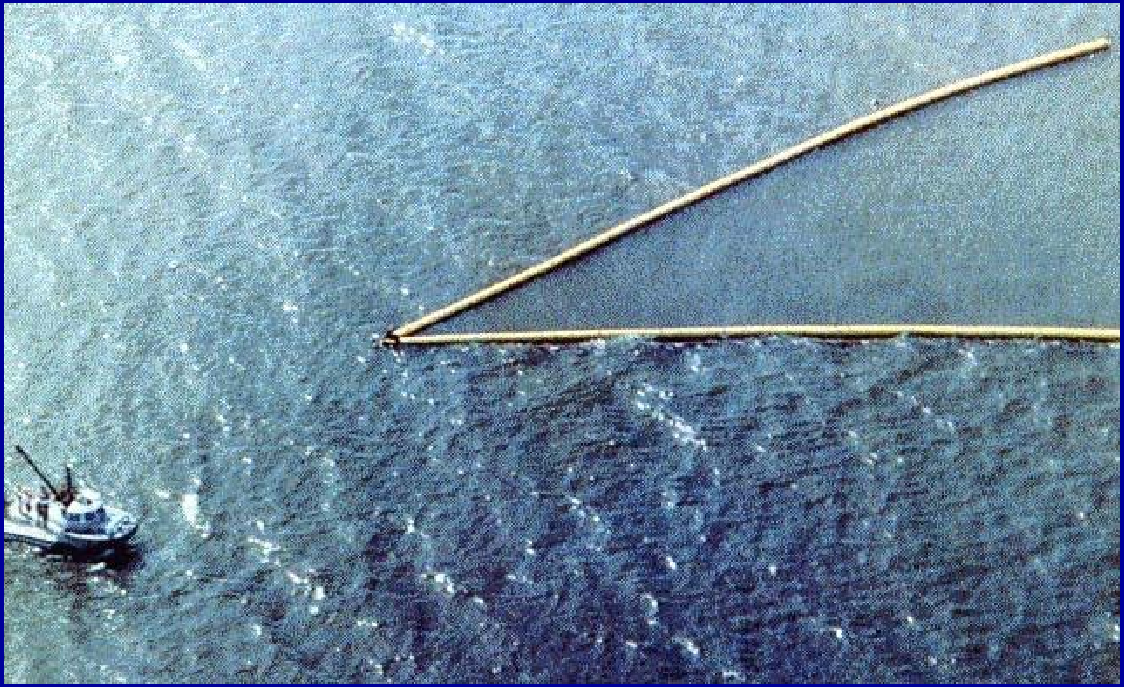
Jetties (Dolos/CoreLoc)
Manasquan Inlet, NJ



Concrete units may be cost effective vs. large stone

Core-Loc units at Manasquan Inlet Jetty, NJ

Floating Breakwaters



Floating Breakwater
RIBS System

- Purpose is to shelter harbor basins and mooring areas
- Reduce waves by reflection and breaking

Combination of Structures (Systems)

Chicago, 31st Beach

Construction of first hydraulically pumped beachfill at Coney Island NY, 1922

Essayons!