



Report on the Effects of Hard Structures on Sandy, Open-Ocean Coastlines



NC Coastal Resources Commission's Science Panel
June 18, 2026

CRC's Charge to the Science Panel

Develop report on the effects of hard structures on sandy, open-ocean coastlines:

1. Introduction

Overview of shoreline change and barrier island dynamics; NC ocean coastline; Categories of erosion management approaches for sandy, ocean coastlines; What is allowed currently in NC and already being used?

2. The effects of structures that trap sand and shoreline hardening, including intended purpose, physical effects, ecological impacts, and tradeoffs

- a. Structures that trap sand: groins; terminal groins; offshore breakwaters
- b. Shoreline hardening: seawalls; revetments; sandbags, geotextile tubes

3. Key Lessons learned - Case Studies

Additions: **4. Policies in Other States; 5. Recommendations**

1. Introduction and Background



Open-Ocean Coastline Issues:

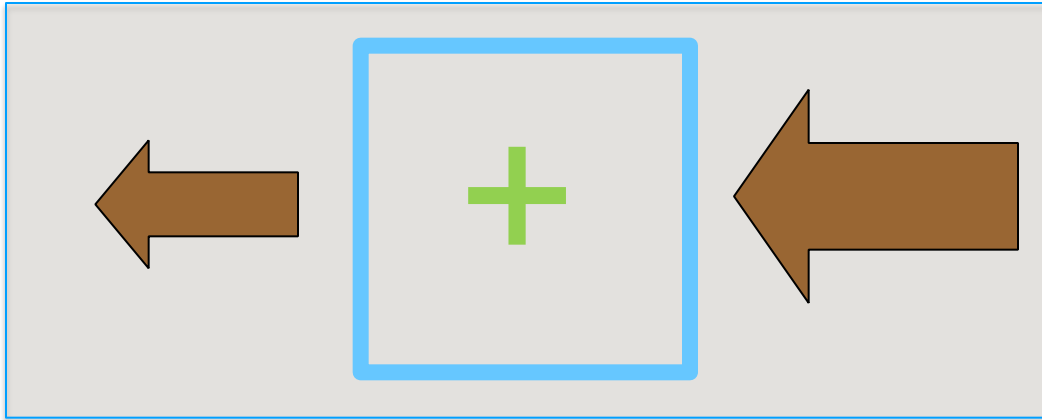
**Long-term,
chronic
erosion**



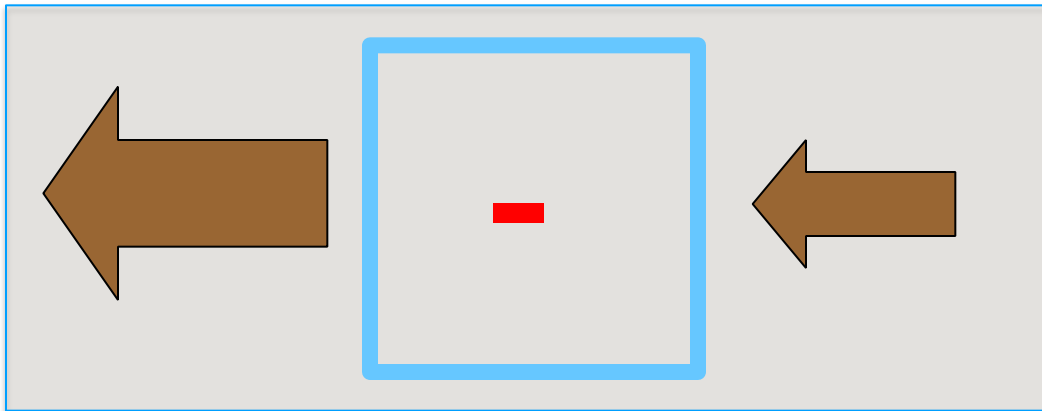
Rodanthe, NC (credit: Lisa Valvo)

**Storm
Impacts**

Change in shoreline position determined by a balance between losses and gains of sand



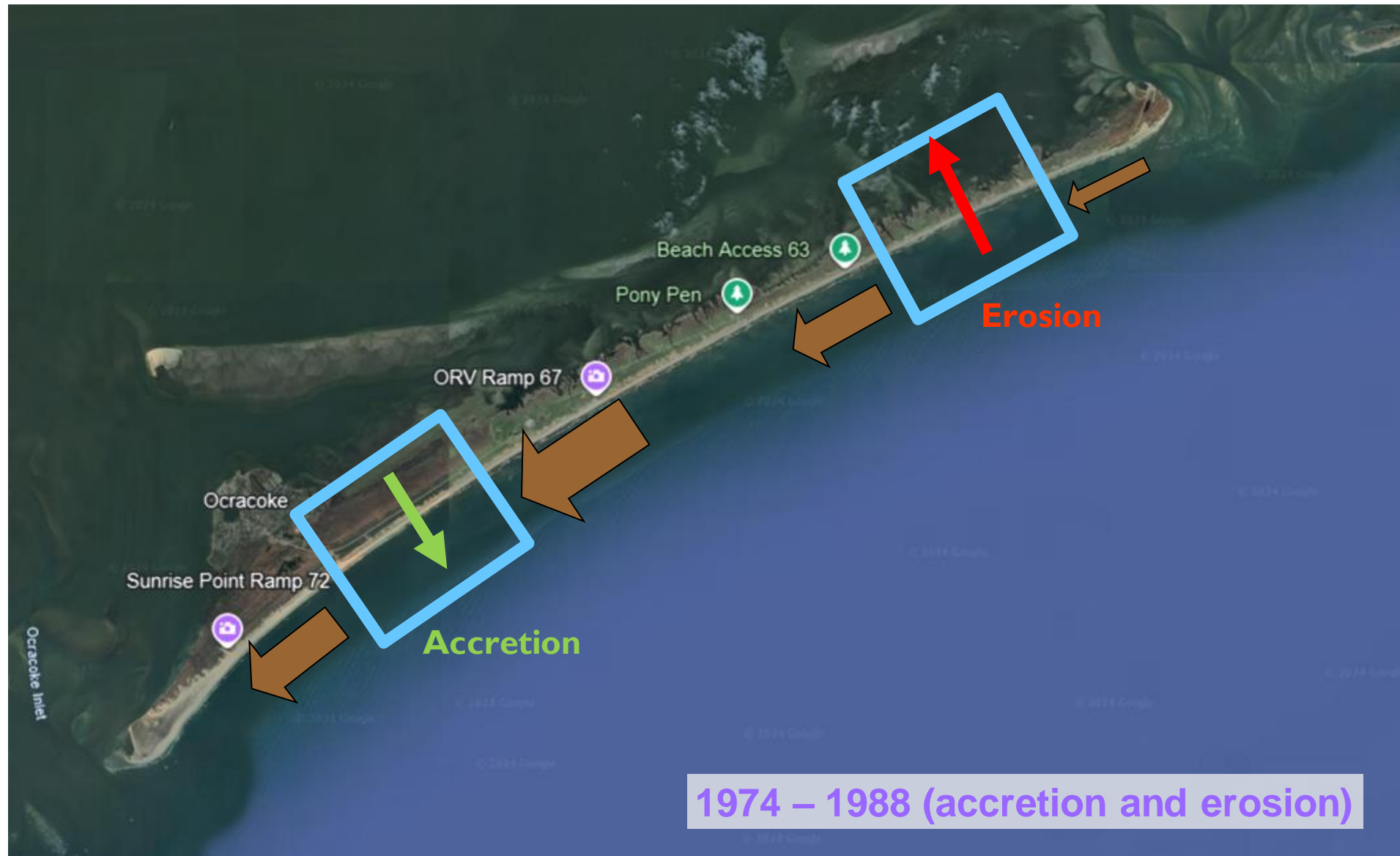
Positive
Balance =
Accretion



Negative
Balance =
Erosion

Both alongshore balance and cross-shore balance matter

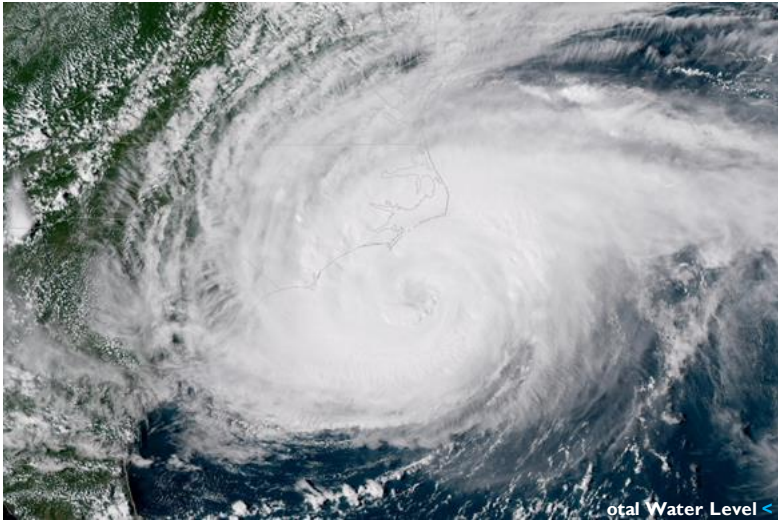
Chronic Shoreline Erosion - alongshore balance



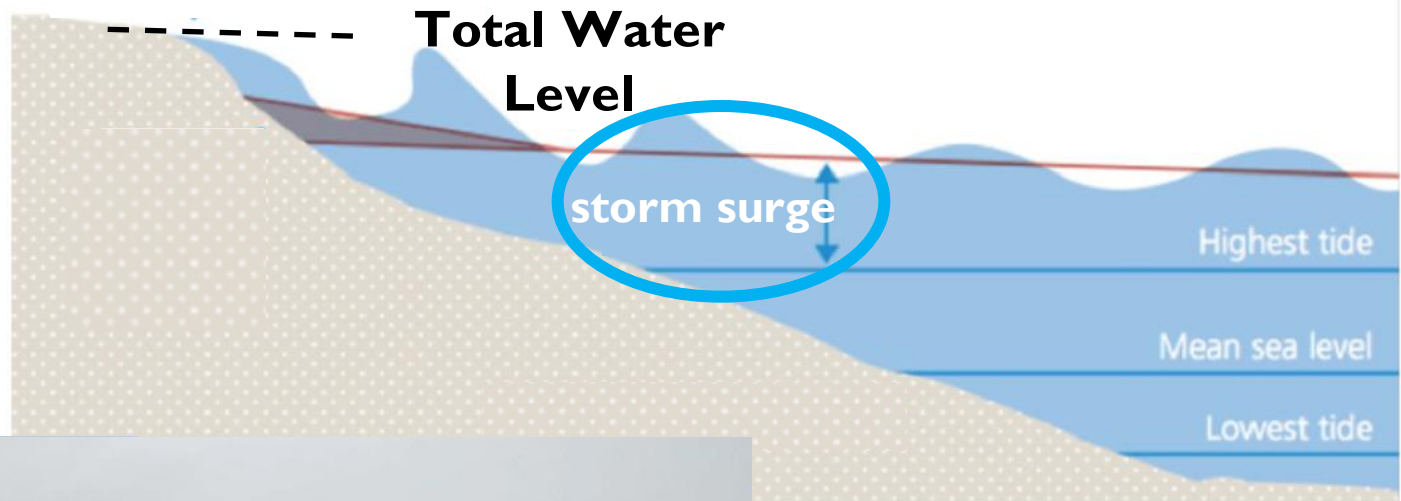
Chronic Shoreline Erosion - alongshore balance



Chronic Shoreline Erosion – cross-shore balance

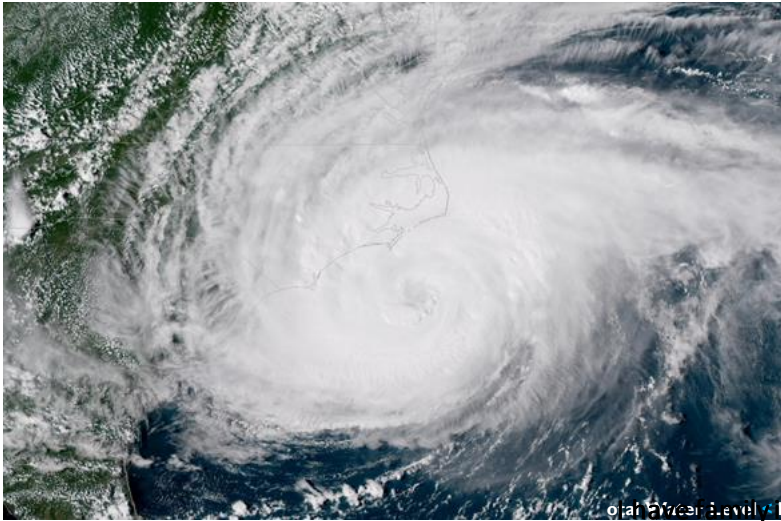


Storm surge + waves elevate Total Water Level

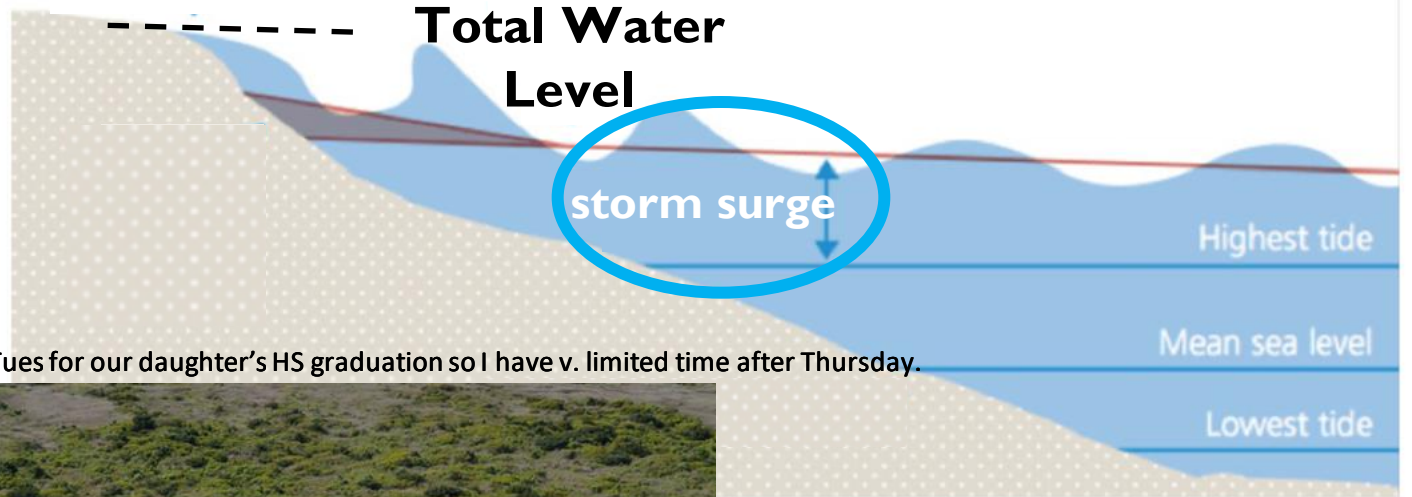


Total Water Level below dune/back-beach = sand moved offshore, returns in fair weather;
most storms don't add to chronic erosion

Chronic Shoreline Erosion – cross-shore balance



Storm surge + waves elevate Total Water Level



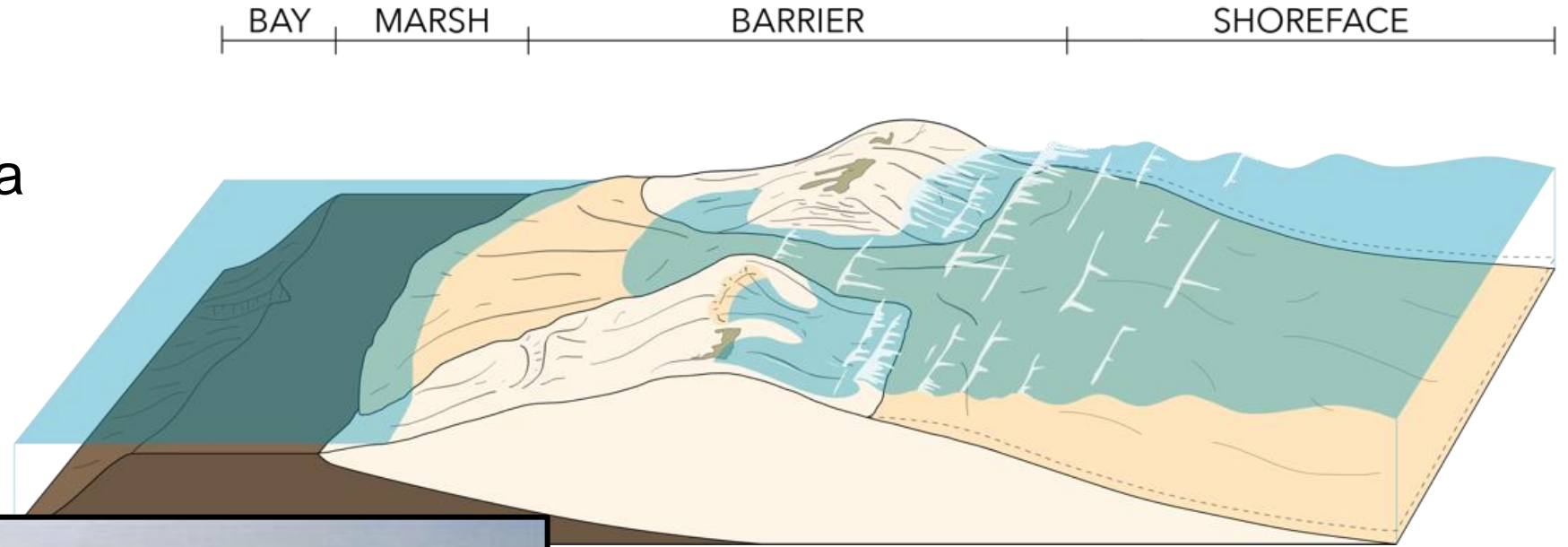
on a beach level. In town Fri-Tues for our daughter's HS graduation so I have v. limited time after Thursday.



Total Water Level
above dune/back-beach
= sand moves onshore
**loss from beach/nearshore
contributes to long-term
shoreline erosion**

On natural barrier islands, overwash maintains elevation

Overwash maintains elevation relative to sea level and drives migration



Islands look similar over time, but are located in a more landward position

On developed islands, management actions affect island processes...



overwash removal
dune construction
Nordstrom 1994, 2004

Image: Greg Kahn, Audubon

overwash filtering



Rogers et al., 2015
Lazarus et al., 2021

sandbag seawall



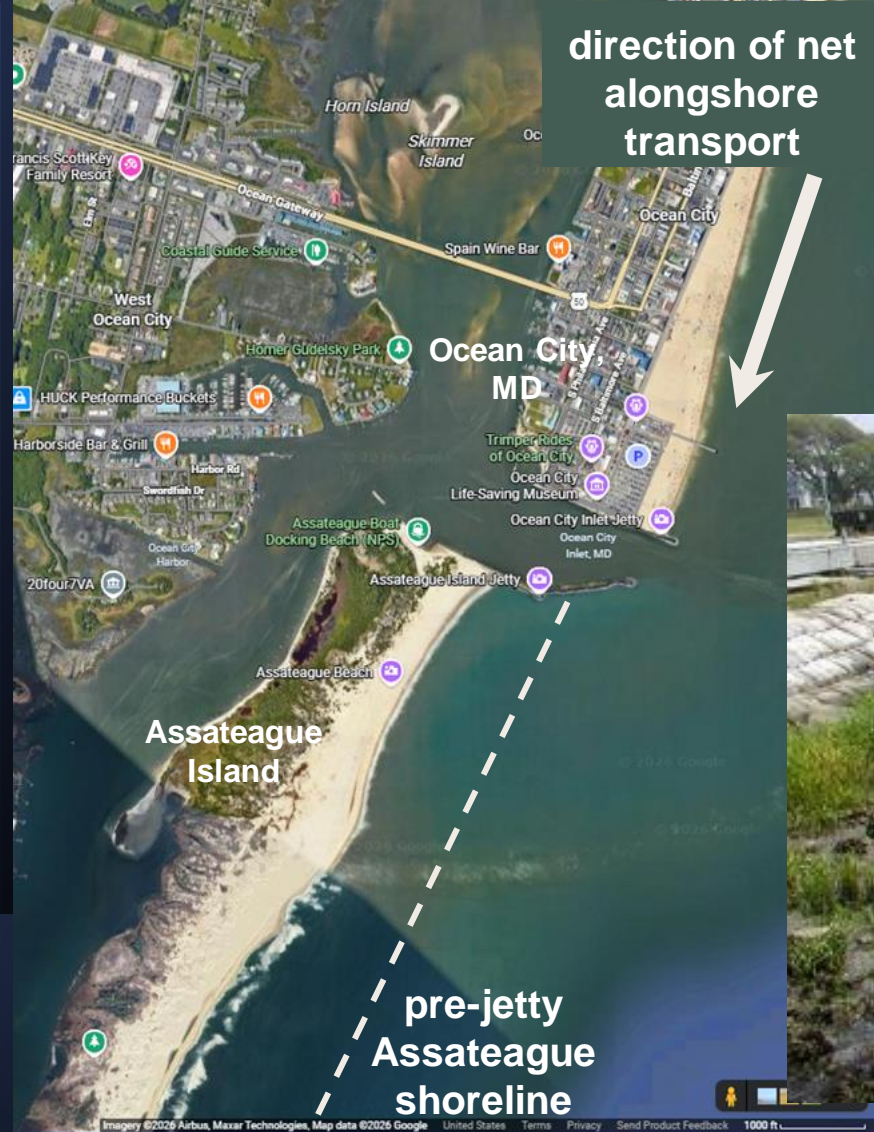
Sand Transport on Open Coast

- **Accretion vs. Erosion determined by**
 - Balance in alongshore sand transport
 - Balance in cross-shore sand transport

Sea-level rise and increased frequency of major hurricanes will tend to make balance more negative over time



Focus on *erosion mitigation & risk-reduction* on open-ocean coastline only



Living shorelines reduce wave impacts; only appropriate for low-energy shorelines



Jetties trap sand, affect shoreline change; intention = stabilize inlets

Photo Credits: Google Earth (right); CoastalReview.org (above)

2. Structures that trap sand or harden the shoreline

Structures that trap sand

Intention = Erosion Mitigation:

Groins and breakwaters trap or collect sand moving alongshore to build a beach



Groins, breakwaters and similar structures

Benefits:

- Can slow erosion and widen the beach updrift

Adverse physical effects:

- Increase erosion rates downdrift

Tradeoffs:

- **Updrift areas benefit to detriment of downdrift areas**
- Requires ongoing repair to structures
- Repeated nourishment is very likely required to maintain benefits

Seawalls redirect or absorb wave energy to reduce wave impacts

*Shoreline
hardening*

**Intention =
Risk
Reduction:**



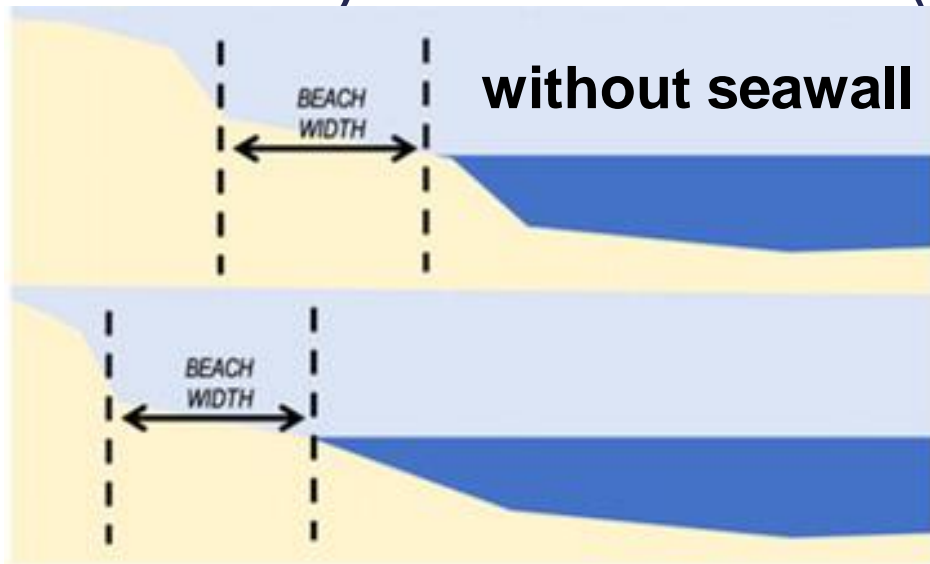
Seawalls, revetments, sandbags, geotextile tubes

Benefits:

- Reduce likelihood of direct wave impact to infrastructure
- Reduce storm flooding and sand deposition

Adverse physical effects:

- Primary: **loss of beach** (fixed structure behind eroding shoreline)



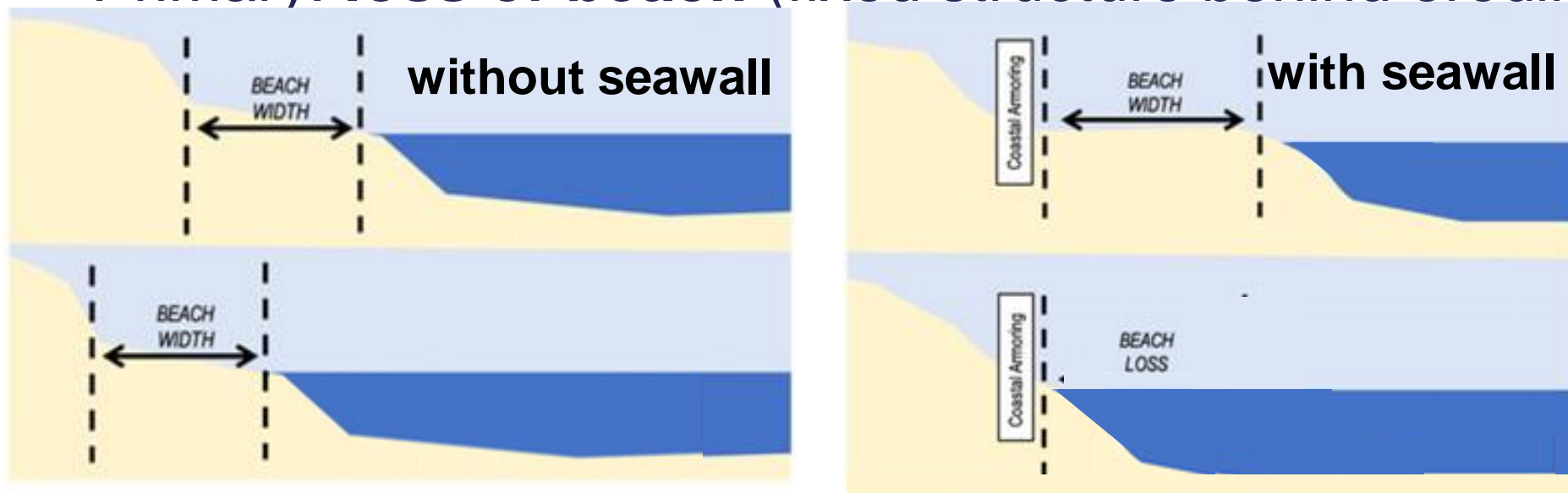
Seawalls, revetments, sandbags, geotextile tubes

Benefits:

- Reduce likelihood of direct wave impact to infrastructure
- Reduce storm flooding and sand deposition

Adverse physical effects:

- Primary: **loss of beach** (fixed structure behind eroding shoreline)



(Modified from Taylor & Francis, 2019)

Seawalls, revetments, sandbags, geotextile tubes

Benefits:

- Reduce likelihood of direct wave impact to infrastructure
- Reduce storm flooding and sand deposition

Adverse physical effects:

- Primary: **loss of beach** (fixed structure behind eroding shoreline)
- Loss of beach/dune area when emplaced
- Reduced overwash sand deposition: eventual sound-side inundation
- Reduced sand supply for adjacent beaches
- Potentially enhanced erosion on adjacent beaches
- Groin-like effect when structure protrudes on eroded beach

Seawalls, revetments, sandbags, geotextile tubes

Tradeoffs:

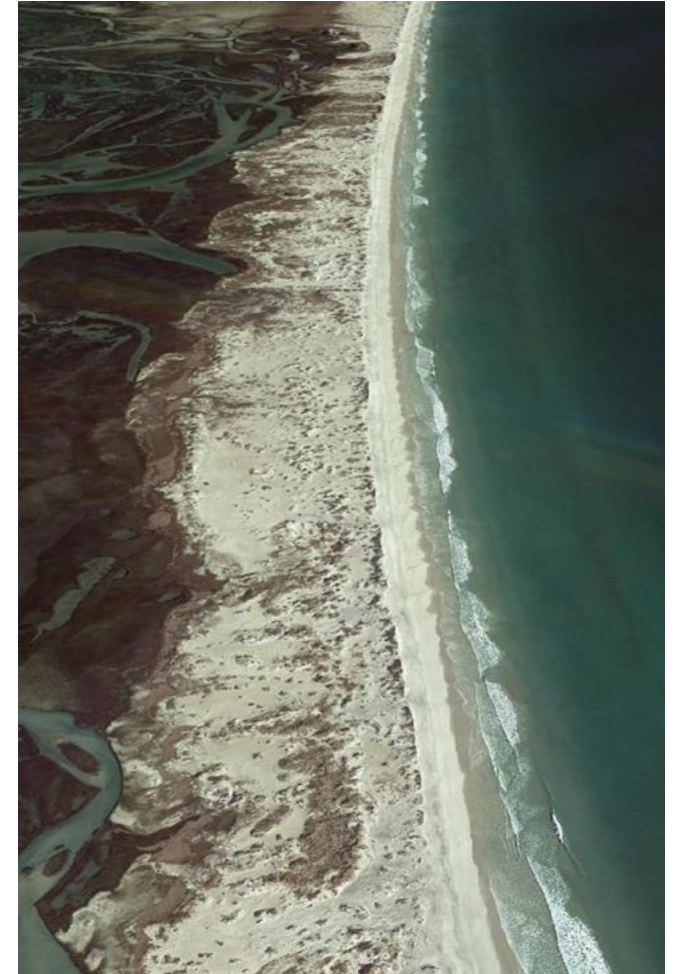
- Reducing risk to infrastructure vs. loss of the beach
- Reducing risk vs. potential impacts on adjacent shorelines
- Reducing risk vs. barrier inundation, loss of long-term habitability
- To maintain a beach requires emplacement of greater amounts of sand over time



Ecological Considerations:

Commercially and recreationally important species depend on the beach for:

- Juvenile habitat
- Migration routes
- Foraging locations
- Nesting



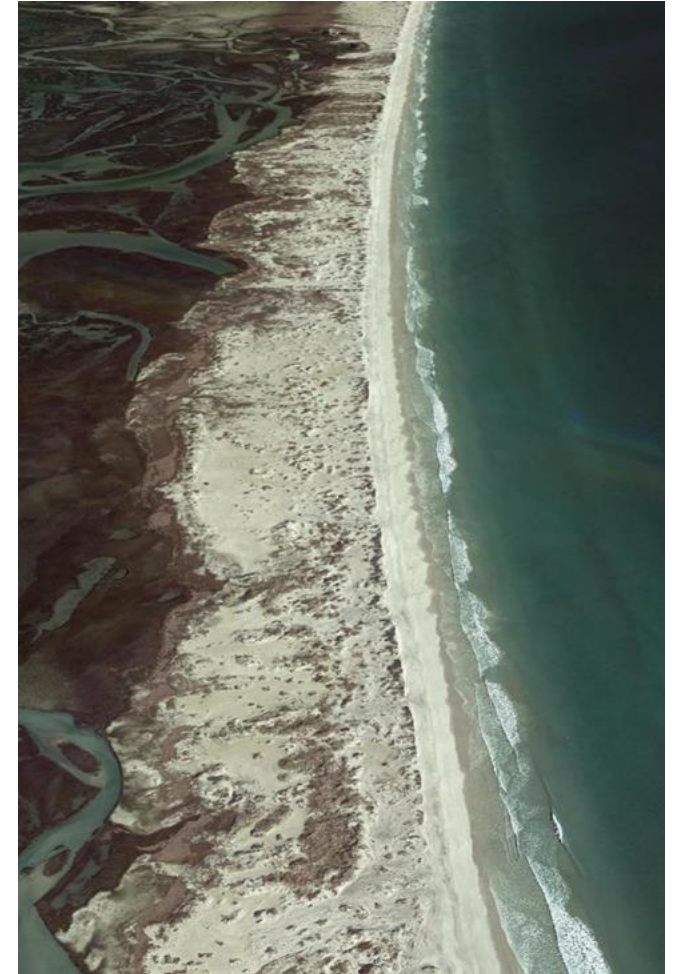
Ecological Considerations:

Commercially and recreationally important species depend on the beach for:

- Juvenile habitat
- Migration routes
- Foraging locations
- Nesting

Loss of beach impacts:

- Sea turtles (nesting / congregation area)
- Shore birds
- Many fish species (and fisheries)



Ecological Considerations:

Commercially and recreationally important species depend on the beach for:

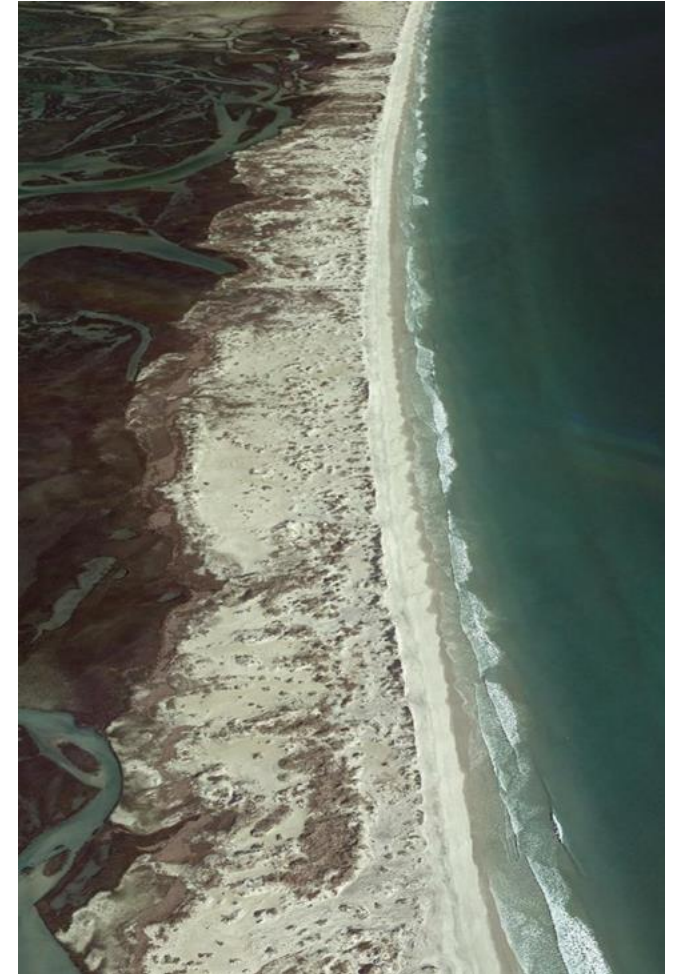
- Juvenile habitat
- Migration routes
- Foraging locations
- Nesting

Loss of beach impacts:

- Sea turtles (nesting/ congregation area)
- Shore birds
- Many fish species (and fisheries)

Groins and other barriers impact:

- Nearshore fish migration



Recreational Considerations:

Recreational fisheries

- Fishing piers
- Shore fishing
- Loss of beaches would reduce econ. benefits



Recreational Considerations:

Recreational fisheries

- Fishing piers
- Shore fishing
- Loss of beaches would reduce econ. benefits

Tourism

- NC among top five states
- Reputation of beaches contributes to visits
- Loss of public beaches & adverse aesthetics could reduce visits



Recreational Considerations:

Recreational fisheries

- Fishing piers
- Shore fishing
- Loss of beaches would reduce econ. benefits

Tourism

- NC among top five states
- Reputation of beaches contributes to visits
- Loss of public beaches & adverse aesthetics could reduce visits

Public Safety

- Structures can present a hazard to boaters, swimmers and surfers



Economic Considerations:

Analysis to determine whether installing a structure makes economic sense requires:

- Accounting for the present value of net benefits over time (PVNBOT), i.e. benefits minus costs, adjusted for inflation and interest rates, integrated over time.
- Comparing project net benefits to those of a projected “counterfactual scenario” (e.g. current conditions).

Economic Considerations:

Analysis to determine whether installing a structure makes economic sense requires:

- Accounting for the present value of net benefits over time (PVNBOT), i.e. benefits minus costs, adjusted for inflation and interest rates, integrated over time.
- Comparing project net benefits to those of a projected “counterfactual scenario” (e.g. current conditions).

To optimize from an economic standpoint:

- Include analysis of PVNBOT for all feasible erosion mitigation and adaptation measures (e.g., hard structures, beach nourishment, managed retreat).
- Find path that maximizes PVNBOT.

Benefits and Costs Associated with Structural Approaches:

Benefits

- **Wider beach** (sand trapping) = increased home value, more fishing use, increased visits
- Reduced risk = fewer homes lost during storms



Benefits and Costs Associated with Structural Approaches:



Benefits

- **Wider beach** (sand trapping) = increased home value, more fishing use, increased visits
- Reduced risk = fewer homes lost during storms

Costs

- **Narrower beach** and change in aesthetic (*downdrift of sand trapping and in project area for shoreline hardening*) = decreased home value
- Eventual loss of public beach (*shoreline hardening*) = decreased home value, loss of fishing use, decreased visits
- Loss of ecosystem services
- Lawsuit exposure due to adverse impacts, personal injury, etc.
- Ongoing maintenance and mitigation

Benefits and Costs Associated with Structural Approaches:



Benefits

- **Wider beach** (sand trapping) = increased home value, more fishing use, increased visits
- Reduced risk = fewer homes lost during storms

Costs

- **Narrower beach** and change in aesthetic (*downdrift of sand trapping and in project area for shoreline hardening*) = decreased home value
 - Eventual loss of public beach (*shoreline hardening*) = decreased home value, loss of fishing use, decreased visits
 - Loss of ecosystem services
 - Lawsuit exposure due to adverse impacts, personal injury, etc.
 - Ongoing maintenance and mitigation
- ***Management strategy affects number of trips to the beach; fewest to beaches with structures, more to nourished beaches, most to beaches where strategy is relocation and removal (Landry and Smith, 2026)***

Benefits and Costs Associated with Different Management Approaches:

Representative Benefits and Costs	Structure to mitigate erosion (e.g., groin, breakwater)	Shoreline hardening (e.g., seawall, revetment)	Beach Nourishment	No project (counterfactual)	Relocation or removal
Potential Benefits					
Reduced erosion rate in project area	✓	NA	✓	NA	NA
Wider beach in project area = increase in home value, tourism, shore fishing	✓	NA	✓	NA	For a time, if threatened homes are removed
Reduction in number of homes lost or damaged	✓	✓	✓	NA	NA
Temporary increase in beach width downdrift	NA	NA	✓	NA	NA
Increase in aesthetics	NA	NA	✓	NA	✓
Increase in ecosystem services	NA	NA	NA	NA	✓
Potential Costs					
Construction, design, engineering	✓	✓	✓	NA	NA
Permitting, compliance	✓	✓	✓	NA	✓
Loss and collapse of threatened homes	Less likely	Less likely	Less likely	✓	N/A
Increased erosion rate downdrift	✓	✓	NA	NA	NA
Narrower beach downdrift = decrease in home value, tourism, shore fishing	✓	✓	NA	NA	NA
Narrower beach in project area = decrease in tourism, shore fishing	NA	✓	NA	✓	NA
Disappearance of beach (public trust) in front of structure	NA	✓	NA	NA	NA
Decrease in Aesthetics and negative impact on property value	✓	✓	NA	NA	NA
Home Purchase or Relocation	NA	NA	NA	NA	✓
Lawsuits against project or for personal injury	✓	✓	✓	✓	✓
Adverse effects on recreation	✓	✓	NA	NA	NA
Adverse effects on ecosystems and ecosystem services	✓	✓	✓	NA	NA

See Table 1 in the Science Panel Report

3. Key Lessons Learned - Case Studies

Ft. Fisher, NC

Buxton, NC

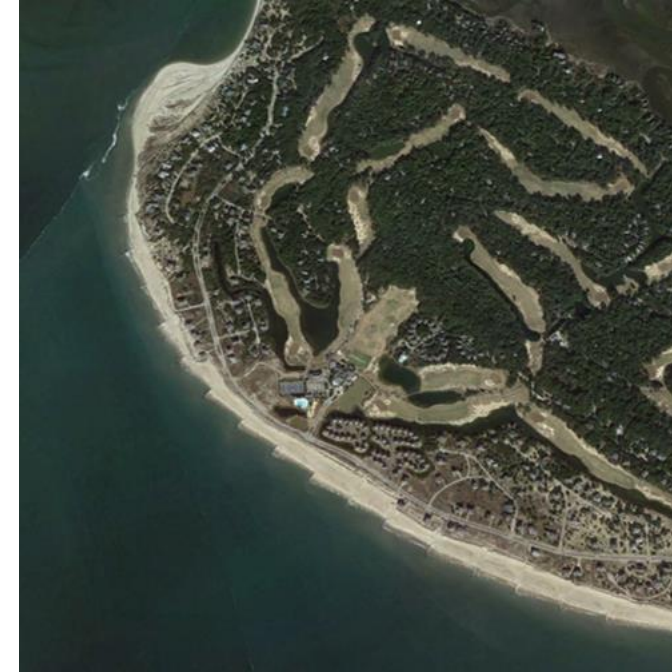
Ft. Macon, NC

Bald Head, NC

Presque Island, PA

Northern New Jersey

Galveston, TX



Shoreline hardening case study: Revetments at Fort Fisher, NC



- Erosion was removing the Civil war fort
- Revetments first emplaced post WWII
- Collapsing revetments replaced in 1995
- **Historic structure protected**
- **No beach in front of revetment**
- Repeated nourishment nearby mitigated erosion on adjacent shorelines



Fort Fisher revetment
(above: Google Earth; right: Spencer Rogers)

Sand trapping case study: Groins at Buxton, NC



- High natural background erosion rate
- > 20 ft/year before erosion mitigation
- Groins installed 1969, repeated nourishment since then
- These actions reduced erosion rates

Shorelines from NCDCCM, 2024 image

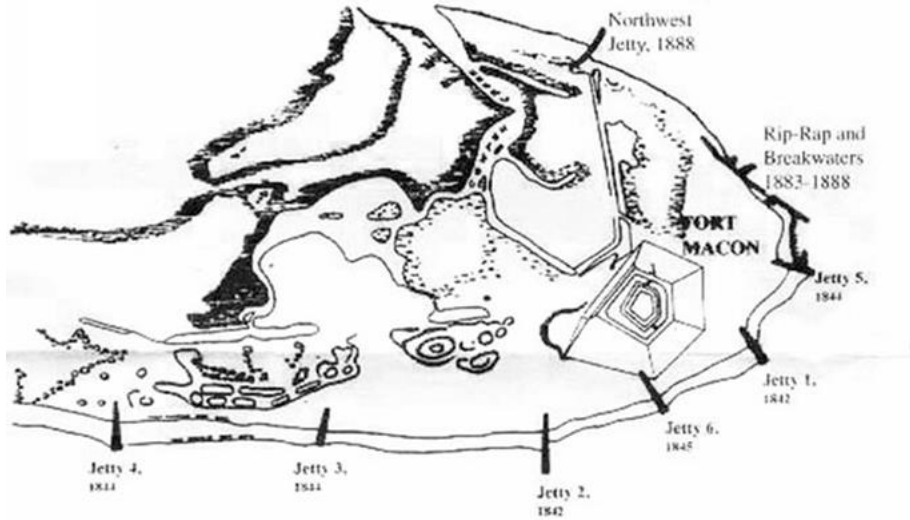
Sand trapping case study: Groins at Buxton, NC



- High natural background erosion rate
- > 20 ft/year before erosion mitigation
- Groins installed 1969, repeated nourishment since then
- These actions reduced erosion rates
- Groins caused shoreline offset downdrift (south)
- With groin deterioration, erosion rates could increase toward natural background rates
- Erosion mitigated by nourishment

Oblique view looking north from Cape Hatteras, 2017

Sand trapping case study: Terminal groin at Fort Macon, NC

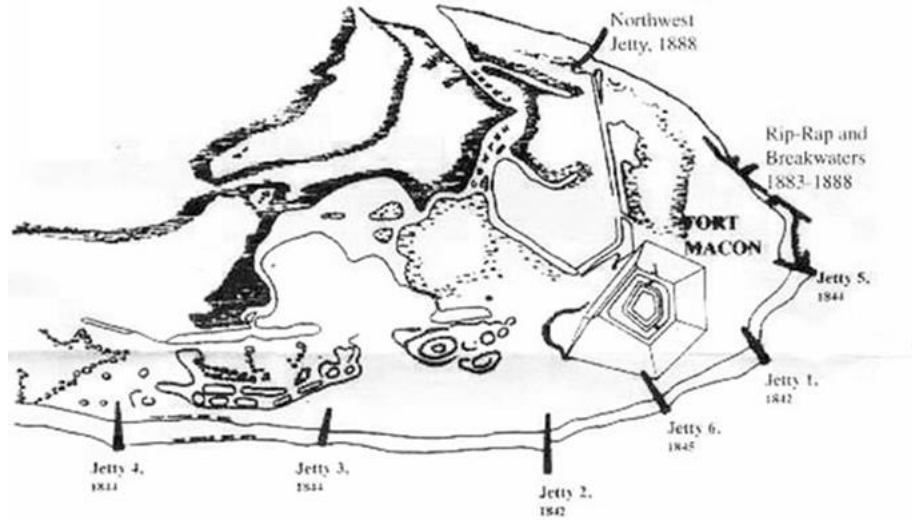


Groins emplaced 1842 - 1888,
under direction of Robert E. Lee.



1971 photo, after terminal groin
construction, USACE

Sand trapping case study: Terminal groin at Fort Macon, NC



Groins emplaced 1842 - 1888, under direction of Robert E. Lee.



1971 photo, after terminal groin construction, USACE



Dredged material placed on beach passes over, through, and around the terminal groin, toward inlet.

Effectiveness depends on three elements:

- Fixed inlet channel position due to federal navigation actions
- Sustained sand supply through dredged material placement
- A permeable groin that enables continued sand bypassing

Removal or degradation of any one would likely result in a different and less stable shoreline condition.

Sand trapping case study: Groins and terminal groin at Bald Head, NC



- Chronic erosion of South Beach documented since 1970's
- Highest erosion rates at western end, adjacent Wilmington Harbor Navigation Channel

Aerial view of Bald Head Island, 2025

Sand trapping case study: Groins and terminal groin at Bald Head, NC



Aerial view of geotextile sand tubes, 2013



Post-terminal groin construction, 2021

- Chronic erosion of South Beach documented since 1970's
- Highest erosion rates at western end, adjacent Wilmington Harbor Navigation Channel
- Geotextile sand tubes installed in 1995; Slowed but did not stop erosion
- Terminal groin constructed in 2015 has helped mitigate erosion
- Continued sand placements (beneficial use) on South Beach

Sand trapping case study: Nearshore breakwaters at Presque Isle, PA



- On a spit in Lake Erie
- Breakwaters installed 1986 to mitigate erosion by trapping sand



Sand trapping case study: Nearshore breakwaters at Presque Isle, PA



- On a spit in Lake Erie
- Breakwaters installed 1986 to mitigate erosion by trapping sand



- Downdrift erosion resulted
- 1000 ft of erosion between 1986 & 2025 (~ 25 ft/yr)
- Trees, shrubs on beach

Sand trapping and shoreline hardening case study: New Jersey



- To mitigate erosion, reduce risk, seawalls and groins since 1915
- Widespread loss of beaches
- Study in 1989 suggested nourishment would last longer if long groins were removed (cost prohibitive)

Sand trapping and shoreline hardening case study: New Jersey



- To mitigate erosion, reduce risk, seawalls and groins since 1915
- Widespread loss of beaches
- Study in 1989 suggested nourishment would last longer if long groins were removed (cost prohibitive)
- Groins 'notched' 1994 - 1999 to allow some sand bypassing
- Ongoing nourishment required (nearly \$1B for 21 miles since 1991)

Shoreline hardening case study: Seawall at Galveston, TX



The Galveston Seawall

(Photo credit Jesse Stevens,

<https://www.sandnsea.com/blog/galveston-seawall/>)

- To reduce risk after a catastrophic hurricane, a three-mile seawall was constructed by 1904 (and the city elevated)
- Lengthened to ~ six miles by 1963
- Achieved risk reduction
- Beaches lost
- Erosion undermining seawall by 1934; further armoring was needed (stone)
- To protect seawall, a groinfield was added; nourishment necessary since 1985

Case Study Insights:

- Adverse effects occur and require ongoing mitigation.
- Where groins are located adjacent to sand sinks adverse effects can be more limited.
- Loss of beach in front of hardened shorelines is inevitable on an eroding coastline, unless sand can be supplied at a rate sufficient to counter erosion
 - nourishment will become more expensive with increasing sea-level rise and intense storms
 - and if infrastructure is threatened, nourishment has already been insufficient

4. Other States & Hard Structures

Summary:

Although hard structures have been permitted in these states, their use is generally discouraged by all due to associated adverse impacts

Structures Regulated
Alabama
California
Connecticut
Delaware
Florida
Georgia
Louisiana
Maryland
Massachusetts
New Jersey
New York
Oregon
<i>South Carolina *</i>
Virginia
Washington

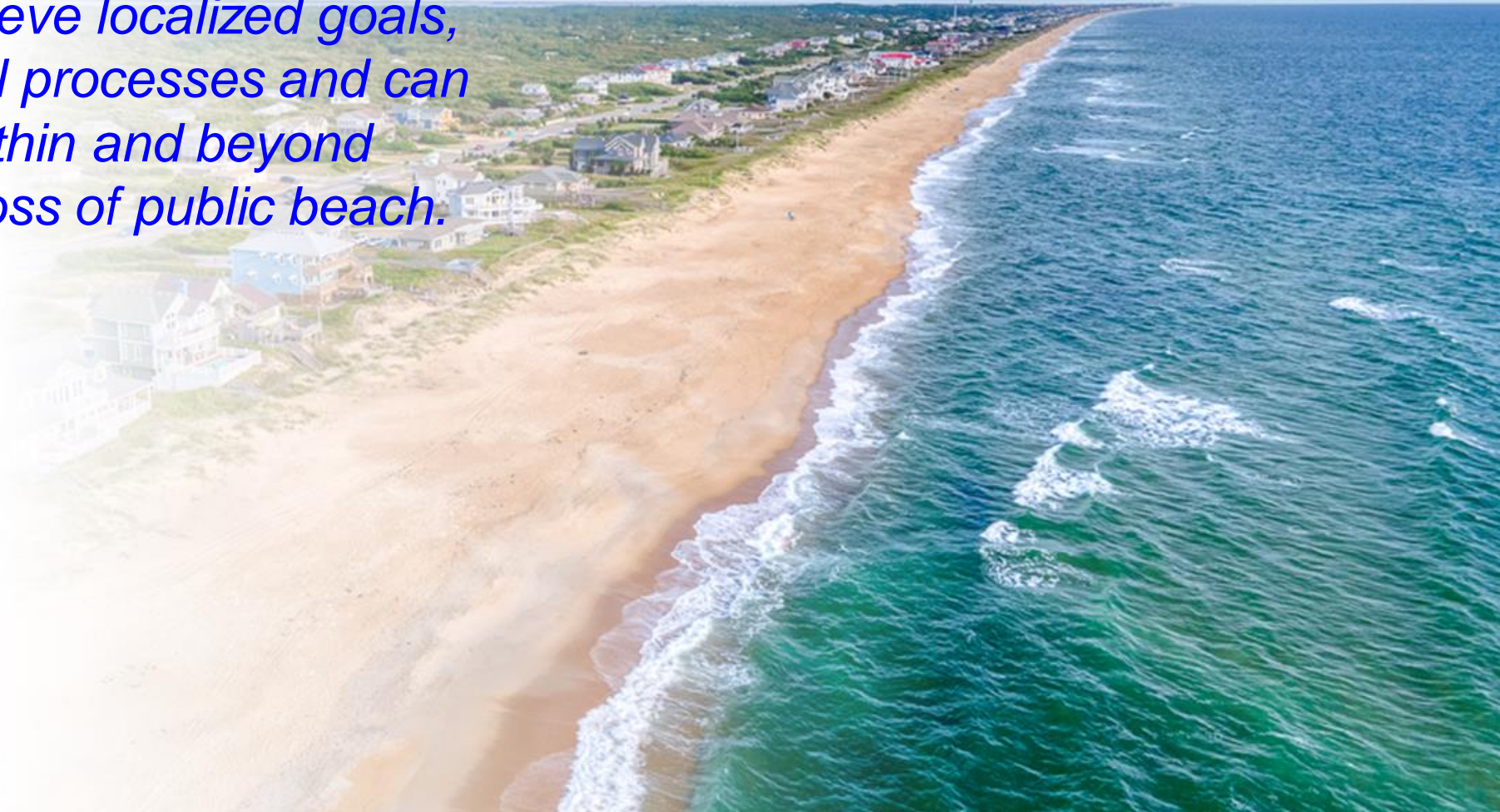
<u>New</u> Structures Not Allowed
Maine
Rhode Island
Texas

** South Carolina prohibits new structures, but may allow groins on nourished beaches*

5. Science Panel Recommendations

- **Maintain a cautious approach to expansion of the use of hard structures:**

Hard structures may achieve localized goals, but they also alter coastal processes and can create adverse effects within and beyond project areas, including loss of public beach.

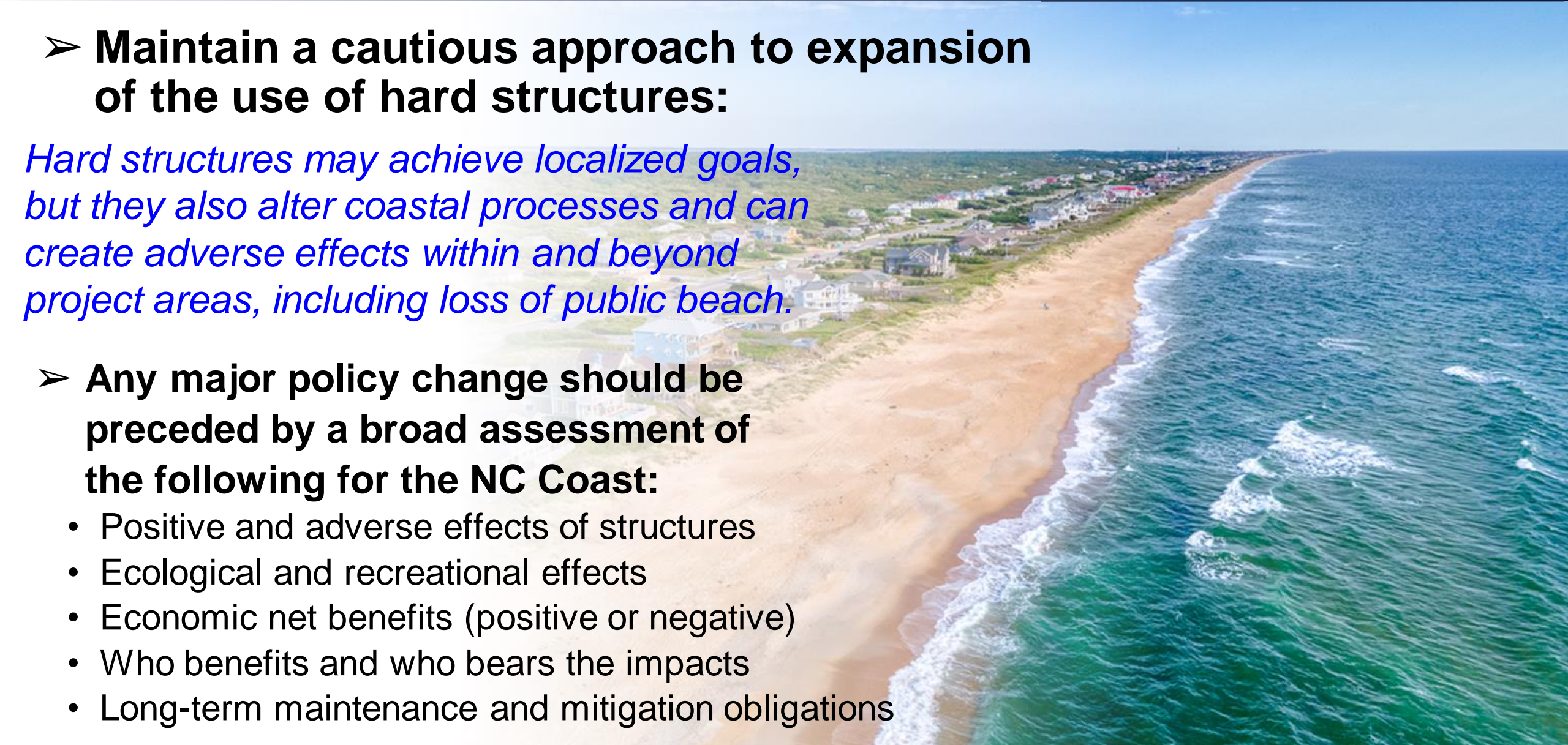


5. Science Panel Recommendations

- **Maintain a cautious approach to expansion of the use of hard structures:**

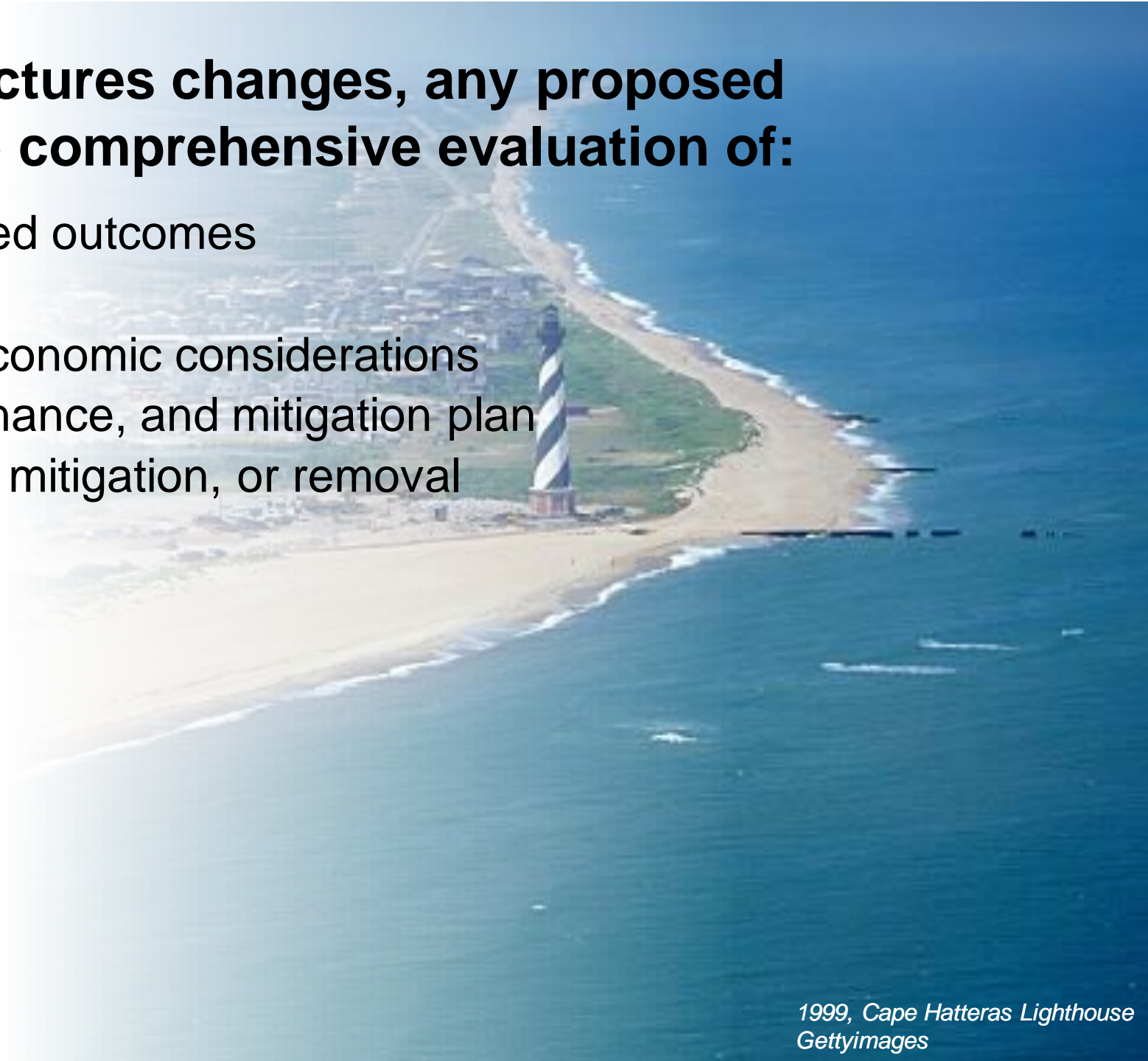
Hard structures may achieve localized goals, but they also alter coastal processes and can create adverse effects within and beyond project areas, including loss of public beach.

- **Any major policy change should be preceded by a broad assessment of the following for the NC Coast:**
 - Positive and adverse effects of structures
 - Ecological and recreational effects
 - Economic net benefits (positive or negative)
 - Who benefits and who bears the impacts
 - Long-term maintenance and mitigation obligations



➤ **If the NC policy on structures changes, any proposed project should undergo comprehensive evaluation of:**

- Likelihood of achieving intended outcomes
- Adverse physical effects
- Ecological, recreational and economic considerations
- A required monitoring, maintenance, and mitigation plan
- Clear triggers for modification, mitigation, or removal



➤ **If the NC policy on structures changes, any proposed project should undergo comprehensive evaluation of:**

- Likelihood of achieving intended outcomes
- Adverse physical effects
- Ecological, recreational and economic considerations
- A required monitoring, maintenance, and mitigation plan
- Clear triggers for modification, mitigation, or removal

➤ **Not authorizing projects for which adverse effects cannot be mitigated sufficiently to make tradeoffs acceptable.**

➤ **If the NC policy on structures changes, any proposed project should undergo comprehensive evaluation of:**

- Likelihood of achieving intended outcomes
- Adverse physical effects
- Ecological, recreational and economic considerations
- A required monitoring, maintenance, and mitigation plan
- Clear triggers for modification, mitigation, or removal

➤ **Not authorizing projects for which adverse effects cannot be mitigated sufficiently to make tradeoffs acceptable.**

Long-term function and habitability of NC barrier islands is more likely if priority remains on strategies that maintain the alongshore sand transport system and allow barrier-island process to occur, rather than attempting to hold the shoreline in place with hard structures.

Lessons from Other Coastlines

Other places are moving cautiously:

- Many U.S. states limit hard structures on sandy oceanfront shorelines.
- Some states that historically allowed more shoreline armoring have moved toward stronger limits.
- Many coastal regions with experience using hard structures are now reassessing their use.
- In parts of Europe (e.g. The Netherlands), hard structures are being removed, modified, or set back so natural coastal processes can resume where feasible (“managed realignment”).



photo credit: The Outer Banks Voice

Lessons from Other Coastlines

Other places are moving cautiously:

- Many U.S. states limit hard structures on sandy oceanfront shorelines.
- Some states that historically allowed more shoreline armoring have moved toward stronger limits.
- Many coastal regions with experience using hard structures are now reassessing their use.
- In parts of Europe (e.g. The Netherlands), hard structures are being removed, modified, or set back so natural coastal processes can resume where feasible (“managed realignment”).

Expanding use of hard structures in North Carolina would run counter to a broader trend among jurisdictions with long-term experience managing adverse effects of structures.



photo credit: The Outer Banks Voice