Reducing Downdrift Impacts through Detailed Analysis of Alternatives Utilizing a Morphology Model, St. Joseph Peninsula, FL

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COASTAL
PROTECTION
ENGINEERING

"All models are wrong, but some are useful"

George E. P. Box, 1976. "Science and Statics".

"Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful."

George E. P. Box, 1987. "Empirical Model-Building and Response Surfaces".

"To find out what happens to a system when you interfere with it, you have to interfere with it"

George E. P. Box, 1987. "Empirical-Model Building and Response Surfaces".

COASTAL STRUCTURES – WHY DO WE NEED IT?

- Excessive proliferation of structures in the 50s, 60s into the 70s.
- 1980s, 1990s shift to beach nourishment. Structures were even banned in some states.
- Nourishment has been very successful over the years, but there are challenges.
- Main challenges in Florida include **lack of sand resources** and **occurrence of erosion hot spots that shorten nourishment lifetime**.
- Some areas cannot be maintained feasibly by adding sand alone.
- 'Surgical' introduction of structures is needed in selected projects.

Miami Beach, early 1970s

COASTAL STRUCTURES – WHY DO WE NEED IT HERE?

- Structures can be useful in areas with extremely high erosion rates (erosion hotspots), to reduce nourishment losses and increase nourishment lifetime.
- Project area is critically eroded as per FDEP and has one has one of the highest rates of erosion in the State of Florida.
- Only one evacuation route and threatened by erosion. Infrastructure at risk.
- Model was used to refine the design of structures by balancing sand retention and magnitude of downdrift impacts.

St. Joseph Peninsula Project Area, Nov. 2024

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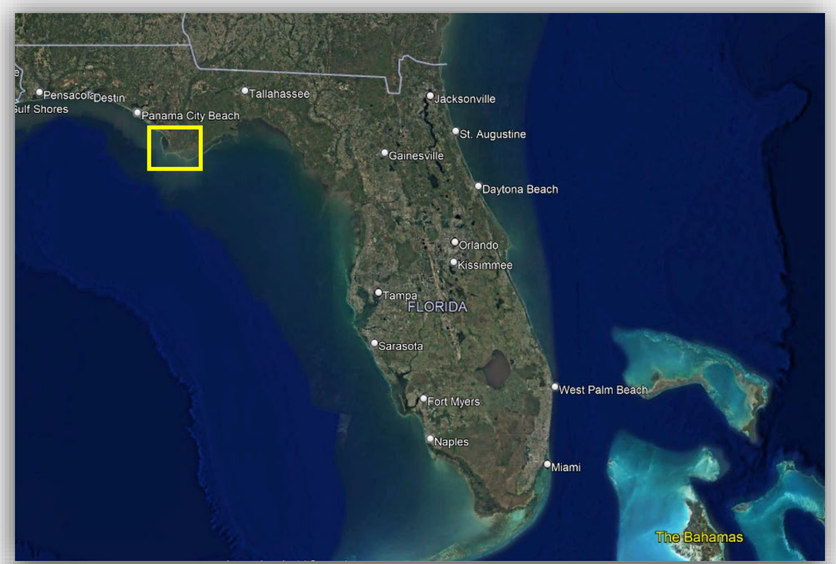
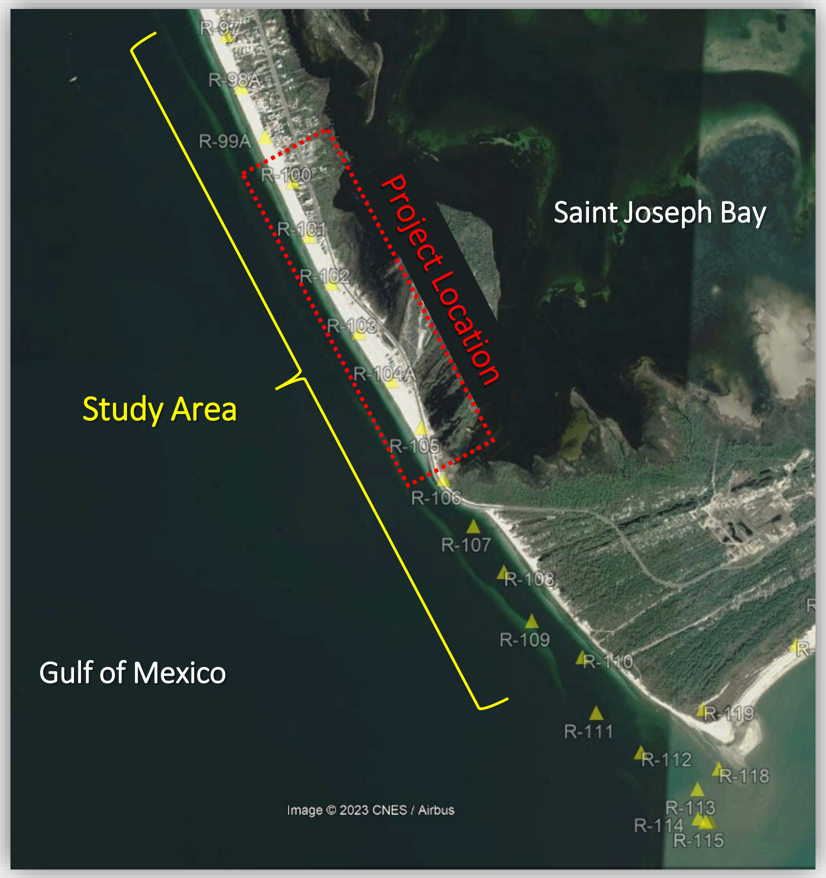
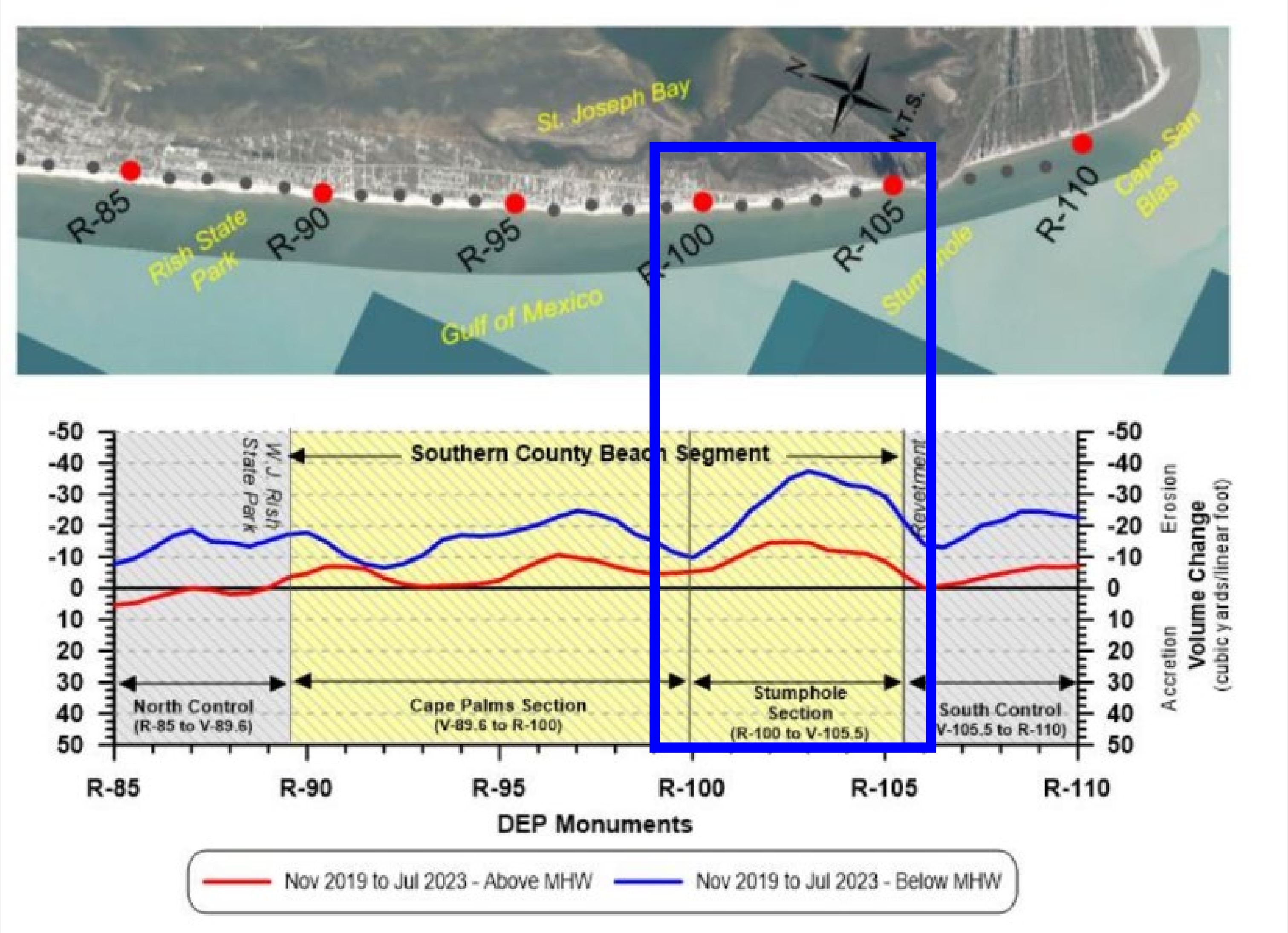
CASE 2. SJP COASTAL STRUCTURES, 2024





POST-CONSTRUCTION EROSION RATES



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CASE 2. SJP COASTAL STRUCTURES, 2024

Beach fill:

~650,000 cy

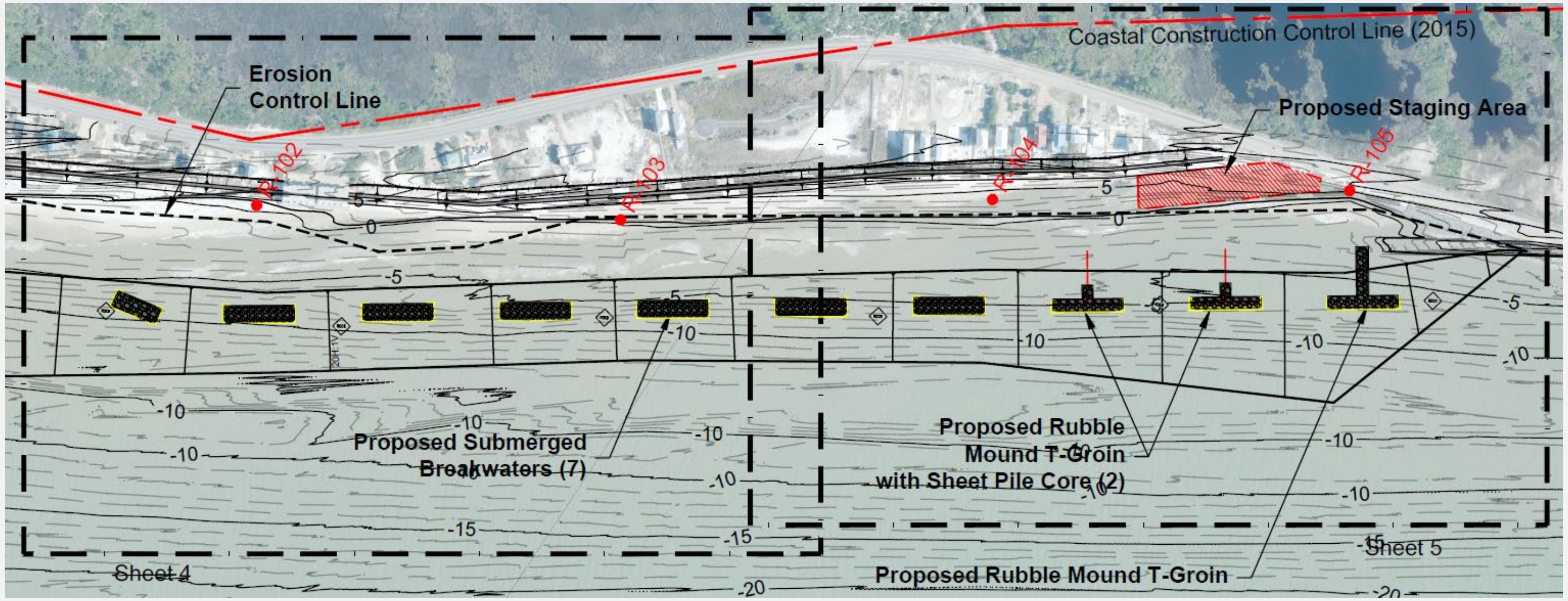
7 submerged breakwaters:

200 ft length
-2 ft NAVD88 height
200 ft spacing

3 T-groins:

200 ft length
+4 ft NAVD88 height
200 ft spacing

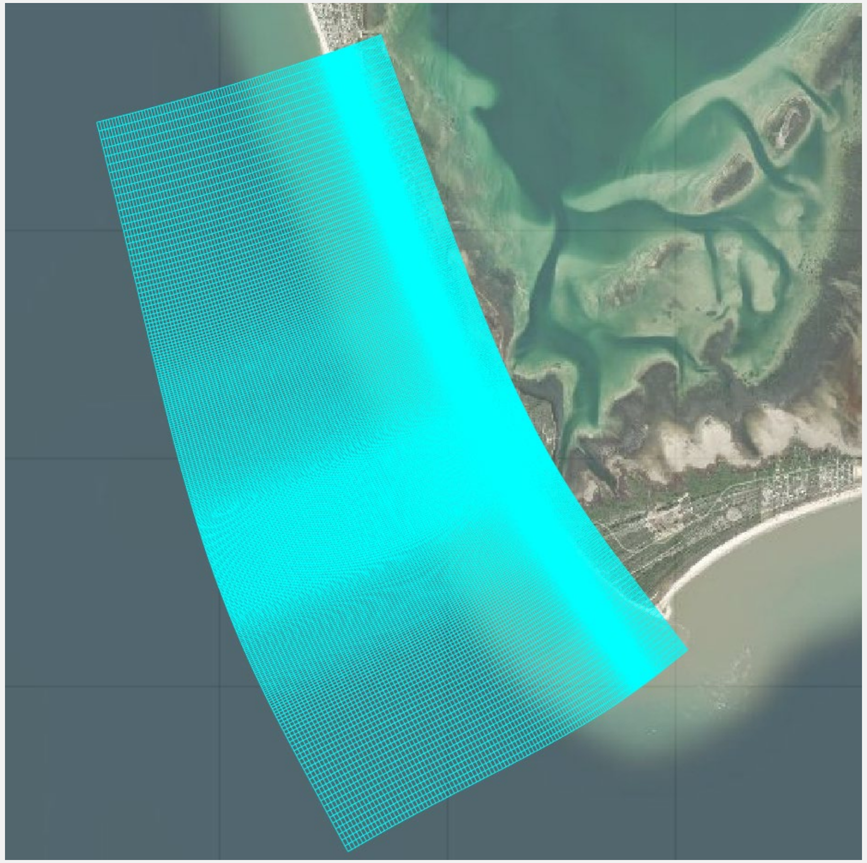
ALT B – PREVIOUS DESIGN



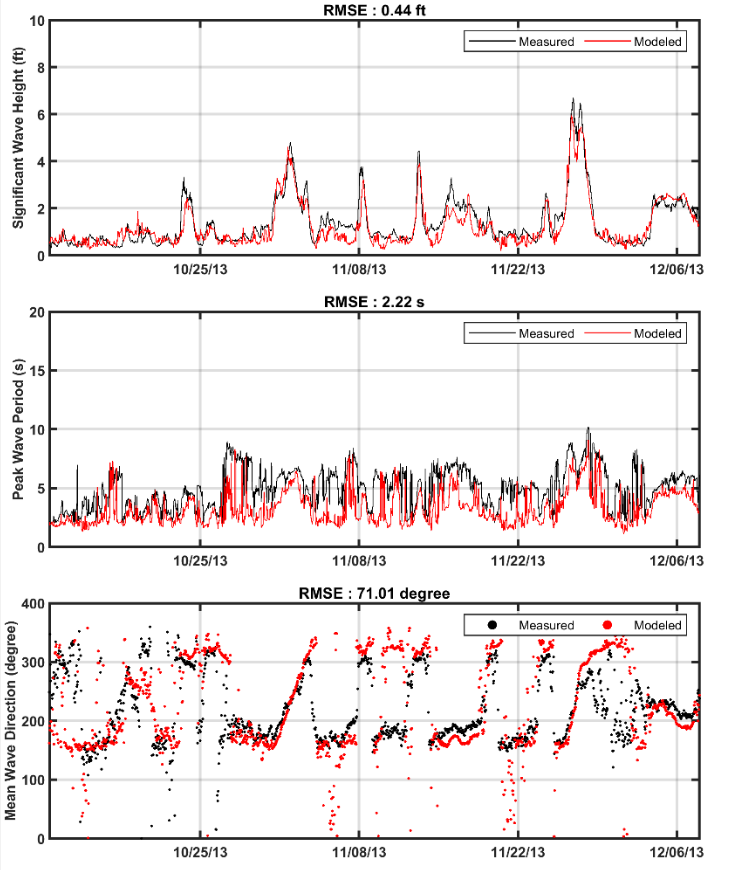
Concerns about downdrift impacts from agencies.
The model was set-up to investigate these concerns and evaluate alternative designs if necessary.

SJP DELFT3D MODEL

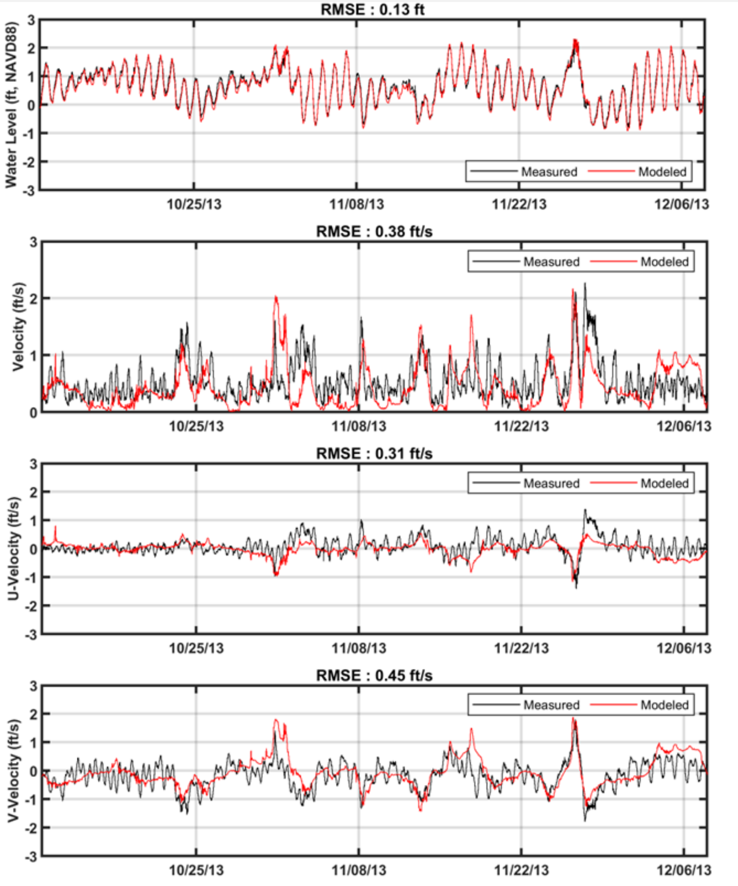
- Wave and flow calibration to local ADCP measurements.
- Morphology calibration to morphology change trends, sediment transport nodal zone location and volume changes.



Detailed flow grid

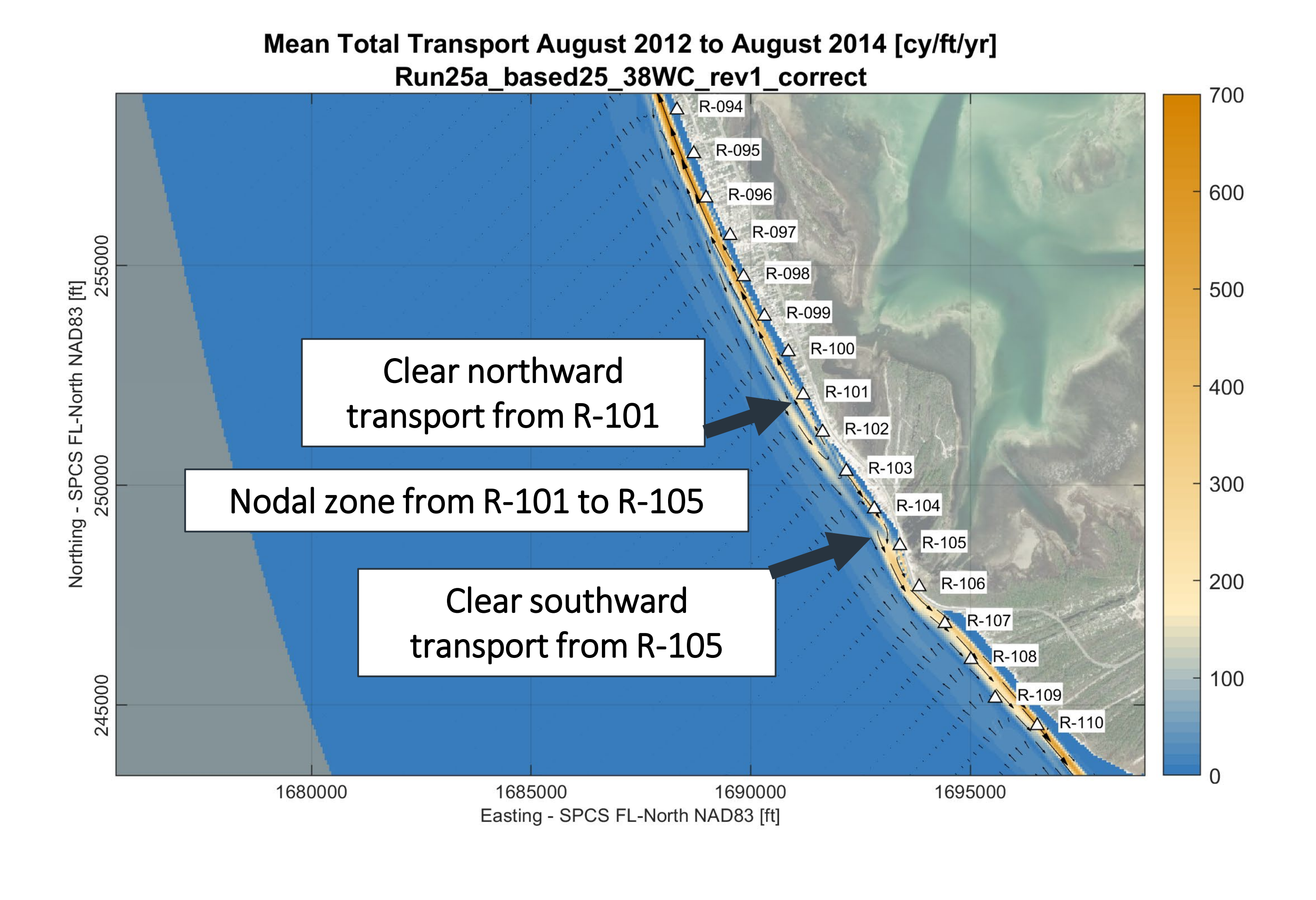


Wave calibration



Flow calibration

SJP DELFT3D MODEL – SEDIMENT TRANSPORT & REVERSAL



- 100+ iterations and every wave climate schematization method tested.
- Novel method of wave climate schematization developed based on potential sediment transport timeseries (Q&A for additional details, future presentation).
- The selected best calibration run reproduces the expected nodal zone.

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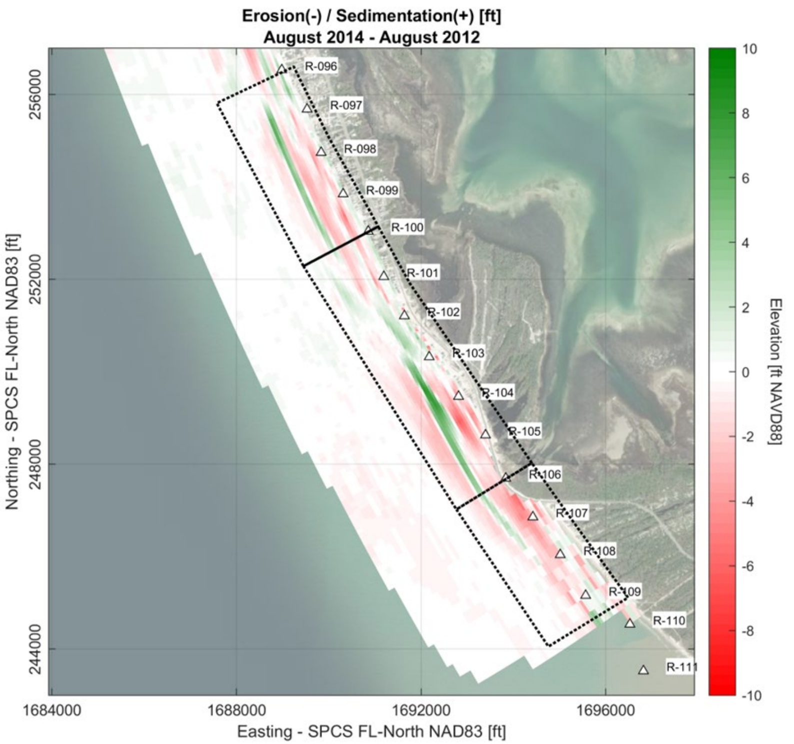
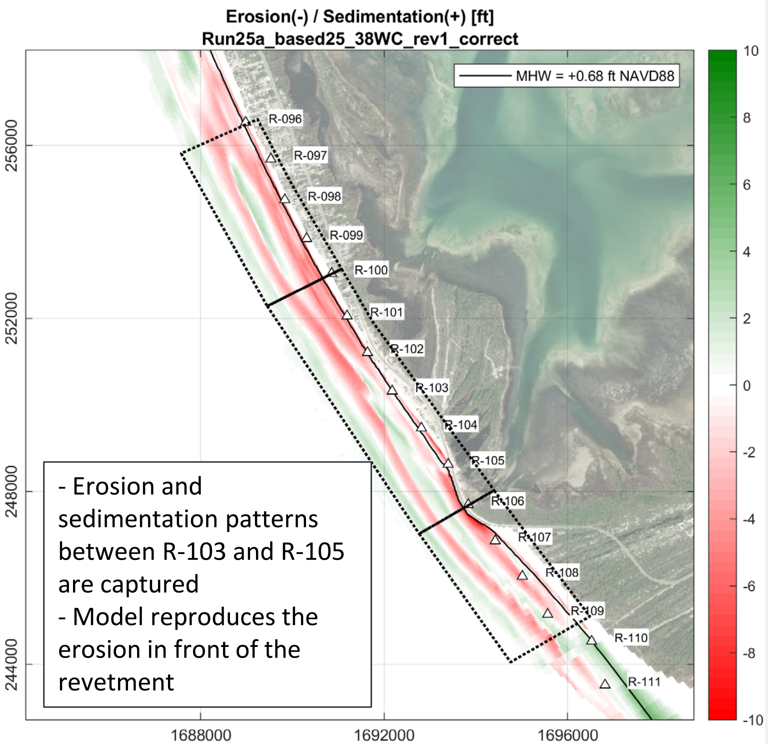
SJP DELFT3D MODEL

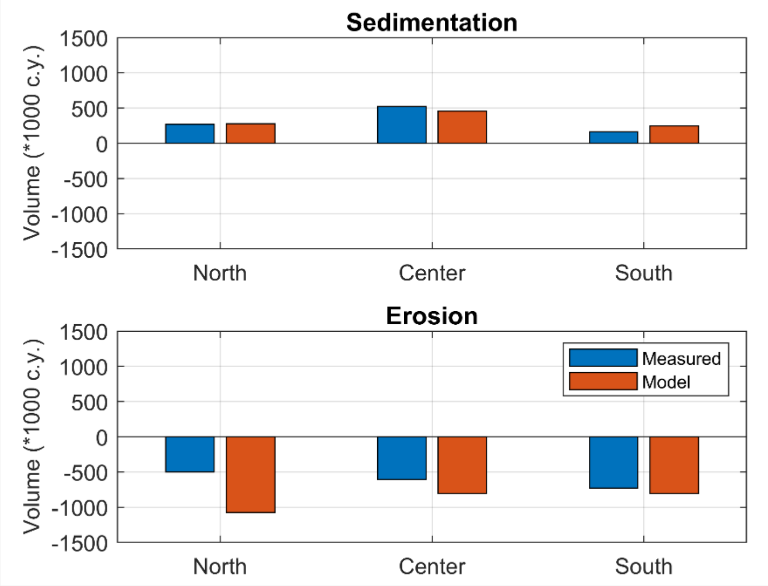
- Morphology Calibration – Input schematization and sediment transport parameters
- Model was able to reproduce measured volume changes within the project area and adjacent areas
- Magnitude of erosion slightly overestimated, but erosion/sedimentation trends matching well



Two Years Morphology Measured



Two Years Morphology Modeled

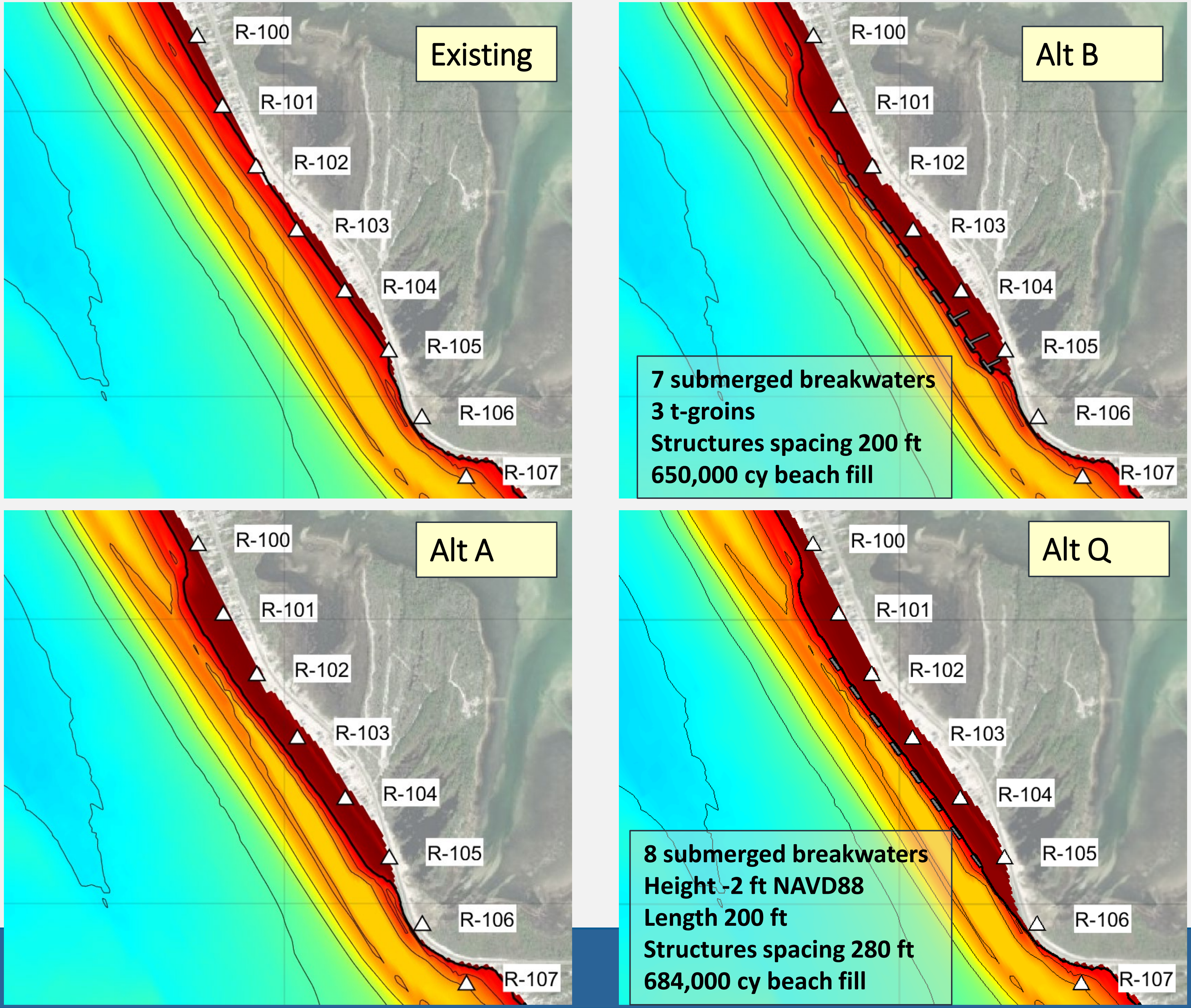


Volume Changes

ALTERNATIVES EVALUATED

	Alternative.	Description
1	Existing Conditions	2023 survey
2	Alternative A	Beach fill only (BF)
3	Alternative B	Previous design (BF + 7 submerged breakwaters, 3 T-groins)
4	Alternative C	BF + 4 submerged breakwaters + 3 T-groins
5	Alternative D	BF + 7 submerged Breakwaters
6	Alternative E	BF + 3 T-groins
7	Alternative F	BF + 10 submerged breakwaters
8	Alternative G	BF + 8 submerged breakwaters
9	Alternative H	Alt. B + extended BF to the north
10	Alternative I	Alt. B with structures shifted 50ft landward
11	Alternative J	Alt. D with structures shifted 50ft landward
12	Alternative K	BF + 7 subm. breakwaters w/ more spacing between structures
13	Alternative L	BF + 5 longer submerged breakwaters
14	Alternative M	BF + every other subm. breakwater from Alt F
15	Alternative N	Alt D + 1 PAG
16	Alternative O	Alt M + last T-groin 50ft landward
17	Alternative P	Alt G + additional fill between R-105 and the revetment
18	Alternative Q	BF w/ additional fill south + 8 subm. breakw. with ↑ spacing
19	Alternative R	BF w/ additional fill south + breakwater height +0.5ft NAVD

- Previous design: Concerns about potential downdrift impacts initially evaluated.
- Screening of 16 additional design alternatives using 2-years morphology simulation.
- Iterative process, new alternatives developed based on results from previous simulation.
- Criteria: Sand retention, downdrift impacts, storm protection.
- Preferred Alt. Q, Existing, Alt. A and Alt. B simulated for 6 years and specific storms.



ALTERNATIVES

- **Alternative A** - Beach fill only (BF). 650k cy, ~130 cy/ft.
- **Alternative B** – Previous design. BF + 7 breakwaters, + 3 T-Groins
- **Alternative Q** – Remove T-Groins, modified breakwater spacing, added an 8th breakwater, added 34K cy extra fill at south end.

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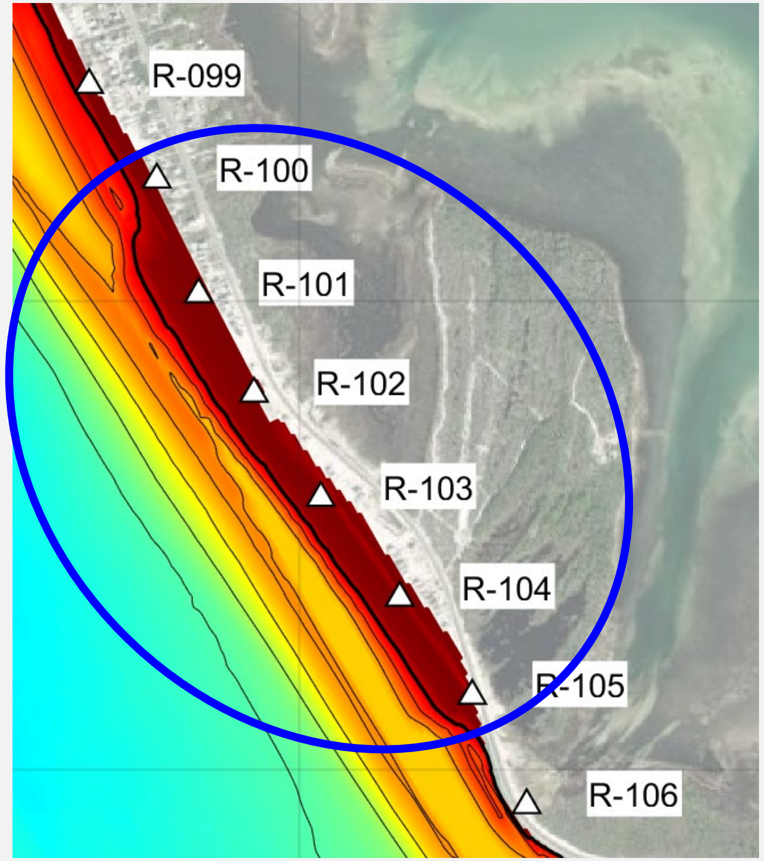
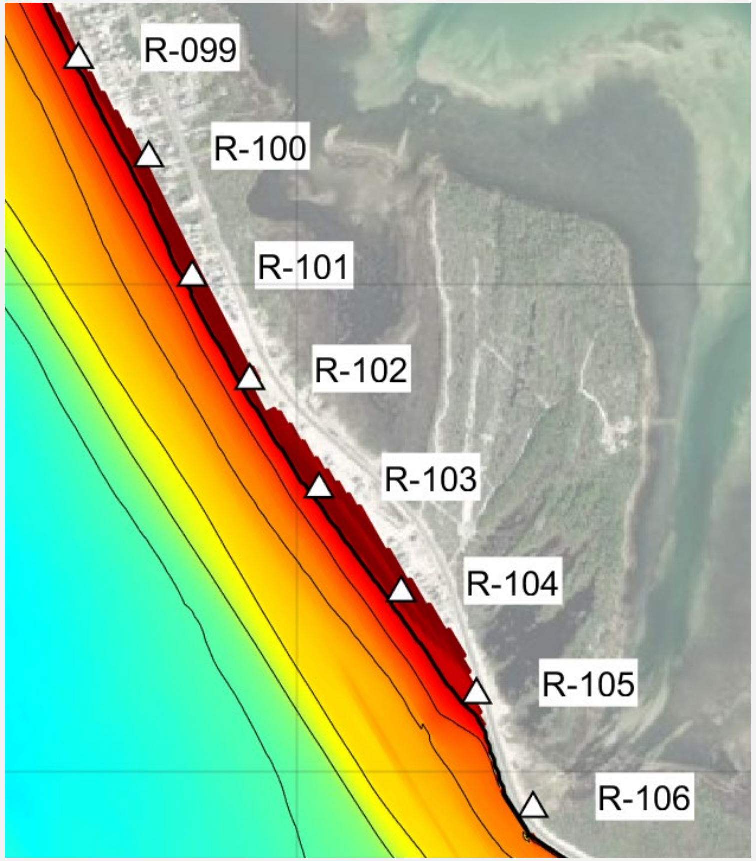
BEACH FILL ONLY

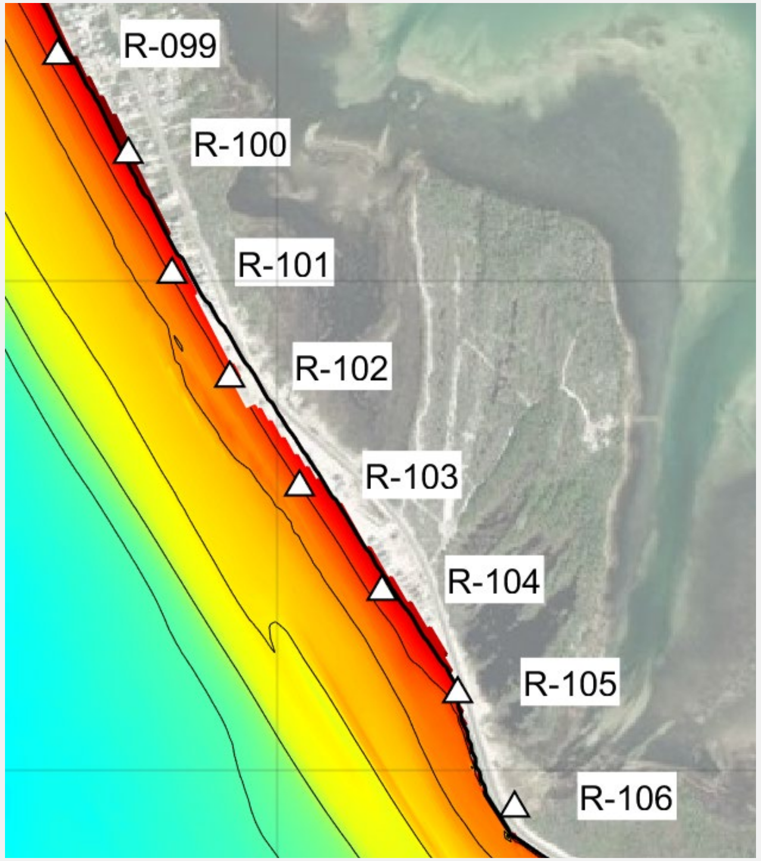
Initial Condition



2-Years Simulation



6-Years Simulation



- Most of fill gone after 2 years.
- Fill completely gone after 6 years.
- 650,000 cy, ~130 cy/ft

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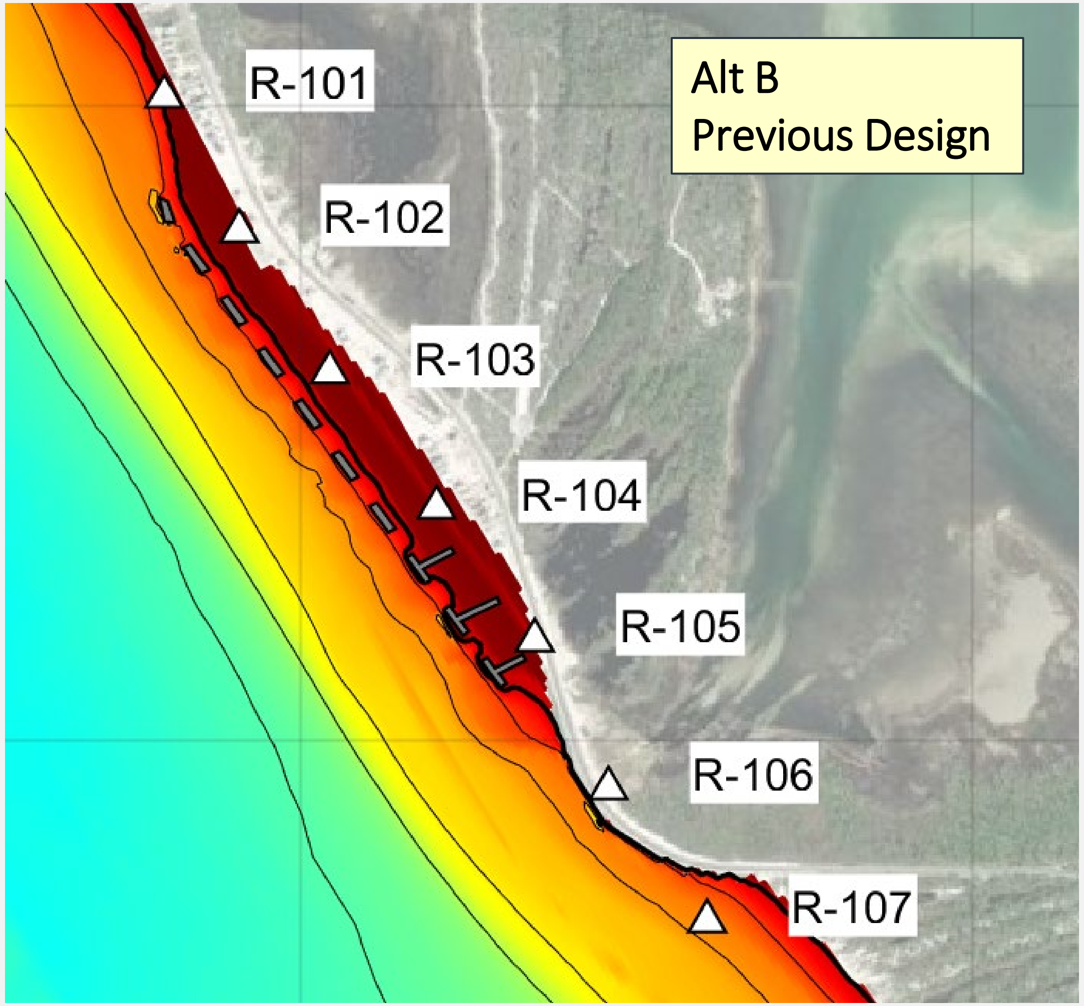
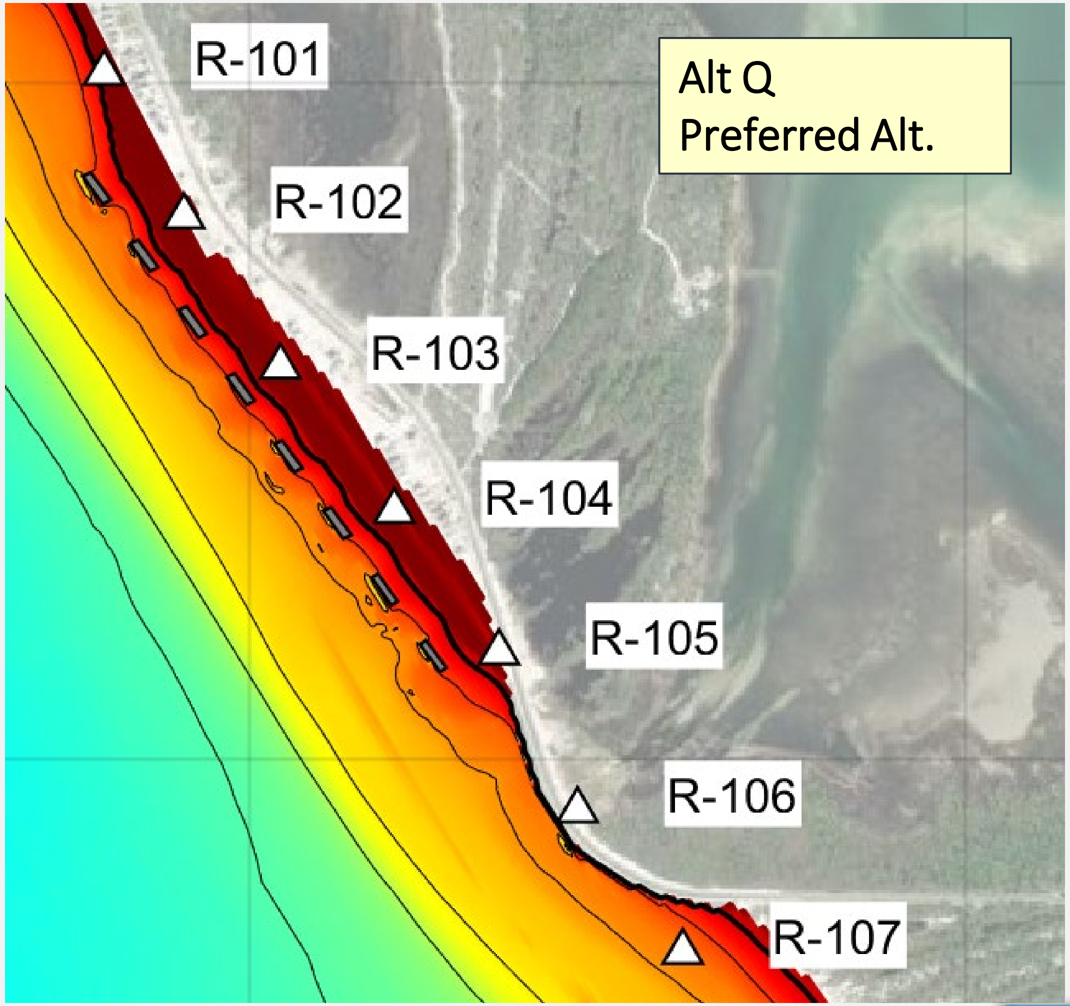
ALT Q VS ALT B AFTER 2 YEARS





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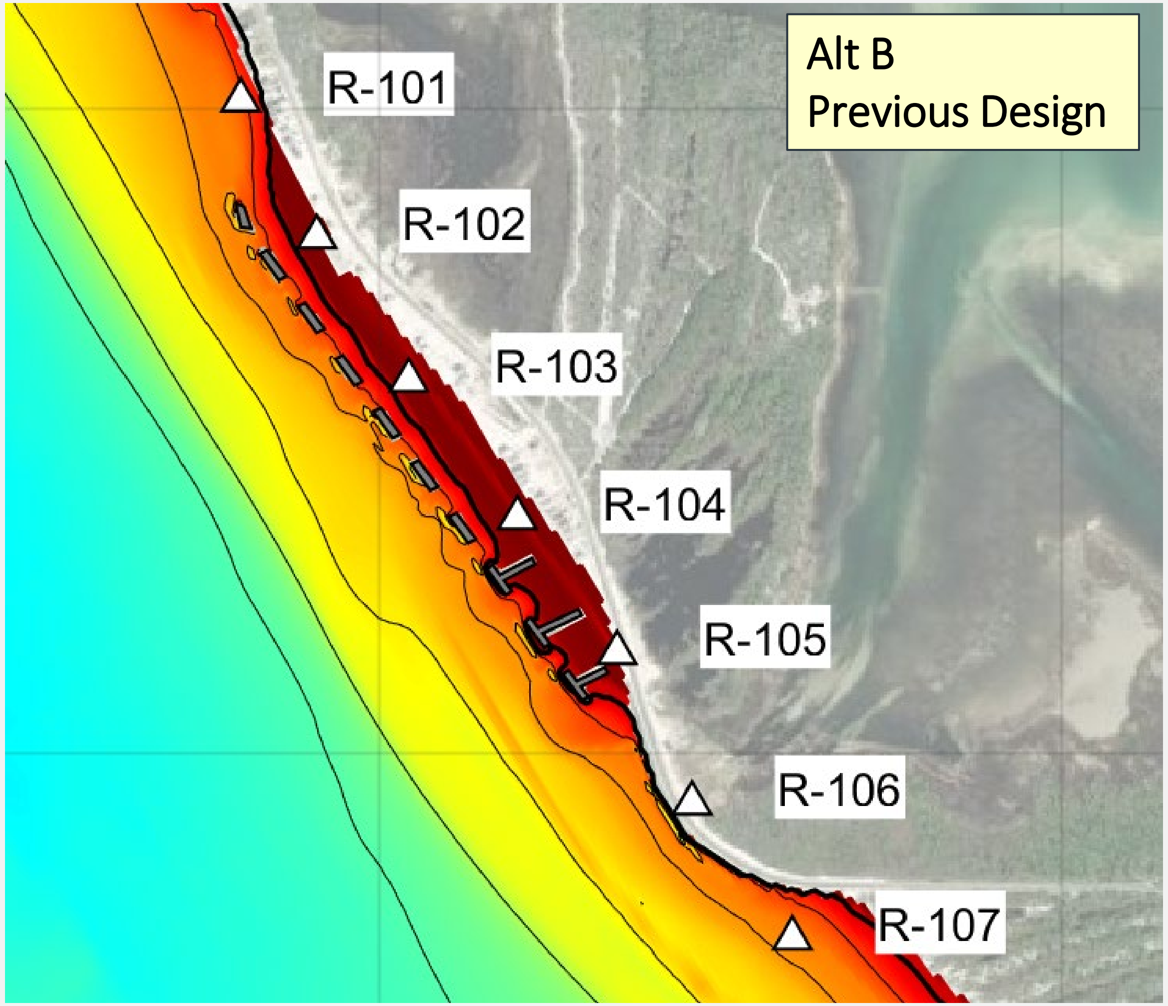
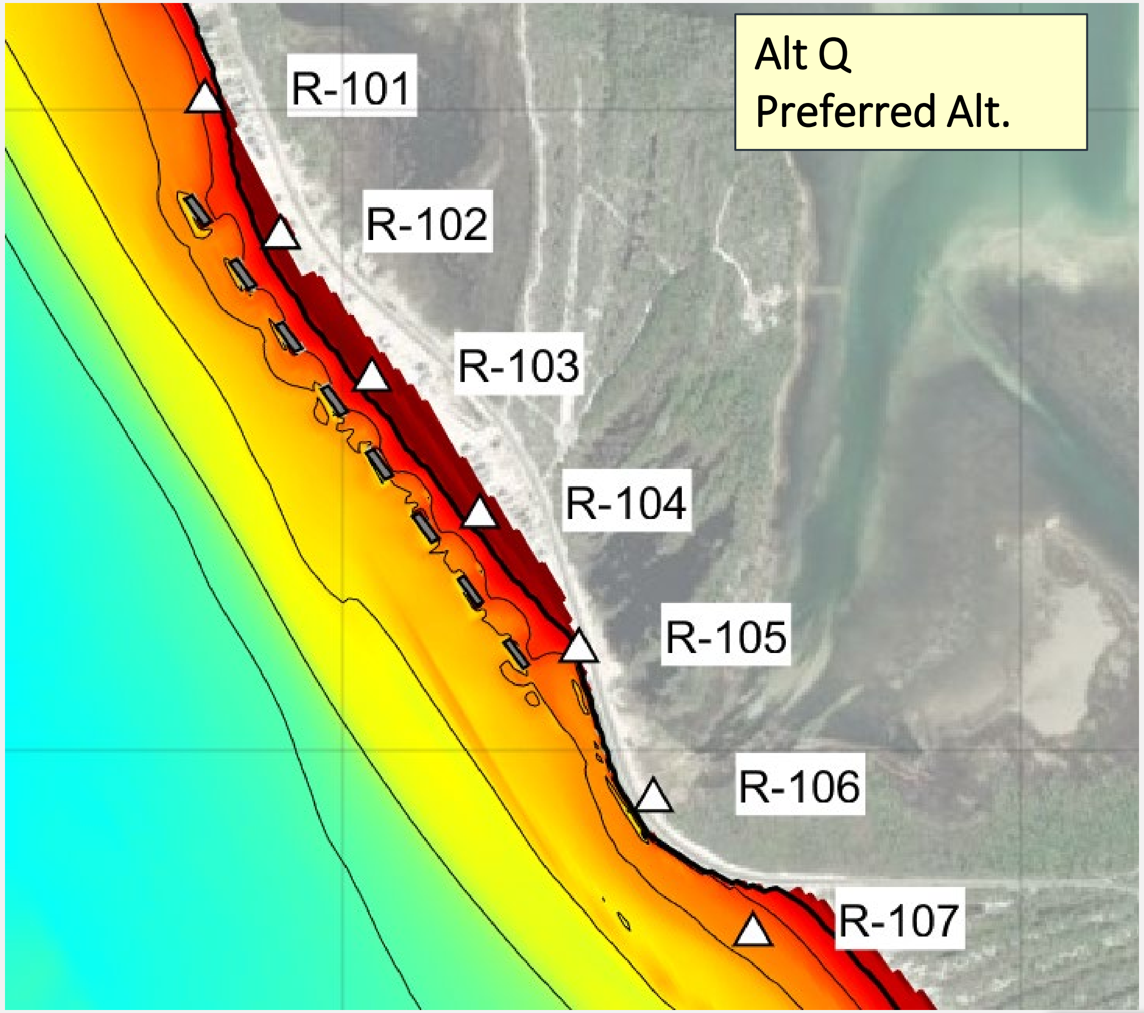
ALT Q VS ALT B AFTER 6 YEARS





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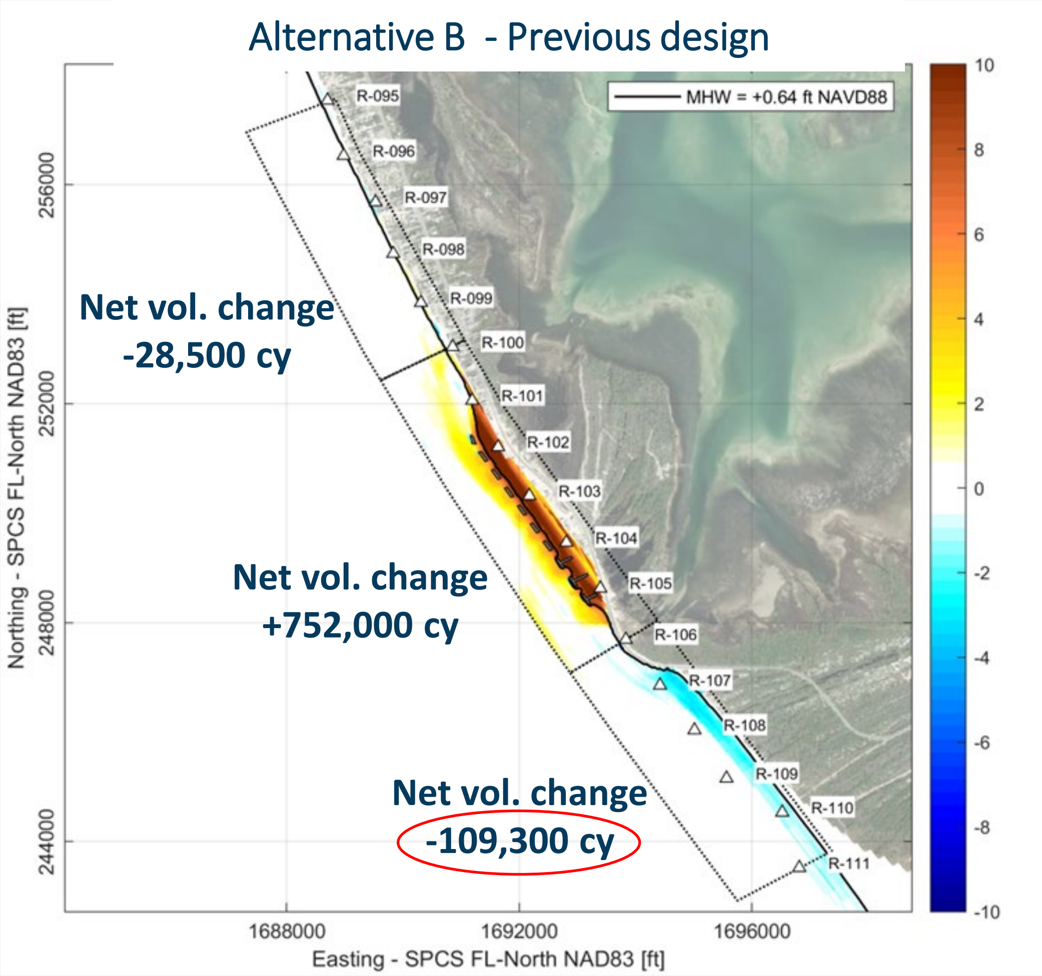
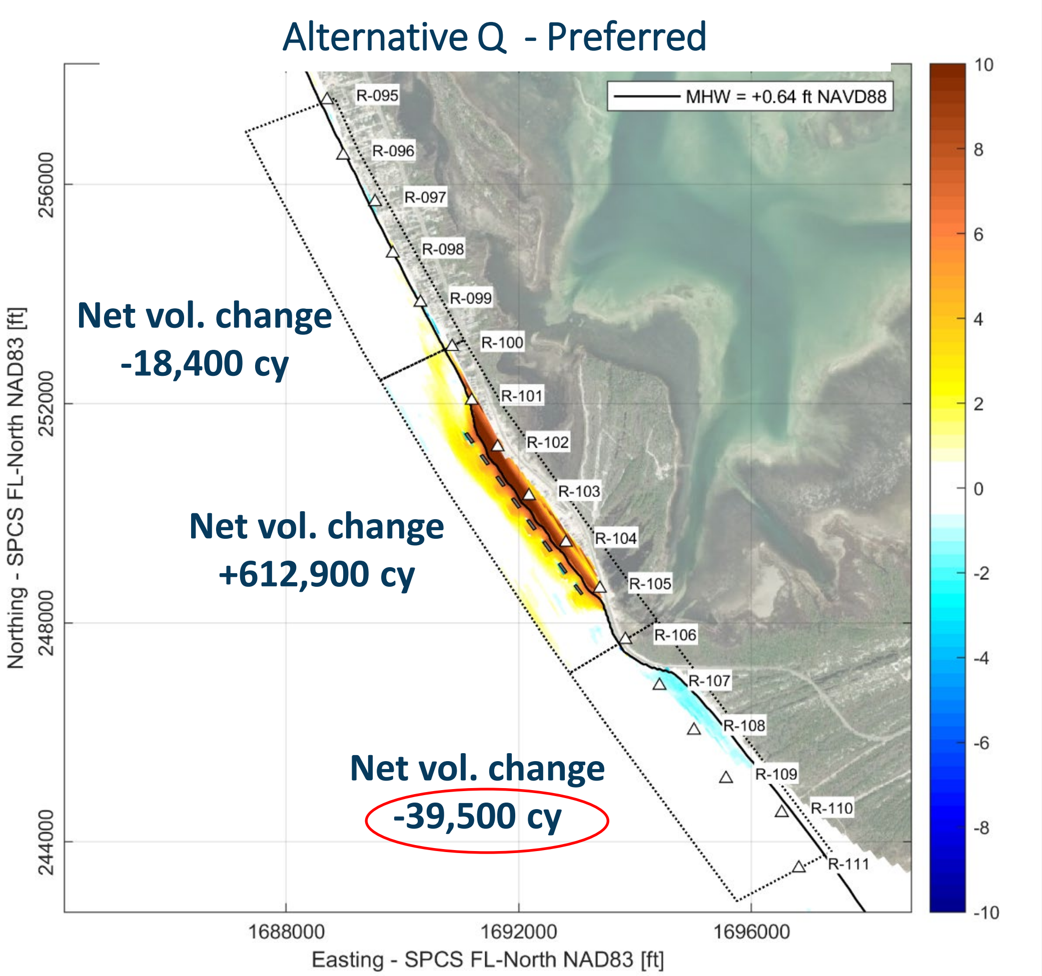
RELATIVE CHANGES AFTER TWO YEARS





- **Relative Changes =** Final simulated bathy of alternative minus final bathy of existing conditions
- Alt. Q reduces impact to manageable volumes, areas impacted are stable/accretional.

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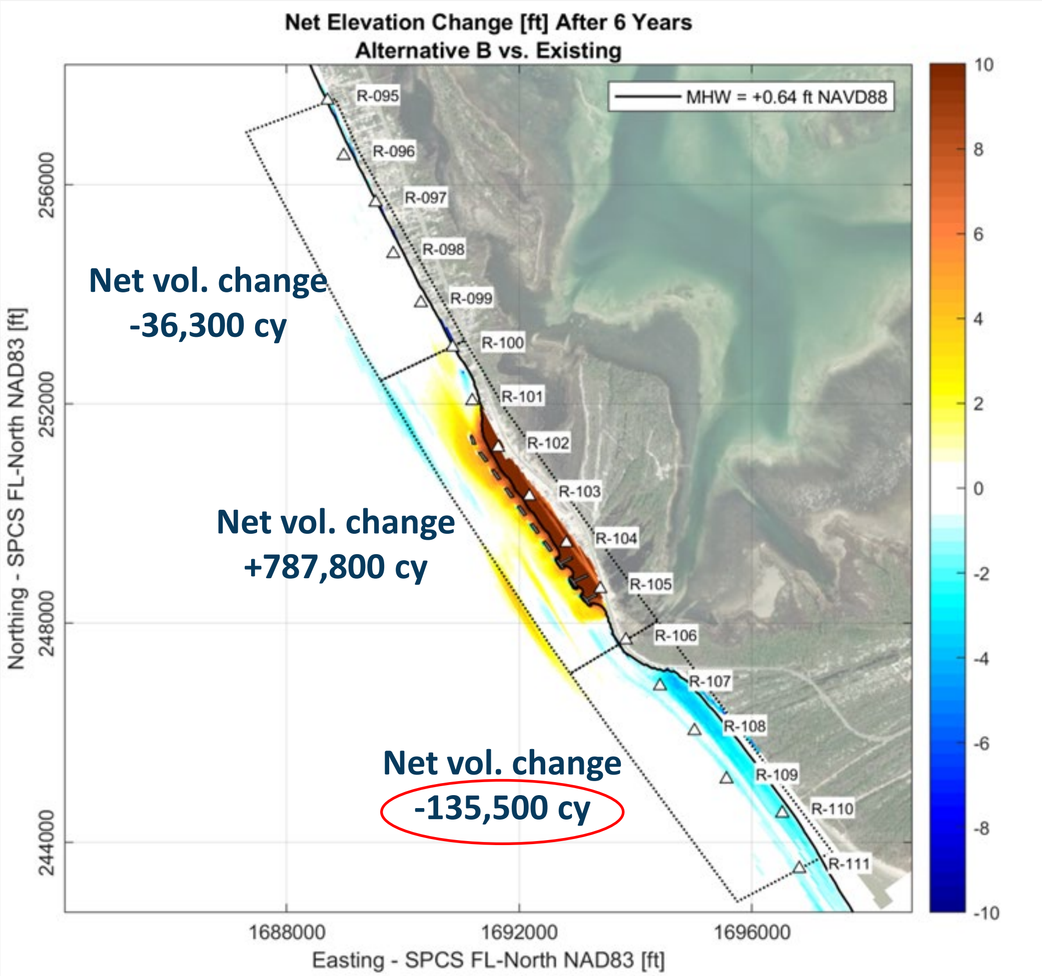
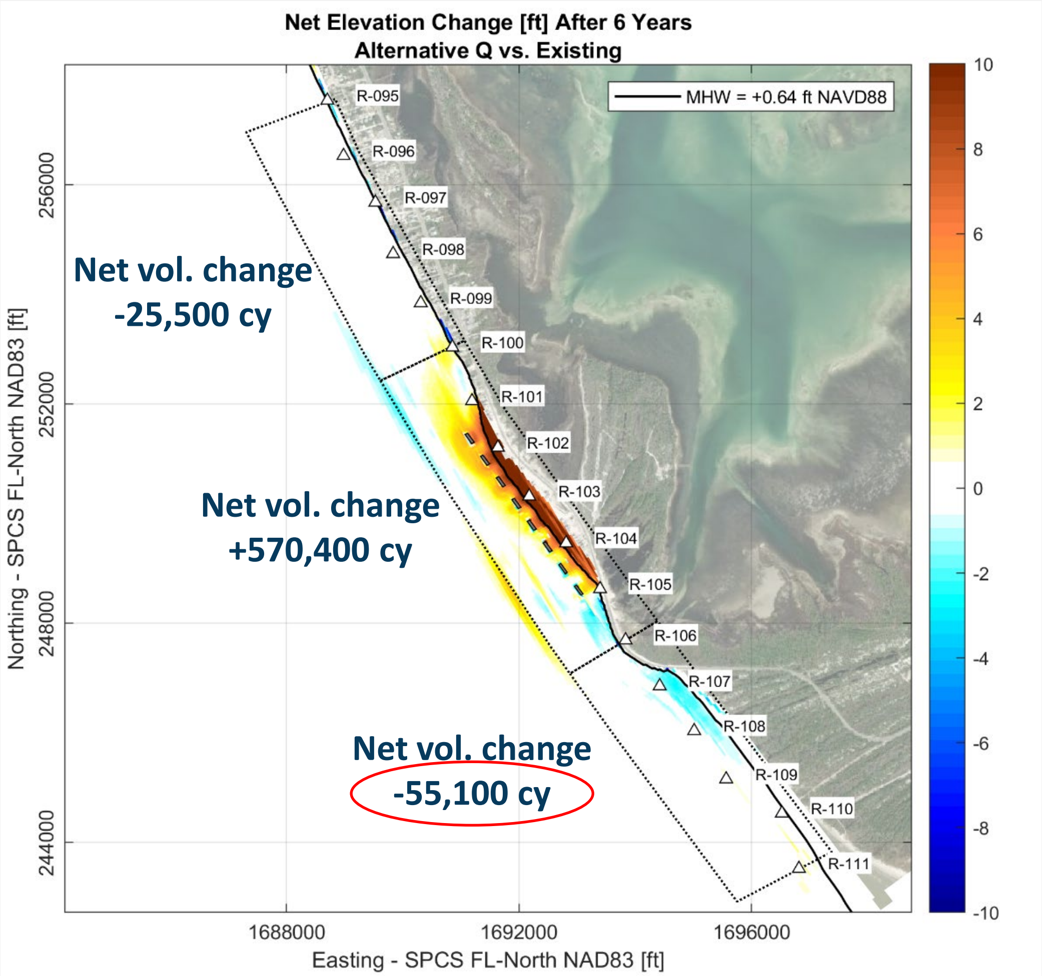
RELATIVE CHANGES AFTER SIX YEARS





- **Relative Changes =** Final simulated bathy of alternative minus final bathy of existing conditions
- Alt. Q reduces impact to manageable volumes, areas impacted are stable/accretional.

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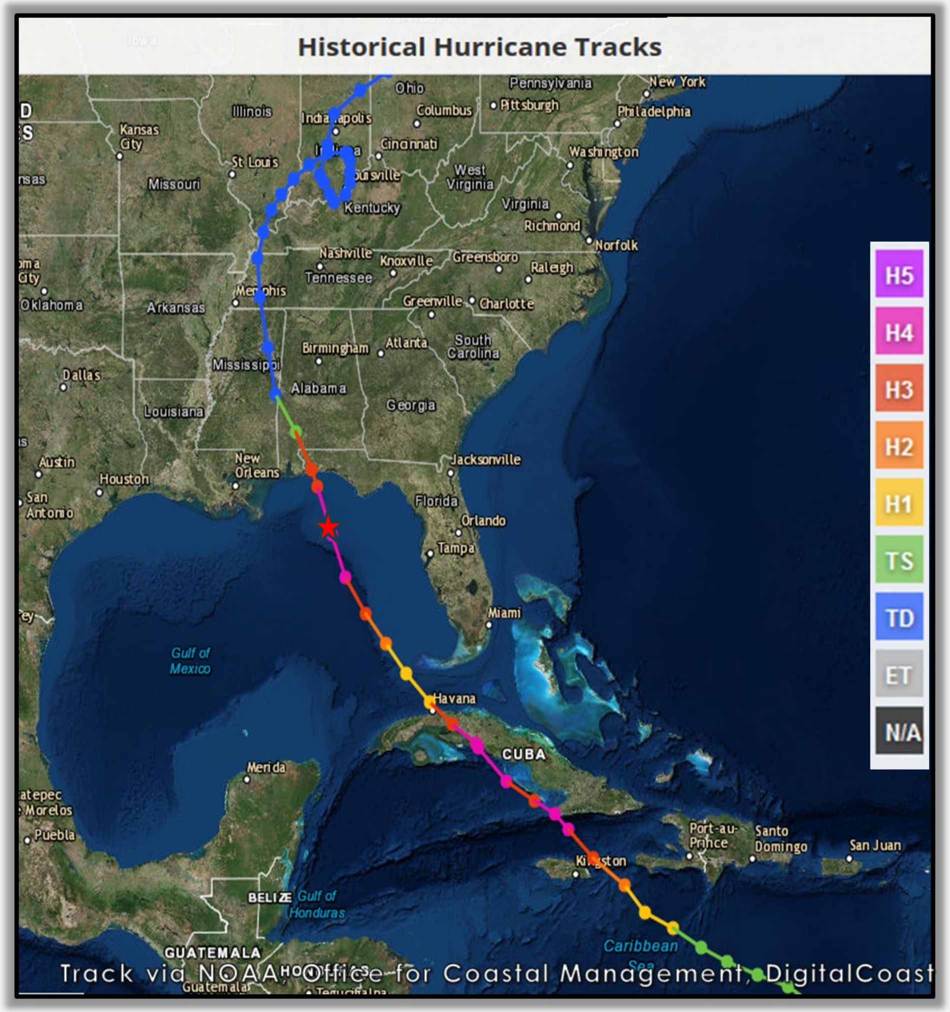
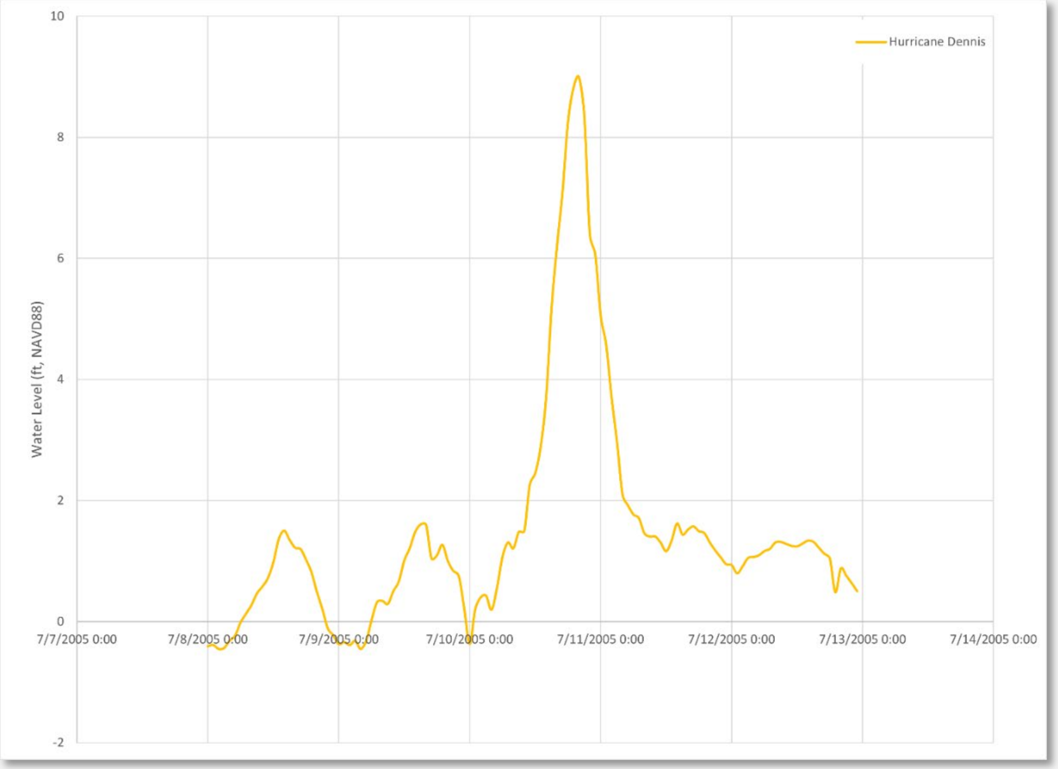
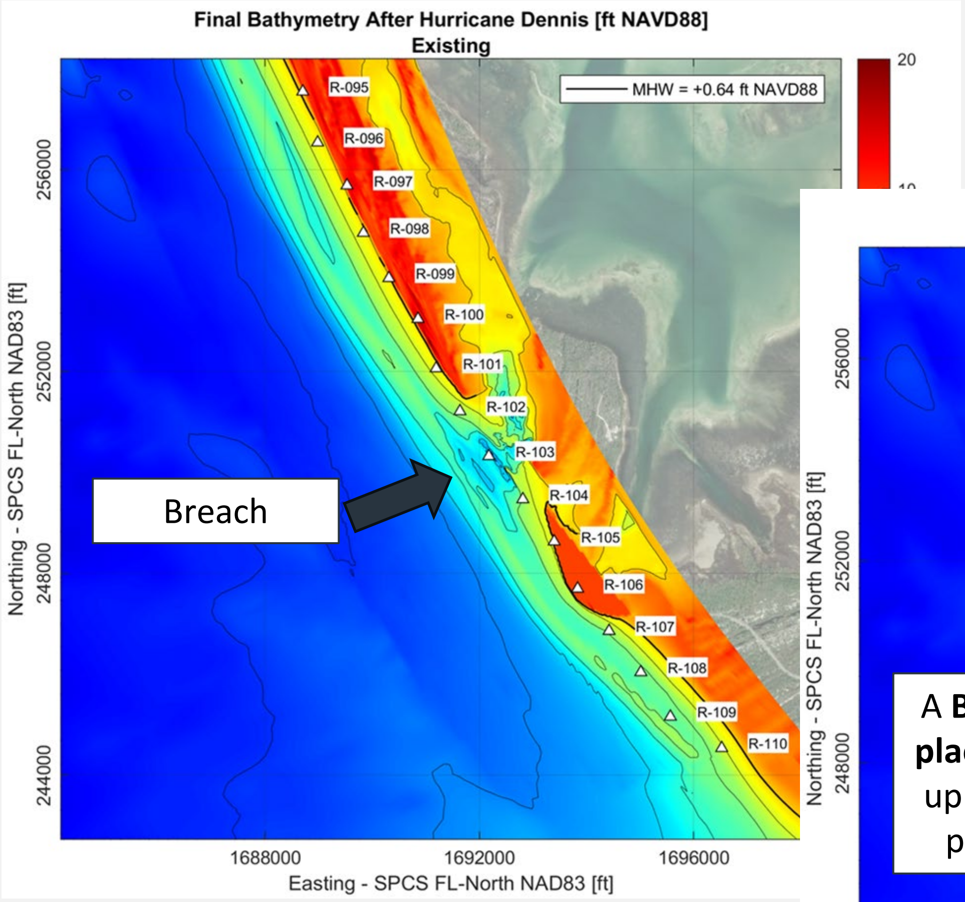
HURRICANE DENNIS (2005) MODEL RESULTS

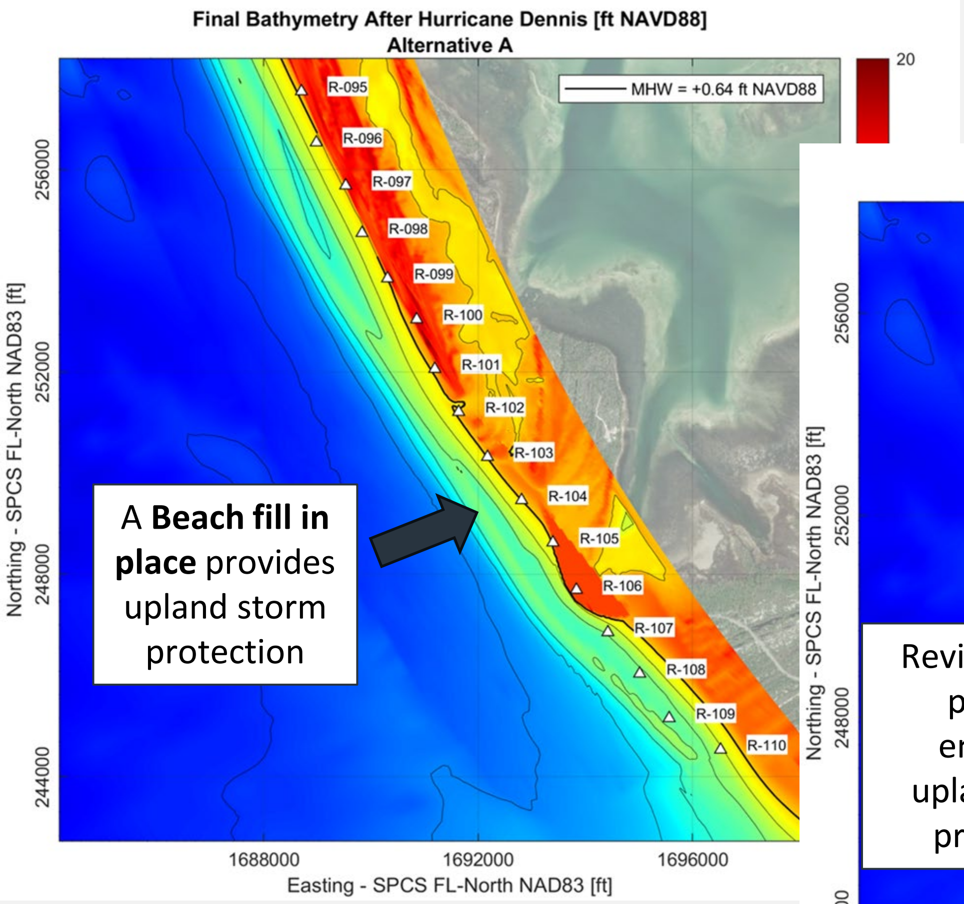


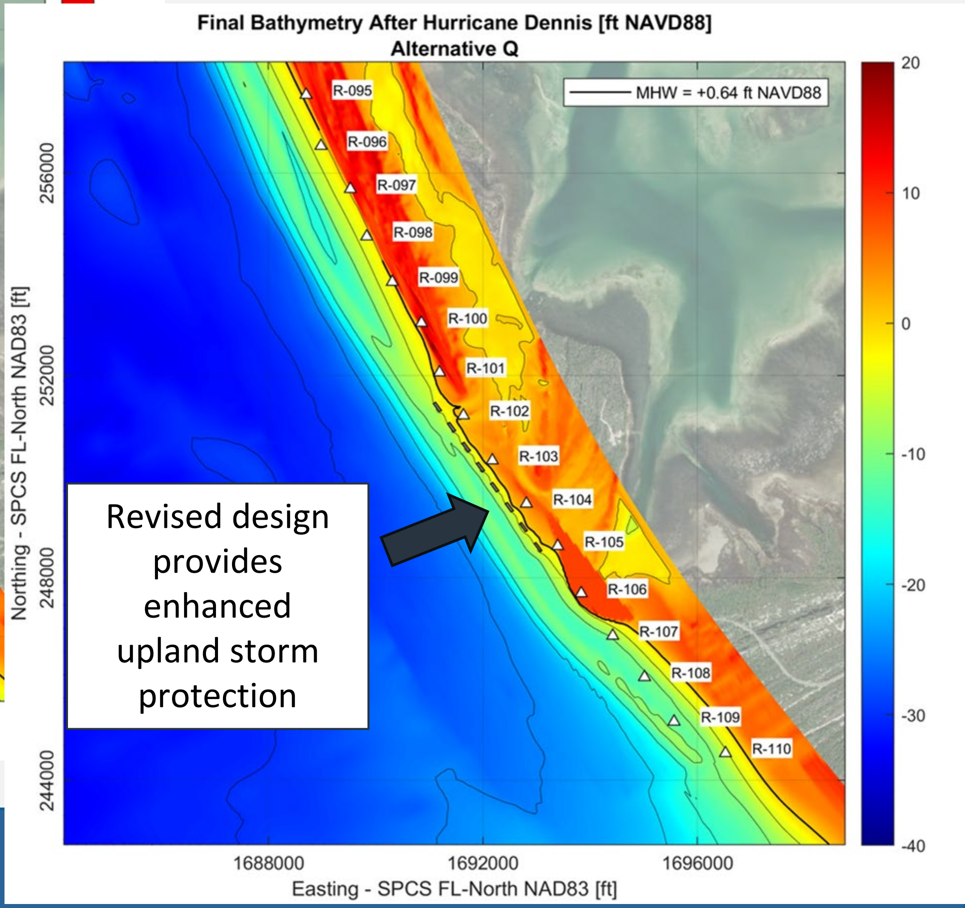
- Hurricane Dennis made landfall at Navarre Beach, FL as a Cat 3 storm



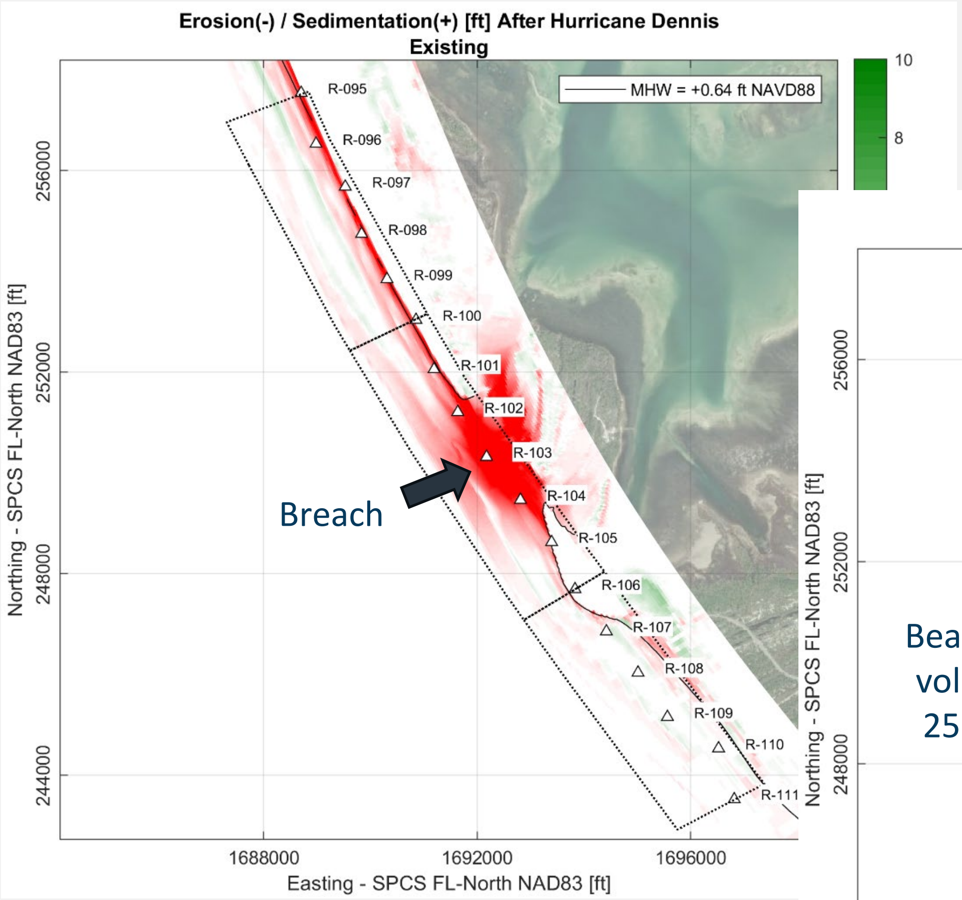
POST-HURRICANE DENNIS BATHYMETRY

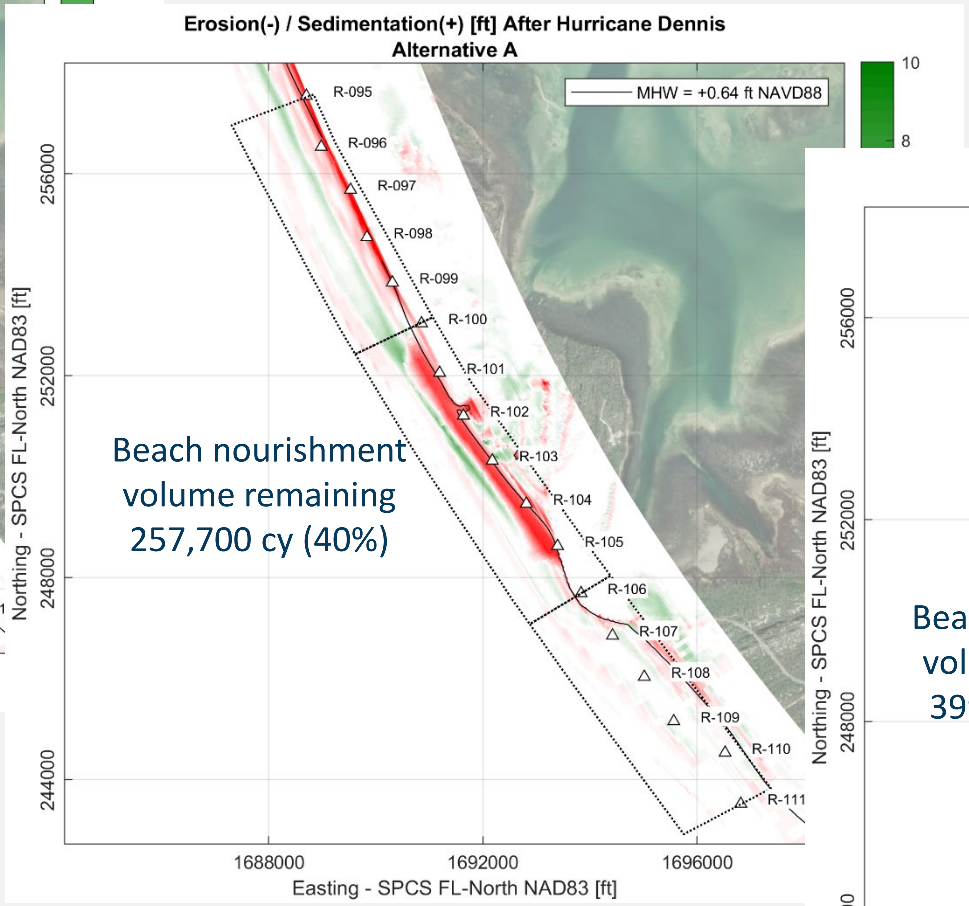


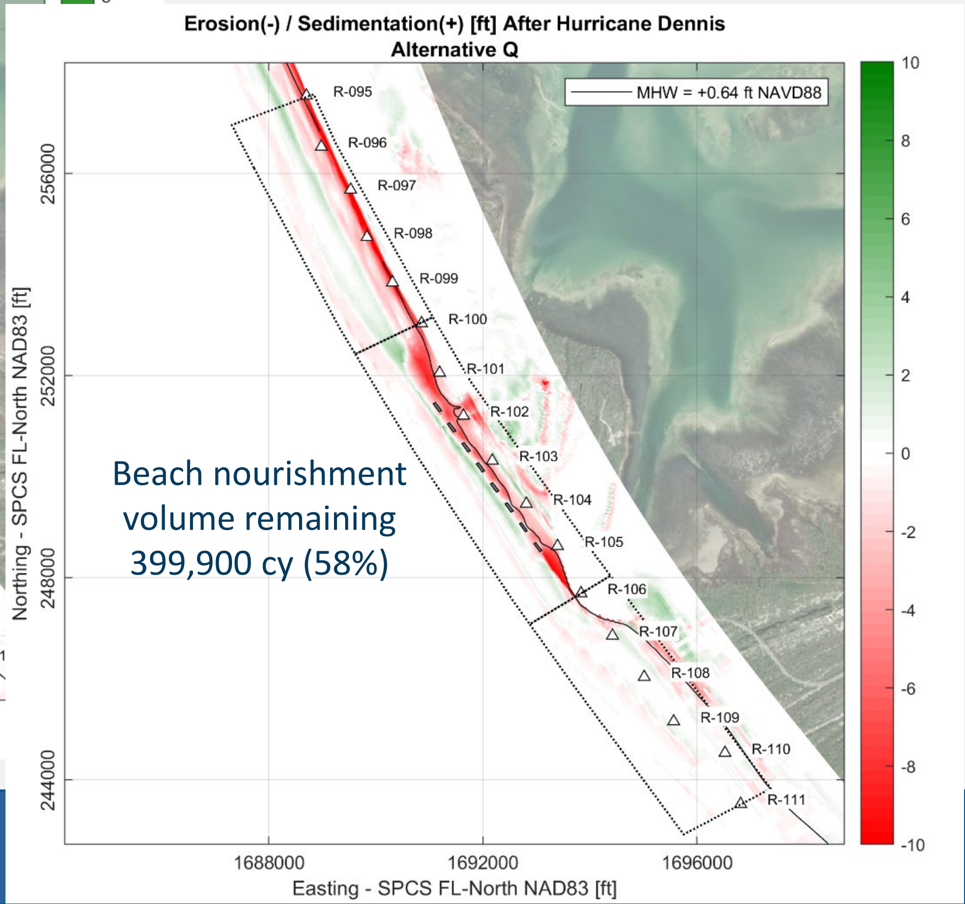




POST-HURRICANE DENNIS EROSION/SEDIMENTATION







Alternative Q (Revised Design)

- Increase upland storm protection
- Higher retainment of beach nourishment

IN SUMMARY...

- Erosion hotspots can benefit from strategic placement of coastal structures. While downdrift impacts are inevitable, they can be managed by allowing some sand to pass through.
- Properly calibrated morphology models can play an important role in refining the design of coastal structures to optimize the balance between amount of sand retention and downdrift impacts.
- 16 design alternatives were evaluated for the St. Joseph Peninsula Project. Preferred Alternative Q, consisting 8 detached submerged breakwaters + beach fill, provided the best balance while providing significant storm protection and reducing breaching potential during major storms.

THANK YOU!

Special thanks to:

Co-Authors and Team
Gulf County
FDEP

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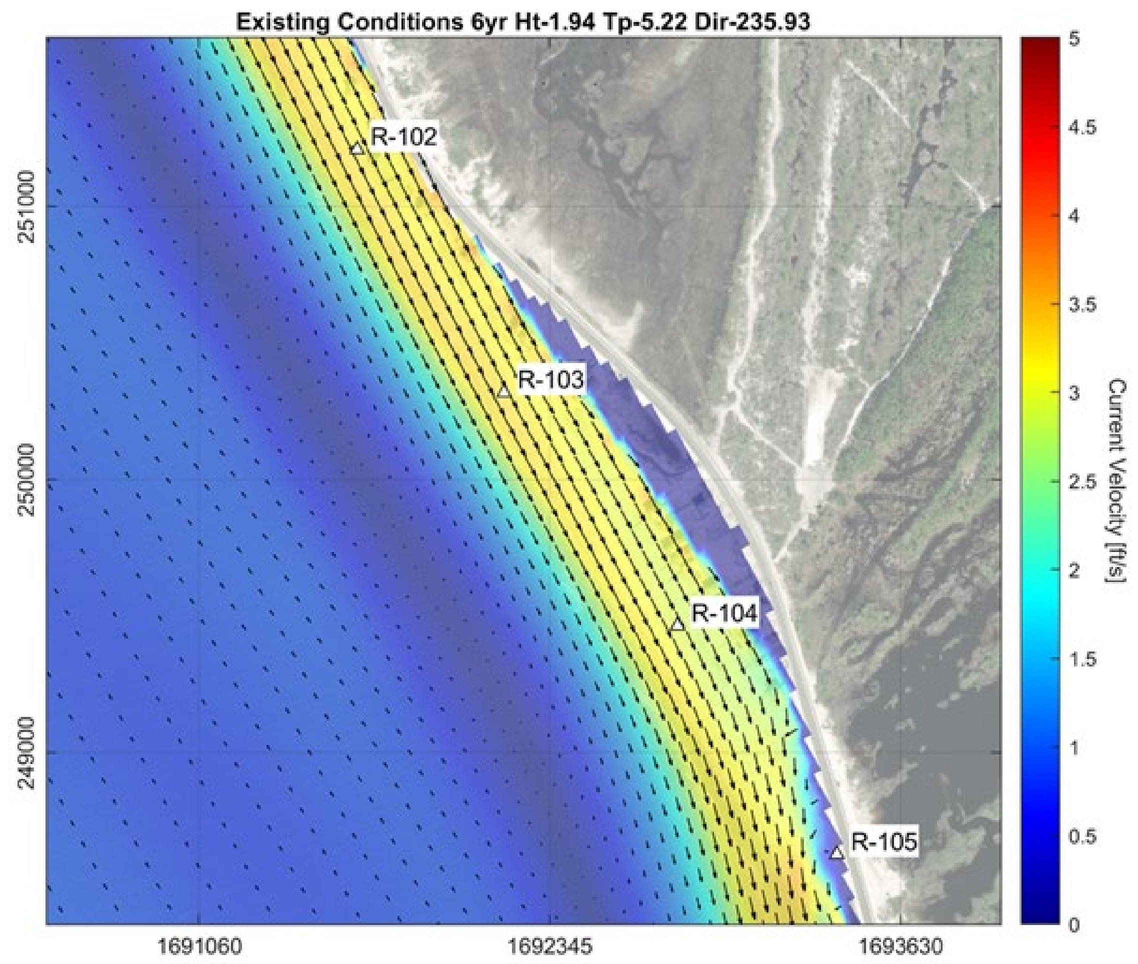
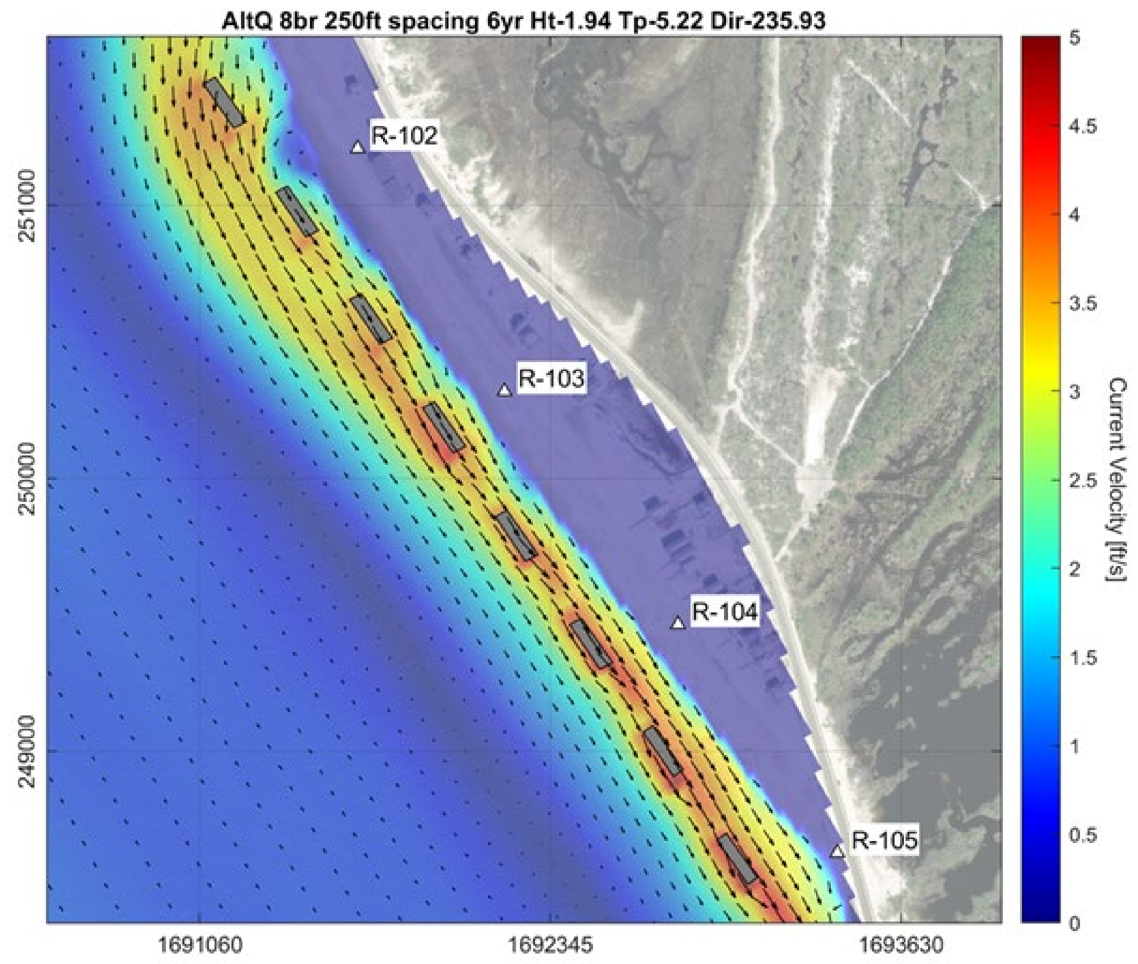
“The use of models is like a map. No one expects a map to represent all aspects of reality, only those that are important for navigation”

Leonard Savage, 1954.

CURRENT SPEED RESULTS





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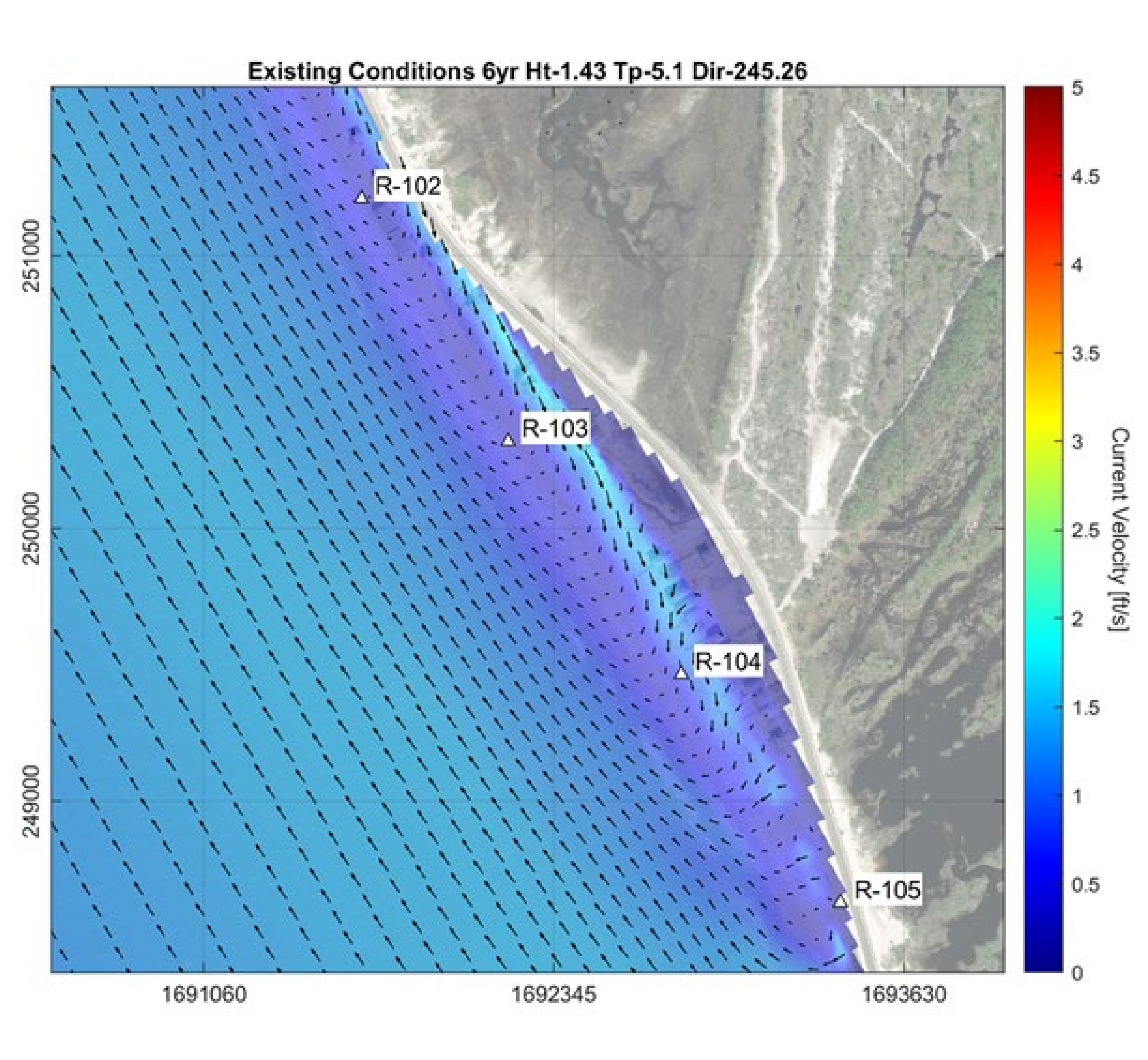
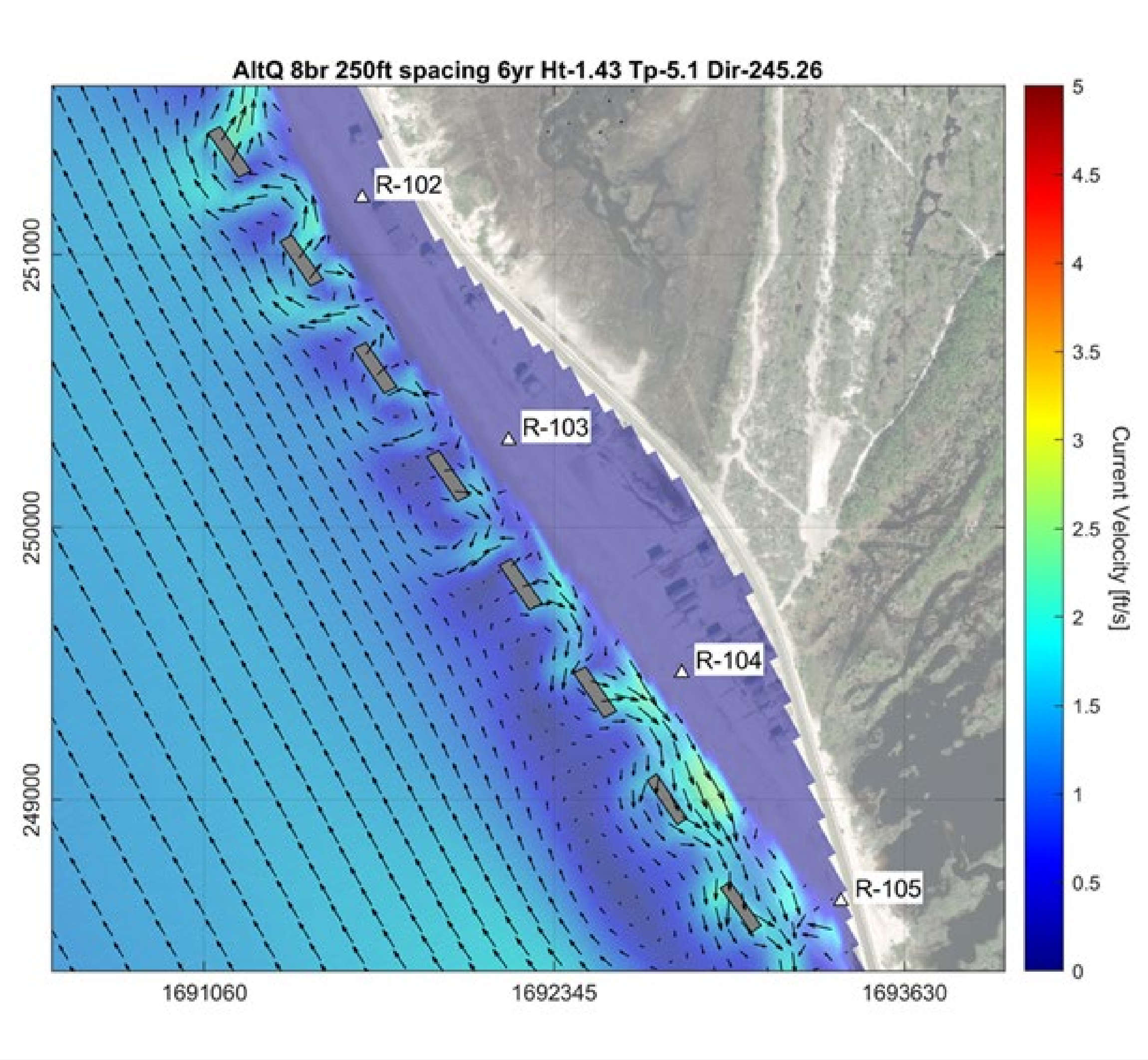
CURRENT SPEED RESULTS





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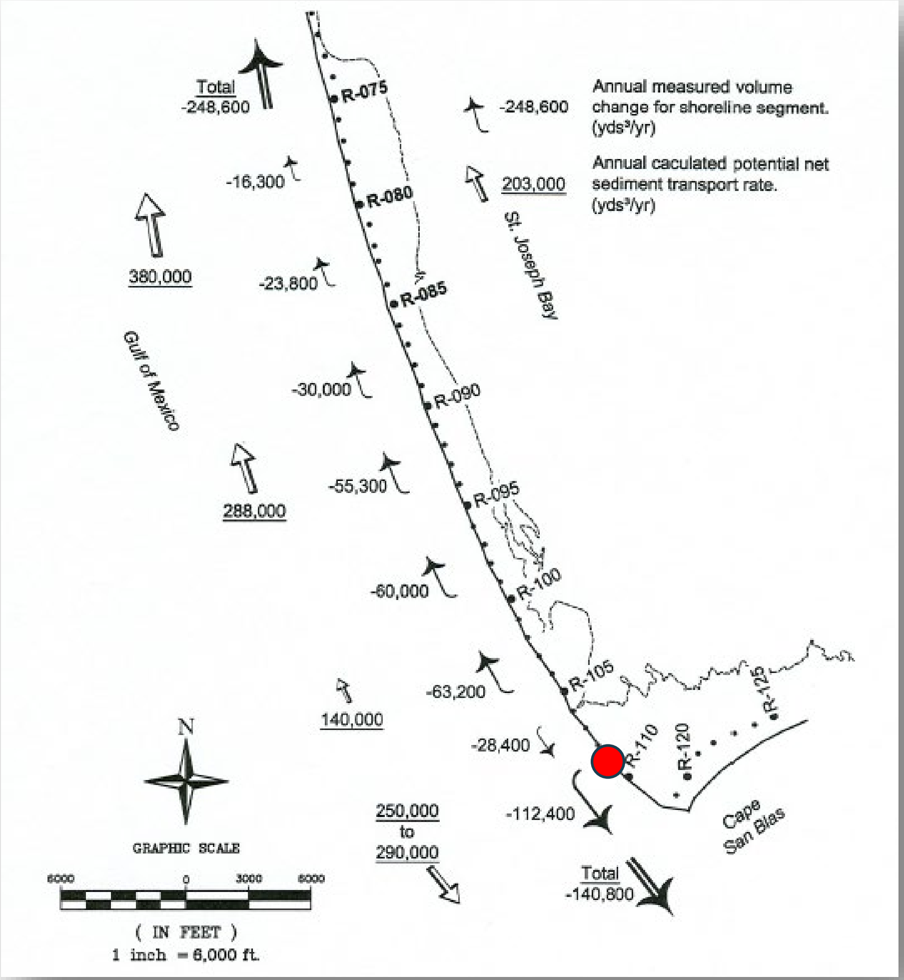
1. SEDIMENT TRANSPORT



- St. Joseph Peninsula Erosion Control Project: Preliminary Design Document (2006)
- Nodal point at R-105
- The specific location of the nodal point can vary from year to year

1. SEDIMENT TRANSPORT

CPE's Methodology for Nodal Point Identification:

1. Use DELFT3D-WAVE (SWAN) to propagate waves from offshore to the DOC
2. Use Hypercube Method for wave selection and extraction at DOC
3. The nearshore waves were transformed to the point of wave breaking to obtain the angle of incidence and significant wave height
4. Application of CERC equation
5. 42-year timeseries of sediment transport at each R-Mon

1. SEDIMENT TRANSPORT

WIS data from 1984 – 2021

362,280 offshore cases

2,200 cases selected for SWAN simulation

Hs 0:1:20 ft

Tp 2:2:18 s

Dir 135:11.25:337.5 deg

362,280 DOC cases for each R-Monument

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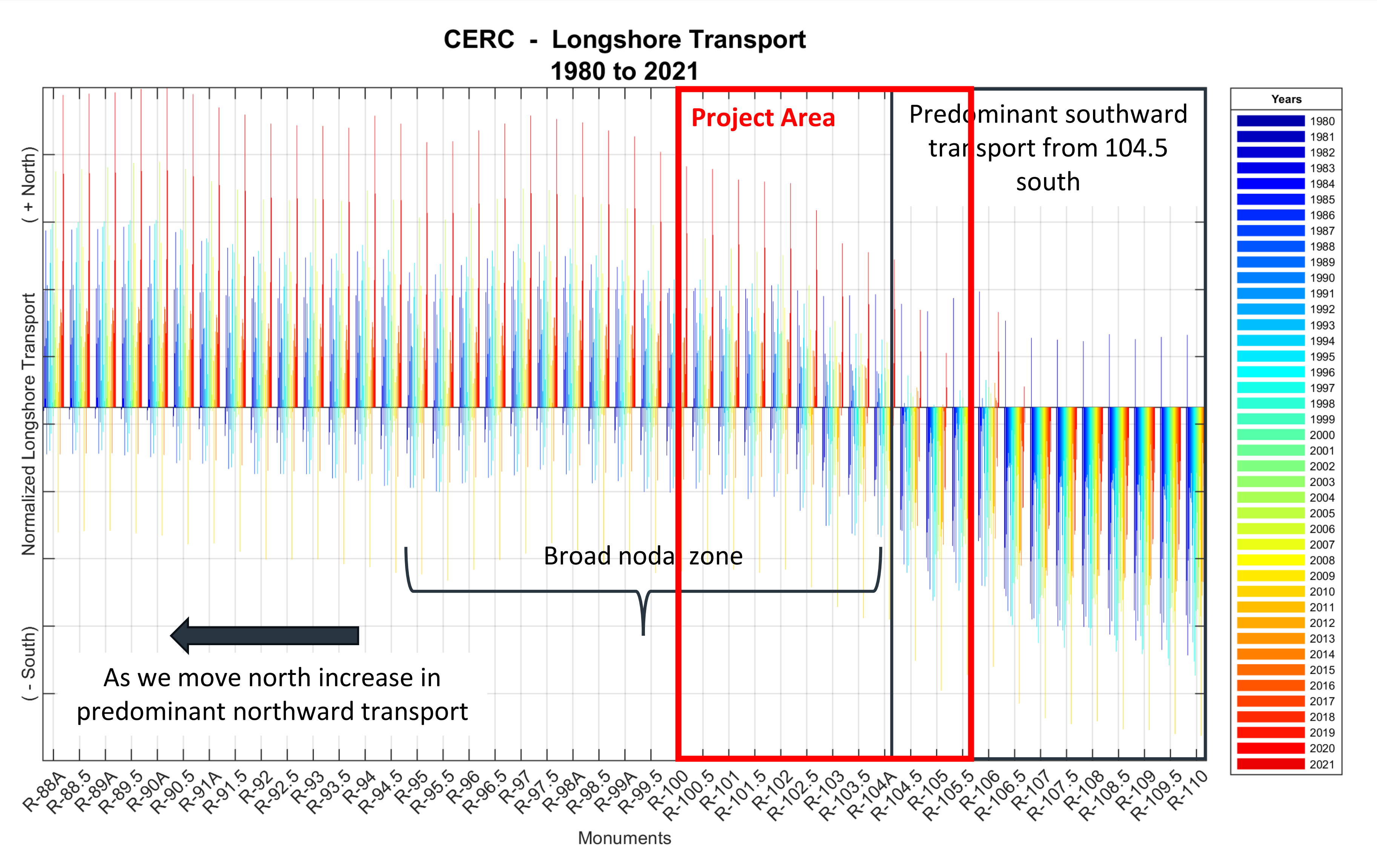
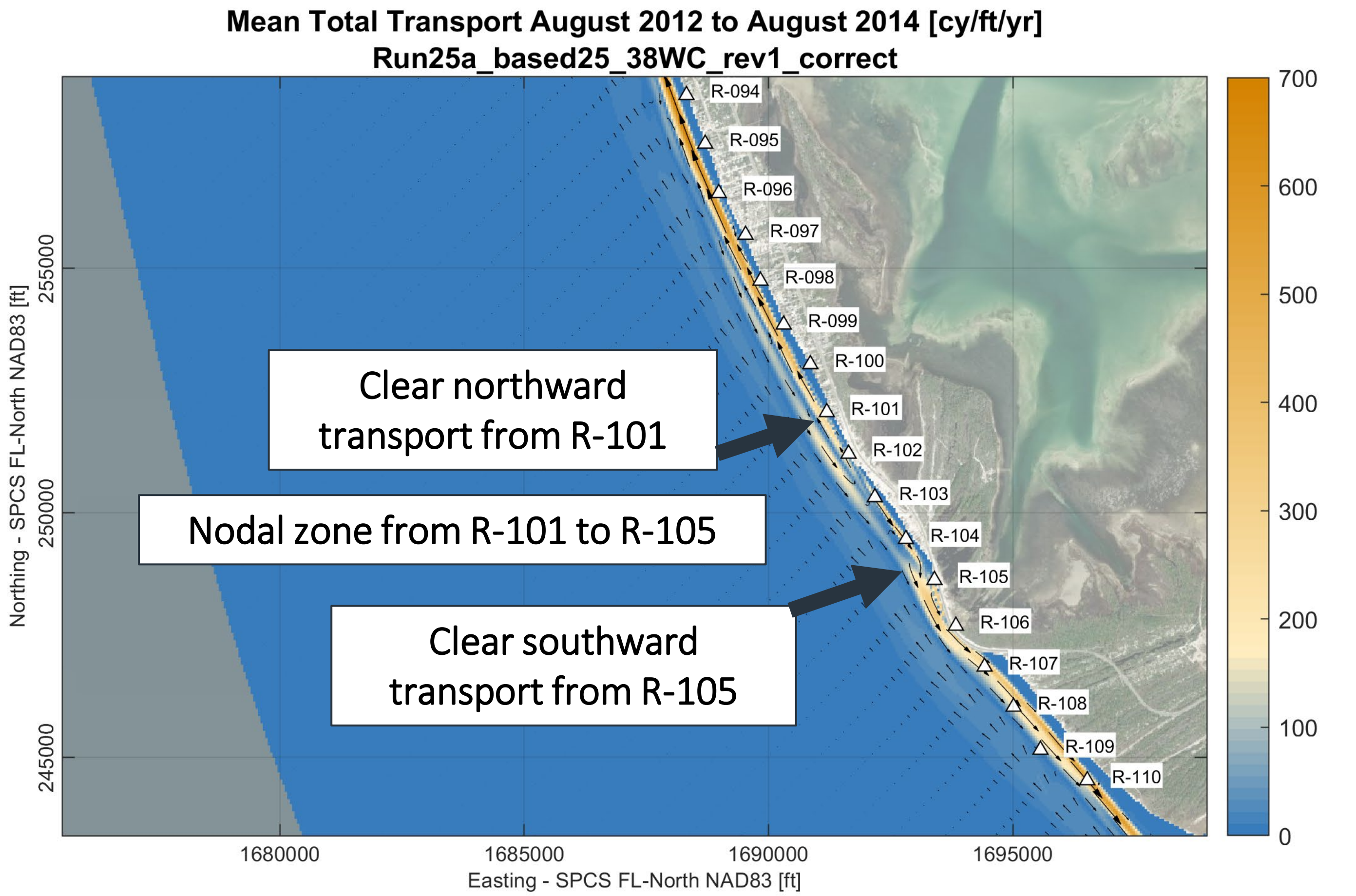
POTENTIAL SEDIMENT TRANSPORT 1980-2021



- Temporal and spatial variability of the nodal point

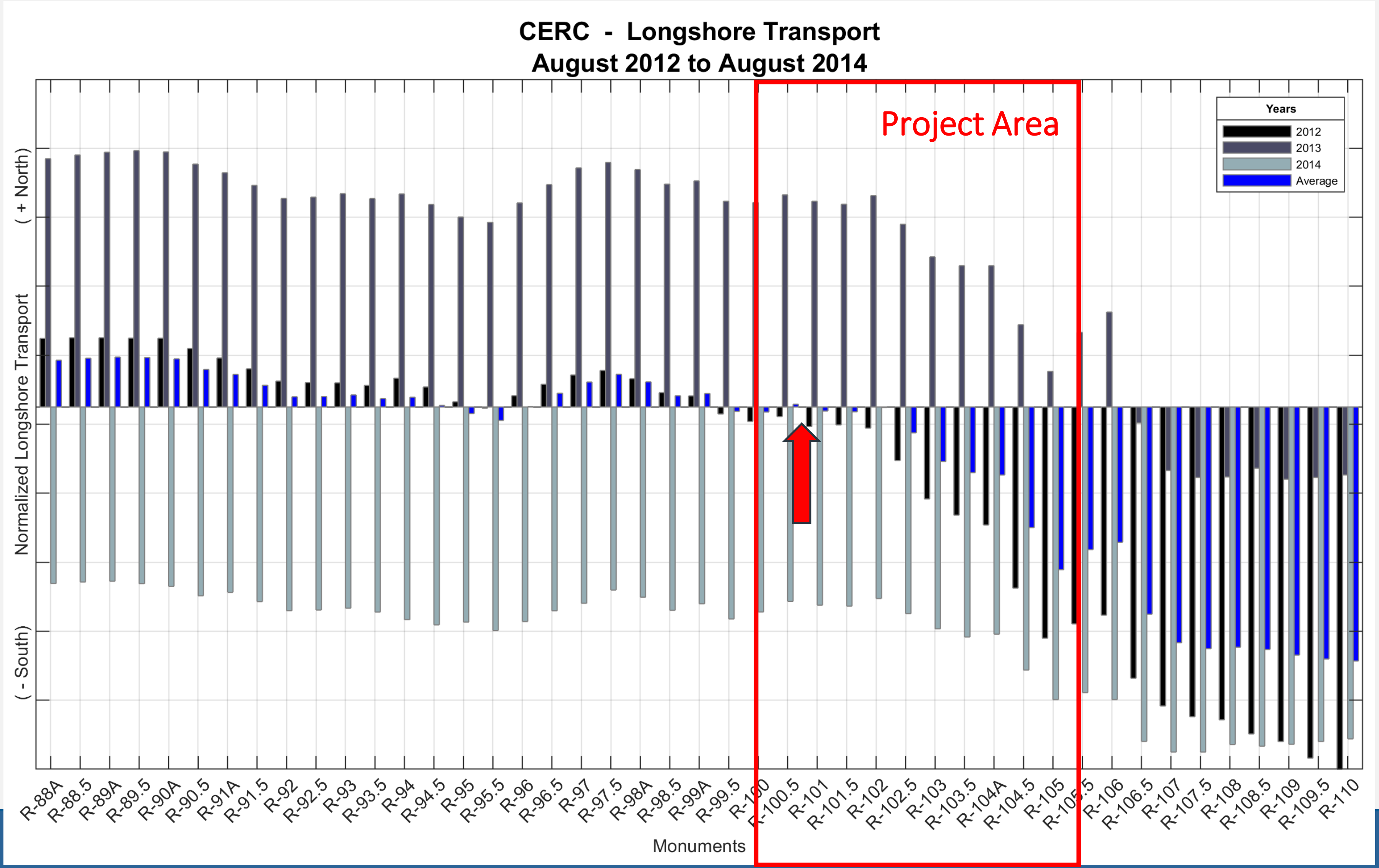
SJP DELFT3D MODEL – SEDIMENT TRANSPORT & REVERSAL



- 100+ iterations and every wave climate schematization method tested
- Novel method of wave climate schematization developed based on potential sediment transport timeseries (Q&A for additional details)
- The selected best calibration run reproduces the expected nodal zone

COASTAL PROTECTION ENGINEERING

1. SEDIMENT TRANSPORT

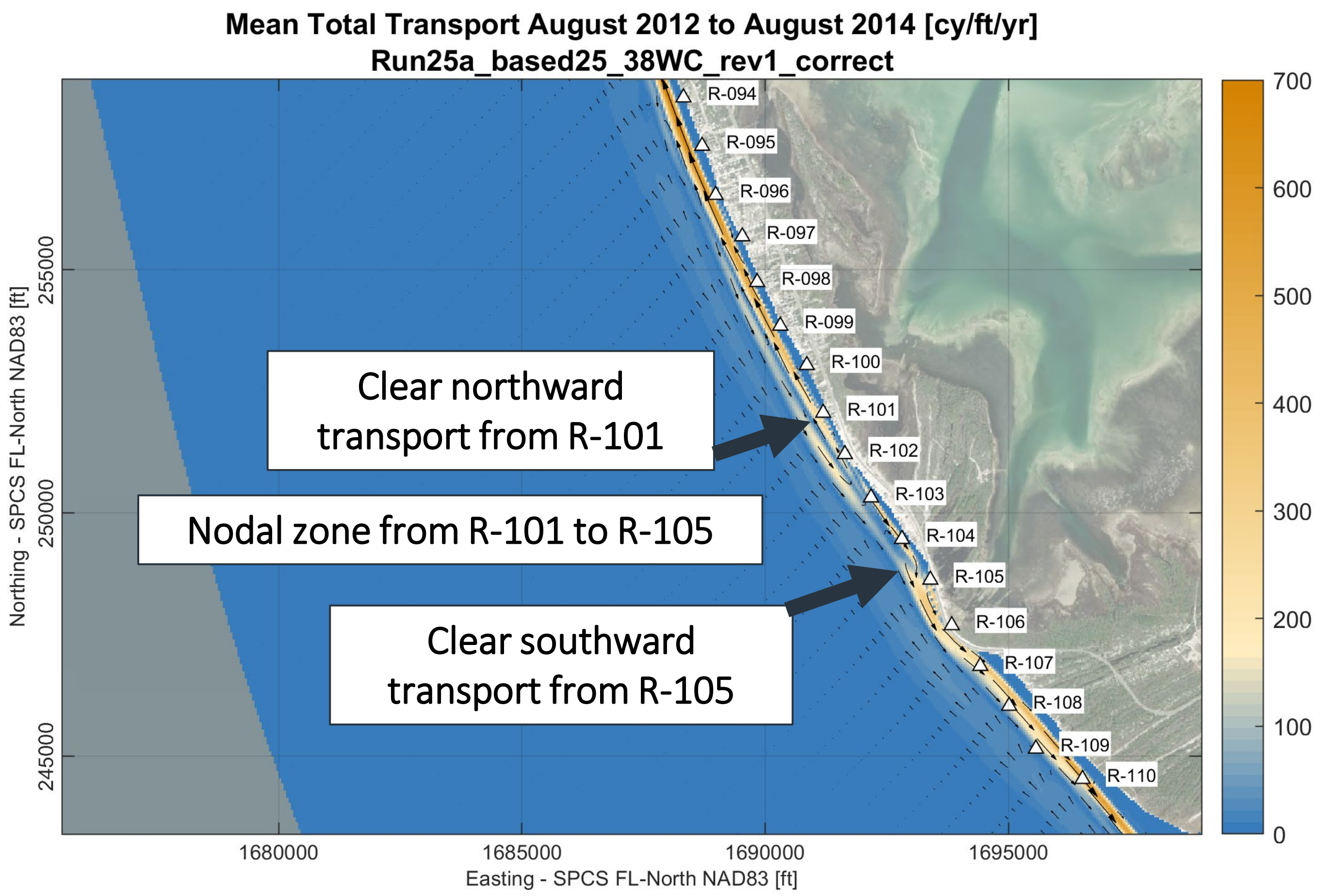


What happens when we select the morphology calibration period?

- 2012 similar to the average
- 2013 transport predominantly to north
- 2014 transport predominantly to south

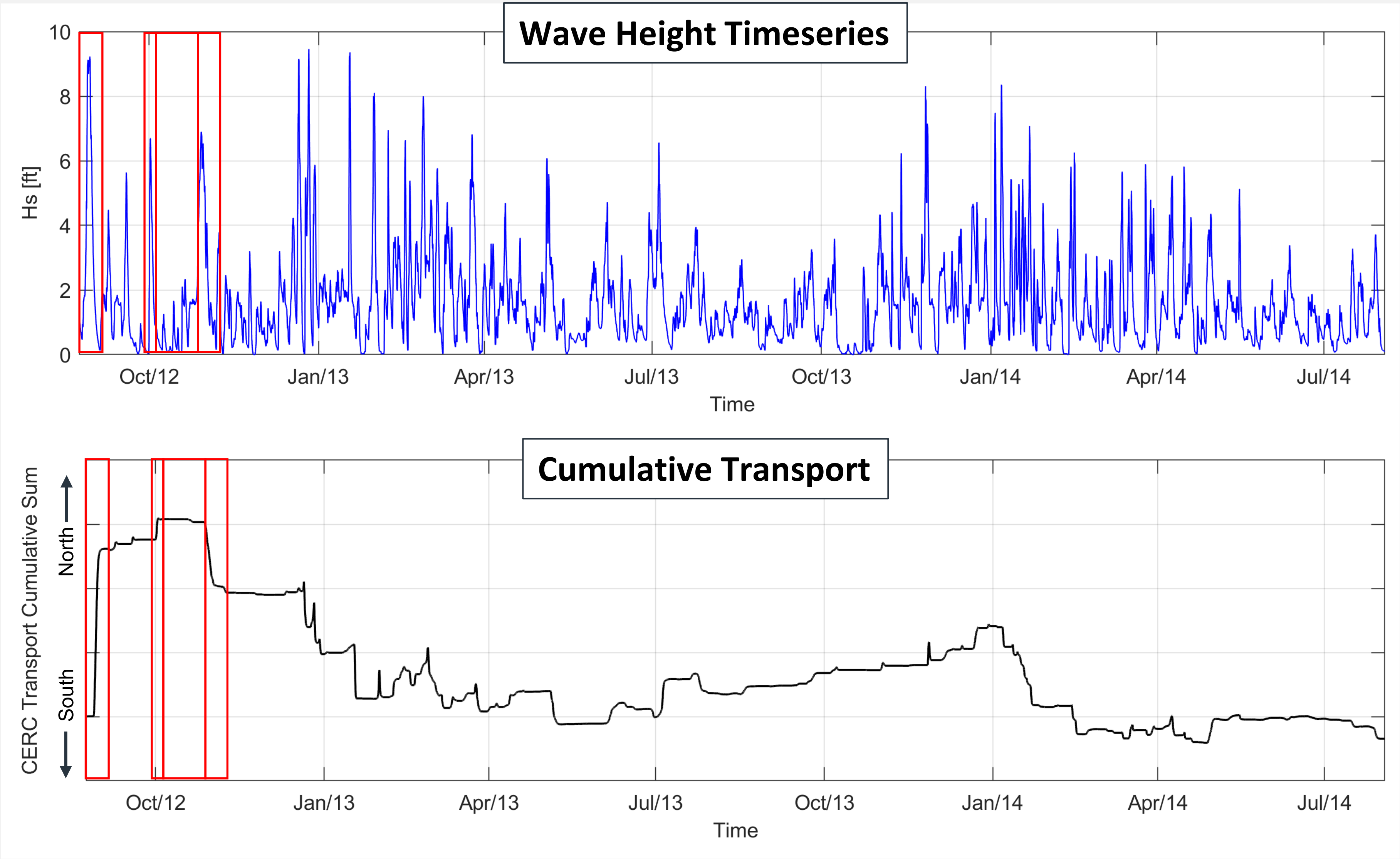
COASTAL PROTECTION ENGINEERING

1. SEDIMENT TRANSPORT



- After approximately 100 iterations…
- The selected best calibration run reproduces the expected nodal zone

WAVE SCHEMATIZATION



- Based on the wave sequence & longshore sediment transport potential (calculated with CERC equation)

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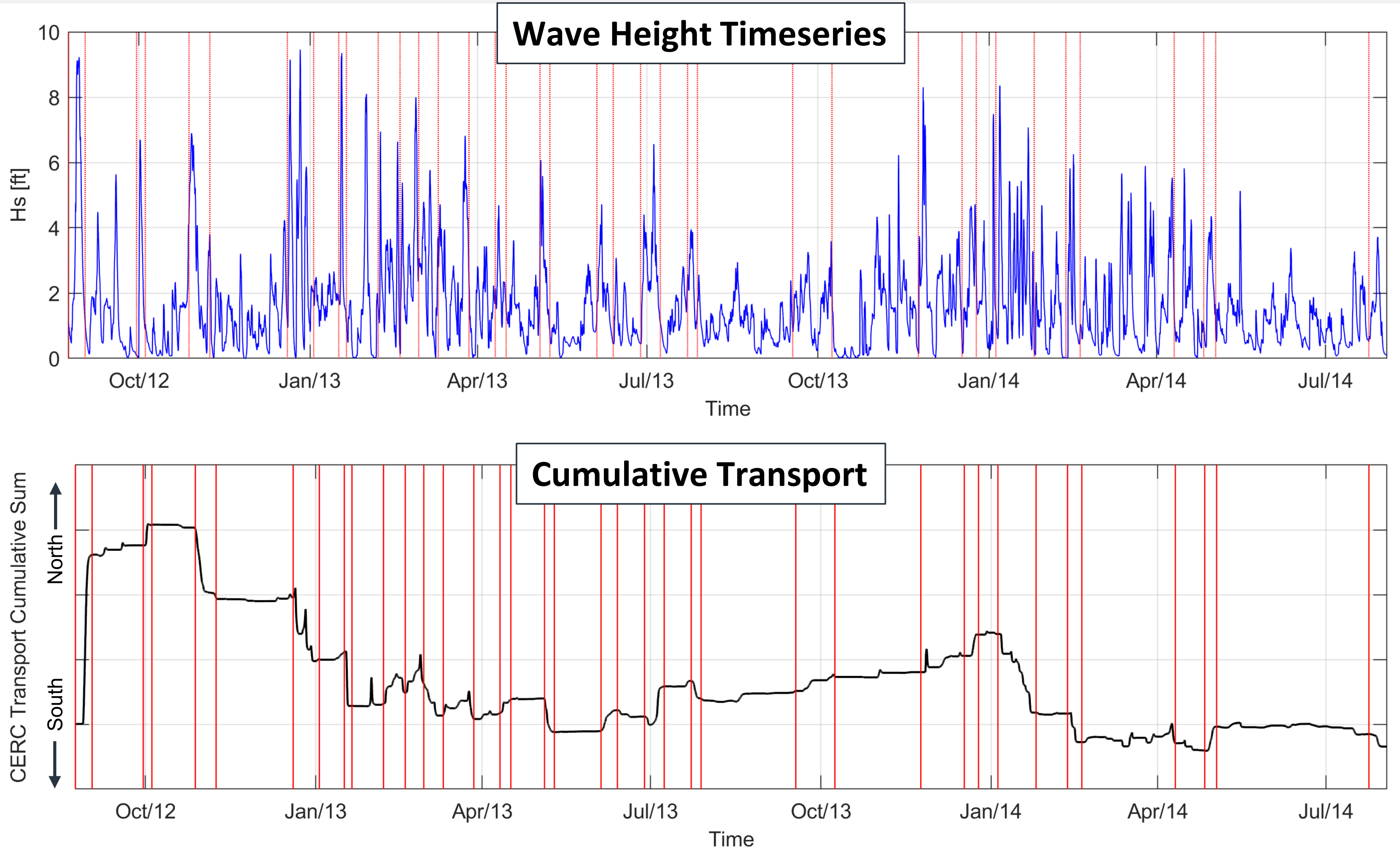
WAVE SCHEMATIZATION



- Definition of "boxes" with similar transport trends and selection of representative wave height and wave direction of each of the selected boxes

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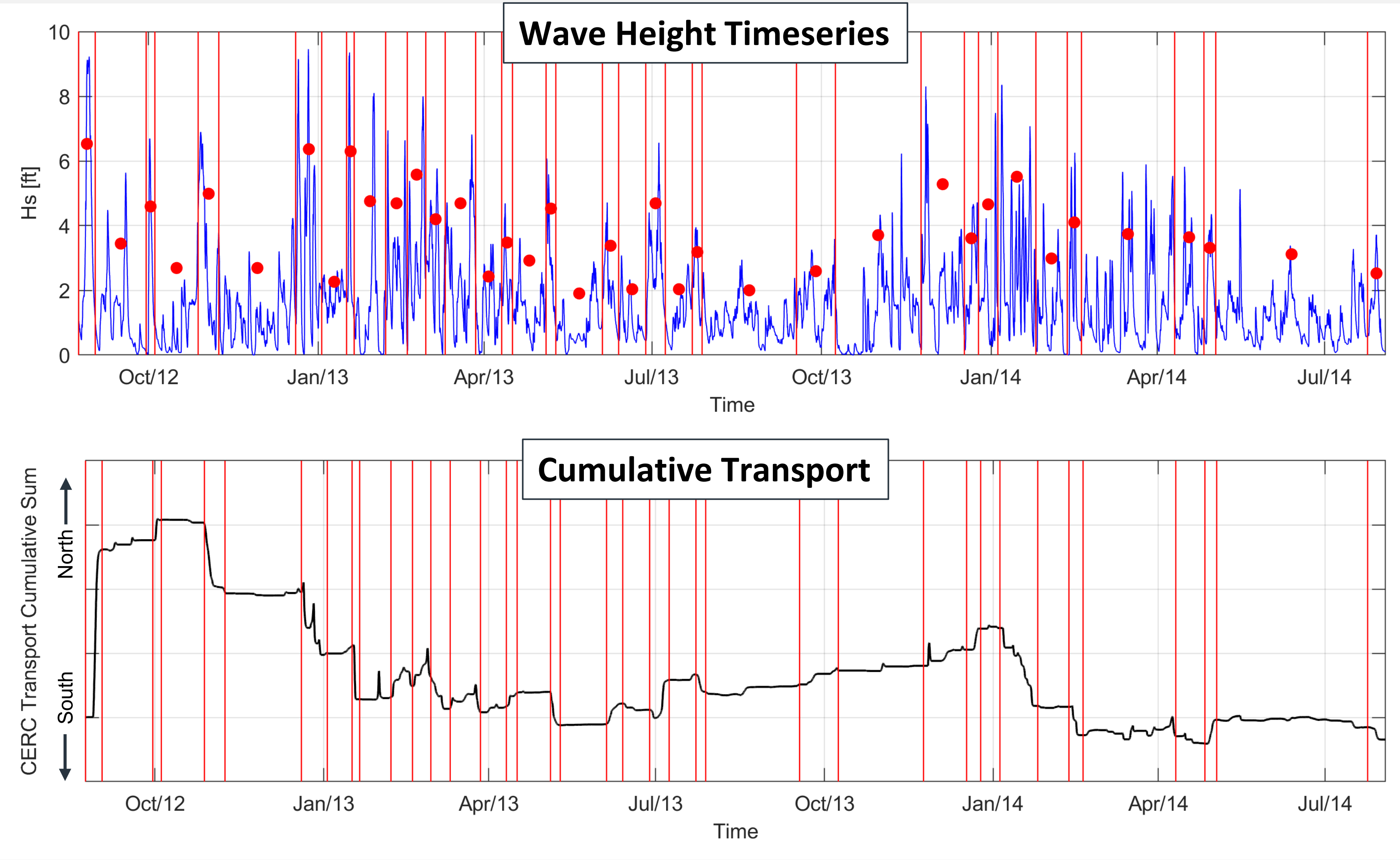
WAVE SCHEMATIZATION



- 38 wave cases selected with the representative have height and direction, average wave period, wind speed and direction, and Morfac associated with of the selection "boxes"

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